

**SCIENCE**  
**CHEMISTRY**      **Additional – Learning Outcomes**

**1. ATOMIC STRUCTURE**

What makes atoms of different elements different from each other?

**Candidates Should:**

(a) know that the relative masses of protons, neutrons and electrons and their relative electric charges are as shown:

	mass	charge
proton	1	+1
neutron	1	0
electron	negligible	-1

(b) understand that the atom as a whole has no electrical charge because the number of electrons in the orbits (shells) is equal to the number of protons in the nucleus.

(c) know that all atoms of a particular element have the same number of protons and atoms of different elements have different numbers of protons.

(d) understand the terms atomic number and mass number.

(e) use data given in the form  ${}_{11}^{23}\text{Na}$  to give the number of protons, neutrons and electrons present in the atom. (w(i)a)

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**2. CHEMICAL BONDING, STRUCTURE AND PROPERTIES**

How do atoms join together?

How can we explain the behaviour of different materials?

**Candidates Should:**

- (a) know that the uses of a material depend on its properties (the way it behaves) and that the properties are closely related to the structure and bonding within the material.
- (b) know that modern materials are designed by chemists for specific purposes.
- (c) examine the properties of substances and use collected data to classify substances as metals, ionic compounds, simple molecular covalent substances or giant covalent substances (w(i)a,c)
- (d) use the accepted structural model for metals to explain their physical properties **and to explain differences in strength between metals such as sodium and aluminium** (w(i)c)
- (e) compare the structure of a metallic glass with that of a typical metal and understand how it leads to differences in properties (w(i)c;(iv)a)
- (f) **use their understanding of atomic structure to explain, diagrammatically or otherwise, how ions are formed and how ionic bonding takes place in simple binary compounds, for example, compounds of Li, Na, K, Mg or Ca with O, S, F or Cl** (w(i)c)
- (g) use the accepted structural model for giant ionic structures to explain the physical properties of ionic substances such as sodium chloride (w(i)c)
- (h) **use their understanding of atomic structure to explain, diagrammatically or otherwise, how covalent bonding takes place to form simple molecules, for example, hydrogen, chlorine, hydrogen chloride, water, methane and ammonia** (w(i)c)
- (i) use the accepted structural model for simple molecular structures to explain the physical properties of simple molecular substances, for example, methane (w(i)c)
- (j) recognise diagrams of the structures of diamond and graphite and describe the bonding present (w(i)c)

- (k) relate the uses of diamond and graphite to their properties (w(i)c)**
- (l) relate the properties of diamond and graphite to their structures and bonding (w(i)c) (m) recognise the structure of carbon nanotubes from given diagrams and understand their intended use in miniature electronic circuitry (w(i)c(iv)a)**
- (n) use given data to evaluate the benefits, risks and drawbacks of new developments in material science, such as metallic glasses, carbon nanotubes and new alloys (w(i)d;(iv)a,b)**

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**3. THE PRODUCTION AND USE OF METALS**

How can we make metals?

Can we use the same method for all metals?

**Candidates Should:**

- (a) examine the relationship between the method of extraction of a metal from its ore and its position in the Reactivity Series (e.g. aluminium, a reactive metal, is extracted by electrolysis; iron, a less reactive metal, by chemical reduction).
- (b) use displacement and competition reactions of metals to determine their relative reactivity
- (c) explain the terms reduction (removal of oxygen) and oxidation (gain of oxygen) and recognise their occurrence in reactions
- (d) know that extraction of a metal requires the process of reduction
- (e) know the meaning of the terms electrolysis, electrode, anode, cathode and electrolyte
- (f) know the processes involved in the commercial extraction of aluminium, including being able to write and interpret word and balanced symbol equations for the reactions at the anode and cathode
- (g) know the reasons for the high cost of the process and how those costs are minimized (w(iv)b)
- (h) know that recycling aluminium uses only about 5% of the energy needed to extract it from bauxite and saves waste. (w(iv)b)
- (i) discuss the factors affecting the siting of an aluminium extraction plant. (w(i)d;(iv)b)
- (j) relate the uses of aluminium, copper and titanium to their properties
- (k) relate the uses of different steels to their composition and properties
- (l) know that steel is recycled on a large scale and that recycling steel saves 50% of the energy used in the extraction of iron, helps to conserve iron ore and also cuts down on the emission of greenhouse gases
- (m) evaluate the social, economic and environmental impact of the use and extraction of metals (w(i)a,d;(iv)b)

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**4. CHEMICAL CALCULATIONS**

**How do scientists compare the masses of different atoms?**

**How can we work out the formula of a compound?**

**How much product can we get from a reaction?**

**Why is atom economy important?**

**Candidates Should:**

- (a) know that atoms of different elements have different masses.
- (b) know that the mass of an atom of an element is measured on a scale which compares masses of atoms with each other, and that this mass is called the relative atomic mass (*A<sub>r</sub>*).
- (c) be able to calculate the relative molecular (formula) mass (*M<sub>r</sub>*) of a compound whose formula is supplied.
- (d) **be able to calculate the formulae of binary compounds from given experimental data.**
- (e) **be able to calculate the reacting masses of reactants or products, given a balanced symbol equation for the reaction.**
- (f) **be able to calculate the percentage yield of a reaction (w(iv)b)**
- (g) **be able to calculate the atom economy of a reaction from a given equation, using the relation**

$$\text{atom economy} = \frac{\text{theoretical mass of required product}}{\text{total mass of reactants used}} \times 100\%$$

(w(iv)b)

- (h) **appreciate the importance of the concept of atom economy in assessing the level of waste in a reaction, e.g. by using given data to calculate and compare the atom economy of the traditional method of extracting Ti with the modern electrolytic method (w(i)c;(iv)b)**

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**5. AMMONIA AND FERTILISERS**

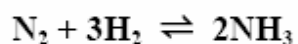
What is a reversible reaction?

How do we make fertilisers?

What are the benefits and drawbacks of using fertilisers?

**Candidates Should:**

- (a) know that ammonia is made from atmospheric nitrogen by the reversible reaction



- b) **interpret given data to show how the yield of product depends upon the conditions used in the manufacture of ammonia** (w(i)a,d;(iv)b)
- (c) know how nitrogenous fertilisers such as ammonium sulphate and ammonium nitrate are obtained by neutralising ammonia solution with sulphuric acid or nitric acid, respectively.
- (d) evaluate the advantages and disadvantages of using nitrogenous fertilisers for individuals, communities and the environment. (w(i)a;(iv)b)
- (e) **identify the presence of an ammonium salt by reaction with sodium hydroxide solution to produce ammonia gas.**
- (f) **identify the alkaline gas ammonia by its action on damp red litmus paper**

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**6. ALKANES, ALKENES AND POLYMERS**

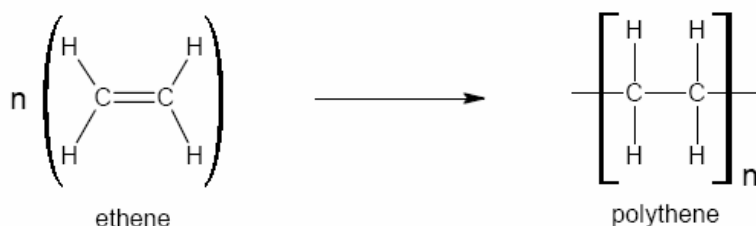
What are polymers and how do we make them?

Why do some polymers soften when heated but others do not?

What are the benefits and drawbacks of the use of plastics?

**Candidates Should:**

- (a) be able to write structural formulae for simple alkanes (C1-C5) and ethene
- (b) **know the meaning of the terms saturated and unsaturated**
- (c) know how large **saturated** hydrocarbons (alkanes) can be cracked by heating in the presence of a catalyst to form smaller more useful hydrocarbon molecules including monomers (alkenes) for making polymers
- (d) know the process of addition polymerisation of ethene to produce polythene **and be able to write and interpret the following equation:**



- (e) **be able to draw the repeating unit for the addition polymers, poly(ethene), poly(tetrafluoroethene) (PTFE) and polyvinyl chloride (PVC) in the form:**



- (f) relate the uses of polythene, PVC and PTFE to their properties (w(i)a,c;(iv)b)
- (g) relate the uses of thermoplastics and thermosets to their properties and structure (w(i)a,c;(iv)b)
- (h) use given data to compare the properties and uses of polymers and traditional materials. (w(i)a,d;(iv)a,b)
- (i) evaluate the social, economic and environmental impact of the widespread use of plastic products, for individuals, communities and the environment. (w(i)a,d(iv)a,b)

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**7. SMART MATERIALS**

**What is a smart material?**

**Should smart materials be called 'intelligent'?**

**How can smart materials be used?**

**Candidates Should:**

(a) know that the term *smart material* has been given to a range of modern materials whose properties change with a change in the surroundings, such as changes in temperature, light, pH etc, for example:

- . thermochromic paint, which changes colour when heated
- . photochromic paint, which changes colour on exposure to light
- . shape memory alloy, such as NiTi or nitinol, an alloy of nickel and titanium, which has the ability to regain it's original shape when heated; uses include coffeepot thermostat, superelastic spectacle frames, stents for veins, etc.
- . shape memory polymer, which has the ability to regain its original shape when heated; potential uses include biodegradable surgical sutures that will automatically tighten to the correct tension and self repairing car bodies that will recover shape on gentle heating after a dent
- . polymer gels, such as hydrogels, have a cross linked polymer structure inflated with a solvent, such as water; the gel has the ability to swell or shrink (up to 1000 times in volume) due to small changes in, e.g. temperature or pH; intended uses include artificial muscles, robot actuators, absorbers of toxic chemicals, etc. (w(i)c)

(b) use given data to evaluate the social, economic and environmental impact of the use of smart materials (w(i)d;(iv)a,b)

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**8. WATER**

**How is water made drinkable?**

**How can we measure the ability of a compound to dissolve?**

**Why does some water use a lot of soap?**

**Candidates Should:**

- (a) describe in outline the treatment of the public water supply, using filter beds and chlorination.
- (b) be able to draw and interpret solubility curves using given data on change of solubility with temperature
- (c) know the causes of hardness in water and distinguish between a hard and a soft water by their action with soap
- (d) plan and carry out experiments to measure the type (temporary or permanent) and amount of hardness using soap solution
- (e) know how the methods of boiling, adding sodium carbonate and ion exchange work to soften water and discuss their advantages and disadvantages
- (f) evaluate the advantages and disadvantages of soft and hard water (w(iv)b)