



Science
Centre

Curriculum Management
and eLearning Department

CHEMISTRY FORM V SYLLABUS

For State Schools

Commencing Scholastic Year 2012 - 2013

Introduction

In view of the changes to the Chemistry SEC syllabus there has been the need to update the State School Chemistry syllabi.

This syllabus for Form V students reflects the changes in the SEC syllabus leading to the SEC Examination from 2013 onwards.

The complete version of the SEC 06 Chemistry syllabus can be accessed directly from the URL address <http://www.um.edu.mt/matsec>

General Aims

This syllabus aims to:

- stimulate students and sustain their interest in, and enjoyment of, the learning of chemistry and its role in our everyday lives
- provide a relevant chemical background for those students who intend to terminate their study of chemistry at secondary level and also lay a sound foundation for those who intend to pursue their studies in chemistry or related subjects further
- enable students to acquire a knowledge and understanding of basic chemical principles and patterns
- encourage students to apply their chemical knowledge and understanding to familiar and unfamiliar situations
- improve students' abilities to perform experiments through a guided development of relevant practical skills whilst having due regard to correct and safe laboratory practice
- develop students' investigative competence in relation to problem solving situations
- develop students' ability to communicate their chemical knowledge and findings in appropriate ways
- develop students' appreciation of the environmental and technological contributions and applications of chemistry

Scheme of assessment

The annual examination paper consists of a 1 hour 45 minutes written paper. The paper has two sections: Section A and Section B.

Section A comprises about eight questions with a total of 60 marks. All the questions in this section are compulsory. Section B includes three questions of the free response type, of which the students are asked to select two. Each question in Section B carries 20 marks. Thus section B includes 40 marks.

The questions in both sections shall test both the recall of chemical concepts as well as the application of knowledge. The questions in the annual examination paper will comprise all the topics covered in Forms III and IV, and up to Topic 14.5 of the Form V Syllabus.

The final mark of the annual examination is worked out by calculating the total theory/exam mark out of 85% and then adding to it the mark attained by the student in the practical/laboratory work (out of 15%).

Practical work

The mark attained for the practical work is based on an average of all the practical reports presented by the student up to the Annual Exam. In Form 5 students must carry out and present a minimum of at least **THREE** practicals, one of which **must** involve a problem solving investigation.

N. B. Since the investigation carries 30 marks, the average mark should be calculated by dividing the marks for say three experiments by four.

It is vital that practical work is ongoing and laboratory reports are regularly marked throughout the scholastic year, such that the average mark for the coursework is finalised prior to the Annual Examination. The students' laboratory report files must be available for the possibility of moderation by the Education Officer or College Head of Department for Chemistry at least a week before the annual examination.

Chemical Laboratory Experience

A requisite of the SEC 06 Chemistry syllabus (2013) is that the laboratory reports of the **thirteen** experiments presented by candidates must include **one experiment from each of ten specified sections**, [Refer to Section 5.4 (A) to (J) of the SEC 06 2013 Chemistry syllabus], and three other experiments.

It is important to note that, **not more than three** reports of experiments can be presented **from the same section**. Furthermore, **two** of the thirteen experiments must be of the **investigative (problem solving)** type of practical (which carry 30 marks in order to reflect the greater amount of work required). **Although candidates can present up to three experiments from the same sections, (A) to (J), candidates should not present more than one experiment (for example one experiment and one investigation) for the same sub-topic. For example an experiment and a problem-solving investigation both based on heat of combustion will not be accepted.**

The experiments which are listed in the SEC syllabus and that can be carried out in Form 5 are as follows:

Unit / Topic	Nature of experiment	SEC syllabus Section 5.4
Unit 12 Topic 12.2	Experiments to illustrate the dependence of rate of reaction on concentration, temperature, catalyst, or state of subdivision	(H) (i)
Unit 14 Topic 14.1	Preparation of carbon dioxide. Investigation of the properties of the gas.	(C) (iii)
Unit 15 Topic 15.4	A simple experiment to estimate the heat of combustion of an alcohol.	(G) (i)
	Determination of the heat of neutralisation	(G) (ii)

Note: The preparations of gases are intended to be carried out on a test-tube scale and accompanied by simple investigations of the properties of the gases.

It is expected that students will be given the opportunity to carry out more than the minimum number of **three** experiments stipulated for Form 5.

N.B. Candidates sitting for the Chemistry SEC 06 Examination in 2013 are required to list the 13 experiments, which they present as coursework, in the table format as shown in Appendix 2 on p.28 of the SEC 06 Chemistry Syllabus (2013).

Practical work should not be limited to carrying out only those experiments specified in the requirements of the SEC 06 Syllabus Section 5.4. Compliance with this syllabus requisite is to be considered as a minimum requirement. Although carrying out exactly thirteen experiments would satisfy the requirements of the SEC coursework, it will limit the opportunity for students to improve on previous experimental work which in itself is a valuable learning experience. It is expected that students will perform more than thirteen experiments by the end of Form 5. Performing more experiments will enable students to select the best 'three other' experiments (that have to be presented in addition to those from ten specified sections) from a large and varied pool of experiment reports.

The experiments that are not included in the coursework assessment are to be listed in a copy of the sheet given in Appendix 3 on p.29 of the SEC 06 Chemistry Syllabus (2013).

CHEMISTRY FORM 5 SYLLABUS

UNIT 12 KINETICS RATES OF REACTION

- Topic 12.1 Classification of reactions by their speed. Measurement of rate.
12.2 Experimental investigations of factors affecting rate of reaction.
12.3 Factors affecting reaction kinetics in terms of the collision theory

UNIT 13 REVERSIBLE REACTIONS EQUILIBRIA

- Topic 13.1 Reversibility of reactions and Dynamic equilibrium. Le Chatelier's principle.
13.2 Experimental investigation of reversibility.
13.3 Equilibria in industry

UNIT 14 CARBON AND ITS COMPOUNDS

- Topic 14.1 Carbon – Inorganic chemistry.
14.2 Carbon – Organic chemistry. An introduction.
14.3 Alkanes.
14.4 Alkenes and alkynes
14.5 Natural gas and Crude oil
14.6 Alcohols
14.7 Carboxylic acids
14.8 Polymers

UNIT 15 ENERGETICS

- Topic 15.1 Law of conservation of energy. Energy 'stored' in chemicals.
Exothermic and endothermic changes. The ΔH convention.
15.2 Energy level diagrams and thermochemical equations.
15.3 Energy changes defined per mole.
15.4 Experimental method to determine ΔH combustion.
15.5 Fuels. Energy sources.

UNIT 16 STRUCTURES

- Topic 16.1 Giant structures – ionic, metallic and giant molecular.
16.2 Small molecules.

Unit 12 KINETICS RATES OF REACTION

□ **Introduction**

In this unit, investigations are suggested into the effects of various factors on the rates of reaction and it is expected that this unit be based firmly on practical experiments. The study of reaction rate is ideally suited to an investigative approach so students should be encouraged to plan and carry out experiments in which these factors are a variable. This ‘problem solving’ type of investigation can be varied to suit different abilities among students: most students will appreciate the qualitative aspects, while more able students should be able to plot and interpret rate curves and use results to make predictions. Ideally, students should be familiar with a different experiment for each of the factors that affect reaction rate.

These experiments can include an investigation of:

- the state of division of a solid reactant in a heterogeneous reaction
- altering the concentration of a reactant in solution
- carrying out the reaction at a different temperature
- the effect of a catalyst
- the effect of light

Where applicable, students should be able to give explanations for these effects using the idea of colliding particles.

Objectives

- (i) To give students the opportunity to investigate factors such as concentration, temperature, particle size, catalysts and light, which influence the rate of a chemical reaction, by considering both quantitative and qualitative relationships.
- (ii) To encourage an investigative approach in practical work on rates where students design and carry out an experiment to solve a problem.
- (iii) To improve and consolidate manipulative and interpretive skills where students need to observe, measure accurately and record systematically; present experimental results graphically; and process results to deduce relationships and draw conclusions.
- (iv) To give a qualitative explanation for factors that affect rates in terms of the theory of collisions between particles.
- (v) To relate the principles of rates of reactions to everyday life and processes associated with the manufacture of new materials.

Unit 12 Kinetics Rates of reaction

□ Content

Topic	Item	Description	Additional notes
12.1	<p>Classification of reactions.</p> <p>Measurement of rate.</p>	<ul style="list-style-type: none"> • Variation in speed: <ul style="list-style-type: none"> instantaneous moderately fast very slow • Difference between a homogeneous and a heterogeneous reaction • Selection of a variable and an appropriate procedure to measure rate of reaction: <ul style="list-style-type: none"> - colour change at a certain point - formation of a precipitate - loss in mass against time - volume of gas liberated against time • Comparison of rates of two or more reactions: <ul style="list-style-type: none"> - in a purely visual way - by using overall reaction times - by plotting rate curves on the same axes 	<p>e.g. precipitation e.g. magnesium + dil. sulfuric acid e.g. rusting of iron</p> <p>e.g. 'iodine clock' experiment e.g. sodium thiosulfate + dil. hydrochloric acid e.g. calcium carbonate + dil. hydrochloric acid e.g. magnesium + dil. hydrochloric acid</p> <p>e.g. observing the rate of effervescence e.g. for sodium thiosulfate + dil. hydrochloric acid e.g. mass / volume against time</p>

Topic	Item	Description	Additional notes
12.2	Experimental investigations.	<ul style="list-style-type: none"> • Concentration: e.g. reaction of sodium thiosulfate with dilute hydrochloric acid • Particle size: e.g. dilute hydrochloric acid on marble chips and on crushed marble • Temperature: e.g. dilute hydrochloric acid on magnesium • Catalyst: to show that a catalyst may participate in a reaction but is reformed at the end of the reaction; to show the catalytic effect on specific reactions • Light: effect on certain reactions 	<p>plot concentration against time taken; with more able students, plot concentration against reciprocal of time</p> <p>either using a top pan (direct reading) balance – plot mass against time; or collect the evolved gas in a burette or gas syringe – plot volume against time</p> <p>collect the evolved gas in a burette or gas syringe – plot volume against time</p> <p>e.g. the reaction of potassium sodium tartrate with hydrogen peroxide in the presence of cobalt (II) chloride</p> <p>e.g. decomposition of hydrogen peroxide, with and without manganese (IV) oxide</p> <p>e.g. exposing a silver halide to different light intensities</p>
12.3	Explaining factors affecting reaction rate in terms of the collision theory.	<ul style="list-style-type: none"> • Concentration of reactant(s) in solution – more / less particles within the same volume resulting in more / less frequent collisions • Particle size of a solid reactant – more/less surface area with which particles in solution can collide • Temperature – more / less frequent collisions which are more / less energetic • Catalyst – positive and negative catalysts; specific nature of catalysts • Light – photoelectric effect on certain reactions • Pressure – concentration effect in gaseous reactions resulting in more frequent collisions 	<p>affecting homogeneous reactions</p> <p>affecting heterogeneous reactions</p> <p>a 10°C rise in temperature will approximately double reaction rates</p> <p>a catalyst as a substance offering an alternative pathway of lower activation energy will be covered in Unit 15</p>

Topic	Item	Learning Outcomes – at the end of this Unit students should be able to:	Time	Difficulty level		
				A	B	C
12.1	Classification of reactions.	appreciate that reactions occur at a widely differing variety of speeds				
		distinguish between a homogeneous and a heterogeneous reaction				
	Measurement of rate.	select an appropriate procedure for investigating and measuring the rate of a specific reaction				
		describe a suitable practical method for investigating the effect of a given variable on the rate of a reaction				
12.2	Experimental investigations	appreciate that in experiments involving measurement of rate, it is important to control all variables except the factor under investigation				
		present results of experiments in tabular or graphical form and interpret data obtained				
		use given data to predict the effect of changes in concentration, temperature, particle size or the presence of a catalyst on the rate of a given reaction				
		use given data / results of experiments on reaction rate to perform calculations involving mole ratios				
12.3	Explaining factors affecting reaction rate in terms of the collision theory.	explain how each factor alters the rate of reaction in terms of the ‘particle collision theory’				
		state that for many reactions, the rate is proportional to the concentration of the reactant(s)				
		state that a small rise in temperature can result in a large increase in rate of reaction				
		explain the effect of particle size on reaction rate in terms of surface area of reactant				
		explain the ‘concentration effect’ of increasing the pressure on gaseous reactions				
		define a catalyst and describe its action				
		give examples of laboratory and industrial uses of catalysts				
		relate the application of factors affecting rate to the dangers involved in using inappropriate conditions for certain reactions				
	relate rate to common everyday processes					

Unit 13 Reversible reactions. Equilibria.

□ Introduction

This unit can be introduced through an investigation / demonstration of a few reversible reactions, leading to the concept of dynamic equilibrium, and the use of the double arrow symbol. Prior to assigning practical work to students it is advisable to introduce a kinetic picture of attaining dynamic equilibrium. It is also imperative that students grasp an understanding of Le Chatelier's principle and its application to systems in equilibrium, in particular, the distinction between the effect of different factors on the *rate of attainment of equilibrium* and the effect on *equilibrium position* (whether the forward or backward reaction is favoured, if at all). Students' practical work could focus on an investigation of some simple systems that go both ways, involving alternate increase / decrease in concentration of a species. The results of such practical work should include an interpretation / explanation of the results in terms of Le Chatelier's principle. The Haber and Contact processes will serve to place the chemical theory of this topic in a context which relates to industrial applications and their social implications. These processes also provide ideal situations to distinguish between the *theoretical conditions* that would favour a high yield of the desired product and the *optimum conditions* actually employed in response to economic and productivity demands.

Objectives

- (i) To demonstrate reactions in the laboratory that can go 'both ways' and utilise them to introduce the concept of a sealed system reaching an equilibrium position.
- (ii) To use models to emphasise that the chemical equilibrium is 'dynamic' in order to eliminate the misconception that at equilibrium both the forward and backward reaction have stopped.
- (iii) To consider qualitatively Le Chatelier's principle as applied to a system in equilibrium and use it to demonstrate examples how the forward or backward reaction can be favoured by altering the external conditions.
- (iv) To distinguish between the effect of altering reaction conditions on the rate or 'attainment of equilibrium' and on the 'equilibrium position'.
- (v) To distinguish between the most suitable 'theoretical conditions' that would favour a high yield of a specific species and the 'optimum' or actual conditions employed in industrial processes; to show that the choice of conditions is a major consideration in some manufacturing processes as exemplified by the Haber process and the Contact process.
- (vi) To emphasise that catalysts are often a key factor in making industrial processes economical as they enable the reaction to occur at a 'compromise' lower temperature, but still obtain a sufficient yield in a relatively shorter time.

Unit 13 Reversible reactions Equilibria

□ **Content**

Topic	Item	Description	Additional notes
13.1	Reversibility of reactions.	Demonstration of some reactions that go both ways Difference between static and dynamic equilibrium	e.g. alternate addition of water / conc. HCl to bismuth trichloride solution; alternate addition of excess dilute NH ₄ OH / dilute H ₂ SO ₄ to copper (II) sulphate solution
	Dynamic equilibrium.	Kinetic picture of attainment of equilibrium; both reactions proceed at same rate; concentration of species remains constant	emphasis that proportion of reactants/products are not necessarily equal
	Le Chatelier's principle.	Demonstration of effect of changing reaction conditions on a system in equilibrium: <ul style="list-style-type: none"> • concentration e.g. alternate addition of dilute NaOH / dilute H₂SO₄ to bromine water • temperature e.g. heating / cooling a U-tube containing a NO₂ / N₂O₄ equilibrium mixture • pressure affecting a gaseous system where the equation shows total unequal volumes (or unequal number of molecules) of reactants and products e.g. $2\text{NO}_2 \rightleftharpoons \text{N}_2\text{O}_4$ • a catalyst as a substance that affects the attainment of dynamic equilibrium but not the equilibrium position 	distinction between the effect on attainment of equilibrium and the effect on equilibrium position in each case, any change/shift in equilibrium position must be explained using Le Chatelier's principle this will require knowledge that ΔH^- = exothermic and ΔH^+ = endothermic; and also that if forward reaction is exothermic the backward reaction is endothermic awareness that pressure causes no change in the equilibrium position of a gaseous system where the equation shows equal volumes of reactants and products e.g. $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$ link this to the use of a catalyst in the Haber process and in the Contact process (see below)

Topic	Item	Description	Additional notes
13.2	Experimental investigation of equilibrium.	<p>Students can investigate some simple systems:</p> <ul style="list-style-type: none"> - alternate addition of dilute H_2SO_4 / dilute NaOH to a chromate / dichromate equilibrium mixture 	an explanation of the shift in equilibrium in terms of increase / decrease in H^+ ion concentration
		<ul style="list-style-type: none"> - heating / cooling of ammonium chloride 	explanation in terms of favouring the endothermic / exothermic reaction respectively
13.3	Equilibria in industry.	<p>An application of the knowledge of reaction rates and equilibria to two well known industrial gaseous systems – the Haber and Contact processes.</p> <p>For each process:</p> <ul style="list-style-type: none"> • mention the raw materials, the starting materials and how they are obtained from the raw materials • give the equation for the system and its associated heat change • discuss the theoretical conditions that, according to Le Chatelier's principle, would favour the forward reaction • discuss the actual operating conditions employed, including the need of a catalyst, as a result of optimisation • revise the uses of ammonia and sulfuric acid 	<p>distinguish between the effect on rate of reaction (rate in attainment of equilibrium) and the effect on the equilibrium position (thus affecting the yield of ammonia and sulfur trioxide)</p> <p>students will be expected to recall the actual operating conditions</p>

Topic	Item	Learning Outcomes – at the end of this Unit students should be able to:	Time	Difficulty level		
				A	B	C
13.1	Reversibility of reactions. Dynamic equilibrium. Le Chatelier's principle.	recall that some chemical reactions are reversible and may reach a state of dynamic equilibrium				
		show an understanding of and explain, in terms of the forward and backward reactions, what is meant by dynamic equilibrium				
		show an awareness that at equilibrium the concentration of species (reactants and products) remains constant though not necessarily equal				
		recall and understand Le Chatelier's principle and be able to use it to predict the effect of changing the reaction conditions on a given reversible reaction at equilibrium, for example <ul style="list-style-type: none"> - given a state equation, to predict the effect of change of concentration at equilibrium - given a reaction and its heat change, to predict the effect of a change in temperature at equilibrium 				
		distinguish between the effect of changes in the reaction conditions on the <i>rate of attainment</i> of equilibrium and their effect on the <i>equilibrium position</i> (or yield of a substance)				
		recall that a catalyst only affects the rate of attainment of equilibrium (or rate of formation of the desired species), but not the equilibrium position (or the proportion of a species)				
13.2	Experimental investigation of equilibrium.	explain the shift in the equilibrium position observed in a simple investigation of dynamic equilibrium				
13.3	Equilibria in industry.	demonstrate an awareness of the importance of chemical equilibrium in the chemical industry				
		apply their understanding of equilibria to consider the theoretical conditions which would favour a high yield of ammonia in the Haber process and sulfur trioxide in the Contact process				
		recall the actual (optimum) operating conditions used in the above processes including the catalyst				
		explain / interpret the optimum conditions in terms of the principles of kinetics and equilibria				
		show an awareness that the industrial operating conditions are a compromise between factors such as rate, yield, cost and catalyst life / activity				
		illustrate the economic importance of the Haber and Contact processes by stating uses of ammonia and sulfuric acid respectively				

Unit 14 Carbon and its compounds.

□ Introduction

The inorganic chemistry of carbon can be covered in the context of non-metals and the Periodic Table, however it is important to emphasise that students are not required to show any knowledge of the chemistry of the other Group 4 elements or trends in the group. The allotropy of carbon should be limited to the existence of the element in different physical forms with distinct physical properties. Too much emphasis need not be placed on structure at this stage. An explanation of the difference in the physical properties of the allotropes in relation to their different three - dimensional structure will be covered in Unit 16. The content of this section follows the usual pattern of listing the typical physical and characteristic chemical properties, and uses, of carbon and its oxides. A detailed description of the laboratory preparation is limited to carbon dioxide. The preparation of insoluble carbonates should be linked to a revision of the general method of preparing insoluble salts by precipitation. Similarly, the properties of carbonates should be considered only as general trends, without detailed knowledge of the chemistry of individual carbonates.

The ability of carbon to catenate can then lead to the central role of carbon in organic chemistry. From the onset of this section, it will be necessary to emphasise those features that are distinctive to organic chemistry. These include

- Nomenclature - the naming of compounds in terms of the number of carbon atoms and the functional groups they contain
- Structural formulae
- Isomerism
- The concept of a homologous series
- Types of reaction and related terms commonly met in organic chemistry e.g. substitution, addition, hydrolysis, esterification, polymerisation

It will probably be necessary to spend some time discussing the first four points listed above before a study of specific homologous series is carried out. The use of 'space filling' and 'ball and spoke' molecular models are ideal aids to illustrate the molecular structure and bonding in simple organic molecules. The concept of homology and isomerism can be utilised to explain the large number of organic compounds. Substitution reactions, typical of alkanes, and the addition reaction across the double bond in alkenes must be clearly linked to saturation and unsaturation respectively.

Many students are of the opinion that there is just one liquid alcohol, commonly found as a constituent of alcoholic drinks. It must be emphasised that there are many other alcohols, all members of a homologous series. The most common of these, ethanol, is studied as an example of the series but students are expected to know the names and formulae of other alcohols and should be capable of predicting their reactions by comparing to ethanol. Similarly, the carboxylic acids can be introduced through ethanoic acid which students will have already met by way of reactions involving the previous group. However, students will be expected to name other carboxylic acids and predict their reactions.

The refining of crude oil provides scope to create a learning context which reflects the importance of chemistry in industry and illustrates how chemists can influence and contribute to the quality of our everyday lives. Similarly, the manufacture of synthetic polymers further emphasises the relevance of carbon chemistry to everyday life and should be seen by students as a response by chemists and the chemical industry to societal requirements. The effect on the natural environment due to pollution from the products of combustion, as also the non-biodegradability of many synthetic polymers, will highlight the adverse effects of the oil industry and petrochemical products.

Unit 14 Carbon and its compounds.

Objectives

- (i) To discuss the different physical characteristics and related uses of the allotropes of carbon.
- (ii) To prepare carbon dioxide in the laboratory and investigate its properties.
- (iii) To discuss the formation of carbon dioxide and carbon monoxide from complete/incomplete combustion of carbon containing fuels, and consider their effect on the environment and on the body.
- (iv) To revise the reducing action of carbon and carbon monoxide on metal oxides and its application to the extraction of metals from their ores.
- (v) To revise the general reactions of carbonates by making links to other related topics in the syllabus.
- (vi) To introduce key basic ideas and terms that are crucial to an understanding of organic chemistry, including types of bonds, molecular formulae, displayed (structural) formulae and nomenclature of organic compounds.
- (vii) To build models of simple organic compounds to highlight the difference between displayed structural formulae and true 3-dimensional distribution of atoms; to utilise such models to show straight and branched chains and to explain isomerism.
- (viii) To illustrate the similar characteristics and trends in a homologous series through a discussion of the properties of the alkanes.
- (ix) To utilise suitable models to distinguish between saturation in alkanes and unsaturation in alkenes/alkynes, and to illustrate the difference between substitution and addition reactions exhibited by these compounds,
- (x) To relate the greater reactivity of alkenes/alkynes to the presence of a double/triple covalent bond between two carbon atoms and discuss a range of reactions exhibited by these compounds.
- (xi) To make students aware of the range of substances that can be derived from crude oil and ways in which chemical processes can transform these substances into new materials.
- (xii) To appreciate the social, economic, environmental and health and safety implications associated with the petrochemical industry.
- (xiii) To describe the formation of ethanol and describe some typical properties of alcohols.
- (xiv) To discuss the chemistry of carboxylic acids as dilute acids and their reactions with alcohols to form esters.
- (xv) To establish the principle that, during addition polymerisation, many small molecules of unsaturated monomers join to form large molecules of polymers.

Unit 14 Carbon and its compounds

□ Content

Carbon - Inorganic Chemistry

Topic	Item	Description	Additional notes
14.1	Carbon.	<ul style="list-style-type: none">• diamond and graphite as allotropes of carbon; difference in physical properties; uses• complete / incomplete combustion of carbon• reaction with steam• reducing action of carbon on metal oxides	<p>a description of the structures is not required at this stage (three dimensional structures will be covered in Unit 16)</p> <p>resulting in formation of carbon dioxide and carbon monoxide respectively (covered in Form 3 Unit 4)</p> <p>linked to its use in the extraction of metals</p>
	Oxides of carbon. Carbon dioxide.	<ul style="list-style-type: none">• laboratory preparation of carbon dioxide• test for carbon dioxide using lime water• physical properties (sublimation, density)• chemical properties: acidic nature (reaction with water) reaction with caustic alkalis• uses of the gas and associated properties	<p>collection of gas over water; or collection of pure dry gas</p> <p>including a chemical explanation of the reaction</p> <p>link to action of H_2CO_3 on limestone (covered in Unit 4)</p> <p>link to absorption of carbon dioxide</p> <p>e.g. use in fire extinguishers (dense gas, does not support combustion); refrigerant (sublimation of dry ice); in fizzy drinks</p>

Topic	Item	Description	Additional notes
	Carbon monoxide.	<ul style="list-style-type: none"> • as a neutral gas • toxic nature; and hence the danger of burning carbon containing fuels in a confined space • combustion of carbon monoxide to form carbon dioxide • use of carbon monoxide as a reducing agent • separation of carbon monoxide from a carbon monoxide / carbon dioxide mixture 	<p>N.B. the laboratory preparation of carbon monoxide is not required</p> <p>can be used as a test for the gas</p> <p>link to extraction of iron in the Blast furnace (Unit 7)</p> <p>by absorbing carbon dioxide in aqueous alkali</p>
	Carbonates.	<p>general properties</p> <ul style="list-style-type: none"> • insolubility of most carbonates • preparation of insoluble carbonates by precipitation • reaction with dilute acids; test for a carbonate • thermal stability of carbonates of potassium and sodium; thermal decomposition of carbonates • revise properties and uses of specific carbonates: washing soda – efflorescence; water softener • limestone - naturally occurring form of calcium carbonate; uses as building material; to produce lime; removal of impurities in Blast furnace 	<p>to be considered only as general trends of common carbonates; detailed knowledge of the reactions of individual carbonates is not necessary</p> <p>revise ‘general ionic equation’ for this reaction</p> <p>revision of relevant reactions covered in Topic 9.1 (Action of heat on materials)</p> <p>(covered in Units 4 and 5)</p> <p>revise role of limestone in formation of temporary hardness of water</p>

Topic	Item	Learning Outcomes – at the end of this Unit students should be able to:	Time	Difficulty level		
				A	B	C
14.1	Carbon and its compounds	define allotropy and name the allotropes of carbon				
		describe and compare the physical properties of diamond and graphite				
		link the reaction of carbon with metal oxides to its use in extracting certain metals				
		describe the preparation and collection of pure, dry carbon dioxide using suitable apparatus				
		recall and explain the chemical test for carbon dioxide				
		illustrate the acidic nature of carbon dioxide through its reaction with water and caustic alkalis				
		relate the uses of carbon dioxide to specific physical and / or chemical properties of the gas				
		recall the products of the complete and incomplete combustion of carbon and carbon containing fuels				
		recall that carbon monoxide is a neutral gas				
		recall that carbon monoxide burns to form carbon dioxide				
		appreciate the toxic nature of carbon monoxide and hence the potential danger of burning carbon containing fuels in a confined space				
		understand and describe the isolation of carbon monoxide from a gaseous mixture of carbon monoxide and carbon dioxide				
		recall that, like carbon, carbon monoxide can also reduce the oxides of less reactive metals				
		appreciate that limestone is a naturally occurring forms of calcium carbonate				
		recall that common carbonates are insoluble except those of potassium, sodium and ammonium				
		describe the preparation of pure, dry samples of insoluble carbonates by the reaction of suitable reagents in solution				
		use the general pattern of the reactions of carbonates to predict the outcome of such reactions				
recall that calcium carbonate is used in the extraction of iron						

Unit 14 Carbon and its compounds

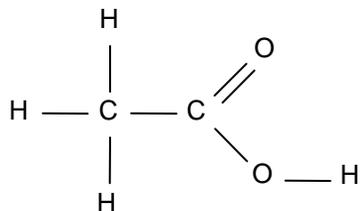
□ Content

Carbon - Organic Chemistry

Topic	Item	Description	Additional notes
14.2	Introduction. Basic terms.	<ul style="list-style-type: none">• definition of an organic compound• ability of carbon to catenate; types of bond• hydrocarbons – grouped into ‘families’ or homologous series• types of hydrocarbon molecules• types of formulae<ul style="list-style-type: none">- empirical, molecular and structural formulae- general formula for a homologous series• naming of organic compounds<ul style="list-style-type: none">- prefix = number of carbon atoms- suffix / ending = homologous series / functional group- alkyl groups• isomers<ul style="list-style-type: none">- structural isomerism in C_4H_{10} and C_5H_{12} only- functional group isomerism of C_2H_6O only• general characteristics of a homologous series	<p>representation of single, double and triple covalent bonds</p> <p>types of bond in each series</p> <p>straight and branched chains as exemplified by the alkanes</p> <p>practise on naming and writing formulae of the first five straight chain hydrocarbons namely –ane, -ene, -yne, -anol and –anoic acid e.g. limited to methyl and ethyl</p> <p>systematic naming of branched isomers is not required can be left for Topic 14.6 (naming of the ether is not required)</p>

Note that an acceptable response to a request for a structural formula will be to give a ‘displayed formula’ which should show both the placing of the atoms of each element and the type / number of bonds between them

e.g.



for ethanoic acid

Topic	Item	Description	Additional notes
14.3	Alkanes.	<ul style="list-style-type: none"> homologous series of hydrocarbons lacking a functional group of general formula C_nH_{2n+2} gradation in physical properties e.g. boiling point reactions of alkanes <ul style="list-style-type: none"> - complete combustion forming carbon dioxide and water; - incomplete combustion forming carbon and carbon monoxide - saturation in alkanes; substitution reactions with halogens; naming of products uses of alkanes – as fuels (e.g. domestic LPG gas); to obtain other chemicals (e.g. hydrogen from methane); use of liquid alkanes as solvents 	<p>Using the general formula to find the molecular formulae of homologues; writing molecular / structural formulae of first five straight chain homologues</p> <p>linked to length of hydrocarbon chain</p> <p>N.B. laboratory preparation of alkanes is not required</p> <p>emphasise clean, blue, non-smoky (non-luminous) flame exothermic reaction – linked to use of alkanes as fuels</p> <p>linked to the danger of burning carbon containing fuels in a limited supply of air</p> <p>limited to monosubstitution e.g. methane with chlorine; ethane with bromine water</p> <p>N.B. No knowledge of preparations and reactions of chlorofluorocarbons is required</p> <p>reasons why alkanes are good fuels</p>
14.4	Alkenes.	<ul style="list-style-type: none"> homologous series with general formula C_nH_{2n} Names, molecular and structural formulae of first five homologues laboratory preparation of ethene <ul style="list-style-type: none"> - by dehydration of ethanol <ol style="list-style-type: none"> using concentrated sulfuric acid as the dehydrating agent using alumina or porous pot (catalytic dehydration) - by small scale cracking (e.g. of paraffin oil) using alumina or porous pot presence of double bond (unsaturation) in alkenes; greater reactivity of alkenes complete combustion of alkenes (ethene), forming carbon dioxide and water 	<p>N.B. Naming of positional isomers is not required</p> <p>The principle of dehydration should be applied to predict the alkene that would be obtained by dehydration of other alcohols</p> <p>N.B. large scale cracking will be covered in Topic 14.5</p> <p>N.B. structural / positional isomerism in alkenes is not required</p> <p>luminous/smoky flame as an indication of unsaturation due to high proportion of carbon (compare to flame of ethane)</p>

Topic	Item	Description	Additional notes
14.4	Alkenes (contd.)	<ul style="list-style-type: none"> addition reactions of alkenes with <ul style="list-style-type: none"> - hydrogen (hydrogenation) to form corresponding alkane - halogens (halogenation) e.g. decolourisation of bromine water 	<p>emphasise that these occur across the double bond</p> <p>reactions should be represented by molecular formula equations and structural formula equations</p> <p>used as a distinguishing test between alkanes and alkenes</p> <p>reaction with potassium manganate (VII) is not required</p>
		<ul style="list-style-type: none"> addition reactions of ethene (only) with <ul style="list-style-type: none"> - hydrogen halide (hydrohalogenation) - steam (hydration) including conditions 	link to preparation of ethanol
		<ul style="list-style-type: none"> uses of alkenes (ethene); starting molecules for manufacture of other organic products 	N.B. polymerisation of ethene to polyethene will be covered in Topic 14.6
	Alkynes.	<ul style="list-style-type: none"> unsaturation due to carbon – carbon triple bond exemplified by reactions with hydrogen and halogens combustion (very sooty flame due to high percentage by mass of carbon) 	a detailed study of the chemistry of the alkynes is not required, however students will be expected to predict the properties of straight chain alkynes in comparison to alkenes.
14.5	Natural gas Crude oil.	<ul style="list-style-type: none"> as a mixture of gaseous alkanes, mainly methane as a mixture of hydrocarbons, mainly alkanes refining of crude oil <ul style="list-style-type: none"> - the principle of fractionation (fractional distillation) to obtain fractions; uses of the fractions - thermal/catalytic cracking of long hydrocarbon chains, limited to forming <u>one</u> shorter chain alkane and ethene pollution problems associated with combustion of fossil fuels; formation of carbon monoxide and carbon from incomplete combustion of hydrocarbons pollution problems associated with crude oil spillage and the release of hydrocarbons into the atmosphere 	<p>special mention of LPG gas as a domestic fuel used in Malta</p> <p>its use as a raw material to obtain other chemicals</p> <p>only a schematic diagram is required; details of the structure and running of the fractionating tower is not required</p> <p>(groups of compounds within a boiling point range); boiling point range of hydrocarbons is related to carbon number</p> <p>cracking of diesel oil to obtain petrol and ethane as an industrial application of this process</p> <p>revision of Form 3 work (Unit 4)</p> <p>with particular reference to the local situation</p>

Topic	Item	Description	Additional notes
14.6	Alcohols.	<ul style="list-style-type: none"> • homologous series with general formula $C_nH_{2n+1}OH$; names/structural formulae of first five homologues • reactions of alcohols <ul style="list-style-type: none"> - combustion (exothermic; clean flame) - with sodium - dehydration by concentrated sulfuric acid to give alkenes - with phosphorus (v) chloride to liberate misty fumes (used as a test for the -OH group) • reactions of ethanol <ul style="list-style-type: none"> manufacture of ethanol <ul style="list-style-type: none"> - by fermentation of glucose - by catalytic hydration of petroleum derived ethene - oxidation to ethanoic acid using acidified potassium dichromate • uses of alcohols as liquid solvents 	<p>naming of positional isomers is not required revise functional group isomerism of C_2H_6O</p> <p>link to use as a clean fuel naming of alkaoxides is not required experimental details are not required naming of the products of this reaction is not required</p> <p>link to manufacture of alcoholic drinks uses of ethanol obtained by this method formal redox reactions are not required</p>
14.7	Carboxylic acids.	<ul style="list-style-type: none"> • homologous series with general formula $C_nH_{2n+1}COOH$ • formation of ethanoic acid by oxidation of ethanol • ethanoic acid as a weak acid; reactions with <ul style="list-style-type: none"> - magnesium - sodium hydroxide - calcium carbonate • esterification <ul style="list-style-type: none"> - reaction between carboxylic acids and alcohols to form esters; dual function of conc. H_2SO_4 as a catalyst and to favour the forward reaction - recognition that the esters are another homologous series characterized by their fruity smell (test for an ester) - uses of the esters 	<p>structural formulae of first five straight chain homologues</p> <p>already covered in Topic 14.6</p> <p>explained in terms of slight ionisation giving acidic character; slow rates of reaction</p> <p>formation of ethanoates</p> <p>N.B. naming of esters formed <u>is limited to</u> ethyl ethanoate the hydrolysis of esters is not required</p> <p>explained in terms of equilibrium position A detailed chemistry of the esters is not required</p> <p>e.g. in flavouring and in perfumes</p>

Topic	Item	Description	Additional notes
14.8	Addition Polymerisation	<ul style="list-style-type: none"> • principle of addition polymerisation of unsaturated monomers to form long chain saturated polymer • three examples of addition polymers: <ul style="list-style-type: none"> ▪ polyethene <ul style="list-style-type: none"> - principle of addition polymerization of ethene to polyethene; structure of monomer and polymer (showing up to three repeating units) - physical/chemical differences between ethene and polythene - uses of polythene related to its properties ▪ polyvinylchloride (PVC) <ul style="list-style-type: none"> - structure of monomer / polymer molecules - uses of PVC and related properties ▪ polytetrafluoroethene (PTFE) <ul style="list-style-type: none"> - structure of monomer / polymer molecules - uses of PTFE related to its properties 	<p>polymer is the only product; has the same empirical formula as the monomer</p> <p>N. B. preparation conditions are not required for any of these examples</p> <p>N.B. knowledge of condensation polymerization is not required</p>

Topic	Item	Learning Outcomes – After completing Topics 14.2 to 14.4 students should be able to:	Time	Difficulty level		
				A	B	C
14.2	Basic terms	interpret and use basic organic nomenclature and terminology associated with organic reactions as specified in the syllabus				
		recall the names and draw the structure of the unbranched alkanes, alkenes, alcohols and carboxylic acids, containing up to five carbon atoms per molecule				
		distinguish between general formulae for a homologous series; empirical, molecular and structural formulae for specific compounds				
		state the type of compound present in an organic chemical ending in -ane, -ene, -ol, or -oic acid				
		identify functional groups (e.g. C = C, -OH, -COOH) and hence give the type or name of a compound, given its structural formula				
		describe and, given molecular structures, identify structural isomerism in C ₄ H ₁₀ and C ₅ H ₁₂ and functional group isomerism of C ₂ H ₆ O				
		describe the concept of a homologous series as a 'family' of similar compounds, with similar properties due to the presence of the same structure or functional group				
		describe the general characteristics of a homologous series				
14.3	Alkanes.	state / explain what is meant by a saturated hydrocarbon				
		describe alkanes as being generally unreactive except in terms of monosubstitution by halogens; give equations for, and name or draw the displayed formulae of the products of substitution reactions				
		describe, with equations, the complete combustion of alkanes, including the appearance of the flame				
14.4	Alkenes and Alkynes	describe the laboratory preparation of ethene by cracking or by dehydration of ethanol				
		describe and explain the difference in the appearance of the flame during complete combustion of an alkene or alkyne, in comparison to the combustion of an alkane				
		state / explain what is meant by unsaturated hydrocarbons				
		describe the properties of alkenes as a result of unsaturation – namely the addition reactions with halogens and hydrogen; describe the reaction of ethene with steam and hydrogen halide				
		show an awareness of unsaturation in alkynes and predict their reactions				
		identify saturated and unsaturated hydrocarbons from molecular structures and describe a distinguishing test between alkanes and alkenes/alkynes by using aqueous bromine				

Topic	Item	Learning Outcomes – After completing Topic 14.5 students should be able to:	Time	Difficulty level		
				A	B	C
14.5	Natural gas and crude oil	name methane as the main constituent of natural gas and describe its use as a fuel				
		state that petroleum is a complex mixture of hydrocarbons; describe and explain its separation into fractions by fractional distillation; recall that fractional distillation produces more long-chain hydrocarbons and less of the short-chain, than required				
		state that a fraction is a group of compounds with boiling points within a given range				
		recall the names of the different fractions and give examples of their uses				
		relate the different fractions to molecular size and show an understanding that the larger the hydrocarbon molecules, the higher the boiling point (and the less volatile) the hydrocarbon is at a given temperature				
		state that liquid petroleum gas (LPG) is a common domestic fuel used in Maltese households and is a mixture containing mainly butane				
		state that hydrocarbons burn completely to produce only carbon dioxide and water; write balanced equations for the combustion of a given hydrocarbon				
		show an awareness of the hazards of incomplete combustion of hydrocarbons resulting in the formation of toxic carbon monoxide				
		give examples of pollution problems associated with the combustion of fossil fuels				
		explain that cracking involves the breaking down of larger hydrocarbon chains in some fractions into smaller ones, some of which have carbon-carbon double bonds				
		describe the principle of cracking crude oil fractions for producing smaller, more useful molecules and in particular, describe the manufacture of ethene by cracking of diesel oil				
		show an awareness that many materials used in households are manufactured from starting materials obtained from crude oil				
		show an awareness that many materials used in households and in industry, including textiles, plastics, detergents, solvents, cosmetics and agricultural products are made from organic chemicals				
		discuss the potential damage to the environment that might arise from the spillage of crude oil and the release of hydrocarbons into the atmosphere				

Topic	Item	Learning Outcomes – After completing Topics 14.6 to 14.8 students should be able to:	Time	Difficulty level		
				A	B	C
14.6	Alcohols	describe and explain how aqueous ethanol is prepared by the fermentation of glucose, followed by fractional distillation to obtain a concentrated solution				
		describe how ethanol is manufactured by the catalytic hydration of ethene				
		name the uses of ethanol; relate the uses of ethanol as a constituent of alcoholic drinks; as a solvent or as a fuel, according to its method of manufacture				
		recall and describe the reaction of phosphorus (V) chloride with ethanol as a test for the presence of the –OH group				
		recall and describe the chemical properties of ethanol in terms of the following reactions: its combustion; reaction with sodium; dehydration to ethene; oxidation to ethanoic acid				
14.7	Carboxylic acids	recall that ethanoic is a product of the oxidation of ethanol using acidified potassium dichromate				
		show an understanding why ethanoic acid is a weak acid due to slight ionisation				
		describe the reactions of ethanoic acid as a weak acid in terms of its reactions with magnesium, with sodium hydroxide and with calcium carbonate, resulting in the formation of ethanoates				
		describe the formation of esters from carboxylic acids using ethyl ethanoate as an example; draw the molecular structure of ethyl ethanoate; explain the dual role of conc. sulfuric acid in esterification				
		state how to test for an ester (recall that esters are another homologous series characterised by their distinct pleasant smells)				
14.8	Polymers	recall that polymers are large molecules which are formed by a combination of many smaller molecules				
		describe different macromolecules as having different monomer units				
		explain how addition polymers are formed from unsaturated monomers				
		recall the uses and associated properties of polythene, polyvinylchloride and polytetrafluoroethene				
		deduce the repeating unit in a polymer from the given monomer or vice-versa				
		identify the monomers present in a given section of a polymer molecule				
		show an awareness of the non-biodegradability of many polymers and the polluting problems they cause				

Unit 15 Energetics.

□ Introduction

The topic of energetics is a difficult one at this level but its inclusion can be justified by its relevance to everyday life and to industry. Students will already be familiar with the fact that chemical reactions are accompanied by energy changes and will have noticed that many test-tube reactions liberate or absorb heat. Some of these reactions could be carried out to refresh the topic of energy changes however it must be emphasised that we observe only the overall effect. It is important for students to realise that a reaction involves rearrangement of particles and that this entails first the breaking of bonds and then the formation of new bonds which means that there is both absorption and liberation of energy. This will lead to the concept of enthalpy change as the overall detectable energy change resulting from both the breaking and of forming of bonds in the course of a chemical reaction.

The ΔH convention is also difficult and therefore needs careful introduction if students are to grasp the main ideas in this section. It is important to emphasise that energy is exchanged between the system and the surroundings and that energy level diagrams and the sign ΔH are considered with respect to the system, not the surroundings. A simple form of energy level diagram showing ΔH as the difference of energy levels between reactants and products is sufficient. Energy level diagrams which include the concept of an energy barrier can be used to explain the function of a catalyst.

Experimental work is limited to the determination of the heat of combustion of an alcohol using simple apparatus even though good results are difficult to obtain but this will provide scope for discussion about experimental errors.

A discussion about energy requirements, finite fuels and the need for alternative energy sources will enhance the relevance to everyday life of a study of energy in chemistry.

Objectives

- (i) To investigate and study chemical reactions in which there is energy transfer to and from the surroundings.
- (ii) To establish that energy transfer in chemical processes is associated with the breaking and reforming of chemical bonds.
- (iii) To introduce simple energy level diagrams to represent the enthalpy change during exothermic and endothermic reactions.
- (iv) To utilise a mathematical equation to calculate the heat change during a chemical reaction.
- (v) To use simple experimental calorimetry involving basic quantitative work to determine heat of neutralisation and estimate the heat of combustion of an alcohol.

Unit 15 Energetics

□ Content

Topic	Item	Description	Additional notes
15.1	Law of conservation of energy.	<ul style="list-style-type: none"> • awareness that energy can be changed from one form to another and that chemical reactions are accompanied by energy changes 	examples of chemical energy converted to other forms of energy (e.g. light, sound, electricity and heat) during chemical reactions
	Energy stored in chemicals.	<ul style="list-style-type: none"> • two main sources of energy: kinetic energy of particles; bond energy inside and between particles • chemical reactions usually involve both bond breaking (energy absorbed) and bond formation (energy liberated) 	bond energy as the most significant source of energy awareness that amount of energy absorbed or released depends on the strength of bonds; whether strong intramolecular or weak intermolecular
	Enthalpy change of a reaction	<ul style="list-style-type: none"> • energy (or heat content) of reactants and products are different • overall heat change depends on sum total of bond breaking and bond formation • endothermic and exothermic reactions described in terms of heat energy difference due to bond breaking and bond formation (simple treatment only) 	Heat content of a substance given the symbol H the kiloJoule, kJ, as a unit of measuring heat energy Students will not be required to use average bond dissociation energies to calculate the energy change during a chemical reaction.
	The ΔH convention	<ul style="list-style-type: none"> • ΔH as the symbol representing the change in heat content (enthalpy) • ΔH as the energy difference between products and reactants • exothermic reactions take symbol $\Delta H = -$ and endothermic reactions take symbol $\Delta H = +$ 	$\Delta H = H_{\text{products}} - H_{\text{reactants}}$ Use of the ΔH notation in writing thermochemical equations

Topic	Item	Description	Additional notes
15.2	Energy level diagrams and thermochemical equations.	<ul style="list-style-type: none"> • Simple energy level diagrams, illustrating the idea of activation energy, to represent an exothermic and endothermic reaction <ul style="list-style-type: none"> - Exothermic: products at lower energy level than reactants - Endothermic: products at higher energy level than reactants • A catalyst as a substance that provides an alternative reaction route with a lower activation energy 	Simple energy level diagram showing how catalysts function by lowering the activation energy
15.3	Energy change defined per mole	<ul style="list-style-type: none"> • Definitions of: <ul style="list-style-type: none"> - heat of combustion - heat of neutralisation - heat of precipitation - heat of solution • Calculation of ΔH values for the above heat changes: <ul style="list-style-type: none"> - finding the heat energy absorbed/liberated using heat (energy) change = $mc\Delta\theta$ - converting the amount of substance reacting into moles - using the above values to calculate ΔH_{mol} for the above heat changes 	explanation why this is constant, using the ionic equation

Topic	Item	Description	Additional notes
15.4	Experiment to estimate ΔH combustion.	<ul style="list-style-type: none"> • a simple method to determine an approximate value for the heat of combustion of an alcohol e.g. using a tin can and spirit lamp • calculating the heat of combustion from the results of the experiment • awareness of limitations and sources of error that contribute to obtaining a low value for the heat of combustion in this experiment 	students will be required to give the practical details of such an experiment in exam questions
	Experimental determination of ΔH neutralisation.	<ul style="list-style-type: none"> • An experiment using simple apparatus (e.g. a lagged polystyrene cup) to determine the heat of neutralisation 	students will be required to give the practical details of such an experiment in exam questions
15.5	Fuels.	<ul style="list-style-type: none"> • a fuel as a source of energy • the finite nature of fossil fuels; coal and oil as non-renewable energy sources • awareness of alternative energy resources: hydroelectric energy, solar energy, wind, wave, tidal, biomass and geothermal. 	<p>link the exothermic burning of fuels to heat of combustion</p> <p>advantages and disadvantages of energy resources</p>

Topic	Item	Learning Outcomes – After completing this Unit students should be able to:	Time	Difficulty level		
				A	B	C
15.1	Energy stored in chemicals.	show an awareness that chemical reactions are often accompanied by energy changes, principally in the form of heat energy				
	Enthalpy change of a reaction	define an exothermic reaction as one in which heat energy is liberated and an endothermic reaction as one in which heat energy is absorbed				
		recall that bond breaking is endothermic and that bond forming is exothermic				
		show an understanding that many reactions involve first the breaking of bonds and then the forming of new bonds, which results in an overall heat change				
		show an understanding that enthalpy change (ΔH) is an energy difference between products and reactants				
15.2	Energy level diagrams	draw simple energy level diagrams to represent the progress of an exothermic or endothermic reaction				
		understand that a catalyst provides an alternative reaction route with a lower activation energy				
		use the ΔH convention in terms of exothermic (ΔH negative) and endothermic (ΔH positive) reactions				
15.3	Energy change per mole	define heats of combustion, solution, neutralisation and precipitation, and write thermochemical equations to represent these heat changes				
		use the kilojoule, kJ, as a unit of energy				
15.4	Experimental determination of ΔH .	carry out and describe a simple calorimetric method to determine the heat of neutralisation and to estimate the heat of combustion of an alcohol				
		calculate heat energy changes from experimental measurements using the relationship 'heat (energy) change = $mc\Delta\theta$ '				
		calculate ΔH_{mol} values, given the heat energy liberated and the quantity of the substance(s) involved in the reaction				
15.5	Fuels.	state that a fuel is a chemical that burns giving out energy and that combustion is an exothermic reaction of a substance with oxygen; link the exothermic burning of fuels to heat of combustion				
		appreciate the finite nature of fossil fuels				
		show an awareness of other sources of energy, and their advantages and disadvantages				

Unit 16 Structures

□ Introduction

The structure in solids – ionic, metallic, giant molecular and small molecules should be illustrated by one or two examples in each case. An appreciation of the dependence of the properties of different solid structures on the packing of particles, and on the nature of the chemical bonding between the particles, is expected. Students should be fully aware that the particles can be atoms, molecules or ions. Because many students find it difficult to think in three dimensions, the use of space filling models and other aids are of utmost importance in assisting students to visualise the regular packing of particles in lattice structures.

Objectives

- (i) To help students form a mental picture of different structures through the use of suitable models that illustrate the packing and 3-dimensional distribution of particles in the different structures.
- (ii) To relate the properties of elements and compounds to their structures, the type of particles and the nature of the bonding between them.
- (iii) To compare and contrast the structures and properties of giant ionic lattices in compounds with the structure of giant metallic lattices.
- (iv) To present the idea that in metals the outermost electrons can ‘delocalise’ across all other atoms in the structure, such that they become attracted to the positively charged nuclei.
- (v) To utilise the conceptual model of a ‘sea’ of electrons to explain key properties, such as electrical and thermal conductivity, in metals.
- (vi) To introduce giant covalent structures and compare and contrast the properties of diamond and graphite in relation to their structures.
- (vii) To emphasise through models, that in simple molecules the bonding holding the atoms together is strong, but in most cases, the bonding between the molecules is relatively weak.
- (viii) To distinguish between inter-molecular and intra-molecular bonds and thus explain the different energy requirements for melting structures composed of simple covalent molecules as opposed to giant covalent molecular substances

Unit 16 Structures

□ Content

Topic	Item	Description	Additional notes
16.1	Giant structures.	<ul style="list-style-type: none"> • giant ionic lattice <ul style="list-style-type: none"> - lattice of closely packed oppositely charged ions - properties related to the structure and the bonding • giant metallic lattice <ul style="list-style-type: none"> - general bonding model in a metallic structure - physical properties explained in terms of this bonding model • giant molecular (macromolecule) <ul style="list-style-type: none"> □ diamond <ul style="list-style-type: none"> - three dimensional picture of distribution of atoms - properties of diamond related to the structure - uses related to the physical properties □ graphite <ul style="list-style-type: none"> - three dimensional picture of graphite consisting of layers of hexagons - properties of graphite explained in relation to the structure - uses related to the physical properties 	<p>exemplified by sodium chloride i.e. high melting point, hard crystalline solid, soluble in water, electrolyte (molten or in solution)</p> <p>closely packed positive ions in a sea of electrons i.e. high melting point, thermal and electrical conductivity, malleability</p> <p>limited to diamond and graphite</p> <p>strong covalent bonding throughout the macromolecule i.e. high sublimation temperature, hardness, non-conductor e.g. cutting / boring tools</p> <p>emphasise the strong covalent bonds between atoms in layers; weak intermolecular forces between layers i.e. high sublimation temperature, soft / slippery, conductor of electricity in terms of free electrons e.g. lubricant; electrodes</p>
16.2	Small molecules.	<ul style="list-style-type: none"> • Solids composed of simple molecules <ul style="list-style-type: none"> - description of the packing of small molecules in a simple covalent structure e.g. iodine or dry ice - distinction between strong covalent bonds 'inside' molecules (intramolecular) and the weak intermolecular forces - physical properties of this structure 	<p>N.B. shapes of molecules are not required Dative covalency not to be discussed</p> <p>a knowledge of the different types of intermolecular forces is not required i.e. low melting / boiling points, non-conductors, etc.</p>
		- distinction between the physical properties of giant covalent structures compared to crystals composed of simple molecules	e.g. high sublimation temperature of diamond and graphite as opposed to low sublimation temperature of iodine and dry ice
		- different energy requirements for simple molecular versus giant molecular lattice explained in relation to the bonding	simple treatment only

Topic	Item	Learning Outcomes – After completing this Unit students should be able to:	Time	Difficulty level		
				A	B	C
16.1	Giant structures.	describe the structure of sodium chloride as a giant three dimensional lattice of closely packed (alternating) positive and negative ions				
		explain the properties of a giant ionic structure in relation to the bonding and packing of particles in the three dimensional lattice				
		describe a bonding model in a metallic structure resulting in a giant lattice of closely packed positive ions in a ‘sea of electrons’				
		relate the physical properties of metals to the close packed structure of atoms and free valence electrons				
		understand that covalent bond formation can result in both simple (small) molecular structures (e.g. iodine) and in giant covalent (macromolecular) structures (e.g. diamond and graphite)				
		describe the giant covalent structures of diamond and graphite				
		compare and contrast the physical properties of diamond and graphite in relation to the bonding in the structures				
		explain electrical conductivity in graphite in terms of free (delocalised) electrons in its structure				
		relate the high sublimation temperatures of diamond and graphite to the strong covalent bonds throughout the three dimensional lattice				
		relate the uses of diamond and graphite to the properties resulting from their structures				
16.2	Small molecules.	describe simple solid covalent structures, (e.g. iodine or dry ice), and their related physical properties				
		show an understanding that in simple covalent structures, the bonds in the molecule (intramolecular) are strong covalent bonds while the forces between molecules (intermolecular) are weak bonds				
		relate low melting points/boiling points of simple covalent structures to the weak intermolecular forces				
		compare the difference in physical properties (e.g. melting and boiling point) of simple molecular substances (e.g. iodine) with those of giant covalent structures (e.g. diamond) in relation to the different types of bond that need to be broken				
		describe and explain the difference in volatility, solubility and electrical conductivity between ionic and covalent compounds				
		deduce the type of structure of a substance from given physical properties				