Summary

Organic Chemistry (Unit 10 & 20)

Subject	Year	Start date	Duration
Chemistry	IB1, IB2	Week 3, September	4 weeks 12 hours

Course Part

Organic Chemistry (SL unit 10 + HL extension unit 20)

Description

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.

This unit explores the structure and properties of organic compounds.

Inquiry & Purpose

Inquiry / Higher Order Questions

Type	Inquiry Questions
Debatable	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 controll
Skills-based	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?
Concept-based	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 developin

Curriculum

Aims

Appreciate scientific study and creativity within a global context through stimulating and challenging opportunities

Develop an ability to analyse, evaluate and synthesize scientific information

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

Develop an appreciation of the possibilities and limitations of science and technology

Objectives

Demonstrate knowledge and understanding of

facts, concepts, and terminology

methodologies and techniques

Apply

methodologies and techniques

Formulate, analyse and evaluate

methodologies and techniques

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, rate = k[halogenoalkane]. For SN2, rate = k[halogenoalkane][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 R1R2C=CR3R4 (R1 ≠ R2, R3 ≠ R4) where neither R1 nor R2 need be different from R3 or R4.

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-superimposeable 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

Thinking

Communication

Research

Developing IB Learners

Learner Profile

Inquirers

Knowledgeable

Risk-takers (Courageous)

Reflective

Assessment

Assessment criteria

SL Criteria

External Assessment

Paper 1

Multiple-choice questions on the core material

Paper 2

Short-answer and extended-response questions on the core material

HL Criteria

External Assessment

Paper 1

Multiple-choice questions on the core and higher level material

Paper 2

Short-answer and extended-response questions on the core and higher level material

Description