

TOPIC 4 BONDING

4.1 Chemical Bonding

Learning outcomes

Topic 4.1

Candidates should be able to:

- describe ionic and covalent bonding (including coordinate bonding) and represent this in terms of appropriate 'dot and cross' diagrams;
- describe qualitatively the nature of the attractive and repulsive forces between ions in an ionic crystal;
- show an understanding of the covalent bond in terms of the sharing (and spin pairing) of electrons and show awareness of the forces of attraction and repulsion within the molecule;
- understand the concepts of electronegativity and of bond polarity, recall that bond polarity is largely determined by differences in electronegativity and use given values to predict such polarities;
- appreciate that many bonds are intermediate in character between purely ionic and purely covalent and understand the way in which the electron density distribution varies with the ionic character of the bond.

4.2 Forces between molecules.

Learning outcomes

Topic 4.2

Candidates should be able to:

- explain the concept of a dipole and give a simple account of van der Waals' forces (dipole-dipole, induced dipole-induced dipole);
- explain the nature of hydrogen bonding and recall the types of elements with which it occurs e.g. with hydrogen attached to highly electronegative atoms;
- describe and explain the influence of hydrogen bonding on boiling points and solubility;
- appreciate that forces **within** molecules generally influence their chemical properties, whilst forces **between** molecules usually affect their physical properties;
- appreciate the relative orders of magnitude of the strength of covalent bonds, hydrogen bonds and van der Waals' forces.

4.3 Shapes of Molecules.

Learning outcomes

Topic 4.3

Candidates should be able to:

- (a) explain what is meant by the terms *lone pairs* and *bonding pairs* of electrons and recall and explain the sequence of repulsions between: two bonding pairs; a bonding pair and a lone pair; two lone pairs;
- (b) explain the VSEPR principle in terms of minimising the total repulsions between electrons in the valence shell of a given molecule or ion, giving examples where appropriate;
- (c) recall and explain the shapes of the species listed (recall of exact bond angles is required for BF_3 , CH_4 , SF_6 and NH_4^+) and apply the VSEPR principle to predict or explain the shapes of other specified simple species involving up to six electron pairs in the valence shell of the central atom.

4.4 Solubility of compounds in water.

Learning outcomes

Topic 4.4

Candidates should be able to:

- (a) use a simple model to explain the ability of certain solutes to dissolve in water either by virtue of hydrogen bonding or dipolar forces and apply this to explain the solubility of ethanol and sodium chloride, and the insolubility (immiscibility) of hydrocarbons, in water;
- (b) understand and use solubility both qualitatively and quantitatively (i.e. in terms of mass or moles per unit volume) and understand the recovery of soluble salts from aqueous solution by crystallisation.

TOPIC 5 Solid Structures.**Learning outcomes****Topic 5**

Candidates should be able to:

- (a) recall and describe the crystal structures of sodium chloride and caesium chloride, including the crystal coordination numbers and a simple explanation of the differences in terms of the relative sizes of the cations;
- (b) recall and describe the structures of diamond and graphite and know that iodine forms a molecular crystal;
- (c) recall and describe the structure of carbon nanotubes and appreciate the analogy with the graphite structure;
- (d) understand and explain the simple 'electron sea' model for bonding in metals and use it to explain their physical properties;
- (e) explain the relationship between physical properties (e.g. hardness, volatility and electrical conductance) and structure and bonding for the examples above;
- (f) understand that a so-called 'smart' material is able to exhibit a change in properties with a change in conditions (temperature, pH, etc) and this is often caused by a change in structure;
- (g) understand that nano-sized materials often exhibit different properties which can lead to new uses.

TOPIC 6

6.1 The Periodic Table.

Learning outcomes

Topic 6.1

Candidates should be able to:

- (a) describe the Periodic Table in terms of the arrangement of elements in groups and periods on the basis of their electronic structure and the classification of elements into *s*, *p* and *d* blocks;
- (b) understand the general trends in ionisation energy, melting temperature, and electronegativity, across periods and down groups;
- (c) recall the occurrence of elements as metals or non-metals in different parts of the Periodic Table, realise that metallic oxides are generally basic and non-metallic oxides acidic;
- (d) assign oxidation states (numbers) to the atoms in a compound or ion and use these to decide which species have been oxidised and which reduced in a redox reaction;
- (e) understand and explain the nature of oxidation and reduction in terms of electron transfer.

6.2 Trends in properties of the elements of the s-block and Group 7 (17).

Learning outcomes

Topic 6.2

Candidates should be able to:

- (a) recall the typical behaviour of the elements of Groups 1 and 2 with O_2 , H_2O and Group 2 elements with dilute acids (*excluding nitric acid*) and the trends in their general reactivity †;
- (b) describe the reactions of the aqueous cations, Mg^{2+} , Ca^{2+} and Ba^{2+} with OH^- , CO_3^{2-} and SO_4^{2-} †;
- (c) recall the formulae of the oxides and hydroxides of Groups 1 and 2 and appreciate their basic character;
- (d) recall the flame colours shown by compounds of Li, Na, K, Ca, Sr and Ba (and that Mg compounds show no colour) and describe their use in qualitative analysis;
- (e) show an awareness of the importance of calcium carbonate and phosphate minerals as skeletons for living systems and the consequent formation of carbonate rocks and the importance of calcium and magnesium in biochemistry;
- (f) recall the trend in volatility shown by the elements Cl, Br and I and relate to chemical bonding;
- (g) recall and explain the tendency of the halogens (F – I) to react by forming anions (F^- , Cl^- , Br^- , I^-), and recollect that this reactivity decreases on descent of the group *;
- (h) recall the reactions of the halogens with metals, their displacement reactions with halides, and explain the group trends and displacements in terms of the relative oxidising power †*;
- (i) understand the displacement reactions of Cl_2 and Br_2 in terms of redox †*;
- (j) recall the nature of the reaction between aqueous Ag^+ and halide (Cl^- , Br^- , I^-) ions* followed by dilute aqueous NH_3 , and understand the analytical importance of these reactions in qualitative analysis (*ionic equations required for precipitation reactions only*).

TOPIC 7

7.1 Organic compounds and their reactions.

Learning outcomes

Topic 7.1

Candidates should be able to:

- (a) write displayed, shortened and skeletal structural formulae of simple alkanes, alkenes, halogenoalkanes, primary alcohols and carboxylic acids given their systematic names, and vice versa;
- (b) describe the effect of increasing hydrocarbon chain length and of the above functional groups on physical properties, melting and boiling temperature and solubility;
- (c) describe structural isomerism and be able to write down the structural isomers of non-cyclic organic compounds (up to and including C₆ homologues) including those of different chemical class;
- (d) describe *E-Z* isomerism in alkenes, give an example, and discuss such isomerism in terms of restricted rotation about the C = C bond, and appreciate that *E-Z* isomers may have different physical and chemical properties;
- (e) derive empirical formulae from elemental composition data and use such results, together with additional data, to deduce molecular formulae;
- (f) identify reactants as electrophilic, nucleophilic or radical in type, explain the basis of this classification, and give examples of each;
- (g) classify the following types of functional group reactions and describe their nature: electrophilic addition, elimination, oxidation, hydrolysis;
- (h) describe the total oxidation of primary alcohols, RCH₂OH, to carboxylic acids, RCOOH. (*Knowledge of the properties of aldehydes is not, at this stage, required*);
- (i) recognise the following functional group tests by the indicated reactions:

C = C addition of Br₂(aq);

-X (Cl, Br, I) hydrolysis by aqueous base, followed by reaction with AgNO₃(aq) / HNO₃(aq).

7.2 Hydrocarbons

Learning outcomes

Topic 7.2

Candidates should be able to:

- (a) understand and explain the meaning of the terms homolytic and heterolytic bond fission;
- (b) describe in outline the general nature of petroleum, its separation into useful fractions by fractional distillation, and the cracking process;
- (c)
 - (i) describe the photochlorination of methane †;
 - (ii) recall the mechanism of the reaction as far as CH_2Cl_2 and be aware that the reaction may proceed to CCl_4 ;
- (d) describe the structure of and bonding in ethene (*hybridisation is not appropriate here*);
- (e) classify the addition reactions of Br_2 and HBr (involving heterolytic fission), with ethene and propene, and relate the orientation of the normal addition of HBr to propene to the recalled mechanism of the reaction and the relative stabilities of the possible carbocations (carbonium ions) involved;
- (f) recall the catalytic hydrogenation (reduction) of alkenes and the preparation of ethene by elimination of HBr from bromoethane †;
- (g) understand the nature of alkene polymerisation and show an awareness of the wide range of important polymers of alkenes and substituted alkenes.

7.3 Halogenoalkanes.

Learning outcomes

Topic 7.3

Candidates should be able to:

- (a) describe the formation of a chloroalkane by direct chlorination of alkanes †*;
- (b) describe the substitution reaction between OH^- and 1-chlorobutane and explain this on the basis of the recalled mechanism. †*;
- (c) show an awareness of the wide use of halogenoalkanes as solvents, the toxicity of some of them, the use of CFCs as refrigerants and in aerosols, and their use in anaesthetics as well as the adverse environmental effects of CFCs;
- (d) understand the adverse environmental effects of CFCs and explain these in terms of the relative bond strengths of the $\text{C}-\text{H}$, $\text{C}-\text{F}$, and $\text{C}-\text{Cl}$ bonds involved;
- (e) show an awareness of the use of organohalogen compounds as pesticides and polymers and assess their environmental impact.

7.4 Alcohols.

Learning outcomes

Topic 7.4

Candidates should be able to:

- (a) describe the physical properties of the lower alcohols, solubility in water and relatively low volatility, and relate this to the existence of hydrogen bonding;
- (b) recall a method for the industrial preparation of ethanol from ethene;
- (c) recall the dehydration reaction (elimination) of primary alcohols †;
- (d) show awareness of the importance of ethanol-containing drinks in society, their ethanol content, breathalysers, and the effects of ethanol excess.

TOPIC 8 Analytical techniques

Learning outcomes

Topic 8

Candidates should be able to:

- (a) use **given** mass spec data in the elucidation of structure;
- (b) use **given** characteristic i.r. vibrational frequencies (expressed in cm^{-1}), to identify simple groupings in organic molecules.