

Summary

Unit 10/20 - Organic Chemistry Current

0 of 6
weeks

Subject	Year	Start date	Duration
Chemistry	IB1	Week 3, May	6 weeks 15 hours

Course Part

Core and Higher level

Description

Organic chemistry focuses on the chemistry of compounds containing carbon.

Organic molecules were once believed to have distinctive chemical properties, making them unique to living organisms. This was part of a theoretical view known as 'vitalism'. For instance, Louis Pasteur, a very important figure in the history of science, believed that fermentation to produce ethanol could only occur in living yeast cells.

However, this thinking was transformed in 1828 when the German chemist Friedrich Wöhler synthesised urea from inorganic materials, in the absence of any biological tissue. Wöhler wrote to his mentor, the eminent chemist Berzelius: 'I must tell you that I can make urea without the use of kidneys, either man or dog. Ammonium cyanate is urea.' Wöhler's experiments showed that organic molecules were not unique to living organisms, and this marked the beginning of a new branch of chemistry called **organic chemistry**.

Inquiry & Purpose

? Inquiry / Higher Order Questions

Type

Concept-based

Inquiry Questions

Green chemistry aims to achieve key synthetic reactions without the use of the more powerful, environmentally damaging reagents such as concentrated hydrochloric acid and sodium hydroxide. One example of this is the electroreduction of nitrobenzene: $C_6H_5NO_2$

Curriculum

🎯 Aims

Acquire a body of knowledge, methods and techniques that characterize science and technology

Apply and use a body of knowledge, methods and techniques that characterize science and technology

Develop an ability to analyse, evaluate and synthesize scientific information

Develop experimental and investigative scientific skills including the use of current technologies

◇ Objectives

Demonstrate knowledge and understanding of

facts, concepts, and terminology

Apply

methodologies and techniques

Formulate, analyse and evaluate

hypotheses, research questions and predictions

scientific explanations

📖 Syllabus Content

Core

10. Organic chemistry

10.1 Fundamentals of organic chemistry

Nature of science:

Serendipity and scientific discoveries - PTFE and superglue.

Ethical implications - drugs, additives and pesticides can have harmful effects on both people and the environment.

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.

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.

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.

Understandings:

Alkanes: Alkanes have low reactivity and undergo free-radical substitution reactions.

Alkenes: Alkenes are more reactive than alkanes and undergo addition reactions. Bromine water can be used to distinguish between alkenes and alkanes.

Alcohols: Alcohols undergo nucleophilic substitution reactions with acids (also called esterification or condensation) and some undergo oxidation reactions.

Halogenoalkanes: 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.

Polymers: Addition polymers consist of a wide range of monomers and form the basis of the plastics industry.

Benzene: Benzene does not readily undergo addition reactions but does undergo electrophilic substitution reactions.

Applications and skills:

Alkanes: 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.

Alkenes: 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.

Alcohols: 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.

Halogenoalkanes: Writing the equation for the substitution reactions of halogenoalkanes with aqueous sodium hydroxide.

Additional higher level

20. Organic chemistry

20.1 Types of organic reactions

Nature of science:

Looking for trends and discrepancies - by understanding different types of organic reactions and their mechanisms, it is possible to synthesize new compounds with novel properties which can then be used in several applications. Organic reaction types fall into a number of different categories.

Collaboration and ethical implications - scientists have collaborated to work on investigating the synthesis of new pathways and have considered the ethical and environmental implications of adopting green chemistry.

Understandings:

Nucleophilic Substitution Reactions: SN1 represents a nucleophilic unimolecular substitution reaction and SN2 represents a nucleophilic bimolecular substitution reaction. SN1 involves a carbocation intermediate. SN2 involves a concerted reaction with a transition state. For tertiary halogenoalkanes the predominant mechanism is SN1 and for primary halogenoalkanes it is SN2. Both mechanisms occur for secondary halogenoalkanes. The rate determining step (slow step) in an SN1 reaction depends only on the concentration of the halogenoalkane, $\text{rate} = k[\text{halogenoalkane}]$. For SN2, $\text{rate} = k[\text{halogenoalkane}][\text{nucleophile}]$. SN2 is stereospecific with an inversion of configuration at the carbon.

SN2 reactions are best conducted using aprotic, non-polar solvents and SN1 reactions are best conducted using protic, polar solvents.

Electrophilic Addition Reactions: An electrophile is an electron-deficient species that can accept electron pairs from a nucleophile. Electrophiles are Lewis acids. Markovnikov's rule can be applied to predict the major product in electrophilic addition reactions of unsymmetrical alkenes with hydrogen halides and interhalogens. The formation of the major product can be explained in terms of the relative stability of possible carbocations in the reaction mechanism.

Electrophilic Substitution Reactions: Benzene is the simplest aromatic hydrocarbon compound (or arene) and has a delocalized structure of π bonds around its ring. Each carbon to carbon bond has a bond order of 1.5. Benzene is susceptible to attack by electrophiles.

Reduction Reactions: Carboxylic acids can be reduced to primary alcohols (via the aldehyde). Ketones can be reduced to secondary alcohols. Typical reducing agents are lithium aluminium hydride (used to reduce carboxylic acids) and sodium borohydride.

Applications and skills:

Nucleophilic Substitution Reactions: Explanation of why hydroxide is a better nucleophile than water. Deduction of the mechanism of the nucleophilic substitution reactions of halogenoalkanes with aqueous sodium hydroxide in terms of SN1 and SN2 mechanisms. Explanation of how the rate depends on the identity of the halogen (ie the leaving group), whether the halogenoalkane is primary, secondary or tertiary and the choice of solvent.

Outline of the difference between protic and aprotic solvents.

Electrophilic Addition Reactions: Deduction of the mechanism of the electrophilic addition reactions of alkenes with halogens/interhalogens and hydrogen halides.

Electrophilic Substitution Reactions: Deduction of the mechanism of the nitration (electrophilic substitution) reaction of benzene (using a mixture of concentrated nitric acid and sulfuric acid).

Reduction Reactions: Writing reduction reactions of carbonyl containing compounds: aldehydes and ketones to primary and secondary alcohols and carboxylic acids to aldehydes, using suitable reducing agents. Conversion of nitrobenzene to phenylamine via a two-stage reaction.

20.2 Synthetic routes

Nature of science:

Scientific method - in synthetic design, the thinking process of the organic chemist is one which invokes retro-synthesis and the ability to think in a reverse-like manner.

Understandings:

The synthesis of an organic compound stems from a readily available starting material via a series of discrete steps. Functional group interconversions are the basis of such synthetic routes.

Retro-synthesis of organic compounds.

Applications and skills:

Deduction of multi-step synthetic routes given starting reagents and the product(s).

20.3 Stereoisomerism

Nature of science:

Transdisciplinary - the three-dimensional shape of an organic molecule is the foundation pillar of its structure and often its properties. Much of the human body is chiral.

Understandings:

Stereoisomers are subdivided into two classes—conformational isomers, which interconvert by rotation about a σ bond and configurational isomers that interconvert only by breaking and reforming a bond.

Configurational isomers are further subdivided into cis-trans and E/Z isomers and optical isomers.

Cis-trans isomers can occur in alkenes or cycloalkanes (or heteroanalogues) and differ in the positions of atoms (or groups) relative to a reference plane. According to IUPAC, E/Z isomers refer to alkenes of the form $R_1R_2C=CR_3R_4$ ($R_1 \neq R_2$, $R_3 \neq R_4$) where neither R_1 nor R_2 need be different from R_3 or R_4 .

A chiral carbon is a carbon joined to four different atoms or groups.

An optically active compound can rotate the plane of polarized light as it passes through a solution of the compound. Optical isomers are enantiomers. Enantiomers are non-superimposable mirror images of each other. Diastereomers are not mirror images of each other.

A racemic mixture (or racemate) is a mixture of two enantiomers in equal amounts and is optically inactive.

Applications and skills:

Construction of 3-D models (real or virtual) of a wide range of stereoisomers.

Explanation of stereoisomerism in non-cyclic alkenes and C₃ and C₄ cycloalkanes.

Comparison between the physical and chemical properties of enantiomers.

Description and explanation of optical isomers in simple organic molecules.

Distinction between optical isomers using a polarimeter.

ATL Skills

Approaches to Learning



Social

- In this unit, we will

have students work in small groups

allocate, or ask students to allocate among themselves, different roles in a classroom discussion or activity

have students peer assess their group performance or process

support students in resolving a conflict in a team

give a group assessment task

give students feedback on how they worked as a group

have students discuss their understanding of a text or idea among themselves and come up with a shared understanding

provide an opportunity for students to analyse the impact of their behaviour on the class or on a group performance

encourage students to consider alternative points of view or to take the perspective of others

provide opportunities for students to make decisions



Developing IB Learners

Learner Profile



Risk-takers (Courageous)



Balanced