2016 Suite

Oxford Cambridge and RSA

Cambridge **TECHNICALS LEVEL 3**

APPLIED SCIENCE

Unit 1

Science fundamentals

D/507/6148

Guided learning hours: 90

Version 4 - revised exemplification - September 2018

ocr.org.uk/science

LEVEL 3

UNIT 1: Science fundamentals

D/507/6148

Guided learning hours: 90

Essential resources required for this unit: A range of chemicals, cell and tissues, microscopes, scales, voltmeters, ohmmeters, ammeters, resistors, circuitry and general science laboratory equipment.

This unit is externally assessed by an OCR set and marked examination.

UNIT AIM

A thorough understanding of scientific principles and practices are essential for science technicians. Knowledge learnt in this unit will create a solid foundation in the fundamentals of science that you will be able to build on in your further study through your choice of additional optional units which will provide you with greater depth of knowledge and practice in your chosen specialisms.

TEACHING CONTENT

The teaching content in every unit states what has to be taught to ensure that learners are able to access the highest grades.
Anything which follows an i.e. details what must be taught as part of that area of content. Anything which follows an e.g. is illustrative.

For externally assessed units, where the content contains i.e. and e.g. under specific areas of content, the following rules will be adhered to when we set questions for an exam:

- a direct question may be asked about unit content which follows an i.e.
- where unit content is shown as an e.g. a direct question will not be asked about that example.

Learning outcomes **The Learner will:**		**Teaching content** **Learners must be taught:**		**Exemplification**
1. Understand the chemical structures of elements and compounds	1.1	The atom is the basic structure, it is made up of subatomic particles i.e.	1.1	
		• nucleus contains protons and neutrons surrounded by electrons		• atomic structure in terms of the numbers of protons, neutrons and electrons for atoms, given the proton number (atomic number) and nucleon number (atomic mass number) • the electron configurations, of atoms, given the proton number (atomic number) up to Z = 20 (limited to main energy levels only)
		• relative masses and charges		relative charges and approximate relative masses of protons, neutrons and electrons
		• nuclear and atomic diameters		• typical size of atoms use $R = r_0 A^{1/3}$ to calculate nucleus radii (where r_0 is a constant and A is the nucleon number)
		• nucleon number, proton number and isotopes		• nucleon number (atomic mass number) as the number of protons plus neutrons • proton number (atomic number) as the number of protons • isotopes as atoms of the same element with the same number of protons but different numbers of neutrons
		• proton number defines the type of atom		as stated in teaching content

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
		• nuclear notation		the use of nuclear notation ${}^{A}_{Z}X$ where A is the nucleon number (atomic mass number), Z is the proton number (atomic number)
		• attractive and repulsive forces within the nucleus		• the strong nuclear force to include short-range nature of the force • the role of the strong nuclear force in keeping nuclei stable • the repulsive nature of the electromagnetic force between protons • the role of the weak nuclear force in radioactive decay
	1.2	• Elements are based on atomic structure and can be classified by the Periodic Table i.e.:	1.2	
		• organisation of elements within the table		• how the location of the elements provides information on the structure of the atom • the arrangement of elements by increasing proton number (atomic number) • use atomic symbols to represent chemical formulae
		• groups		groups have the same number of outer electrons and similar chemical properties
		• periods		• periods show repeating trends in physical and chemical properties (periodicity) • periodic trends in electron configurations across Periods 2 and 3 limited to (s-, p-, and d- orbitals only)
		• atomic number		number of protons in the nucleus of an atom
		• atomic mass		the weighted mean mass of an atom compared to 1/12th of the mass of an atom of Carbon-12
		• atomic radius		trend in atomic radius across Periods 2 and 3, and down a Group, in terms of attraction, proton number (atomic number) and electron shells
	1.3	• Elements react together to form compounds by i.e.:	1.3	
		• ionic bonding		• ionic bonding as electrostatic attraction between positive and negative ions • the construction of '*dot-and-cross*' diagrams • balanced ionic half equations

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
		• covalent bonding		• covalent bond as the strong electrostatic attraction between a shared pair of electrons and the nuclei of the bonded atoms • construction of '*dot-and-cross*' diagrams of molecules and ions (up to 4 electron pairs round the central atom) to describe: ○ single covalent bonding ○ multiple covalent bonding ○ dative covalent (coordinate) bonding • unequal sharing of electrons in covalent molecules can lead to polarity (interpretation of Pauling electronegativity values not required)
2. Understand reactions in chemical and biological systems	2.1	Chemicals interact and react with each other i.e.:	2.1	
		• mixtures and alloys		• types of mixtures to include solutions, colloids and suspensions • difference between colloids and suspensions in terms of particle size • uses of common colloids in nature and medicine • types of colloids to include aerosols, emulsions, foams, gels and sols • significance of colloids in nature and medicine • alloys as mixtures of metals • the character and features of alloys • uses of common alloys to include amalgam, solder, bronze, titanium alloy
	2.2	Reactions i.e.	2.2	
		• oxidation and reduction		oxidation and reduction (redox) reactions in terms of: • loss and gain of oxygen • loss and gain of hydrogen • loss and gain of electrons to include overall balanced ionic equations
		• addition		addition reactions of alkenes to include full balanced symbol equations (reaction mechanism not required)
		• substitution		substitution reactions of alkanes and haloalkanes to include full balanced equations (reaction mechanisms not required)

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
		• polymerisation		• addition polymerisation to include identification of monomers and repeating units • condensation polymerisation to include identification of monomers and repeating units • balanced symbol equations for addition and condensation polymerisation are required
		• radical reactions		• definition of a radical • the role played by UV light in producing chlorine radicals from CFCs in the depletion of the ozone layer • equations to show how chlorine radicals can destroy many ozone molecules (knowledge of homolytic and heterolytic fission are not required)
		• displacement		displacement reactions to include full balanced equations for: • metal and metal salts • halogens and halides
	2.3	Rate of reaction can be affected by factors, i.e.:	2.3	
		• physical state		explanation in terms of frequency of collisions
		• temperature		explanation in terms of frequency of collisions
		• pressure		explanation in terms of frequency of collisions
		• solvents		the idea that highly polar solvents (e.g. water) have different effects on reaction rates compared to less polar solvents (e.g. methanol)
		• catalysts and enzymes		• how a catalyst increases reaction rate without being used up by the overall reaction • how a catalyst allows a reaction to proceed via a different route with lower activation energy • enzymes as biological catalyst • the active site in enzymes • enzyme specificity (lock and key and induced fit hypotheses) • the effect of temperature on enzyme activity • the effect of pH on enzyme activity
		• surface area		explanation in terms of frequency of collisions
		• light intensity		the effect of light intensity on the rate of some reactions to include photosynthesis
		• electromagnetic radiation		electromagnetic radiation gives particles of a reaction more energy and may increase the rate of reaction

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
3. Understand cell organisation and structures	3.1	Types of cells i.e.:	3.1	
		• prokaryotic cells		• be able to identify prokaryotic cells from diagrams and electron micrographs • typical cell features to include but not limited to cell surface/plasma membrane, cytoplasm, DNA in a loop, no membrane-bound organelles, 70S-type ribosomes, mesosomes and photosynthetic membranes (in photosynthetic bacteria)
		• eukaryotic cells		• ability to identify eukaryotic cells from diagrams and electron micrographs • typical cell features to include cell surface/plasma membrane, cytoplasm and DNA in a nucleus (surrounded by nuclear envelope), 70S and 80S-type ribosomes, membrane-bound organelles including mitochondria and chloroplasts (in plant cells)
				Compare similarities and differences between prokaryotic and eukaryotic cells
	3.2	Components of the cell and their role in the cell i.e.:	3.2	
		• cell wall		• made from the polysaccharide cellulose • cellulose microfibers form cross-links which give the wall strength • gives shape and support to plant cells
		• plasma membrane		• a phospholipid bilayer permeable to small, non-polar molecules • the role of carrier proteins and ion channels for the movement of large polar molecules and charged ions • acts as a barrier/interface between cell contents and surrounding environment • contains receptors on surface of the plasma membrane to allow cell-to-cell recognition and to enable other molecules to be recognised
		• cytoplasm		• watery matrix, forming the bulk of the cell • site of many cell reactions
		• mitochondria		• membrane-bound organelle • outer membrane is smooth but inner membrane highly folded to form cristae, surrounding the watery matrix • site of aerobic respiration (knowledge of the stages of Krebs cycle not required) • abundant in cells requiring much energy/ATP
		• chloroplasts		• membrane-bound organelle found in plant cells • watery stroma contains stacks of folded membranes or thylakoids • the site of photosynthesis

Learning outcomes The Learner will:	Teaching content Learners must be taught:	Exemplification
	• Golgi apparatus	• membraneous structure • modifies proteins and packages them into vesicles • vesicles may be secretory vesicles and leave the cell or lysosomes which stay in the cell

	• lysosome	• membrane-bound vesicle
		• release digestive enzymes to breakdown
		  ○ pathogens (bacteria and viruses) (knowledge of phagocytosis not required)
		  ○ to destroy the cell (knowledge of autolysis not required)
		  ○ unwanted organelles

	• endoplasmic reticulum (rough and smooth)	• membraneous structure • rough endoplasmic reticulum has ribosomes attached • rough endoplasmic reticulum is responsible for the synthesis and transport of proteins • smooth endoplasmic reticulum involved in the production and storage of lipids and carbohydrates
	• ribosomes	• non membrane-bound organelle • made up of rRNA molecules and amino acids • 80S form found freely in cytoplasm and attached to rough endoplasmic reticulum • 70S form found in the matrix of the mitochondrion in eukaryotic cells • site of protein synthesis (knowledge of protein synthesis not required)

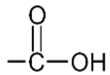
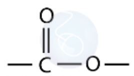
	• nucleus
	  ○ nuclear membrane
	  ○ chromatin material, chromosomes
	  ○ DNA and RNA
		• membrane-bound organelle found in eukaryotic cells
		• nuclear membrane or envelope is a double membrane and is porous
		• contains DNA in the form of chromatin material/chromosomes
		• nucleolus is an area within the nucleus responsible for producing ribosomes
		• comparison of DNA and RNA to include:
		  ○ length
		  ○ structure
		  ○ sugars
		  ○ bases and base pairing
		• controls the cell activities

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
				• identify the following cell organelles from diagrams, and light and electron micrographs (both scanning and transmission): ○ cell wall ○ plasma membrane ○ cytoplasm ○ mitochondria ○ chloroplasts ○ Golgi apparatus ○ lysosome ○ endoplasmic reticulum (rough and smooth) ○ ribosomes ○ nucleus
	3.3	Understand how tissues types are related to their function i.e.:	3.3	
		• epithelial		• cover the outside of a structure • layer of cells that sit on a basement membrane • squamous epithelial ○ very thin cells for rapid diffusion across the surface • ciliated epithelial ○ contain 'hair-like' structures on the surface called cilia which move in a rhythmic manner ○ goblet cells also present to release mucus ○ the cilia act to move the mucus • striated epithelia ○ highly folded layers of cells protective lining of the intestines
		• connective		• contains cells (fibrocytes), fibres (elastin and collagen) held in a gelatinous matrix • supports or binds other tissues together

Learning outcomes The Learner will:	Teaching content Learners must be taught:	Exemplification
	• muscle	• contains muscle cells/fibres which are striated or unstriated • muscle cells connected to each other and contract as a whole • functions to include movement of the skeleton (striated/skeletal muscle), of blood along vessels (smooth muscle) and of blood through the heart (cardiac muscle) • the role of sarcoplasmic reticulum and actin/myosin myofibrils in the contraction of muscle cells/fibres
	• bone	• special form of connective tissue • bone cells (osteocytes) held in a calcified matrix • functions to support the body, protect the body, for movement, production of blood cells and storage of minerals
	• nerve	• contains nerve cells (neurons) held in bundles • structure of a neuron includes cell body, axon and may be surrounded by myelin sheath (to increase speed of nerve transmission) • sensory, relay and motor neurons are connected to form the spinal reflex arc • functions to transmit impulses around the body
	• ovary and testis	• ovaries and testis are both gonads • ovaries produce gametes (eggs/oocytes) and release the hormones oestrogen and progesterone • testes produce gametes (sperm) and release testosterone

		• identify the following tissue types from light and electron micrographs and diagrams:
		  ○ epithelial
		  ○ connective
		  ○ muscle
		  ○ bone
		  ○ nerve
		  ○ ovary and testis

		how different tissues work together to perform a function e.g. in organs

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
4. Understand the principles of carbon chemistry	4.1	Carbon forms a vast number of different types of compounds with other elements due to the nature of the carbon atom i.e.	4.1	
		• alkanes, alkenes, alkynes		• alkanes as saturated hydrocarbons containing single C-C and C-H bonds • alkenes as unsaturated hydrocarbons containing a C=C double bond • alkynes as unsaturated hydrocarbons containing a C ≡ C triple bond • name and draw structural and skeletal formulae of the first four members of alkanes, alkenes and alkynes
		• aldehydes and ketones		• aldehydes and ketones as organic compounds containing the C=O group • name and draw the structural formulae of the first four aldehydes and the first two ketones
		• alcohols		• alcohols as organic compounds containing the OH group • name and draw structural and skeletal formulae of the first four alcohols • the conversion of alcohols to form aldehydes and ketones is classified as an oxidation reaction (full equations and reaction conditions not required)
		• carboxylic acids		• carboxylic acids as organic compounds containing the  group • name and draw structural and skeletal formulae of the first four carboxylic acids • reaction of carboxylic acids with an alkali, to include full equations using structural formulae
		• esters		• esters as organic compounds containing the group  • name and draw structural and skeletal formulae of the four C_4H_8O esters • how an ester can be made from a carboxylic acid and an alcohol, to include full equations using structural formulae (reaction conditions not required)

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
	4.2	Carbon compounds can be represented using empirical and structural formulae i.e. • polymers ○ polyethene, polypropene, polylactate, polystyrene, polyvinyl chloride (PVC)	4.2	• draw structural and skeletal formulae of the polymers listed • deduce the empirical formulae of the polymers listed
	4.3	Carbon compounds form different types of isomer i.e	4.3	
		• structural isomers		compounds with the same molecular formula but different structural formulae
		• geometric isomers		• as a type of stereoisomer in which there is restricted rotation about a C=C double bond • as compounds which have two different groups attached to each carbon atom of the C=C bond
		• optical isomers		• as a type of stereoisomerism in which the two isomers are non-superimposable mirror images • as compounds which have at least one chiral centre (or asymmetric carbon) • a chiral centre as a carbon with four different groups attached to it • deduce the number of chiral centres given the structural or skeletal formula of an organic molecule
				be able to identify and draw structural, geometric and optical isomers

Learning outcomes The Learner will:		Teaching content Learners must be taught:	Exemplification	
	4.4	Carbon compounds can form large complex molecules	4.4	
		• complex carbohydrates (starch, glycogen, cellulose)		• carbohydrates found as monosaccharides, disaccharides, or polysaccharides (monomers, dimers or polymers) • monomers held together by glycosidic bonds to form dimers and polymers, via condensation reactions • monosaccharides include glucose, fructose and galactose • disaccharides include maltose, sucrose and lactose • polysaccharides include starch, glycogen and cellulose • cellulose is found in plant cell walls where it provides strength/support and pliability • starch and glycogen are energy sources
		• proteins and peptides from amino acids		• dipeptides are formed from two amino acids joined by a peptide bond, via a condensation reaction • polypeptides are chains of amino acids joined by peptide bonds • proteins/polypeptides have physiological or functional roles, including enzymes, carrier proteins in the plasma membrane, and structural roles, including collagen and elastin fibres in connective tissue
		• lipids from fatty acids, glycerol and phosphorus compounds		• monoglycerides, diglycerides and triglycerides are esters of fatty acids and glycerol • an ester bond forms between each fatty acid and the glycerol, via condensation reactions • phospholipids contain glycerol plus two fatty acids and a phosphate group • lipids act as an energy source within cells, as an insulation layer around animal organs, in the myelin sheath (found around some nerve fibres/axons) to increase speed of nerve transmission • phospholipids form a bilayer in the plasma membrane

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
		protein synthesis (transcription, translation) RNA, messenger, ribosomal and transfer		• the nucleic acids, DNA and RNA, are polymers of nucleotides • peptide bonds form between amino acids to create polypeptide chains/proteins • recall a simple description of protein synthesis, in which: ○ a copy of a gene is made from messenger RNA (mRNA) ○ the mRNA travels to a ribosome in the cytoplasm ○ the ribosome joins amino acids together in an order determined by the code on the mRNA ○ transfer RNA (tRNA) brings the amino acids to the ribosome
5. Understand the importance of inorganic chemistry in living systems	5.1	Inorganic Chemistry is the study of elements and compounds which do not include carbon-hydrogen bonds	5.1	
		• metal ions		metal ions as cofactors that are required for enzyme activity
		• inorganic compounds i.e.: ○ oxides eg CO_2, NO_x, MgO		• the essential role of carbon dioxide in living systems, to include photosynthesis in plant cells and acting as a ‘chemical trigger’ for ventilation in animals • the role of nitric oxide in the body in vasodilation and as a signalling molecule in nerve cells • the role of magnesium oxide as a mineral supplement for healthy muscles and bones
		○ peroxide H_2O_2		the production of peroxides during amino acid metabolism and their degradation in the liver
		○ nitrates		the conversion of nitrates in plants into ammonium ions and hence into amino acids
		○ phosphates		the role of phosphates in the structure of DNA and in phospholipids
		○ sulfates		the role of sulfates in the formation of sulphur-containing amino acids, cysteine and methionine

Learning outcomes The Learner will:	Teaching content Learners must be taught:	Exemplification
	• bioinorganic - biological functions of metal ions i.e.	
	○ Ni^{2+}: hydrogenase, hydrolase	• nickel-containing enzymes to include hydrogenase and hydrolase • hydrogenase catalyses the reversible oxidation of molecular hydrogen • hydrolase catalyses the hydrolysis of a chemical bond
	○ Fe^{2+},Fe^{3+},Cu^{2+}:oxygen transport and storage, electron transfer	• iron is important in the carriage of oxygen in haemoglobin and myoglobin (found within each haem group attached to a polypeptide chain) • copper transports oxygen in haemocyanin in some invertebrates
	○ Na^{+}, K^{+}: osmotic balance, charge carrier	• sodium and potassium are important in the maintenance of a constant internal environment in the cell, creating an isotonic balance between the cell cytoplasm and surrounding tissue fluid • both are also involved in the transmission of the nerve impulse along nerve fibres/axons, creating a potential difference (charge) across the plasma membrane of the neuron
	○ Ca^{2+}: structural, charge carrier	• in animals, calcium is important in muscle contraction and as a structural component of bone (in matrix) • in plants, calcium is a component of cell walls of adjacent cells and is responsible for cell adhesion
	○ Mn^{2+} oxidase, structural, photosynthesis	• manganese is a component of the enzyme, oxidase • it is an activator of other enzymes involved in the formation of the organic matrix in bone and cartilage structure • involved in the biosynthesis of choline, important for normal liver function • a cofactor for the water splitting (photolysis) enzyme systems in photosynthesis and in some protein based transporter systems
	○ Li^{+}: treatment of hypertension, bipolar disorder	• lithium can be used to treat hypertension • can be used in the form of lithium carbonate or lithium citrate to treat depression and bipolar affective disorder as a mood stabilizer
	○ Pt^{2+} treatment in chemotherapy	platinum is a component of the drug Cisplatin used in cancer treatment (interferes with DNA replication in cancer cells)

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
6. Understand the structures, properties and uses of materials	6.1	The properties of a material determine its uses, and can be explained by its chemistry • mechanical properties, i.e.:	6.1	learners should be able to interpret the results of laboratory tests of mechanical properties of different materials (including metals, composites, ceramics and polymers)
		○ strength (compression and tension) ○ stiffness		• interpret laboratory tests to include the use of stress-strain graphs and Young's modulus • Young's modulus is a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression • awareness that repeated loading cycles may cause failure by fatigue below the yield strength
		○ maleability ○ ductility ○ brittleness ○ hardness		use of diagrams to understand that the way molecules are arranged in polymers determines the properties: chain length, crosslinking, use of plasticizers and crystallinity
		○ density		use the equation: density (kg/m^3) = mass (kg) ÷ volume (m^3)
		• physico-chemical properties i.e.: ○ boiling point ○ melting point		• melting and boiling points of metallic, giant covalent and simple molecular lattices in terms of the types of particle present and the relative strengths of the forces and bonds between them • interpret phase diagrams
		○ sublimation		• sublimation as the process which occurs when a solid turns directly into a gas on heating e.g. solid carbon dioxide (dry ice) • interpret phase diagrams
		• electrical properties, i.e.:		apply an understanding of the electrical properties of materials to solve problems in electrical circuits
		○ charge flow (in conductors, semiconductors and insulators) ○ current		• current as flow of charge in a conductor. • use the equation: $I = \Delta Q \div \Delta t$ • Ohm's law illustrates the relationship of $V \propto I$ • use the equation: potential difference (V) = current (A) × resistance (Ω)

Learning outcomes The Learner will:		Teaching content Learners must be taught:		Exemplification
		○ internal resistance and combined resistances		• resistor combination equations using Ohm's Law and Kirchhoff's laws to illustrate an understanding of current flow. • use the equations: Series $R_t = R_1 + R_2 + R_3$ Parallel $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
		○ electromotive force (e.m.f) and potential difference (voltage)		• recall and apply the relationship between I, R, and V, to calculate the currents, potential differences and resistances in d.c. series circuits: potential difference (voltage) as energy transfer per unit charge • use the equation: potential difference (V) = current (A) × resistance (Ω)
		○ number of charge carriers per unit		• recall and use the relationship between quantity of charge, current and time. use the equation: charge (C) = current (A) × time (s) • recognise $I = nAvq$ related to charge carrier density consider presenting equation as: current (A) = number of electrons per m^3 × cross-sectional area of conductor (m^2) × drift velocity ($m\ s^{-1}$) × electron charge (C)
		○ volume of conductors and insulators		as stated in teaching content
		○ electrical energy and power		• use the equation: energy transferred (work done) (J) = charge (C) × potential difference (V) • in the context of energy transfers use the equation: energy transferred (J, kWh) = power (W, kW) × time (s, h) • explain, with reference to examples, how the power transfer in any circuit device is related to the energy transferred from the power supply to the device and its surroundings over a given time. use the equation: power (W) = energy (J) ÷ time (s) • relationships between power transferred in any circuit device, the potential difference across it, and the current through it. use the equation: power (W) = potential difference (V) × current (A)

LEARNING OUTCOME (LO) WEIGHTINGS

Each learning outcome in this unit has been given a percentage weighting. This reflects the size and demand of the content you need to cover and its contribution to the overall understanding of this unit. See table below:

LO1	15-20%
LO2	15-20%
LO3	15-20%
LO4	15-20%
LO5	15-20%
LO6	15-20%

ASSESSMENT GUIDANCE

All Learning Outcomes are assessed through externally set written examination papers, worth a maximum of 90 marks and 2 hours in duration.

The learners will be assessed through external examination but it would be helpful if they could undertake a series of time constrained assessment to test their knowledge, understanding application during the learning process. These should include a range of assessment content such as short questions which test knowledge, understanding and application. Questions which include two or more of these elements would be particularly helpful. These should not demand long, theoretical answers but concentrate on the learner's ability to interpret realistic or real information in order to explain or carry out particular scientific tasks.

To find out more
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