

Topic 10: Organic chemistry

11 hours

Essential idea: Organic chemistry focuses on the chemistry of compounds containing carbon.

10.1 Fundamentals of organic chemistry

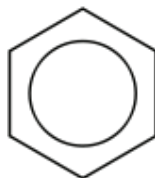
Nature of science:

Serendipity and scientific discoveries—PTFE and superglue. (1.4)

Ethical implications—drugs, additives and pesticides can have harmful effects on both people and the environment. (4.5)

Understandings:

- A homologous series is a series of compounds of the same family, with the same general formula, which differ from each other by a common structural unit.
- Structural formulas can be represented in full and condensed format.
- Structural isomers are compounds with the same molecular formula but different arrangements of atoms.
- Functional groups are the reactive parts of molecules.
- Saturated compounds contain single bonds only and unsaturated compounds contain double or triple bonds.



- Benzene is an aromatic, unsaturated hydrocarbon.

Applications and skills:

- Explanation of the trends in boiling points of members of a homologous series.
- Distinction between empirical, molecular and structural formulas.

International-mindedness:

- A small proportion of nations have control over the world's oil resources. The interdependence of the countries that are net importers and those that are net exporters is an important factor in shaping global policies and economic developments.
- The octane rating (octane number) can be described as a standard measure of the performance of the fuel used in cars and aircraft. Octane ratings often vary quite widely regionally throughout the globe, and are complicated by the fact that different countries use different means of expressing the values.

Theory of knowledge:

- The label “organic chemistry” originates from a misconception that a vital force was needed to explain the chemistry of life. Can you think of examples where vocabulary has developed from similar misunderstandings? Can and should language ever be controlled to eliminate such problems?
- Kekulé claimed that the inspiration for the cyclic structure of benzene came from a dream. What role do the less analytical ways of knowledge play in the acquisition of scientific knowledge?

Utilization:

- Fractional distillation makes great use of many petrochemicals.
- Dyes, pesticides, herbicides, explosives, soap, cosmetics, synthetic scents and flavourings.

10.1 Fundamentals of organic chemistry	
<ul style="list-style-type: none"> • Identification of different classes: alkanes, alkenes, alkynes, halogenoalkanes, alcohols, ethers, aldehydes, ketones, esters, carboxylic acids, amines, amides, nitriles and arenes. • Identification of typical functional groups in molecules eg phenyl, hydroxyl, carbonyl, carboxyl, carboxamide, aldehyde, ester, ether, amine, nitrile, alkyl, alkenyl and alkynyl. • Construction of 3-D models (real or virtual) of organic molecules. • Application of IUPAC rules in the nomenclature of straight-chain and branched-chain isomers. • Identification of primary, secondary and tertiary carbon atoms in halogenoalkanes and alcohols and primary, secondary and tertiary nitrogen atoms in amines. • Discussion of the structure of benzene using physical and chemical evidence. <p>Guidance:</p> <ul style="list-style-type: none"> • Skeletal formulas should be discussed in the course. • The general formulas (eg C_nH_{2n+2}) of alkanes, alkenes, alkynes, ketones, alcohols, aldehydes and carboxylic acids should be known. • The distinction between class names and functional group names needs to be made. Eg for OH, hydroxyl is the functional group whereas alcohol is the class name. • The following nomenclature should be covered: <ul style="list-style-type: none"> – non-cyclic alkanes and halogenoalkanes up to halohexanes. – alkenes up to hexene and alkynes up to hexyne. – compounds up to six carbon atoms (in the basic chain for nomenclature purposes) containing only one of the classes of functional groups: alcohols, ethers, aldehydes, halogenoalkanes, ketones, esters and carboxylic acids. 	<p>Syllabus and cross-curricular links:</p> <p>Topic 1.2—empirical and molecular formulas Topics 4.2 and 4.3—Lewis (electron dot) structures, multiple bonds, VSEPR theory, resonance and bond and molecular polarity Topic 4.4—intermolecular forces Topic 5.3—exothermic reactions and bond enthalpies Topic 8.4—weak acids Option A.5—materials and polymers Options B.2 and B.7—proteins Option D.9—organic structure in medicines</p> <p>Aims:</p> <ul style="list-style-type: none"> • Aim 6: Either use model kits or suitable computer-generated molecular graphics programmes to construct three-dimensional models of a wide range of organic molecules. • Aim 6: Experiments could include distillation to separate liquids or the use of a rotary evaporator to remove a solvent from a mixture. • Aim 8: There are consequences in using fossil fuels as our main source of energy. Many products can be obtained from fossil fuels due to the inherently rich chemistry of carbon. This raises some fundamental questions—are fossil fuels too valuable to burn and how do they affect the environment? Who should be responsible for making decisions in this regard? • Aim 8: Discuss the use of alcohols and biofuels as fuel alternatives to petrol (gasoline) and diesel.

Essential idea: Structure, bonding and chemical reactions involving functional group interconversions are key strands in organic chemistry.

10.2 Functional group chemistry	
Nature of science:	
Use of data—much of the progress that has been made to date in the developments and applications of scientific research can be mapped back to key organic chemical reactions involving functional group interconversions. (3.1)	
<p>Understandings:</p> <p><i>Alkanes:</i></p> <ul style="list-style-type: none"> Alkanes have low reactivity and undergo free-radical substitution reactions. <p><i>Alkenes:</i></p> <ul style="list-style-type: none"> Alkenes are more reactive than alkanes and undergo addition reactions. Bromine water can be used to distinguish between alkenes and alkanes. <p><i>Alcohols:</i></p> <ul style="list-style-type: none"> Alcohols undergo nucleophilic substitution reactions with acids (also called esterification or condensation) and some undergo oxidation reactions. <p><i>Halogenoalkanes:</i></p> <ul style="list-style-type: none"> Halogenoalkanes are more reactive than alkanes. They can undergo (nucleophilic) substitution reactions. A nucleophile is an electron-rich species containing a lone pair that it donates to an electron-deficient carbon. <p><i>Polymers:</i></p> <ul style="list-style-type: none"> Addition polymers consist of a wide range of monomers and form the basis of the plastics industry. <p><i>Benzene:</i></p> <ul style="list-style-type: none"> Benzene does not readily undergo addition reactions but does undergo electrophilic substitution reactions. 	<p>International-mindedness:</p> <ul style="list-style-type: none"> Methane is a greenhouse gas, and its release from ruminants in countries such as Brazil, Uruguay, Argentina and New Zealand contributes significantly to total greenhouse gas emissions. Landfills are also a source of methane, and technologies are developing in some countries to capture the gas as a source of energy for electricity and heat generation. Alcohol misuse is a growing problem in many countries and can have an impact on their economies and social structures. <p>Utilization:</p> <ul style="list-style-type: none"> Alkane usage as fuels. The role of ethene in fruit ripening. Alcohols, usage as fuel additives. Alcohols, role in the breathalyser. Esters, varied uses—perfumes, food flavourings, solvents, nitroglycerin, biofuels and painkillers. <p>Syllabus and cross-curricular links: Topic 9.1—redox processes Option A.5—polymers Option B.3—lipids</p>

10.2 Functional group chemistry	
<p>Applications and skills:</p> <p><i>Alkanes:</i></p> <ul style="list-style-type: none"> • Writing equations for the complete and incomplete combustion of hydrocarbons. • Explanation of the reaction of methane and ethane with halogens in terms of a free-radical substitution mechanism involving photochemical homolytic fission. <p><i>Alkenes:</i></p> <ul style="list-style-type: none"> • Writing equations for the reactions of alkenes with hydrogen and halogens and of symmetrical alkenes with hydrogen halides and water. • Outline of the addition polymerization of alkenes. • Relationship between the structure of the monomer to the polymer and repeating unit. <p><i>Alcohols:</i></p> <ul style="list-style-type: none"> • Writing equations for the complete combustion of alcohols. • Writing equations for the oxidation reactions of primary and secondary alcohols (using acidified potassium dichromate(VI) or potassium manganate(VII) as oxidizing agents). Explanation of distillation and reflux in the isolation of the aldehyde and carboxylic acid products. • Writing the equation for the condensation reaction of an alcohol with a carboxylic acid, in the presence of a catalyst (eg concentrated sulfuric acid) to form an ester. <p><i>Halogenoalkanes:</i></p> <ul style="list-style-type: none"> • Writing the equation for the substitution reactions of halogenoalkanes with aqueous sodium hydroxide. 	<p>Aims:</p> <ul style="list-style-type: none"> • Aim 6: Experiments could include distinguishing between alkanes and alkenes, preparing soap and the use of gravity filtration, filtration under vacuum (using a Buchner flask), purification including recrystallization, reflux and distillation, melting point determination and extraction. • Aim 8: Discuss the significance of the hydrogenation of alkenes in the food production including <i>trans</i>-fats as by-products.

10.2 Functional group chemistry**Guidance:**

- Reference should be made to initiation, propagation and termination steps in free-radical substitution reactions. Free radicals should be represented by a single dot.
- The mechanisms of S_N1 and S_N2 and electrophilic substitution reactions are not required.