T-LEVELS | Institute for Apprenticeships & Technical Education

Qualification specification

T Level Technical Qualification in Science

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NCFE CACHE

T Level Technical Qualification in Science
Qualification Specification

Science

[603/6989/9]

Contents

Section 1: Introduction

A T Level[1] is a composite technical study programme, aimed at preparing young people for work, higher level apprenticeships or higher education (HE). It comprises 4 key components:

- an approved technical qualification, which includes the opportunity to specialise in at least one occupational role
- a substantial industry placement with an external employer (further information regarding the required number of hours can be found on page 10)
- employability, enrichment and pastoral (EEP) elements
- in some cases, it may also include mandatory additional requirements (MAR), such as important licence to practise qualifications

The T Level Technical Qualification in Science forms part of the new T Level in Health and Science. The outline content has been produced by T Level panels based on the same standards as those used for apprenticeships. The outline content formed the basis of this qualification and has been further developed by NCFE.

The Technical Qualification (TQ) in Science has 2 components:

- core component:
  - route core elements
  - pathway core elements
- occupational specialism components:
  - technical: laboratory sciences
  - technical: food sciences
  - technical: metrology sciences

The core, comprising route and pathway core components, provides a variety of knowledge and skills relevant to the health and science route as a whole, as well as the occupational specialism components within the science pathway. Some of the core topics and ideas are broken down and contextualised in more detail within the occupational specialisms, allowing students to apply the knowledge and skills in their own specific context.

Each occupational specialism component covers the knowledge, understanding, skills and behaviours required to achieve threshold competence in a chosen occupational specialism. Threshold competence refers to the level of competence deemed by employers as sufficient to secure employment in roles relevant to an occupational specialism. Achievement of threshold competence signals that a student is well placed to develop full occupational competence, with further support and development, once in work.

English, mathematics and digital skills have also been embedded throughout the TQ and must be taught when highlighted in the content.

[1] T Level is a registered trade mark of the Institute for Apprenticeships and Technical Education

About this TQ specification

To ensure that you are using the most up-to-date version of this TQ specification, please check the version number and date in the page footer against that of the TQ specification on the NCFE website.

If you advertise this qualification using a different or shortened name, you must ensure that students are aware that their results will state the full regulated qualification title.

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Section 2: Summaries

Technical qualification summary

Qualification title

Level 3 T Level Technical Qualification in Science

Qualification number (QN)

603/6989/9

Aim reference

60369899

Qualification level

Level 3

Guided learning hours (GLH) and total qualification time (TQT)

	GLH for delivery	GLH for assessment	Total GLH	TQT
Core component	495	23 hours	518 hours	570
Technical: laboratory sciences	650	16	666	733
Technical: food sciences	700	23	723	795
Technical: metrology sciences	600	16	616	678

The guided learning hours shown above only include time for the technical qualification element of the T Level programme; they do not include time allocated for the additional components of the T Level programme.

GLH will vary across the technical qualification (TQ), due to the different requirements of each occupational specialism.

Minimum age

T Level technical qualification students must be a minimum of 16 years of age.

Qualification purpose

The purpose of the Level 3 TQ in Science is to ensure students have the knowledge and skills needed to progress into skilled employment or higher level technical training relevant to the T Level.

Objectives

The objectives of this qualification are to equip students with:

- the core knowledge and core skills relevant to science
- up-to-date occupational knowledge and skills that have continued currency amongst employers and others
- the necessary English, mathematics and digital skills
- threshold competence that meets employer expectations and is as close to full occupational competence as possible
- opportunities to manage and improve their own performance

Industry placement experience

Industry placements are intended to provide students with the opportunity to develop the knowledge, skills and behaviours required for skilled employment in their chosen occupation and which are less easily attainable by completing a qualification alone.

As part of achieving the overall T Level programme, students are required to complete a minimum of 315 hours industry placement. In order to demonstrate threshold competence in their chosen occupational specialism, the student will be observed during their industry placement.

It is the provider's responsibility to ensure the minimum number of hours is undertaken by the student.

There may be specific requirements for providers and employers to consider prior to the student commencing a work placement. Please see the industry placement guidance from the Institute for Apprenticeships and Technical Education.

There are specific requirements for providers and employers relating to the insurance of students in the workplace. Further information about insurance can be found at www.abi.org.uk or www.hse.gov.uk/youngpeople/index.htm.

Temporary flexibilities for industry placements

Recognising the ongoing impact of Covid-19, the Department for Education has introduced temporary flexibilities for 2021 T Level students undertaking health and science. These flexibilities will ensure that industry placements are deliverable and aligned to current working practices. They will be withdrawn in July 2023.

For full details, please refer to: temporary flexibilities for Wave 1 and Wave 2 industry placements. Providers must still plan to deliver placements against the core principles set out in the T Level industry placement delivery guidance. These flexibilities should be used by exception and as a last resort.

Rules of combination

Students are required to complete:

- the core component

- one occupational specialism component

Students must not complete more than one occupational specialism component.

Approved providers can select which occupational specialism component to deliver to their students.

Grading

Component	Grade
Core component	A* to E and U
Occupational specialism components	Distinction/merit/pass and ungraded

Assessment method

Core component

- 2 written examinations
- employer-set project (ESP)

In order to achieve a grade for Core Component, students must have results for both sub-components (the core (written) examination and the employer-set project).

The combined results from these sub-components will be aggregated to form the overall Core Component grade (A*–E and U).

If students fail to reach the minimum standard across all sub-components, they will receive a U grade. No overall grade will be issued for the core component until both sub-components have been attempted.

Occupational specialism component

- synoptic assignments

The student is also required to successfully achieve a distinction/merit/pass grade in one of the occupational specialism components. If the student fails to reach the specified level of attainment, they will receive a U grade.

Progression including job roles (where applicable)

Students who achieve this qualification could progress to the following, depending on their chosen occupational specialism:

- employment:
  - science technician (for example, food technologist, laboratory technician, metrology technician)
- higher education
- apprenticeship (progression onto lower level apprenticeships may also be possible in some circumstances, if the content is sufficiently different)

UCAS

The T Level study programme is eligible for UCAS points. Please check the UCAS website for more information.

Regulation information

This is a regulated qualification.

Funding

This qualification is eligible for funding. For further guidance on funding, please contact the Education and Skills Funding Agency (ESFA).

English, mathematics and digital content

English, mathematics and digital content are embedded and contextualised within the science qualification content. This content must be taught to all students and will be subject to assessment.

Entry guidance

This qualification is designed for post-16 students.

There are no specific prior skills/knowledge a student must have for this qualification. However, students would be expected to have a level 2 qualification or equivalent.

Providers are responsible for ensuring that this qualification is appropriate for the age and ability of students. Providers must make sure that students can fulfil the requirements of the core and chosen occupational specialism and comply with the relevant literacy, numeracy, digital and health and safety aspects of this qualification.

Students registered on this qualification should not undertake another qualification at the same level with the same or a similar title, as duplication of learning may affect funding eligibility.

Transition programme

For those students who are not yet ready to start a T Level programme at 16, they will be able to study a new T Level transition programme. This is a new 16 to 19 study programme designed to give young people effective, tailored preparation specifically to help them progress onto and succeed in a T Level.

The T Level transition programme will be introduced through phased implementation, working initially with a small number of volunteer T Level schools, colleges and training companies, to explore different approaches to delivery and develop good practice in effectively preparing students for a T Level. More information on the T Level transition programme can be found on the government's website.

Registering students on T Levels

We expect students to make a decision about their T Level pathway within the first few weeks of their course, supported by good information, advice and guidance from their provider. For example, a student might know that they want to do a Digital T Level, but not be clear at the outset whether that should be Digital Production, Design and Development; Digital Support Services; or Digital Business Services. If a provider is offering 2 or 3 of the available pathways, there may be some co-delivery or other activity in the first few weeks which provides students with the opportunity to find out about different occupations, for example through employer visits. A student's

chosen T Level pathway and OS should be recorded on the Individual Learner Record (ILR) or School Census in October of year 1.

To ensure there is sufficient time to cover the curriculum, decisions about OSs should be confirmed by the end of the first year, although this could be much earlier depending on a provider's curriculum model. For example, some providers start teaching the OS early on in first year and require students to make a decision about this at the start of their course, whereas other providers may only start teaching OSs in the second year. In order to ensure that providers receive the right level of funding, a student's OS must be confirmed in the final data return of year 1 (ILR R14/Autumn Census), although changes after this date are possible.

Providers will also need to ensure that they register their students on the TQ with the awarding organisation and enter them for assessments as relevant.

Transferring between T Levels and occupational specialisms (OSs)

We expect some students to switch between T Levels. Providers should consider the degree of overlap between the 2 T Levels and the remaining time before any assessments in determining if a transfer is possible – or whether a student will need to restart their T Level. Attainment from one T Level cannot count towards another, and all students will need to take and pass the relevant assessments in order to pass their T Level.

Some students may also want to switch to a different OS within the same T Level pathway, including in the second year. It is less likely that there will be any overlap between OSs, so any decision will depend on the provider's curriculum model and the stage a student has reached in their OS learning. Any changes to a student's T Level – whether pathway or OS – should be recorded on the ILR/Census as soon as possible and should also match the registration and assessment entries submitted to the relevant awarding organisation.

Achieving this qualification

To achieve this qualification, the student must successfully demonstrate their achievement of the core component and one occupational specialism component.

In order to achieve a grade for the core component, the student must attempt both the external examination and ESP sub-components. The results from these will be aggregated to form the overall core component grade (A* to E and U). If students do not attempt one of the sub-components, an overall component grade will be withheld pending the attempt of both. If students fail to reach the minimum standard across sub-components after attempting both, they will receive a U grade for the component.

The student is required to successfully achieve a distinction/merit/pass grade in one of the occupational specialism components. If the student fails to reach the specified level of attainment, they will receive a U grade.

Retakes

Core component retakes

There is the opportunity for students to retake the core assessments in order to improve their marks. This includes:

- 2 written examinations
- ESP

The core component’s written examination is made up of 2 papers. If the student wants to retake the written examination assessment, they must retake both papers, in the same series..

Students can retake the core components in different series, meaning they could sit the ESP in one series and the core exams (both exam papers to be taken in the same series) in the next. There is no limit to the number of retakes a student can complete. However, any retake must be completed within 2 years after the completion of the student's T Level programme.

When determining each student’s overall achievement for the core component, the highest achievement in each core assessment (written examination and ESP) is used.

Occupational specialism component retakes

Although retakes are permitted for the occupational specialism, it is unlikely that students will be able to fit a retake opportunity into the delivery timetable.

If a retake opportunity is scheduled, the student must retake all synoptic assignments for the chosen occupational specialism. There will be one opportunity per year to sit the occupational specialism, meaning a retake of the occupational specialism would be sat in the next academic year of study. There is no limit to the number of retakes a student can complete. However, any retake must be completed within 2 years after the completion of the student's T Level programme.

Technical qualification components

Component	Level	Content
Core component (Section A: the health and science sector)	3	A1 Working within the health and science sector A2 The science sector A3 Health, safety and environmental regulations in the health and science sector A4 Application of safety, health and environmental practices in the workplace A5 Managing information and data within the health and science sector A6 Data handling and processing A7 Ethics A8 Good scientific and clinical practice A9 Scientific methodology A10 Experimental equipment and techniques

Component	Level	Content
Core component (Section B: science concepts)	3	B1 Core science concepts B2 Further science concepts

Component	Level	Content
Employer-set project – core skills	3	CS1 Project management CS2 Researching CS3 Working with others CS4 Creativity and innovation CS5 Communication CS6 Reflective evaluation

Students are required to complete one occupational specialism option.

Component	Level	Content
Technical: laboratory sciences	3	1 Perform a range of appropriate scientific techniques to collect experimental data in a laboratory setting, complying with regulations and requirements 2 Plan, review, implement and suggest improvements to scientific tasks relevant to a laboratory setting 3 Identify and resolve issues with scientific equipment or data errors
Technical: food sciences	3	1 Perform appropriate activities to support the food supply chain complying with regulatory requirements 2 Develop new food and food related products to support the food supply chain 3 Identify and resolve issues in the food supply chain 4 Collect, analyse and interpret food production data
Technical: metrology sciences	3	1 Plan appropriate scientific measurement for any measure and to comply with regulatory requirements 2 Perform scientific measurement tasks using the most appropriate measurement for a measure and to ensure accuracy 3 Collect, analyse and interpret data from measurement tasks 4 Identify and resolve issues with measurement tools and equipment

Employer involvement

The outline content for this qualification was devised by T Level panels. The panels consisted of employers and industry stakeholders.

We have worked in partnership with employers and other stakeholders to elaborate the content further, create the assessments and set the standards to ensure students achieve the level of competence needed to enter skilled employment.

Progression to higher level studies

This qualification aims to provide students with a number of progression options, including higher level studies at university or FE colleges. The skills required to progress to higher academic studies are different from those required at levels 1 and 2. Level 3 qualifications enable the development of these skills. Although there is no single definition of higher level learning skills, they include:

- checking and testing information
- supporting points with evidence
- self-directed study
- self-motivation
- thinking for yourself
- analysing and synthesising information/materials
- critical thinking and problem solving
- working collaboratively
- reflecting upon learning and identifying improvements
- presenting information in written and verbal formats

Level 3 criteria can require students to analyse, draw conclusions, interpret or justify, which are all examples of higher level skills and support progression and further learning. If you need any further information, please refer to the Progression to Higher Education section of the CACHE website.

How the qualification is assessed

Assessment is the process of measuring a student's skill, knowledge and understanding against the standards set in a qualification.

The core component is 100% externally assessed. External assessments are set and marked by NCFE. The external examinations and ESP will assess students' core knowledge, core understanding and core skills relevant to the occupations within the science TQ.

The occupational specialism components are also externally assessed through synoptic assignments, except for the observation element, which is internally marked by providers and externally moderated by NCFE. These synoptic assignments will assess the knowledge, understanding, skills and behaviours required to achieve threshold competence in the student's chosen occupational specialism.

Providers must not give any feedback to the student about their performance in any of the externally assessed components or observation elements.

The assessment consists of:

- core component:
  - 2 written examinations
  - ESP
- occupational specialism component:
  - synoptic assignments (specific to each occupational specialism)

Quality of written communication

Quality of written communication is assessed within targeted marks for the core examinations and is embedded throughout the assessment objectives within the ESP. No specific marks are available within the occupational specialism; however, a good command of communication and written work is anticipated for success at this level.

Application of mathematics, significant figures and decimal places

Throughout the core examinations for all pathways, students will be assessed on their understanding and application of mathematics. Some questions may require answers to be given to a number of significant figures or a given number of decimal places.

A paper may contain marks that are dependent on students giving final answers to a specified number of significant figures or decimal places. A significant figure mark may not be awarded for an answer given in surd form. In questions where the command word is calculate and the final answer is required in either format, the question should be calculated to at least one additional significant figure or decimal place before giving the final answer as requested in the question.

In all cases where an answer is required to a number of significant figures or decimal places, this will be specified in the question.

Rationale for synoptic assessment

Synoptic assessment tests students' understanding of the connections between the topics covered across the performance outcomes within the chosen occupational specialism.

Synoptic assessment enables students to integrate and apply knowledge, understanding and skills with breadth and depth. It also requires them to demonstrate their capability to apply knowledge, understanding and skills across the chosen occupational specialism.

Scheme of assessment for each component

Each component in the core is worth the following weighting:

	% weighting of the core component
Paper A	34
Paper B	36
Sub-total	70
ESP	30
Total	**100%**

External examinations (core)

Overview of assessment

Paper A

Written examination

Duration: 2 hours 30 minutes

100 marks (plus 12 marks for Quality of Written Communication) = 112 marks total

This paper is composed of 4 sections, which may consist of multiple-choice questions, short-answer and extended writing:

- Section A: 25 marks
- Section B: 25 marks
- Section C: 25 marks
- Section D: 25 marks

Paper B

Written examination

Duration: 2 hours 30 minutes

110 marks inclusive of 8 to 10 marks for maths (plus 9 marks for Quality of Written Communication) = 119 marks total

This paper is composed of 4 sections, which may consist of multiple-choice questions, short-answer and extended writing:

- Section A: 45 marks
- Section B: 27 marks

- Section C: 18 marks
- Section D: 20 marks

Content subject to assessment

Paper A: route and pathway core elements A1 to A10

Section 1 – Working within the science sector

- A1 - Working within the health and science sector (R)
- A2 - The science sector (P)
- A8 - Good scientific and clinical practice (R)

Section B – Ethics, data and managing personal information in the science sector

- A5 - Managing information and data within the health and science sector (R)
- A6 - Data handling and processing (P)
- A7 - Ethics (P)

Section C – Health and safety in the science sector

- A3 - Health, safety and environmental regulations in the health and science sector(R)
- A4 - Application of safety, health and environmental practices in the workplace (P)

Section D – Scientific methodology, equipment and techniques

- A9 - Scientific methodology (P)
- A10 - Experimental equipment and techniques (P)

Paper B: route and pathway core elements B1 to B2

Section A – B1 Biology

- structure and function of cells and tissues(R)
- large molecules (R)
- exchange and transport mechanisms (R)
- genetic information and genetics(R)
- microbiology (R)
- immunology (R)
- classification of biological materials (P)
- enzyme and protein structure (P)
- cell cycle (P)
- cellular respiration (P)
- pathogens (causative agents) (P)

- formulae and equations (P)
- units (R)

Section B - B1 Chemistry

- structure of materials and chemical properties (R)
- acids/bases and chemical change (R)
- rates of reaction and energy changes (R)
- chemical analysis of substances (P)
- analytical techniques (P)
- gas laws (P)
- formulae and equations (P)
- units (R)

Section C – B1 Physics

- electricity (R)
- magnetism and electromagnetism (R)
- waves (R)
- particles and radiation (R)
- formulae and equations (P)
- kinetic changes (P)
- pressure/fluid/viscosity (P)
- units (R)

Section D – B2 Further Scientific Concepts

- taken from any of the above content areas: Biology, Chemistry and Physics

P= Pathway

R= Route/Core

Assessment objectives and weightings

The external (core) examinations will assess how students have achieved the following assessment objectives (AOs):

	Assessment objectives	Weighting*
AO1	Demonstrate knowledge and understanding of contexts, concepts, theories and principles in science.	29%

AO2	Apply knowledge and understanding of contexts, concepts, theories and principles in science to different situations and contexts	40%
AO3	Analyse and evaluate information and issues related to contexts, concepts, theories and principles in science to make informed judgements, draw conclusions and address individual needs.	31%

*Both paper A and paper B allocate 6 marks to the Quality of Written Communication (QWC) or maths. These marks are bolted on and do not impact on the AO weightings. For example, paper A totals 112 marks of which the AO weightings apply to a total of 100 marks, with the remaining 12 assessing QWC.

Total marks

Paper	Assessment length	% weighting of the core component	Maximum raw mark	Max UMS
Paper A	2 hours 30 minutes	34%	112	140
Paper B	2 hours 30 minutes	36%	119	140

AO	Paper A	Paper B	Total
AO1	28 marks (28%)	33 marks (30%)	61 marks (29%)
AO2	40 marks (40 %)	44 marks (40%)	84 marks (40%)
AO3	32 marks (32%)	33 marks (30%)	65 marks (31%)
QWC	12 marks	9 marks	21 marks
Total	112 marks	119 marks	231 marks

The tables above show how each core examination will target the AOs in this qualification. Each version of the core examination will adhere to these mark and percentage weightings.

Additional marks allocated for QWC or maths are not included in the overall AO weightings.

Assessment availability

There will be 2 assessment opportunities per year in summer (May/June) and autumn (November/December). Please refer to the Assessment Timetable on the NCFE website for further information.

Assessment conditions

The core external examinations must be invigilated.

All students' scripts must be submitted to NCFE for marking. All assessment material must be securely stored by the approved provider. Onscreen assessments will be submitted through the online assessment platform.

Please refer to the regulations for conduct of external assessments for further information on the assessment conditions. Please refer to the NCFE website for an up-to-date copy of the regulations.

ESP (core component)

Overview of assessment

Externally-set (in conjunction with employers) project

The purpose of the employer-set project is to ensure that students have the opportunity to apply core knowledge and skills to develop a substantial piece of work in response to an employer-set brief. The brief and tasks are contextualised around an occupational area and chosen by the student ahead of the assessment window.

Duration: 18 hours

Subject content to be assessed

The ESP is designed to target the core skills and relevant core knowledge in a valid and sufficient manner, which will be consistent over time.

Core skills

In completing the employer-set project, the student will demonstrate 7 core skills, supported by underpinning knowledge and understanding set out in the core component.

Core skill 1	Project management: to include independently producing a high-level project plan taking into account: timing of activities, resource and financial considerations, adherence to health and safety and the maintenance of quality outcomes
Core skill 2	Researching: from independently identified sources including scientific literature and other appropriate sources, prior to the project commencement and referencing these sources appropriately
Core skill 3	Working with others: for example, to ensure that any scientific techniques meet all safety, health and environmental requirements
Core skill 4	Creativity and innovation: within a science context to improve practice processes and outcomes
Core skill 5	Problem solving: within a science context and where appropriate making use of new technologies to solve problems
Core skill 6	Communication: for example, providing results and recommendations in appropriate formats to clients and wider stakeholders which take into consideration ‘business benefits’ or show commercial awareness in a variety of formats including written reports and verbal presentations
Core skill 7	Reflective evaluation: to be able to make improvements to own practice, for example having completed a task reviewing and suggesting improvements and considerations of lessons learnt for own professional development

Assessment objectives

Assessment objectives (AOs)		Weighting
AO1	Plan their approach to meeting the project brief	12 8.1%
AO2	Apply core knowledge and skills to the development of a scientific project	69 46.9%
AO3	Select relevant techniques and resources to meet the brief	16 10.9%
AO4	Use English, maths, and digital skills as appropriate	22 15.0%
AO5	Realise a project outcome and review how well the outcome meets the brief	28 19.0%

AO/Task:	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	
AO1	0	12	0	0	0	0	8.1%
AO2	18	12	16	12	4	7	46.9%
AO3	0	0	6	6	2	2	10.9%
AO4	4	4	6	4	0	4	15.0%
AO5	0	8	6	6	3	5	19.0%
Total	22 marks	36 marks	34 marks	28 marks	9 marks	18 marks	147/100%

Total marks 147

Assessment availability

There will be 2 assessment opportunities per year in summer (May/June) and autumn (November/December). Please refer to the Assessment Timetable on the NCFE website for further information.

Assessment conditions

All tasks must be completed under supervised conditions. This means students can access resources in order to complete their assessment.

The approved provider must securely retain all students' evidence and submit that evidence to NCFE for marking.

Please refer to the regulations for conduct of external assessments for further information on the assessment conditions. Please refer to the NCFE website for an up-to-date copy of the regulations.

UMS

The core component is modular, which means that a student can take and resit the assessments in different assessment windows. Assessments may vary slightly in levels of difficulty and, therefore, the mark that represented a C grade in the external examination in one assessment window may not be appropriate in the following assessment window.

To address this, we convert raw marks to uniform marks. The uniform mark scale (UMS) also allows us to account for the relative weighting of the assessment to the qualification as a whole. The maximum UMS points available for each assessment, and the UMS points relating to each grade boundary, are fixed. These are shown in the following table:

Grade boundary	External examination	ESP	Overall
Max	280	120	400
A*	252	108	360
A	224	96	320
B	196	84	280
C	168	72	240
D	140	60	200
E	112	48	160
U	0	0	0

The external examination comprises 2 papers, the results of which are combined before conversion to UMS. Combined grade boundaries for each series will be set by adding together the equivalent boundaries for each paper.

The raw mark grade boundaries are set after each assessment window. NCFE sets these boundaries judgementally, following both qualitative and quantitative analysis, and then converts them to UMS.

Although the raw mark grade boundaries in assessment window 1 and assessment window 2 are different, they have the same value in terms of UMS marks (168 for a C and 196 for a B) when contributing to the qualification as a whole. NCFE will publish the raw mark grade boundaries following the completion of each assessment window.

Scheme of assessment for each component

Occupational specialism – Technical: laboratory sciences

Overview of assessment

Synoptic assignments comprise 3 assessments.

Duration: 16 hours

Content subject to assessment

All performance outcomes within a chosen occupational specialism are subject to assessment:

- **Performance outcome 1:** Perform a range of appropriate scientific techniques to collect experimental data in a laboratory setting, complying with regulations and requirements
- **Performance outcome 2:** Plan, review, implement and suggest improvements to scientific tasks relevant to a laboratory setting
- **Performance outcome 3:** Identify and resolve issues with scientific equipment or data errors

Assessment weightings

Assignment	% weighting of the occupational specialism	Max raw mark	Scaling factor	Max scaled mark
Assignment 1	25	102	1.000	102
Assignment 2	50	70	2.914	204
Assignment 3	25	41	2.488	102
Total	100%	213		408

Total marks

213

Assessment availability

There will be one assessment opportunity per year from summer 2022. Please refer to the Assessment Timetable on the NCFE website for further information.

Assessment conditions

All tasks must be completed under specified conditions. See the tutor guidance in the tutor guidance pack for more detail.

The approved provider must securely retain all students' evidence and submit that evidence to NCFE for marking.

Please refer to the regulations for conduct of external assessments for further information on the assessment conditions. Please refer to the NCFE website for an up-to-date copy of the regulations.

Occupational specialism – Technical: food sciences

Overview of assessment

Synoptic assignments comprise 4 assessments.

Duration: 23 hours

Content subject to assessment

All performance outcomes within a chosen occupational specialism are subject to assessment:

- **Performance outcome 1:** Perform appropriate activities to support the food supply chain complying with regulatory requirements
- **Performance outcome 2:** Develop new food and food related products to support the food supply chain
- **Performance outcome 3:** Identify and resolve issues in the food supply chain
- **Performance outcome 4:** Collect, analyse and interpret food production data

Assessment weightings

Assignment	% weighting of the occupational specialism	Max raw mark	Scaling factor	Max scaled mark
Assignment 1	45	115	1.604	184.5
Assignment 2	30	112	1.098	123
Assignment 3	10	41	1.000	41
Assignment 4	15	42	1.464	61.5
Total	100%	310		410

Total marks

310

Assessment availability

There will be one assessment opportunity per year from summer 2022. Please refer to the Assessment Timetable on the NCFE website for further information.

Assessment conditions

All tasks must be completed under specified conditions. See the tutor guidance in the tutor guidance pack for more detail.

The approved provider must securely retain all students' evidence and submit that evidence to NCFE for marking.

Please refer to the regulations for conduct of external assessments for further information on the assessment conditions. Please refer to the NCFE website for an up-to-date copy of the regulations.

Occupational specialism – Technical: metrology sciences

Overview of assessment

Synoptic assignments comprise 3 assessments.

Duration: 16 hours

Content subject to assessment

All performance outcomes within a chosen occupational specialism are subject to assessment:

- **Performance outcome 1:** Plan appropriate scientific measurement for any measurand to comply with regulatory requirements
- **Performance outcome 2:** Perform scientific measurement tasks using the most appropriate measurement for a measurand to ensure accuracy
- **Performance outcome 3:** Collect analyse and interpret data from measurand tasks
- **Performance outcome 4:** Identify and resolve issues with measurement tools and equipment

Assessment weightings

Assignment	% weighting of the occupational specialism	Max raw mark	Scaling factor	Max scaled mark
Assignment 1	25	67	1.000	67
Assignment 2	50	104	1.288	134

Assignment 3	25	63	1.063	67
Total	100%	234		268

Total marks

234

Assessment availability

There will be one assessment opportunity per year from summer 2022. Please refer to the Assessment Timetable on the NCFE website for further information.

Assessment conditions

All tasks must be completed under specified conditions. See the tutor guidance in the tutor guidance pack for more detail.

The approved provider must securely retain all students' evidence and submit that evidence to NCFE for marking.

Please refer to the regulations for conduct of external assessments for further information on the assessment conditions. Please refer to the NCFE website for an up-to-date copy of the regulations.

Paper-based examination

The core written examinations will be available as onscreen and as paper-based examinations. A different version of each examination will be available per mode.

The ESP and the occupational specialism assessments will be released and accessed by providers electronically. The submission of any assessment evidence from providers will also be digital and provided to NCFE electronically, unless otherwise specified.

For instructions on conducting external assessments (including information on malpractice/maladministration), please refer to our regulations for the conduct of external assessments and qualification specific instructions for delivery documents, which are available on the Policies and Documents page on the NCFE website.

Sample assessment materials

Sample assessment materials can be found on the qualification page on the NCFE website.

Results

Results for each component will be released in accordance with the assessment windows. Please refer to the assessment windows on the NCFE website for further information.

Enquiries about results

If a provider believes a student's result is at variance with their reasonable expectations, they can submit an enquiry about a result in line with our enquiries about results and assessment decisions policy, which is available on the Policies and Documents page on the NCFE website.

Grading

Core component

The core component is graded A* to E and U.

Core component grade descriptors

Grade	Demonstration of attainment
A	A grade A student can:
	consistently demonstrate a comprehensive range of relevant and appropriate terminology, and do so, accurately
	consistently demonstrate a comprehensive range of relevant skills, appropriate to the task
	consistently demonstrate a comprehensive understanding of ideas, processes and procedures applied to familiar and unfamiliar contexts
	consistently and accurately use a comprehensive range of mathematical skills relevant to the sector
	critically analyse novel information and data, in a variety of formats, and support this with relevant examples and analysis
	construct reasoned arguments, make substantiated judgements and reach valid conclusions
	consistently organise and present information clearly, concisely and accurately, and support this with relevant examples and analysis
	evaluate information in a variety of formats, to make detailed and relevant comments on strengths and limitations
	effectively link appropriate principles and concepts from the sector, to further understanding
E	A grade E student can:
	demonstrate a limited use of terminology, but this may be inconsistent and inaccurate

Grade	Demonstration of attainment
	demonstrate a limited range of skills, however these may not always be relevant to the task
	demonstrate a limited understanding of ideas, processes and procedures, applied to some familiar and unfamiliar contexts
	use a limited range of simple mathematical skills relevant to the sector
	demonstrate a limited ability to analyse novel information and data, the links to any supporting examples may be tenuous or unclear
	effective organisation and presentation of information is limited, if supported with examples and analysis, this will be rudimentary and may not be relevant
	make limited and simplistic comments on strengths and weaknesses
	make simplistic links between some principles and concepts to further understanding

Occupational specialism components

The occupational specialism components are graded distinction, merit, pass and ungraded.

Technical: laboratory sciences grade descriptors

Grade	Demonstration of attainment
Pass	The evidence is logical but displays minimal relevant knowledge or understanding in response to the demands of the brief
	The student makes some use of relevant knowledge and understanding of how it informs practices of the sector and demonstrates a limited understanding of skills or approaches associated with the laboratory sciences sector
	The student makes adequate use of facts/theories/approaches/concepts and attempts to demonstrate breadth and depth of knowledge and understanding of the different aspects of the task

Grade	Demonstration of attainment
	The student is able to identify some information from appropriate sources and makes use of appropriate information/appraise relevancy of information and can combine information to make decisions
	The student makes minimal judgements/takes appropriate action/seeks clarification with guidance and is able to make limited progress towards solving non-routine problems in real life situations
	The student attempts to demonstrate skills and knowledge of the relevant concepts and techniques reflected in a lab science setting and generally applies this across different contexts
	The student shows adequate understanding of unstructured problems that have not been seen before, using limited knowledge to find solutions to problems and make justification for strategies for solving problems, explaining their reasoning
Distinction	The evidence is precise, logical and provides a detailed and informative response to the demands of the brief
	The student makes extensive use of relevant knowledge and has extensive understanding of the principles and practices of the sector and demonstrates an understanding of the different approaches/skills associated with the laboratory science sector
	The student makes decisive use of facts/theories/approaches/concepts, demonstrating extensive breadth and depth of knowledge and understanding and selects highly appropriate skills/tasks/techniques/methods
	The student is able to comprehensively identify information from a range of suitable sources and makes exceptional use of appropriate information/appraises relevancy of information and can combine information to make coherent decisions
	The student makes well founded judgements/takes appropriate action/seeks clarification and guidance and is able to use that to reflect on real life situations in a lab science role
	The student demonstrates extensive knowledge of relevant concepts and techniques reflected in a lab science role and precisely applies this across a variety of contexts and tackles unstructured problems that have not been seen before, using their knowledge to analyse and find suitable solutions to the problems
	The student can thoroughly examine data/information in context and apply appropriate analysis in confirming or refuting conclusions and carrying out further work to justify strategies for solving problems, giving concise explanations for their reasoning

Technical: food sciences grade descriptors

Grade	Demonstration of attainment
Pass	The evidence is logical but displays minimal knowledge in response to the demands of the brief.
	The student makes some use of relevant knowledge and understanding of how it informs practices of the sector and demonstrates a limited understanding of perspectives or approaches associated with food science and food product development processes.
	The student makes adequate use of facts/theories/approaches/concepts/data and attempts to demonstrate breadth and depth of knowledge and understanding.
	The student is able to identify some information from appropriate sources and makes use of appropriate information/appraise relevancy of information and can combine information to make decisions and recommendations.
	The student makes minimal judgements/takes appropriate action/seeks clarification with guidance and is able to make limited progress towards solving non-routine problems in real life situations.
	The student attempts to demonstrate skills and knowledge of the relevant concepts and techniques reflected in a food science and/or food product development role and generally applies this across different contexts.
	The student shows adequate understanding of problems that have not been seen before, using limited knowledge to find solutions to problems and make justification for strategies for solving problems, explaining their reasoning.
Distinction	The evidence is precise, logical and provides a detailed and informative response to the demands of the brief.
	The student makes extensive use of relevant knowledge and has extensive understanding of the practices of the sector and demonstrates an understanding of the different perspectives/approaches associated with food science and food development processes.
	The student makes decisive use of facts/theories/approaches/concepts/data, demonstrating extensive breadth and depth of knowledge and understanding and selects highly appropriate skills/techniques/methods.
	The student is able to comprehensively identify information from a range of suitable sources and makes exceptional use of appropriate information/appraises relevancy of information and can combine information to make coherent decisions.

Grade	Demonstration of attainment
	The student makes well founded judgements/takes appropriate action/seeks clarification and guidance and is able to use that to reflect on real life situations in a food science and/or food development role.
	The student demonstrates extensive knowledge of relevant concepts and techniques reflected in a food science and/or food development role and precisely applies this across a variety of contexts and tackles unstructured problems that have not been seen before, using their knowledge to analyse and find suitable solutions to the problems.

Technical: metrology sciences grade descriptors

Grade	Demonstration of attainment
Pass	The evidence is logical but displays minimal knowledge of basic metrological content in response to the demands of the brief.
	The student makes some use of relevant knowledge and understanding of how metrology informs practices in many sectors and demonstrates a limited understanding of perspectives or approaches associated with basic measurement tasks and principles.
	The student makes adequate use of facts/theories/approaches/concepts and attempts to demonstrate breadth and depth of metrological knowledge and understanding.
	The student is able to identify some metrological information from appropriate sources and makes use of appropriate information/appraise relevancy of information and can combine information to make decisions.
	The student makes minimal judgements/takes appropriate action/seeks clarification with metrological sources of guidance and is able to make limited progress towards solving non-routine problems in real life measurement activities/situations.
	The student attempts to demonstrate metrological skills and knowledge of the relevant concepts and techniques reflected in a measurement services role and generally applies this across different contexts and measurement skill sets.
	The student shows adequate understanding of unstructured measurement-related problems that have not been seen before, using limited knowledge to find solutions to problems and make justification for strategies for solving problems, explaining their reasoning.
Distinction	The metrological evidence is precise, logical and provides a detailed and informative response to the measurement related demands of the brief.
	The student makes extensive use of relevant knowledge and understanding of how metrology informs practices in many sectors and demonstrates an understanding of perspectives or approaches associated with basic measurement tasks and principles.
	The student makes decisive use of facts/theories/approaches demonstrating extensive breadth and depth of metrological knowledge, understanding and selects highly appropriate skills/techniques/methods.

Grade	Demonstration of attainment
	The student is able to comprehensively identify metrological information from a range of suitable sources and makes exceptional use of appropriate information/appraise relevancy of information and can combine information to make coherent measurement decisions.
	The student makes well founded judgements/takes appropriate action/seeks clarification with metrological sources of guidance and is able to use that to reflect on real life measurement activities/situations.
	The student demonstrates extensive metrological skills and knowledge of the relevant concepts and techniques reflected in a measurement services role and precisely applies this across a variety of contexts and tackles unstructured problems that have not been seen before, using their knowledge and measurement skill sets to analyse and find suitable solutions to the measurement problems.
	The student can thoroughly examine metrological data/information in context and apply appropriate analysis in confirming or refuting conclusions and carrying out further work to justify strategies for solving problems, giving concise explanations for their reasoning.

* “threshold competence” refers to a level of competence that:

- signifies that a student is well placed to develop full occupational competence, with further support and development, once in employment
- is as close to full occupational competence as can be reasonably expected of a student studying the TQ in a classroom-based setting (for example, in the classroom, workshops, simulated working and (where appropriate) supervised working environments)
- signifies that a student has achieved at least a pass in relation to the relevant occupational specialism component

U grades

If a student is not successful in reaching the minimum threshold for the core and/or occupational specialism component, they will be issued with a U grade.

Awarding the final grade for each component of the TQ

Each core component’s marks will be combined to form the overall grade for the core component.

The marks from the occupational specialism assignment will form the occupational specialism grade.

These grades will be submitted to the Institute for Apprenticeships and Technical Education who will issue an overall grade for the T Level TQ.

Calculating the final grade for the T Level programme

To be awarded an overall T Level grade, a student must successfully pass both components of their TQ, complete an industry placement, and meet any other requirements set by the Institute's T Level panel. The overall grade for the T Level programme is based on a student's performance in the TQ and would reflect:

- the comparative size of the core component and the occupational specialism
- the grades achieved for the core component (A* to E) and the occupational specialism (Pass/Merit/Distinction)

This grading approach also makes it possible to recognise exceptional achievement, through the award of an overall distinction* grade for students that achieve an A* for the core component and a distinction in their occupational specialism.

The following table shows how the core component and occupational specialism grades are aggregated to produce an overall result for this T Level programme:

- Core component 40%/Occupational specialism 60%:

	Occupational specialism grade			
Core component grade		**Distinction**	**Merit**	**Pass**
	A*	Distinction*	Distinction	Distinction
	A	Distinction	Distinction	Merit
	B	Distinction	Merit	Merit
	C	Distinction	Merit	Pass
	D	Merit	Merit	Pass
	E	Merit	Pass	Pass

Overall T Level grade

This matrix shows the overall TQ grade when both components are combined.

For example, if a student achieved a B grade in the core component assessment (indicated by the vertical column on the left) and a merit grade in the occupational specialism assessment (indicated by the horizontal top row), they would achieve a merit grade for the overall TQ:

	Occupational specialism grade			
Core component grade		**Distinction**	**Merit**	**Pass**
	A*	Distinction*	Distinction	Distinction
	A	Distinction	Distinction	Merit
	B	Distinction	Merit	Merit
	C	Distinction	Merit	Pass

Merit

	D	Merit	Merit	Pass
	E	Merit	Pass	Pass

Section 3: General competency framework

General competency framework

Technical qualifications are required to contain sufficient and appropriate English, mathematics and digital content to help students reach threshold competence in their chosen occupational specialism. As such, a framework of competencies has been developed which awarding organisations are required to use and embed in all technical qualifications (where appropriate):

General English competencies	General mathematics competencies	General digital competencies
GEC1. Convey technical information to different audiences **GEC2. Present information and ideas** **GEC3. Create texts for different purposes and audiences** **GEC4. Summarise information/ideas** **GEC5. Synthesise information** **GEC6. Take part in/lead discussions**	**GMC1. Measuring with precision** **GMC2. Estimating, calculating and error spotting** **GMC3. Working with proportion** **GMC4. Using rules and formulae** **GMC5. Processing data** **GMC6. Understanding data and risk** **GMC7. Interpreting and representing with mathematical diagrams** **GMC8. Communicating using mathematics** **GMC9. Costing a project** **GMC10. Optimising work processes**	**GDC1. Use digital technology and media effectively** **GDC2. Design, create and edit documents and digital media** **GDC3. Communicate and collaborate** **GDC4. Process and analyse numerical data** **GDC5. Be safe and responsible online** **GDC6. Controlling digital functions**

The following table identifies the English, mathematics and digital competencies that we have embedded in the skills throughout this technical qualification. The tutor may also teach competencies that are not listed here, where they naturally occur, but these will not be subject to assessment.

English, mathematics and digital competencies relevant to the health and science: science qualification

General competencies	Core skills	Technical: laboratory sciences	Technical: food sciences	Technical: metrology sciences
English				
GEC1	CS1.1, CS6.1	S1.70, S2.23	S1.78, S4.10	S1.61, S3.11
GEC2	CS2.1, CS6.1	S2.29	S2.26, S2.33, S4.10	S3.11
GEC3	CS1.1, CS6.1		S1.79, S4.10	
GEC4	CS2.1, CS7.1	S2.16	S2.33	S1.60
GEC5	CS2.1		S2.26	
GEC6	CS6.1	S2.26, S3.11	S1.83, S3.11	S1.65, S4.5, S4.6
Mathematics				
GMC1		S1.75	S1.81, S4.9	S2.9
GMC2	CS4.1	S3.14		
GMC3		S1.77	S2.27	
GMC4				S1.52
GMC5	CS4.1		S2.34, S4.7, S4.8	
GMC6	CS7.1	S2.23	S2.26, S4.9, S4.10	S3.8, S4.4
GMC7				S3.11
GMC8	CS1.1, CS6.1	S1.75, S2.22	S4.10	S3.10
GMC9			S2.31	S1.59

General competencies	Core skills	Technical: laboratory sciences	Technical: food sciences	Technical: metrology sciences
GMC10	CS5.1		S3.9	S4.7
Digital				
GDC1		S1.87, S2.23, S3.8	S1.79, S3.11	
GDC2	CS6.1	S2.23		S1.61
GDC3	CS3.1	S3.11		S1.65
GDC4		S1.87, S2.20, S2.22, S3.13	S1.76, S2.34, S4.7, S4.8	S3.5
GDC5		S2.16	S4.7	S3.5
GDC6				

Section 4: TQ content

Introduction

This section provides details of the structure and content of this qualification.

Qualification structure

The Level 3 Technical Qualification (TQ) in Science has 2 components:

- core component, comprising core knowledge and core skills
- occupational specialism components:
  - technical: laboratory sciences
  - technical: food sciences
  - technical: metrology sciences

This combined content indicates the relevant knowledge and understanding of concepts, theories and principles relevant to all occupations within science. The knowledge and skills are all externally assessed through 2 written examinations and an ESP.

The occupational specialisms are divided into performance outcomes, each of which indicates the knowledge and skills required to enable students to achieve threshold competence in the chosen occupational specialism. These performance outcomes are all externally assessed through synoptic assignments, in which the student will be expected to demonstrate required knowledge and skills.

Delivery of content

The content does not have to be taught in a linear fashion. However, providers must pay attention to when the assessments are due to take place to ensure that all of the mandatory content (all elements and performance outcomes) has been taught to students prior to sitting the assessments.

What you need to teach

This section contains all of the mandatory teaching content that underpins the knowledge and skills. The content provided in some cases may not be exhaustive, and providers may wish to teach beyond what is included in the specification in order to support the student's knowledge and understanding.

English, mathematics and digital competencies have been integrated and contextualised within the skills, throughout the qualification content. These competencies are mandatory and subject to assessment. The tutor may also teach competencies that are not listed in this specification, but these will not be subject to assessment.

Core component section A: the health and science sector

A1 Working within the health and science sector

What you need to teach

The student must understand:

A1.1 The purpose of organisational policies and procedures in the health and science sector, including:

- equality, diversity and inclusion policy:
  - complying with legislation
  - ensuring equality
  - eliminating discrimination
- safeguarding policies:
  - ensuring the protection from harm of individuals, including those working within the organisation and visitors
- employment contracts:
  - setting out employment conditions, rights, responsibilities and duties
- performance reviews:
  - evaluating work performance against standards and expectations
  - facilitating feedback to improve
  - providing opportunities to raise concerns or issues
  - contributing to continuing professional development (CPD)
- disciplinary policy:
  - setting and maintaining expected standards of work and conduct
  - ensuring consistent and fair treatment
  - establishing a sequence for disciplinary action
- grievance policy:
  - providing opportunities for employees to confidentially raise and address grievances
  - establishing a sequence for raising grievances

A1.2 The importance of adhering to quality standards, quality management and audit processes within the health and science sector:

- ensuring consistency
- maintaining health and safety

What you need to teach

- monitoring processes and procedures
- facilitating continuous improvement
- facilitating objective, independent review

A1.3 The key principles of ethical practice in the health and science sectors:

- autonomy and informed consent
- truthfulness and confidentiality (for example, ensuring validity of outcomes)
- beneficence
- nonmaleficence
- justice (for example, fairness, equality and respect for all)

A1.4 The purpose of following professional codes of conduct:

- clarifies missions, values, principles and standards that everyone must adhere to by:
  - outlining expected professional behaviours and attitudes
  - outlining rules and responsibilities within individual organisations
  - promotes confidence in the organisation

A1.5 The difference between technical, higher technical and professional occupations in health, healthcare science and science, as defined by the Institute for Apprenticeships and Technical Education Occupational Maps:

- technical: skilled occupations that a college leaver or an apprentice would be entering, typically requiring qualifications at levels 2/3
- higher technical: require more knowledge and skills acquired through experience in the workplace or further technical education, and typically require qualifications at levels 4/5
- professional: occupations where there is a clear career progression from higher technical occupations, as well as occupations where a degree apprenticeship exists

A1.6 Opportunities to support progression within the health and science sector:

- undertaking further/higher education programmes
- undertaking apprenticeship/degree apprenticeship
- undertaking continuing professional development (CPD)
- gaining professional registration
- undertaking an internship
- undertaking a scholarship

A2 The science sector

What you need to teach

The student must understand:

A2.1 Factors that contribute to the diversity of employers/organisations within the science sector:

- size of employer/organisation
- funding streams
- commercial status
- working environments (for example, laboratory, manufacturing plants, field work)
- geographic location

A2.2 The diversity of work undertaken in different job roles within the science sector:

- research and development
- data analysis
- clinical testing/trials
- quality control
- quality assurance
- product development
- scientific publishing
- manufacturing

A2.3 Possible employers and job roles that require the application of science in non-science sectors:

- communication and outreach (for example, science journalist, publisher, public relations, science communication)
- education (for example, teacher, museum education officer)
- policy (for example, officer/administrator of a scientific professional body/trade association)
- public service (for example, civil servant)

A2.4 The difference between a job description and a person specification:

- job description: a detailed description of the individual roles, including responsibilities, objectives and requirements
- person specification: a profile of the necessary skills and attributes

A2.5 How individual roles fit into teams within an organisation:

- whom you work with (for example, colleagues/teams/departments, as seen in an organigram)
- whom you report to (for example, managers/supervisors)

What you need to teach
• whom you manage (for example, direct reports, trainees) **A2.6 The individual's responsibilities in relation to the wider team:** • health and safety (for example, storing, handling and disposing of hazardous substances) • security (for example, complying with access requirements, using technology safely and securely) • organisational policies and procedures (for example, following standard operating procedures (SOPs)) • deadlines (for example, completing work to schedule) • departmental dependencies (for example, preparing samples for colleagues to analyse) **A2.7 The principles of good laboratory practice (GLP):** • quality, reliability and integrity of studies • reporting of verifiable conclusions • traceability of data **A2.8 The principles of good manufacturing practice (GMP) in ensuring that products:** • are of consistent high quality • are appropriate for their intended use • meet the requirements of the product specification **A2.9 The key principles of continuous improvement in relation to scientific tasks:** • reviewing costs (for example using new reagents or products to lower expenditure) • standardising and optimising procedures (for example using new technologies/outsourcing) • using the evaluation cycle: o plan: identify potential problems and plan required improvements o do: implement potential solution o check: analyse the results o act: review the solution and retest if necessary • capturing data at each stage of production (to feed into the evaluation cycle) **A2.10 The difference between quality assurance and quality control:** • quality assurance procedures are designed to prevent errors and defects in products or processes • quality control focuses on the identification of errors and defects in completed products or processes **A2.11 How organisations in the science sector ensure compliance with internal and external regulations:** • ensuring that all individuals follow SOPs

What you need to teach

- complying with requirements for internal and external audits, including reporting to regulators as appropriate
- making sure that staff are adequately trained (for example, knowing the relevant legislation/licences that apply to a specific occupation)

A2.12 How regulatory controls apply in different working environments within the science sector in relation to:

- type and level of required personal protective equipment (PPE)
- standards of health and safety and housekeeping
- requirements for mandatory training to comply with guidance or legislation, refreshed as required
- requirements for disposal of waste
- requirements for health screening and inoculation
- controls specified within SOPs

A2.13 Factors that may have an impact on the commercial activities (for example, pharmaceuticals, cosmetics, manufacturing, services) of science organisations:

- government priorities/policies (for example, food labelling, environmental policies)
- public perception and media influence
- funding streams (for example, changes to private/public funding)
- availability of materials (for example, shortage of feed stocks)
- market demand (for example, increase in vegan food production)
- cost-effectiveness (for example, cost of research, development and production)
- environmental concerns (for example, reducing waste, reducing carbon footprint)

A2.14 The importance and impact of innovation in the science sector:

- fosters economic development (for example, development of genetically modified crops)
- solves large-scale problems (for example, alternative energy)
- improves healthcare (for example, more efficient diagnoses, through the use of Artificial Intelligence (AI), genomic sequencing and genetic tests to personalise treatments)
- develops new products (for example, new drugs, composite materials, for example, graphene)
- enables new scientific discoveries (for example, genome editing, bioinformatics, computational biology)

A3 Health, safety and environmental regulations in the health and science sector

What you need to teach

The student must understand:

A3.1 The purpose of the following legislation and regulations in the health and science sector:

- Health and Safety at Work etc. Act 1974:
  - purpose: defines employers' responsibilities to protect the health, safety and welfare at work of employees and members of the public, and defines employees' duties to protect themselves and each other
- Management of Health and Safety at Work Regulations 1999:
  - purpose: aims to reduce the number and severity of accidents in the workplace, through assessment and management of risk
- Control of Substances Hazardous to Health (COSHH) Regulations 1994 and subsequent amendments 2004:
  - purpose: requirement for employers to control substances hazardous to health by reducing or preventing employees' exposure to these substances
- Personal Protective Equipment at Work (Amendment) Regulations 2022 :
  - purpose: defines employers' responsibilities to provide appropriate personal protective equipment (PPE) to reduce harm to employees, visitors and clients. This can include safety helmets, masks, goggles and gloves
- Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR):
  - purpose: defines employers' duties to report serious workplace accidents, occupational diseases and specified dangerous occurrences ('near misses')
- Environmental Protection Act 1990:
  - purpose: makes provision for the improved control of pollution to the air, water and land by regulating the management of waste and the control of emissions
- Special Waste Regulations 1996:
  - purpose: measures relating to the regulation and control of the transit, import and export of waste (including recyclable materials), the prevention, reduction and elimination of pollution caused by waste and the requirement for an assessment of the impact on the environment of projects likely to have significant effects on the environment
- Hazardous Waste Regulations 2005:
  - purpose: controls the storage, transport and disposal of hazardous waste (waste stream) to ensure it is appropriately managed and any risks are minimised
- Waste Electrical and Electronic Equipment Regulations (WEEE) 2013 :

What you need to teach

- purpose: to reduce the amount of electronic and electrical equipment incinerated or sent to landfill sites. Places onus on all businesses to correctly store and transport electrical waste

- Regulatory Reform (Fire Safety) Order (RRO) 2005:
  - purpose: to reduce death, damage and injury caused by fire by placing legal responsibilities on employers to carry out a fire risk assessment. All organisations are required to have procedures for evacuation in the event of a fire
- Manual Handling Operations Regulations 1992 (as amended):
  - purpose: requires employers to assess and minimise the risk to employees' health involved in the manual handling, moving and positioning of an object, person or animal and workplace ergonomics
- Health and Safety (Display Screen Equipment) Regulations 1992:
  - purpose: defines employers' responsibilities in carrying out risk assessments of workstations used by employees, including the use of display screen equipment, to minimise identified risks

A3.2 How to assess and minimise potential hazards and risks, including specific levels of risk, by using the Health and Safety Executive's 5 Steps to Risk Assessment:

- step 1: identifying the hazards
- step 2: deciding who might be harmed and how
- step 3: evaluating the risks and deciding on precautions
- step 4: recording findings and implementing them, including completing risk assessment documentation
- step 5: reviewing your assessment and updating if necessary

A3.3 How health and safety at work is promoted:

- encouraging individuals to take reasonable care of their own and others' safety
- modelling good practice (for example, washing hands and wearing appropriate PPE)
- following organisational policies and standard operating procedures (SOPs), including site-specific emergency procedures
- ensuring that there is clearly visible information and guidance
- following processes for recording and reporting issues and concerns
- maintaining equipment and removing faulty equipment
- following correct manual handling techniques
- ensuring working environments are clean, tidy and hazard free
- appropriately storing equipment and materials
- completing statutory training

What you need to teach
A3.4 How to deal with situations that can occur in a health or science environment that could cause harm to self or others (for example, spillage of hazardous material): • following organisational health and safety procedures • keeping oneself and others safe, including evacuation as appropriate • securing the area • reporting and/or escalating as appropriate • debriefing and reflecting on the root causes, to prevent the situation from recurring

A4 Application of safety, health and environmental practices in the workplace

What you need to teach
The student must understand: **A4.1 The purposes of Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) guidelines in relation to the use of chemicals in the science sector:** • to provide a high level of protection of human health and the environment from the use of chemicals • to make the people who place chemicals on the market (manufacturers and importers) responsible for understanding and managing the risks associated with their use • to promote the use of alternative methods for the assessment of the hazardous properties of substances (for example, quantitative structure-activity relationships and read across) **A4.2 How the Environmental Protection Act 1990 relates to practices in scientific workplaces, including:** • waste management collection, treatment and disposal • containment and uses of genetically modified organisms (for example, risk assessment, inspection) **A4.3 The consequences of breaching environmental legislation, including:** • enforcement notices • business closures • clean-up orders • fines • prison sentences • damage to reputation **A4.4 The purpose of the Control of Major Accident Hazards Regulations 2015 (COMAH):**

What you need to teach
• to prevent or limit the consequences of major accidents involving dangerous substances and to mitigate the effects on people and the environment of those that do occur **A4.5 The COSHH definition of a biohazard (biological agent):** • a microorganism, cell culture or human endoparasite, whether or not genetically modified, which may cause infection, allergy, toxicity, or otherwise create a hazard to human health **A4.6 The 4 hazard groups in relation to biohazards (biological agents):** • category 1: unlikely to cause human disease • category 2: can cause human disease and may be a hazard to employees, unlikely to spread to the wider population and there are usually effective vaccines or other treatments available • category 3: can cause human disease and may be a serious hazard to employees, it may spread to the wider population but there are usually effective vaccines or other treatments available • category 4: causes severe human disease and is a serious hazard to employees, it is likely to spread to the wider population and there are usually no effective vaccines or other treatments available **A4.7 The potential implications of not adhering to COSHH regulations when dealing with biohazards (biological agents):** • risks to employees' health (short and long-term effects of infection) • risks to the wider population (disease spread) • risks to the environment (vegetation, water supply, soil) **A4.8 Containment measures that are used in relation to the 4 hazard groups:** • levels of personal protective equipment (PPE) • laboratory location, access and controls • required laboratory facilities (for example, HEPA filters, showers) • complying with specific waste disposal regulations (for example, chemical decontamination or autoclaving **A4.9 The procedures to be followed when working with regulated substances (as defined by Control of Poisons and Explosive Precursors Regulations 2015) and controlled drugs (as defined in the Misuse of Drugs Act 1971 and the Misuse of Drugs Regulations 2001):** • undertaking health and safety training • ensuring safe and secure storage, including storage requirements and restricting personnel access • undertaking inventory record-keeping • following sign-in/sign-out protocols **A4.10 The purpose of pressurised clean rooms and localised extraction and ventilation:** • protecting individuals and materials against contamination

What you need to teach
• protecting the external environment against contamination **A4.11 The purpose of the Control of Noise at Work Regulations 2005:** • specifies the level of noise at which employers must provide hearing protection when employees are exposed to noise on a daily or weekly basis (85 decibels) **A4.12 How employers can protect employees from noise:** • generating and ensuring compliance with risk assessments • providing PPE (for example, ear defenders) • providing regular health checks for employees, (for example, free hearing checks) **A4.13 Employers' responsibilities in relation to the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR):** • find out what dangerous substances are in their workplace and what the risks are • put control measures in place to either remove those risks or, where this is not possible, control them • put controls in place to reduce the effects of any incidents involving dangerous substances • prepare plans and procedures to deal with accidents, incidents and emergencies involving dangerous substances • make sure employees are properly informed about and trained to control or deal with the risks from the dangerous substances • identify and classify areas of the workplace where explosive atmospheres may occur and avoid ignition sources (from unprotected equipment, for example) in those areas **A4.14 How to work safely in high risk environments or with substances that can cause harm to health, such as gases, explosive environments, lasers or ionising radiation:** • following risk assessments • following SOPs • adhering to regulations • undertaking appropriate training • wearing appropriate PPE • reporting all accidents, however minor **A4.15 The purpose of the Control of Electromagnetic Fields at Work Regulations 2016:** • specifies requirements for minimising risks of electromagnetic fields **A4.16 The consequences of using devices such as radios and mobile phones in the proximity of specific equipment and instrumentation:** • interference

What you need to teach
• effect on reliability of results • damage to the equipment (both the scientific instrumentation and the devices) **A4.17 How to decontaminate a range of common scientific equipment and substances:** • sterilisation (for example, autoclave, antisepsis, ultraviolet) • disinfection (for example, using hydrogen peroxide) • incineration (for example, clinical waste and sharps) • dissolution (for example, rinsing with a solvent in order to remove solid contaminants) • neutralisation (for example, spillage kits) **A4.18 The purpose of material safety data sheets and associated hazard and precautionary codes:** • contains the information necessary to allow employers to do a risk assessment, as required by the Control of Substances Hazardous to Health Regulations (COSHH), when handling certain chemicals **A4.19 The importance of ensuring that material data sheets are kept up to date, in line with relevant legislation, when:** • new hazard information, or information that may affect risk management measures, becomes available • a substance or mixture is classified according to the classification, labelling and packaging of substances and mixtures (CLP) Regulation • an authorisation under REACH is granted or refused • a restriction under REACH has been imposed

A5 Managing information and data within the health and science sector

What you need to teach
The student must understand: **A5.1 A range of methods used to collect data:** • focus groups • open question surveys/interviews • observation • public databases • journals and articles • carrying out practical investigations

What you need to teach
• closed question surveys • official statistics **A5.2 The considerations to make when selecting a range of ways to collect and record information and data:** • data type: qualitative or quantitative data (for example, laboratory results versus patient history) • the most appropriate method of data collection (manual versus automated) • the most appropriate way to present the information or data (for example, graphs, charts and tables) • depth of analysis required spreadsheets and databases • the intended audience • storage method (for example, digital or paper-based) **A5.3 The importance of accuracy, attention to detail and legibility of any written information or data in order to:** • comply with legal requirements (for example, UK General Data Protection Regulations (UK GDPR)) • limit liability (for example, ensuring anonymity and informed consent) • provide an accurate account of events • inform integrated working and data sharing • ensure accurate analysis of findings • support with audit trails • ensure reproducibility of results **A5.4 The strengths and limitations of a range of data sources when applied in a range of health and science environments:** • results of investigations: o strengths (for example, consistent results produced under controlled conditions) o limitations (for example, possibility of over-extrapolation) • patient history: o strengths (for example, provides detailed information over time) o limitations (for example, may not be accurate or complete) • patient test results: o strengths (for example, laboratory and test accreditation ensures standardisation) o limitations (for example, results are open to subjectivity) • published literature:

What you need to teach

- strengths (for example, peer review improves validity)
- limitations (for example, could be based on small-scale/biased research or come from fraudulent sources)

- real-time observation:
  - strengths (for example, immediate data)
  - limitations (for example, possible subjectivity)

A5.5 How new technology is applied in the recording and reporting of information and data:

- AI/machine learning (for example, use of bioinformatics tools to analyse and process large data sets)
- mobile technology and applications (for example, to capture health informatics and location data - track and trace)
- cloud-based systems (for example, use of electronic health records (EHRs) enables easier data sharing for further analysis)
- digital information management systems (for example, to enable a digital audit trail)
- data-visualisation tools (for example, to consolidate multiple data sources for presentation)

A5.6 How personal information is protected by data protection legislation, regulations and local ways of working/organisational policies:

- Data Protection Act 2018:
  - controls the use of personal information by organisations, businesses or the Government
- UK GDPR:
  - provides a set of principles with which any individual or organisation processing sensitive data must comply
- local ways of working/organisational policies to ensure compliance with legislation and regulations, depending on the sector:
  - ensuring that data is stored securely (electronically or paper-based)
  - restricting the use of mobile devices in order to ensure confidentiality
  - preventing potential conflicts of interest

A5.7 How to ensure confidentiality when using screens to input or retrieve information or data:

- logging out of a system when leaving the screen
- protecting login and password information
- being aware of the surroundings
- using secure internet connections
- using privacy screen filters where appropriate

What you need to teach

A5.8 The positive use of, and restrictions on the use of, social media in health and science sectors:

- positive uses:
  - awareness campaigns/disseminating information
  - correcting misinformation
  - crisis communication/monitoring
  - monitoring public health
  - data gathering
  - establishing support networks
  - recruitment
  - marketing
- restrictions:
  - not posting sensitive/personal information about oneself or others on social media, in line with an organisation's code of conduct
  - maintaining professional boundaries when interacting with individuals external to the organisation
  - sharing inaccurate/non-evidence-based information

A5.9 The advantages and risks of using IT systems to record, retrieve and store information and data:

- advantages:
  - ease of access
  - ease of sharing and transferring data
  - speed of data analysis
  - security (for example, password protected)
  - standardisation of data
  - enables continuous and/or real-time monitoring of data
  - cost and space saving
  - enables integrated working and supports safeguarding practices
- risks:
  - security breaches - accidental or malicious
  - potential for corruption of data
  - lack of access due to system failure

A5.10 How security measures protect data stored by organisations, by:

What you need to teach
• controlling access to information (for example, levels of authorised logins and passwords) • allowing only authorised staff into specific work areas • requiring regular and up-to-date staff training in complying with data security • making regular back-ups of files • using up-to-date cyber security strategies to protect against unintended or unauthorised access • ensuring that back-up data is stored externally (for example, cloud-based or separate servers) **A5.11 What to do if information is not stored securely:** • secure the information where possible • record and report the incident to the designated person, following organisational policies and procedures

A6 Data handling and processing

What you need to teach
The student must understand: **A6.1 The stages of data handling and processing:** • collect • record • analyse • interpret **A6.2 The difference between qualitative and quantitative data:** • qualitative - subjective, categorical data that approximates and characterises (for example, focus groups) • quantitative - objective, measurable data that can be defined as a value (for example, official statistics) **A6.3 The advantages and limitations of different methods of data storage and recording:** • physical lab notebooks: ○ advantages: ▪ safe from computer failure ▪ cannot be accessed by external hackers ▪ can be used in conditions that would be unsuitable for computers/tablets

What you need to teach

- limitations:
  - can be accessed by anyone in the workplace
  - can be altered without changes being tracked
  - cannot be easily shared or searched
  - can be lost, damaged and degraded over time
- laboratory information management systems LIMs - (electronic filing cabinet):
  - advantages:
    - enables data visualisation and reports
    - data is easily shared
    - can be searched
    - can be accessed remotely
    - cloud storage ensures safety from physical damage
    - highlights errors in the system or the data
  - limitations:
    - can be accessed by hackers, where IT security is not robust
    - vulnerable to technology failure
    - expensive
    - requires maintenance
    - requires an internet connection for synchronising

A6.4 The purposes of software systems used for data capture in scientific settings:

- capturing data specific to each scientific setting
- sharing with other scientists/stakeholders as appropriate
- securely storing commercially sensitive data
- enabling easy analysis and interpretation

A6.5 The difference between systematic and random data errors:

- systematic errors are consistent errors caused by flawed design, execution of experiments, or problems with equipment
- random errors are caused by unpredictable or unknown changes during an experiment (for example, interference on electronic equipment)

A6.6 How to minimise errors occurring in a scientific setting:

- using controlled variables

What you need to teach
• staff training and monitoring • maintenance and calibration of equipment • correctly storing materials • using automated processes • good experimental planning **A6.7 The different methods of data processing and analysis in science environments:** • tabulating raw data • using specialist software to analyse large data sets • graphical/statistical analysis • identifying trends in the data • drawing conclusions if appropriate **A6.8 Ways to present data in the appropriate format, including:** • table • scatter graph • line graph • bar chart • box and whisker plot • flow charts **A6.9 How to carry out the following statistical techniques when analysing data and their purpose :** • mean and median • standard deviation - to measure the dispersion of a set of values from the mean • range - to determine the difference between the lowest and highest values • Chi Square test - to test the significance of the difference between observed and expected results • T-test - to determine if there is a significant difference between the means of 2 groups • Spearman’s rank - to assess the correlation between 2 variables **A6.10 How to review data and make decisions based on that review:** • interpreting the statistical analysis against the original hypothesis/performance criteria • comparing data with predicted/similar results in published work • checking tolerance levels

What you need to teach
• deciding on next steps (for example, collection of more data, publishing, sharing results with the client) **A6.11 The consequences of bias in data analysis:** • inaccurate findings inferred from the results • wasted time and resources • damage to reputation • risks to health and safety **A6.12 How to prevent or reduce bias in data evaluation:** • ensuring sufficient sample size and appropriate sampling techniques • comparing to known standards and literature values • sending out results for peer review • using critical experts to independently review the data • blind analysis • using informatics tools to analyse data **A6.13 Links between sample size and effective statistical analysis:** • sample size determination is often constrained by factors such as cost, time, availability of samples and ethical considerations • sample size needs to be sufficient to provide adequate statistical power to reduce risks of error when accepting or rejecting an experimental hypothesis • different statistical analysis techniques take account of sample size by specifying the accuracy with which the results are returned **A6.14 How to order numbers by relative size in a data set, using:** • powers of 10 • decimal places **A6.15 How to ensure proportionality while scaling up or down quantities in a formulation:** • keeping the same factor (for example, multiply all quantities by a factor of 10)

A7 Ethics

What you need to teach

A7.1 The key aims of ethical scientific practices as outlined in 'Rigour, Respect, Responsibility: a Universal Ethical Code for Scientists 2007':

- to foster ethical research
- to encourage active reflection among scientists on the implications and impact of their work
- to support communication between scientists and the public on complex and challenging issues

A7.2 How to demonstrate integrity in a scientific setting:

- maintaining high quality ethical and professional standards (for example, objectivity, clarity, reproducibility)
- following organisational codes of practice
- following regulatory guidance
- aspiring to excel, not just meet the minimum standards

A7.3 The purpose of codes of practice within organisations:

- defines how employees can remain compliant with policies or legislation

A7.4 The importance of respect in the workplace:

- promoting equality and supporting diversity
- minimising conflict and stress
- increasing productivity and job satisfaction
- inspiring individuals to be loyal to the organisation and each other

A7.5 How intellectual property (IP) rights apply to scientific settings:

- patents
- trademarks
- copyrights

A7.6 What may be considered as IP within the science sector:

- theories/ideas
- papers/research
- experimental results and design
- bespoke equipment
- anything with a potentially commercial application (for example, product/formulation/recipe, software, apps)

A8 Good scientific and clinical practice

What you need to teach

The student must understand:

A8.1 The principles of good practice in scientific and clinical settings:

- using standard operating procedures (SOPs)
- effectively managing calibration and maintenance of equipment and work areas
- effectively managing stock
- appropriately storing products, materials and equipment

A8.2 What a SOP is:

- a set of sequential steps or instructions designed to standardise the approach to a process or action

A8.3 Why it is important for everyone to follow SOPs:

- maintaining health and safety
- enabling consistency of approach
- meeting any legal or organisational requirements
- upholding professional standards
- demonstrating compliance for audit purposes

A8.4 How to access SOPs for a given activity:

- carrying out detailed index searches (for example, via intranet/manual)
- completing detailed staff induction and ongoing training
- ensuring the SOP is the most up-to-date version
- ensuring all relevant documentation has been completed and signed

A8.5 The potential impacts of not regularly cleaning and preparing work areas for use:

- risks to health and safety:
  - spread of infection
  - production of toxic/dangerous by-products
- invalid results:
  - contamination or cross-contamination (for example, environmental, samples, reagents, DNA)
- inefficient working practices:
  - leads to increased costs and timescales
- damage to equipment:
  - leads to increased costs and timescales

What you need to teach

A8.6 The potential impacts of not maintaining, cleaning and servicing equipment:
• risks to health and safety:
  ○ increased risk of injury
  ○ spread of infection
• invalid results:
  ○ contamination or cross-contamination (for example, environmental, samples, reagents)
• reduced function of equipment:
  ○ decreased lifespan of equipment
  ○ increased cost and timescales (for example, due to repair of equipment and equipment being out of service)
A8.7 Why it is important to calibrate and test equipment to ensure it is fit for use:
• ensuring accuracy and reliability of measurements
• prolonging the life of equipment
• meeting legal requirements
A8.8 How to escalate concerns if equipment is not correctly calibrated/unsuitable for intended use:
• taking the equipment out of action
• labelling the equipment as being out of use, if appropriate
• reporting concerns to the relevant person, in line with organisational policies and procedures
• recording concerns according to organisational procedures
A8.9 Why it is important to order and manage stock:
• ensuring sufficient supply of required consumables and materials
• ensuring that materials are used before their expiry date
• reducing the costs of excess stock
• improving efficiency
• improving productivity
• ensure safety of stock (bottles aren't damaged/degraded)
A8.10 The potential consequences of incorrectly storing products, materials and equipment:
• cross-contamination
• breakdown of limited stability products
• products exceeding expiry dates

What you need to teach
• loss of samples or degradation of reagents not stored at the correct temperature (-20°C, -4°C, 4°C or room temperature) • risks to health and safety (for example, spread of infection, release of dangerous chemicals, or heavy items not stored at correct height) • stock is difficult to locate • financial loss

A9 Scientific methodology

What you need to teach
The student must understand: **A9.1 The importance of experimental design and planning when undertaking scientific experiments in order to:** • manage time efficiently (for example, ensuring that the minimum required number of measurements is carried out) • ensure sufficient resources (for example, checking supplies of required reagents, availability of equipment and personnel) • ensure safety throughout the experiment (for example, completing a risk assessment) • address ethical considerations (for example, justifying the necessity of an experiment) • minimise errors (for example, calibrating equipment in advance) **A9.2 The importance of a hypothesis/performance criteria, in experimental design:** • defining outcomes that can be tested • deciding on variables: o independent o dependent o controls • clarifying the experiment's objective **A9.3 How the following planning methodologies contribute to successful experimental design:** • objective setting: defines the purpose and outputs required • critical path analysis: maps out the key tasks in order, including dependencies • financial forecasting: defines what is feasible for a given budget

What you need to teach
• risk management: assessing and managing risks for the workforce • time management: defines timescales and workflows **A9.4 How customer/client requirements may affect the scientific methodology by:** • defining timescales • setting a budget • specifying scale (for example, number of replicates and sample size) • specifying objectives **A9.5 How to provide results and recommendations in appropriate formats to customers/clients:** • answering the brief/research questions • tailoring language and technical information to the audience • selecting the most appropriate way of presenting data (for example, visualisations/infographics) • highlighting the commercial/business benefits for the customer/client **A9.6 How to access and critically evaluate scientific literature and research databases, taking into account:** • searching for relevant existing scientific research/literature: o selecting relevant databases o choosing key terms and phrases for which to search • the differences between primary and secondary sources: o primary sources: direct access to the original information (for example, journal articles) o secondary sources: an interpretation of information from a primary source (for example, commentary from a researcher) • age/relevance of literature • reliability of sources (for example, conflicts of interest, citations, impact factor) • reliability of data (sample sizes, collection method used) **A9.7 The principles that inform sampling techniques:** • avoiding bias • ensuring a large enough sample size to produce valid results • practical constraints (for example, timescales, costs) **A9.8 A range of techniques for measuring scientific subject matter at micro and macro scales:** • mass (for example, balances to different decimal places) • length (for example, eyepiece graticule, laser measure)

What you need to teach
• volume (for example, micro or graduated pipette) **A9.9 The need for reliable, verifiable, and accurate recording in order to ensure that:** • data or information is repeatable • data or information is relevant to the experimental purpose (valid recording) • data or information truly reflects the results obtained (accurate recording) **A9.10 How to use the following step-by-step process to isolate and solve problems or inconsistencies in scientific data:** • identify and define the problem • investigate and examine possible causes • decide on changes to be made • implement the changes • evaluate the impact and continue to monitor any changes **A9.11 How to evaluate a scientific methodology and make recommendations for improvement, including:** • reflecting on experimental design • assessing the reliability of methods, and precision, accuracy, repeatability and reproducibility of results • identifying areas for improvement • making recommendations for future improvement **A9.12 The purpose of International Organisation for Standardisation (ISO) standards in scientific settings:** • enables accredited laboratories to demonstrate competency and validity through collaborative testing • facilitates cooperation between organisations by generating wider acceptance of results • improves international trade as test reports and certificates can be accepted from one country to another without the need for further testing • specifies the general requirements for the competence to carry out tests and/or calibrations, including sampling

A10 Experimental equipment and techniques

What you need to teach
A10.1 Common causes of equipment and technical faults that may have an impact on scientific results:

What you need to teach

- user error
- setting-up errors
- poor maintenance (including calibration)
- electrical faults

A10.2 The requirements for positive and negative controls in identifying faults:

- positive control - produces a known result so can be used to ensure that any negative results are true negatives and not a result of an issue with equipment or reagents
- negative control - confirms that no other variable is responsible for positive results in the test

A10.3 Applications of the following equipment when undertaking scientific techniques:

- autoclaves: to decontaminate/sterilise equipment and some consumables
- centrifuges: to separate suspensions
- cryogenic equipment: to produce exceptionally low temperatures
- data loggers: for the collection, storing, and recording of data over a period of time
- digital (for example, mechanical) and non-digital (for example, volumetric) pipettes: to accurately measure and transfer solutions
- fume cupboards: as a safety measure to capture and remove airborne hazards
- glassware: to store, measure, transfer and collect reagents and samples
- glove boxes: to provide a contained and controlled environment (sealed atmosphere) for manipulating samples, substances, and objects
- incubators: to provide a controlled and accurately maintained environment (for example, temperature, humidity)
- microbiological equipment: to perform a range of microbiological techniques whilst maintaining an aseptic environment
- multimeter: a meter than can measure voltage, current and therefore resistance in a circuit
- pH meters: to measure pH (for example, how acidic or alkaline a substance is)
- refrigerators and freezers: to provide a controlled and accurately maintained temperature
- scientific balances: to accurately determine the mass of a sample, including small samples
- thermometer: to monitor temperature or temperature changes

A10.4 The appropriate techniques for handling a range of different substances (for example, solids, liquids and gases), including:

- referring to material safety data sheets (for example, for corrosive substances)
- using personal protective equipment (PPE) (for example, using gloves to handle phenol)

What you need to teach

- using equipment for safe handling (for example, using tongs to handle alkali metals)
- applying containment controls (for example, using a fume cupboard when producing any chlorine)
- procedures for dealing with compressed gases (for example, storing at the correct temperature)

A10.5 Appropriate equipment to measure accurate results for the following scales:

- kilo (for example, balance)
- milli (for example, analytical balance)
- micro (for example, micrometer)
- nano (for example, atomic clock)

A10.6 How to use a light microscope, including:

- preparing slides using different staining techniques (for example, Gram staining)
- altering magnification and focus
- setting scale, using an eyepiece graticule
- cell counting, using a haemocytometer

A10.7 The reasons for using aseptic techniques, including:

- to avoid contamination of products (for example, food production)
- to avoid transmission of disease (for example, from samples to individuals/animals)

A10.8 How to follow aseptic techniques:

- flaming equipment (for example, wire loop, necks of bottles and test tubes)
- transfer cultures/samples as quickly as possible with minimal exposure to the air
- holding bottles and tubes at an angle to prevent contamination
- sterilising tools (autoclaving, radiation, chemical sterilisation)
- working in a sterile air environment (for example, in a downflow cupboard, close to a blue flame Bunsen burner)
- refraining from contaminating any sterile objects by placing them on non-sterile surfaces
- not consuming food or drink
- following correct handwashing techniques
- donning and doffing suitable clothing and PPE
- preparing surfaces and equipment (for example, cleaning down surfaces and only having the necessary equipment available)
- minimising human traffic in the area
- reducing draughts by closing windows/doors

Core component section B: science concepts

B1 Core science concepts

What you need to teach

The student must understand:

Cells and tissues

B1.1 The 3 principles of cell theory:

- all living things are made up of one or more cells
- cells are the most basic unit of structure and function in all living things
- all cells are created by pre-existing cells

B1.2 The different types of cells that make up living organisms:

- eukaryotic cells (for example, plant, yeast, algae and animals)
- prokaryotic cells (for example, bacteria)

B1.3 The structure and function of the organelles found within eukaryotic cells including:

- cell-surface membrane
  - control of passage of substances into and out of the cell
  - site of antigens
- nucleus
  - contains chromosomes
- mitochondria
  - respiration producing adenosine triphosphate (ATP)
- ribosomes
  - protein synthesis / translation
- rough and smooth endoplasmic reticulum
  - protein synthesis and packaging
  - lipid synthesis and storage
- Golgi apparatus and Golgi vesicles
  - packaging of proteins for transport
- centrioles
  - involved with separation of chromosomes during cell division
- lysosomes

What you need to teach

- digestion / breakdown of worn out cell parts and invading microbes
- chloroplasts (in plants)
  - photosynthesis
- cell wall (in plants)
  - structure and protection
- cell vacuole (in plants)
  - store water and maintain internal hydrostatic pressure

B1.4 The similarities and differences between plant and animal cells in relation to the presence of specific organelles and their function:

- overall cell shape
- presence of the same organelles
- presence of different organelles for specialised functions (for example, chloroplasts)

B1.5 How eukaryotic cells become specialised in complex multi-cellular organisms:

- eukaryotic cells are specialised to perform particular functions
- specialisation occurs through differentiation from stem cells
- examples of specialised cells, such as different types of blood cell

B1.6 How prokaryotic cells differ from eukaryotic cells:

- they have cytoplasm that lacks membrane-bound organelles
- they have smaller ribosomes
- they have no nucleus; instead, they have a single circular DNA molecule that is free in the cytoplasm and is not associated with proteins
- they have a cell wall that contains murein/peptidoglycan, a glycoprotein
- they may have one or more plasmids
- they may have a capsule surrounding the cell
- they may have one or more simple flagella

Proteins

B1.7 The relationship between the structure, properties and functions of proteins:

- amino acids are the small molecules (monomers) from which all proteins are made
- amino acids contain NH_2 which is the amine group, COOH represents a carboxyl group and R represents a side chain
- there are twenty amino acids common in organisms, each differs by the side chain (R)

What you need to teach

- dipeptides are formed by the condensation of 2 amino acids
- polypeptides are formed by the condensation of many amino acids
- functional proteins, such as fibrous proteins or globular proteins, contain a number of polypeptide chains which will determine the shape and size and function

Carbohydrates

B1.8 The relationship between the structure, properties and functions of carbohydrates:

- monosaccharides are the small molecules (monomers) from which all larger carbohydrates are made (disaccharides and polysaccharides)
- glucose, galactose and fructose are common monosaccharides
- disaccharides are formed from 2 monosaccharides (for example, maltose and sucrose)
- polysaccharides are formed from many monosaccharide molecules
- as polysaccharides are such large molecules, they are usually insoluble which makes them suitable to carry out storage and support functions (for example, glycogen, starch and cellulose)

Lipids

B1.9 The relationship between the structure, properties and functions of lipids:

- lipids are a diverse group of substances which all contain carbon, hydrogen and oxygen
- they are generally insoluble in water
- the main groups of lipids are triglycerides (for example, fats and oils) and phospholipids
- the main role of phospholipids is in plasma membranes to provide flexibility and transport mechanisms
- other roles of lipids include providing an energy store, insulation and protection

Exchange and transport mechanisms

B1.10 How the surface area to volume ratio affects the process of exchange and gives rise to specialised systems:

- the surface area must be large in comparison to the volume for efficient exchange
- where the surface area is small compared to the volume, specialised exchange and transport mechanisms are required to maximise the rate of diffusion
- additional factors, such as diffusion distance, temperature and metabolic rate

B1.11 The principles of cellular exchange and the transport mechanisms which exist to facilitate this exchange:

- the structure of the cell surface membrane with reference to the fluid mosaic model
- passive transport through the cell surface membrane: diffusion, facilitated diffusion and osmosis

What you need to teach

- active transport through the cell surface membrane
- co-transport mechanisms

B1.12 The advantages of having specialised cells in relation to the rate of transport across internal and external membranes.

Genetics

B1.13 The purpose of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) as the carrying molecules of genetic information and the role they play in the mechanism of inheritance:

- DNA holds genetic information
- RNA transfers genetic information from DNA to the ribosomes where proteins are synthesised

B1.14 The relationship between the structure of DNA and RNA and their role in the mechanism of inheritance:

- nucleotides are the molecules (monomers) from which DNA and RNA are formed
- each nucleotide is formed from pentose, a nitrogen containing organic base and a phosphate group
- the components of a DNA nucleotide are deoxyribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or thymine
- the components of an RNA nucleotide are ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil
- a condensation reaction between 2 nucleotides forms a phosphodiester bond
- a DNA molecule is a double helix with 2 polynucleotide chains held together by hydrogen bonds between specific complementary base pairs
- an RNA molecule is a relatively short single stranded polynucleotide chain

B1.15 The function of complementary base pairing in forming the helical structure of DNA.

B1.16 The process and stages of semi-conservative replication of DNA:

- DNA is progressively unwound
- breakage of the hydrogen bonds between complementary bases
- this leaves 2 chains with unpaired bases
- each chain then acts as a guiding base (or template) for the building of a new strand
- role of DNA helicase and DNA polymerase in this process

B1.17 How this semi-conservative replication process ensures genetic continuity between generations of cells.

B1.18 The link between the semi-conservative replication process and variation:

- a mutation (spontaneous change in the DNA sequence) can lead to genetic variation

What you need to teach

B1.19 The difference between genetics and genomics:

- genetics focuses on the functioning and composition of single genes
- genomics focuses on the entire genetic material of an organism (including coding and non-coding DNA)

Microbiology

B1.20 The classification and characteristics (size of cell, type of cell, presence of organelles) of the following microorganisms:

- bacteria
- fungi
- parasites
- viruses

B1.21 The benefits of using the following microscopes when investigating microorganisms:

- light microscopes:
  - low cost
  - easy to use - requires little training
  - allows for examination of living microorganisms
- scanning electron microscopes:
  - higher resolution
  - reveals more surface detail
  - displays a 3D view of the surface
- transmission electron microscopes:
  - higher resolution
  - reveals internal structures
  - displays a 2D view of the inner surface

B1.22 How to calculate magnification from the size of the image and the size of the object:

- magnification = $\frac{\text{size of image}}{\text{size of object}}$

B1.23 The uses of differential staining techniques:

- Gram staining:
  - to identify Gram- and Gram+ bacteria
- Giesma staining:
  - to identify specific bacteria (for example, *Chlamydia trachomatis*) or parasites (malarial)

What you need to teach

- to identify any pathophysiology of blood cells
- haematoxylin and eosin staining:
  - staining human or animal tissue in order to give a differentiated image of the nuclear and cytoplasmic components of a cell

Immunology

B1.24 The nature of infection:

- a microorganism replicating inside the body, resulting in disease

B1.25 Pathogens (causative agents) of infection and examples of resulting diseases:

- bacteria (for example, chlamydia, gonorrhoea, tuberculosis)
- viruses (for example, common cold, mumps and measles)
- fungi (for example, yeast infection (thrush))
- prions (for example, Creutzfeldt-Jakob disease (CJD))
- protists (for example, malaria)
- parasites (for example, toxoplasmosis)

B1.26 The different ways in which pathogens (causative agents) may enter the body (for example, transmission routes):

- direct transmission:
  - physical contact with an infected person or contaminated surface (for example, skin-to-skin contact)
  - sharing of needles
  - unprotected sexual contact
  - airborne: pathogens (causative agents) is carried by dust or droplets in the air, can exist in the air for some time (for example, inhaling infected droplets)
- indirect transmission:
  - vehicle transmission (for example, ingesting infected food or water (faecal-oral)): blood from inanimate objects (for example, bedding)
  - being bitten by an infected ‘vector’ (for example, insect bites)

B1.27 How infectious diseases can spread amongst populations and communities:

- inadequate sanitation (for example, lack of access to clean water and inadequate sewage disposal)
- dense populations (social distancing)
- inadequate healthcare/infrastructure
- lack of accessible health promotion information

What you need to teach

B1.28 The definition of an antigen and an antibody:

- antigen - a substance that is recognised by the immune system as self or non-self and stimulates an immune response
- antibody - a blood protein produced in response to, and counteracting, a specific antigen

B1.29 The link between antigens and the initiation of the body's response to invasion by a foreign substance:

- antigens as chemical markers
- ability of the body to recognise self and non-self antigens

B1.30 The stages and cells involved in the body's response to an antigen, including:

- use of physical and chemical barriers
- inflammation
- phagocytosis
- actions of T cells
- actions of B cells

B1.31 The differences between cell-mediated immunity and antibody-mediated immunity including:

- cell-mediated response is associated with T lymphocytes destroying pathogens (causative agents) without producing antibodies
- antibody-mediated response is associated with B lymphocytes destroying pathogens (causative agents) by producing antibodies against it

B1.32 The role of T and B memory cells in the secondary immune response:

- they trigger a stronger and more rapid immune response after encountering the same antigen
- role of vaccinations in relation to T and B memory cells

Materials and chemical properties

B1.33 The relationship between the atomic structure and physical and chemical properties of metals, including:

- physical properties:
  - conductivity (electrical and thermal)
  - malleability/ductility
  - strength
- chemical properties:
  - group 1:
    - reactivity of group 1 metals with water and oxygen

What you need to teach

        - reactivity of group 1 metals in terms of their electronic configurations
    - transition metals:
        - reactivity of transition metals with oxygen and acids
        - the difference in properties of transition metals compared with group 1 metals in their melting points, densities, strength, hardness and reactivity with oxygen, chlorine and water
- the relationship between the structure and properties of the following materials:
    - composite materials (for example, concrete, fibreglass and carbon fibre):
        - structure - made of 2 or more materials with different properties to combine those properties into one material
        - properties - strong, lightweight
    - ceramics (for example, clay and glass):
        - structure - moulded and then baked to form strong bonds between atoms in the structure
        - properties - hard, strong under compression, chemically unreactive
    - polymers (for example, high density (HD) and low density (LD) polyethene, thermosetting and thermosoftening polymers):
        - structure - long chain molecules with forces or bonds between the chains
        - properties - strong, chemically unreactive, electrical insulators
- how the properties of these materials are related to their uses

B1.34 How the arrangement of electrons is linked to the way in which elements are situated within groups in the periodic table:

- elements with the same number of electrons in the outer shell are in the same group of the periodic table

B1.35 The correct names for sub-atomic particles and their position in an atom - protons, electrons and neutrons:

- protons - found in the nucleus
- neutrons - found in the nucleus
- electrons - found in orbitals around the nucleus

Acids/bases and chemical change

B1.36 The physical and chemical properties of acids:

- irritant or corrosive
- neutralise bases
- react with metals to form H_2

What you need to teach

- pH less than 7

B1.37 The concept of strong and weak acids (as distinct from dilute and concentrated solutions):

- strong acids are completely dissociated in aqueous solution (for example, sulfuric, hydrochloric and nitric acids)
- weak acids are only partially dissociated in aqueous solution (for example, ethanoic and carbonic)
- for a given concentration of aqueous solution, the stronger the acid, the lower the pH
- as the pH of an acid decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10

B1.38 How to determine the name of the salt produced in the following acid-base reactions:

- acid + base → salt + water (for example, HCl + NaOH → NaCl + H2O)

Rates of reaction and energy changes

B1.39 The principles of collision theory:

- molecules must collide
- molecules must collide with enough energy to break and reform bonds (activation energy)
- molecules must be in the correct spatial orientation

B1.40 The effect of temperature on rates of reaction:

- an increase in temperature makes molecules move faster, resulting in increased collisions and rates of reaction
- lower temperatures result in decreased collisions and rates of reaction

B1.41 The definition of a catalyst and the role of catalysts in a reaction:

- catalysts are substances that increase the rate of a chemical reaction without themselves being permanently chemically changed
- principles of reaction kinetics Maxwell-Boltzmann distribution curve

Chemical analysis of substances

B1.42 The principles of the following tests and techniques used to separate substances in order to detect or identify chemical composition:

- thin layer chromatography:
  - used to separate non-volatile mixtures based on their affinity for a mobile (solvent) or stationary phase (on a coated plate)
  - used to detect the number of components
  - used to identify the compounds and their purity
- column chromatography:

What you need to teach

- used to separate a single chemical compound from a mixture (in a vertical column)

- gas chromatography:
  - used to separate and analyse compounds that can be vaporised (in a capillary or packed column)
- high performance liquid chromatography:
  - used to separate substances based on their affinity for a mobile (pressurised solvent) or stationary phase (in a capillary or packed column)
- mass spectrometry:
  - used to separate substances due to their mass to charge ratio and to identify molecular ions and ion fragments
  - used to identify the components of an unknown sample due to their molecular weights

B1.43 The tests that could be used to quantify components in a mixture:

- gas chromatography
- high performance liquid chromatography
- mass spectrometry

B1.44 The principle of titration:

- determining the volumes of acids and alkalis required for neutralisation to occur

Electricity

B1.45 The definitions of, and how to calculate, charge and current using Q = It

B1.46 The definitions of, and how to calculate, current, potential difference and resistance, using Ohm's law V = IR

B1.47 How to calculate total resistance of multiple fixed resistors in a series and parallel circuit:

- series: the total resistance is equal to the sum of the individual resistors
- parallel: $\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{Rn}$

B1.48 The difference between alternating and direct current.

B1.49 The properties of mains electricity in the United Kingdom:

- alternating current
- potential difference ensures electricity is supplied to residences and businesses at 230 volts
- generated at a frequency of 50Hz

Magnetism and electromagnetism

B1.50 Magnetism and magnetic poles:

- north and south magnetic poles are where the magnetic forces are strongest

What you need to teach

- attraction/repulsion of magnets in close proximity - attraction and repulsion between magnetic poles are examples of non-contact forces
- the difference between permanent and induced magnets
- the uses of permanent and temporary magnetic materials (for example, iron, steel, cobalt, nickel)

B1.51 Magnetic fields:

- the shape and direction of the magnetic field around bar magnets, and the relationship between the strength of the field and concentration of field lines
- how a magnetic field is produced by the flow of current through conducting wire, including the relationship between:
  - strength of the field
  - size of the current
  - distance from the wire

B1.52 The uses of electromagnetism and electromagnets:

- portative and tractive electromagnets
- principles of electromagnetic induction - the production of voltage
- principles of the motor effect - causing movement in a motor
- applications of electromagnets in electric and electromechanical devices (for example, transformers, induction heating, MRI machines)

Waves

B1.53 The definition of a wave:

- the transfer of energy, not matter

B1.54 The relationship between frequency, wavelength and speed using the wave equation $v = f\lambda$.

B1.55 The properties of longitudinal and transverse waves:

- longitudinal waves move in the same direction in which the particles are vibrating
- transverse waves move in a direction at right angles to the way in which the particles are vibrating

B1.56 The uses of different types of waves:

- communication (for example, radio waves)
- medical uses (for example, x-rays for imaging, gamma rays for cancer treatment and sterilisation, ultrasound in scanning and cleaning laboratory equipment)
- food processing (for example, infrared heating and microwave heating)

Particles and radiation

B1.57 The types and properties of ionising radiation:

What you need to teach

- alpha:
  - high ionising but low penetrating power
  - range is 1 to 2 centimetres of air
- beta:
  - medium ionising and penetrating power
  - range is approximately 15 centimetres of air
- gamma:
  - low ionising and high penetrating power
  - range is many kilometres of air

B1.58 The definitions of half-life and count-rate:

- half-life - the time taken for half the unstable nuclei in a sample to decay
- count-rate - the number of decays recorded each second

B1.59 The main types of radioactive decay in relation to unstable nuclei:

- an alpha particle - consists of 2 neutrons and 2 protons and is equivalent to a helium nucleus
- a beta particle - a high speed electron ejected from the nucleus as a neutron turns into a proton
- a gamma ray - electromagnetic radiation from the nucleus

B1.60 How radiation interacts with matter:

- ionisation - by causing electrons to break apart from atoms or molecules
- excitation - by transferring energy to atoms or molecules

B1.61 The applications of radioactivity within the health and science sector:

- radioactive tracers
- medical diagnostic applications
- food preservation
- dating deceased organisms

Units

B1.62 The use of the international system of units (SI):

- ampere (A) - electric current
- candela (cd) - luminous intensity
- kelvin (K) - temperature
- kilogram (kg) - mass

What you need to teach
• metre (m) - length • mole (mol) - amount of substance • second (s) - time **B1.63 How to convert between units:** • millimetres to metres • milligrams to grams • millilitres to litre **B1.64 The importance of using significant figures and science notation:** • makes calculations with large or small numbers less cumbersome • reduces the chances of data errors

B2 Further science concepts

What you need to teach
The student must understand: **Classification of biological molecules** **B2.1 The molecular structures and functions of the following:** • proteins: o the role of hydrogen bonds, ionic bonds and disulfide bridges (a covalent bond) in the structure and shape of proteins and their relation to R groups of the amino acid monomers o the relationship between primary, secondary, tertiary and quaternary structure and protein property and function o globular proteins - formed of long chains which are arranged in a variety of coiled shapes. This diversity of shapes reflects the range of functions performed by these proteins, such as binding, signalling and transport (for example, enzymes and haemoglobin) o fibrous proteins - formed of long chains which run parallel, linked by cross bridges to form stable molecules to act as structural polymers (for example, collagen) • carbohydrates: o the basic units of carbohydrates are monosaccharides. Monosaccharides are composed of carbon, hydrogen and oxygen. Examples of monosaccharides include: glucose, fructose and galactose o when combined in pairs, monosaccharides form disaccharides through a condensation reaction and the formation of glycosidic bonds

What you need to teach

- polysaccharide can be made from different isomers of the same monosaccharide or by the combination of different monosaccharides (for example, glycogen and starch are formed by the condensation of alpha (α) glucose and cellulose is formed by condensation of beta (β) glucose)

- lipids:
  - fatty acids and glycerol are the molecules from which triglycerides and phospholipids are formed
  - triglycerides are formed by the condensation of 1 molecule of glycerol and 3 molecules of fatty acid
  - phospholipids are formed when one of the fatty acids of a triglyceride is substituted by a phosphate-containing group
  - fatty acid molecules repel water (hydrophobic) and glycerol molecules attract water (hydrophilic)
  - phospholipid is made up of 2 parts, a hydrophilic head and a hydrophobic tail. This molecular structure forms a bi-layer that is important for all membrane functions
- nucleic acid:
  - nucleic acids are large molecules composed of nucleotides
  - each nucleotide in DNA is made up of a sugar (deoxyribose), a phosphate and an organic base
  - DNA is made up of 2 strands of nucleotides joined together by hydrogen bonds. The nucleotides form a double helix structure
  - DNA provides genetic information

Enzyme and protein structure

B2.2 The role of DNA bases in the production of amino acid chains, which form proteins, including:

- a gene is a sequence of nucleotides along a strand of DNA, each nucleotide consists of a sugar molecule attached to a phosphate group and a nitrogen-containing base
- nucleotides comprise ribose sugar, phosphate and a base which can be guanine (G), cytosine (C), adenine (A) and thymine (T)
- the order of bases along a single strand constitutes the genetic code. A sequence of 3 DNA bases is known as a triplet or a codon. Each codon codes for a specific amino acid or a start or stop codon
- the genetic code is universal, non-overlapping and degenerate, meaning that each amino acid can be coded for by more than one codon
- the sequence of bases within a gene specifies the sequence of amino acids that are linked together to form a polypeptide chain

B2.3 How the process of protein synthesis occurs:

- DNA acts as a template providing the instructions for the synthesis of each protein from specific amino acids via the coding sequence of bases
- a complementary section of part of this sequence is made into messenger RNA (mRNA) by a process known as transcription

What you need to teach

- the messenger RNA acts as a template to which complementary transfer RNA (tRNA) molecules attach and the amino acids they carry are then linked to form a polypeptide by a process known as translation
- in RNA thymine is replaced by uracil (U)

B2.4 The properties of enzymes that are determined by their tertiary structure, including:

- the shape of the active site
- the role of bonding
- the effect of pH and temperature

B2.5 How enzymes' mechanism of action allows them to catalyse a wide range of intracellular reactions including:

- models of lock and key hypothesis
- the effect of enzyme concentration and substrate concentration
- induced fit

Cell cycle

B2.6 The function of both mitosis and meiosis in nuclear division within cells:

- mitosis produces 2 daughter nuclei that have the same number of chromosomes as the parent cell and each other (diploid)
- meiosis produces 4 daughter nuclei each with half the number of chromosomes (haploid) of the parent cell
- mitosis division results in each of the daughter cells having an exact copy of the DNA of the parent cell
- meiosis produces cells that are not genetically identical, and plays an important role in bringing about variation in living organisms

B2.7 How the process of mitosis results in the formation of 2 genetically identical daughter cells:

- interphase: stage that always proceeds mitosis when DNA and organelles are replicated
- characteristics of each of the stages of mitosis, including the behaviour of chromosomes and the cellular structure at each stage:
  - prophase: stage in which chromosomes become visible and the nuclear envelope disappears
  - metaphase: stage in which the chromosomes arrange themselves at the centre of the cell
  - anaphase: the stage in which each of the 2 threads of a chromosome (chromatid) migrates to the opposite pole
  - telophase: stage in which the nuclear envelope reforms to produce 2 daughter cells

What you need to teach

B2.8 How the process of meiosis, including phase 1 and phase 2, results in the formation of haploid gametes from diploid cells in the reproductive organs:

- meiosis takes place in the reproductive organs to form haploid gametes (cells that unite to form a new organism)
- it is necessary to have haploid gametes to maintain a constant number of chromosomes from one generation to the next
- meiosis involves 2 stages or divisions (meiosis I and meiosis II), such that each diploid cell divides to produce 4 haploid gametes
- in meiosis I the chromosome number is halved and the process of 'crossing over' takes place
- crossing over (or genetic recombination) is the process where homologous chromosomes pair up with each other and exchange different segments of genetic material to form a recombinant chromosome
- the process of crossing over, where genetic material is exchanged creates genetic variation
- the second stage of meiosis is identical to mitosis

B2.9 The significance of the differences between mitosis and meiosis:

- as mitosis produces genetically identical cells to parent cells it is used to grow new cells from the original which always have the same set of genetic information
- as cells produced by the process of mitosis are identical, the production of new differentiated cells results in cells and tissues that perform the function they were intended to perform
- if cells are damaged or die, it is important that new cells produced have identical structure and function to the cells that have been lost, mitosis is therefore the process by which new cells replace damaged or dead ones
- meiosis occurs only in reproductive cells to ensure that the cells produced have half (haploid) number of chromosomes to ensure when gametes (for example, eggs and sperm) combine the resulting zygote (fertilised egg) has the correct number of chromosomes (diploid)
- the 2 stages of meiosis (rather than the one stage of mitosis) results in genetic variation within daughter cells compared to the parent cells

Cellular respiration

B2.10 How respiration results in the breakdown of glucose to produce the energy-carrying molecule Adenosine Triphosphate (ATP):

- aerobic respiration - the chemical breakdown of substrate molecules (for example, glucose) in cells to release energy in the form of ATP when oxygen is present
- involves a series of oxidation and reduction reactions
- glucose + oxygen → carbon dioxide + water (produces ATP) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (produces ATP)

B2.11 How ATP provides a source of energy for biological processes:

What you need to teach

- Adenosine Triphosphate (ATP) consists of an adenosine molecule bonded to 3 phosphate groups in a row
- the bond between the phosphate groups in ATP are easily hydrolysed to form ADP and inorganic phosphate, with energy released in this reaction
- this reaction is catalysed by the enzyme ATPase
- ATP + water = ADP + P_i (energy released)

B2.12 The comparative amounts of energy produced by different respiratory substrates (lipids, proteins and carbohydrates).

Pathogens (causative agents)

B2.13 The definition of a pathogen:

- a biological agent that causes illness or disease by damaging host tissues and/or by producing toxins

B2.14 Examples of different types of pathogens (causative agents) and the diseases they can cause:

- bacteria:
  - Escherichia coli (E. coli) causes gastrointestinal disorders
- fungi:
  - Candida auris (C. auris) causes fever and possible sepsis
- prions:
  - proteins that can cause prion diseases, (for example, Creutzfeldt-Jakob disease (CJD))
- protists:
  - Plasmodium sp. that cause malaria
- viruses:
  - hepatitis A virus (HAV) causes hepatitis A

Formulae and equations

B2.15 How to balance a given equation based on the following reactions:

- group 1 metals with water and oxygen
- transition metals with oxygen and strong acids (hydrochloric, sulfuric and nitric acid)

B2.16 How an empirical formula represents the simplest ratio of atoms of each element in a compound:

- C_2H_5 is a 2:5 ratio

B2.17 How to use the empirical formula and relative molecular mass to work out the molecular formula of a compound:

- divide the relative molecular mass by the mass of the atoms in the empirical formula

What you need to teach

- multiply the ratio to arrive at the formula

B2.18 The definition of an isotope and relative isotopic mass:

- isotopes are atoms of the same element with different masses due to a different number of neutrons (for example, C^{12} and C^{13})
- relative isotopic mass is the mass of an atom of an isotope relative to 1/12 of the mass of a C^{12} atom

B2.19 The link between balanced equations and the ratio of moles of a substance in a reaction (for example, $2CH_4$ is 2 moles).

B2.20 The relationship between the number of moles of solute and the volume in dm^3 of solvent as a measure of concentration (mol/dm^3).

Kinetic changes

B2.21 A range of factors affecting the rates of chemical reactions:

- surface area
- temperature
- concentration
- pressure

B2.22 How to calculate the rate of reaction: $\frac{\text{amount of reactant or product}}{\text{time}}$

B2.23 The definition of activation energy:

- the minimum amount of energy required to start a reaction

B2.24 The action of a catalyst, in terms of providing an alternative pathway with a lower activation energy.

B2.25 The advantages of using a catalyst in industrial reactions:

- the increase in the rate of reaction gives a faster turnaround time and so reduces costs
- reducing the activation energy reduces costs and energy consumption

B2.26 How to use the Maxwell Boltzmann distribution of molecular energies to explain, qualitatively, how changes in temperature and the presence of a catalyst affect the rate of a reaction.

Analytical techniques

B2.27 How chromatography can be used to separate substances due to their attraction to the mobile or stationary phase.

B2.28 How to calculate and use the Rf value to identify a substance:

- the distance travelled by the substance divided by the distance travelled by the solvent
- the Rf value should be the same if it is the same substance (under the same conditions)

What you need to teach

B2.29 The stages of an acid-base titration, including the role of the following indicators in determining the end point:

- phenolphthalein
- methyl orange

B2.30 The following applications of chromatography in industry:

- forensic investigation (for example, to detect the presence of substances like alcohol within human tissue)
- water analysis (for example, to determine the presence of pesticides in rivers)

B2.31 The following applications of chromatography and titration in industry:

- used in quality control (for example, to test food products for consistency)
- purity analysis (for example, to test raw materials for the chemical industry)

Gas laws

B2.32 How the following gas laws describe the behaviour of gases in particular conditions:

- Boyle's Law ($P_1V_1 = P_2V_2$)
- Charles's Law ($V_1T_2 = V_2T_1$)
- the Pressure Law ($P_1/T_1 = P_2/T_2$)

B2.33 The use of the kelvin temperature scale in describing the behaviour of gases in particular conditions, including:

- the effect of a temperature of absolute zero on the movement of particles

B2.34 The effect of compression when storing gases in cylinders:

- high pressure could be hazardous due to risk of explosion or leakage
- changes to temperature can affect the pressure
- cylinders must be stored at a determined temperature range

Pressure/fluid/viscosity

B2.35 The definitions of:

- density - mass per unit volume
- pressure - force per unit area
- fluid - a substance that is capable of flowing, with no fixed shape
- viscosity - a measure of resistance (internal friction) of a fluid (for example, high viscosity = low flow)

B2.36 The properties of Newtonian and non-Newtonian fluids, as defined by Newton's law:

- Newtonian - a fluid whose viscosity remains constant as the applied force changes

What you need to teach
• non-Newtonian - a fluid whose viscosity does not remain constant as the applied force changes **B2.37 How depth affects hydrostatic pressure in a liquid (an increase in depth causes an increase in pressure).** **B2.38 The definitions of volumetric and mass flow rates:** • volumetric flow rate - the volume of a fluid moving through a given area per unit of time • mass flow rate - the mass of a fluid moving through a given area per unit of time **B2.39 The difference between steady and turbulent flow:** • steady flow is when all parts of a fluid have the same velocity at a certain point • turbulent flow is when different parts of the fluid have a different velocity **B2.40 The coefficient of viscosity of a fluid:** • a measure of the resistance to flow of a fluid

Core skills

The employer-set project (ESP) requires that students apply and contextualise core knowledge through the demonstration of the following core skills. Parameters have been provided for each skill in order to define what students must be able to demonstrate to fully satisfy the requirements of the ESP.

CS1 Project management

What you need to teach:

The student must be able to:

CS1.1 Independently produce a high-level project plan, written in a clear, unambiguous way and taking into account the document's purpose, including:

- project deliverables:
  - including a project scope statement that clearly and concisely outlines the intended outcomes
  - opportunities and benefits
- project inputs:
  - people (for example, customers/clients)
  - products and materials (for example, samples, raw materials)
  - equipment
- a timetable of activities, providing the appropriate level of detail to reflect the project's purpose, including:
  - total time required for the overall project
  - a breakdown of time required for individual scientific activities
  - important milestones
  - resource availability (for example, people, rooms, equipment)
- a financial forecast, taking into account resource requirements:
  - using mathematical processes (for example, calculations, diagrams, data representations) to support forecasting
- ethical considerations (for example, codes of practice, intellectual property rights)
- a completed risk assessment, including details of how risks will be mitigated:
  - written in style and level of detail appropriate to the document's purpose
- how quality outcomes will be maintained (for example, through complying with relevant ISO standards)

(GEC1, GEC3, GMC8)

CS2 Researching

What you need to teach:

The student must be able to:

CS2.1 Conduct a review of independently selected scientific literature and other appropriate primary/secondary sources, including:

- introduction: the scope of the review and the criteria for the selection of sources - what was included in the review, what was not, and why
- main body, including:
  - evaluation of sources, including:
    - age/relevance of literature
    - reliability of sources (for example, peer review, conflicts of interest, citations, impact factor)
    - reliability of data (for example, sample sizes, what collection method was used)
    - logically ordered discussion of themes, including how the literature relates to each other and to the project
    - correct use of a recognised referencing system (for example, Harvard, Vancouver, AMA in-text citation)
- conclusion, including:
  - a summary of the key points, using appropriate technical terms
  - agreements and disagreements in the literature
  - any gaps or potential future areas of study
  - a full bibliography of sources

(GEC2, GEC4, GEC5)

CS3 Working with others

What you need to teach:

The student must be able to:

CS3.1 Identify their own role in relation to the wider team, including:

- team structure (for example, position within the team, any direct reports)
- team working, using digital collaboration tools to meet with, share and collaborate with colleagues
- wider organisational structure (for example, relationships between individual teams/departments)
- contact with external stakeholders/clients (for example, directly or through third-parties)
- establishing own accountability for tasks and deliverables
- establishing own and others' area of expertise

CS3.2 Meet their responsibilities when working in a wider team by ensuring that the project is compliant with relevant:

- health and safety requirements (for example, if storing and handling hazardous substances)
- environmental requirements (for example, when disposing of waste)
- data protection regulations (for example, when using information technology)
- SOPs specific to the lab in which they are working
- project timescales (for example, equipment and spaces are used in the allotted times)

(GDC3)

CS4 Creativity and innovation

What you need to teach:

The student must be able to:

CS4.1 Make creative, innovative improvements to scientific practice, processes and outcomes by following an evaluation cycle:

- plan:
  - identify a potential area for improvement, taking into account:
    - who will benefit from the improvement
    - the desired outcome
  - gather information to understand more about the need for the required improvement (for example, talk to more experienced colleagues, collect data, research literature)
  - generate ideas and screen them against the desired outcome (which approach will achieve the best results?)
- do:
  - use their knowledge of context to find appropriate and approximate solutions
  - implement the improvement
  - record the results, systematically organising and recording data prior to any scaling or processing that may be required
- check:
  - use data to analyse the results against the desired outcome, applying appropriate statistical techniques from the list below:
    - mean and median
    - standard deviation
    - range
    - Chi Square test
    - T-test
    - Spearman's rank
- act:
  - review the improvement and recommend next steps

(GMC2, GMC5)

CS5 Problem solving

What you need to teach:

The student must be able to:
CS5.1 Solve a problem within a science context, by:
• identifying and clearly defining the problem:
  o demonstrating a thorough understanding of the context of the problem
• deciding on change to be made, taking into account:
  o steps required to implement the change
  o success criteria for measuring the impact of the change
• implementing the changes, using new technologies as appropriate:
  o gathering data
  o recording results
• evaluating the impact and continuing to monitor any changes:
  o making recommendations for further improvement
(GMC10)

CS6 Communication

What you need to teach:
The student must be able to: **CS6.1 Provide results and recommendations (written and verbal) to customers/clients, by:** • communicating in a clear and unambiguous way, tailoring language and technical information to the audience • selecting the most appropriate way of presenting data, using images and other tools (for example, visualisations or infographics) to clarify complex information • actively listening to the client's contributions and asking questions to test understanding • responding to the client's questions, using a tone and register that reflects the audience • speaking clearly and confidently, using appropriate tone and register • answering the brief/research questions, providing supporting documentation in different formats • highlighting the commercial/business benefits for the customer/client, using calculations, diagrams and data to support these assertions

What you need to teach:
(GEC1, GEC2, GEC3, GEC6, GMC8, GDC2)

CS7 Reflective evaluation

What you need to teach:

The student must be able to:
CS7.1 Evaluate the project's processes and outcomes, focusing on:
• experimental design:
  ○ was the project designed to yield the maximum results from the minimum repeated experiments?
• the accuracy and reliability of the results, using appropriate technical terms:
  ○ was the sample size sufficient for reliability?
  ○ was the equipment appropriate to ensure accuracy?
• reproducibility:
  ○ can the results easily be replicated?
• suitability of equipment:
  ○ was the chosen equipment appropriate for the experiment?
• suitability of methods:
  ○ were the chosen methods the most suitable?
• own actions during the project:
  ○ what did I do well and how can I improve?
• quality of the data, including how the data have been processed and scaled:
  ○ were there sufficient data (from different methodologies if necessary) to draw valid conclusions?
• fulfilment of objectives:
  ○ were the project's objectives met?
• recommendations for improvement:
  ○ how could the experiment be more effective?
(GEC4, GMC6)

Occupational specialism - technical: laboratory sciences

Knowledge and skills are set out side-by-side within their themed sections. The numbering is sequential throughout the performance outcome, from the first knowledge statement, following on through the skills statements. The ‘K’ and ‘S’ indicate whether the statement belongs to knowledge or skills.

Mandatory content

Performance outcome 1: Perform a range of appropriate scientific techniques to collect experimental data in a laboratory setting, complying with regulations and requirements

Performance outcome 2: Plan, review, implement and suggest improvements to scientific tasks relevant to a laboratory setting

Performance outcome 3: Identify and resolve issues with scientific equipment or data errors

Glossary

Technique

Overarching term for the many ways of obtaining information and results in a systematic way in science, examples would include preparation techniques, separating techniques.

Method

A scientific plan that specifies the procedures or processes that will be followed, this would include specifying the scientific techniques that will be used.

Task

A specific activity which needs to be accomplished as part of following a scientific method and undertaking a scientific technique.

Practical activities

Students taking this occupational specialism must have practical experience of the following laboratory activities:

- paper and thin layer chromatography (TLC)
- distillation
- acid-base and redox titration
- refluxing
- filtration
- differential staining (microorganisms)
- aseptic culture of microorganisms
- preparation of serial dilution
- prepare a solution of defined molar concentration

- colorimetry
- pressure using a U-tube manometer
- temperature using a probe and data logger
- radioactive count rate using Geiger counter
- conductivity meter to measure conductivity of a solution
- electrical polarity using ammeter and voltmeter
- calibrating a pH Meter, balance and a mechanical (variable volume) pipette

Performance outcome 1: Perform a range of appropriate scientific techniques to collect experimental data in a laboratory setting, complying with regulations and requirements

Safety, health and environmental practices in laboratory science	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.1 How health, safety and environmental practices are applied when performing scientific techniques:** • planning to perform a scientific technique: o completing an appropriate risk assessment for typical hazards in a laboratory setting (for example, biological and chemical hazards) o selecting equipment and personal protective equipment (PPE) suitable to the task (for example, suitable eye protection and gloves) o selecting an appropriate space for the procedure (for example, one that includes a fume cupboard, cell hood) • safely performing a scientific technique: o using the correct PPE at all appropriate times o using resources and equipment appropriately for the scientific technique being performed (for example, keeping yourself and others safe)	The student must be able to: **S1.68 Work safely in a laboratory when performing specific scientific techniques by:** • following SOPs • following safe laboratory practice • maintaining excellent housekeeping • selecting an appropriate space • using equipment appropriately • using resources safely and efficiently (for example, only using the required amount for hazardous materials) **S1.69 Comply with relevant health and safety legislation and regulations, including COSHH and biosafety containment levels, when handling and disposing of solids, liquids and gases relevant for the scientific technique being performed, including:** • toxic (for example, methanol, chlorine, potassium dichromate (VI)) • corrosive (for example, acid) • irritants (for example, copper sulfate solution)

Safety, health and environmental practices in laboratory science	
○ following standard operating procedures (SOPs) and safe laboratory practice when performing the scientific technique ○ safely handling materials, in line with Control of Substances Hazardous to Health Regulations 2002 (COSHH): ▪ toxic (for example, methanol, chlorine, potassium dichromate VI) ▪ corrosive (for example, acid) ▪ irritants (for example, copper sulfate solution) ▪ sensitisers (for example, chromium compounds, sulfur dioxide) ▪ flammable (for example, ethanol, hydrogen) ▪ air/water sensitive materials (for example, alkali metals) ▪ compressed gases (for example, oxygen) ▪ pyrophoric (for example, magnesium) ▪ oxidising agents (for example, hydrogen peroxide) ▪ radioactive materials (for example, radioactive iodine) ▪ biohazards (for example, micro-organism cultures) ▪ serious health hazards (for example, formaldehyde) ▪ liquid nitrogen ▪ carcinogens (for example, ninhydrin) • completing a scientific technique: ○ safely disposing of materials, in line with COSHH: ▪ organic waste (for example, propanone)	• sensitisers (for example, chromium compounds, sulfur dioxide) • flammable (for example, ethanol, hydrogen) • air/water sensitive materials (for example, alkali metals) • compressed gases (for example, oxygen) • pyrophoric (for example, magnesium) • oxidising agents (for example, hydrogen peroxide) • radioactive sources (for example, caesium-137) • biohazards (for example, micro-organism cultures) • organic waste (for example, propanone) **S1.70 Complete a risk assessment to minimise potential hazards and risks when performing a scientific technique:** • step 1 - identifying the hazards, taking account of warning symbols and using model risk assessments: ○ chemical (for example, compressed gases, cleaning agents) ○ biological (for example, biological samples) ○ physical (for example, repetitive tasks, noise levels) • step 2 - assessing the risks: ○ how likely is the scientific technique to go wrong? ○ who might be harmed? ○ what could be the consequences? • step 3 - evaluating the risks and selecting control measures:

Safety, health and environmental practices in laboratory science	
▪ toxic (for example, methanol, chlorine, potassium dichromate (VI)) ▪ corrosive (for example, acid) ▪ flammable (for example, ethanol, hydrogen) ▪ compressed gases (for example, oxygen) ▪ pyrophoric (for example, magnesium, alkali metals) ▪ oxidising agents (for example, hydrogen peroxide) ▪ radioactive sources (for example, caesium -137) ▪ biohazards (for example, micro-organism cultures) ▪ serious health hazards (for example, formaldehyde) ▪ carcinogens (for example, ninhydrin) ○ reporting any near misses, accidents or injuries, following the appropriate processes ○ maintaining excellent housekeeping (for example, washing/autoclaving glassware effectively and storing equipment and chemicals appropriately) **K1.2 How to use resources efficiently when performing scientific techniques:** • energy (for example, heating to a required temperature and not above) • water (for example, recycling of water) • waste (for example, using re-usable equipment)	○ identifying alternate or safer methods than those proposed (for example, using a different concentration of chemicals) ○ identifying the appropriate PPE to use • step 4 - recording findings, following the risk assessment and amending the control measures as necessary: ○ in a clear and unambiguous way ○ using technical language correctly ○ organising the findings logically and coherently ○ using the appropriate vocabulary, spelling and grammar • step 5 - reviewing risk assessment and modifying method where required (GEC1) **S1.71 Use appropriate PPE when performing scientific tasks (for example, suitable eye protection and gloves).**

Ethics	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.3 The principles of the 'Universal Ethical Code for Scientists 2007' and how it affects ethical practices in a laboratory setting:** • rigour: o acting with skill and care in all scientific work o maintaining up-to-date skills and assisting with their development in others o taking steps to prevent corrupt practices and professional misconduct o declaring conflicts of interest o being alert to the ways in which research derives from and affects the work of other people, and respecting the rights and reputations of others • respect: o ensuring that your work is lawful and justified o minimising and justifying any adverse effect your work may have on people, animals and the natural environment • responsibility: o seeking to discuss the issues that science raises for society o listening to the aspirations and concerns of others o not knowingly misleading, or allowing others to be misled, about scientific matters	The student must be able to: **S1.72 Adhere to ethical practice and codes of conduct to ensure confidentiality and meet intellectual property requirements:** • physical security (for example, locked doors, opaque glass, individual workstations) • electronic security (for example, controlled access systems, video surveillance) • operational security (for example, sign-in sheets, restricted access, following non-disclosure policies) • information security (for example, passwords, back-up systems, recording results securely by using a permanent bound lab book and having each page countersigned)

Ethics	
○ presenting and reviewing scientific evidence, theory or interpretation honestly and accurately **K1.4 Ethical issues and wider implications of scientific practices:** • misusing or misinterpreting published research • conducting unethical research (for example, with human tissue samples) **K1.5 The importance of adhering to codes of conduct to ensure confidentiality:** • to avoid improper disclosure of information and data that could harm the science organisation or individuals within it • to avoid accidental loss or release of sensitive information or data • to comply with regulatory requirements and guidance **K1.6 The importance of adhering to codes of conduct to protect intellectual property:** • to avoid sharing commercially sensitive information and research through improper disclosure • to avoid accidental loss or release of sensitive information and research • to respect the intellectual property of other scientists' work	

Core scientific knowledge	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **Atomic structure:** **K1.7 The definitions of orbital and nucleus:** • orbital - a region of space with the greatest chance of finding an electron • nucleus - a dense group of protons and neutrons in the centre of an atom **K1.8 How electrons are arranged in s and p sub-orbitals from periods 1 to 4:** • filling electron sub-shells in order of increasing energy from $1s^2$ to $4p^6$ **K1.9 How the electron arrangement in s and p orbitals is linked to the way in which elements are situated in s and p blocks in the periodic table:** • s-block elements have their outer electrons in s shells • p-block elements have their outer electrons in p shells • d-block elements have their outer electrons in d shells **K1.10 How the position of the element in the periodic table (arrangement of electrons) is related to the reactivity of that element:** • metal reactivity generally decreases as you go from left to right in the periodic table • non-metal reactivity generally increases as you go from left to right in the periodic table (apart from group 0 which are unreactive) **Amount of substance:** **K1.11 The definitions of relative atomic mass and relative molecular mass:**	The student must be able to: **S1.73 Apply scientific knowledge when undertaking scientific techniques by:** • choosing and justifying appropriate scientific techniques: ○ paper and thin layer chromatography: molecular structure and bonding (for example, choice of a polar or non-polar solvent) ○ distillation: molecular structure/bonding and kinetic changes (for example, differences in the boiling points of components due to differences in bonding) ○ refluxing: molecular structure/bonding and kinetic changes (for example, choice of refluxing due to organic components) ○ acid base and redox titration: oxidation and reduction (for example, identification of reaction from given equation) ○ differential staining techniques: characteristics of microorganisms (for example cell wall components by gram staining) ○ aseptic culturing: nature of infection and pathogens (causative agents)/transmission routes (for example, dilution, streaking and spread plates to culture micro-organisms) ○ preparation of serial dilutions: amount of substance (for example, use of calculations to determine dilutions needed) ○ filtration: molecular structure/bonding (for example, choice of filtering as some substances like metals are insoluble)

Core scientific knowledge	
• relative atomic mass is the average mass of the atoms of an element compared to carbon-12 • relative molecular mass is the sum of the relative atomic mass of the atoms in the molecule **K1.12 How to use balanced equations to apply the mole and Avogadro's constant to calculate mass and molar concentration (in g/dm^3 or mol/dm^3) in order to make a solution of defined molar concentration (n = cV).** **K1.13 How to perform calculations for acid-base titrations, based on mean titres, using n = cV and mass = n/Mr.** **K1.14 The relationship between volume of a gas and the number of moles:** • 1 mole of gas occupies a volume of 22.4dm^3 at standard temperature and pressure **Molecular structure and bonding:** **K1.15 The different types of bonds including ionic, metallic and covalent and how they are formed in relation to electrons:** • ionic bonding involves the electrostatic attraction between positive and negative ions formed by the transfer of one or more electrons from a metal to non-metal • covalent bonding involves sharing of electron pairs • metallic bonding forms a sea of delocalised electrons throughout the structure **K1.16 The structure of substances in relation to ionic, metallic and covalent bonding:** • ionic lattice as a large 3D structure containing oppositely charged ions • covalent structures as simple molecules or giant covalent structures of many atoms	• planning the steps of the technique in the correct order, ensuring correct quantities and concentrations are used

Core scientific knowledge	
• metallic structures as an arrangement of closely packed metal ions with a sea of delocalised electrons **K1.17 The relationship between the electron pair repulsion theory and the shapes of the following molecules:** • linear: 2 electron pairs repel to be 180^{o} apart • tetrahedral: 4 electron pairs repel to be 109.5^{o} apart • trigonal planar: 3 electron pairs repel to be 120^{o} apart **K1.18 The effect of structure and bonding on a range of properties including:** • solubility and dissolution: ○ ionic substances tend to be soluble in polar solvents like water ○ metallic substances tend to be insoluble ○ simple covalent substances can be soluble, polar molecules tend to be soluble in polar solvents and non-polar tend to be soluble in non-polar solvents • electrical conductivity: ○ ionic substances conduct electricity only if molten or dissolved ○ metallic substances conduct electricity even as solids ○ simple covalent substances do not conduct electricity • melting/boiling point: ○ ionic substances have high melting and boiling points ○ metallic substances have high melting and boiling points ○ simple covalent substances have low melting and boiling points	

Core scientific knowledge	
Organic chemistry: **K1.19 How to apply the International Union of Pure and Applied Chemistry (IUPAC) rules to name the following organic compounds:** • straight chain alkanes and cycloalkanes: o methane, ethane, propane, butane, cyclopropane and cyclobutane • straight chain alkenes: o ethene, propene, butene and pentene • alcohols: o methanol, ethanol, propan-1-ol, propan-2-ol and butan-1-ol, butan-2-ol • carboxylic acids: o methanoic acid, ethanoic acid, propanoic acid and butanoic acid • aldehydes and ketones: o ethanal, propanal, propanone and butanone • amines: o ethylamine and propylamine **K1.20 The word and symbol equations to show reactions of the following organic compounds:** • alkenes (ethene, propene, butene and pentene): o reactions with bromine, hydrogen bromide and hydrogen • alcohols (methanol, ethanol, propanol and butanol): o combustion o oxidation to a ketone or carboxylic acid with the use of [O] as the oxidising agent **K1.21 The possible uses of the following techniques used during organic synthesis:**	

Core scientific knowledge	
• refluxing - used for long reactions with volatile components • recrystallisation - used for purifying a substance • separating funnel - used for separating and purifying a substance **Oxidation and reduction:** **K1.22 The oxidation and reduction process:** • oxidation: o gaining oxygen: ▪ oxidising agents providing oxygen o losing hydrogen: ▪ oxidising agents removing hydrogen o losing electrons: ▪ oxidising agents removing electrons • reduction: o losing oxygen: ▪ reducing agents removing oxygen o gaining hydrogen: ▪ reducing agents providing hydrogen o gaining electrons: ▪ reducing agents providing electrons • redox: o where reduction and oxidation happen in the same reaction **K1.23 How to use standard electrode potentials to determine the direction of electron flow in electrochemical cells:** • electrode that is relatively more negative (oxidation half-cell) will release electrons more readily and electrons will flow from this electrode **Enthalpy and Entropy:**	

Core scientific knowledge	
K1.24 The definition of enthalpy and entropy: • enthalpy change is the amount of energy taken in or given out in a reaction at constant pressure • entropy is a measure of disorder in how energy is dispersed in a system **K1.25 How to calculate free energy change to link enthalpy and entropy:** • using the Gibbs equation ($\Delta G = \Delta H - T \Delta S$ system) **K1.26 Factors that affect the stability of compounds and the chance of chemical reactions occurring:** • the stability of compounds: o depends on their internal energy o the lower the internal energy the more stable a compound is • the chance of chemical reactions occurring: o depends on the free energy change (ΔG) o a negative value for free energy means the reaction is likely to be feasible at that temperature **K1.27 How to perform calculations of enthalpy changes:** • from an existing Hess cycle: o calculate the sum of the enthalpy changes for each reaction on the indirect route for the chosen reaction (reversing the sign for reactions that are reversed). Students are not expected to know definitions of enthalpy changes, such as enthalpy change of formation and enthalpy change of combustion • bond enthalpy values:	

Core scientific knowledge	
○ add up the bond enthalpies for the reactants (gives a positive value, as bond breaking is endothermic) ○ add up the bond enthalpies for products (gives a negative value, as bond making is exothermic) ○ add the enthalpies for bond breaking to bond making (keeping their original signs) **Materials science:** **K1.28 How the properties of the following materials are related to their applications:** • synthetic polymers: ○ properties: electrical insulator, lightweight, chemically unreactive ○ applications: examples could include - personal protective equipment (PPE) is chemically unreactive yet lightweight, non-stick coating and containers are chemically unreactive • alloys: ○ properties: strong, lightweight, resistant to corrosion ○ applications: examples could include - machine parts are strong but lightweight, lab benching and fume cupboards are strong but resistant to corrosion • composites: ○ properties: strong, lightweight ○ applications: examples could include - structures are strong, electronic screens are lightweight yet still strong **K1.29 The definitions and the characteristics of:** • addition polymerisation: ○ definition: a polymer made of monomers without generation of other products	

Core scientific knowledge	
○ characteristics: high atom economy • condensation polymerisation: ○ definition: polymer made by chemical reaction producing a small molecule as a by product ○ characteristics: lower atom economy **Metabolic pathways and bioenergetics:** **K1.30 The differences between anabolic and catabolic pathways in terms of energy change:** • anabolic pathways: pathways which require energy to synthesise larger molecules (for example, synthesis of proteins from amino acids) • catabolic pathways: pathways that release energy by breaking down complex molecules to simpler compounds (for example, glycolysis, Krebs cycle) **K1.31 The main activities and outputs of the 4 pathways of aerobic respiration involving glucose and how each of these stages is linked:** • glycolysis: ○ initial stage of aerobic respiration involving glucose ○ takes place in the cytoplasm ○ involves 10 reactions ○ reactions at each step are catalysed by different enzymes ○ via the hydrolysis of 2 ATP molecules, coverts a glucose molecule into two pyruvate molecules and transfers two hydrogen ions to nicotinamide adenine dinucleotide (NAD) forming reduced NAD	

Core scientific knowledge	
○ energy released is sufficient for the regeneration of 2 molecules of adenosine triphosphate (ATP) • link reaction Acetyl-Coenzyme A oxidation (acetyl-CoA): ○ short pathway in comparison with other pathways ○ pyruvate (from the glycolysis pathway) diffuses from the cytoplasm to the mitochondrial matrix through active transport ○ pyruvate is converted to acetyl-CoA • Krebs cycle: ○ Acetyl-CoA (from the link reaction) enters the Krebs cycle ○ the cycle involves a series of oxidation-reduction reactions that take place in the mitochondrial matrix ○ the Krebs cycle is a closed loop; the last part of the pathway reforms the molecule used in the first step ○ the cycle includes 8 major steps ○ the Krebs cycle produces 2 molecules of carbon dioxide, 3 molecules of reduced NAD, 1 reduced flavin adenine dinucleotide (FAD) and 1 molecule of ATP ○ NAD and FAD are high energy coenzyme molecules that act as hydrogen acceptors ○ the Krebs cycle goes around twice for each molecule of glucose that enters cellular respiration (1 cycle for each of the two acetyl-CoA molecules produced from the two pyruvate molecules) • electron transport chain (ETC) and oxidative phosphorylation:	

Core scientific knowledge	
○ the electron transport chain is a series of carriers and pumps found in the inner mitochondrial membranes ○ the hydrogen acceptors, reduced NAD and FAD from the Krebs cycle and links reaction transfer their hydrogen atoms to NADH dehydrogenase within the first complex on the ETC, which split them into electrons and hydrogen ions ○ in the process, the coenzymes can be reused in other steps of cellular respiration ○ as electrons are passed down the redox carriers in the inner membrane, they flow from a higher to lower energy level, releasing enough energy to pump in hydrogen ions into the intermembrane space – the hydrogen ions flow through chemiosmosis through ATP synthase, providing the energy for the formation of ATP **K1.32 The main activities and outputs of beta-oxidation and the role of beta-oxidation in aerobic respiration when an alternative initial substrate is used:** • beta-oxidation: ○ lipid is used as a respiratory substrate when carbohydrate levels are low; in aerobic respiration, beta-oxidation becomes the first pathway, rather than glycolysis ○ lipid is first split into its constituent molecules of glycerol and fatty acids ○ the pathway then involves the breakdown of the fatty acids into acetyl-CoA which can enter the Krebs cycle ○ the 4 reactions involved in this pathway are repeated until the entire fatty acid	

Core scientific knowledge	
chain has been converted into individual acetyl-CoA molecules **K1.33 How metabolic pathways are regulated by enzymes and feedback mechanisms:** • enzymes both catalyse reactions in metabolic pathways and are key to the regulation of the reactions in the metabolic pathways • enzymes are inhibited by certain substances known as inhibitors • if the substance which inhibits an enzyme is a substrate or intermediate product in a pathway reaction, this sets up a feedback system to regulate the pathway • examples: ○ phosphofructo kinase (PFK) is an important enzyme in glycolysis, it is inhibited by several substrates, including ATP ○ citrate synthase is responsible for the rate of reaction in the first step of the Krebs cycle; it is inhibited by high concentrations of ATP, Acetyl-CoA and reduced NAD **Genotyping and Phenotyping:** **K1.34 The differences between genotyping and phenotyping:** • genotyping determines the sequence of nucleotide bases, which can be used to determine the presence of specific genes, regulating sequences and abnormalities that could result in a disease/disorder • genotyping is used to determine the difference or similarities between samples of DNA • phenotyping is the process of predicting physical appearance based on genotyping	

Core scientific knowledge	
• phenotyping is used within forensics to indicate characteristics such as ethnicity, sex, eye colour and hair colour. It will only ever be a prediction and not a completely accurate representation **K1.35 How to determine genotype through investigating deoxyribonucleic acid (DNA) sequencing, using genotyping techniques such as polymerase chain reaction (PCR):** • PCR is the replication of DNA in a test tube • a sample of target DNA is heated to its melting point to break the bonds between DNA strands and separate these into single strands • the solution is cooled and the enzyme DNA polymerase, nucleotides and primers are added; the process of DNA amplification is initiated • further heating takes place and the DNA polymerase catalyses the synthesis of complementary strand for each of the single DNA strands • the process is repeated until sufficient DNA is produced to determine genotype **Ecosystems:** **K1.36 The term ecosystem:** • biological community (plants, animals and micro-organisms) and the abiotic factors (light, temperature, water, atmosphere, wind and chemical elements) with which they react • an ecosystem is made up of both living and non-living components **K1.37 How the following contribute to an ecosystem:** • habitats: the physical site where an organism or group of organisms live	

Core scientific knowledge	
• populations: group of organisms of the same species • community: all the organisms or populations in an ecosystem • niche: role and position a species has within an ecosystem **K1.38 The following processes within ecosystems:** • biomass transfer: o transfer of biomass (energy) from producers and consumers through a food chain o transfer is from one trophic level to the next o in healthy ecosystems about 10 percent of biomass is transferred from one trophic level to the next • recycling: o nutrients, such as through the carbon and nitrogen cycle, as well as minerals and water are recycled within ecosystems o decomposing bacteria and fungi break down dead organisms which recycles minerals and nutrients • primary succession from pioneer species to a climax community: o the colonisation of an environment which has previously been devoid of other organisms o colonisation of an area for the first time • bioaccumulation: o gradual accumulation of contaminants within an ecosystem	

Core scientific knowledge	
○ toxins, chemicals and pesticides can all accumulate within ecosystems and negatively affect organisms **K1.39 How to measure the distribution and abundance of organisms in an ecosystem:** • using sampling techniques: ○ quadrat ○ belted transect ○ mark release capture • calculating percentage cover or population density from these techniques **Nanoscience and nanotechnology:** **K1.40 The considerations that need to be made when manipulating matter whose basic components are of a nanoscale size:** • the scale of the particles • exposure limits • using specialised equipment (for example, atomic force microscope) • appropriately trained personnel **Electronics:** **K1.41 The difference between analogue and digital signals:** • analogue signals are continuous • digital signals are discrete **K1.42 How analogue signals are converted to digital signals so that computers can further interpret them:** • the analogue signal is first converted into binary code and then into a digital signal **K1.43 The advantage of using a digital signal over an analogue signal:** • to improve accuracy by reducing the effect of noise and interference	

Core scientific knowledge	
K1.44 The advantages of using analogue sensors to detect physical inputs and convert them to digital readouts, (for example, in a pH probe or temperature probe): • analogue sensors are more precise, with higher resolution • analogue sensors measure continuously **Nuclear physics:** **K1.45 The properties of stable and unstable nuclei:** • stable: a balance between the number of protons and neutrons in the nucleus • unstable: an imbalance between the number of protons and neutrons in the nucleus **K1.46 The link between mass and energy (mass-energy equivalence) in nuclear fission, using $E = MC^2$.**	

Scientific tasks	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.47 When scientific and mathematical skills are applied when performing a range of scientific techniques:** • measuring: ○ volume using a burette ○ mass on a 3-Decimal Place (DP) balance (analytical or top pan balance) • manual dexterity: ○ when using a pipette	The student must be able to: **S1.74 Follow multistep scientific methods (for example, make a defined molar concentration and perform a titration) based on relevant SOPs when performing a range of practical scientific techniques.** **S1.75 Apply a range of science and mathematical skills when performing practical scientific techniques:** • measuring: ○ with accuracy and precision

Scientific tasks	
○ performing aseptic technique ○ setting up a microscope • observing: ○ colour changes at titration end point ○ microscopic observations • quantifying: ○ cell counts ○ abundance of organisms in an ecosystem • predicting: ○ melting and boiling points ○ possible components of a mixture in chromatography • analysing: ○ trend charts ○ calculations ○ statistical analysis • evaluating: ○ evaluating the success of the scientific method **K1.48 The factors to consider when choosing between a range of scientific techniques:** • health, safety and ethical considerations • equipment availability and cost • substance/sample to be investigated • strengths and limitations of the technique • objective of the investigation **K1.49 The purpose of:** • analysing substances and chemical environments: ○ to confirm composition and/or quantity of materials	○ avoiding any cumulative errors • manual dexterity: ○ using equipment competently and safely ○ manipulating and manoeuvring equipment and samples effectively • observing: ○ accurately reading displays and scales ○ distinguishing fine changes in appearance • quantifying: ○ accurately counting and measuring ○ using appropriate units and scaling ○ using appropriate equipment where applicable • predicting: ○ using evidence and verifiable scientific information • analysing: ○ using mathematical processes to support technical arguments • evaluating: ○ making summary judgements based on adequate and appropriate data (GMC1, GMC8) **S1.76 Use the following practical scientific techniques to measure a range of physical properties:** • pressure using a U-tube manometer: ○ setting up the manometer vertically ○ opening one tube to the atmosphere or attaching to gas supply ○ measuring the height difference in the u-tube

Scientific tasks	

• micro and nano science:
  ○ to analyse matter on an atomic, molecular and supramolecular scale
K1.50 Why the following techniques are used:
• titration (for example, purity analysis):
  ○ purity analysis and determining concentration
• preparation of serial dilutions:
  ○ to alter concentrations to enable analysis
K1.51 When it is appropriate to use the following techniques to identify/determine, separate or analyse substances and environments:
• calorimetry to analyse energy changes in chemical reactions
• characterisation using mass spectrometry to identify compounds and infra-red spectroscopy to identify functional groups
• colorimetry to determine concentration
• chromatography to separate and therefore identify the components of a mixture
• distillation to separate the components of a mixture
• filtration (for example, vacuum and fluted) to separate insoluble components of a mixture
• electrolysis to separate compounds (for example, chlorine gas from chlorine compounds)
K1.52 When it is appropriate to use the following laboratory techniques:
• tissue culture to grow cells or tissues on a culture medium
• cloning to generate genetically identical copies of a cell
• protein purification to isolate specific proteins for further analysis
	• temperature using a probe and data logger:
	  ○ attaching the probe to data logger
	  ○ inserting the probe into substance to be tested
	  ○ taking the reading from data logger
	• radioactive count rate using Geiger counter:
	  ○ measuring the background count rate
	  ○ measuring the count rate for a defined period of time, using shielding if appropriate
	• conductivity meter to measure conductivity of a solution:
	  ○ calibrating the equipment with a solution of known conductivity
	  ○ rinsing the probe with deionised water and then inserting into test solution
	  ○ rinsing further between subsequent readings including repeats
	• electrical polarity using an ammeter and a voltmeter:
	  ○ setting up the circuit with ammeter in series or voltmeter in parallel
	  ○ noting down the sign and reading from the meter, then reversing the wires on the meter to check that the sign is opposite
	S1.77 Use the following practical scientific techniques to analyse substances:
	• acid base and redox titration:
	  ○ measuring quantity of unknown solution using a pipette
	  ○ determining the end point by colour change
	  ○ using n = cV to work out concentration
	• preparation of serial dilutions:

Scientific tasks	

• extraction and sequencing of DNA to identify genes
• microbiology techniques:
  ○ aseptic culturing to analyse biological environments to confirm the presence of microorganisms
  ○ differential staining to identify microorganisms (for example, Gram staining to identify Gram negative or Gram positive)
  ○ cell counting methods to count/quantify number of cells present in a sample, including manual counting methods such as using a haemocytometer or colony-forming unit (CFU), or automated cell counting, such as coulter counters or flow cytometry
 	
K1.53 The purpose of the following environmental laboratory techniques:
• biochemical oxygen demand (BOD) to determine the amount of dissolved oxygen needed by microorganisms in a water sample
• chemical oxygen demand (COD) to determine the amount of oxygen needed for complete chemical oxidation in a water sample
• total organic carbon (TOC) to determine the total amount of organic carbon in a sample
• total suspended solids (TSS) to determine the dry weight of suspended solids from a water sample
• measuring toxicity to determine median lethal dose (LD_{50}) and lethal concentration (LC_{50})
 	
K1.54 The purpose of laboratory techniques used in the science manufacturing environment:
• sampling:
	○ determining the required dilution
	○ working with proportion by applying the numerical form of proportion to reach target concentration
	○ measuring accurately and transferring the solution to the subsequent diluent
	• colorimetry:
	○ selecting the appropriate filter
	○ zeroing the colorimeter using a cuvette containing the solvent only
	○ measuring the absorbance of a cuvette with test solution
	
	(GMC3)
	
	S1.78 Use the following practical scientific techniques to analyse environments and identify microorganisms within biological environments:
	• aseptic culturing:
	○ manipulating the equipment to limit contamination (for example, when transferring the microorganism culture to growth medium)
	○ sterilising equipment throughout the technique (for example, flaming of the wire loop)
	○ following disinfection procedures upon completion of the technique
	• differential staining techniques:
	○ preparing the slide and introducing the smear, using aseptic technique
	○ fixing the smear (for example, heat fix)
	○ applying stains and rinses in the correct order
	○ examining the smear using a light microscope and identifying if bacteria are

Scientific tasks	
○ part of the process for quality assurance of intermediates where a representative sample is taken in order to determine any impurities within the product • testing: ○ to identify the presence of microbiological organisms (for example, in pharmaceutical products) ○ to determine the stability of products and chemicals ○ to determine the level of an active ingredient (for example, in a pharmaceutical product) ○ to determine the levels and identity of impurities in process starting materials • scaling up to pilot plant: ○ to determine how increases in scale may affect the manufacturing process (for example, flow rates, reaction times) **K1.55 How physics laboratory techniques are applied in different fields:** • electronics to determine input and output voltages of logic circuits • mechanics to determine stress (force/area) on an object under tension • ionising radiation to determine half-value layer (HVL) of a substance • thermal to determine thermal conductivity • electricity to determine the voltage across and current through a component) • magnetism to measure the magnetic flux density **K1.56 The purpose of the following techniques, particularly those related to genomics:** • nuclear magnetic resonance spectroscopy (NMR) (Carbon-13 and proton NMR), used	Gram-positive (violet in colour) or Gram-negative (pink in colour) **S1.79 Use the following practical scientific techniques to prepare, isolate and separate materials:** • paper and thin layer chromatography: ○ applying sample onto chromatogram ○ adding solvent to appropriate level (for example, below baseline) ○ using a location agent, if appropriate (for example, iodine, UV light and ninhydrin) ○ measuring substance from baseline • distillation: ○ correctly setting up the equipment (for example, attaching condenser correctly) ○ using appropriate heating method for sample (for example, heating mantle) ○ reading off boiling point using correctly placed thermometer • filtration (for example, vacuum and fluted): ○ correctly setting up the equipment (for example, attach aspirator correctly) ○ choosing and preparing the appropriate size filter paper (for example, fluting if necessary) ○ adding suspension at appropriate rate • refluxing: ○ correctly setting up the equipment (for example, attaching condenser correctly) ○ using appropriate heating method for sample (for example, heating mantle) ○ adjusting heat and condenser for appropriate drip rate **S1.80 Prepare a solution of defined molar concentration, by:**

Scientific tasks	
to identify the presence of certain atoms and environments in a sample using electromagnetic radiation • polymerase chain reaction (PCR), used to sequence multiple copies of specific sequences of new DNA strands, complementary to a presented template strand • gel electrophoresis, used to separate DNA fragments according to their size, also used to separate other macromolecules dependent on size and charge • flow cytometry, used in genomics to determine genome size, to give an estimate of amount of nuclear content • next generation sequencing range of techniques that allow for sequencing of DNA quickly and cost effectively. These techniques enable the sequencing of thousands to millions of DNA molecules simultaneously	• calculating the relative molecular mass for the concentration needed (n = cV) • using a balance and volumetric flask correctly • ensuring the transfer of all solid and liquid without spilling • rinsing equipment into volumetric flask **S1.81 Use appropriate international system of units (SI) and be able to work with a range of appropriate scales when conducting scientific tasks:** • length - metre (m) • time - second (s) • amount of substance - mole (mol) • electric current - ampere (A) • temperature - kelvin (K) • mass - kilogram (kg) **S1.82 Convert between SI and non-SI measurement units when conducting scientific tasks:** • mass (for example, ounces to kilograms) • temperature (for example, fahrenheit to kelvin) **S1.83 Follow a method from a scientific paper when performing a technique:** • selecting key information from a method or scientific paper and summarise for use to perform the scientific technique • selecting relevant facts from the scientific paper

Scientific equipment, instrumentation and use of raw materials and reagents	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.57 A range of laboratory equipment used to identify and separate samples:** • chromatography columns (for example, in column chromatography and gas liquid chromatography (GLC)) • mass spectrometer • infra-red spectrometer • nuclear magnetic resonance spectrometer **K1.58 The purpose of electrical calorimeters:** • to measure energy change with minimal heat loss **K1.59 A range of laboratory equipment that is used to analyse biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) content:** • dissolved oxygen probe (BOD) • reflux equipment and calorimeter (COD) • TOC analysers to measure CO_2 from organic carbon (TOC) **K1.60 The purpose of cryogenic equipment in a laboratory environment:** • to maintain the integrity of biological material **K1.61 The purpose of the following physics laboratory equipment:** • oscilloscopes: used to display time-varying signals in a graphical form • search coil: used to measure magnetic flux • capacitors: used as part of a circuit to store electrical charge	The student must be able to: **S1.84 Select appropriate equipment to complete practical scientific techniques:** • measuring cylinders • light microscope • burette • 3 Decimal Place (DP) balance (analytical or top pan) • volumetric, graduated and mechanical (variable volume) pipettes • meters - ammeters, voltmeters, multimeters • Geiger counter • heating apparatus • pH meters • TLC plates • microbiological equipment - (for example, incubator) • data loggers with temperature probe • fume cupboard • autoclave • condenser **S1.85 Demonstrate practical technical competence in the use of equipment:** • taking accurate measurements • correctly manipulating the equipment • using equipment safely and for intended purpose **S1.86 Calibrate scientific equipment and check it is fit for use:** • pH meters:

Scientific equipment, instrumentation and use of raw materials and reagents	

• lasers: used to look at wave patterns
• light gates: used to measure speed/acceleration
• meters:
  ○ ammeters: used to measure current
  ○ voltmeters: used to measure potential difference
  ○ multimeters: used to measure voltage, current and resistance
  ○ Geiger counter: used to detect ionising radiation
• thermistors: used to change resistance with changing temperature in a circuit, used as temperature sensors
• light dependant resistors (LDR): used to change resistance with changing light intensity in a circuit, used as light sensors
• data logger with temperature probes: used to measure changing temperature
K1.62 The importance of using appropriate reagents and raw materials to complete practical scientific tasks, considering factors such as:
• sources and suppliers (for example, using reputable suppliers to ensure quality)
• handling and storage (for example, adhering to expiry date to ensure integrity)
• quality control and assurance of raw materials and reagents (for example, ensuring reagents meet the standards of those previously used, appropriate purity)
	○ using buffer solutions
	• balances:
	  ○ using calibration masses
	• mechanical (variable volume) pipette:
	  ○ using distilled water and balances

Scientific equipment, instrumentation and use of raw materials and reagents	
Data collection and recording	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.63 The principles of producing reliable and verifiable results:** • recording in a clear and unambiguous way (for example, use of tables, indelible ink, not using sticky notes or loose papers, ensuring writing is legible) • using appropriate units, notation and correct number of significant figures • critically reviewing data obtained (for example, identifying any anomalous results) • repeating investigations and referencing why any action was taken, where appropriate **K1.64 The purpose of the following analysis methods to produce reliable and verifiable results when dealing with large sets of data in genomics:** • computation and statistical analysis: used to manage and appropriately analyse the large data sets that result from genome sequencing • algorithms: programmed codes which allow large data sets from genome sequencing to be analysed and compared effectively and efficiently	The student must be able to: **S1.87 Produce data from scientific techniques, which are reliable and verifiable, by:** • recording data and records in a clear and unambiguous way: ○ using appropriate units, notation and correct number of significant figures ○ organising ideas logically and coherently • selecting and using appropriate digital technology (for example, PC-connected data logger, multimeter): ○ to gather data evidence efficiently (for example, using a temperature data logger instead of multiple manual recordings) ○ demonstrating a secure level of competence and confidence in configuring and using digital devices • critically reviewing data obtained and repeating investigations where appropriate (GDC1, GDC4) **S1.88 Contribute to the preparation of the following sections of a scientific report including:** • abstract which concisely summarises the completed scientific techniques and the results obtained • introduction • methods • results, including using reliable and verifiable data

Scientific equipment, instrumentation and use of raw materials and reagents	
	• discussion/evaluation which includes using calculations, diagrams and data representations to support technical arguments • conclusion

Legislation, regulations, standards and guidelines	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.65 How the following regulations are applied when performing scientific techniques in a laboratory environment:** • good laboratory practice (GLP): o requires all techniques that are performed are of high quality, following standard operating procedures. o requires that all techniques performed and results obtained demonstrate uniformity, consistency, reliability, traceability and reproducibility o requires accurate record-keeping o often results in automated approaches being implemented within a laboratory setting • good manufacturing practice (GMP): o requires that all products produced within a laboratory are of high quality o requires all batches of products to be of consistent quality o requires that all products are safe to use, uncontaminated and effective • quality management systems (QMS):	The student must be able to: **S1.89 Follow SOPs to ensure compliance with regulations and quality standards when performing scientific techniques.**

Legislation, regulations, standards and guidelines	
○ ensures processes and procedures within a laboratory setting are undertaken in specific ways to guarantee the highest level of accuracy and reliability ○ are applied across all steps of activity within a laboratory setting, including documentation requirements, use of equipment and chemicals, as well as requirements for staff training ○ ensures that decisions within a laboratory setting are data-driven • good clinical practice (GCP): ○ requires that all clinical research be performed to international ethical (including confidentiality), scientific and practical standards **K1.66 The role of the following standards and regulatory bodies (including industry-specific) within a laboratory environment:** • United Kingdom Accreditation Service (UKAS): ○ the sole national accreditation body recognised by the government to assess, against internationally agreed standards, any laboratories that provide certification, testing, inspection and calibration services. ○ accreditation by UKAS demonstrates the competence, impartiality and performance capability of laboratories • ASTM International: ○ International Standards Organisation (ISO) which develops and publishes technical standards to ensure the quality and safety of a wide range of products and services including plastics and adhesives	

Legislation, regulations, standards and guidelines	
○ laboratories involved in the production or testing of such products or providing specific scientific services are often required to demonstrate compliance with these standards • International Organisation for Standardisation (ISO): ○ independent, non-governmental international organisation which develops voluntary, consensus-based market relevant international standards to which organisations, including science laboratories, adhere ○ these standards cover a wide range of processes, procedures and practices; for example, in forensic science laboratory settings there is an ISO standard relating to recording, collecting, transport and storage of items • Pharmacopoeia (British standards): ○ provides quality standards for UK pharmaceutical substances and medicinal products • Medicines and Healthcare products Regulatory Agency (MHRA): ○ government agency which regulates and licenses medicines, medical devices and blood components for transfusion in the UK ○ regulates what products are safe and what products are not, to decide which products can enter the marketplace • Food and Drug Administration (FDA): ○ government agency in the United States responsible for regulating medicines, medical devices, food dietary supplements, cosmetics and blood products	

Legislation, regulations, standards and guidelines	
○ organisations intending to sell or supply any such products in the United States must prove to the FDA that these products are both safe and effective • European Medicines Agency (EMA): ○ independently evaluates market authorisation applications of medicines for sale or supply within the European Union ○ works closely with national regulatory agencies such as MHRA in the UK • Office for Nuclear Regulation (ONR): ○ independently regulates nuclear safety and security at licensed sites within the UK **K1.67 The purpose and importance of SOPs within a laboratory environment:** • maintaining health and safety by detailing all relevant health and safety requirements (for example, when using hazardous materials) • enabling consistency of approach across all technicians • meeting any legal or organisational requirements (for example, safe storage of controlled materials) • demonstrating compliance for audit purposes (for example, using standard documentation)	

Performance outcome 2: Plan, review, implement and suggest improvements to scientific tasks relevant to a laboratory setting

Planning laboratory techniques and use of equipment	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K2.1 How the following considerations inform the planning of a laboratory task:** • customer/client requirements for laboratory analysis (for example, customer needs, what objectives need to be achieved) • laboratory sampling requirements (for example, what samples are required, frequency of sampling, quantity of sample) • laboratory health, safety, environmental and regulatory requirements (for example, identifying risks through a risk assessment) • resources required including laboratory equipment, reagents and consumables (for example, identifying the sources of equipment, reagents and consumables) • scheduling of laboratory testing (for example, planning timings and potential use of Gantt charts, taking into consideration shared resources) • scientific methods (for example, identifying the most appropriate methods to meet the objectives) • storage and transportation of samples (for example, correct temperature, correct storage container, temperature monitoring) • presentation of the data (for example, identifying most appropriate way of displaying the data, demonstrating whether objectives have been achieved or not including statistical significance) • the role of others within the laboratory environment:	The student must be able to: **S2.15 Design a scientific task to address a particular hypothesis, taking into consideration a range of factors:** • the customer/client requirements • laboratory sampling requirements • laboratory health, safety, environmental and regulatory requirements (for example, COSHH, REACH) • resources required, including laboratory equipment, reagents and consumables • appropriate scientific methods, equipment and techniques • appropriate controls • any specific storage requirements • the most appropriate way to present data **S2.16 Perform a literature review to extract relevant information to support the planning of a scientific task by:** • assessing the quality and reliability of the information accessed • extracting main ideas/key information (for example, methods), from appropriate sections of the paper, relevant to the purpose of the scientific task • selecting fact from opinion • recording relevant information accurately and concisely (GDC5, GEC4)

Planning laboratory techniques and use of equipment	
○ limits of job role and the laboratory itself ○ identifying who would need to be involved, roles and responsibilities of the laboratory team • developing a specific hypothesis, where appropriate, for a scientific task: ○ translating the client objectives into the hypothesis ○ identifying the most appropriate techniques for the scientific task ○ positive and negative controls: ▪ identifying the most appropriate controls to produce robust data ▪ identifying adequate control groups or sample groups, if appropriate **K2.2 How to undertake literature searches and use scientific papers to plan scientific tasks, by:** • accessing appropriate databases (for example, Pubmed, Merck Index* Online, National Institute for Health and Care Excellence (NICE), IOPscience) • using keywords and Boolean in searches • assessing the quality and reliability of the literature to the planned scientific task (for example, who the author is, size of the sample, peer-reviewed status, commercial implications, primary or secondary sources) **K2.3 The principles of laboratory method validation when planning scientific tasks:** • using accepted sample preparation methods • using certified standards to determine accuracy of the method • following accepted guidelines and/or requirements (for example, International Council for Harmonisation of Technical	**S2.17 Apply knowledge of scientific techniques to an unfamiliar context when planning a scientific task, taking into account:** • appropriate scientific techniques and methods • required scientific equipment, reagents and consumables • laboratory health, safety, environmental and regulatory requirements **S2.18 Keep sufficient stock levels of all required laboratory equipment, reagents and consumables for planned scientific tasks by:** • assessing stock levels through regular inventory management • ensuring all reagents are labelled and dated correctly • ordering stock as required

Planning laboratory techniques and use of equipment	
Requirements for Pharmaceuticals for Human Use (ICH) requirements) • following the manufacturers' guidelines for use, where appropriate **K2.4 The principles of laboratory equipment validation when planning scientific tasks:** • using certified standards to determine accuracy of the equipment • checking the equipment is running the up-to-date operating system • checking that the equipment is within calibration and service dates (fit for purpose) • following the manufacturers' guidelines for use, where appropriate **K2.5 The difference between concrete and abstract modelling techniques:** • concrete: a trial task prior to planning • abstract: planning on paper or using computer simulations	

Laboratory data processing and analysis	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K2.6 How the following considerations inform data processing and subsequent analysis of the results in a laboratory environment:** • regulatory requirements (for example, validation, conformity to known analytical standards) • relevant calculations (for example, magnification and Rf values) • conversion of units (for example, consistent use of units across different data sets) • appropriate statistical techniques to determine the validity or significance of the results (for example, standard deviation, p value, uncertainty values) • customer requirements for the presentation of data (for example, graphs) • using complementary experimental methodologies from existing peer-reviewed studies to confirm results (for example, by the use of online databases) • using laboratory control charts and trend charts (for example, to confirm equipment and/or protocols are within tolerance) **K2.7 How to establish the validity of results against standards and controls:** • by using ongoing calculations to monitor results and identify anomalies • calculating Rf values and comparing to known values • using certified reference material (CRMs) **K2.8 The purpose of data processing and analysis in supporting improvements to laboratory techniques:**	The student must be able to: **S2.19 Complete relevant calculations on data obtained in the laboratory environment:** • relative molecular mass • concentration • magnification • Rf values • percentages • ratios • number of bacteria in a population using known division time • electrical resistance • pressure difference (from u-tube manometer) • percentage uncertainty **S2.20 Select appropriate statistical techniques to analyse and interpret results from scientific tasks:** • mean • standard deviation • Chi-square test • T-test (GDC4) **S2.21 Process results, using statistical software, for the following statistical techniques:** • standard deviation • Chi-square test • T-test **S2.22 Use the results of calculations and statistical analysis to interpret and evaluate data from scientific tasks to:**

Laboratory data processing and analysis	
• stability studies: to determine the most appropriate storage for preservation of reagents and consumables • laboratory trend charts: to determine that laboratory equipment is working within specification (for example, colony-forming unit (CFU) data) • laboratory method validation results: revalidating methods if results are outside of specification • proficiency testing (inter-laboratory comparison): to determine the accuracy and reliability of a laboratory's test results against results obtained by a certified laboratory	• determine trends • assess statistical validity • support technical arguments • draw conclusions • communicate effectively to a range of stakeholders (GDC4, GMC8) **S2.23 Present data in an appropriate format:** • using appropriate statistical techniques, including the use of data from laboratory information management systems (LIMS) • in a clear and unambiguous way, taking into account the level and experience of the audience and the purpose • using technical language correctly, and using graphics and other tools to aid understanding • using digital technology competently and confidently to produce, design and create charts and graphs: o line graphs o pie charts o bar chart o results tables o histogram • organising data logically and coherently (GMC6, GEC1, GDC1, GDC2) **S2.24 Use relevant information from online databases to review scientific tasks, in relation to:** • appropriateness of statistical techniques (for example, similar published studies)

Laboratory data processing and analysis	
	• data previously obtained (for example, from a laboratory information management system (LIMS)) **S2.25 Recognise when results are invalid against standards and controls by:** • using ongoing calculations to monitor results and identify anomalies • calculating Rf values and comparing to known values **S2.26 Source expert help, when required, in relation to laboratory data processing and analysis by:** • accurately describing the issue • summing up key points • expressing opinions and supporting these with relevant and persuasive arguments • asking and responding to questions for clarification (GEC6) **S2.27 Use standard software to process, analyse and present results from scientific tasks:** • spreadsheets: process data and produce graphical representations • word processing: present results • presentation software: present results

Reviewing and improving laboratory methods and use of equipment	
Knowledge - What you need to teach	**Skills - What you need to teach**

Reviewing and improving laboratory methods and use of equipment	
The student must understand: **K2.9 The importance of using laboratory-reviewing strategies:** • to identify possible problems and recommend improvements with laboratory methods, tasks and use of equipment **K2.10 Why laboratory documents are created, reviewed and approved:** • to ensure consistency and quality • to follow regulatory requirements (for example, good laboratory practice (GLP) **K2.11 How laboratory documents can be amended to implement improvements both to methods and equipment use, by:** • proposing amendments to working instructions/procedure • gaining approval for changes and amendments • validating amendments • adopting amendments and editing associated documentation • monitoring the process/results **K2.12 The purpose of computer modelling and simulation in the laboratory environment:** • to identify the possible effects of modelling changes to complex procedures before implementing them • to try out changes to method or equipment without dismantling and incurring the associated costs or disruption **K2.13 The stages of analytical method transfer when adopting an alternative laboratory method, following regulatory guidelines:** • determining the feasibility of methods and available equipment for own laboratory (receiving laboratory)	The student must be able to: **S2.28 Review and modify a scientific method to improve the task:** • ensuring correct order of steps for efficiency and effectiveness (for example, substances are at the correct temperature at the required stage) • equipment in terms of precision and accuracy (for example, measuring cylinder versus burette) • ensuring the techniques used are efficient and effective **S2.29 Implement changes to a scientific task through the adoption of a continuous improvement cycle:** • identify the issue, organise ideas and information logically (for example, faulty equipment/reagents) • plan and record required improvements, using digital tools and other aids • implement the improvements • check the effectiveness of the improvements by responding to questions/feedback from colleagues • review improvements and adjust, if required (GEC2)

Reviewing and improving laboratory methods and use of equipment	
• setting the scope and objectives of the transfer • acquiring samples or standards from the transferring laboratory • training of laboratory staff at the receiving laboratory • validating results from both laboratories • adopting the alternative method within the laboratory **K2.14 The importance of quality control in the laboratory environment:** • to determine appropriate performance of laboratory equipment • to ensure methods are producing consistent results	

Performance outcome 3: Identify and resolve issues with scientific equipment or data errors

Equipment management	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K3.1 The principles of maintaining, cleaning, calibrating and validating laboratory equipment used to undertake scientific techniques commonly found in a laboratory environment:** • interpreting manufacturers' instructions • employing the correct test equipment • following appropriate SOPs for cleaning and maintenance • using appropriate cleaning materials	The student must be able to: **S3.7 Resolve issues with a range of scientific equipment:** • ensuring equipment is in working order and free from dirt or contamination • recalibrating equipment according to manufacturers' instructions and standard operating procedures (SOPs) • resetting, following manufacturers' instructions and SOPS **S3.8 Carry out and record routine cleaning and maintenance of equipment:**

Equipment management	
• maintaining cleaning and equipment records • notifying issues with equipment to other users and sourcing expert help when required • safely disposing of equipment that cannot be repaired **K3.2 The importance of recognising equipment faults/technical issues in laboratory equipment used to undertake scientific techniques commonly found in a laboratory environment:** • the potential impact on laboratory results • potential health and safety risks • financial impact (for example, lost time, equipment needs to be replaced) • impact on other users' ability to use the equipment	• following appropriate SOPs for cleaning and maintenance (for example, maintenance schedule) • using appropriate cleaning materials before use (for example, rinsing burette with deionised water) • using appropriate cleaning materials after use • using relevant technology effectively (for example, on LIMS) (GDC1) **S3.9 Recognise when a piece of equipment is producing inaccurate data by:** • identifying anomalous results from repeated measurements • the use of appropriate controls **S3.10 Recognise when equipment is likely to be damaged or cause injury due to malfunction:** • inability of the equipment to be zeroed • fails calibration check • visual checks of the equipment (for example, exposed wires) • by the use of appropriate controls • through anomalous results of repeated measurements **S3.11 Report faults and source expert help when required, by:** • following escalation process • communicating the issue appropriately: o labelling the equipment as out of action o using digital communication where appropriate (for example, email, virtual/collaborative meeting tools) • accurately describing the issue:

Equipment management	
	○ summing up key points ○ expressing opinions and supporting these with relevant and persuasive arguments ○ asking and responding to questions for clarifications (GDC3, GEC6)

Laboratory data errors	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K3.3 The factors that can contribute to data errors (random or systematic) in a laboratory:** • contamination of samples or equipment • incorrect sample storage (for example, temperature) • working outside acceptable tolerances • incorrect laboratory equipment used (for example, using the wrong sized pipette) • inadequate training (for example, use of the equipment or procedure) • equipment incorrectly set up, calibrated, or used • method not followed (for example, standard operating procedure not followed) • transcription errors **K3.4 How to minimise errors in scientific tasks, by:** • reading and following the risk assessment and COSHH sheets	The student must be able to: **S3.12 Identify how data errors could have occurred in scientific tasks:** • contamination of samples or equipment • incorrect sample storage • equipment working outside acceptable tolerances • incorrect laboratory equipment used (for example, using the wrong sized pipette) • equipment incorrectly used or set up • method not followed (for example, standard operating procedure not followed) • transcription errors **S3.13 Identify when a random or systematic error has occurred in scientific tasks:** • gathering and interpreting data efficiently and in an appropriate format (for example, chart or graph) • comparing results against previous data (GDC4)

Laboratory data errors	
• planning the work and workplace requirements • following a validated method • maintaining excellent housekeeping (for example, ensuring samples do not become contaminated) • ensuring equipment is calibrated, set up and used correctly • only undertaking scientific tasks following adequate training • storing and labelling samples and standards correctly • working safely in a laboratory setting (for example, safely disposing of materials) **K3.5 The principles of good documentation practice (GDocP) to prevent data errors:** • creation: o recording information as the work is performed o handwritten entries are in indelible ink and are legible and in full • approval: o signed and dated by authorised personnel • document maintenance: o regularly reviewed and kept current o ensuring electronic records are backed up • document modification: o signed and dated by authorised personnel o ensuring access to documents is controlled **K3.6 How to report and correct recording errors:**	**S3.14 Address non-routine problems with samples and instrumentation in a scientific task:** • identify the error • quantify the error to determine if this is within accepted tolerance • remove or minimise the sources of error • record the source of error and the action taken (GMC2) **S3.15 Take steps to minimise errors in scientific tasks following continuous improvement techniques:** • plan: o planning the work and workplace requirements o reading the risk assessment and COSHH sheets • do: o following the risk assessment and COSHH sheets o following a validated method o maintaining excellent housekeeping (for example, ensuring samples do not become contaminated) o only undertaking scientific tasks following adequate training o working safely in a laboratory setting (for example, safely disposing of materials) • check: o checking equipment is calibrated, set up and used correctly o checking that storage and labelling of samples and standards is correct

Laboratory data errors	
• crossing out the error so it is still visible and entering new value • signing and dating correction • reattaching sheets that have become loose with sticky tape and ensuring the edges have been signed • implementing tracked changes on electronic databases • giving reasons why the correction has been made • following laboratory protocols for error reporting	○ continuously monitor data and ensuring procedures are carried out correctly • act: ○ implementing changes to equipment or method ○ repeating any measurements as required

Occupational specialism - technical: food sciences

Knowledge and skills are set out side-by-side within their themed sections. The numbering is sequential throughout the performance outcome, from the first knowledge statement, following on through the skills statements. The ‘K’ and ‘S’ indicate whether the statement belongs to knowledge or skills.

Mandatory content

- Performance outcome 1: Perform appropriate activities to support the food supply chain complying with regulatory requirements
- Performance outcome 2: Develop new food and food related products to support the food supply chain
- Performance outcome 3: Identify and resolve issues in the food supply chain
- Performance outcome 4: Collect, analyse and interpret food production data

Glossary

Customer

The organisation who buys goods or services from a supplier or manufacturer is known as the customer. The customer may also be known as buyer or client. For the purposes of this qualification, the customer is always the retailer (for example food service).

Consumer

The consumer is the ultimate user of the goods. The consumer is the shopper who will consume the bought product.

Performance outcome 1: Perform appropriate activities to support the food supply chain complying with regulatory requirements

Planning methodologies	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.1 How the following planning methodologies support performance of activities within the food supply chain:** • time management: o supports in meeting customer deadlines • risk assessment: o supports in working safely • critical path analysis: o supports in identifying areas of weakness in process • objective setting: o supports in working effectively as opposed to efficiently	The student must be able to: **S1.71 Use a range of planning methodologies when performing activities to support the food supply chain:** • time management: o planning time to achieve objectives o prioritising tasks • risk assessments: o identifying how to mitigate risk • critical path analysis: o identifying areas of weakness • objective setting: o determining specific, measurable, achievable, realistic and timely objectives **S1.72 Identify the appropriate food safety and health and safety procedures that need to be in place to support food safety and regulatory compliance, within a specific area of the food supply chain (for example, growers/suppliers, transportation, production, distribution, retail):** • health and safety: applicable to all areas of the food supply chain • Hazard Analysis and Critical Control Points (HACCP): applicable to all areas of the food supply chain • food safety management: applicable to all areas of the food supply chain

Planning methodologies	
	• technical and quality management: applicable to all areas of the food supply chain • microbiology: applicable to all areas of the food supply chain • raw materials: applicable to growers and suppliers • food science: applicable to production • food technology: applicable to food production • food supply chain from end to end: applicable to all areas of the food supply chain

Legislation, regulations and ethics in the food and drink industry	
K1.2 The difference between safety and quality within the food and drink industry: • safety - ensuring food and drink products are not going to cause foodborne illness, or anything injurious to health • quality - ensuring food and drink products are consistent with the quality and contents indicated on the nutritional information and ingredient labels **K1.3 The required legal characteristics of food and drink businesses:** • the requirement to register any food/drink business with the local authority before trading, either online or direct to the public (including the number of days in advance the registration needs to take place) • the requirement for all food handlers to be trained commensurate with the activities they intend to undertake within the food/drink business	**S1.73 Identify the labelling requirements of food and drink products to comply with the required legislation and regulations:** • nutritional information • quantitative ingredients declaration (QUID) • calorific values • all ingredients, with allergens emphasised (for example, in bold) • origin of raw materials • use by and best before dates • weights and measures **S1.74 Carry out a supplier assurance risk assessment to ensure food safety, by checking:** • achievement grading and how recent external certification has been achieved by the supplier (for example, Brand Reputation

Legislation, regulations and ethics in the food and drink industry	
• the requirement for specific authorisation to practice in certain industries (for example, meat, dairy, slaughterhouse) • the requirement for traceability of raw materials from point of origin, including cattle movement (field to fork) • the requirement for the welfare and handling of animals **K1.4 The purpose of relevant legislation and regulations that apply to the food and drink industry, in relation to:** • food and drink safety: ensure the production environment is suitable, food is safe to eat, product is as specified, and food will not cause harm to the consumer • food and drink labelling: ensure consumers can make informed choices about food by making it mandatory to display certain information (for example, allergen information) • weights and measures: ensure product meets required standards and protects the consumer **K1.5 The difference between legislation and industry standards/codes of practice within the food and drink industry:** • legislation: what food and drink suppliers must do by law • industry standard/code of practice: what food and drink suppliers do to ensure that what is produced meets the required standard **K1.6 The requirements of industry standards and codes of practice within the food and drink industry:** • industry standards (for example, BRCGS, Red Tractor Assurance): requires that food is produced to a specified standard	Compliance Global Standards (BRCGS), Safe and Local Supplier Approval (SALSA)) • the controls that the supplier has in place (for example, pre-requisites, HACCP plan, allergen controls) • the training of the supplier's staff (for example, food safety, health and safety, standard operating procedures) • the supplier's reputation in industry (for example, references from other companies, customer satisfaction) • the supplier's experience of supplying that ingredient • previous use of the supplier **S1.75 Carry out a Threat Assessment and Critical Control Points (TACCP) risk assessment on the following potential areas of weakness:** • people: o internal, including disaffected workers and agency staff o external, including screening and escorting of contractors and visitors, unauthorised access by radical groups (bioterrorism) • premises: o access for people, including between car parks and production areas o access for delivery vehicles o general site security, including boundary fencing/walls, lighting, mail security, prohibited use of portable electronic equipment • process: o access to production areas (for example, lone workers unsupervised access in production areas)

Legislation, regulations and ethics in the food and drink industry	
• technical processes/quality management systems (for example, good manufacturing practice): provides frameworks for processes and procedures to ensure that food is safe to eat • industry codes of practice (for example, ice cream, meat, dairy): provides industry/product specific processes and procedures to ensure food and drink meet required standards • internal and external specifications (for example, raw material specifications, internal manufacturing/production specifications and final product specifications): defines the food safety and quality of the product to meet customer requirements **K1.7 The purpose of relevant environmental legislation and regulations that apply to the food and drink industry:** • pollution of water sources (for example, avoiding the release of effluent into streams/water courses, avoiding flushing food down drains): to avoid contamination of water sources • recycling (for example, food and packaging waste): to reduce waste going to landfill • emissions (for example, light, noise or odour from food and drink processing): to reduce emissions **K1.8 The purpose of social, environmental and economic sustainability within the food supply chain:** • to protect local communities and the environment from the impact of the food and drink industry **K1.9 The purpose of the following risk assessment procedures used at each stage of the food supply chain, including**	○ machine security to prevent unauthorised access ○ raw material intake checks, product security (for example, tamper proof packaging) • services: ○ protection of utilities, drainage systems, air inlets/vents, cleaning systems, particularly chemical controls • distribution: ○ access to depot and vehicles, vehicles en route, service and rest areas **S1.76 Utilise horizon scanning tools to search for and gather evidence efficiently, in relation to potential food fraud:** • alerts: ○ checking the Food Standards Agency (FSA) website ○ checking the Food Authenticity Network website ○ checking the Rapid Alert System for Food and Feed website portal (RASFF) • natural disasters: ○ checking the Foreign and Commonwealth Office website • civil disturbance: ○ checking the Home Office website (GDC4)

Legislation, regulations and ethics in the food and drink industry	
procurement, food production, processing, packaging, storage requirements and distribution: • supplier assurance risk assessment: ensures raw materials are purchased from safe sources • TACCP: protects food from malicious acts (for example, food defence) • Vulnerability Assessment and Critical Control Points (VACCP): prevents adulteration or substitution of ingredients (for example, food fraud) • horizon scanning: to identify potential alerts, natural disasters and civil disturbances that could result in food fraud **K1.10 The purpose of ethical trading initiatives in the food and drink industry:** • to ensure the sustainability of raw materials (for example, fishing, farming and use of palm oil) • to ensure the welfare of workers including modern slavery, working time and fair trade • to ensure the welfare of animals including free range, transportation and slaughter	

Health and safety in the food and drink industry	
The student must understand: **K1.11 The importance of the following in the food and drink industry to support health and safety:** • personal protective equipment (PPE): to protect the employee and reduce the possibility of physical contamination and injury risks	The student must be able to: **S1.77 Work safely in a food or drink environment, when carrying out a specific task, by always adhering to SOPs, including:** • wearing the appropriate PPE correctly • using correct manual handling techniques: ○ not picking up loads from the floor if possible

Health and safety in the food and drink industry	
• correct manual handling: to prevent injury • ergonomics techniques: to improve the fit between employees and the environment in which they work • using the correct equipment for the task: to prevent injury • safe use of equipment: to prevent injury • standard operating procedures (SOPs): to ensure the safety of employees **K1.12 An employee's responsibility in adhering to health and safety controls within the food and drinks industry:** • PPE: o wearing PPE • staff training: o only carrying out tasks and using equipment for which the individual is trained • risk assessments: o carrying out and following risk assessments • SOPs: o following the step-by-step guide which includes photographic instructions and PPE requirements o knowing who to escalate issues to • Control of Substances Hazardous to Health (COSHH): o following controls for food additives o following SOPs for use and storage of chemicals	o ensuring adequate space to prevent twisting or bending o ensuring a clear, level work area o taking rest breaks when needed o not carrying double loads o adhering to job rotation policies • using the specified equipment safely • using ergonomic techniques: o minimising repetition o varying tasks **S1.78 Carry out a health and safety risk assessment, identifying risks and mitigating factors:** • step 1: identifying the hazard: o machinery and facility hazards (for example, equipment without guards, maintenance of building and equipment) o microbiological hazards (for example, hygiene practices) o chemical hazards (for example, ammonia leak, cleaning fluids mixed incorrectly) o manual handling hazards (for example, incorrect lifting) o slips, trips and falls hazards (for example, spillages, incorrectly stored materials, obstructions in walkways) o blocked fire exit hazards (for example, incorrectly stored materials) o electrical hazards (for example, isolation of equipment) o vehicle hazards (for example, forklifts, vehicles reversing into loading bays)

Health and safety in the food and drink industry	
	• step 2: identifying who might be harmed (for example, machine operator, visitors, contractors, hygiene specialists) • step 3: evaluating the risk and selecting appropriate control measures (for example, identifying if any alternative or safer methods than those proposed can be used; identifying control measures that need to be in place to minimise risks at all times; identifying appropriate PPE; ensuring adequate guarding; identifying the isolation and lock-off of machinery) • step 4: recording the findings and implementation (for example, ensuring any significant findings that require further changes to manage the risks better are recorded, for example, use of additional PPE): o in a clear and unambiguous way o using technical language correctly o organising the findings logically and coherently o using the appropriate grammar, vocabulary and spelling • step 5: monitoring and reviewing risk management o are the current controls still working? o is there any new equipment that needs to be considered? o have any processes changed? o have any lessons been learnt from recent near misses or accidents? (GEC1)

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
The student must understand: **K1.13 The importance of implementing an effective HACCP-based food safety management procedure:** • legal requirement for all food and drink organisations • to identify hazards and put controls in place to eliminate the hazard or reduce it to a safe level • assures the product is safe to eat **K1.14 The pre-requisites procedures that need to be in place in a food or drink business prior to implementing a HACCP-based food safety management system:** • approved suppliers: o process for supplier approval • allergen procedure and controls: o segregation o separate, colour coded PPE (for example, red hairnets) o captive tools, utensils and equipment • incoming materials specifications: o goods-in checks • training for staff: o basic food hygiene o critical control points • cleaning: o schedules o equipment • suitable premises: o glass/hard plastic procedure • pest control: o types of pests	The student must be able to: **S1.79 Contribute to a HACCP plan for a simple product, by creating a HACCP flow diagram as outlined in step 4 of the 12 HACCP steps:** • using the appropriate style for the type of communication and audience (for example, technical function, engineering function, production function) • ensuring that the diagram is clear and concise • using the appropriate level of detail for audience and purpose • using correct terminology, grammar, spelling and punctuation, proofreading to ensure accuracy • using relevant digital devices and media as appropriate (for example, computer and application diagramming software) to construct the flow diagram (GEC3, GDC1)

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
○ use of contractors • internal auditing to maintain best practice: ○ good manufacturing practice (GMP) ○ good hygiene practice (GHP) **K1.15 The application of the 7 principles of HACCP in order to implement and maintain a HACCP-based food safety management system:** • principle 1: conducting a hazard analysis, considering all possible hazards, risk-assessing all hazards and identifying controls: ○ microbiological hazards: bacteria, viruses, protozoans, moulds, parasites, algae: ▪ controls: effective training, effective personal hygiene, effective cleaning procedures, effective cooking procedures, effective cooling procedures, effective stock control ○ physical hazards: foreign bodies which may be from the following sources: people, pests, raw materials, packaging, equipment, cleaning activities, buildings, sabotage: ▪ controls: effective training and supervision of staff, effective personal hygiene, effective pest control, following SOPs, regular planned preventative maintenance, effective cleaning ○ chemical hazards: which may be from following sources: in raw materials from pesticides, fungicides, metals in fish or vegetables, antibiotics/hormones in meat, industrial chemicals, natural toxins, during preparation, fumes, cleaning chemicals, pesticides, metals, excess additives, migration from packaging:	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
▪ controls: use of reputable suppliers and safe packaging, following manufacturer instructions for use of cleaning chemicals, correct storage of cleaning chemicals, use of approved pest control contractors, no cleaning over open food ○ allergenic hazards: introduced as a result of poor segregation or cleaning: ▪ controls: use of approved suppliers, following stringent allergen control procedure, strict segregation • principle 2: identifying critical control points (CCPs): ○ control is used to eliminate a food safety hazard or reduce it to a safe level • principle 3: establishing the critical limits: ○ a maximum and/or minimum value (must not be a range) is allocated to a hazard in order to prevent, eliminate or reduce the hazard to an acceptable level • principle 4: monitoring CCP: ○ what: is being monitored (for example, critical limits, target levels and tolerances) ○ how: the monitoring should be undertaken, including equipment and calibration ○ where: the monitoring should be undertaken (at, or as close as possible to, the CCP) ○ who: is responsible for the monitoring ○ when: the monitoring should be undertaken, including continuous or batch (must be frequent enough to ensure that the hazard is controlled - without requiring significant destruction of product)	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	

• principle 5: establishing corrective actions:
  ○ identifying actions to be taken if the process breaches the critical limits
  ○ corrective actions should take place before the critical limit is breached
  ○ corrective actions will bring CCP back under control and deal with any effected product
• principle 6: verifying and validating:
  ○ verification: the methods, procedures, tests, which are used, in addition to monitoring, to establish if the HACCP system is functioning as planned
  ○ verification questions such as:
  ▪ are the critical limits being complied with?
  ▪ are monitoring procedures being accurately followed?
  ▪ are corrective actions being implemented as per the HACCP plan?
  ▪ is the plan being regularly verified?
  ○ validation: obtaining evidence (for example, from scientific literature, legislation, ongoing reviews, international guidance, food standards and industry guides, pre-production trials) to validate that the HACCP plan is effective, especially the CCP and critical limits
  ○ reviews - at regular intervals (at least annually): if new scientific data emerges, when a confirmed complaint or illness occurs, when the raw materials or recipe changes, when equipment or the process is changed, when storage conditions or product use changes, when packing or distribution is changed, following modification of the HACCP plan	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
• principle 7: record-keeping, documentation required for: due diligence, legal requirement, customer requirement, assists in investigation of complaints, identifying areas of weakness, may identify training needs, can be used for trend analysis. Records to include: o HACCP plan, including details of how it was developed o pre-requisites programmes o floor plan including segregation of high/low risk areas o approved supplier list o monitoring records **K1.16 How to implement and maintain a HACCP-based food safety management system, by following the detailed requirements of the following 12 steps:** • step 1: assembling the HACCP team, including: o training of staff o responsibilities of the team • step 2: describing the product and its distribution, including: o composition o hazards o suitability for microbial growth o processing methods o storage o distribution o shelf life o packaging o labelling o legal requirements	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	

• step 3: identifying the intended use of the product and consumers, including:
  ○ likely consumers, including sensitive and vulnerable groups
• step 4: constructing the flow diagram to describe the process:
  ○ a systematic representation of the steps or operations involved, often from purchase to the consumer
• step 5: on-site confirmation of flow diagram:
  ○ ensuring the flow diagram represents what happens in practice (for example, is it accurate for every occasion, and over every shift?)
• step 6: conducting a hazard analysis:
  ○ identifying possible hazards at the steps in which they are likely to occur
  ○ risk-assessing all hazards
  ○ identifying controls to mitigate the risks
• step 7: determining critical control points:
  ○ determining the steps in the process where control measures need to be in place to prevent, eliminate or reduce the hazard to an acceptable level
  ○ control procedures must be in place for each CCP
  ○ CCPs to be identified using the Codex Alimentarius decision tree, which is essentially a series of questions to determine whether a step is a control point or a critical control point
• step 8: establishing critical limits for each critical control point:
  ○ these are the values of monitored actions, separating the acceptable from the unacceptable	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
○ quantifiable limits are preferred and, if possible, the results should be obtained immediately on site ○ target levels can also be identified, and these may enable a potential breach of a critical limit to be detected and remedied before the food becomes unfit • step 9: establishing a monitoring system for each critical control point, including: ○ monitoring of control measures at each CCP ○ this is essential to confirm that a process is under control and critical limits are not exceeded ○ it can be automatic or manual, and must permit rapid detection and correction ○ procedures should state what the critical limits are, where the monitoring should be undertaken, when the monitoring should be done and who is responsible for the monitoring • step 10: establishing corrective actions, including: ○ the actions to take when a critical limit is breached ○ usually there are 2 distinct actions: ▪ deal with the affected product ▪ bring the process back under control ○ procedures should specify the action to be taken, who is responsible for taking the action, who should be notified and whether production needs to be stopped/restarted • step 11: establishing verification procedures: ○ this involves the use of methods, procedures and tests in addition to those used in monitoring to determine	

Hazard Analysis and Critical Control Points in the food and drink industry (HACCP)	
compliance with the HACCP plan and ensure it is effective and valid • step 12: establishing documentation and record-keeping requirements: o these must be proportionate to the size and type of business o must demonstrate food safety is being managed and records are also useful to support a due-diligence defence, when investigating complaints and when auditing a system	

Food safety management	
The student must understand: **K1.17 The importance of food safety management systems in a food and drink industry:** • ensures a systematic approach • ensures regulatory compliance required by law • ensures control of risks and hazards to ensure food is safe • ensures the production of safe food • ensures traceability • ensures due diligence (for example, record-keeping) **K1.18 The importance of following the correct practices for maintaining good personal hygiene within the food and drink industry:** • handwashing: to reduce the risk of microbiological contamination • PPE, including restrictions of use: to reduce the risk of physical contamination	The student must be able to: **S1.80 Maintain and implement a food safety management system within a production facility by:** • following policies and procedures (for example, pre-requisite and critical control procedures) • completing necessary paperwork (for example, for monitoring and recording) • wearing the PPE provided • being fit for work and reporting illnesses, as per organisational policies and procedures • escalating hazards **S1.81 Carry out monitoring and recording of food safety controls, ensuring all information is recorded accurately and precisely:** • temperature checks: o to check consistent cooking and chilling temperatures and times • equipment and maintenance checks:

Food safety management	
• restrictions on the wearing of make-up (for example, false nails, eyelashes): to reduce the risk of physical contamination • restrictions on the wearing of jewellery: to reduce the risk of physical contamination • fitness to work including reporting of illnesses and infections: to reduce the risk of microbiological contamination • covering of wounds with correct dressings (for example, blue, waterproof, metal-detectable strip): reduce the risk of microbiological or physical contamination • restrictions on the use of perfumes/aftershaves: reduce the risk of chemical contamination **K1.19 The correct procedures for maintaining good food safety and hygiene within the food and drink industry (the 4Cs):** • cleaning, including cleaning schedules • cooking, including correct temperature and cooking times • chilling, including correct temperature, keeping food out of the danger zone and correct storage • cross-contamination, including segregation **K1.20 The 4 food safety hazards and the risks associated with them:** • microbiological (for example, bacteria, viruses, fungi - yeasts and moulds): o risks to include: food poisoning, foodborne disease, food spoilage • physical (for example, hairs, buttons, fingernails, pest droppings/fur/feathers): o risks to include: choking, cuts in the mouth, broken teeth	o to detect the potential for physical contamination, calibration of equipment to ensure accuracy of equipment • incoming raw material verification checks: o to ensure they meet the raw materials specifications and are contamination free • final product checks: o to ensure it meets the final product specifications • cleaning checks: o to ensure work/production areas are contamination free • training records: o to ensure staff are trained to carry out the task against the current procedure • allergen controls: o to ensure allergenic ingredients are segregated (GMC1) **S1.82 Review food safety management controls, by:** • identifying non-conformities • suggesting corrective actions

Food safety management	

• chemical (for example, cleaning chemicals, natural chemicals, pesticides, food additives):
  ○ risks to include: sickness, unpleasant taste, long-term damage to the body
• allergenic (for example, peanuts, cereals containing gluten, tree nuts, sesame seeds, eggs, milk, soya beans, mustard, sulphur dioxide, lupin, celery, fish, crustaceans, molluscs):
  ○ risks to include: mild to moderate allergic reactions, anaphylaxis, death
K1.21 The main responsibilities for all food and drink businesses in relation to food safety management, with reference to the relevant food safety legislation:
• businesses must not include anything in food or drink, remove anything from food or drink, or treat food or drink in any way which means it would be injurious to the health of the identified consumer
• the food and drink that businesses serve, or sell must be of the nature, substance or quality which consumers would expect
• food and drink must be labelled, advertised and presented in a way that is not false or misleading
K1.22 The potential implications of not complying with the relevant food safety legislation:
• prosecution of individual and/or business
• loss of custom
• reputational damage
• fines
• prison sentence
• staff wellbeing (for example, morale)
• loss of job	

Food safety management	
• possible closure of food and drink operations • injury to consumer **K1.23 The responsibilities of employers in relation to the maintenance of a food safety management system in a food and drink business:** • providing the correct premises and equipment, including PPE • providing ongoing resource (for example, raw materials, staffing, utilities) • carrying out preventative maintenance • implementing the correct pre-requisite requirements • implementing an effective food safety management system based on the HACCP principles • staff training • internal audits **K1.24 The responsibilities of employees in relation to the maintenance of the food safety management in a food business:** • undertaking mandatory training dependent on role • following policies and procedures as detailed in the SOPs • completing necessary paperwork • wearing the PPE provided • being fit for work and reporting illnesses, as per organisational policies and procedures • escalating hazards **K1.25 The purpose of monitoring food safety management systems:** • ensuring food safety hazards are under control	

Food safety management	

• ensuring procedures are being correctly implemented and followed
• ensuring regulatory requirements are met
K1.26 The purpose of a range of checks that are carried out to verify food safety:
• equipment and maintenance checks: to detect the potential for physical contamination, calibration of equipment
• incoming raw material verification checks: to ensure the required specifications are met and the raw materials are free from contaminants
• cleaning: to ensure work/production areas are free from contaminants
• training records: to ensure staff are competent to carry out the task in line with the current procedures
• allergen controls: to ensure allergenic materials are handled correctly to prevent cross-contamination
• temperature checks: to ensure the product meets the required cooking/chilling temperature and remains safe to consume
• final product checks: to ensure it meets the final product specifications
K1.27 The methods used for pest control and prevention within the food and drink industry:
• staff training to recognise and report signs and types of pests
• pest-proofing of premises:
  ○ fly screens on windows
  ○ strip curtains
  ○ drain covers
• clean-as-you-go procedures
• waste control procedures	

Food safety management	

• reduction of vegetation around buildings
• building maintenance (for example, having a rock or gravel perimeter around facility)
• correct storage of raw materials
• scheduled monitoring procedures:
  ○ the use of external qualified contractors for monitoring and control
  ○ bait boxes
  ○ electric fly killers
  ○ traps
• inspection of deliveries:
  ○ raw materials and their transportation	

Technical and quality management in the food industry	
The student must understand:	The student must be able to:

K1.28 The difference between quality assurance and quality control within the food and drink industry:
• quality assurance:
  ○ failure prevention
  ○ in-process checks against specification
  ○ ongoing planned maintenance
  ○ instrument calibration
  ○ ownership of stages in the process
• quality control:
  ○ failure detection
  ○ final product testing
  ○ final specification checks
	S1.83 Carry out an internal audit by following the appropriate stages and demonstrating skills of a good auditor:
	• carrying out an opening meeting, responding to any questions for clarification as appropriate
	• carrying out the audit using an audit checklist, ensuring all previous non-conformities have been closed out
	• observing practices, asking appropriate and relevant questions to clarify any required areas, and listening actively to responses
	• recording non-conformities and good practice
	• writing the report

Technical and quality management in the food industry	
K1.29 The function of the following organisations in relation to the safety and quality of food and drink: • FSA: ensures food is safe to consume, concerned with national and global issues • local authority: concerned with local issues: o Trading Standards: to maintain integrity of product, weights and measures o Environmental Health: ensures food is safe to consume • advisory research organisations (for example, Leatherhead Food Research, Campden BRI): provide expertise and specialist advice to manufactures to help make food safe **K1.30 The procedures and controls that contribute to a food safety and quality management system within food and drink operations:** • pre-requisite procedures • traceability procedures • industry standards including specific product standards, labelling requirements and Brand Reputation Compliance Global Standards (BRCGS) • customer specifications • nutritional analysis process • critical controls • weight control/portion size as identified in the product specification **K1.31 The difference between internal and external audits in the food and drinks industry:** • internal audits: carried out by an employee (first-party audit) o to ensure the whole operation is meeting the specified requirements • carrying out a closing meeting, summing up key points, agreeing corrective actions and timescales for completion (GEC6) **S1.84 Review a specific food safety and quality management procedure to ensure that the food quality or food safety standard will be met (for example, cooking temperature, overall product quality, storage requirements, allergen controls, product nutritional value).**	

Technical and quality management in the food industry	
○ identifying actions and controls to improve systems • external audits: carried out by the manufacturer on the supplier (second-party audit) and/or carried out by an external organisation (for example, FSA/local authorities/certification bodies such as BRCGS) on the food and drink manufacturer (third-party audit) ○ to ensure the business is meeting customer and/or accreditation requirements **K1.32 The purpose of different types of audits:** • system audit: identifies if a documented food safety and quality system meets specific requirements of a relevant food safety and quality standard (ISO 17025) • compliance audit: examines if all aspects of a prescribed food safety and quality system, including observation of the activity, are being complied with, working well and are maintained on a continual basis • horizontal audit: looks at one discrete or particular aspect of the quality system (for example, training) • vertical audit: a narrow focus on a particular aspect of a product • follow-up audit: to verify corrective actions have been implemented and have resolved the non-conformity • unannounced audit: unscheduled; used to ensure audit standards are maintained at all times, and can be implemented if a customer has complained, if there is an internal non-conformity or if there is a breakdown in process	

Microbiology	
The student must understand: **K1.33 A range of common pathogenic bacteria that can cause foodborne illness and disease and examples of the food products with which they are associated:** • Campylobacter jejuni - chicken, other raw meats • Bacillus cereus - white rice • Salmonella spp. - chicken, eggs • Clostridium botulinum - low acid canned goods • Clostridium perfringens - stews, rolled meats • Staphylococcus aureus - poor personal hygiene • Listeria monocytogenes - soft cheese, chilled products • Escherichia coli O157 - raw and undercooked meats **K1.34 How pathogenic agents may affect at-risk groups:** • infants and babies (for example, pathogenic agents, such as Salmonella spp. and Escherichia coli O157 can cause diarrhoeal diseases, which can lead to dehydration in babies and infants • the elderly (for example, gastrointestinal pathogenic bacteria, such as Campylobacter jejuni, Clostridium perfringens and Salmonella spp. can affect the elderly as they have slower digestion, which allows bacteria extended time to grow in the gastrointestinal tract) • pregnant people (for example, Listeria monocytogenes infection during pregnancy can cause miscarriage, stillbirth, uterine infection and preterm delivery)	The student must be able to: **S1.85 Take swabs from food contact surfaces, including hard-to-reach areas, following a sampling procedure:** • identifying the area to be swabbed (food contact surfaces, non-food contact surfaces, zones of risk) • identifying the required number of swabs • taking appropriate number of swabs to produce reliable results • following the specified swabbing process: ○ removing moistened sterile swabs from the holding tube and wiping across the test area in a rotating movement • maintaining integrity of swabs **S1.86 Use laboratory techniques, skills and equipment to identify any pathogens (causative agents) present on swabbed food surface areas:** • laboratory skills: ○ accurate recording of information ○ hand-to-eye coordination ○ problem solving • laboratory techniques and equipment: ○ using pre-prepared detection kits: ▪ after swabbing the area, the swabs should immediately be placed into the detection tube ▪ detection tubes should be incubated as per manufacturer's instructions ▪ detection tubes are observed for colour changes and results recorded ○ using aseptic technique to transfer sample from swabs to growth medium:

Microbiology

- immuno-compromised: (for example, decreased immune systems means they may be more susceptible to foodborne illness)

K1.35 How to identify pathogenic bacteria which cause foodborne illness and disease:

- observation of, and reported, symptoms can signal initial awareness of a foodborne illness
- laboratory techniques used to identify pathogens (causative agents):
  - general identification techniques (for example, Gram-positive, Gram-negative):
    - aseptic techniques (for example, plating): purposeful growing of pathogens (causative agents) to allow for identification, can make use of selective media to allow for isolation of specific pathogens (causative agents)
  - differential staining techniques: use of specific stains and dyes that provide contrast images that enable identification of specific pathogens (causative agents) by their shape or specific features
    - microscopic examinations: identification of pathogens (causative agents) by direct observation of the gross structures and specific observable features, using a range of microscopes, including scanning electron microscopes
  - specific identification techniques (for example, identification of a specific strain of bacteria):
    - biochemical reactions: identification based on biochemical characteristics of pathogens (causative agents) such as nutritional and metabolic capabilities
    - holding the swab in one hand, using sterile tweezers (if required) and lifting the lid of the petri dish with the other hand
    - only lifting the lid as far as required to drag the swab across the surface in a zig-zag pattern
    - replacing the lid of the petri dish, sealing, and labelling
    - disposing of the swab correctly (for example, not placing it on the bench)
  - using differential staining technique for Gram staining:
    - rolling the swab over a clean slide, using sterile tweezers if needed
    - heat-fixing the slide
    - applying stains and rinses in the correct order
    - examining the smear, using a light microscope, and identifying if bacteria are Gram-positive (violet in colour) or Gram-negative (pink in colour)

S1.87 Identify hygiene process failures, by:

- interpreting results of samples
- providing evidence-based recommendations to improve the hygiene controls of the swabbed areas (for example, cleaning procedures, personal hygiene improvements)

Microbiology	
▪ subtyping: genetic analysis of different samples of pathogens (causative agents) to identify the similarity between them ▪ serological typing: identification of pathogens (causative agents), particularly those that are difficult to culture, through testing for the presence of pathogen-specific antibodies in blood ▪ phage typing: used for the identification of a single strain of bacteria by the use of bacteriophages ▪ immunoassay: identification of pathogens (causative agents) through testing for the presence of pathogen-specific antibodies **K1.36 How a range of food safety and hygiene measures are used to control pathogenic bacteria:** • HACCP: o food safety management system which identifies hazards and puts controls in place • personal and environmental hygiene practices: o cleaning schedules o handwashing procedures • policies and procedures: o staff sickness reporting procedure o sickness exclusion **K1.37 How to sample an environment, using appropriate laboratory skills and equipment, to identify pathogens (causative agents):** • scheduled environmental swab testing: o conducted on both food contact surfaces and non-food contact surfaces (for	

Microbiology	
example, conveyor belts, drains and rollers) ○ frequency of swabbing of specific areas and number of swabs, determined by where they are within the production process ○ approach taken to environmental swabbing is of 'zones of risk', which is dependent on product and environment ○ following the swabbing process • hand swabs: ○ conducted to ensure the implementation of effective personal hygiene requirements (including handwashing techniques) ○ frequency of swabbing dependent on products being handled and an individual's role in the production process ○ following the swabbing process • water testing: ○ conducted on water samples from a range of sources within the production process ○ frequency of testing determined by regulatory guidelines and organisational SOPs (including HACCP) ○ samples taken by trained individuals ○ processing of samples in-house or by contracted laboratories • adenosine triphosphate (ATP) swabbing and monitoring techniques: ○ a test which determines if ATP is present within a sample ○ ATP is present in all animal, vegetable and microorganisms, and, therefore, the	

Microbiology	
presence of ATP is used as an assessment of contamination ○ standard swabbing techniques used in environmental and hand swabbing are employed but with ATP specific swab sticks ○ these swab sticks are then analysed using a luminometer, which determines the level of contamination in a sample	

Raw materials in the food industry	
The student must understand: **K1.38 What to consider when choosing sources and suppliers of raw materials:** • supplier reputation • self-assessment and/or external audit results • ability to meet specification requirements • industry recognised certification • sustainability • risk assessment to determine suitability of supplier and procedures for any subsequent vetting required **K1.39 The purpose of specifications of raw materials:** • to ensure that companies purchase and distribute food that is safe, of good quality and able to satisfy the needs of each customer • to specify requirements for raw materials • to ensure consistency of raw material supply (for example, seasonal and geographical variations, soil chemical composition)	The student must be able to: **S1.88 Select raw materials as per recipe/client requirement, to ensure that the finished product:** • meets recipe requirements • provides the required nutritional value and organoleptic requirements • meets product specification (for example, preservatives, colour, binding agent, emulsifier, origin of raw materials) **S1.89 Follow segregation procedures for handling raw materials in order to protect the integrity of products, and to ensure origin of product is maintained, by:** • using separate PPE/equipment • using separate storage areas • following personal hygiene procedures **S1.90 Follow segregation procedures for handling raw materials to prevent deoxyribonucleic acid (DNA), allergen or microbial cross-contamination, by:** • using separate PPE/equipment • using contaminant free preparation areas

Raw materials in the food industry	
K1.40 What the minimum requirements are for a specification of raw materials: • physical parameters (for example, size, shape, colour) • appearance • odour • flavour • texture • foreign bodies/physical defects • the name of the product and the supplier's item number • components or composition of the material • the presence of regulated or customer-recognised food allergens • pertinent physical, chemical, and microbiological information • shipping and storage information • shelf life • handling instructions **K1.41 The functionality of raw materials:** • to meet recipe requirements • to provide the required nutritional value and organoleptic requirements • to meet specific product requirements (for example, preservatives, colour, binding agent, emulsifier) **K1.42 Systems available for handling raw materials to ensure the integrity of the product is maintained and to prevent cross-contamination:** • storage systems and handling equipment: o racks/trays o shelves	• using separate storage areas • following personal hygiene procedures

Raw materials in the food industry	
○ segregated areas ○ storage bins ○ colour coded utensils and equipment • engineered systems: ○ conveyor ○ robotic • handling of bulk items: ○ bucket elevators ○ silos • industrial trucks: ○ hand trucks ○ pallet jacks ○ forklifts • stock rotation procedures: ○ date coding/day coding/batch identification **K1.43 What to consider when selecting raw materials for a particular product:** • legal requirements • functionality requirements • food safety requirements (for example, allergens) • final product specification **K1.44 How to ensure the quality assurance of raw materials:** • best before and use by dates • checking batch codes • checking labelling • supplier approval • ensuring packaging is not damaged • food allergen information	

Raw materials in the food industry	
• organoleptic • physical testing **K1.45 The importance of the correct storage of raw materials, in particular segregation and protection of integrity:** • to prevent contamination (for example, microbial, foreign bodies, pest infestation, chemical) • to prevent cross-contamination (for example, DNA, allergens and pathogens (causative agents)) • to ensure durability and prevent spoilage • to ensure functionality and materials are fit for purpose **K1.46 The considerations to make when storing raw materials:** • designated areas • segregated areas • temperatures and humidity • stock rotation • adequate space and lighting	

Food science	

The student must understand:
 	
K1.47 The general composition and fundamental role of the main components of different foods:
 	
• carbohydrates:
  ○ macromolecules, composed of one or more monomers containing carbon, hydrogen and oxygen atoms. Classified as monosaccharides, disaccharides or polysaccharides
  ○ a source of energy
  ○ glucose and fructose are examples of monosaccharides; sucrose and maltose are examples of disaccharides; starch is an example of a polysaccharide
  ○ found naturally in honey and fruit (sugars)
  ○ found naturally in the form of fibre, within wholegrain cereals and certain vegetables
  ○ added to a range of confectionery, chocolates and drinks (sugars)
  ○ found in bread, rice, potatoes and pasta (starch)
• lipids:
  ○ a diverse range of molecules, the lipids found in food are commonly referred to as oils and fats and are mainly triglycerides
  ○ used as an energy store, as insulation, in hormone production and in cell membrane formation
  ○ lipids in food include the oils of seeds and grains, as well as animal fats that are found in cheese, milk and meat
• proteins:
  ○ complex macromolecules made up of amino acids, consisting mainly of carbon, hydrogen, nitrogen, oxygen and sulphur
	The student must be able to:
	
	S1.91 Check all customer requirements have been met in order to ensure quality of product and shelf life of food:
	
	• quality of product (for example, to meet nutritional requirements, to reduce additives and preservatives, product formulation)
	• shelf life of product (for example, increasing additives and preservatives, change of packaging, processing methods)

Food science	
○ play a role in the structure and function of cells, including growth and development ○ found in eggs, milk, meat (animal sources) and nuts, grains, legumes (vegetable sources) • water: ○ is a simple molecule ○ plays an essential role in all the activities of body cells, as well as specific roles such as the absorption of nutrients and the removal of waste ○ has a number of roles within food including: maintaining texture, enabling enzyme activity in food, and conducting heat within food ○ the amount of water activity in food (aw) affects the growth of bacteria in food; for example, lowering water content can slow down microbial growth ○ found in virtually all foods, but amount varies considerably; fruit and vegetables are 80 to 90% water • vitamins: ○ a range of compounds that are either water soluble (for example, vitamin C) or fat soluble (for example, vitamin D) ○ required in small amounts for essential metabolic reactions, contributing to the prevention of diseases, and supporting immune system processes. Specific vitamins have specific functions. Vitamins work together (synergistically), supporting a large number of different functions in the body ○ found in fruit and vegetables (vitamins A, C, E, K) meat, poultry, fish, eggs and dairy (vitamin B, D) • minerals:	

Food science	
○ a range of chemical elements, such as calcium, phosphorus, magnesium, iron and zinc ○ required for various functions in the body including developing strong teeth and bones, controlling body fluids inside and outside of cells and to support the transfer of food into energy. Different minerals are needed in different amounts by the body ○ often work synergistically with vitamins ○ found in a range of foods such as cereals, bread, meat, fish, milk fruit and vegetables • enzymes: ○ a specific group of proteins which act as catalysts for biochemical reactions both inside the human body as well as in food ○ many foods contain useful digestive enzymes that can help the body's digestive process, but if food is cooked/processed these enzymes will be destroyed ○ foods containing enzymes include fruit and vegetables (for example, pineapple; also spices such as ginger and natural products such as honey) • food additives: ○ a diverse group of substances ○ some food additives are natural additives or are found in natural sources ○ there is a system for the numbering of additives and different groups of additives such as anticaking agents, carriers and stabilisers ○ used to enhance taste or appearance of foods, also for preservation of food	

Food science	
○ many synthetically produced additives are now common in a range of processed foods • flavourings: ○ a range of natural and artificial compounds used in very small amounts, considered to be a food additive ○ used to enhance flavours, modify taste and/or smell of foods ○ found in a majority of processed foods • colourings: ○ a range of substances from natural sources (for example, lycopene) or artificially produced (for example, titanium dioxide); considered to be a food additive ○ used to modify or enhance the colour of food ○ caramel is an example of a natural food colouring which is widely used in a range of food products from soft drinks to bread **K1.48 The purpose of daily reference intake (RI) in relation to human nutritional requirements (as recommended by the NHS):** • provides an approximation of the quantity of nutrients an individual should consume daily (for example, how much energy, fat, saturates, carbohydrates, total sugars, protein and salt) • provides guidance to support customers in making healthy dietary choices based on an average-sized woman doing an average amount of physical activity **K1.49 What RIs are used to show:** • whether a product is high (red), medium (amber) or low (green) in fat, saturated fat, salt and sugars	

Food science	
• how much energy (calories and kilojoules) it provides **K1.50 The characteristics of a range of fermentation processes, including the food and drink products that are produced as a result of these processes:** • lactic acid fermentation: ○ anaerobic conversion of carbohydrates by a group of bacteria (lactic acid bacteria) ○ these bacteria can independently initiate the fermentation process but may also act in combination with yeast, as in the production of sourdough ○ process does not necessarily require heat ○ results in the preservation and production of a range of food products, including yoghurts and sauerkraut • ethanol fermentation: ○ also known as alcohol fermentation ○ anaerobic conversion of simple sugars into ethanol and carbon dioxide by the action of yeasts ○ in this process venting the carbon dioxide (allowing it to escape) is an especially important requirement to avoid pressure build-up which could cause an explosion within the fermentation vessel ○ wine is produced using this process through the fermentation of natural sugars in grapes ○ beer, whiskey and vodka are produced using this process, through the fermentation of grain starches • fermentation in baking: ○ anaerobic conversion of sugars within bakery products (such as bread) will	

Food science	
produce carbon dioxide, which will cause a dough to rise ○ this conversion is carried out mainly by yeast ○ this process is usually carried out at room temperature, but there are instances where the temperature can be altered ○ it is possible to use additives in the dough to speed up the fermentation process ○ the length of fermentation time has an impact on the overall taste, texture and quality of bakery products, especially in the case of bread **K1.51 The intrinsic and extrinsic factors used to determine the shelf life of food:** • intrinsic factors: ○ initial quality ○ ingredients ○ the inherent nature of the food ○ the product formulation • extrinsic factors: ○ processing methods ○ packaging ○ transportation and storage ○ consumer handling **K1.52 The differences between the use by and best before dates of food and drink and when each are applicable:** • use by: unsafe to eat beyond the use by date and illegal to sell beyond the use by date ○ applicable to: short shelf life, high-risk products including chilled salads, chilled cooked meats • best before: refers to the quality of food, not unsafe to eat beyond the best before date	

Food science	
○ applicable to: long shelf life, low-risk products including canned foods and dried foods **K1.53 How a range of food additives (including preservatives) and ingredients with food additive properties, can extend the shelf life of food:** • salt: reduces bacteria • sugar: reduces water • nitrates: inhibits microbial growth • sulphites: inhibits microbial growth and enzymic action • sorbic acid: inhibits mould and yeast growth • calcium propionate: inhibits mould and yeast growth • sodium benzoate: inhibits mould and yeast growth in high-acid foods	

Food technology	
The student must understand: **K1.54 The 3 main types of energy transfer used in food technology, including examples of where they are used:** • conduction: transferring heat to another item by contact (for example, frying, grilling) • radiation: transferring heat through waves (for example, in the use of microwaves) • convection: transferring heat through the use of liquids (for example, boiling)	The student must be able to: **S1.92 Verify existing procedures are meeting food safety and quality standards:** • heat processing techniques: ○ checking core temperature in food is being achieved • heat removal: ○ checking product is cooled/chilled/frozen within specified timeframe and to right temperature • customer specifications:

Food technology	
K1.55 The difference between a range of heat-processing techniques: • pasteurisation: o involves heating to a specific temperature, usually less than 100°C o acidity of the food determines the exact time and temperature required o can be undertaken on food and drink either before or after packaging • sterilisation: o involves heating to a specific temperature above 100°C o usually the product is canned or bottled and then heat-treated in a steriliser with steam or hot (superheated) water • ultra heat treatment: o involves a very short heat treatment of temperatures above 135°C for one second o can only be used within specific production plants that are able to maintain a sterile atmosphere • baking: o dry heat cooking method carried out in an enclosed space o used as a way to uniformly cook foods o time and temperature dependent on food being produced • frying: o involves the immersion of food in boiling oil o time and temperature dependent on food being produced • grilling: o checking finished product against specification o comparing the colour of cooked product to photographic specification evidence • packaging and labelling meet the required safety and quality standards: o checking the correct packaging and labelling have been used	

Food technology	
○ involves cooking food on a rack over a heat source ○ direct heat quickly sears the outside of food, producing distinctive robust, roasted and sometimes pleasantly charred flavour and crust ○ time and temperature dependent on food being produced • boiling: ○ is a moist-heat cooking method that happens when the temperature of the liquid reaches 100˚ C ○ food is completely submerged in water for even heat distribution ○ the full boil is a vigorous one, where bubbles rapidly and violently break over the entire surface of the water • blanching: ○ involves the rapid immersion of food in steam or boiling water followed by a rapid cooling ○ often used with fruit and vegetables to maintain flavour, colour, texture and nutritional value • evaporation: ○ evaporation is the partial removal of water from liquid food by boiling (for example, liquid products can be concentrated from 5% dry solids to 72%, or even higher, depending on the viscosity of the concentrates) ○ evaporation is used to pre-concentrate food, to increase the solid content of food, to change the colour of food and to reduce the water content of a liquid product almost completely	

Food technology	
K1.56 How heat processing techniques may change food and drink: • colour (for example, caramelisation) • texture (for example, coagulation, gelatinisation) • flavour • nutritional value • enzyme functionality • microbial growth, spore formation and survival which impacts on shelf life of food **K1.57 The difference between a range of heat-removal based food technology used within the food and drink industry:** • pellet freezing: o involves freezing liquids and semi-solids into pellet form o commonly used for spinach, cream, orange juice, eggs and soups • plate freezing: o used for food packed in flat cartons, such as ready meals o cartons are placed in between narrow metal shelves in which a very cold refrigerant circulates to ensure freezing o revolving plate freezers are used; for example, for boil-in-the-bag products o plate freezing usually takes 2 to 3 hours • blast freezing: o air blast freezers are the most common methods used for blast freezing and include: ▪ static tunnels, where trolleys of boxed products such as beef and cakes are pushed through	

Food technology	
▪ solid continuous belt freezers, which are used for fish fillets, burgers and pizzas ▪ spiral belt freezers, which are relatively small and allow the refrigerated air to pass through the open belt o air circulates around the food at temperatures of -30˚C to -40˚C o freezing time depends on the dimensions of the product but normally takes between 2 to 3 hours • nitrogen freezing: o is a rapid freezing technique where the food is sprayed with, or dipped into, liquid nitrogen o normally used for high-cost, small products such as prawns or raspberries • chilling: o food is portioned and chilled to below 3˚C within 2 hours of cooking o chillers must be capable of reducing the temperature of a 50mm layer of food from 70˚C to 3˚C in under 90 minutes when fully loaded o automatic controls are required including an accurate (0.5˚C) indicating thermometer and recorder o product depth may need to be reduced to achieve the chilling specification o joints of meats should not exceed 2kg and 100mm in thickness • blast chill: o cools food rapidly without freezing o chilled air at 2˚C to -7˚C is circulated around the product	

Food technology	
○ some blast chillers may also use liquid nitrogen and solid carbon dioxide **K1.58 Why heat-removal based food technology is used within the food and drink industry:** • to prevent the growth and multiplication of microorganisms • to keep food out of the danger zone (for example, between 5^0C - 63^0C) • to achieve a specific processing requirement **K1.59 The difference between a range of ambient temperature processing technologies:** • fermentation: ○ the process of converting carbohydrates to alcohol or organic acids using microorganisms (yeasts or bacteria) under anaerobic conditions ○ usually used for the chemical conversion of sugars into ethanol to produce alcoholic drinks such as wine, beer and cider ○ a similar process takes place in the leavening of bread (CO_2 produced by yeast activity) and in the preservation of sour foods with the production of lactic acid such as in sauerkraut and yogurts ○ other fermented foods include vinegar, olives and cheese • irradiation: ○ used to kill bacteria that cause food poisoning such as Salmonella spp., Campylobacter spp. and Escherichia coli ○ also helps to preserve food and extend shelf life ○ during irradiation food is exposed to electron beams, X-rays or gamma rays	

Food technology	
○ the effect is similar to pasteurisation or cooking but the appearance and texture of the food changes less during irradiation • chemical preservation methods: ○ chemical preservatives commonly used in food include benzoates (for example, sodium benzoate), nitrates (for example, sodium nitrate), sulphites (for example, sulphur dioxide) ○ these chemicals either inhibit the activity of the bacteria or destroy them; sorbic acid is also used for the same purpose **K1.60 Why ambient temperature processing is used within the food and drink industry:** • to control pH levels and water activity • to retain nutritional quality and sensory characteristics of food • to prevent the growth and multiplication of microorganisms **K1.61 The advantages, limitations and uses of the following different types of packaging used in the food and drink industry:** • aseptic processing (for example, Tetra Pack): aseptic processing is a high-temperature, short-time thermal process to commercially sterilise a product and fill the cooled sterile product into a pre-sterilised package, all within a sterile environment ○ advantages: ▪ aseptic technology keeps food safe and flavourful for at least 6 months, without refrigeration or preservatives ▪ extends the storage life of food products, optimising product quality and reducing cost	

Food technology	
▪ allows food to retain more colour, texture, taste and nutrients ○ limitations: ▪ requires sterilisation ▪ more expensive than other types of packaging as the materials require different machinery and can be complex ▪ maintaining air sterility in the processing room can be difficult ▪ only low-viscosity liquids can be processed using steam injection, and high-quality steam is required to ensure sterilisation ▪ dairy products could have a cooked flavour because of exposure to sulfhydryl groups and could change in colour, an effect caused by Maillard browning ○ uses: ▪ milk ▪ fruit juice ▪ salad dressing ▪ liquid egg • modified atmosphere packaging (MAP): uses gases such as carbon dioxide, nitrogen and oxygen, which are set at appropriate concentrations for the product. A mixture of the right type of gases is injected during sealing. Products must be stored in a refrigerated environment to maintain quality, food safety and shelf life ○ advantages: ▪ the atmosphere in which the food is packaged is modified so that spoilage is markedly reduced, and the shelf life	

Food technology	
of the product is increased, without the need of additives ○ limitations: ▪ risk of oxidation (for example, in the red colour pigments in red meat, especially prominent in beef) ▪ loss of colour in the food product can result in an unappetising appearance ▪ a low oxygen content in protective gas packaging may result in oxidation ▪ seal integrity is vital to ensure carefully selected proportion of MAP gases do not escape, which has an impact on the quality and safety of the product ○ uses: ▪ beef ▪ pork ▪ chicken ▪ fish (cooked or fresh) • canning: various types of hermetically sealed containers can be used for canning, including cans, restorable plastic trays, and pouches. Use of the term ‘canning’ applies to all of these: ○ advantages: ▪ canning alters the food chemically, by changing the moisture, pH or salinity levels to protect it against bacteria, moulds and yeasts ▪ canning also limits food enzyme activity ○ limitations: ▪ canning is time-consuming ▪ improper methods can be dangerous	

Food technology	
▪ when jars fail to seal, spoilage will occur ▪ inadequate processing or poor sanitation can result in Clostridium botulinum contamination ○ uses: ▪ canned fish, meats and vegetables • trays/bags/boxes/cartons: paper or plastic trays, bags, boxes or cartons ○ advantages: ▪ protects fragile products which are easily broken or damaged such as eggs, fruit or cakes ▪ can hold multiple items together such as bagged fruit, multi-can packs ○ limitations: ▪ large amounts of waste which is not always recyclable ○ uses: ▪ used to pack multiple items such as eggs in trays and multipack products • flexible packaging: shape of the packaging can be easily changed; this includes bags, pouches, shrink films, tubes, sleeves and carded packaging ○ advantages: ▪ lightweight bags or pouches which can be modified or customised with ease ▪ the packaging life will exceed the product shelf life ▪ it will remain functional until consumption ▪ barrier properties prevent product change	

Food technology	
▪ maintains food safety and preserves product quality ▪ shape can match the product and/or function o limitations: ▪ chemical release from packaging into food may occur (mass transfer migration) o uses: ▪ leafy vegetables ▪ frozen vegetables ▪ frozen flash-fried meat products **K1.62 The advantages, limitations and uses of the following packing techniques used in the food and drink industry:** • engineered packing: o advantages: ▪ depending on the type of automation and the number of products to be packaged, this can increase productivity time and ensure a faster production line o limitations: ▪ requires engineering know-how ▪ susceptible to breakdowns and downtimes ▪ requires expertise ▪ increased foreign body contaminant risk o uses: ▪ wide range of uses across food manufacturing, for example, leafy salad packaging lines	

Food technology	
▪ sophisticated and self-learning automated packaging and sorting units • hand packing: o advantages: ▪ suitable for products with greater variables, such as size or shape ▪ used for more specialised (for example, handmade, handpicked) food products or food products with greater fragility (for example, sandwiches) o limitations: ▪ lower productivity; focus on quality rather than production volumes o uses: ▪ sandwiches, certain fruits (for example, mangoes) **K1.63 The information included on packaging for pre-packed and non-pre-packed products:** • name of food • list of ingredients (including alcohol and strength) • allergen information (in bold) • quantity of ingredients • weight • use by, best before and display until dates • origin of raw materials (where origin is claimed) • origin of product • nutritional information • specialist storage conditions • specific instructions for use (for example, cooking times, mixing instructions)	

Food technology	
• additional information that must be obvious to consumers (for example, packed in a protective atmosphere, contains raw milk) • position of labels on product (for example, front of pack, back of pack, side of pack) • contact address of the seller (for example, retailer, farm, brand)	
Food supply chain from end to end and relationships within it	
The student must understand: **K1.64 How food fraud could occur within the food supply chain:** • adulteration • substitution • illegal processing • waste diversion • falsifying documentation **K1.65 Where, within the food supply chain, food fraud could occur:** • suppliers • during transportation • manufacturing plant • during storage • at point of sale **K1.66 Why food fraud may occur within the food supply chain:** • criminal activity (for example, by manufacturer, consumer) • profit (for example, by manufacturer, consumer)	The student must be able to: **S1.93 Assess, using VACCP, when food adulteration could be taking place:** • how it has occurred (for example, adulteration) • where, within the food supply chain it has occurred (for example, suppliers) • why it has occurred (for example, criminal activity) • who to escalate the issue to (for example, local concerns would be escalated to the police; global and national concerns would be escalated to the FSA)

Food technology	
• increased demand (for example, by manufacturers) • shortages of product and/or ingredients (for example, by suppliers) **K1.67 How VACCP can be used for the systematic prevention of any adulteration of food, particularly in relation to economically motivated adulteration:** • by identifying possible areas of weaknesses and, therefore, implementing additional checks to reduce likelihood of occurrence **K1.68 Food and drink organisations' responsibilities in confirming the traceability of products, one step forward and one step back, within the food supply chain:** • provide batch numbers • documented systems in place for traceability • record-keeping **K1.69 Food and drink organisations' responsibilities in confirming the quality of products within the food supply chain:** • quality assurance procedures • quality control procedures • certificate of conformance/analysis **K1.70 Food and drink organisations' responsibilities in highlighting potential concerns within the food supply chain:** • recall procedures • crisis management procedures • escalation process: ○ notify external agencies when appropriate: ▪ local concerns must be escalated to the police	

Food technology	
▪ global and national concerns must be escalated to the FSA	

Performance outcome 2: Develop new food and food related products to support the food supply chain

Product development process	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K2.1 The stages and principles of the product development process, from concept to launch:** • product brief: o what the product is o why it is being developed o intended market o specific info about the product (for example, raw/cooked/ready to eat/ready to cook/starter/main/dessert) o total weight of final product o cost to sell to consumer • idea generation: o research and development on trends o innovation o viability • review meeting (for example, with sales, customer service, promotions departments) to discuss: o initial idea o viability of product o margins and profitability o cost (for example, production, raw materials, packaging, staff) • feasibility study: o legal checks o production (for example, pilot plant or scaled factory production)	The student must be able to: **S2.26 Perform an impact assessment of consumer trends on the design of both a new product development and an existing product development:** • using different sources of information to gather evidence • reading, understanding and synthesising the information for the intended purpose, taking into consideration any potential bias • presenting the information to suit audience and purpose in an appropriate format (for example, presentation, written report, graphs, tables), ensuring the information is organised logically and coherently • consumer trends: o health (for example, low fat, high protein, vegan) o environmental (for example, palm oil) o ethical (for example, fair trade) o economic factors (for example, low cost) o influence of media and peers (for example, celebrity endorsement, social media) (GEC2, GEC5, GMC6)

Product development process	
○ technical (for example, food safety) ○ procurement ○ planning ○ resource ○ raw materials ○ sales/marketing ○ engineering ○ process development • customer (for example, retailer) review of product: ○ taste panel (for example, colour/texture/viscosity/consistency) ○ discuss costs ○ suitable alternatives (for example, to ingredients or packaging) • concept approval and handover to production: ○ labelling ○ total weight of product ○ total ingredients for the trial run ○ breakdown of costings at each stage ○ packaging, including format and artwork ○ allergens in product ○ raw material specification (for example, raw materials, ingredients by weight, process, image of product, image of packaging) • trial run of product: ○ ingredient procurement ○ process development ○ label sign-off, including nutritional information, allergens and shelf life of food	

Product development process	
○ confirming costings are accurate ○ required standard operating procedures (SOPs) created (for example, mixing, sieving, cooking, allergen and integrity controls) ○ Hazard Analysis and Critical Control Points (HACCP) flow ○ supplier approval ○ undertake nutritional analysis ○ primary packaging sealing and closure testing ○ secondary packaging review - physical fit and text review ○ identify number of trials required to ensure product meets requirements ○ potential external testing to confirm product is well received/fit for purpose ○ customer (retailer or brand) approval • review trial of product: ○ variables (for example, cooking times, HACCP flow, production environment, required additional skills and training) ○ yields (for example, issues with raw materials and packaging, volume, cooking process, batch sizes) • pre-production: ○ to confirm process • launch product: ○ marketing to end point consumers ○ taste panels of end point consumers • post launch review of product: ○ rate of sell, rate of waste in store ○ customer (for example, retailer) feedback ○ complaints	

Product development process	
○ issues from taste panels ○ microbiology testing and results ○ issues with production of raw materials ○ any changes required **K2.2 Why an existing product may need to be changed:** • cost • improve sales • scarcity of raw materials • customer request • change of packaging • change in the law • improve quality • issue with food safety **K2.3 How the process for changing an existing product would differ to that of a new product development process:** • reduction in number of stages (for example, may not include feasibility study or taste panels) **K2.4 Different consumer trends which may drive the design of a new product:** • health (for example, low fat, high protein, vegan) • environmental (for example, palm oil) • ethical (for example, fair trade) • economic factors (for example, low cost) • influence of media and peers (for example, celebrity endorsement, social media) **K2.5 How impact assessments are used to investigate the viability of a new product:** • costs of people, process, equipment, raw materials, packaging	

Product development process	
• feasibility of production • brand reputation	

Advanced recipe formulation	
The student must understand: **K2.6 The first principles of recipe balance:** • proportionality: ratio of each individual ingredient within a recipe • nutrient balance: ensuring the correct nutrients are included, dependent upon the consumer requirements (for example, low sugar, high protein) • organoleptic properties: ensuring acceptable colour, taste, odour, texture, dependent on customer specification • ingredient substitution where appropriate: the substitution of ingredients, dependent upon the functionality and cost of the product **K2.7 Why ingredients may need to be substituted:** • seasonality • environmental • media influence • allergenic • cost • availability • religion/culture • organoleptic properties **K2.8 How the functionality of ingredients can be used to enhance a recipe:**	The student must be able to: **S2.27 Formulate a recipe from first principles, taking into consideration the customer requirements for:** • proportionality of ingredients • nutrient balance (for example, requirement for high protein) • organoleptic properties (for example, requirement for low salt) • ingredient substitution (for example, requirement for gluten free) (GMC3) **S2.28 Enhance an existing recipe, selecting the correct ingredients based on their functionality, to improve the flavour of the product:** • taste: o sweet (for example, sucrose, fructose, glucose, maltose, dextrose) o sour (for example, citric, acetic, lactic, malic and tartaric acid) o salt (for example, sodium chloride, potassium chloride) o bitter (for example, quinine sulphate, caffeine) o umami (for example, monosodium glutamate (MSG))

Advanced recipe formulation	
• emulsifiers: makes 2 incompatible components compatible, such as water and oil (for example, lecithin) • raising agents: causes expansion by release of gases (for example, yeast) • stabilisers: preserves structure (for example, gelatin) • flavourings/seasoning: used to enhance taste (for example, spices, salt) • preservatives: used to reduce available water and enhance shelf life (for example, sugar, salt, potassium sorbate) • colour enhancers: used to enhance organoleptic properties (for example, caramel, beetroot powder) • firming agents: strengthens the structure of food to keep firm or crisp (for example, calcium chloride) • sweeteners: used to reduce sugar content (for example, aspartame) • anti-caking agents: used to stop powdered or granulated foods sticking together (for example, silicon dioxide) • foaming agents: helps make foam by dispersing a gas in a liquid or solid (for example, quillaia extract) **K2.9 The reasons for selecting ingredients for specific applications.** • reasons for selecting ingredients: o functionality o physical properties of the ingredient (for example, whether it can withstand the processing requirements) o suitability for specific applications • specific applications: o age of consumer	• aroma: o odour of food which can be affected by mastication and air intake (for example, fruit flavours) • trigeminal response: o burning (for example, mustard, chilli, horseradish) o cooling (for example, mint, menthol) o tingling (for example, citric, acidic) **S2.29 Develop a new food product to meet customer requirements, taking into account:** • the suitability of all raw materials • substituting raw materials, dependent on consumer need and seasonality

Advanced recipe formulation	
○ nutritional requirements (for example, increase protein, low fat) ○ allergenic (for example, free-from) ○ social/religion/culture/lifestyle (for example, vegetarian) **K2.10 A range of raw material alternatives that can be used when formulating a recipe:** • soya protein instead of meat protein • sweeteners instead of sugar • vegetable fats instead of animal fats • cashew/almond milk instead of dairy	

Packaging innovation	
The student must understand: **K2.11 A range of packaging innovations used to reduce plastic waste/increase opportunities for recycling:** • use of innovative materials (for example, bamboo) • package free (for example, fill your own containers) • compostable packaging (for example, made from plant-based materials) • single-layer packaging	The student must be able to: **S2.30 Recommend packaging when developing a new food product, considering innovations in packaging, to reduce plastic waste and increase opportunities for recycling.**

Costing the production of products	
The student must understand: **K2.12 How individual costs of different components contribute to the overall product cost:**	The student must be able to: **S2.31 Carry out a product costing on a new product and on a modification to an existing product, by:**

Costing the production of products	
• premium ingredients versus cheaper substitutions (for example, sicilian lemons versus non-sicilian lemons) • handmade versus machine produced (for example, labour-intensive versus automated) • low volume versus high volume (for example, small batches versus mass-produced) • types of packaging (for example, boxed versus unboxed) • recyclable waste versus non-recyclable waste (for example, collecting excess dusting flour and reusing for other dusting) **K2.13 How to calculate total production run costs:** • raw material cost (recipe ingredients and packaging x number of products) • labour cost (number of people x hourly rate x number of hours) • utility costs (hourly rate x number of hours) • equipment (hourly rate x number of hours) • distribution and transportation costs (batch size and number of vehicles required)	• calculating individual component costs and production run costs to give a total cost: o individual component costs: ▪ ingredients ▪ process ▪ batch size ▪ packaging ▪ re-use of waste o production run costs: ▪ raw material costs ▪ labour costs ▪ utility costs ▪ equipment ▪ distribution and transportation costs • undertaking cost-comparison in order to reduce costs where appropriate (for example, premium ingredients versus cheaper substitutions) (GMC9)

Sustainability	
The student must understand: **K2.14 The importance of procuring raw materials from sustainable sources (for example, sustainable palm oil):** • to ensure traceability of the raw materials • to minimise harm to the environment • to maintain reputation and integrity	The student must be able to: **S2.32 Carry out a sustainability analysis on a new product, by identifying the social, environmental and economic implications of the:** • raw materials • packaging • reuse of waste

Sustainability	
• to demonstrate accreditation of particular raw materials/ingredients (for example, Marine Stewardship Council, Roundtable on Sustainable Palm Oil (RSPO)) **K2.15 Ways in which the use of plastic (particularly black plastic) can be reduced in the packaging of food and drink, whilst ensuring the packaging remains fit for purpose:** • reducing plastics wherever possible: o boxes instead of bottles o paper bags instead of plastic • re-use plastics wherever possible: o re-useable bags and containers • recycle plastics wherever possible: o use recyclable plastics polyethylene terephthalate (PET) o high-density polyethylene (HDPE) o plastics with On-Pack Recycling Label (OPRL) **K2.16 Ways in which to re-use waste:** • composting • anaerobic digestion • food waste recycling • biomass products • thermal treatment with energy recovery **K2.17 Ways in which to reduce energy usage when developing a new product:** • use of energy efficient equipment (for example, insulated refrigeration) • efficient use of existing equipment and resources (for example, turning down thermostats, use of LED light bulbs)	• energy usage • transportation • social, environmental and economic impact may include: o use of natural resources and stewardship of natural resource global and local o energy efficiency and use of natural resource/recycling o business ethics, fair trade, human rights and employment rights **S2.33 Present information on a sustainability analysis of a new product (for example, using a presentation, written report, graphs, tables):** • summarising information concisely • selecting fact from opinion • using technical terms where appropriate • organising information logically and coherently • using appropriate grammar • listening actively, recording information accurately and concisely, and requesting clarification where appropriate (for example, requesting additional information from support functions/specialists such as the maintenance team regarding energy usage) • responding to questions/feedback from colleagues/customers (GEC2, GEC4)

Sustainability	
• good manufacturing processes (for example, keeping areas clean and minimising movement/transportation) **K2.18 How to reduce the effect of transportation on the environment:** • consider type of fuel used for transport • change from ‘food miles’ to ‘green food miles’ • minimise packaging and containers • consider transport method (for example, aerodynamic vehicles, rail versus road)	

Continuous improvement (CI) management in the food industry	
The student must understand: **K2.19 How to use workplace organisational techniques for continuous improvement:** • lean approach: o determining value (for example, establishing who the customer is and their exact requirements) o map the value stream (for example, the activities or processes required to deliver the product to the customer) o enable the flow (for example, eliminate queuing and waiting times) o pull (for example, pulling the product through to the customer as and when they need it) o seek perfection (for example, embedding new ways of working and improve customer experience) • the Deming cycle: o plan	The student must be able to: **S2.34 Contribute to continuous improvement to drive down costs and drive up quality by following the Deming cycle:** • plan: o identify where improvements may be made, using IT systems to analyse and interpret data to identify trends (for example, volumes, run times) o identify key stakeholders to gain agreement on proposed changes (internal or external) • do: o apply the lean approach to implement identified improvements • check: o use IT systems to analyse and interpret data to measure effectiveness of implemented improvements • act:

Continuous improvement (CI) management in the food industry	
○ do ○ check ○ act • 5Ss: ○ sort: keeping what you need and getting rid of what you do not ○ set in order: having a place for everything and everything in its place ○ shine: keeping everything clean ○ standardise: everything is the same (for example, use of colour coding) ○ sustain: maintaining a consistent standard **K2.20 Ways to maximise equipment efficiency:** • using equipment at optimum speed (for example, overall equipment efficiency) • reducing stoppage time (for example, single-minute exchange of dies) • reviewing what has gone wrong to reduce future failure (for example, failure mode and effect analysis) **K2.21 The considerations of process limitations (for example, bottlenecks):** • ensuring consistent quality of product (for example, if machine is not being used at optimum speed it may affect output) • batch size • machine capacity and capability • resources (for example, labour, raw materials) • environment (for example, other processes that may affect each other) • production planning	○ recommend improvements and agree with key stakeholders (for example, improvements to the product, process, people management) ○ use IT systems to demonstrate before and after results ○ review results to maintain improvements (GMC5, GDC4)

Continuous improvement (CI) management in the food industry	

K2.22 How to manage the 8 types of waste within a food and drink manufacturing process:
• transportation:
  ○ reducing transportation both external (from supplier) and internal (within manufacturing plant)
• inventory:
  ○ minimising the amount of raw materials on-site
• motion:
  ○ minimising the amount of movement within the production facility
• waiting:
  ○ reducing the time that is spent between each stage in the process
• over-production:
  ○ avoiding making more than is required
• over-processing:
  ○ avoiding adding unnecessary value, finished products that are over or under weight
• defects:
  ○ avoiding mistakes through effective quality assurance, quality rejections, machinery breakdowns
• skills:
  ○ ensuring staff are trained appropriately for their role
K2.23 The relationship between the drivers for cost and quality and improving value:
• drivers for cost and quality:
  ○ increased productivity
  ○ improved quality
  ○ lowered costs	

Continuous improvement (CI) management in the food industry	
○ decreased delivery times ○ improved staff morale ○ understanding the market and competitors ○ understanding internal and external failure costs ○ continuous review of business requirements • improving value: ○ value-creating (for example, improve or increase) ○ non-value-creating but necessary (for example, reduce) ○ pure waste (for example, eliminate)	

Selecting a suitable sampling method	
The student must understand: **K2.24 How the sample size, sample numbers per batch and frequency of sampling are determined for the procedural requirements:** • type of product (high risk/low risk) • type of process (high care/low care) • volume of product • any known associated risks with the product	The student must be able to: **S2.35 Follow procedural requirements to collect samples, including:** • collecting the correct sample size • collecting the correct numbers per batch • collecting the sample at the correct frequency

Selecting a suitable test method	
The student must understand: **K2.25 The purpose of different test methods that can be used to test new food products**	The student must be able to:

Selecting a suitable test method	

and/or identify and resolve issues in the food supply chain:
• ensure compliance with product specification:
  ○ nutritional analysis meets requirements
  ○ taste/sensory panels; comparing against customer quality assurance sheets, including types and quantity of raw materials; photographic representation of plated, finished product and sample of approved packaging
• ensure product quality:
  ○ taste/sensory panels, through the use of organoleptic and physiological testing
• ensure product safety:
  ○ microbiological
  ○ food allergen testing
  ○ food contaminant testing
	S2.36 Select a suitable test method, depending on the purpose of the test:
	• compliance
	• product quality
	• product safety
	S2.37 Analyse test results to confirm nutritional requirements and ensure product safety:
	• quantitative results (for example, presence/absence and type of pathogens (causative agents), allergens or contaminants)
	• qualitative results (for example, numbers of pathogens (causative agents) present or percentage of nutrients)

Performance outcome 3: Identify and resolve issues in the food supply chain

Technical and quality solving problems in the food supply chain	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K3.1 The purpose of using problem solving techniques (for example, root cause analysis) when investigating and resolving problems within the food and drink industry:** • to identify the cause, rather than the symptoms, of the problem • to generate possible solutions • to evaluate and identify the most appropriate solution • to fully resolve and prevent reoccurrence **K3.2 The importance of identifying and resolving problems relating to customer complaints and quality issues:** • prevents re-work • reduces waste • maintains brand reputation • reduces customer complaints • increases customer satisfaction	The student must be able to: **S3.8 Identify and resolve problems relating to quality issues and/or customer complaints using appropriate problem-solving techniques:** • receiving feedback and evidence from customer • establishing if complaint is valid • identifying the batch • reviewing taste panel results: o identifying if it is a one-off incident or whether it affects a whole batch o considering the risks associated with the incident o considering whether the batch needs to be recalled • reviewing retained samples of the same batch against complaint • sharing results of investigation, including proposed solution **S3.9 Apply the 8 stages of root cause analysis to investigate problems and/or customer complaint and recommend suggestions for improvement:** • stage 1: defining the incident through the use of open questions to ensure a thorough understanding of the problem/customer complaint • stage 2: identifying initial corrective action to contain and address the immediate consequences • stage 3: categorising the incident by drawing up a fish bone diagram, focusing on

Technical and quality solving problems in the food supply chain	
	the key factors that need to be taken into account, including packaging, ingredients, process, procedures, people • stage 4: determining the root causes by utilising the 5 whys (for example, risks, probabilities and other factors) • stage 5: identifying management procedures that have failed • stage 6: defining preventative actions and implementing solutions to resolve problem/customer complaint • stage 7: reviewing effectiveness of preventative actions, including validity of the solution • stage 8: sustaining and maintaining improvements, sharing outcomes and best practice where appropriate (GMC10)

Testing and evaluation in the food supply chain	
The student must understand: **K3.3 The principles of sensory evaluation used in food operations:** • using the 5 senses (sight, odour, taste, texture, sound) to evaluate the quality of the product to ensure it meets the specification • to gain qualitative and quantitative data to maintain the consistency of product quality **K3.4 How to carry out sensory evaluation:** • at specified times • controlled by trained staff • using screened participants	The student must be able to: **S3.10 Carry out procedures for quality control testing and sensory analysis:** • step 1: screening all taste panel participants to check for: o colour blindness o ability to taste salt, sweet, sour, bitter, umami o ability to describe a product objectively o ability to detect odour • step 2: ensuring facilities and resources are appropriate: o separated, designated tasting area

Testing and evaluation in the food supply chain	
K3.5 How to determine the sampling required as part of the sensory analysis panels: • batch size • specification requirements • outcomes of previous panels **K3.6 How different procedures are used to measure quality control and sensory analysis in food operations:** • following customer specifications: o following pack instructions (for example, cooking or mixing) to ensure customer requirements are met o checking visible ingredients o checking finished product against photo image o checking packaging against photo image • on-line tasting (for example, on the production line): o checking that the flavour, aroma and texture meets customer specifications • finished product tasting: o carrying out a formal taste panel with screened participants **K3.7 The importance of maintaining specifications when carrying out sensory evaluation in food operations:** • to ensure updates are factored into evaluation • to avoid traceability issues (for example, taste panel participant has an allergic reaction)	o minimal décor o neutral work surfaces o well lit o good ventilation o access to bottled or filtered water and palate cleansers o access to white crockery, clear glasses, white plastic cutlery o adequate cooking sample preparation facilities o copies of the product specification available o questionnaires to record results **S3.11 Carry out a taste panel and evaluate results:** • step 3: leading the taste panel: o ensuring sample is in place prior to participants' arrival o clarifying the process and responding to any questions that arise o ensuring participants do not influence each other's opinion o ensuring there is no communication during the taste panel o ensuring all participants are facing away from each other o ensuring participants undertake the tasting and grading of the product • step 4: collect, collate and analyse data from the taste panels using digital devices and applications: o ensure all participant data is considered o ensure the product is graded (for example, red, amber, green or numerical values)

Testing and evaluation in the food supply chain	
	○ make recommendations based on analysis of trends (GEC6, GDC1)

Performance outcome 4: Collect, analyse and interpret food production data

Food production data	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K4.1 Where to collect food production data from in relation to:** • food safety: o Hazard Analysis and Critical Control Points (HACCP) records o cleaning records (for example, good hygiene practices (GHP) o product recalls/withdrawals o customer complaints o consumer complaints o audit results (for example, good manufacturing practice (GMP), supplier assurance, external) o risk assessments (for example, vulnerability, traceability, allergen, integrity) o laboratory testing (for example, microbiology, allergen and nutritional) • food quality: o taste panels o audit results (for example, GMP, supplier assurance, external) o customer feedback (for example, customer complaints or compliments) o risk assessments (for example, vulnerability, traceability, allergen, integrity) o cleaning records (for example, GHP) • customer requirements: o trend analysis	The student must be able to: **S4.6 Create a spreadsheet to track production trends.** **S4.7 Input management data to track production trends, demonstrating digital critical literacy by ensuring confidentiality processes are followed to ensure safety, security and privacy (for example, when using screens to input data).** (GDC4, GDC5, GMC5) **S4.8 Systematically organise data in order to track production trends.** (GDC4 GMC5) **S4.9 Critically interpret the data, considering process and scale, and any out of tolerance results that breach the critical limits.** (GMC1, GMC6) **S4.10 Present information:** • in a written and visual format and/or presentation (for example, in a variety of texts) • in a clear and unambiguous way • using technical language correctly • using mathematical processes to support technical arguments (for example, deviation from acceptable microbiology results) • using images and other tools (for example, graphs as appropriate) • organising information logically and coherently

Food production data	
○ changes to specifications ○ customer feedback **K4.2 How to interpret and analyse food production data:** • identifying out-of-tolerance results in relation to process and scale • identifying trends • identifying root cause • identifying corrective actions required • providing recommended preventative actions **K4.3 How different applications, including spreadsheets, databases and data loggers, can be used to support the interpretation and analysis of food production data:** • storage of large amounts of data, over long periods of time • organisation of data • presentation of data **K4.4 Why electronic resource planning systems (management information system) are used within the food and drink industry:** • to support all business transactions within the food production facility by providing a central integrated system • to store different types of data (for example, supplier information, quantity of raw material, specification requirements, batch numbers) • to retrieve food production data (for example, sales and trends, test analysis results) **K4.5 How trends in food production data can be used for continuous improvement within the food and drinks industry:**	• proofreading information to ensure appropriate use of grammar, vocabulary, spelling and punctuation (GEC1, GEC2, GEC3, GMC6, GMC8)

Food production data	
• to make improvements to product (for example, making the nutritional value of the product healthier such as sugar or salt reduction or reducing the yeast levels in a product by perfecting the cooking process to reduce micro-organisms to a safe level, while preserving quality) • to make improvements to processes (for example, meeting exact weight tolerances to improve consistency of filling weight) • to make improvements to people management (for example, utilising skills to maintain quality and safety levels) • to make improvements to packaging (for example, improving the seal integrity of a piece of packaging) • to make improvements to raw materials (for example, using cheaper raw materials whilst maintaining recipe functionality) • to make cost savings • to identify training needs and skills gaps • to make changes within the supply chain (for example, shortening the route to market and improving the product shelf life)	

Occupational specialism - technical: metrology sciences

Knowledge and skills are set out side-by-side within their themed sections. The numbering is sequential throughout the performance outcome, from the first knowledge statement, following on through the skills statements. The ‘K’ and ‘S’ indicate whether the statement belongs to knowledge or skills.

Mandatory content:

- **Performance outcome 1:** Plan appropriate scientific measurement for any measurand to comply with regulatory requirements
- **Performance outcome 2:** Perform scientific measurement tasks using the most appropriate measurement for a measurand to ensure accuracy
- **Performance outcome 3:** Collect, analyse and interpret data from measurement tasks
- **Performance outcome 4:** Identify and resolve issues with measurement tools and equipment

Glossary

Equipment standard

A comparison object with a stated quantity value and an associated uncertainty of measurement.

Measurand

The quantity that is intended to be measured.

Written standard

A document which prescribes procedures, practices and maximum permissible errors or best practice advice for users.

Reference material/standard

Is characterised by a metrologically valid procedure for one or more specified properties, which may be accompanied by a certificate that provides the value of the specified property, its associated uncertainty, and a statement of metrological traceability.

Conformity assessment

Any activity undertaken to determine, directly or indirectly, whether a product, process, system, person or body meets relevant standards and fulfils specified requirements.

Performance outcome 1: Plan appropriate scientific measurement for any measurand to comply with regulatory requirements

Fundamentals of metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.1 The concept of measurement:** • obtaining quantitative data that describes a property of an object or event (for example, how heavy an object is) • measurements are made using an instrument/device (for example, a ruler, thermometer) • results are normally expressed as a number and a unit to allow for traceable comparison (for example, 2 metres) **K1.2 How metrology is defined:** • the science of measurement and its application **K1.3 The importance of metrology to society and everyday life (for example, industry and trade, science and innovation, quality of life):** • provides traceability of measurements • allows fair competition in the marketplace • gives a level playing field in the pricing of goods and commodities • helps business make informed data-driven decisions **K1.4 The definition of measurement standards:** • reference materials/standards or measuring systems, against which all other measurements are compared **K1.5 The use of measurement standards in the calibration of measuring equipment when planning scientific measurements:**	The student must be able to: **S1.48 Make informed decisions about the needs of the measurement task:** • purpose: o the purpose of the measurement task • measurement process cost: o is an in-house measurement sufficient? • tolerance: o which standard of measurement or calibration is applicable? • timescales: o the more accurate the measurement or calibration, the longer the measurement takes **S1.49 Determine the design of the measurement, taking into account:** • appropriate sampling strategy • number of repeated measured values • operators involved • components and/or features to be inspected **S1.50 Read a simple uncertainty budget for a measurement task and use it to:** • identify the most significant sources of uncertainty • suggest improvements to the measurement plan **S1.51 Use the correct terminology for measurement in metrology:** • measurement uncertainty

Fundamentals of metrology	
• primary standards as the realisation of the international system of units (SI) • secondary standards as calibrated against primary standards • working standards as references used to calibrate end user equipment **K1.6 How the accuracy of measurements is related to:** • tolerance: the tighter the tolerance specified on a measurement, the more accurate the measurement needs to be • cost and timescales (fitness for purpose): more accurate measurement may involve increased cost and greater timescales, through the use of more complex instruments **K1.7 The concept and purpose of measurement uncertainty:** • concept: o the quantification of doubt in a measured value • purpose: o to identify how good/reliable a measurement is and if it is good enough to use o allows the comparison of measured values/reference values **K1.8 The different ways sources of uncertainty may be categorised:** • the measuring instrument • the item being measured • the measurement procedure • the skill of the operator • environmental effects • sample size and representative sample	• calibration • accuracy • measurement error • precision • repeatability • reproducibility • resolution • sensitivity • maximum permissible error (MPE) • measurand • measurement standard • bias **S1.52 Use different unit systems (SI and non-SI units) and be able to convert between units, using appropriate conversion factors or formulae:** • converting between units within the SI • converting between SI and non-SI units (GMC4)

Fundamentals of metrology	
• calibration uncertainty **K1.9 The difference between repeatability and reproducibility of measurement results:** • repeatability of measurements refers to repeat measurements made on the same instrument/device under identical conditions (for example, by the same operator) • reproducibility refers to the variation in measurements made on a subject under different conditions (for example, by another operator, in different locations, with different instruments) **K1.10 The concept of Type A and Type B evaluations of uncertainty:** • Type A: based on a statistical approach • Type B: based not on statistical analysis of data, but on other forms of information **K1.11 The concept of random and systematic effects:** • random: component of measurement error that in replicate measurements varies in an unpredictable manner • systematic: component of measurement error that in replicate measurements remains constant or varies in a predictable manner **K1.12 How to mitigate for random and systematic effects (for example, using best practice for the measurement system to minimise uncertainty):** • random: can be mitigated by increasing the number of measurements and via averaging • systematic: can be mitigated by applying a correction/allowance (although there will be uncertainty associated with the correction applied)	

Fundamentals of metrology	
K1.13 The role of measurement uncertainty in conformity assessment: • provides a level of confidence in the stated result **K1.14 The concept of level of confidence using k = 1 (≈68%), k = 2 (≈95%) and k = 3 (≈99.7%):** • the coverage factor (k) is based on an assumption of a normal distribution of results • expanded uncertainty is determined by multiplying the measurement uncertainty by the coverage factor **K1.15 How an unbroken chain of comparisons, directly related to SI units, ensures confidence in results through:** • calibration (for example, comparison against a higher standard) • testing (for example, certified reference materials (CRMs)) • accreditation (for example, method and instrument validation) **K1.16 The links within a traceability chain:** • SI units (International Bureau of Weights and Measures, BIPM) • primary standards (National Measurement Institutes) • reference standards (accredited calibration labs) • working standards (in-house calibration labs) • measuring equipment (end users) **K1.17 Techniques for gaining confidence in measurement:** • verification tests: conformity of the instrument to legal, manufacturers', British, European or international standards	

Fundamentals of metrology	
• interim checks of equipment: to determine if the instrument is behaving as expected • field checks: to determine if the instrument or device is behaving as expected in a given location • measurement systems analysis: to confirm reliability of results • third-party assessment: to provide expertise or equipment if required by law or if it is unavailable **K1.18 The purpose of measurement instruments** • used for indicating, measuring and recording specific physical and chemical quantities (for example, ammeter to measure electrical current, ICP-MS to measure trace metals in river water by inductively coupled plasma mass spectrometry) **K1.19 The differences between automated and manual measuring instruments:** • automated: o time saving o used for manufacturing on a large scale o removing manual error • manual: o low cost o used for small volume of samples o portability of instruments and devices **K1.20 How to apply best practice principles in measurement:** • choosing the correct measurement for the property you are trying to measure (for example, tension or compression) • using appropriate equipment for the measurement task	

Fundamentals of metrology	
• ensuring operators are suitably skilled and trained • using suitable procedures, including standard operating procedures (SOPs) where appropriate • using a defensible sampling strategy • ensuring equipment is in good working order and fully calibrated • use of traceable reference materials/standards **K1.21 The purpose of an uncertainty budget:** • to calculate uncertainty of a measurement • to help plan and prioritise improvements to a measurement procedure **K1.22 The components of an uncertainty budget, used to calculate measurement uncertainty:** • source of uncertainty • uncertainty value • probability distribution: o normal o rectangular o triangular o u-shaped • divisor • standard uncertainty/standard deviation • sensitivity coefficient • contribution to combined standard uncertainty • combined standard uncertainty • expanded uncertainty **K1.23 Factors that may influence the number of repeated measurements in a measurement task:**	

Fundamentals of metrology	
• level of uncertainty • time available • cost • measurands that cannot be measured repeatedly • amount of available sample **K1.24 Factors that may influence the sampling strategy:** • time available • cost • quality of data • type of sample (for example, gas, liquid or solid) **K1.25 The difference between validation and verification of scientific measurement equipment:** • verification: to verify conformity of measurement equipment with specifications • validation: to determine if the measurement equipment is fit for use **K1.26 The correct terminology for measurement in metrology:** • measurement uncertainty: the quantification of doubt in a measured value • calibration: an action to determine the relationship between a displayed value of the measuring instrument against a traceable standard • accuracy: the closeness of agreement between a measured value and the true quantity value • measurement error: the difference between the measured value and the 'true value' of the measurand	

Fundamentals of metrology	
• true value: the result of a perfect measurement • precision: the closeness of agreement between measured values • repeatability: the degree of agreement in successive measurements undertaken under identical conditions • reproducibility: the degree of agreement in successive measurements undertaken under different conditions • resolution: the smallest difference that can be displayed on an instrument • sensitivity: the change of the display of a measuring instrument when a known input is applied • maximum permissible error (MPE): the largest deviation allowed (usually ±) from that prescribed for the instrument before action is needed • measurand: is the quantity that is intended to be measured • bias: statistically, the difference between the test results of a known reference value and the given reference value **K1.27 The impact of using incorrect terminology when communicating about measurement:** • inability to obtain the required measurement information • not meeting customer expectations • erosion of trust between the customer and the supplier • loss of reputation • time/cost of repeating measurements **K1.28 The sources which may be used to calculate maximum permissible error (MPE) of a system:**	

Fundamentals of metrology	
• standard • specifications • regulations **K1.29 The international system of units (SI), including:** • how the 7 SI base units are defined and realised: ○ metre ○ kilogram ○ second ○ ampere ○ kelvin ○ mole ○ candela • how combinations of the base units provide derived units (for example, area, volume and pascals) • how to use unit pre-fixes and their symbols correctly, including in unit conversions: ○ pico (10^{-12}) ○ nano (10^{-9}) ○ micro (10^{-6}) ○ milli (10^{-3}) ○ centi (10^{-2}) ○ deci (10^{-1}) ○ kilo (10^{3}) ○ mega (10^{6}) ◦ giga (10^{9}) ○ tera (10^{12}) • how conversion factors or formulae are used when converting within the SI:	

Fundamentals of metrology	
○ use of appropriate conversion factor or formulae • how conversion factors or formulae are used when converting between SI and non-SI units: ○ use of appropriate conversion factor or formulae for the non-SI unit, which gives you the value in SI	

Operating principles, equipment and tools	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.30 The tools and equipment (and software programs where applicable) used within the following operating principles:** • length: ○ handheld dimensional measurement tools ○ coordinate measuring machine ○ laser tracker ○ articulated arm ○ global positioning system (GPS), photogrammetry, structured light scanner, laser line scanners ○ laser radar scanner ○ interferometer • temperature: ○ liquid-in-glass thermometers ○ resistance thermometers ○ thermistors ○ thermocouples	The student must be able to: **S1.53 Select appropriate tools/equipment/instrumentation (with any associated software) when planning for a specific measurement task, using:** • length • temperature • time • mechanical quantities • pressure • flow • electrical quantities • chemical analysis • microscopy • volume • mass

Operating principles, equipment and tools	
○ radiation thermometers ○ thermal imagers • time: ○ stopwatch ○ atomic clock • mechanical: ○ stress tester ○ hardness tester ○ torque driver ○ skidded and skidless surface probes • pressure (absolute, gauge and differential): ○ direct and indirect pressure measurement techniques • flow: ○ differential pressure flowmeters ○ mechanical flowmeters ○ vortex flowmeters ○ hydrometer (density for liquids) • electrical: ○ analogue and digital meters for measurement of voltage, current and resistance ○ bridge circuits ○ oscilloscopes ○ capacitor ○ resistor • chemical analysis: ○ pH meter ○ mass spectrometer (MS) ○ high performance liquid chromatograph (HPLC)	

Operating principles, equipment and tools	
○ infrared spectrometer (IR) • microscopy: ○ atomic force microscope ○ scanning electron microscope ○ confocal microscopy ○ focus variation • volume: ○ pipettes ○ burettes ○ volumetric flasks ○ measuring cylinders • mass: ○ weighing scales ○ balances (for example, top pan and analytical) **K1.31 The considerations when deciding on the most appropriate equipment and tools to be used:** • the size, type, toxicity and stability of the item being measured • the measuring environment (for example, humidity, temperature, dust) • skills required by the operator • cost of the equipment • the required accuracy of the measurement	

Measurement systems	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand:	The student must be able to:

Measurement systems	
K1.32 The advantages and limitations of different commercially available equipment and instrumentation used within the following operating principles: • length (for example, micrometer versus vernier calliper) • temperature (for example, liquid-in-glass versus thermistor) • mechanical (for example, hardness testers versus tensile testers) • time (for example, stopwatch versus digital timer) • pressure (absolute, gauge and differential) (for example, dial gauge versus deadweight tester) • flow (for example, ultrasonic meter versus positive displacement meter) • electrical (for example, multimeter versus oscilloscope) • chemical analysis (for example, mass spectrometer versus infrared spectrometer) • microscopy (for example, scanning electron microscope versus transmission electron microscope) • volume (for example, pipette versus measuring cylinder) • mass (for example, top pan versus analytical balance)	**S1.54 Provide reasoned decisions for the selection of equipment and instrumentation, taking into account the advantages and limitations.**

Different sample preparation methods	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand:	The student must be able to:

Different sample preparation methods	
K1.33 Why different sample preparation methods are required when preparing an item for measurement: • cleaning: to ensure the sample is adequately prepared for the measurement (for example, to remove surface contaminants) • normalisation (for example, soaking): to ensure the sample has enough time to reach ambient temperature before making the measurement • fixturing and clamping: to stop the work piece/test item moving during the measurement task • solution preparation: to ensure all liquids or other materials required for the scientific measurement are of the correct quantities and have the correct properties for the measurement to occur • staining: to enhance the sample and allow the visualisation of specific components under the microscope • sectioning: to provide a thin enough section of the sample to permit the required inspection under the microscope • mounting: to allow samples to be handled easily and orientated correctly, such that the required features can be inspected under a microscope • polishing: is used to create a flat, defect-free surface for examination of the sample's microstructure under a microscope • coating: to enable or improve the imaging of nonconductive samples or poorly conductive samples by electron microscopy	**S1.55 Plan any specific preparation methods needed on the item to be measured:** • fixturing and clamping • normalisation • cleaning

Extracting measurement requirements	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.34 The most relevant sources to use to extract measurement requirements:** • legislation • ISO and other standards • manuals • specification sheets • catalogues • calibration certificates • accrediting bodies • technical drawings and/or computer aided design models (CAD) • product labels • historical data	The student must be able to: **S1.56 Access and interpret information and documentation (for example, legislation, ISO and other standards, manuals, specification sheets) to extract measurement requirements as appropriate to the measurement task, taking into account:** • the precision of measurement required • cost • time available

Measurement plans	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.35 The purpose of planning a task in metrology:** • to identify the measurement need • to plan and allocate adequate resources (for example, time to complete required tasks/meet customer deadlines) • to identify critical tasks and their dependencies (for example, repeat count, sample size and measurement system to be used)	The student must be able to: **S1.57 Create a measurement plan, taking into account:** • selection of the measurement system to be used: o instruments and accessories o measurement procedure (including the use of SOPs) o personnel who perform the measurements

Measurement plans	
• to ensure verifiable results • to ensure compliance with health and safety legislation and safe working practices	• specification standards relating to the equipment • health and safety requirements • operating environmental conditions required • environment conditions for the sample/test piece (for example, stability of sample to light, heat and if special storage conditions are required) • number of repeated measured values to be obtained for the measurement • sampling strategy in relation to checking a sample of a large number of products/goods • how the data will be processed: o recording, tracking and storing data o using controlled software o data analysis • reporting

Environmental effects	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.36 How environmental conditions such as temperature, vibration, humidity and lighting can affect both the measuring equipment and the item to be measured, and consequently the data collected:** • the measuring equipment: o dust and particles in the air could cause friction in moving parts o variations in air movement or vibrations could cause instability in the equipment	The student must be able to: **S1.58 Plan and record how to deal with potential environmental conditions, including:** • controlling the effect • compensating for the effect • accepting the effect

Environmental effects	

• the item to be measured:
  ○ variations in temperature could cause deformation in the item
  ○ poor lighting could cause inaccurate readings
K1.37 General approaches to dealing with environmental conditions:
• controlling the effect: normalising the item to be measured to laboratory conditions
• compensating for the effect: determining the effect on the measurement and making a correction for it
• accepting the effect and reporting the limitations of the measurement	

Application of metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**

The student must understand:
K1.38 The role of:
• scientific metrology:
  ○ developing and maintaining measurement standards
• industrial metrology:
  ○ ensuring adequate functioning of measuring instruments and traceability through calibration
• legal metrology:
  ○ application of legal requirements to measurements and measuring instruments
	(no skills in this section)

Application of metrology	
K1.39 The roles of different organisations that support metrology practices: • the International Bureau of Weights and Measures (BIPM): o representing the worldwide measurement community o being a centre for scientific and technical collaboration o being the coordinator of the worldwide measurement system • the General Conference of Weights and Measures (CGPM) and the International Committee for Weights and Measures (CIPM): o working with member states on issues relating to measurement standards and measurement science o the CIPM promotes worldwide uniformity in units of measurement • the CIPM Mutual Recognition Arrangement (MRA): o framework through which National Metrology Institutes demonstrate the international equivalence of their measurement standards and the calibration and measurement certificates they issue • regional metrology organisations (RMOs) (for example, the European Association of National Metrology Institutes (EURAMET) in Europe): o coordinating the procedures and practices across member states • national measurement institutes (NMIs) and designated institutes (DIs), (for example, National Physical Laboratory (NPL) physical metrology, National Measurement	

Application of metrology	
Laboratory at LGC Ltd (chemical and bio-metrology)): ○ developing and maintaining the national primary measurement standards ○ providing representation when liaising with other NMIs and the international metrology and standards organisations ○ responsible for national standards and other services not covered by NMIs • International Standards Organisation (ISO): ○ independent, non-governmental international organisation which develops voluntary, consensus-based, market relevant international standards to which organisations, including science laboratories, adhere ○ providing internationally recognised methods and standards • accredited laboratories: ○ performing types of testing, measurement and calibration in line with the universally accepted international system of units (SI) ○ complying with ISO standards • legal metrology organisations, such as the International Organization of Legal Metrology (OIML): ○ providing mutual recognition systems which reduce trade barriers and global market costs ○ representing the interests of the legal metrology community in matters relating to standardisation, testing, certification and accreditation ○ promoting and facilitating the exchange of knowledge and competencies within the global legal metrology community	

Application of metrology	
K1.40 How metrology can play a role in a range of industries: • healthcare (for example, standardisation of medical products) • forensics (for example, standardisation of analysing equipment) • trade and business (for example, standardisation of packaged goods) • finance (for example, standardisation of coin weight) • infrastructure and buildings (for example, standardisation of building materials) • environment (for example, standardisation of water quality and pollution measurement and control) • food (for example, standardisation of methods ensuring the quality of UK food)	

Customer requirements	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.41 The considerations to make when interpreting customer requirements:** • tolerances: knowing what the measurement needs to achieve based upon the functionality of the item being inspected, and what are the acceptable limits of error for the item • timescales: more accurate measurements typically require more time to complete, so understanding the tolerance requirements will dictate what inspection times are required to achieve the tolerances	The student must be able to: **S1.59 Interpret and review customer requirements from a customer brief and identify relevant factors relating to:** • tolerances (for example, the level of accuracy required - insufficient accuracy can prevent an effective evaluation of tolerance) • timescales (for example, the level of accuracy required may affect the time it takes to perform the measurement) • costs (for example, more accurate measurements can be more expensive to

Customer requirements	

• costs:
  ○ the inspection of an item is often at the end of a process, so the measurement must add sufficient value to the quality of the component to offset the cost of the measurement
  ○ in-house or third-party certification can impact on the cost
• methodology and techniques: depend upon the accuracy required and the maximum permissible error
	perform due to equipment costs and/or time costs; higher accuracy than required can lead to increased cost)
	• preferred methodology and techniques (for example, for the required accuracy)
	(GMC9)
	S1.60 Summarise key information relating to customer requirements:
	• appropriate to the audience and purpose
	• using appropriate technical terms
	• listening actively and requesting clarification where appropriate
	(GEC4)

Health and safety in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**

The student must understand:
K1.42 How to mitigate risk, using control measures:
• elimination: redesigning the activity to remove the hazard
• substitution: replacing a material or process with a less hazardous one
• engineering controls: redesigning the process or equipment to reduce workers' exposure to hazards
• administrative controls: implementing procedures needed to work safely
• PPE: using appropriate equipment to protect the user against risks related to the measurement task
	The student must be able to:
	S1.61 Complete a risk assessment appropriate to the measurement task:
	• step 1: identifying the hazards, including using material and safety data sheets and COSHH sheets for handling possible hazardous samples:
	  ○ chemical (for example, compressed gases, cleaning agents)
	  ○ biological (for example, biological samples)
	  ○ physical (for example, repetitive tasks, noise levels, manual handling)
	• step 2: identifying who might be harmed:
	  ○ how likely is the measurement task to go wrong?

Health and safety in metrology	
	○ who might be harmed? ○ what could be the consequences? • step 3: evaluating the risk and selecting appropriate control measures to plan mitigation (for example, elimination, substitution, engineering and administrative controls and PPE) • step 4: recording the findings and implementation: ○ in a clear and unambiguous way ○ using technical language correctly ○ organising the findings logically and coherently ○ using the appropriate vocabulary, spelling and grammar • step 5: monitoring and reviewing risk management: ○ presenting findings in an appropriate format, using multimedia tools (for example, text and images) (GEC1, GDC2)

Regulations and standards in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.43 The hierarchy of written standards and their application in a metrology environment:** • international and national regulations and standards • industry standards and guidelines • organisational policies, procedures and requirements	The student must be able to: **S1.62 Document in the measurement plan the SOPs that should be followed during the measurement task, including those relevant to safe working practices (for example, handling of tools, equipment, instrumentation and software programs).** **S1.63 Identify in the measurement plan the relevant regulatory procedures and**

Regulations and standards in metrology	
• codes of conduct **K1.44 The importance of following SOPs when carrying out measurement tasks:** • improving reproducibility and consistency • improving reliability and validity of measurement results • ensuring compliance • increasing accountability • ensuring safe working practice relating to the preparation, storage, standards, control and handling of samples, tools, equipment and instrumentation when carrying out measurement tasks	**standards required for the measurement task, taking into account:** • national and international regulations and standards • industry standards • organisational policies, procedures and requirements • codes of conduct

Quality requirements in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K1.45 The importance of quality requirements within a metrology environment:** • ensures the quality of processes and products • ensures compliance of a product, service or system • provides a framework for managing and continually improving processes • gives formal recognition that an individual or organisation is competent to carry out specific tasks	The student must be able to: **S1.64 Document in the measurement plan the specific quality requirements needed for the measurement task, including:** • quality assurance (QA) and quality control (QC): o are there documented procedures to complete the measurement task? • verification: o is all the required instrumentation calibrated and traceable? • validation: o is the proposed methodology for the measurement task based on good practice, able to provide consistent and traceable results?

Quality requirements in metrology	

	• quality management system (QMS):
	  ○ does the measurement task need to comply with recognised quality management systems, such as ISO standards?
	• accreditation:
	  ○ does the measurement task require formal recognition from a nationally or internationally recognised body, such as UKAS?
	• certification:
	  ○ does the organisation require third-party authorisation to conduct the task?
	• audit systems:
	  ○ does the measurement task need to have a full audit trail? (for example, personnel, standards, instruments used, results, certificates)

Employment and working environments in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**

The student must understand:
K1.46 Why undertaking continuing professional development (CPD) is important in metrology.
• awareness of new developments within industry, ensuring knowledge stays current and up to date
• demonstrating competency
• allowing for progression in the organisation
• highlighting training needs
	The student must be able to:
	S1.65 Use feedback to develop and improve, by:
	• gaining feedback from peers and teachers in a variety of ways (for example, verbal, written and audio/visual):
	  ○ listening actively to feedback given
	  ○ asking questions for clarification
	  ○ adopting appropriate tone of voice
	• undertaking personal reflection
	(GDC3, GEC6)

Employment and working environments in metrology	
K1.47 Why it is important to remain up to date with the following developments in metrology: • state-of-the-art technology (for example, boosting efficiency and profitability) • automation (for example, increasing efficiency and reducing overall running costs) • large data sets (for example, can be analysed for information to help businesses make better decisions and gain insights) • industry 4.0 (for example, creating new growth opportunities by supporting innovation)	

Performance outcome 2: Perform scientific measurement tasks using the most appropriate measurement for a measurand to ensure accuracy

Accuracy in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K2.1 The purpose of validation or verification techniques for measuring equipment:** • to comply with any applicable regulatory requirements • to comply with quality standards • to comply with standard operating procedures (SOPs) and/or manufacturers' instructions • to ensure that the environmental conditions are optimal for the instrument (for example, ambient conditions for ideal instrument performance) • to verify that the most up-to-date software is being used **K2.2 The purpose of calibrating and testing metrology equipment:** • to ensure accuracy and traceability of the measurement • to give confidence in the measurement **K2.3 How to check the current calibration status, using:** • calibration labels • calibration certificates • calibration intervals (for example, using calibration history graph and trending) **K2.4 Why it is important to follow the correct escalation route if an instrument's calibration status is not identifiable, or if the instrument is clearly out of calibration:**	The student must be able to: **S2.6 Prepare the work environment in order to perform measurement tasks by:** • measuring the temperature and humidity in order to ensure the suitability and stability of the environment (for example, hygrometer) • setting up the measuring system and the item to be measured **S2.7 Set up the equipment and the item to be measured:** • correctly setting up the equipment in accordance with SOP or manufacturers' instructions • correctly setting up the item (for example, fixturing or clamping) **S2.8 Read and follow a calibration procedure:** • in accordance with SOP or manufacturers' instructions **S2.9 Determine the current calibration status of a system to ensure the equipment is at the required level of accuracy, using:** • calibration labels • calibration certificates • calibration intervals • calibration history graphs and trending, to ensure upper and lower tolerances are not exceeded (GMC1) **S2.10 Select/prepare the correct reference material/standard for the measurement task, taking into account:**

Accuracy in metrology	
• to ensure the integrity of the measuring equipment • to ensure the integrity of the measurement result **K2.5 The escalation route if the calibration status is not identifiable, or if the instrument is clearly out of calibration:** • taking the piece of equipment out of use • labelling the equipment as out of use • reporting the issue to senior colleagues • following the SOP for calibration procedure	• purpose of the measurement task (for example, checking the weighing scales of a coal merchant versus checking the assay of a pharmaceutical product) **S2.11 Perform a measurement task using a developed plan including:** • adhering to relevant standard operating procedures (SOPs), regulatory and quality procedures and standards • using the appropriate equipment for the task • ensuring equipment is used competently and safely, according to relevant SOP, manufacturers' instructions or recognised best practice • manipulating and manoeuvring equipment and the item to be measured effectively • accurately reading displays and measurement scales • accurately recording the results

Performance outcome 3: Collect, analyse and interpret data from measurement tasks

Processing data from measurement tasks	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K3.1 The stages of processing raw data:** • retrieving data: o populations and samples o random and non-random samples o recording data using statistical techniques (for example, using frequency tables)	The student must be able to: **S3.5 Use digital technology to process raw data and record measurement results in line with specifications by:** • retrieving/observing raw data from the measurement task by manual methods or using automated systems: o recording raw data from the measurement task

Processing data from measurement tasks	

• analysing data:
  ○ measures of locations (for example, averages and quartiles)
  ○ measures of spread (for example, range, standard deviation)
• interpreting data:
  ○ representing data (for example, charts, tables, graphs)
  ○ correlation (for example, identifying positive, negative and no correlation)
  ○ regression (for example, interpolate, extrapolate)
  ○ outliers (for example, spurious results)
• evaluating validity of the data in line with specifications:
  ○ expectation and variance
• recognising patterns within the data:
  ○ modelling using a probability distribution
• assessing repeatability and reproducibility:
  ○ hypothesis testing
  ○ confidence intervals
  ○ critical region
K3.2 The purpose of the following techniques to remove spurious results from metrology data:
• image processing: to manipulate images in order to more effectively interpret them
• filtration: to exclude some data in order to analyse subsets of data
• alignments: to arrange and access data in order to identify spurious results
• corrections: to check data in order to remove any obvious spurious measurements
	○ checking raw data for inaccuracies
	  ○ cleansing and organising data for processing
	• processing:
	  ○ inputting cleansed data into appropriate software
	  ○ converting raw data, using algorithms, into meaningful information
	• validating:
	  ○ comparing results against tolerances, through decisions on control limits
	  ○ comparing results against relevant standards (for example, Weights and Measures (Packaged Goods) Regulations 2006)
	• output:
	  ○ representing data in a usable format (for example, graphs, tables, charts)
	  ○ using statistical process control, where appropriate (for example, control charts, control, warning and information limits)
	• storage:
	  ○ storing data securely (for example, password protected spreadsheets, locking computer screens)
	  ○ controlling access to the data
	(GDC4, GDC5)
	S3.6 Identify patterns in collected data:
	• establishing consistent or recurring trends in data
	• using mathematical diagrams (for example, scatter plot or line graphs)
	S3.7 Assess repeatability and reproducibility of measurements to determine any variation

Processing data from measurement tasks	
• data recording: to use the most appropriate recording method to reduce spurious results	**within the data and establish a degree of confidence.**

Analysing data from measurement tasks	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K3.3 Why the following are used to interrogate and critically analyse measurement data:** • statistics: o to gather information from a data set o to make predictions • measurement systems analysis and statistical process control: o to evaluate the measurement process and instruments to ensure the integrity of data for analysis • algebraic formulae: o to perform calculations that contain unknown values • calculations on measurement data: o to characterise the spread in data set in order to calculate standard uncertainty	The student must be able to: **S3.8 Interrogate and critically analyse measurement data to identify any anomalous results:** • using statistics: o mean and range o population and sample standard deviations o standard uncertainty o probability distributions: ▪ normal distribution ▪ rectangular distribution ▪ triangular distribution ▪ u-shaped distribution • using measurement systems analysis and statistical process control: o consistency studies o gauge repeatability and reproducibility studies o control charts o capability and performance indices • using calculations on measurement data: o standard deviation

Analysing data from measurement tasks	
	○ standard uncertainty from Type A evaluations (from statistical analysis of repeated measured values) ○ combined standard uncertainty in the case of an additive measurement model (from Type A and Type B evaluations of uncertainty) ○ expanded uncertainty using the correct coverage factor for a given coverage probability, assuming a normal distribution ○ appropriate number of significant figures when reporting results • by comparing the measurement results to the specification/customer requirements (GMC6) **S3.9 Re-run investigations to assess invalid data.** **S3.10 Contribute to the production of reports and other measurement documentation by:** • using calculations, diagrams and data representations to support technical arguments • reasoning with mathematics and drawing conclusions (for example, pass, fail and concept of shared risk) • using industry standard conventions/notations as required (GMC8) **S3.11 Present data/results in the most appropriate format to meet customer requirements (for example, production of reports and other measurement documentation):** • using appropriate technology for the task • using appropriate numbers and significant figures

Analysing data from measurement tasks	

	• organising ideas logically and coherently
	• explaining data in a clear and unambiguous way, taking into account the level and experience of the customer
	• using technical language correctly, and using graphics and other tools to aid understanding
	• reports and other measurement documentation may include:
	  ○ diagrams, tables, charts and graphs
	  ○ uncertainty statements
	  ○ results of conformity assessment
	  ○ measurement system analysis and statistical process control reports
	(GEC1, GEC2, GMC7)

Reviewing data obtained	
Knowledge - What you need to teach	**Skills - What you need to teach**

The student must understand:
K3.4 How to review the measurement data obtained against measurement requirements, by:
• assessing data throughout the measurement:
  ○ checking for anomalies and repeating measurement if required
  ○ checking consistency of repeated measurements
• checking accuracy of calculations and transcription of data
• assessing conformity to specifications:
	(no skills in this section)

Reviewing data obtained	
○ the role of tolerances and measurement uncertainty in assessing whether an item meets the specification ○ requirements of ISO14253 and JCGM 106:2012 from the Joint Committee for Guides in Metrology (JCGM)	

Performance outcome 4: Identify and resolve issues with measurement tools and equipment

Identifying and resolving issues in metrology	
Knowledge - What you need to teach	**Skills - What you need to teach**
The student must understand: **K4.1 How to recognise when measuring equipment is operating incorrectly:** • based on observation/visual inspection: ○ obvious damage to the equipment ○ missing components from the equipment ○ calibration certificate is out of date • based on the operation of the equipment: ○ drift in the display of the instrument ○ inability to zero the equipment ○ positioning, alignment and/or levelling of equipment ○ environmental factors which may affect results • based on measurement data: ○ unacceptably large standard deviation of repeated measured values ○ identification of systematic effects ○ results of verification tests and interim checks	The student must be able to: **S4.4 Use problem solving techniques to identify issues relating to measuring equipment by:** • interrogating and critically analysing measurement data • using results from verification tests and interim checks • using measurement system analysis • conducting an observation/visual inspection of equipment (GMC6) **S4.5 Discuss measurement results and issues with peers to determine when issues need to be escalated by:** • summing up key points • making relevant and constructive contributions to move discussions forward • encouraging contributions from other participants • actively listening to others' contributions (GEC6)

Identifying and resolving issues in metrology	
○ measurement system analysis techniques **K4.2 The employee's responsibilities when an anomaly in the measurement process has been identified:** • discussing anomalies with peers to sense-check • judging when to pause or stop a process • following the organisation's quality management system (for example, recording information as appropriate) • escalating to senior metrology colleagues as appropriate **K4.3 The considerations to make when measuring equipment is in need of repair:** • is the piece of equipment critical to operations? • are there relevant SOPs and/or manufacturer information available to support the repair? • who is competent enough to carry out the repairs? ○ the individual ○ another colleague ○ approved repairers or manufacturer • is the repair complex (for example, include issues with the internal systems of the instrument) or basic (for example, blown fuse)? • who needs to be informed of the issue?	**S4.6 Source expert help from senior colleagues or others on metrology issues by:** • following the appropriate escalation process • accurately describing the issue to a senior colleague by: ○ summing up key points ○ expressing opinions and supporting these with relevant and persuasive arguments ○ asking and responding to questions for clarification (GEC6) **S4.7 Follow the process for basic repairs on measurement equipment by:** • having a thorough understanding of the issue (for example, power interruption to equipment, instrument not levelled, leads pulled out from equipment, misalignment, environmental issues) • labelling the item as 'not in use' • following relevant SOPs for basic repair and maintenance • verifying the item against specification before it is put back into service • communicating that the equipment is back in use (for example, updating the equipment record) (GMC10)

Section 5: TQ glossary

TQ specification

Student:

The person studying the technical qualification (‘The student must…’).

Tutor:

The individual delivering the technical qualification.

Provider

The centre delivering the technical qualification.

Series

Assessments which must be attempted in the same assessment window, such as paper A and paper B of the core examination.

Assessment mode

The assessment mode is how an assessment is made available and/or administered to students. For example, a written examination can be administered to students via an onscreen platform or via a traditional paper-based document.

Section 6: Additional information

Annual monitoring visits

Our quality assurance team will monitor all approved TQ providers on an ongoing basis. All providers delivering the TQ will be quality assured at least once a year to ensure that they are delivering in line with required standards. Annual monitoring reviews will be carried out either face-to-face or remotely by quality assurers appointed, trained and monitored by us. Providers will be allocated a quality assurer upon approval. Our quality assurers will complete a report following each annual review to record and share their findings.

Guided learning hours (GLH)

Guided learning is the activity of a student being taught or instructed by - or otherwise participating in education or training under the immediate guidance or supervision of - a lecturer, supervisor, tutor or other appropriate provider of education or training.

For these purposes, the activity of ‘participating in education or training’ shall be treated as including the activity of being assessed, if the assessment takes place under the immediate guidance or supervision of a lecturer, supervisor, tutor or other appropriate provider of education or training.

Total qualification time (TQT)

Total qualification time is an estimate of the minimum number of hours that an average student would require in order to complete a qualification.

Total qualification time comprises:

- the guided learning hours for the qualification
- an estimate of the number of hours a student will likely spend in preparation, study or any other form of participation in education or training, including assessment, which takes place as directed by - but not under the immediate guidance or supervision of - a lecturer, supervisor, tutor or other appropriate provider of education or training

Essential skills

While completing this qualification, students have an opportunity to develop the knowledge, understanding and essential skills employers look for in employees. These range from familiar ‘key skills’, such as team working, independent learning and problem solving, to more tricky-to-measure skills, such as:

- appropriate workplace behaviour and dress
- appropriate interpersonal skills
- communicating with professional colleagues/peers and/or hierarchical seniors
- supporting other aspiring employees
- personal manners
- understanding work practices and how different roles and departments function within an organisation

Recognition of prior learning (RPL)

Recognition of prior learning may be applied to the core component only.

Providers may, at their discretion, recognise prior learning if they are satisfied that the evidence provided meets the qualification's requirements.

For more information, please refer to the Recognition of Prior Learning (RPL) Credit Accumulation and Transfer (CAT) Policy on the Policies and Documents page on the NCFE website.

Qualification dates

We review qualifications regularly, working with sector representatives, vocational experts and stakeholders to make any changes necessary to meet sector needs and to reflect recent developments.

If a decision is made to withdraw a qualification, we will set an operational end date and provide reasonable notice to our providers. We will also take all reasonable steps to protect students' interests.

An operational end date will only show on the regulator's qualification database and on our website if a decision has been made to withdraw a qualification. After this date, we can no longer accept student registrations.

This qualification has external assessments, which can only be taken up to the last assessment date set by us. No external assessments must be permitted after this date, so students must be entered in sufficient time. Please visit the NCFE website for more information.

Staffing requirements

Providers delivering any of our qualifications must:

- have a sufficient number of appropriately qualified/experienced tutors to deliver the technical qualification to the volume of students they intend to register
- ensure that all staff involved in delivery are provided with appropriate training and undertake meaningful and relevant continuing professional development
- implement effective processes to ensure all delivery is sufficient and current, this should include standardisation to ensure consistency of delivery
- provide all staff involved in the delivery process with sufficient time and resources to carry out their roles effectively

Core staffing requirements

Staff involved in the delivery of the core component must be able to demonstrate that they have (or are working towards) the relevant occupational knowledge and/or occupational competence in science, at the same level or higher as the qualification being delivered. This may be gained through experience and/or qualifications.

Occupational specialism staffing requirements

Staff involved in the delivery of the occupational specialism content must be able to demonstrate that they have (or are working towards) the relevant occupational knowledge and/or occupational competence in the relevant occupational specialism area, at the same level or higher as the qualification being delivered. This may be gained through experience and/or qualifications.

Resource requirements

Providers must ensure that the student has access to the necessary materials, resources and workspaces for delivery and assessment of mandatory knowledge and skills. The following lists are not exhaustive. Please refer to the qualification content for a more detailed indication of the required resources.

General:

- computer
- internet access
- audio/visual recording equipment

Occupational specialism - Technical: laboratory sciences

- access to a standard teaching science laboratory
- access to standard teaching laboratory equipment including microbiological equipment
- data analysis software; SPSS or Microsoft Excel
- access to computer exam room for online assessments
- printers/computer access
- various stationery
- PPE

Occupational specialism - Technical: food sciences

- access to a standard teaching kitchen or development kitchen
- access to standard teaching kitchen/food technology equipment including microbiological equipment
- data analysis software; SPSS or Microsoft Excel
- access to computer exam room for online assessments
- printers/computer access
- various stationery
- resources for hosting a food tasting panel
- PPE

Occupational specialism - Technical: metrology sciences

- access to a laboratory or workshop suitable for accurate metrological measurement
- access to standard metrology laboratory equipment including a range of measuring devices
- data analysis software; SPSS or Microsoft Excel
- access to computer exam room for online assessments
- printers/computer access

- various stationery
- PPE

Customer support team

Our customer support team will support you with approvals, registrations, moderation, external assessment, results and general queries.

Fees and pricing

Fees will be made available to eligible and approved providers.

Training and support for providers

Our provider development team's primary purpose is to support providers and teaching teams in the delivery of this qualification. There are a number of ways in which we can do this, which include:

- providing bespoke one-to-one support with the delivery staff
- delivering face to face events at numerous locations throughout the country
- facilitating delivery and CPD webinars
- signposting you to teaching and learning resources
- providing you with delivery updates on the technical qualification

The variety of support available includes:

- content structure
- teaching strategies
- SEN guidance
- quality assurance
- assessment preparation and blended learning

Should you wish to discuss your teaching and delivery requirements, please email: provider.development@ncfe.org.uk.mailto:

Useful websites and sources of information

Core

Section B: science concepts

Cell structure and function

What is a cell: www.yourgenome.org/facts/what-is-a-cell

What is mitosis: www.yourgenome.org/facts/what-is-mitosis

What is meiosis: www.yourgenome.org/facts/what-is-meiosis

Mitosis versus meiosis: www.yourgenome.org/facts/mitosis-versus-meiosis

What is a stem cell: www.yourgenome.org/facts/what-is-a-stem-cell

Genomics/genetics

What is a genome: www.yourgenome.org/facts/what-is-a-genome

What is DNA: www.yourgenome.org/facts/what-is-dna

What is a gene: www.yourgenome.org/facts/what-is-a-gene

What is DNA replication: www.yourgenome.org/facts/what-is-dna-replication

What is genetic variation: www.yourgenome.org/facts/what-is-genetic-variation

What is a mutation: www.yourgenome.org/facts/what-is-a-mutation

DNA replication 3d animation: www.yourgenome.org/video/dna-replication

DNA to protein 3d animation: www.yourgenome.org/video/from-dna-to-protein

Pathogens

What is antibiotic resistance: www.yourgenome.org/facts/what-is-antibiotic-resistance

What are staphylococcal infections: www.yourgenome.org/facts/what-are-staphylococcal-infections

What are streptococcal infections: www.yourgenome.org/facts/what-are-streptococcal-infections

What is TB: www.yourgenome.org/facts/what-is-tuberculosis

What is salmonella: www.yourgenome.org/facts/what-is-salmonella

What are helminths: www.yourgenome.org/facts/what-are-helminths

What is malaria: www.yourgenome.org/facts/what-is-malaria

Occupational specialism: laboratory sciences

Stem Learning - www.stem.org.uk/

www.stem.org.uk/resources/curated-collections/secondary-and-level-science-0

Health and Safety Executive - www.hse.gov.uk/simple-health-safety/risk/index.htm

The Essential Chemical Industry - online - www.essentialchemicalindustry.org

Wellcome - wellcome.ac.uk/

The Association of the British Pharmaceutical Industry (ABPI) - www.abpischools.org.uk/

Association for Science Education - www.ase.org.uk/

Occupational specialism: food sciences

Health and Safety Executive - www.hse.gov.uk/simple-health-safety/risk/index.htm

National Health Service (NHS) - www.nhs.uk/live-well/eat-well/what-are-reference-intakes-on-food-labels/

Food Standards Agency - www.food.gov.uk

Chilled Food Association - www.chilledfood.org

Campden BRI - www.campdenbri.co.uk

Food manufacture - www.foodmanufacture.co.uk/

Food Authenticity Network - www.foodauthenticity.uk

Occupational specialism: metrology sciences

National Physical Laboratory (NPL) - www.npl.co.uk/

UK National Measurement Laboratory - www.lgcgroup.com/measurement-services/training-and-consultancy/best-practice-guides/

Eurachem - www.eurachem.org/index.php/publications/guides

WELMEC (European Cooperation in Legal Metrology) - www.welmec.org

International Organization of Legal Metrology - www.oiml.org

National Institute of Standards and Technology (USA) - www.nist.gov

Learning resources

We offer a wide range of bespoke learning resources and materials to support the delivery of this qualification, including:

- schemes of work
- tutor delivery guides

Please check the qualifications page on the NCFE website for more information on the resources available for this qualification.

Equal opportunities

We fully support the principle of equal opportunities and oppose all unlawful or unfair discrimination on the grounds of ability, age, colour, culture, disability, domestic circumstances, employment status, gender, marital status, nationality, political orientation, racial origin, religious beliefs, sexual orientation and social background. We aim to ensure that equality of opportunity is promoted and that unlawful or unfair discrimination, whether direct or indirect, is eliminated both in our employment practices and in access to qualifications. A copy of our diversity and equality policy is available on request.

Diversity, access and inclusion

Our qualifications and associated assessments are designed to be accessible, inclusive and non-discriminatory. We regularly evaluate and monitor the 6 diversity strands (gender, age, race, disability, religion, sexual orientation) throughout the development process as well as throughout the delivery, external quality assurance and external assessment processes of live qualifications. This ensures that positive attitudes and good relations are promoted, discriminatory language is not used and our assessment procedures are fully inclusive.

This policy is aimed at anyone who uses our products and services and who submits requests for reasonable adjustments and special considerations. Students who require reasonable adjustments or special consideration should discuss their requirements with their tutor.

The most up-to-date version of the policy can be found on the NCFE website where providers can find details of how to request a reasonable adjustment or special consideration.

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* To continue to improve our levels of customer service, telephone calls may be recorded for training and quality purposes.

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Owner: Qualifications Development Manager

Change history record

Version	Description of change	Approval	Date of Issue
v1.0	Post approval, updated for publication.		January 2021
v1.1	Update to Section 1 (Institute reference: ODSR_S_001 - ODSR_S_004)		March 2021
v1.2	Update to Section 2 and Section 4 (Institute reference ODSR_S_021 and ODSR_S_022)		April 2021
v1.3	Branding updated Updates to Sections 1, 2 and 4 (Institute reference ODSR_S_025-ODSR_S_033)		September 2021
v1.4	Updated title of personal protective equipment regulations to correct version (1992) (Institute reference ODSR_S_034)	October 2021	January 2022
v1.5	Updates to English and Mathematics exit requirements (ODSR_S_119, 120, 123) Added temporary flexibilities for industry placements (ODSR _S_122) Minor amends to terminology (ODSR_S_124, 125,) Additional clarification in CS4.1 around analysing results (ODSR_S_126) Other minor updates/typos (ODSR_S_121, 127, 128, 129) Further clarification to content in Section 4/Section B (ODSR_S_TBC)	May 2022	January 2023

v2.0	The following amendments have been made to this qualification specification following annual review. **General changes:** • clarification provided regarding registering students on T Levels and transferring between T Levels and occupation specialisms • amending language to make it more consistent • updated assessment information • updated wording to give clarity of internet usage for assessments • training and support for providers information has been updated • legislations, regulations and acts have been added and dates updated, where applicable • separating or merging bullet points that cover different or similar information • resource requirements section updated to specify that 'providers must ensure that the student has access to the necessary materials, resources and workspaces for delivery and assessment of mandatory knowledge and skills. The following lists are not exhaustive' and reference to PPE has been added • resource list has been updated • the glossary section has been updated to include 'Measurand' • throughout the specification, where referenced, 'causative agents' has been amended to 'pathogens (causative agents)' • all reference to GDPR has been updated to UK GDPR **Amendments made to the core component section:** • in A6.9 wording has been amended from 'the purpose of the following statistical techniques when analysing data' to 'how to carry out the following statistical techniques when analysing data and their purpose' • in B1.14, reference to 'nucleotides are the molecules from which DNA and RNA are formed' has been amended to 'nucleotides are the molecules (monomers) from which DNA and RNA are formed' • in B1.18, 'a spontaneous change in the DNA sequence can lead to genetic variations' has been amended to 'a mutation (spontaneous change in the DNA sequence) can lead to genetic variation'	May 2023	19 June 2023

	• in B1.24, reference to ‘organism’ has been amended to a “microorganism” • in B1.25, reference to ‘protoctists’ has been updated to ‘protists’ • in B1.32 ‘role of vaccinations in relation to T and B memory cells’ has been added as a bullet point • in B1.51, ‘the shape and direction of the magnetic field around bar magnets, and the relationship between the strength of the field and concentration of lines’ has been updated to ‘the shape and direction of the magnetic field around bar magnets, and the relationship between the strength of the field and concentration of field lines’ • in B1.56, reference to ‘X-rays’ has been amended to ‘X-rays for imaging’, and ‘cleaning computer equipment’ has been amended to ‘cleaning laboratory equipment’ • in B2.6, reference to ‘diploid’ has been added • in B2.7, ‘how the process of mitosis results in the formation of 2 genetically identical daughter cells’ has been amended and updated • in B2.10, the term ‘energy’ has been removed from the equation • in B2.11, the equation has been updated **Amendments made to the Laboratory Sciences occupational specialism section, including:** • in K1.31, reference to ‘NADH reductase’ has been updated with ‘NADH dehydrogenase’ • in K1.31, amendments have been made to the bullet points to provide further clarification and clarity • in K1.31, reference to ‘power’ has been amended ‘energy’ • in K1.31, further clarification regarding Krebs cycle has been added • in K1.31, reference to ‘involves 9 steps with 10 reactions’ has been updated to read ‘involves 10 reactions’ • in K1.33, ‘enzymes are inhibited by certain substances’ has been updated to ‘enzymes are inhibited by certain substances known as inhibitors’ • in K1.51, ‘electrochemistry to separate and then identify parts of a compound (for example, chlorine gas)’ has been amended to ‘electrolysis to separate compounds (for example, chlorine gas from chlorine compounds)’ • in K1.51, reference to ‘thermochemistry to analyse energy changes in chemical or physical transformations’ has been removed		