

## UNIT 4: ORGANIC CHEMISTRY I

**Recommended Prior Knowledge:** Unit 1 (Theoretical Chemistry) should have been studied before this unit. Although most of Unit 2 is not immediately relevant to this Unit, some prior discussion of bond energies, acids and bases, and kinetics of reactions, would be beneficial.

**Context:** This Unit should be studied before Unit 5, but can either precede or follow Units 2 and 3 (but see comment above).

**Outline:** This Unit is the first of two dealing with Organic Chemistry. It covers the formulae, names and shapes of organic compounds; isomerism; alkanes; alkenes; addition polymerisation; and halogenoalkanes.

section	Learning Outcomes	Suggested Teaching Activities	Lesson allocation (approx.%)	Other references
10.1(a)	interpret, and use the nomenclature, general formulae and displayed formulae of the following classes of compound: (i) alkanes and alkenes (ii) halogenoalkanes (iii) alcohols (primary, secondary and tertiary) (iv) aldehydes and ketones (v) carboxylic acids and esters (vi) amines (primary only) and nitriles [Candidates will be expected to recognize the shape of the benzene ring when it is present in organic compounds. Knowledge of benzene or its compounds is not required for AS.]	General rules of nomenclature could be given at the start, i.e. finding the longest chain; numbering of substituents from the end that gives the lowest numbers; the general shape of a name: prefix-stem-suffix. More specific examples could be covered when functional groups are dealt with in detail. Practice translating name into structural formula and vice versa. Distinguish between the molecular formula (e.g. $C_3H_7Cl$ ), the structural formula (e.g. $(CH_3)_2CHCl$ or $CH_3CH_2CH_2Cl$ ) and the displayed formula, which shows all bonds as lines (but also includes all atoms, incl. H atoms). For ring compounds (incl. benzene) the "skeletal" formula, showing bonds but not C or H atoms, is acceptable as a structural or displayed formula.	10	<a href="#">site 1</a> (nomenclature) <a href="#">site 2</a> (AS $\Rightarrow$ functional groups) <a href="#">site 8</a> (nomenclature) <a href="#">site 9a</a> (organic chemistry)  C+H 22.4-22.5 M109
10.1(b)	interpret, and use the following terminology associated with organic reactions: (i) functional group (ii) homolytic and heterolytic fission (iii) free radical, initiation, propagation, termination (iv) nucleophile, electrophile (v) addition, substitution, elimination, hydrolysis (vi) oxidation and reduction. [in equations for organic redox reactions, the symbols [O] and [H] are acceptable]	These terms should be introduced when the reactions of the relevant functional group are being studied.		C+H 22.7-22.8 M109
10.1(c)	(i) describe the shapes of the ethane and ethene molecules (ii) predict the shapes of other related molecules	Tetrahedral and 3-dimensional, and trigonal planar and 2-dimensional respectively. The tetrahedral arrangement of bonds around a 4-coordinated $sp^3$ carbon atom, and the trigonal arrangement of bonds around a 3-coordinated $sp^2$ carbon atom.	6	C+H 22.3 M109
10.1(d)	explain the shapes of the ethane and ethene molecules in terms of $\sigma$ and $\pi$ carbon-carbon bonds	The $\pi$ bond being due to the sideways overlap of two 2p orbitals, creating electron density above and below the plane		

		of the molecule.		
10.1(e)	describe structural isomerism	Relate to nomenclature. Include both chain isomerism (butane, 2-methylpropane) and positional isomerism (propan-2-ol and propan-1-ol).	18	<a href="#">site 1</a> (structural isomerism)
10.1(f)	describe <i>cis-trans</i> isomerism in alkenes, and explain its origin in terms of restricted rotation due to the presence of $\pi$ bonds	Emphasise that the groups at <b>both</b> ends of the double bond must be different from each other. Give practice with various structures (e.g. the three dichloroethenes; alkenes up to $C_6$ ). Stereochemical formulae should include wedge and dashed bonds. Use 2-chlorobutane as the simplest example, but also include 2-hydroxypropanoic acid. Large ball-and-stick models and a large mirror are useful to demonstrate this. Suitable examples are $C_5H_{12}$ , $C_5H_{10}$ (incl. rings), $C_4H_{10}O$ (mention ethers in passing), $C_4H_8O_2$ (acids and esters). Practice reading the various ways that structural formula can be written.		<a href="#">site 2</a> (AS $\Rightarrow$ stereochemistry)
10.1(g)	explain what is meant by a <i>chiral centre</i> and that such a centre gives rise to optical isomerism			<a href="#">site 3</a> (organic $\Rightarrow$ chirality)
10.1(h)	deduce the possible isomers for an organic molecule of known molecular formula			C+H 22.6, 23.2
10.1(i)	identify chiral centres and/or <i>cis-trans</i> isomerism in a molecule of given structural formula			M109
				M110
10.2(f)	explain the use of crude oil as a source of both aliphatic and aromatic hydrocarbons	Brief outline of fractional distillation - separation according to boiling point. Fractions are mixtures; not all same chain length or no. of C-atoms due to branched chains having lower b.pts. than straight chains.	9	C+H 23.3
10.2(g)	suggest how 'cracking' can be used to obtain more useful alkanes and alkenes of lower Mr from larger hydrocarbon molecules	Makes more use of those hydrocarbons that are commonest in crude oil, but are not particularly useful in themselves by breaking up longer chain alkanes into shorter ones, plus alkenes or hydrogen, using zeolites (catalytic cracking) or heat (thermal cracking).		M111
				P(AS) 25
10.2(a)	be aware of the general unreactivity of alkanes, including towards polar reagents	Due to lack of polarity in, and strength of, the C-H and C-C bonds. High activation energy.	3	<a href="#">site 2</a> (AS $\Rightarrow$ alkanes)
				<a href="#">site 5c</a> (alkanes)
				<a href="#">site 8</a> organic $\Rightarrow$ isomer of the alkanes)
				C+H 23.5
				M111
10.2(b)	describe the chemistry of alkanes as exemplified by the following reactions of ethane: (i) combustion.	Balanced equations for $CH_4$ , $C_2H_6$ , $C_8H_{18}$	3	C+H 23.5
				M111
				P(AS) 24
10.2(h)	describe and explain how the combustion reactions of alkanes lead to their use as fuels in industry, in the home and in transport	Practical work could include an estimate of the $\Delta H_c^\circ$ of various alkanes by burning known masses underneath a copper calorimeter or similar.	3	<a href="#">site 1</a> (combustion of hydrocarbons)
10.2(i)	recognise the environmental consequences of carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the internal combustion engine and of their catalytic removal	The poisonous nature of CO ( $\rightarrow$ carboxyhaemoglobin); $NO_x$ causing smog, acid rain (on their own, and as a catalyst for $H_2SO_4$ production from $SO_2$ ); unburnt h/c $\rightarrow$ smog. Use of Pt-Rh catalyst in car exhaust systems. Main reactions are $CO + NO$ ; $CO + O_2$ ; $C_nH_m + O_2$ .		C+H 23.4
10.2(b)	describe the chemistry of alkanes as exemplified by	In the presence of UV light, giving poly- as well as mono-	10	<a href="#">site 1</a> (halogenation of

10.2(c)	the following reactions of ethane: (ii) substitution of hydrogen in ethane by chlorine and by bromine. describe the mechanism of <b>free-radical substitution</b> at methyl groups with particular reference to the initiation, propagation and termination reactions	substituted halogenoethanes. Balanced equations. Best demonstrated with $C_6H_{14} + Br_2$ . Only one initiation reaction, but 3 possible termination reactions. The sum of the two propagation equations equals the overall stoichiometric equation. Mention the 4-carbon byproducts obtained from ethane.		alkanes) <a href="#">site 3</a> (organic $\Rightarrow$ reaction mechanisms) C+H 23.5 M111 P(AS) 24
10.2(d)	describe the chemistry of alkenes as exemplified, where relevant, by the following reactions of ethene: (i) addition of hydrogen, steam, hydrogen halides and halogens (ii) oxidation by cold, dilute manganate(VII) ions to form the diol (iii) oxidation by hot, concentrated manganate(VII) ions leading to the rupture of the carbon-to-carbon double bond in order to determine the position of alkene linkages in larger molecules	(i) addition of hydrogen to ethene (Ni catalyst) is never carried out commercially, but mention unsaturated oils $\rightarrow$ margarine. Other three reagents undergo <b>electrophilic addition</b> . Steam (with $H_3PO_4$ catalyst) is a useful manufacture of ethanol. $Br_2$ + alkenes (emphasise that light is <i>not</i> needed) is a good test for $C=C$ . (ii). This is also a good test for an alkene. (iii) Give lots of practice with various alkenes, both predicting products according to the following table or vice versa. $\begin{array}{lcl} CH_2= & \longrightarrow & CO_2 \\ CHR= & \longrightarrow & RCO_2H \\ CR_2= & \longrightarrow & R_2CO \end{array}$	12	<a href="#">site 1</a> (various reactions) <a href="#">site 2</a> (AS $\Rightarrow$ alkenes) <a href="#">site 5c</a> (alkenes) C+H 24.3 M112 P(AS) 26
10.2(e)	describe the mechanism of electrophilic addition in alkenes, using bromine/ethene as an example	Polarisation of $Br_2$ into $Br^{\delta+}-Br^{\delta-}$ by the $C=C$ double bond, following by electrophilic addition giving a carbocation + $Br^-$ , which then react together. Mention of the cyclic bromonium ion is not essential.	3	<a href="#">site 3</a> (organic $\Rightarrow$ reaction mechanisms) C+H 24.3 M112
10.2(d) 10.8(a)  10.8(b)	(iv) polymerisation of alkenes describe the characteristics of addition polymerisation as exemplified by poly(ethene) and pvc  recognise the difficulty of the disposal of poly(alkene)s, i.e. non-biodegradability and harmful combustion products	Describe the free-radical conditions using $O_2$ + pressure. Definition of addition polymerisation. Practice drawing repeat units of polymers from various monomers (incl. the "spare" bonds at each end, with brackets ( ) <sub>n</sub> around the repeat unit), and vice versa. Branched chain polyalkenes are especially difficult to biodegrade. phosgene ( $COCl_2$ ) and dioxins can be formed if the incineration temperature for PVC is not high enough. Newer disposal techniques include cracking, to regenerate the monomer, and v.high temperature combustion, giving useful heat for power generation.	5	<a href="#">site 1</a> (ethene) <a href="#">site 1</a> (polythene) <a href="#">site 5d</a> (polymerisation) C+H 24.4 M112, 127-8
10.3(a)	(a) recall the chemistry of halogenoalkanes as exemplified by (i) the following nucleophilic substitution reactions of bromoethane: hydrolysis; formation of nitriles; formation of primary amines by reaction with ammonia (ii) the elimination of hydrogen bromide from 2-bromopropane	Balanced equations for all reactions. Include essential conditions (e.g. solvent, temperature, sealed tube under pressure for $NH_3$ )  Note especially the change of solvent for NaOH from water to ethanol.	5	<a href="#">site 2</a> (AS $\Rightarrow$ halogenoalkanes) <a href="#">site 5c</a> (Halo_compounds) C+H 25.3 M115
10.3(b)	describe the mechanism of nucleophilic substitution in halogenoalkanes.	Both the $S_N1$ and the $S_N2$ mechanism should be described. The essential features are the $\delta^+$ carbon atom, and curly	10	<a href="#">site 3</a> (organic $\Rightarrow$ reaction mechanisms)

10.3(c)	interpret the different reactivities of halogenoalkanes with particular reference to hydrolysis and to the relative strengths of the C-Hal bonds eg CFCs; anaesthetics; flame retardants; plastics	arrows showing the C-Br bond breaking, and the formation of the bond to carbon from the lone pair on the nucleophile. $C-I > C-Br > C-Cl$ . Relative rates can be shown by warming R-X with aqueous-alcoholic $AgNO_3$ . The inertness of the C-Cl, and especially the C-F bonds make them useful for the purposes specified.		C+H 25.3 M115
10.3(d)	explain the uses of fluoroalkanes and fluorohalogenoalkanes in terms of their relative chemical inertness			
10.3(e)	recognise the concern about the effect of chlorofluoroalkanes on the ozone layer	Inertness now becomes a problem – long lifetime in the troposphere allowing migration to the stratosphere, where the C-Cl bond undergoes light-induced homolysis to give Cl atoms which initiate a chain reaction destroying ozone.	3	<a href="#">site 1</a> (CFCs and ozone depletion) C+H 25.4