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**T-level Laboratory Science Course Booklet**

**Teaching Team**

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**Key Information**

Qualification title: Level 3 T Level Technical Qualification in Science

Qualification number (QN) : 603/6989/9

Qualification level : Level 3

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.

**Course Requirements**

Students are required to complete:

1. **core component** (core A Core B and employer set project (ESP) ) (Year 1)
2. **occupational specialism component + work placement** (year 2)

**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)

**Occupational specialism component :** Synoptic assignments

**Course structure**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Component** |  |  | **Level** |  |  | **Content** |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | 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 |
|  | Core component |  |  |  |  |  | workplace |
|  | (Section A: the health | 3 |  |  | A5 | Managing information and data within the health and science sector |
|  | and science sector) |  |  |  |  |
|  |  |  |  |  | A6 | Data handling and processing |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | A7 | Ethics |
|  |  |  |  |  |  |  | A8 | Good scientific and clinical practice |
|  |  |  |  |  |  |  | A9 | Scientific methodology |
|  |  |  |  |  |  |  | A10 | Experimental equipment and techniques |
|  |  |  |  |  |  |  |  |  |  |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Component** |  |  | **Level** |  |  | **Content** |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  | Core component |  |  |  |  | B1 | Core science concepts |
|  | (Section B: science | 3 |  |  |
|  |  |  | B2 | Further science concepts |
|  | concepts) |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  | Core Science covers a variety of topics in Biology, Chemistry and Physics |
| **Occupational specialism Laboratory Science**

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| --- | --- | --- | --- |
| Technical: laboratorysciences | Level 3 | **Outcome 1** | Perform a range of appropriate scientific techniques to collect.experimental data in a laboratory setting, complying with regulations. and requirements |
| **Outcome 2** | Plan, review, implement and suggest improvements to scientific |
| **Outcome 3** | Identify and resolve issues with scientific equipment or data errors |

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**Expectations of the course**

* All Laboratory safety procedures and behaviours to be followed, to ensure safety for al.
* All mobile phones and musical gadgets should be switched off during lessons.
* All students should be in class at the start of the lesson, except with acceptable reason.
* No drinking (except water in a water bottle) or eating in class.
* No bullying of any form / kind in class
* When doing practical work in groups, the students should take in turn to do the various aspects of the experiment (e.g., not just one person do the practical work whilst the other documents etc. for every experiment)
* If you do not manage to complete the experimental write-up and analysis of an experiment in class, then the work should be completed outside of class prior to the next lesson.
* All homework should be handed in on time.
* Students should set and review their SMART targets on a regular basis.
* Students’ attendance should not drop below 95% without just cause.
* Students should be prepared to do independent study.
* Students should be prepared to engage in work placement tasks on Campus with technicians and lecturers.
* Students will need to complete a 45-day work placement with a New college Industry partner.

**Progressions of course**

Students can progress onto Level 5 Laboratory science at the IOT or onto university for a science degree or apprenticeships.

**Assessment plan**

**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 (employer set Project) | 30 |
| **Total** | **100%** |

**External examinations (core)**

**Overview of assessment**

**Paper A:** Written examination Duration: 2 hours 30 minutes (June end of first year)

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

This paper is composed of 4 sections:

1. Section A: multiple choice questions, short-answer and extended writing, 25 marks
2. Section B: multiple choice questions, short-answer and extended writing, 25 marks
3. Section C: multiple choice questions, short-answer and extended writing, 25 marks
4. Section D: multiple choice questions, short-answer and extended writing, 25 marks

**Paper B:** Written examination Duration: 2 hours 30 minutes (June end of first year)

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:

1. Section A: multiple choice questions, short-answer and extended writing, 45 marks
2. Section B: multiple choice questions, short-answer and extended writing, 27 marks
3. Section C: multiple choice questions, short-answer and extended writing, 18 marks
4. Section D: multiple choice questions, short-answer and extended writing, 20 marks
5. **Assessment of the Course: weightings, content and grading**
6. Core paper A: elements A1 to A10 Core paper B: elements B1 to B2
7. **Assessment objectives and weightings**
8. 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 | 29% |
|  | principles in science. |  |
|  |  |  |
| **AO2** |  | Apply knowledge and understanding of contexts, concepts, theories and principles in | 40% |
|  | science to different situations and contexts |  |
|  |  |  |
|  |  | Analyse and evaluate information and issues related to contexts, concepts, theories and | 31% |
| **AO3** | principles in science to make informed judgements, draw conclusions and address |  |
|  |  | individual needs. |  |

1. \*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.

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

1. **ESP Employer set project (core component)**
2. **Overview of assessment**
3. Externally-set (in conjunction with employers) project
4. The purpose of the employer-set project is to ensure that students can 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.
5. Duration: 18 hours in May of the First year
6. **Subject content to be assessed.**
7. 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.
8. **Core skills**
9. 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 |
|  |  |

**Internal Assessments**

* Formal assessments will take place:
	+ At the end of each Unit for Core A and Topic in core B, with an overall assessment in December and again during the mock week (as per the college time table)
	+ Skills will be assessed on a matrix (using the passport to science)
	+ Student progress on Personal skills, laboratory skills and knowledge assessed and discussed 1-2-1
* Independent work is to be set by lecturers which may include research, quizzes and data analysis.
* All assessments to be tracked on Promonitor

**In year activities and trips**

External speakers, webinars and workplace experiences are integral to the course.

**Health and Safety**

In the Science labs there are obviously some risks which need to be monitored and managed constantly. It is our aim to ensure that all students feel safe and secure in science lessons and never come to any harm. All students can ensure this by being sensible at all times and following teacher instructions and the basic laboratory rules below.

* Never eat or chew in the laboratories (microbiological risk)
* Never run in the laboratory
* Always stand for practical activities
* Follow instructions carefully during practical activities.
* If required, allow equipment to cool down before tidying away.
* If required, wash hands following practical activities.
* Report spills and accidents to the lecturer immediately
* Never leave equipment unattended
* Always wear safety equipment in the correct way
* Keep work area tidy.

**Appeals**

Appeals for marks for homework and internal assessments should be made to the lecturer in the first place. Appeals for other things should be via the tutor and the college appeals procedure.

**Reference to results and retakes**

The marks and papers for the internal assessments will be made available to the students. In special circumstance students may be able to retake the paper or take it at a different time to the rest of the class.

With respect to appeal regarding external exams and retake of external exams the college procedure should be followed.

**Annex A – Contents of course**

**Core component section A: the health and science sector**

**A1 Working within the health and science sector**

 **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 o 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 o ensuring consistent and fair treatment
* establishing a sequence for disciplinary action
* grievance policy:
* providing opportunities for employees to confidentially raise and address grievances o 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
* 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**

 **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)
* 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:
* plan: identify potential problems and plan required improvements
* do: implement potential solution
* check: analyse the results
* 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
* 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)
* 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**

 **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 2002:**

* purpose: requirement for employers to control substances hazardous to health by reducing or preventing employees’ exposure to these substances

**Personal Protective Equipment (Enforcement) Regulations 1992:**

* 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) 2012/19/EU:**

* 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

**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**

**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):**

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
* 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
* 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**

**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
* 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, General Data Protection Regulations (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:**

* strengths (for example, consistent results produced under controlled conditions)
* limitations (for example, possibility of over-extrapolation)

**patient history:**

* strengths (for example, provides detailed information over time)
* limitations (for example, may not be accurate or complete)

**patient test results:**

* strengths (for example, laboratory and test accreditation ensures standardisation)
* limitations (for example, results are open to subjectivity)

**published literature:**

* 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

**GDPR 2018:**

* 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) o restricting the use of mobile devices in order to ensure confidentiality o 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

**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 o correcting misinformation
* crisis communication/monitoring o monitoring public health
* data gathering
* establishing support networks o 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 o 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 o speed of data analysis
* security (for example, password protected) o 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:**

* 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**

**A6.1** **The stages of data handling and processing:**

1. collect
2. record
3. analyse
4. 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

**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
* 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** **The purpose of the following statistical techniques when analysing data:**

* 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
* 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**

**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**

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

1. using standard operating procedures (SOPs)
2. effectively managing calibration and maintenance of equipment and work areas
3. effectively managing stock
4. appropriately storing products, materials and equipment

**A8.2** **What a SOP is:**

1. 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:**

1. maintaining health and safety
2. enabling consistency of approach
3. meeting any legal or organisational requirements
4. upholding professional standards
5. demonstrating compliance for audit purposes

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

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

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

1. risks to health and safety: o spread of infection

o production of toxic/dangerous by-products

1. invalid results:

o contamination or cross-contamination (for example, environmental, samples, reagents, DNA)

1. inefficient working practices:

o leads to increased costs and timescales

1. damage to equipment:

o leads to increased costs and timescales

**A8.6** **The potential impacts of not maintaining, cleaning and servicing equipment:**

1. risks to health and safety: o increased risk of injury o spread of infection
2. invalid results:

o contamination or cross-contamination (for example, environmental, samples, reagents)

1. reduced function of equipment:

o decreased lifespan of equipment

o 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:**

1. ensuring accuracy and reliability of measurements
2. prolonging the life of equipment
3. meeting legal requirements

**A8.8** **How to escalate concerns if equipment is not correctly calibrated/unsuitable for intended use:**

1. taking the equipment out of action
2. labelling the equipment as being out of use, if appropriate
3. reporting concerns to the relevant person, in line with organisational policies and procedures
4. recording concerns according to organisational procedures

**A8.9** **Why it is important to order and manage stock:**

1. ensuring sufficient supply of required consumables and materials
2. ensuring that materials are used before their expiry date
3. reducing the costs of excess stock
4. improving efficiency
5. improving productivity
6. ensure safety of stock (bottles aren’t damaged/degraded)

**A8.10** **The potential consequences of incorrectly storing products, materials and equipment:**

1. cross-contamination
2. breakdown of limited stability products
3. products exceeding expiry dates
4. loss of samples or degradation of reagents not stored at the correct temperature (-20°C, -4°C, 4°C or room temperature)
5. risks to health and safety (for example, spread of infection, release of dangerous chemicals, or heavy items not stored at correct height)
6. stock is difficult to locate
7. financial loss

**A9 Scientific methodology**

**A9.1** **The importance of experimental design and planning when undertaking scientific experiments in**

**order to:**

1. manage time efficiently (for example, ensuring that the minimum required number of measurements is carried out)
2. ensure sufficient resources (for example, checking supplies of required reagents, availability of equipment and personnel)
3. ensure safety throughout the experiment (for example, completing a risk assessment)
4. address ethical considerations (for example, justifying the necessity of an experiment)
5. minimise errors (for example, calibrating equipment in advance)

**A9.2** **The importance of a hypothesis/performance criteria, in experimental design:**

1. defining outcomes that can be tested
2. deciding on variables: o independent

o dependent

Controls

1. clarifying the experiment’s objective

**How to access and critically evaluate scientific literature and research databases, taking into account:**

**How to provide results and recommendations in appropriate formats to customers/clients:**

**How customer/client requirements may affect the scientific methodology by:**

**How the following planning methodologies contribute to successful experimental design:**

**A9.3**

objective setting: defines the purpose and outputs required

1. critical path analysis: maps out the key tasks in order, including dependencies
2. financial forecasting: defines what is feasible for a given budget
3. risk management: assessing and managing risks for the workforce
4. time management: defines timescales and workflows

**A9.4**

1. defining timescales
2. setting a budget
3. specifying scale (for example, number of replicates and sample size)
4. specifying objectives

**A9.5**answering the brief/research questions

1. tailoring language and technical information to the audience
2. selecting the most appropriate way of presenting data (for example, visualisations/infographics)
3. highlighting the commercial/business benefits for the customer/client

**A9.6**

1. searching for relevant existing scientific research/literature: o selecting relevant databases

o choosing key terms and phrases for which to search

1. 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)

1. age/relevance of literature
2. reliability of sources (for example, conflicts of interest, citations, impact factor)
3. reliability of data (sample sizes, collection method used)

**A9.7** **The principles that inform sampling techniques:**

1. avoiding bias
2. ensuring a large enough sample size to produce valid results
3. practical constraints (for example, timescales, costs)

**A9.8** **A range of techniques for measuring scientific subject matter at micro and macro scales:**

1. mass (for example, balances to different decimal places)
2. length (for example, eyepiece graticule, laser measure)
3. volume (for example, micro or graduated pipette)

**A9.9** **The need for reliable, verifiable, and accurate recording in order to ensure that:**

1. data or information is repeatable
2. data or information is relevant to the experimental purpose (valid recording)
3. 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:**

1. identify and define the problem
2. investigate and examine possible causes
3. decide on changes to be made
4. implement the changes
5. evaluate the impact and continue to monitor any changes

**A9.11 How to evaluate a scientific methodology and make recommendations for improvement, including:**

1. reflecting on experimental design
2. assessing the reliability of methods, and precision, accuracy, repeatability and reproducibility of results
3. identifying areas for improvement
4. making recommendations for future improvement

**A9.12 The purpose of International Organisation for Standardisation (ISO) standards in scientific settings:**

1. enables accredited laboratories to demonstrate competency and validity through collaborative testing
2. facilitates cooperation between organisations by generating wider acceptance of results
3. improves international trade as test reports and certificates can be accepted from one country to another without the need for further testing
4. specifies the general requirements for the competence to carry out tests and/or calibrations, including sampling

**A10 Experimental equipment and techniques**

**A10.1** **Common causes of equipment and technical faults that may have an impact on scientific results:**

1. user error
2. setting-up errors
3. poor maintenance (including calibration)
4. electrical faults

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

1. 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
2. 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:**

1. autoclaves: to decontaminate/sterilise equipment and some consumables
2. centrifuges: to separate suspensions
3. cryogenic equipment: to produce exceptionally low temperatures
4. data loggers: for the collection, storing, and recording of data over a period of time
5. digital (for example, mechanical) and non-digital (for example, volumetric) pipettes: to accurately measure and transfer solutions
6. fume cupboards: as a safety measure to capture and remove airborne hazards
7. glassware: to store, measure, transfer and collect reagents and samples
8. glove boxes: to provide a contained and controlled environment (sealed atmosphere) for manipulating samples, substances, and objects
9. incubators: to provide a controlled and accurately maintained environment (for example, temperature, humidity)
10. microbiological equipment: to perform a range of microbiological techniques whilst maintaining an aseptic environment
11. multimeter: a meter than can measure voltage, current and therefore resistance in a circuit
12. pH meters: to measure pH (for example, how acidic or alkaline a substance is)
13. refrigerators and freezers: to provide a controlled and accurately maintained temperature
14. scientific balances: to accurately determine the mass of a sample, including small samples
15. 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:**

1. referring to material safety data sheets (for example, for corrosive substances)
2. using personal protective equipment (PPE) (for example, using gloves to handle phenol)
3. using equipment for safe handling (for example, using tongs to handle alkali metals)
4. 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:**

1. kilo (for example, balance)
2. milli (for example, analytical balance)
3. micro (for example, micrometer)
4. nano (for example, atomic clock)

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

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

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

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

**A10.8** **How to follow aseptic techniques:**

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

**Core component section B: science concepts**

**B1 Core science concepts**

**Cells and tissues**

**B1.1** **The 3 principles of cell theory:**

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

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

1. eukaryotic cells (for example, plant, yeast, some algae and animals)
2. prokaryotic cells (for example, bacteria)

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

1. cell surface membrane
2. nucleus (containing chromosomes)
3. mitochondria
4. ribosomes
5. rough and smooth endoplasmic reticulum
6. Golgi apparatus and Golgi vesicles
7. centrioles
8. lysosomes
9. chloroplasts (in plants)
10. cell wall (in plants)
11. cell vacuole (in plants)

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

1. overall cell shape
2. presence of the same organelles
3. presence of different organelles for specialised functions (for example, chloroplasts)

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

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

**B1.6** **How prokaryotic cells differ from eukaryotic cells:**

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

**Proteins**

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

1. amino acids are the small molecules (monomers) from which all proteins are made
2. amino acids contain NH2 which is the amine group, COOH represents a carboxyl group and R represents a side chain
3. there are twenty amino acids common in organisms, each differs by the side chain (R)
4. dipeptides are formed by the condensation of 2 amino acids
5. polypeptides are formed by the condensation of many amino acids
6. 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:**

1. monosaccharides are the small molecules (monomers) from which all larger carbohydrates are made (disaccharides and polysaccharides)
2. glucose, galactose and fructose are common monosaccharides
3. disaccharides are formed from 2 monosaccharides (for example, maltose and sucrose)
4. polysaccharides are formed from many monosaccharide molecules
5. 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:**

1. lipids are a diverse group of substances which all contain carbon, hydrogen and oxygen
2. they are generally insoluble in water
3. the main groups of lipids are triglycerides (for example, fats and oils) and phospholipids
4. the main role of phospholipids is in plasma membranes to provide flexibility and transport mechanisms
5. 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:**

1. the surface area must be large in comparison to the volume for efficient exchange
2. where the surface area is small compared to the volume, specialised exchange and transport mechanisms are required to maximise the rate of diffusion
3. 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:**

1. the structure of the cell surface membrane with reference to the fluid mosaic model
2. passive transport through the cell surface membrane: diffusion, facilitated diffusion and osmosis
3. active transport through the cell surface membrane
4. 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:**

1. DNA holds genetic information
2. 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:**

1. nucleotides are the molecules from which DNA and RNA are formed
2. each nucleotide is formed from pentose, a nitrogen containing organic base and a phosphate group
3. the components of a DNA nucleotide are deoxyribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or thymine
4. the components of an RNA nucleotide are ribose, a phosphate group and one of the organic bases adenine, cytosine, guanine or uracil
5. a condensation reaction between 2 nucleotides forms a phosphodiester bond
6. a DNA molecule is a double helix with 2 polynucleotide chains held together by hydrogen bonds between specific complementary base pairs
7. 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:**

1. DNA is progressively unwound
2. breakage of the hydrogen bonds between complementary bases
3. this leaves 2 chains with unpaired bases

1. each chain then acts as a guiding base (or template) for the building of a new strand
2. 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:**

1. a spontaneous change in the DNA sequence can lead to genetic variation

**B1.19** **The difference between genetics and genomics:**

1. genetics focuses on the functioning and composition of single genes
2. 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:**

1. bacteria
2. fungi
3. parasites
4. viruses

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

1. light microscopes: o low cost

o easy to use - requires little training

o allows for examination of living microorganisms

1. scanning electron microscopes: o higher resolution

o reveals more surface detail

o displays a 3D view of the surface

1. transmission electron microscopes: o higher resolution

o reveals internal structures

o 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 = size of image

size of object

**B1.23** **The uses of differential staining techniques:**

1. Gram staining:

o to identify Gram- and Gram+ bacteria

1. Giesma staining:

o to identify specific bacteria (for example, *Chlamydia trachomatis*) or parasites (malarial) o to identify any pathophysiology of blood cells

1. haematoxylin and eosin staining:

o 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:**

1. an organism replicating inside the body, resulting in disease

**B1.25** **Causative agents of infection and examples of resulting diseases:**

1. bacteria (for example, chlamydia, gonorrhoea, tuberculosis)
2. viruses (for example, common cold, mumps and measles)
3. fungi (for example, yeast infection (thrush))
4. prions (for example, Creutzfeldt-Jakob disease (CJD))
5. protoctists (for example, malaria)
6. parasites (for example, toxoplasmosis)

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

1. direct transmission:

o physical contact with an infected person or contaminated surface (for example, skin-to-skin contact)

o sharing of needles

o unprotected sexual contact

o airborne: causative agent is carried by dust or droplets in the air, can exist in the air for some time (for example, inhaling infected droplets)

1. indirect transmission:

o vehicle transmission (for example, ingesting infected food or water (faecal-oral)): blood from inanimate objects (for example, bedding)

o being bitten by an infected ‘vector’ (for example, insect bites)

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

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

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

1. antigen - a substance that is recognised by the immune system as self or non-self and stimulates an immune response

1. 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:**

1. antigens as chemical markers
2. 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:**

1. use of physical and chemical barriers
2. inflammation
3. phagocytosis
4. actions of T cells
5. actions of B cells

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

1. cell-mediated response is associated with T lymphocytes destroying causative agents without producing antibodies
2. antibody-mediated response is associated with B lymphocytes destroying causative agents by producing antibodies against it

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

1. they trigger a stronger and more rapid immune response after encountering the same antigen

**Materials and chemical properties**

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

1. physical properties:

o conductivity (electrical and thermal) o malleability/ductility

o strength

1. chemical properties: o group 1:
	1. reactivity of group 1 metals with water and oxygen
	2. reactivity of group 1 metals in terms of their electronic configurations
	3. transition metals:
		1. reactivity of transition metals with oxygen and acids
		2. 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
2. the relationship between the structure and properties of the following materials:
	1. composite materials (for example, concrete, fibreglass and carbon fibre):
		1. structure - made of 2 or more materials with different properties to combine those properties into one material

1. properties - strong, lightweight
2. ceramics (for example, clay and glass):
	1. structure - moulded and then baked to form strong bonds between atoms in the structure
	2. properties - hard, strong under compression, chemically unreactive
	3. polymers (for example, high density (HD) and low density (LD) polyethene, thermosetting and thermosoftening polymers):
		1. structure - long chain molecules with forces or bonds between the chains
		2. properties - strong, chemically unreactive, electrical insulators
3. 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:**

1. 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:**

1. protons - found in the nucleus
2. neutrons - found in the nucleus
3. electrons - found in orbitals around the nucleus

**Acids/bases and chemical change**

**B1.36** **The physical and chemical properties of acids:**

1. irritant or corrosive
2. neutralise bases
3. react with metals to form H2
4. pH less than 7

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

1. strong acids are completely ionised in aqueous solution (for example, sulfuric, hydrochloric and nitric acids)
2. weak acids are only partially ionised in aqueous solution (for example, ethanoic and carbonic)
3. for a given concentration of aqueous solution, the stronger the acid, the lower the pH
4. 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:**

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

**Rates of reaction and energy changes**

**B1.39** **The principles of collision theory:**

1. molecules must collide
2. molecules must collide with enough energy to break and reform bonds

1. molecules must be in the correct spatial orientation

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

1. an increase in temperature makes molecules move faster, resulting in increased collisions and rates of reaction
2. 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:**

1. catalysts are substances that increase the rate of a chemical reaction without themselves being permanently chemically changed

**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:**

1. thin layer chromatography:

o used to separate non-volatile mixtures based on their affinity for a mobile (solvent) or stationary phase (on a coated plate)

o used to detect the number of components

o used to identify the compounds and their purity

1. column chromatography:

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

1. gas chromatography:

o used to separate and analyse compounds that can be vaporised (in a capillary or packed column)

1. high performance liquid chromatography:

o used to separate substances based on their affinity for a mobile (pressurised solvent) or stationary phase (in a capillary or packed column)

1. mass spectrometry:

o used to separate substances due to their mass to charge ratio and to identify molecular ions and ion fragments

o 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:**

1. gas chromatography
2. high performance liquid chromatography
3. mass spectrometry

**B1.44** **The principle of titration:**

1. 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:**

1. series: the total resistance is equal to the sum of the individual resistors
2. parallel: R1 = R11 + R21 + Rn1

**B1.48** **The difference between alternating and direct current.**

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

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

**Magnetism and electromagnetism**

**B1.50** **Magnetism and magnetic poles:**

1. north and south magnetic poles are where the magnetic forces are strongest
2. attraction/repulsion of magnets in close proximity - attraction and repulsion between magnetic poles are examples of non-contact forces
3. the difference between permanent and induced magnets
4. the uses of permanent and temporary magnetic materials (for example, iron, steel, cobalt, nickel)

**B1.51** **Magnetic fields:**

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

o strength of the field o size of the current

o distance from the wire

**B1.52** **The uses of electromagnetism and electromagnets:**

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

**Waves**

**B1.53** **The definition of a wave:**

1. the transfer of energy, not matter

**B1.54** **The relationship between frequency, wavelength and speed using the wave equation v = fλ.**

**B1.55** **The properties of longitudinal and transverse waves:**

1. longitudinal waves move in the same direction in which the particles are vibrating
2. 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:**

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

**Particles and radiation**

**B1.57** **The types and properties of ionising radiation:**

1. alpha:

o high ionising but low penetrating power o range is 1 to 2 centimetres of air

1. beta:

o medium ionising and penetrating power

o range is approximately 15 centimetres of air

1. gamma:

o low ionising and high penetrating power o range is many kilometres of air

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

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

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

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

**B1.60** **How radiation interacts with matter:**

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

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

1. radioactive tracers

1. medical diagnostic applications
2. food preservation
3. dating deceased organisms

**Units**

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

1. ampere (A) - electric current
2. candela (cd) - luminous intensity
3. kelvin (K) - temperature
4. kilogram (kg) - mass
5. metre (m) - length
6. mole (mol) - amount of substance
7. second (s) - time

**B1.63** **How to convert between units:**

1. millimetres to metres
2. milligrams to grams
3. millilitres to litre

**B1.64** **The importance of using significant figures and science notation:**

1. makes calculations with large or small numbers less cumbersome
2. reduces the chances of data errors

**B2 Further science concepts**

****

**Classification of biological molecules**

**B2.1** **The molecular structures and functions of the following:**

1. 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)

1. 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

o 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)

1. lipids:

o fatty acids and glycerol are the molecules from which triglycerides and phospholipids are formed

o triglycerides are formed by the condensation of 1 molecule of glycerol and 3 molecules of fatty acid

o phospholipids are formed when one of the fatty acids of a triglyceride is substituted by a phosphate-containing group

o fatty acid molecules repel water (hydrophobic) and glycerol molecules attract water (hydrophilic)

o 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

1. nucleic acid:

o nucleic acids are large molecules composed of nucleotides

o each nucleotide in DNA is made up of a sugar (deoxyribose), a phosphate and an organic base

o DNA is made up of 2 strands of nucleotides joined together by hydrogen bonds. The nucleotides form a double helix structure

o 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:**

1. 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
2. nucleotides comprise ribose sugar, phosphate and a base which can be guanine (G), cytosine (C), adenine (A) and thymine (T)
3. 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
4. the genetic code is universal, non-overlapping and degenerate, meaning that each amino acid can be coded for by more than one codon
5. 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:**

1. DNA acts as a template providing the instructions for the synthesis of each amino acid via the coding sequence of bases
2. a complementary section of part of this sequence is made into messenger RNA (mRNA) by a process known as transcription

 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

1. in RNA thymine is replaced by uracil (U)

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

1. the shape of the active site
2. the role of bonding
3. the effect of pH and temperature

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

1. models of lock and key hypothesis
2. the effect of enzyme concentration and substrate concentration
3. induced fit

**Cell cycle**

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

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

**B2.7** **The characteristics of each of the stages of mitosis, including the behaviour of chromosomes and the cellular structure at each stage:**

1. interphase: stage that always proceeds mitosis when DNA is replicated
2. prophase: stage in which chromosomes become visible and the nuclear envelope disappears
3. metaphase: stage in which the chromosomes arrange themselves at the centre of the cell
4. anaphase: the stage in which each of the 2 threads of a chromosome (chromatid) migrates to the opposite pole
5. telophase: stage in which the nuclear envelope reforms to produce 2 daughter cells

**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:**

1. meiosis takes place in the reproductive organs to form haploid gametes (cells that unite to form a new organism)
2. it is necessary to have haploid gametes to maintain a constant number of chromosomes from one generation to the next
3. meiosis involves 2 stages or divisions (meiosis I and meiosis II), such that each diploid cell divides to produce 4 haploid gametes

1. in meiosis I the chromosome number is halved and the process of ‘crossing over’ takes place
2. 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
3. the process of crossing over, where genetic material is exchanged creates genetic variation
4. the second stage of meiosis is identical to mitosis

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

1. 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
2. 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
3. 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
4. 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)
5. 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):**

1. 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
2. involves a series of oxidation and reduction reactions
3. glucose + oxygen *→* carbon dioxide + water + energy (ATP)
4. C6H12O6 + 6O2 → 6CO2 + 6H2O + energy (ATP)

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

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

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

**Pathogens**

**B2.13** **The definition of a pathogen:**

1. 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 and the diseases they can cause:**

1. bacteria:

o Escherichia coli (E. coli) causes gastrointestinal disorders

1. fungi:

o Candida auris (C. auris) causes fever and possible sepsis

1. prions:

o proteins that can cause prion diseases, (for example, Creutzfeldt-Jakob disease (CJD))

1. protists:

o Plasmodium sp. that cause malaria

1. viruses:

o hepatitis A virus (HAV) causes hepatitis A

**Formulae and equations**

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

1. group 1 metals with water and oxygen
2. 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:**

1. C2H5 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:**

1. divide the relative molecular mass by the mass of the atoms in the empirical formula
2. multiply the ratio to arrive at the formula

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

1. isotopes are atoms of the same element with different masses due to a different number of neutrons (for example, C12 and C13)
2. relative isotopic mass is the mass of an atom of an isotope relative to 1/12 of the mass of a C12 atom

**B2.19 The link between balanced equations and the ratio of moles of a substance in a reaction (for example, 2CH4 is 2 moles).**

**B2.20 The relationship between the number of moles of solute and the volume in dm3 of solvent as a measure of concentration (mol/dm3).**

**Kinetic changes**

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

1. surface area
2. temperature
3. concentration
4. pressure

**B2.22** **How to calculate the rate of reaction:**

**B2.23** **The definition of activation energy:**

**amount of reactant or product**

**time**

1. 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:**

1. the increase in the rate of reaction gives a faster turnaround time and so reduces costs
2. 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:**

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

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

1. phenolphthalein
2. methyl orange

**B2.30** **The following applications of chromatography in industry:**

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

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

1. used in quality control (for example, to test food products for consistency)
2. 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:**

1. Boyle’s Law (P1V1 = P2V2)
2. Charles’s Law (V1T2 = V2T1)
3. the Pressure Law (P1/T1 = P2/T2)

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

1. the effect of a temperature of absolute zero on the movement of particles

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

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

**Pressure/fluid/viscosity**

**B2.35** **The definitions of:**

1. density - mass per unit volume
2. pressure - force per unit area
3. fluid - a substance that is capable of flowing, with no fixed shape
4. 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:**

1. Newtonian - a fluid whose viscosity remains constant as the applied force changes
2. 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:**

1. volumetric flow rate - the volume of a fluid moving through a given area per unit of time
2. 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:**

1. steady flow is when all parts of a fluid have the same velocity at a certain point
2. turbulent flow is when different parts of the fluid have a different velocity

**B2.40** **The coefficient of viscosity of a fluid:**

1. a measure of the resistance to flow of a fluid

**Year 2: Occupational specialism**

**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 alaboratory setting, complying with regulations and requirements

**Performance outcome 2:** Plan, review, implement and suggest improvements to scientific tasks relevant to alaboratory 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:

1. paper and thin layer chromatography (TLC)
2. distillation
3. acid-base and redox titration
4. refluxing
5. filtration
6. differential staining (microorganisms)
7. aseptic culture of microorganisms
8. preparation of serial dilution
9. prepare a solution of defined molar concentration
10. colorimetry
11.
12. pressure using a U-tube manometer
13. temperature using a probe and data logger
14. radioactive count rate using Geiger counter
15. conductivity meter to measure conductivity of a solution
16. electrical polarity using ammeter and voltmeter
17. 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 -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K1.1 How health, safety and environmental** | **S1.68 Work safely in a laboratory when** |
| **practices are applied when performing** | **performing specific scientific techniques** |
| **scientific techniques:** | **by:** |  |
| • planning to perform a scientific technique: | • | following SOPs |
| o | completing an appropriate risk | • | following safe laboratory practice |
|  | assessment for typical hazards in a | • | maintaining excellent housekeeping |
|  | laboratory setting (for example, |
|  |  |  |
|  | biological and chemical hazards) | • | selecting an appropriate space |
| o selecting equipment and personal | • | using equipment appropriately |
|  | protective equipment (PPE) suitable to | • using resources safely and efficiently (for |
|  | the task (for example, suitable eye |
|  | protection and gloves) |  | example, only using the required amount |
| o selecting an appropriate space for the |  | for hazardous materials) |
|  |  |
|  | procedure (for example, one that | **S1.69 Comply with relevant health and safety** |
|  | includes a fume cupboard, cell hood) | **legislation and regulations, including** |
| • safely performing a scientific technique: | **COSHH and biosafety containment levels,** |
| o using the correct PPE at all appropriate | **when handling and disposing of solids,** |
| **liquids and gases relevant for the scientific** |
|  | times |
| o using resources and equipment | **technique being performed, including:** |
|  |  |
|  | appropriately for the scientific | • toxic (for example, methanol, chlorine, |
|  | technique being performed (for |  | potassium dichromate (VI)) |
|  | example, keeping yourself and others | • corrosive (for example, acid) |
|  | safe) |
|  |  |  |
| o | following standard operating | • irritants (for example, copper sulfate |
|  | procedures (SOPs) and safe laboratory |  | solution) |
|  | practice when performing the scientific | • sensitisers (for example, chromium |
|  | technique |
|  |  | compounds, sulfur dioxide) |
|  |  |  |  |
| o safely handling materials, in line with | • flammable (for example, ethanol, |
|  | Control of Substances Hazardous to |
|  |  | hydrogen) |
|  | Health Regulations 2002 (COSHH): |  |
|  | • air/water sensitive materials (for example, |
|  | ▪ toxic (for example, methanol, |
|  |  | alkali metals) |
|  |  | chlorine, potassium dichromate VI) |  |
|  |  | • compressed gases (for example, oxygen) |
|  | ▪ corrosive (for example, acid) |
|  |  |  |
|  | ▪ irritants (for example, copper sulfate | • pyrophoric (for example, magnesium) |
|  |  |  |
|  |  | solution) | • oxidising agents (for example, hydrogen |
|  | ▪ sensitisers (for example, chromium |  | peroxide) |
|  |  |  |
|  |  | compounds, sulfur dioxide) | • | radioactive sources (for example, |
|  | ▪ | flammable (for example, ethanol, |  | caesium-137) |
|  |  |  |  |
|  |  | hydrogen) |  |  |
|  |  |  |  |  |

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**Safety, health and environmental practices in laboratory science**

* 1. air/water sensitive materials (for example, alkali metals)
	2. compressed gases (for example, oxygen)
	3. pyrophoric (for example, magnesium)
	4. oxidising agents (for example, hydrogen peroxide)
	5. radioactive materials (for example, radioactive iodine)
	6. biohazards (for example, micro-organism cultures)
	7. serious health hazards (for example, formaldehyde)
	8. liquid nitrogen
	9. carcinogens (for example, ninhydrin)
1. completing a scientific technique:

o safely disposing of materials, in line with COSHH:

* 1. organic waste (for example, propanone)
	2. toxic (for example, methanol, chlorine, potassium dichromate (VI))
	3. corrosive (for example, acid)
	4. flammable (for example, ethanol, hydrogen)
	5. compressed gases (for example, oxygen)
	6. pyrophoric (for example, magnesium, alkali metals)
	7. oxidising agents (for example, hydrogen peroxide)
	8. radioactive sources (for example, caesium -137)
	9. biohazards (for example, micro-organism cultures)
	10. serious health hazards (for example, formaldehyde)
	11. carcinogens (for example, ninhydrin)
1. reporting any near misses, accidents or injuries, following the appropriate processes
2. biohazards (for example, micro-organism cultures)
3. organic waste (for example, propanone)

**S1.70** **Complete a risk assessment to minimise**

**potential hazards and risks when performing a scientific technique:**

1. step 1 - identifying the hazards, taking account of warning symbols and using model risk assessments:

o chemical (for example, compressed gases, cleaning agents)

o biological (for example, biological samples)

o physical (for example, repetitive tasks, noise levels)

1. step 2 - assessing the risks:

o how likely is the scientific technique to go wrong?

o who might be harmed?

o what could be the consequences?

1. step 3 - evaluating the risks and selecting control measures:

o identifying alternate or safer methods than those proposed (for example, using a different concentration of chemicals)

o identifying the appropriate PPE to use

1. step 4 - recording findings, following the risk assessment and amending the control measures as necessary:

o in a clear and unambiguous way o using technical language correctly

o organising the findings logically and coherently

o using the appropriate vocabulary, spelling and grammar

1. 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).**

**Safety, health and environmental practices in laboratory science**

1. 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:**

1. energy (for example, heating to a required temperature and not above)
2. water (for example, recycling of water)
3. waste (for example, using re-usable equipment)

**Ethics**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K1.3 The principles of the ‘Universal Ethical** | **S1.72 Adhere to ethical practice and codes of** |
| **Code for Scientists 2007’ and how it affects** | **conduct to ensure confidentiality and meet** |
| **ethical practices in a laboratory setting:** | **intellectual property requirements:** |
| • | rigour: | • physical security (for example, locked |
|  | o acting with skill and care in all scientific | doors, opaque glass, individual |
|  | workstations) |
|  | work |
|  |  |
|  | o maintaining up-to-date skills and | • electronic security (for example, controlled |
|  | access systems, video surveillance) |
|  | assisting with their development in |
|  |  |
|  | others | • operational security (for example, sign-in |
|  | o taking steps to prevent corrupt | sheets, restricted access, following non- |
|  | disclosure policies) |
|  | practices and professional misconduct |
|  |  |
|  | o declaring conflicts of interest | • information security (for example, |
|  | passwords, back-up systems, recording |
|  | o being alert to the ways in which |
|  | results securely by using a permanent |
|  | research derives from and affects the | bound lab book and having each page |
|  | work of other people, and respecting | countersigned) |
|  | 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 |  |
|  |  |  |
|  |  |  |

**Ethics**

1. 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

o presenting and reviewing scientific evidence, theory or interpretation honestly and accurately

**K1.4** **Ethical issues and wider implications of**

**scientific practices:**

1. misusing or misinterpreting published research
2. conducting unethical research (for example, with human tissue samples)

**K1.5** **The importance of adhering to codes of**

**conduct to ensure confidentiality:**

1. to avoid improper disclosure of information and data that could harm the science organisation or individuals within it
2. to avoid accidental loss or release of sensitive information or data
3. to comply with regulatory requirements and guidance

**K1.6** **The importance of adhering to codes of**

**conduct to protect intellectual property:**

1. to avoid sharing commercially sensitive information and research through improper disclosure
2. to avoid accidental loss or release of sensitive information and research
3. to respect the intellectual property of other scientists’ work

**Core scientific knowledge**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **Atomic structure:** | **S1.73 Apply scientific knowledge when** |
| **K1.7 The definitions of orbital and nucleus:** | **undertaking scientific techniques by:** |
|  |  |
| • orbital - a region of space with the greatest | • choosing and justifying appropriate |
| scientific techniques: |
| chance of finding an electron |
|  |  |
| • nucleus - a dense group of protons and | o paper and thin layer chromatography: |
|  | molecular structure and bonding (for |
| neutrons in the centre of an atom |  |
|  | example, choice of a polar or non-polar |
|  |  |
| **K1.8 How electrons are arranged in s and p sub-** |  | solvent) |
|  |  |
| **orbitals from periods 1 to 4:** | o | distillation: molecular structure/bonding |
| • filling electron sub-shells in order of |  | and kinetic changes (for example, |
|  | differences in the boiling points of |
| increasing energy from 1s2 to 4p6 |  |
|  | components due to differences in |
|  |  |
| **K1.9 How the electron arrangement in s and p** |  | bonding) |
|  |  |
| **orbitals is linked to the way in which** | o | refluxing: molecular structure/bonding |
| **elements are situated in s and p blocks in** |  | and kinetic changes (for example, |
| **the periodic table:** |  | choice of refluxing due to organic |
|  | components) |
| • s-block elements have their outer |  |
| o acid base and redox titration: oxidation |
| electrons in s shells |
|  | and reduction (for example, |
|  |  |
| • p-block elements have their outer |  | identification of reaction from given |
| electrons in p shells |  | equation) |
| • d-block elements have their outer | o | differential staining techniques: |
| electrons in d shells |  | characteristics of microorganisms (for |
| **K1.10 How the position of the element in the** |  | example cell wall components by gram |
|  | staining) |
| **periodic table (arrangement of electrons) is** | o aseptic culturing: nature of infection |
| **related to the reactivity of that element:** |
|  | and causative agents/transmission |
| • metal reactivity generally decreases as |  | routes (for example, dilution, streaking |
|  | and spread plates to culture micro- |
| you go from left to right in the periodic |  |
|  | organisms) |
| table |  |
|  |  |
| • non-metal reactivity generally increases as | o preparation of serial dilutions: amount |
|  | of substance (for example, use of |
| you go from left to right in the periodic |  |
|  | calculations to determine dilutions |
| table (apart from group 0 which are |  |
|  | needed) |
| unreactive) |  |
|  |  |
| **Amount of substance:** | o | filtration: molecular structure/bonding |
|  | (for example, choice of filtering as |
|  |  |
| **K1.11 The definitions of relative atomic mass and** |  | some substances like metals are |
|  | insoluble) |
| **relative molecular mass:** |  |
| • planning the steps of the technique in the |
| • relative atomic mass is the average mass |
| correct order, ensuring correct quantities |
| of the atoms of an element compared to |
| and concentrations are used  |
| carbon-12 |
|  |  |
|  |  |  |

1. 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/dm3 or**

**mol/dm3) 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. 1 mole of gas occupies a volume of

22.4dm3 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:**

1. 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
2. covalent bonding involves sharing of electron pairs
3. 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:**

1. ionic lattice as a large 3D structure containing oppositely charged ions
2. covalent structures as simple molecules or giant covalent structures of many atoms
3. 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:**

1. linear: 2 electron pairs repel to be 180o apart

1. tetrahedral: 4 electron pairs repel to be 109.5o apart
2. triagonal planar: 3 electron pairs repel to be 120o apart

**K1.18** **The effect of structure and bonding on a**

**range of properties including:**

1. solubility and dissolution:

o ionic substances tend to be soluble in polar solvents like water

o metallic substances tend to be insoluble

o 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

1. electrical conductivity:

o ionic substances conduct electricity only if molten or dissolved

o metallic substances conduct electricity even as solids

o simple covalent substances do not conduct electricity

1. melting/boiling point:

o ionic substances have high melting and boiling points

o metallic substances have high melting and boiling points

o simple covalent substances have low melting and boiling points

**Organic chemistry:**

**K1.19** **How to apply the International Union of**

**Pure and Applied Chemistry (IUPAC) rules**

**to name the following organic compounds:**

1. straight chain alkanes and cycloalkanes:

o methane, ethane, propane, butane, cyclopropane and cyclobutane

1. straight chain alkenes:

o ethene, propene, butene and pentene

1. alcohols:

o methanol, ethanol, propan-1-ol, propan-2-ol and butan-1-ol, butan-2-ol

1. carboxylic acids:

* 1. methanoic acid, ethanoic acid, propanoic acid and butanoic acid
1. aldehydes and ketones:
	1. ethanal, propanal, propanone and butanone
2. amines:
	1. ethylamine and propylamine

**K1.20** **The word and symbol equations to show**

**reactions of the following organic**

**compounds:**

1. alkenes (ethene, propene, butene and pentene):

o reactions with bromine, hydrogen bromide and hydrogen

1. 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:**

1. refluxing - used for long reactions with volatile components
2. recrystallisation - used for purifying a substance
3. separating funnel - used for separating and purifying a substance

**Oxidation and reduction:**

**K1.22** **The oxidation and reduction process:**

1. oxidation:

o gaining oxygen:

1. oxidising agents providing oxygen
2. losing hydrogen:

▪ oxidising agents removing hydrogen

* 1. losing electrons:
		1. oxidising agents removing electrons
1. reduction:
	1. losing oxygen:
		1. reducing agents removing oxygen
2. gaining hydrogen:

▪ reducing agents providing hydrogen

* 1. gaining electrons:

▪ reducing agents providing electrons

1. redox:
	1. 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:**

1. electrode that is relatively more negative (oxidation half-cell) will release electrons more readily and electrons will flow from this electrode

**Enthalpy and Entropy:**

**K1.24** **The definition of enthalpy and entropy:**

1. enthalpy change is the amount of energy taken in or given out in a reaction at constant pressure
2. 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:**

1. using the Gibbs equation (ΔG = ΔH - T ΔS system)

**K1.26** **Factors that affect the stability of**

**compounds and the chance of chemical**

**reactions occurring:**

1. the stability of compounds:

o depends on their internal energy

o the lower the internal energy the more stable a compound is

1. 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:**

1. 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

1. bond enthalpy values:

o add up the bond enthalpies for the reactants (gives a positive value, as bond breaking is endothermic)

o add up the bond enthalpies for products (gives a negative value, as bond making is exothermic)

o 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:**

1. synthetic polymers:

o properties: electrical insulator, lightweight, chemically unreactive

o applications: examples could include - personal protective equipment (PPE) is chemically unreactive yet lightweight, non-stick coating and containers are chemically unreactive

1. alloys:

o properties: strong, lightweight, resistant to corrosion

o applications: examples could include - machine parts are strong but lightweight, lab benching and fume cupboards are strong but resistant to corrosion

1. composites:

o 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:**

1. addition polymerisation:

o definition: a polymer made of monomers without generation of other products

o characteristics: high atom economy

1. condensation polymerisation:

o definition: polymer made by chemical reaction producing a small molecule as a by product

o characteristics: lower atom economy

**Metabolic pathways and bioenergetics:**

**K1.30** **The differences between anabolic and**

**catabolic pathways in terms of energy**

**change:**

1. anabolic pathways: pathways which require energy to synthesise larger molecules (for example, synthesis of proteins from amino acids)
2. 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:**

1. glycolysis:

o initial stage of aerobic respiration involving glucose

o takes place in the cytoplasm

o involves 9 steps, with 10 reactions

o reactions at each step are catalysed by different enzymes

o converts glucose molecules into pyruvate, and hydrogen ions

o energy released is sufficient for the synthesis of 2 molecules of adenosine triphosphate (ATP) and also produces

2 molecules of reduced nicotinamide

adenine dinucleotide (NAD)

1. link reaction Acetyl-Coenzyme A oxidation (acetyl-CoA):

o short pathway in comparison with other pathways

o pyruvate (from the glycolysis pathway) diffuses from the cytoplasm to the mitochondrial matrix through active transport

o pyruvate is converted to acetyl-CoA

1. Krebs cycle:

o Acetyl-CoA (from the link reaction) enters the Krebs cycle

o the cycle involves a series of oxidation-reduction reactions that take place in the mitochondrial matrix

o the Krebs cycle is a closed loop; the last part of the pathway reforms the molecule used in the first step

o the cycle includes 8 major steps

o 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

o reduced NAD and reduced FAD are high energy coenzyme molecules that act as hydrogen acceptors

o the Krebs cycle goes around twice for each molecule of glucose that enters cellular respiration

1. electron transport chain (ETC) and oxidative phosphorylation:

o the electron transport chain is a series of carriers and pumps found in the inner mitochondrial membranes

o the hydrogen acceptors, reduced NAD and FAD from the Krebs cycle and links reaction transfer their hydrogen atoms to NADH reductase on the ETC, which split them into electrons and hydrogen ions

o in the process, the coenzymes can be reused in other steps of cellular respiration

1. 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, powering 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:**

1. beta-oxidation:

o lipid is used as a respiratory substrate when carbohydrate levels are low; in aerobic respiration, beta-oxidation becomes the first pathway, rather than glycolysis

o lipid is first split into its constituent molecules of glycerol and fatty acids

o the pathway then involves the breakdown of the fatty acids into acetyl-CoA which can enter the Krebs cycle

o the 4 reactions involved in this pathway are repeated until the entire fatty acid chain has been converted into individual acetyl-CoA molecules

**K1.33** **How metabolic pathways are regulated by**

**enzymes and feedback mechanisms:**

1. enzymes both catalyse reactions in metabolic pathways and are key to the regulation of the reactions in the metabolic pathways
2. enzymes are inhibited by certain substances
3. 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
4. examples:

o phosphofructo kinase (PFK) is an important enzyme in glycolysis, it is inhibited by several substrates, including ATP

o 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:**

1. 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
2. genotyping is used to determine the difference or similarities between samples of DNA
3. phenotyping is the process of predicting physical appearance based on genotyping
4. phenotyping is used within forensics to indicate characteristics such as ethnicity, gender, 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):**

1. PCR is the replication of DNA in a test tube
2. a sample of target DNA is heated to its melting point to break the bonds between DNA strands and separate these into single strands
3. the solution is cooled and the enzyme DNA polymerase, nucleotides and primers are added; the process of DNA amplification is initiated
4. further heating takes place and the DNA polymerase catalyses the synthesis of complementary strand for each of the single DNA strands
5. the process is repeated until sufficient DNA is produced to determine genotype

**Ecosystems:**

**K1.36** **The term ecosystem:**

1. biological community (plants, animals and micro-organisms) and the abiotic factors (light, temperature, water, atmosphere,

wind and chemical elements) with which

they react

1. an ecosystem is made up of both living and non-living components

**K1.37** **How the following contribute to an**

**ecosystem:**

1. habitats: the physical site where an organism or group of organisms live
2. populations: group of organisms of the same species
3. community: all the organisms or populations in an ecosystem
4. niche: role and position a species has within an ecosystem

**K1.38** **The following processes within**

**ecosystems:**

1. 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

1. 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

1. 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

1. bioaccumulation:

o gradual accumulation of contaminants within an ecosystem

1. 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:**

1. using sampling techniques: o quadrat

o belted transect

o mark release capture

1. 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:**

1. the scale of the particles
2. exposure limits
3. using specialised equipment (for example, atomic force microscope)
4. appropriately trained personnel

**Electronics:**

**K1.41** **The difference between analogue and digital**

**signals:**

1. analogue signals are continuous
2. digital signals are discrete

**K1.42** **How analogue signals are converted to**

**digital signals so that computers can**

**further interpret them:**

1. 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:**

1. to improve accuracy by reducing the effect of noise and interference

**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):**

1. 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 = MC2.**

**Scientific tasks**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K1.47 When scientific and mathematical skills are** | **S1.74 Follow multistep scientific methods (for** |
| **applied when performing a range of** | **example, make a defined molar** |
| **scientific techniques:** | **concentration and perform a titration) based** |
| • | measuring: | **on relevant SOPs when performing a range** |
| **of practical scientific techniques.** |
|  | o volume using a burette |
|  |  |  |
|  | o mass on a 3-Decimal Place (DP) | **S1.75 Apply a range of science and mathematical** |
|  | **skills when performing practical scientific** |
|  | balance (analytical or top pan balance) |
|  | **techniques:** |
| • | manual dexterity: |
| • |  |
|  | o when using a pipette | measuring: |
|  |  |  |
|  | o performing aseptic technique |  | o with accuracy and precision |
|  |  |  |
|  | o setting up a microscope |  | o avoiding any cumulative errors |
|  | • |  |
| • | observing: | manual dexterity: |
|  |  |
|  | o colour changes at titration end point |  | o using equipment competently and |
|  |  | safely |
|  |  |  |
|  | o microscopic observations |  | o manipulating and manoeuvring |
|  |  |  |
| • | quantifying: |  | equipment and samples effectively |
|  | o cell counts | • | observing: |
|  | o abundance of organisms in an |  | o accurately reading displays and scales |
|  | ecosystem |  | o distinguishing fine changes in |
|  |  |  |
| • | predicting: |  | appearance |
|  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | o melting and boiling points | • | quantifying: |
|  | o possible components of a mixture in |  | o accurately counting and measuring |
|  |  | chromatography |  | o using appropriate units and scaling |
| • |  |  |  |
| analysing: |  | o using appropriate equipment where |
|  |  |  |  |
|  | o | trend charts |  | applicable |
|  | o | calculations | • | predicting: |
|  | o | statistical analysis |  | o using evidence and verifiable scientific |
| • | evaluating: |  | information |
|  |  |
|  | o evaluating the success of the scientific | • | analysing: |
|  |  |  |
|  |  | method |  | o using mathematical processes to |
| **K1.48 The factors to consider when choosing** |  | support technical arguments |
| • |  |
| **between a range of scientific techniques:** | evaluating: |
| • health, safety and ethical considerations |  | o making summary judgements based on |
|  | adequate and appropriate data |
| • equipment availability and cost |  |
|  | (GMC1, GMC8) |
| • substance/sample to be investigated |  |
| **S1.76 Use the following practical scientific** |
| • strengths and limitations of the technique |
| **techniques to measure a range of physical** |
|  |  |  |
| • | objective of the investigation | **properties:** |
| **K1.49 The purpose of:** | • pressure using a U-tube manometer: |
| • | analysing substances and chemical |  | o setting up the manometer vertically |
|  | environments: |  | o opening one tube to the atmosphere or |
|  |  |  |  |
|  | o to confirm composition and/or quantity |  | attaching to gas supply |
|  |  | of materials |  | o measuring the height difference in the |
|  |  |  |  |
| • micro and nano science: |  | u-tube |
|  | o to analyse matter on an atomic, | • temperature using a probe and data |
|  |  | molecular and supramolecular scale |  | logger: |
| **K1.50 Why the following techniques are used:** |  | o attaching the probe to data logger |
| • titration (for example, purity analysis): |  | o inserting the probe into substance to be |
|  | o purity analysis and determining |  | tested |
|  |  | o taking the reading from data logger |
|  |  | concentration |  |
|  |  |  |  |
| • preparation of serial dilutions: | • radioactive count rate using Geiger |
|  | counter: |
|  | o to alter concentrations to enable |  |
|  |  | o measuring the background count rate |
|  |  | analysis |  |
|  |  |  |  |
| **K1.51 When it is appropriate to use the following** |  | o measuring the count rate for a defined |
|  | period of time, using shielding if |
| **techniques to identify/determine, separate** |  |
|  | appropriate |
| **or analyse substances and environments:** |  |
| • conductivity meter to measure conductivity |
| • calorimetry to analyse energy changes in |
|  | of a solution: |
|  | chemical reactions |  | o calibrating the equipment with a |
| • characterisation using mass spectrometry |  |
|  | solution of known conductivity |
|  | to identify compounds and infra-red |  |  |
|  | spectroscopy to identify functional groups |  |  |
|  |  |  |  |  |

1. colorimetry to determine concentration
2. chromatography to separate and therefore identify the components of a mixture
3. distillation to separate the components of a mixture
4. filtration (for example, vacuum and fluted) to separate insoluble components of a mixture
5. electrochemistry to separate and then identify parts of a compound (for example, chlorine gas)
6. thermochemistry to analyse energy changes in chemical or physical transformations

**K1.52 When it is appropriate to use the following laboratory techniques:**

1. tissue culture to grow cells or tissues on a culture medium
2. cloning to generate genetically identical copies of a cell
3. protein purification to isolate specific proteins for further analysis
4. extraction and sequencing of DNA to identify genes
5. microbiology techniques:

o aseptic culturing to analyse biological environments to confirm the presence of microorganisms

o differential staining to identify microorganisms (for example, Gram staining to identify Gram negative or Gram positive)

o 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:**

1. biochemical oxygen demand (BOD) to determine the amount of dissolved oxygen needed by microorganisms in a water sample
2. rinsing the probe with deionised water and then inserting into test solution
	1. rinsing further between subsequent readings including repeats
3. electrical polarity using an ammeter and a voltmeter:
	1. setting up the circuit with ammeter in series or voltmeter in parallel
4. 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:**

1. acid base and redox titration:

o measuring quantity of unknown solution using a pipette

o determining the end point by colour change

o using n = cV to work out concentration

1. preparation of serial dilutions:

o determining the required dilution

o working with proportion by applying the numerical form of proportion to reach target concentration

o measuring accurately and transferring the solution to the subsequent diluent

1. colorimetry:

o selecting the appropriate filter

o zeroing the colorimeter using a cuvette containing the solvent only

o 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:**

1. aseptic culturing:

o manipulating the equipment to limit contamination (for example, when transferring the microorganism culture to growth medium)

|  |  |  |  |
| --- | --- | --- | --- |
|  • chemical oxygen demand (COD) to |  | o | sterilising equipment throughout the |
|  | determine the amount of oxygen needed |  |  | technique (for example, flaming of the |
|  | for complete chemical oxidation in a water |  |  | wire loop) |
|  | sample |  | o | following disinfection procedures upon |
|  |  |  |
| • total organic carbon (TOC) to determine |  |  | completion of the technique |
|  | the total amount of organic carbon in a | • | differential staining techniques: |
|  | sample |
|  |  |  |  |
| • total suspended solids (TSS) to determine |  | o preparing the slide and introducing the |
|  |  | smear, using aseptic technique |
|  | the dry weight of suspended solids from a |  |  |
|  |  |  | fixing the smear (for example, heat fix) |
|  | water sample |  | o |
| • measuring toxicity to determine median |  | o | applying stains and rinses in the |
|  | lethal dose (LD50) and lethal concentration |  |  | correct order |
|  | (LC50) |  | o | examining the smear using a light |
|  |  |  |
| **K1.54 The purpose of laboratory techniques used** |  |  | microscope and identifying if bacteria |
|  |  | are Gram-positive (violet in colour) or |
| **in the science manufacturing environment:** |  |  |
|  |  | Gram-negative (pink in colour) |
|  |  |  |  |
| • | sampling: | **S1.79 Use the following practical scientific** |
|  |  |
|  | o part of the process for quality | **techniques to prepare, isolate and separate** |
|  | assurance of intermediates where a | **materials:** |
|  | representative sample is taken in order |
|  |  |  |  |
|  | to determine any impurities within the | • | paper and thin layer chromatography: |
|  | product |  | o | applying sample onto chromatogram |
| • |  |  |
| testing: |  | o | adding solvent to appropriate level (for |
|  |  |  |
|  | o to identify the presence of |  |  | example, below baseline) |
|  | microbiological organisms (for |  | o | using a location agent, if appropriate |
|  | example, in pharmaceutical products) |  |
|  |  |  | (for example, iodine, UV light and |
|  |  |  |  |
|  | o to determine the stability of products |  |  | ninhydrin) |
|  | and chemicals |  | o | measuring substance from baseline |
|  |  |  |
|  | o to determine the level of an active | • | distillation: |
|  | ingredient (for example, in a |
|  |  |  |  |
|  | pharmaceutical product) |  | o | correctly setting up the equipment (for |
|  | o to determine the levels and identity of |  |  | example, attaching condenser |
|  |  |  | correctly) |
|  | impurities in process starting materials |  |  |
|  |  |  |  |
| • scaling up to pilot plant: |  | o using appropriate heating method for |
|  |  | sample (for example, heating mantle) |
|  | o to determine how increases in scale |  |  |
|  |  | o | reading off boiling point using correctly |
|  | may affect the manufacturing process |  |
|  |  |  | placed thermometer |
|  | (for example, flow rates, reaction times) |  |  |
|  |  |  |  |
| **K1.55 How physics laboratory techniques are** | • filtration (for example, vacuum and fluted): |
|  |  |  |
| **applied in different fields:** |  | o | correctly setting up the equipment (for |
| • electronics to determine input and output |  |  | example, attach aspirator correctly) |
|  | o | choosing and preparing the appropriate |
|  | voltages of logic circuits |  |
|  |  |  | size filter paper (for example, fluting if |
| • mechanics to determine stress |  |  |
|  |  | necessary) |
|  | (force/area) on an object under tension |  | o | adding suspension at appropriate rate |
| • ionising radiation to determine half-value |  |
| • | refluxing: |
|  | layer (HVL) of a substance |
|  |  |  |  |

1. thermal to determine thermal conductivity

|  |  |  |
| --- | --- | --- |
| • electricity to determine the voltage across |  | o correctly setting up the equipment (for |
| and current through a component) |  | example, attaching condenser |
| • magnetism to measure the magnetic flux |  | correctly) |
|  | o using appropriate heating method for |
| density |  |
| **K1.56 The purpose of the following techniques,** |  | sample (for example, heating mantle) |
|  | o adjusting heat and condenser for |
| **particularly those related to genomics:** |  |
|  | appropriate drip rate |
|  |  |
| • nuclear magnetic resonance spectroscopy | **S1.80 Prepare a solution of defined molar** |
| (NMR) (Carbon-13 and proton NMR), used |
| to identify the presence of certain atoms | **concentration, by:** |
| and environments in a sample using | • calculating the relative molecular mass for |
| electromagnetic radiation |
|  | the concentration needed (n = cV) |
|  |  |
| • polymerase chain reaction (PCR), used to | • using a balance and volumetric flask |
| sequence multiple copies of specific |
|  | correctly |
| sequences of new DNA strands, |  |
| • ensuring the transfer of all solid and liquid |
| complementary to a presented template |
| strand |  | without spilling |
| • gel electrophoresis, used to separate DNA | • rinsing equipment into volumetric flask |
| fragments according to their size, also | **S1.81 Use appropriate international system of** |
| used to separate other macromolecules |
| **units (SI) and be able to work with a range** |
| dependent on size and charge |
| • flow cytometry, used in genomics to | **of appropriate scales when conducting** |
| **scientific tasks:** |
| determine genome size, to give an |
|  |  |
| estimate of amount of nuclear content | • length - metre (m) |
|  |
| • next generation sequencing range of | • time - second (s) |
| techniques that allow for sequencing of |
| • |  |
| DNA quickly and cost effectively. These | amount of substance - mole (mol) |
| techniques enable the sequencing of | • electric current - ampere (A) |
| thousands to millions of DNA molecules |
|  |  |
| simultaneously | • | 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 |
|  |  |  |

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**Scientific equipment, instrumentation and use of raw materials and reagents**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K1.57 A range of laboratory equipment used to** | **S1.84 Select appropriate equipment to complete** |
| **identify and separate samples:** | **practical scientific techniques:** |
| • chromatography columns (for example, in | • | measuring cylinders |
|  | column chromatography and gas liquid | • | light microscope |
|  | chromatography (GLC)) |
|  |  |  |
| • | mass spectrometer | • | burette |
|  |  |
| • infra-red spectrometer | • 3 Decimal Place (DP) balance (analytical |
|  | or top pan) |
| • nuclear magnetic resonance spectrometer |  |
| • volumetric, graduated and mechanical |
|  |  |
| **K1.58 The purpose of electrical calorimeters:** |  | (variable volume) pipettes |
| • to measure energy change with minimal | • | meters - ammeters, voltmeters, |
|  | heat loss |  | multimeters |
| **K1.59 A range of laboratory equipment that is** | • | Geiger counter |
| **used to analyse biochemical oxygen** | • | heating apparatus |
| **demand (BOD), chemical oxygen demand** | • | pH meters |
| **(COD) and total organic carbon (TOC)** |
| • | TLC plates |
| **content:** |
|  |  |
| • dissolved oxygen probe (BOD) | • microbiological equipment - (for example, |
|  | incubator) |
| • reflux equipment and calorimeter (COD) |  |
| • data loggers with temperature probe |
| • TOC analysers to measure CO2 from |
| • | fume cupboard |
|  | organic carbon (TOC) |
|  |  |  |
| **K1.60 The purpose of cryogenic equipment in a** | • | autoclave |
| • |  |
| **laboratory environment:** | condenser |
| • to maintain the integrity of biological | **S1.85 Demonstrate practical technical** |
|  | material | **competence in the use of equipment:** |
| **K1.61 The purpose of the following physics** | • | taking accurate measurements |
| **laboratory equipment:** | • correctly manipulating the equipment |
|  |  |
| • oscilloscopes: used to display time-varying | • using equipment safely and for intended |
|  | signals in a graphical form |
|  |  | purpose |
|  |  |  |
| • search coil: used to measure magnetic flux | **S1.86 Calibrate scientific equipment and check it** |
| • capacitors: used as part of a circuit to | **is fit for use:** |
|  | store electrical charge | • | pH meters: |
| • lasers: used to look at wave patterns |
|  | o using buffer solutions |
| • light gates: used to measure |  |
| • | balances: |
|  | speed/acceleration |
|  |  |  |
| • | meters: |  | o using calibration masses |
|  |  |
|  | o ammeters: used to measure current | • mechanical (variable volume) pipette: |
|  |  |  |
|  |  |  |  |

**Scientific equipment, instrumentation and use of raw materials and reagents**

|  |  |
| --- | --- |
| o voltmeters: used to measure potential | o using distilled water and balances |
| difference |  |

1. multimeters: used to measure voltage, current and resistance
	1. Geiger counter: used to detect ionising radiation
2. thermistors: used to change resistance with changing temperature in a circuit, used as temperature sensors
3. light dependant resistors (LDR): used to change resistance with changing light intensity in a circuit, used as light sensors
4. 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:**

1. sources and suppliers (for example, using reputable suppliers to ensure quality)
2. handling and storage (for example, adhering to expiry date to ensure integrity)
3. quality control and assurance of raw materials and reagents (for example, ensuring reagents meet the standards of those previously used, appropriate purity)



**Data collection and recording**

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

 **Legislation, regulations, standards and guidelines**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K1.65 How the following regulations are applied** | **S1.89 Follow SOPs to ensure compliance with** |
| **when performing scientific techniques in a** | **regulations and quality standards when** |
| **laboratory environment:** | **performing scientific techniques.** |

1. 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

1. 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

1. quality management systems (QMS):

o ensures processes and procedures within a laboratory setting are undertaken in specific ways to guarantee the highest level of accuracy and reliability

o 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

o ensures that decisions within a laboratory setting are data-driven

1. good clinical practice (GCP):

o 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:**

1. United Kingdom Accreditation Service (UKAS):

o 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.

o accreditation by UKAS demonstrates the competence, impartiality and performance capability of laboratories

1. ASTM International:

o 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

o laboratories involved in the production or testing of such products or providing specific scientific services are often required to demonstrate compliance with these standards

1. International Organisation for Standardisation (ISO):

o independent, non-governmental international organisation which develops voluntary, consensus-based market relevant international standards to which organisations, including science laboratories, adhere

o 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

1. Pharmacopoeia (British standards):

o provides quality standards for UK pharmaceutical substances and medicinal products

1. Medicines and Healthcare products Regulatory Agency (MHRA):

o government agency which regulates and licenses medicines, medical

**Legislation, regulations, standards and guidelines**

devices and blood components for

transfusion in the UK

* 1. regulates what products are safe and what products are not, to decide which products can enter the marketplace
1. Food and Drug Administration (FDA):
	1. government agency in the United States responsible for regulating medicines, medical devices, food dietary supplements, cosmetics and blood products
	2. 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
2. European Medicines Agency (EMA):
	1. independently evaluates market authorisation applications of medicines for sale or supply within the European Union
	2. works closely with national regulatory agencies such as MHRA in the UK
3. Office for Nuclear Regulation (ONR):
	1. independently regulates nuclear safety and security at licensed sites within the

UK

**K1.67** **The purpose and importance of SOPs within**

**a laboratory environment:**

1. maintaining health and safety by detailing all relevant health and safety requirements (for example, when using hazardous materials)
2. enabling consistency of approach across all technicians
3. meeting any legal or organisational requirements (for example, safe storage of controlled materials)
4. 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 -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K2.1 How the following considerations inform the** | **S2.15 Design a scientific task to address a** |
| **planning of a laboratory task:** | **particular hypothesis, taking into** |
| • customer/client requirements for | **consideration a range of factors:** |
|  |  |
| laboratory analysis (for example, customer | • | the customer/client requirements |
| needs, what objectives need to be | • | laboratory sampling requirements |
| achieved) |
| • laboratory sampling requirements (for | • laboratory health, safety, environmental |
| example, what samples are required, |  | and regulatory requirements (for example, |
| frequency of sampling, quantity of sample) |  | COSHH, REACH) |
| • laboratory health, safety, environmental | • resources required, including laboratory |
| and regulatory requirements (for example, |  | equipment, reagents and consumables |
| identifying risks through a risk | • appropriate scientific methods, equipment |
| assessment) |
|  | and techniques |
|  |  |
| • resources required including laboratory | • | appropriate controls |
| equipment, reagents and consumables |
| • any specific storage requirements |
| (for example, identifying the sources of |
| equipment, reagents and consumables) | • the most appropriate way to present data |
| • scheduling of laboratory testing (for |
| **S2.16 Perform a literature review to extract** |
| example, planning timings and potential |
| **relevant information to support the planning** |
| use of Gantt charts, taking into |
| consideration shared resources) | **of a scientific task by:** |
| • scientific methods (for example, identifying | • assessing the quality and reliability of the |
| the most appropriate methods to meet the |  | information accessed |
| objectives) | • extracting main ideas/key information (for |
| • storage and transportation of samples (for |
|  | example, methods), from appropriate |
| example, correct temperature, correct |  | sections of the paper, relevant to the |
| storage container, temperature monitoring) |  | purpose of the scientific task |
| • presentation of the data (for example, | • | selecting fact from opinion |
| identifying most appropriate way of | • recording relevant information accurately |
| displaying the data, demonstrating |
|  | and concisely |
| whether objectives have been achieved or |  |
|  |  |
| not including statistical significance) |  | (GDC5, GEC4) |
|  |  |
| • the role of others within the laboratory | **S2.17 Apply knowledge of scientific techniques to** |
| environment: |
| **an unfamiliar context when planning a** |
| o limits of job role and the laboratory |
| **scientific task, taking into account:** |
| itself |
|  |  |
| o identifying who would need to be | • appropriate scientific techniques and |
|  | methods |
| involved, roles and responsibilities of |  |
|  |  |
| the laboratory team | • | required scientific equipment, reagents |
|  |  | and consumables |
|  |  |  |

|  |  |
| --- | --- |
| • developing a specific hypothesis, where | • laboratory health, safety, environmental |
| appropriate, for a scientific task: | and regulatory requirements |
| o translating the client objectives into the | **S2.18 Keep sufficient stock levels of all required** |
| hypothesis | **laboratory equipment, reagents and** |
|  |
| o identifying the most appropriate | **consumables for planned scientific tasks** |
| techniques for the scientific task | **by:** |
|  |
| o positive and negative controls: | • assessing stock levels through regular |
|  |
| ▪ identifying the most appropriate | inventory management |
| controls to produce robust data | • ensuring all reagents are labelled and |
|  |
| ▪ identifying adequate control groups | dated correctly |
| or sample groups, if appropriate | • ordering stock as required |
|  |
| **K2.2 How to undertake literature searches and** |  |
| **use scientific papers to plan scientific** |  |
| **tasks, by:** |  |

1. accessing appropriate databases (for example, Pubmed, Merck Index\* Online, National Institute for Health and Care Excellence (NICE), IOPscience)
2. using keywords and Boolean in searches
3. 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:**

1. using accepted sample preparation methods
2. using certified standards to determine accuracy of the method
3. following accepted guidelines and/or requirements (for example, International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) requirements)
4. following the manufacturers’ guidelines for use, where appropriate

**K2.4** **The principles of laboratory equipment**

**validation when planning scientific tasks:**

1. using certified standards to determine accuracy of the equipment
2. checking the equipment is running the up-to-date operating system

1. checking that the equipment is within calibration and service dates (fit for purpose)
2. following the manufacturers’ guidelines for use, where appropriate

**K2.5** **The difference between concrete and**

**abstract modelling techniques:**

1. concrete: a trial task prior to planning
2. abstract: planning on paper or using computer simulations

**Laboratory data processing and analysis**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K2.6 How the following considerations inform** | **S2.19 Complete relevant calculations on data** |
| **data processing and subsequent analysis of** | **obtained in the laboratory environment:** |
| **the results in a laboratory environment:** | • | relative molecular mass |
|  |  |
| • regulatory requirements (for example, | • | concentration |
|  | validation, conformity to known analytical |
|  | • | magnification |
|  | standards) |
| • | relevant calculations (for example, | • | Rf values |
|  | magnification and Rf values) | • | percentages |
| • conversion of units (for example, |
| • | ratios |
|  | consistent use of units across different |
|  |  |  |
|  | data sets) | • number of bacteria in a population using |
| • appropriate statistical techniques to |  | known division time |
|  |  |
|  | determine the validity or significance of the | • | electrical resistance |
|  | results (for example, standard deviation, p | • pressure difference (from u-tube |
|  | value, uncertainty values) |
|  |  | manometer) |
| • customer requirements for the |  |
| • | percentage uncertainty |
|  | presentation of data (for example, graphs) |
|  |  |  |
| • | using complementary experimental | **S2.20 Select appropriate statistical techniques to** |
|  | methodologies from existing peer- | **analyse and interpret results from scientific** |
|  | reviewed studies to confirm results (for | **tasks:** |
|  | example, by the use of online databases) | • | mean |
| • using laboratory control charts and trend |
| • | standard deviation |
|  | charts (for example, to confirm equipment |
|  | and/or protocols are within tolerance) | • Chi-square test |
|  |  |
|  |  | • | T-test |
|  |  |  |  |

**K2.7** **How to establish the validity of results against standards and controls:**

1. by using ongoing calculations to monitor results and identify anomalies
2. calculating Rf values and comparing to known values
3. using certified reference material (CRMs)

**K2.8** **The purpose of data processing and analysis in supporting improvements to laboratory techniques:**

1. stability studies: to determine the most appropriate storage for preservation of reagents and consumables
2. laboratory trend charts: to determine that laboratory equipment is working within specification (for example, colony-forming unit (CFU) data)
3. laboratory method validation results: revalidating methods if results are outside of specification
4. proficiency testing (inter-laboratory comparison): to determine the accuracy and reliability of a laboratory’s test results against results obtained by a certified laboratory

(GDC4)

**S2.21 Process results, using statistical software, for the following statistical techniques:**

1. standard deviation
2. Chi-square test
3. T-test

**S2.22 Use the results of calculations and statistical analysis to interpret and evaluate data from scientific tasks to:**

1. determine trends
2. assess statistical validity
3. support technical arguments
4. draw conclusions
5. communicate effectively to a range of stakeholders

(GDC4, GMC8)

**S2.23** **Present data in an appropriate format:**

1. using appropriate statistical techniques, including the use of data from laboratory information management systems (LIMS)
2. in a clear and unambiguous way, taking into account the level and experience of the audience and the purpose
3. using technical language correctly, and using graphics and other tools to aid understanding
4. 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

1. 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)

• 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 -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K2.9 The importance of using laboratory-** | **S2.28 Review and modify a scientific method to** |
| **reviewing strategies:** | **improve the task:** |
| • to identify possible problems and | • ensuring correct order of steps for |
|  | recommend improvements with laboratory | efficiency and effectiveness (for example, |
|  | methods, tasks and use of equipment | substances are at the correct temperature |
| **K2.10 Why laboratory documents are created,** | at the required stage) |
| • equipment in terms of precision and |
| **reviewed and approved:** |
| accuracy (for example, measuring cylinder |
| • to ensure consistency and quality |
| versus burette) |
| • to follow regulatory requirements (for | • ensuring the techniques used are efficient |
|  | example, good laboratory practice (GLP) | and effective |
| **K2.11 How laboratory documents can be amended** | **S2.29 Implement changes to a scientific task** |
| **to implement improvements both to** | **through the adoption of a continuous** |
| **methods and equipment use, by:** | **improvement cycle:** |
| • proposing amendments to working | • identify the issue, organise ideas and |
|  | instructions/procedure | information logically (for example, faulty |
| • gaining approval for changes and | equipment/reagents) |
| • plan and record required improvements, |
|  | amendments |
| • | validating amendments | using digital tools and other aids |
| • implement the improvements |
| • adopting amendments and editing |
| • check the effectiveness of the |
|  | associated documentation |
| • | monitoring the process/results | improvements by responding to |
| questions/feedback from colleagues |
|  |  |
| **K2.12 The purpose of computer modelling and** | • review improvements and adjust, if |
| **simulation in the laboratory environment:** |
| required |
| • to identify the possible effects of modelling | (GEC2) |
|  | changes to complex procedures before |  |
|  | implementing them |  |

1. 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:**

1. determining the feasibility of methods and available equipment for own laboratory (receiving laboratory)
2. setting the scope and objectives of the transfer
3. acquiring samples or standards from the transferring laboratory
4. training of laboratory staff at the receiving laboratory
5. validating results from both laboratories
6. adopting the alternative method within the laboratory

**K2.14** **The importance of quality control in the**

**laboratory environment:**

1. to determine appropriate performance of laboratory equipment
2. to ensure methods are producing consistent results

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

**Equipment management**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K3.1 The principles of maintaining, cleaning,** | **S3.7 Resolve issues with a range of scientific** |
| **calibrating and validating laboratory** | **equipment:** |
| **equipment used to undertake scientific** | • ensuring equipment is in working order and |
| **techniques commonly found in a** |
| free from dirt or contamination |
| **laboratory environment:** | • recalibrating equipment according to |
|  |
| • interpreting manufacturers’ instructions | manufacturers’ instructions and standard |
| • employing the correct test equipment | operating procedures (SOPs) |
| • resetting, following manufacturers’ |
| • following appropriate SOPs for cleaning |
| instructions and SOPS |
| and maintenance |
|  |
| • using appropriate cleaning materials | **S3.8 Carry out and record routine cleaning and** |
| **maintenance of equipment:** |
| • maintaining cleaning and equipment |
| • following appropriate SOPs for cleaning |
| records |
| and maintenance (for example, |
| • notifying issues with equipment to other |
| maintenance schedule) |
| users and sourcing expert help when | • using appropriate cleaning materials before |
| required |
| use (for example, rinsing burette with |
| • safely disposing of equipment that cannot |
| deionised water) |
| be repaired | • using appropriate cleaning materials after |
|  |
|  | use |
|  |  |

**Equipment management**

**K3.2** **The importance of recognising equipment faults/technical issues in laboratory equipment used to undertake scientific techniques commonly found in a laboratory environment:**

1. the potential impact on laboratory results
2. potential health and safety risks
3. financial impact (for example, lost time, equipment needs to be replaced)
4. impact on other users’ ability to use the equipment
5. using relevant technology effectively (for example, on LIMS)

(GDC1)

**S3.9** **Recognise when a piece of equipment is producing inaccurate data by:**

1. identifying anomalous results from repeated measurements
2. the use of appropriate controls

**S3.10** **Recognise when equipment is likely to be damaged or cause injury due to malfunction:**

1. inability of the equipment to be zeroed
2. fails calibration check
3. visual checks of the equipment (for example, exposed wires)
4. by the use of appropriate controls
5. through anomalous results of repeated measurements

**S3.11** **Report faults and source expert help when required, by:**

1. following escalation process
2. 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)

1. accurately describing the issue: o summing up key points

o expressing opinions and supporting these with relevant and persuasive arguments

o asking and responding to questions for clarifications

(GDC3, GEC6)

 **Laboratory data errors**

|  |  |
| --- | --- |
| **Knowledge -**  | **Skills -**  |
|  |  |
|   | The student must be able to: |
| **K3.3 The factors that can contribute to data** | **S3.12 Identify how data errors could have** |
| **errors (random or systematic) in a** | **occurred in scientific tasks:** |
| **laboratory:** | • contamination of samples or equipment |
|  |  |
| • contamination of samples or equipment | • | incorrect sample storage |
|  |  |
| • incorrect sample storage (for example, | • equipment working outside acceptable |
|  | temperature) |
|  |  | tolerances |
|  |  |  |
| • working outside acceptable tolerances | • incorrect laboratory equipment used (for |
|  |  |
| • incorrect laboratory equipment used (for |  | example, using the wrong sized pipette) |
|  | example, using the wrong sized pipette) | • equipment incorrectly used or set up |
|  |  |
| • inadequate training (for example, use of | • method not followed (for example, |
|  | the equipment or procedure) |
|  |  | standard operating procedure not |
|  |  |  |
| • equipment incorrectly set up, calibrated, or |  | followed) |
|  | used | • | transcription errors |
|  |  |
| • method not followed (for example, | **S3.13 Identify when a random or systematic error** |
|  | standard operating procedure not |
|  | **has occurred in scientific tasks:** |
|  | followed) |
|  |  |  |
| • | transcription errors | • gathering and interpreting data efficiently |
| **K3.4 How to minimise errors in scientific tasks,** |  | and in an appropriate format (for example, |
|  | chart or graph) |
| **by:** |  | • comparing results against previous data |
|  |  |
| • reading and following the risk assessment |  | (GDC4) |
|  | and COSHH sheets |  |
|  |  |  |
| • planning the work and workplace | **S3.14 Address non-routine problems with** |
| **samples and instrumentation in a scientific** |
|  | requirements |
| • following a validated method | **task:** |
|  |  |
| • maintaining excellent housekeeping (for | • | identify the error |
|  |  |
|  | example, ensuring samples do not | • quantify the error to determine if this is |
|  | become contaminated) |  | within accepted tolerance |
| • ensuring equipment is calibrated, set up | • remove or minimise the sources of error |
|  | and used correctly | • record the source of error and the action |
| • only undertaking scientific tasks following |
|  | taken |
|  | adequate training |  | (GMC2) |
| • storing and labelling samples and |  |
| **S3.15 Take steps to minimise errors in scientific** |
|  | standards correctly |
| • working safely in a laboratory setting (for | **tasks following continuous improvement** |
| **techniques:** |
|  | example, safely disposing of materials) |
| **K3.5 The principles of good documentation** | • | plan: |
| **practice (GDocP) to prevent data errors:** |  | o planning the work and workplace |
| • | creation: |  | requirements |
|  |  |
|  |  |  |  |

 Recording information as the work is performed

* 1. handwritten entries are in indelible ink and are legible and in full
1. approval:
	1. signed and dated by authorised personnel
2. document maintenance:
	1. regularly reviewed and kept current
	2. ensuring electronic records are backed up
3. document modification:
	1. signed and dated by authorised personnel
4. ensuring access to documents is controlled

**K3.6** **How to report and correct recording errors:**

1. crossing out the error so it is still visible and entering new value
2. signing and dating correction
3. reattaching sheets that have become loose with sticky tape and ensuring the edges have been signed
4. implementing tracked changes on electronic databases
5. giving reasons why the correction has been made
6. following laboratory protocols for error reporting
	1. reading the risk assessment and COSHH sheets
7. do:
	1. following the risk assessment and COSHH sheets
8. following a validated method
9. maintaining excellent housekeeping (for example, ensuring samples do not become contaminated)
10. only undertaking scientific tasks following adequate training
	1. working safely in a laboratory setting (for example, safely disposing of materials)
11. check:
	1. checking equipment is calibrated, set up and used correctly
12. checking that storage and labelling of samples and standards is correct
	1. continuously monitor data and ensuring procedures are carried out correctly
13. act:
	1. implementing changes to equipment or method
14. repeating any measurements as required