Cambridge Assessment
Admissions Testing

BIOMEDICAL ADMISSIONS TEST (BMAT)
TEST SPECIFICATION

2018

BioMedical Admissions Test (BMAT) test specification

Purpose of the test

The purpose of the BioMedical Admissions Test is solely to provide an assessment of candidates' potential in an academically demanding undergraduate biomedical degree, and not their fitness to practise medicine or dentistry – which universities will continue to assess in other ways. The test results are intended to be used as a significant component of the selection decision in conjunction with other information available to admissions tutors. Test items draw upon generic academic skills and basic science knowledge, rather than recent specialist teaching, and provide an objective basis for comparing candidates from different backgrounds, including mature applicants and those from different countries. The test is designed to be challenging, in order to discriminate effectively between able applicants for university courses, including those who may have achieved the highest possible grades in school examinations.

Qualities to be assessed

Knowledge

Familiarity with concepts, terms and propositional knowledge typically covered by non-specialist secondary school courses in Science and Mathematics.

Skills

Handling of number and communication, specifically:

- ability to read formal English and follow written instructions;
- ability to work quickly and accurately;
- ability to perform very simple mental arithmetic;
- ability to identify the straightforward meaning of particular phrases within a longer text;
- ability to extract the meaning intended by an author, where to do so requires more than one syntactical element of the text to be understood and synthesised;
- ability to read simple quantitative data presented numerically or graphically and to understand their straightforward meaning and to be able to produce simple and appropriate graphs or diagrams of quantitative data;
- ability to generalise from quantitative data, for example to interpret a trend, a pattern, or a rate and to be able to apply the generalisation to the particular or hypothetical context;
- ability to make logical inferences or deductions from textual information and quantitative data and to identify illogical inferences;
- ability to communicate knowledge, understanding, interpretation, inferences, arguments, deductions and predictions by the appropriate use of clear and concise written English and diagrams;
- a tendency to take approaches that are critical, evidence-based, and which consider alternatives.

Structure of the test

The test has three elements: a 60-minute test of Aptitude and Skills, a 30-minute test of Scientific Knowledge and Applications and a 30-minute Writing Task. The structure of each of these three elements is outlined below. Example test papers are available at www.admissionstesting.org/bmat-preparation

1: Aptitude and Skills

This element tests generic skills often utilised in undergraduate study. The range of these and the approximate balance between them in terms of the time and number of marks which will be available is outlined below. Questions will be in multiple-choice format. Calculators may not be used.	Minutes	Number of questions
Problem Solving demands insight to determine how to encode and process numerical information so as to solve problems, using simple numerical and algebraic operations. Problem solving will require the capacity to: • select relevant information • recognise analogous cases • determine and apply appropriate procedures	30 (approx)	13 3–7 3–7 3–7
Understanding Argument presents a series of logical arguments and requires respondents to: • identify reasons, assumptions and conclusions • detect flaws • draw conclusions	15 (approx)	10 2–4 2–4 2–4
Data Analysis & Inference demands the use of information skills (vocabulary, comprehension, basic descriptive statistics and graphical tools), data interpretation, analysis and scientific inference and deduction to reach appropriate conclusions from information provided in different forms, namely: • textual • statistical • graphical	15 (approx)	12 3–5 3–5 3–5
Total	60	35

2: Scientific Knowledge and Applications

This element tests whether candidates have the core knowledge and the capacity to apply it, which is a pre-requisite for high-level study in biomedical sciences. Questions will be restricted to material typically included in non-specialist school Science and Mathematics courses. They will however require a level of understanding appropriate for such an able target group. The balance between the subject areas in terms of time and marks available is outlined below. Questions will be in multiple-choice format. Calculators may not be used.	Minutes	Number of questions
Biology	8 (approx)	6–8
Chemistry	8 (approx)	6–8
Physics	8 (approx)	6–8
Mathematics	6 (approx)	5–7
Total	30	27

For the Section 2 content specification, see page 4 of this document – Appendix BMAT Section 2: Assumed Subject Knowledge.

3: Writing Task

	Minutes
A selection of tasks will be available, from which one must be chosen. These will include brief questions based on topics of general, medical or scientific interest. Questions will provide a short proposition and may require candidates to: • explain or discuss the proposition's implications; • suggest a counter proposition or argument; • suggest a (method for) resolution. The Writing Task provides an opportunity for candidates to demonstrate the capacity to consider different aspects of a proposition, and to communicate them effectively in writing. Skills to be assessed include those concerning communication, described above. All specified skills may be assessed. The question paper will brief candidates about the nature and purpose of the task. They will be required to produce a written communication, without the assistance of a dictionary or automated spelling and grammar-checking software. Whilst they may make preliminary notes, the final product is strictly limited to one A4 page, to promote the disciplined selection and organisation of ideas, together with their concise, accurate and effective expression. When scoring responses, consideration will be given to the degree to which candidates have: addressed the question in the way demanded; organised their thoughts clearly; expressed themselves using concise, compelling and correct English; used their general knowledge and opinions appropriately. Admitting institutions will be provided with a copy of the applicant's response.	30

Scoring and reporting

For both Aptitude and Skills (Section 1) and Scientific Knowledge and Applications (Section 2), scores will be reported (to one decimal place) on a 9-point BMAT scale.

The Writing Task will be scored by Cambridge Assessment Admissions Testing. Scores are reported for the quality of content on a scale from 1 to 5, and for the quality of English on a scale from A to E. An image of the response will be supplied to each institution to which the candidate has applied. In addition to scores, the task provides the institution with a basis for qualitative assessments of writing skills.

Test format

There will be separate question papers for each of Sections 1, 2 and 3.

With the exception of the Writing Task (Section 3), all questions will be in multiple-choice format. All multiple-choice questions will be worth one mark. For Sections 1 and 2, answer sheets are scanned and verified, followed by automated marking, psychometric analysis, test calibration and the issue of results.

Appendix
BMAT Section 2: Assumed Subject Knowledge

Overview

Science, despite the way it is taught in the 21st century, is not confined to the rigid subject areas of Chemistry, Physics and Biology. Developments across science often require a sound grasp of Mathematics.

In the development of the modern Periodic Table, many major figures were physicists, e.g. J.J. Thomson (discovering the electron and identifying isotopes), Niels Bohr (the model of the atom and quantum theory), Werner Heisenberg (quantum mechanics) and Max Planck (quantum theory). Without their contributions to the theory of atomic structure, the Periodic Table would not have the structure it has now.

Modern analytical techniques such as X-ray crystallography, used to identify the double-helix structure of DNA by Francis Crick and James Watson, span all three disciplines. The crossover of research work and disciplines is seen in Biology (Biochemistry and Genetics), Astrophysics and Astronomy.

Examples of this changing multi-disciplinary approach to scientific knowledge and research are many.

Computers are driven by mathematical programming and understanding of Physics in the development of software, and in hardware through advances in technology and the development of new materials by chemists and physicists, e.g. nano-technology. The applications of computers both in the practice and advancement of medical diagnosis and treatment are immense. Medical and veterinary sciences use all three disciplines and their applications along with modern analytical and technological techniques.

The development of science is a vast and separate subject, usually called ‘History and Philosophy of Science’.

This overview is intended purely to give BMAT candidates an opportunity to reflect on the nature of science and the contribution it makes to our understanding of the world.

Content specification

The material that follows outlines the scientific and mathematical knowledge that BMAT Section 2 questions can draw upon. Throughout this specification, it should be assumed that, where mention is made of a particular quantity, knowledge of the SI unit of that quantity is also expected (including the relationship of the unit to other SI units through the equations linking their quantities). Candidates will be expected to be familiar with the SI prefixes milli-, centi-, deci- and kilo- when used in connection with any SI unit.

Biology

1. Cells

1.1 Describe the structure and function of animal cells to include:

a. cell membrane
b. cytoplasm
c. nucleus
d. mitochondrion.

1.2 Describe the structure and function of plant cells to include:

a. cell membrane
b. cytoplasm
c. nucleus
d. cell wall
e. chloroplast
f. mitochondrion
g. vacuole.

1.3 Describe the structure and function of a bacterial cell to include:

a. cell membrane
b. cytoplasm
c. cell wall
d. chromosomal DNA/no 'true' nucleus.

1.4 Know the levels of organisation as: cells to tissues to organs.

2. Movement across membranes

2.1. Know the definition of and examples of diffusion, osmosis and active transport.

3. Cell division and sex determination

3.1 Mitosis:

a. define as cell division that produces two daughter cells that have the same number of chromosomes so are genetically identical
b. recall the role of mitosis in growth and repair, plus replacement.

3.2 Meiosis:

a. define as cell division that produces four daughter cells, known as gametes, which have a single set of chromosomes (are haploid), each with different combinations of parent cells' DNA
b. recall the role of meiosis in reducing the chromosome number so that the full chromosome complement is restored at fertilisation.

3.3 Asexual and sexual reproduction:

a. understand that asexual reproduction involves one parent and that offspring are genetically identical
b. recall that asexual reproduction produces clones
c. understand that sexual reproduction involves two parents and that offspring are genetically different, leading to (increased) variation.

3.4 Sex determination:

a. recall that, in most mammals, females are XX and males are XY
b. be able to establish the gender of offspring
c. work out gender ratio.

4. Inheritance

4.1 Recall the nucleus as a site of genetic material/chromosomes/genes in plant and animal cells.

4.2 Describe and understand the following genetic terms:

a. genes
b. alleles
c. dominant
d. recessive
e. heterozygous
f. homozygous
g. phenotype
h. genotype.

4.3 Monohybrid crosses:

a. use and interpret genetic diagrams to depict monohybrid crosses
b. use family pedigrees/family trees
c. express outcome as ratio, numbers or percentage
d. understand the concept of inherited disease and the use of screening to identify it, e.g. cystic fibrosis, polydactyly, Huntington's Disease.

5. DNA

5.1 Understand that chromosomes contain DNA.

5.2 Describe the structure of DNA.

5.3 Protein synthesis:

a. understand that genes carry the code for proteins
b. understand that the genetic code is 'read' as triplets and each triplet codes for an amino acid
c. understand that protein synthesis involves the production of proteins from amino acids.

5.4 Gene mutations:

a. appreciate that a change in the gene/DNA is a gene mutation.

6. Gene technologies

6.1 Genetic modification/genetic engineering:

a. understand the process of genetic modification to include:
    i. taking a copy of a gene from (DNA/chromosomes of) one organism
    ii. insertion of that gene into the DNA of another organism
b. recall examples of genetic modification in different cell types.

6.2 Stem cells:

a. understand that embryonic stem cells can give rise to any cell type
b. understand that cells lose this ability as an animal matures
c. recall that there are embryonic and adult stem cells.

7. Variation

7.1 Natural selection and evolution:

a. understand the sequence as:
(1) variation (2) leads to differential survival (3) as those best adapted survive; (4) these can reproduce and (5) pass on genes/alleles/characteristics to the next generation.

b. recall antibiotic-resistance/MRSA as an example of evolution through natural selection.

7.2 Sources of variation:

a. recall that variation can be genetic/inherited

b. recall that variation can be environmental.

7.3 Extinction:

a. understand that extinction can occur if organisms cannot adapt quickly enough.

8. Enzymes

8.1 Biological catalysts:

a. recall that enzymes are biological catalysts

b. understand the meaning of the term *biological catalyst*.

8.2 Understand the mechanism of enzyme action.

8.3 Understand the factors affecting enzyme action, such as:

a. temperature

b. pH.

8.4 Digestive enzymes:

a. know the role of amylase, protease and lipase in digestion.

9. Animal physiology

9.1 Respiration:

a. define respiration

b. describe aerobic respiration

c. recall the word equation for aerobic respiration

d. describe anaerobic respiration in animals

e. recall the word equation for anaerobic respiration in animals

f. compare aerobic respiration with anaerobic respiration in animals.

9.2 Organ systems:

a. recall that the central nervous system comprises the brain and spinal cord; describe the structure and function of sensory neurons, relay neurons, motor neurons, synapses and the reflex arc; describe the effect of drugs on synapses

b. recall the structure and function of the respiratory (breathing) system, including the structure of the thorax, and the processes of ventilation and gas exchange

c. recall the structure and function of the circulatory system, including the heart (and the presence and role of the SAN and AVN), heart rate and ECGs, the blood vessels (arteries, veins and capillaries) and the blood, including blood groups

d. recall the structure and function of the digestive system, including the processes of digestion and absorption

e. recall the structure and function of the kidney and the nephron, and the role of the kidneys in homeostasis.

9.3 Homeostasis:

a. recall that homeostasis is the maintenance of a constant internal environment, and understand the concept of negative feedback
b. recall the regulation of blood glucose, water content and temperature as examples.

9.4 Hormones:

a. recall that hormones travel in the blood to their target organs.

9.5 Disease and body defence:

a. describe the functions of white blood cells as producing antibodies and engulfing/ingesting pathogens (names of the cells do **not** need to be known).

10. Environment

10.1 Food chains:

a. understand the flow of energy in a food chain
b. understand that the energy flow limits the length of a food chain
c. understand the pyramid of biomass.

10.2 Organism interactions:

a. appreciate that organisms interact.

10.3 Population size:

a. appreciate that a population can change in size.

10.4 Cycles:

a. recall the carbon cycle to include the following processes:
    i. photosynthesis
    ii. respiration
    iii. combustion
    iv. decomposition
b. recall the nitrogen cycle, to include the following:
    i. bacteria are involved
    ii. process of nitrification
    iii. process of decomposition
    iv. nitrogen fixation
    v. denitrification.

Chemistry

1. Atomic structure

1.1 Describe the structure of the atom as a central nucleus (containing protons and neutrons) surrounded by electrons moving in shells/energy levels/orbits.

1.2 Know the relative masses and charges of protons, neutrons and electrons and recognise that most of the mass of an atom is in the nucleus.

1.3 Know that atomic number = number of protons.

1.4 Know that mass number = number of protons + number of neutrons.

1.5 Understand that in an atom the number of protons = the number of electrons so that atoms have no overall charge.

1.6 Use the standard notation (e.g. $^{12}_{6}C$) for any atom to calculate the number of protons, neutrons and electrons in an atom (and so any ion of the atom).

1.7 Use the atomic number to write the electronic configurations of the first 20 elements in the Periodic Table (H to Ca) in the comma-separated format (e.g. 2,8,8,1 for a potassium atom).

1.8 Define isotopes as atoms of an element with the same number of protons but different numbers of neutrons (so having different mass numbers). Use data to identify the relative abundances of isotopes.

1.9 Know and use the concept of relative atomic mass, A_r.

1.10 Use A_r values to calculate the relative molecular (formula) mass, M_r, of a compound.

1.11 Understand that chemical composition can be identified from spectra.

1.12 Understand the role of a mass spectrometer in identifying isotopes and the structure of molecules.

2. The Periodic Table (IUPAC)

2.1 Know that Periods are horizontal rows and Groups are vertical columns.

2.2 Recall the position of metals and non-metals in the table.

2.3 Understand the use of displacement reactions in establishing the order of reactivity of metals.

2.4 Explain how the uses of metals are related to their physical and chemical properties, e.g. Al, Fe, Cu, Ag, Au, Ti.

2.5 Know that most metal ores are the oxides of the metal, and that the extraction of metals always involves reduction processes.

2.6 Know the position of the alkali metals (Group 1), the halogens (Group 17), the noble gases (Group 18), and the transition metals (*d*-block elements).

2.7 Know and use the relationship between the position of an atom in the Periodic Table (Group and Period) and the electronic configuration of the atom.

2.8 Know that the elements are arranged in the order of increasing atomic number.

2.9 Understand that elements in the same Group have similar chemical properties and that down a metal Group, reactivity increases and down a non-metal Group, reactivity decreases.

2.10 Know the physical and chemical properties of the alkali metals (Group 1), the halogens (Group 17) and the noble gases (Group 18).

2.11 Know the position in the Periodic Table of the transition metals (*d*-block elements) and their common properties (coloured ions, multiple stable ions, use as catalysts).

2.12 Demonstrate an understanding that elements with relative atomic masses that are not whole numbers (e.g. Cl) have isotopes that are responsible for this fact.

2.13 Calculate the relative atomic mass of an element from its isotopes given their relative isotopic masses and their relative abundances.

3. Chemical reactions and equations

3.1 Know and understand each of the following:

a. in a chemical reaction, new substances are formed by the rearrangement of atoms but no atoms are destroyed or created; energy may be absorbed or released by the reaction

b. a chemical reaction can be described using a word equation

c. the → symbol is used to show a reaction where all the reactant can be converted into products (when the correct reacting amounts are used)

d. formulae for a compound can be written from:

i. the names of many covalent compounds, e.g. SO_3 as sulfur trioxide

ii. recall of the names of some common compounds, e.g. H_2SO_4 as sulfuric acid

iii. the ionic charges for ionically bonded compounds. Cations (positive ions) for metal elements can be found from their Group number in the Periodic Table, as can the anions (negative ions) of non-metal ions. The charges of polyatomic anions need to be learned, e.g. CO_3^{2-} and OH^-. Where a cation can have more than one charge, e.g. Cu, Fe, then Roman numerals are used, e.g. iron(III) chloride as $FeCl_3$

e. word equations can be turned into balanced chemical equations using the formulae of compounds and the symbols of elements; state symbols for each species in a chemical reaction can be added to a fully balanced chemical equation (s, l, g, aq)

f. how to write balanced ionic equations either from a balanced chemical equation or to represent the processes, for example in electrolysis and redox

g. in some chemical reactions, all the reactants never turn into all the products; these equations use the symbol ⇌ and are called reversible

h. factors that can affect the position of the equilibrium and the rate at which the equilibrium is achieved (reactants, products, catalysts, temperature, pressure).

4. Quantitative Chemistry

4.1 Know that 1 mole of a substance is the A_r or M_r in grams and perform conversions of grams to moles and vice versa (including working in tonnes and kilograms). Amount (of a substance) = number of moles (of a substance).

4.2 When given the molar volume of a gas (1 mole of any gas occupies 24 dm^3 at rtp and 22.4 dm^3 at stp), calculate mass or moles to volume and vice versa.

4.3 Calculate the percentage composition by mass of a compound given A_r values.

4.4 Find the empirical formula of a compound given the percentage composition by mass of the elements present and the A_r values. Find the molecular formula from the empirical formula if given the M_r value.

4.5 Use balanced chemical equations to calculate the masses of reactants and products. Then perform scaling from the reacting ratio in the equation to find any reactant that may be in excess or amounts of reactants that completely react with each other (limiting reactants).

4.6 For balanced chemical equations involving only gases, be able to arrive at the mole ratio of reacting volumes of gases (or vice versa) or the ratio for the balanced equation as a whole.

4.7 Solutions:

a. understand that concentration can be measured in dm^{-3} or mol dm^{-3} and be able to calculate the concentration given the moles (or grams) and the volume of solvent by using the equation: $$\text{number of moles} = \frac{\text{volume cm}^{-3}}{1000} \times \text{concentration mol dm}^{-3}$$ (or any of the other variations of this equation); find any of the three quantities in the equation if given two of the others.

b. use the concentrations of solutions (or find the concentrations from given data) and the reacting ratio of reactants from the balanced equation to perform titration calculations.

4.8 Know the term *saturated*, and be able to calculate solubility.

4.9 Calculate the percentage yield of a reaction using the balanced chemical equation and the equation: $$\text{percentage yield} = \frac{\text{actual yield (g)}}{\text{predicted yield (g)}} \times 100$$

4.10 Be able to give logical reasons why, in practical situations, the percentage yield is rarely 100%.

5. Oxidation, reduction and redox

5.1 Know that on a basic level, oxidation is the gain of oxygen or the removal of hydrogen and that reduction is the removal of oxygen or the addition of hydrogen.

5.2 Identify any reaction as being oxidation only, reduction only, redox (both oxidation and reduction taking place) or no change in oxidation/reduction.

5.3 Understand the concept of disproportionation and recognise reactions (species) where this occurs.

5.4 Link oxidation and reduction to the transfer of electrons, i.e. reduction as a gain of electrons and oxidation as a loss of electrons.

5.5 Know how to determine the oxidation state of atoms in elements and simple compounds.

6. Chemical bonding, structure and properties

6.1 Know definitions of elements and of compounds, and the distinction between them.

6.2 Understand that the reason atoms react to form compounds is to attain the electronic configuration of a noble gas (the most stable configuration in the Periodic Table). Understand that the type of bonding taking place depends on the atoms involved in the reaction:

a. understand the characteristics of ionic, covalent (simple and giant) and metallic bonding, and recognise examples of each
b. understand the structure and properties of ionically, covalently (simple and giant) and metallically bonded structures.

7. Group Chemistry

7.1 Group 1 (alkali metals):

a. recognise that Group 1 metals are highly reactive, and define metals as electron donors producing cations
b. describe their physical properties as being soft and having, for metals, relatively low melting and boiling points
c. explain the need for storing under oil (reaction with moist air)
d. know that reactivity increases down Group 1
e. describe what is observed when the metals react with:
    i. water
    ii. oxygen
    iii. Group 17 (halogens).

For the above reactions, write balanced chemical equations (including state symbols).

7.2 Group 17 (halogens):

a. recognise that the halogens are the most reactive non-metals (defining non-metals as acceptors of electrons so forming anions)
b. know that reactivity decreases down the group
c. explain what is meant by a displacement reaction (in terms of reactivity competition) and how the reactions between halogens and other halide ions can be used to establish the order of reactivity; be able to write ionic equations for these reactions (including state symbols)
d. describe the tests for chloride, bromide and iodide ions using silver nitrate solution.

7.3 Group 18 (noble gases):

a. describe noble gases as the least reactive of the elements in the Periodic Table, and relate this to their electronic configurations.

7.4 Transition metals (*d*-block elements):

a. identify the position of the *d*-block elements in the Periodic Table
b. describe transition metals as having the following properties:
    i. form different stable ions in different conditions
    ii. form coloured compounds
    iii. are used as catalysts (as ions or atoms).

8. Separation techniques

8.1 Know that chemical procedures are capable of separating:

a. compounds (by chemical reactions, e.g. displacement or electrolysis)

b. mixtures (defined as substances that may be mixed together but not chemically joined).

8.2 Know that mixtures include:

a. i. **miscible** liquids which can be separated by fractional distillation (because of the differences in boiling points), or for non-volatile liquids, paper chromatography (including use of R_f values)
ii. **immiscible** liquids which can be separated using a separating funnel (the layers can be removed one at a time)

b. soluble solids mixed with insoluble solids (using dissolving, filtering, evaporation or distillation and crystallisation).

9. Acids, bases and salts

9.1 Know the definitions, properties and reactions of strong and weak acids and bases (including acid categorisations, such as strong, weak, and mono-, di-, tri-, poly-protic/basic).

10. Rates of reaction

10.1 Describe the qualitative effects on a rate of reaction of concentration, temperature, particle size, catalyst and, for gases, pressure.

10.2 Know that the rate of reaction can be found by measuring the loss of a reactant or gain of a product measured over time.

10.3 Given the balanced chemical equation (including state symbols), be able to identify which reactant decrease or product increase can be measured, e.g. loss in mass, production of a gas, electrical conductivity or thermal conductivity. Describe practical procedures to measure such changes.

10.4 Interpret data in graphical form about the rate of a reaction.

10.5 Use collision theory to explain that for a reaction to occur, particles must come into contact and not every collision causes a reaction. Explain that particles must have sufficient energy when they collide to produce change, and that this energy is called the activation energy (E_a).

10.6 Explain, using collision theory, the effect on reaction rate of changing temperature, changing surface area, changing concentration, and changing pressure (for gases).

10.7 Catalysts:

a. know that a catalyst is a substance which alters the rate of a reaction without being used up/consumed by the reaction

b. recognise that (positive) catalysts increase the rate of a reaction by providing an alternative route/reaction mechanism that has a lower activation energy

c. recognise that catalysts are chemically unchanged at the end of a reaction and are not used up in the reaction (although there may be some physical changes, e.g. lumps to powder).

11. Energetics

11.1 Understand the concepts of exothermic (ΔH –ve values) and endothermic (ΔH +ve values) reactions, their energy level profiles and the effect of catalysts on the profiles.

12. Electrolysis

12.1 Be able to explain the terms *electrode*, *cathode (negative electrode)*, *anode (positive electrode)* and *electrolyte*.

12.2 Explain why dc is used in electrolysis and not ac.

12.3 Recognise that in electrolysis at the cathode, the cations receive electrons (reduction) to change into atoms or molecules and at the anode, the anions lose electrons to form atoms or molecules (oxidation).

12.4 Be able to outline the electrolysis of the following:

a. brine (sodium chloride solution) including the concept of preferential discharge of ions
b. electroplating using copper (copper sulfate).

For each of the above processes, write half-equations for the processes taking place at each electrode.

13. Carbon/Organic Chemistry

Candidates should know the IUPAC guidelines for the systematic naming of carbon compounds and apply the guidelines to be able to name all the compounds in this section of the specification.

13.1 Hydrocarbons:

a. Alkanes:
   i. describe alkanes as being members of the same homologous series with the same general formula of C_nH_{2n+2}
   ii. know that the term *saturated* is applied to alkanes because they only have single carbon-to-carbon bonds
   iii. know that alkanes are chemically unreactive because of the stability of the C–C and C–H bonds
   iv. know the IUPAC names of the straight chain alkanes from C_1 to C_6 and be able to write their condensed formulae and their displayed structures
   v. know that hydrocarbons burn in a plentiful supply of oxygen to produce only CO_2 and H_2O and be able to write balanced chemical equations for these combustion processes

b. Alkenes:
   i. describe alkenes as a homologous series with the general formula C_nH_{2n}
   ii. know that alkenes contain a C=C double bond that makes them more reactive than alkanes
   iii. know the IUPAC names of the straight chain alkenes C_2 to C_6 and know how to write the name to show the position of the double bond in the chain
   iv. know that the presence of the C=C bond makes them unsaturated and that the test for unsaturation is the ability to decolourise bromine water
   v. be able to write the balanced chemical equation for the combustion of alkenes in a plentiful supply of oxygen
   vi. recognise that the increased reactivity is due to the C=C bond opening up (to form a single bond) to enable other atoms to be added on, i.e. addition reactions
   vii. know that addition reactions take place with hydrogen, halogens, hydrogen halides and steam, and be able to write the balanced chemical equations for these reactions as well as drawing the displayed formulae of the products formed.

13.2 Polymers:

a. know that alkenes or other molecules with a C=C bond will react with each other to form long-chain saturated molecules called polymers by addition reactions called polymerisation, and that the unsaturated molecules are called monomers
b. understand that polymers are giant molecules
c. given an unsaturated monomer molecule, be able to draw the structure of the polymer and vice versa
d. explain the terms *biodegradable* and *non-biodegradable* as applied to polymers, and explain the related pollution problems of their disposal, i.e. burning or landfill sites.

13.3 Alcohols and carboxylic acids:

a. know the general formulae
b. know their chemical properties
c. know their common uses.

Physics

1. Electricity

1.1 Electrostatics:

a. charging of insulators by friction
b. object gaining electrons becomes negatively charged
c. object losing electrons becomes positively charged
d. forces between charged objects (attraction, repulsion)
e. uses and dangers of electrostatics (including paint spraying, dust extraction).

1.2 Electric current:

a. conductors and insulators
b. current = charge / time
c. use of voltmeter and ammeter
d. resistance = voltage / current
e. V–I graphs for a fixed resistor and a filament lamp
f. series and parallel circuits – current and voltage rules
g. resistor combinations in series (but not parallel)
h. voltage = energy / charge
i. basic circuit symbols and diagrams.

1.3 Power and energy:

a. power = current × voltage
b. energy transfer = power × time $= VIt$

1.4 Specifically step-up and step-down transformers:

a. know and use the relationship between the number of turns of the primary and secondary coils and voltage ratio $\left(\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{n_\mathrm{p}}{n_\mathrm{s}}\right)$
b. know that a consequence of 100% efficiency is total transfer of electrical power, and that this gives rise to the following relationship $V_\mathrm{p} I_\mathrm{p} = V_\mathrm{s} I_\mathrm{s}$. Know and use this relationship to solve problems.

1.5 Power generation:

a. know that electromagnetic induction occurs when a wire moves relative to a magnet or when a magnetic field changes
b. be familiar with a generator being a coil rotating in a magnetic field.

2. Motion and energy

2.1 Kinematics:

a. speed = distance / time
b. difference between speed and velocity
c. acceleration = change in velocity / time
d. distance–time and velocity–time graphs
e. calculations using gradients and areas under graphs
f. average speed.

2.2 Forces and motion:

a. inertia and Newton's first law
b. momentum = mass × velocity
c. conservation of momentum
d. Newton's second law: force = mass × acceleration
e. force = rate of change of momentum
f. resultant force
g. difference between mass and weight, and the relationship between them ($W = mg$)
h. gravitational field strength (approximated as 10 N / kg on Earth)
i. free-fall acceleration
j. terminal velocity and forces involved
k. Newton's third law.

2.3 Energy:

a. work = force × distance moved in direction of force
b. appreciation of work done as a transfer of energy
c. potential energy = mgh
d. kinetic energy = $\frac{1}{2}mv^2$
e. applications to crumple zones and road safety – stopping distances
f. power = energy transfer / time.

2.4 Energy conversion:

a. law of conservation of energy
b. forms of energy
c. ideas of useful energy and wasted energy
d. percentage efficiency = (useful output / total input) × 100.

3. Thermal Physics

3.1 Conduction:

a. thermal conductors and insulators
b. factors affecting rate of conduction.

3.2 Convection:

a. effect of temperature on density of fluid
b. fluid flow caused by differences in density
c. factors affecting rate of convection.

3.3 Radiation:

a. infrared radiation (see 4. Waves)
b. absorption and emission of radiation
c. factors affecting rate of absorption/emission.

3.4 Matter:

a. particle models of solids, liquids and gases
b. state changes
c. evaporation
d. density = mass / volume
e. experimental determination of densities
f. comparison of densities of the three states.

4. Waves

4.1 Wave nature:

a. transfer of energy without net movement of matter
b. transverse and longitudinal waves
c. examples (including electromagnetic waves, sound, seismic)
d. amplitude, wavelength, frequency and period
e. frequency = 1 / period; the SI unit of frequency is hertz (Hz), 1 Hz means one wave per second
f. speed = distance / time
g. wave speed = frequency × wavelength.

4.2 Wave behaviour:

a. reflection at a surface
b. refraction at a boundary
c. effect of reflection and refraction on speed, frequency and wavelength
d. analogy of reflection and refraction of light with that of water waves
e. the Doppler effect.

4.3 Optics:

a. understand ray diagrams for refraction at a planar boundary (qualitative only), and reflection (angle of incidence is equal to angle of reflection).

4.4 Sound waves:

a. longitudinal waves
b. reflection causes echoes
c. ultrasound and uses (sonar, scanning, animals).

5. Electromagnetic spectrum

5.1 EM waves:

a. understand the nature and properties of electromagnetic waves (transverse, travel at speed of light in vacuum).

5.2 The spectrum:

a. parts of the spectrum (radio waves, microwaves, IR, visible light, UV, X-rays, gamma)
b. distinction by different wavelengths and frequencies
c. order of component parts by wavelength and frequency
d. applications
e. dangers.

6. Radioactivity

6.1 Atomic structure:

a. protons, neutrons and electrons
b. popular models of atomic structure
c. relative charges and masses of sub-atomic particles
d. atomic number, atomic mass
e. isotopes
f. ionisation caused by gain/loss of electrons.

6.2 Radioactive decay:

a. emissions from the nucleus
b. random and spontaneous nature
c. alpha, beta and gamma emission
d. nature of alpha and beta particles, gamma radiation
e. radioactive decay equations
f. effect of decay on atomic number and mass
g. activity of a radioactive sample.

6.3 Ionising radiation:

a. penetrating abilities of alpha, beta and gamma
b. ionising abilities of alpha, beta and gamma
c. background radiation – existence and origins
d. applications, dangers and hazards of ionising radiation.

6.4 Half-life:

a. decrease in activity over time
b. graphical representation of decay (including of decay products)
c. meaning of half-life.

6.5 Nuclear fission:

a. caused by absorption of neutrons
b. fission of uranium-235, including equation
c. chain reaction.

6.6 Nuclear fusion:

a. fusion of hydrogen to form helium
b. need for high temperatures
c. significance as energy source.

Mathematics

1. Number

1.1 Order, add, subtract, multiply and divide whole numbers, integers, fractions, decimals and numbers in index form (division involving cancelling of common factors is assumed, but long division is not required).

1.2 Use the concepts and vocabulary of factor, multiple, common factor, highest common factor, least common multiple, prime number and prime factor decomposition.

1.3 Use the terms square, positive and negative square root, cube and cube root.

1.4 Use index laws to simplify and for multiplication and division of integer, fractional and negative powers.

1.5 Interpret, order and calculate with numbers written in standard index form.

1.6 Understand equivalent fractions.

1.7 Convert between fractions, decimals and percentages.

1.8 Understand and use percentages, including repeated proportional change and calculating the original amount after a percentage change.

1.9 Understand and use direct and indirect proportion.

1.10 Interpret fractions, decimals and percentages as operators.

1.11 Use ratio notation including dividing a quantity in a given ratio, and solve related problems (using the unitary method).

1.12 Understand and use number operations including inverse operations and the hierarchy of operations.

1.13 Use surds and π in exact calculations, simplify expressions that contain surds.

1.14 Calculate upper and lower bounds to contextual problems.

1.15 Approximate to a specified and appropriate degree of accuracy, including rounding to a given number of decimal places or significant figures.

1.16 Know and use approximation methods to produce estimations of calculations.

2. Algebra

2.1 Distinguish between the different roles played by letter symbols.

2.2 Manipulate algebraic expressions by collecting like terms; by multiplying a single term over a bracket; by expanding the product of two linear expressions; and by factorising to identify structure and possible simplifications.

2.3 Set up and solve simple equations including simultaneous equations involving two unknowns.

2.4 Simplify rational expressions by cancelling or factorising and cancelling; use the four rules on algebraic rational expressions.

2.5 Set up quadratic equations and solve them by factorising.

2.6 Set up and use equations to solve problems involving direct and indirect proportion.

2.7 Derive a formula, substitute into a formula.

2.8 Change the subject of a formula.

2.9 Solve linear inequalities in one or two variables.

2.10 Generate terms of a sequence using term-to-term and position-to-term definitions.

2.11 Use linear expressions to describe the n^{th} term of a sequence.

2.12 Use Cartesian coordinates in all four quadrants.

2.13 Recognise equations of straight lines, understand $y = mx + c$ and the gradients of parallel lines.

2.14 Graphically solve simultaneous equations, where one is linear and one is quadratic.

2.15 Recognise and interpret graphs of simple cubic functions, the reciprocal function, trigonometric functions and the exponential function $y = k^x$ for integer values of x and simple positive values of k.

2.16 Construct linear functions from real-life problems; interpret graphs modelling real situations.

2.17 Generate points of simple quadratic functions.

2.18 Use index laws in algebra for multiplication and division of integer, fraction and negative powers.

2.19 Interpret and analyse transformations of functions ($y = af(x), y = f(ax), y = f(x) + a,$ $y = f(x - a)$ only).

3. Geometry

3.1 Recall and use properties of angle at a point, on a straight line, perpendicular lines and opposite angles at a vertex.

3.2 Understand and use the angle properties of parallel lines, intersecting lines, triangles and quadrilaterals.

3.3 Calculate and use the sums of the interior and exterior angles of polygons.

3.4 Recall the properties and definitions of special types of quadrilateral.

3.5 Recognise and use reflectional and rotational symmetry of 2-D shapes.

3.6 Understand congruence and similarity.

3.7 Use Pythagoras' theorem in 2-D and 3-D.

3.8 Use the trigonometric ratios, between 0° and 180°, to solve problems in 2-D and 3-D (candidates are **not** expected to recall trigonometry function values, or use sine or cosine rules).

3.9 Understand and construct geometrical proofs, including using circle theorems:
   a. the angle subtended at the circumference in a semicircle is a right angle
   b. the tangent at any point on a circle is perpendicular to the radius at that point

3.10 Use 2-D representations of 3-D shapes.

3.11 Describe and transform 2-D shapes using single or combined rotations, reflections, translations or enlargements, include the use of vector notation.

4. Measures

4.1 Calculate perimeters and areas of shapes made from triangles, rectangles and other shapes.

4.2 Find circumferences and areas of circles, including arcs and sectors.

4.3 Calculate the volumes and surface areas of right prisms, pyramids, spheres, cylinders, cones and solids made from cubes and cuboids (formulae will be given for the sphere and cone).

4.4 Use vectors, including the sum of two vectors, algebraically and graphically.

4.5 Use and interpret maps and scale drawings.

4.6 Understand and use the effect of enlargement for perimeter, area and volume of shapes and solids.

4.7 Recognise the inaccuracy of measurement.

4.8 Understand and use three-figure bearings.

4.9 Understand and use compound measures.

5. Statistics

5.1 Identify possible sources of bias.

5.2 Identify flaws in data-collection sheets and questionnaires in an experiment or a survey.

5.3 Group, and understand, discrete and continuous data.

5.4 Extract data from lists and tables.

5.5 Design and use two-way tables.

5.6 Interpret bar charts, pie charts, grouped frequency diagrams, line graphs and frequency polygons.

5.7 Interpret cumulative frequency tables and graphs, box plots and histograms (including unequal class width).

5.8 Calculate and interpret mean, median, mode, modal class, range and inter-quartile, including the estimated mean of grouped data.

5.9 Calculate average rates when combining samples or events, including solving problems involving average rate calculations (e.g. average survival rates in different wards of different sizes, average speed of a car over a journey where it has travelled at different speeds).

5.10 Interpret scatter diagrams and recognise correlation, drawing (by eye) and using lines of best fit.

5.11 Compare sets of data by using statistical measures (as in 5.8) or by interpreting graphical representations of their distributions (5.6 and 5.7).

6. Probability

6.1 Understand and use the vocabulary of probability and the probability scale.

6.2 Understand and use estimates or measures of probability, including relative frequency and theoretical models.

6.3 List all the outcomes for single and combined events.

6.4 Identify different mutually exclusive outcomes and know that the sum of the probabilities of all these outcomes is 1.

6.5 Construct and use Venn diagrams to solve union and intersection categorisation problems and determine probabilities when required.

6.6 Know when to add or multiply two probabilities, and understand conditional probability.

6.7 Understand the use of tree diagrams to represent outcomes of combined events:

a. when the probabilities are independent of the previous outcome
b. when the probabilities are dependent on the previous outcome

6.8 Compare experimental and theoretical probabilities.

6.9 Understand that if an experiment is repeated, the outcome may be different.

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