

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.

AO	Learning Outcomes	Suggested Teaching Activities	Learning Resources
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 ₃ H ₇ Cl), the structural formula (e.g. (CH ₃) ₂ CHCl or CH ₃ CH ₂ CH ₂ Cl) 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.	C+H 22.4-22.5 M 109 R+N 15.1 site 8 (organic general principles)
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 M 109
10.1(c)	(i) describe the shapes of the ethane and ethene molecules (ii) predict the shapes of other related molecules	ethane: tetrahedral and 3-dimensional ethene: trigonal planar and 2-dimensional 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. The use of molecular models would help greatly here.	C+H 22.3 M 109
10.1(d)	explain the shapes of the ethane and ethene molecules in terms of σ and π carbon-carbon bonds	The π bond being due to the sideways overlap of two 2p orbitals, creating electron density above and below the plane of the molecule, and restricting rotation about the bond (see also Unit 1, AO 3e)	R+N 16b.7
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).	C+H 22.6, 23.2 M 109, M110

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 π bonds	Emphasise that the groups at both 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).	R+N 15.4
10.1(g)	explain what is meant by a <i>chiral centre</i> and that such a centre gives rise to optical isomerism	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). Give practice in reading the various ways that structural formula can be written, including displayed and skeletal formulae.	
10.1(h)	deduce the possible isomers for an organic molecule of known molecular formula		
10.1(i)	identify chiral centres and/or <i>cis-trans</i> isomerism in a molecule of given structural formula		
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.	C+H 23.5 M 111 R+N 16a.3
10.2(b)	(describe the chemistry of alkanes as exemplified by the following reactions of ethane): (i) combustion.	Students should generate balanced equations for CH_4 , C_2H_6 , C_8H_{18} Practical work could include an estimate of the ΔH_c^\ominus of various alkanes by burning known masses underneath a copper calorimeter or similar. A survey of the various energy sources (oil, gas, coal) used in local homes, colleges, offices and factories, and where the fuel comes from. 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 23.5 M 111 R+N 16a.4 P(AS) 24 site 4 (alkanes) site 7 (N-ch3-04,06) C+H 23.4 R+N 16c.26-27
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		
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		
10.2(b)	(describe the chemistry of alkanes as exemplified by the following reactions of ethane): (ii) substitution of hydrogen in ethane by chlorine and by bromine.	In the presence of UV light, giving poly- as well as mono-substituted halogenoethanes. Give the balanced equations. Best demonstrated with $C_6H_{14} + Br_2$.	C+H 23.5 M 111 R+N 16a.4 P(AS) 24 R+N 16a.5
10.2(c)	describe the mechanism of free-radical substitution at methyl groups with particular reference to the initiation, propagation and termination reactions	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.	
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. [This can be demonstrated with a synthetic mixture of 40-60 petroleum ether; methylbenzene and paraffin (kerosene)]. Fractions are mixtures; not all same chain length or no. of C-atoms due to branched chains having lower b.pts. than straight chains. This 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). Student practical on cracking.	C+H 23.3 M 111 R+N 16c.21 P(AS) 25 R+N 16c.23-25
10.2(g)	suggest how 'cracking' can be used to obtain more useful alkanes and alkenes of lower Mr from larger hydrocarbon molecules		
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	(i) addition of hydrogen to ethene (Ni catalyst) is never carried out commercially, but mention unsaturated oils \rightarrow margarine. Other three reagents undergo electrophilic addition . Steam (with H_3PO_4 catalyst) is a useful manufacture of	C+H 24.3 M 112 R+N 16b.9-13

	<p>halogens</p> <p>(ii) oxidation by cold, dilute manganate(VII) ions to form the diol</p> <p>(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</p>	<p>ethanol. Br₂ + alkenes (emphasise that light is <i>not</i> needed) is a good test for C=C.</p> <p>(ii). This is also a good test for an alkene.</p> <p>(iii) Give lots of practice with various alkenes, both predicting products according to the following table or vice versa</p> $\begin{array}{l} \text{CH}_2= \longrightarrow \text{CO}_2 \\ \text{CHR}= \longrightarrow \text{RCO}_2\text{H} \\ \text{CR}_2= \longrightarrow \text{R}_2\text{CO} \end{array}$	<p>P(AS) 26</p> <p>site 4 (alkenes)</p> <p>site 16 (organic chemistry)</p> <p>site 21a</p>
10.2(e)	describe the mechanism of electrophilic addition in alkenes, using bromine/ethene as an example	<p>Polarisation of Br₂ into Br^{δ+}—Br^{δ-} 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, and may confuse students.</p>	<p>C+H 24.3</p> <p>M 112</p>
10.2(d) 10.8(a) 10.8(b)	<p>(iv) polymerisation of alkenes</p> <p>describe the characteristics of addition polymerisation as exemplified by poly(ethene) and pvc</p> <p>recognise the difficulty of the disposal of poly(alkene)s, i.e. non-biodegradability and harmful combustion products</p>	<p>Describe the free-radical conditions using O₂ + pressure. Definition of addition polymerisation. Practice drawing repeat units of polymers from various monomers (incl. the “spare” bonds at each end, with brackets ()_n around the repeat unit), and vice versa.</p> <p>Branched chain polyalkenes are especially difficult to biodegrade. phosgene (COCl₂) 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.</p>	<p>C+H 24.4</p> <p>M 112, 127-8</p> <p>R+N 16b.14-16</p> <p>site 4 (polymers)</p> <p>R+N 16b.18-20</p>
10.3(a)	<p>(a) recall the chemistry of halogenoalkanes as exemplified by</p> <p>(i) the following nucleophilic substitution reactions of bromoethane: hydrolysis; formation of nitriles; formation of primary amines by reaction with ammonia</p> <p>(ii) the elimination of hydrogen bromide from 2-bromopropane</p>	<p>Include balanced equations for all reactions. Include essential conditions (e.g. solvent, temperature, sealed tube under pressure for NH₃)</p> <p>Note especially the change of solvent for NaOH from water to ethanol.</p>	<p>C+H 25.3</p> <p>M 115</p> <p>R+N 17.1, 17.5</p> <p>site 4 (haloalkanes)</p> <p>site 7 (N-ch3-08)</p>
10.3(b) 10.3(c) 10.3(d)	<p>describe the mechanism of nucleophilic substitution (by both S_N1 and S_N2 mechanisms) in halogenoalkanes.</p> <p>interpret the different reactivities of halogenoalkanes eg CFCs; anaesthetics; flame retardants; plastics with particular reference to hydrolysis and to the relative strengths of the C-Hal bonds</p> <p>explain the uses of fluoroalkanes and fluorohalogenoalkanes in terms of their relative chemical inertness</p>	<p>Both mechanisms should be described. Connect the terminology with reaction rates in Unit 2. The essential features are the δ+ carbon atom, and curly arrows showing the C-Br bond breaking, and the formation of the bond to carbon from the lone pair on the nucleophile.</p> <p>C-I > C-Br > C-Cl. Relative rates can be shown by warming R-X with aqueous-alcoholic AgNO₃. The inertness of the C-Cl, and especially the C-F bonds make them useful for the purposes specified.</p>	<p>C+H 25.3</p> <p>M 115</p> <p>R+N 17.2, 17.3</p> <p>site 2 (interactive organic mechanisms)</p> <p>R+N 17.4</p> <p>P(AS) 27</p>
10.3(e)	recognise the concern about the effect of chlorofluoroalkanes on the ozone layer	<p>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. An interesting internet search would be to see how the holes in the ozone layer are now, at last, starting to decrease.</p>	<p>C+H 25.4</p> <p>R+N 17.7</p>