ORGANIC MOLECULES & THEIR PROPERTIES 29 JANUARY 2013

Lesson Description

In this lesson we will

- Draw the structure formula and name organic molecules by applying IUPAC rules
- Identify different functional groups
- Identify how the size and shape of a molecule determines the type and strength of the inter-molecular forces
- Describe how inter-molecular forces determine the physical properties of organic substances

Key Concepts

Chemistry of Carbon

Carbon has a valency of 4 and therefore forms four bonds. These bonds are covalent bonds – a pair of electrons is shared in each bond. Carbon can form long chains or rings. The simplest organic molecules are formed when carbon atoms combined with hydrogen atoms. This group of organic molecules are called the hydrocarbons. Hydrocarbon molecules with the same ratio of carbon to hydrogen will have very different chemical and physical properties.

Examples of hydrocarbons

- C_2H_4 (Gas)
- C_5H_5 (Liquid)
- $C_{20}H_{40}$ (Solid)

Each of these molecules needs a different name. Chemists follow the IUPAC rules for naming (leave till later)

Inter-molecular forces

The intermolecular forces in organic molecules are governed by two major types:

Van der Waals forces are the weakest and are present in all organic substances:

London forces or Temporary dipole are the weakest type of van der Waals forces. These are temporary movements in the electrons around molecules. This causes one side of the molecule to become temporarily positive, and the other negative.

Dipole-dipole attraction is stronger than London forces. When molecules are polar, they have a permanent positive side and a permanent negagtive side. When molecules are close to one another, the positive end of one will attract the negative of the other.

Hydrogen bonds are very strong and are stronger than both types of van der Waals forces. When a molecule contains hydrogen covalently bonded to oxygen or nitrogen, hydrogen bonds can occur. As a result, the melting and boiling points of these substances will be higher than those held together by Van der Waals forces.

Physical Properties

Melting point: The temperature at which a substance changes from solid to liquid.

Boiling point: The temperature at which a substance changes from liquid to gas (vapour pressure = atmospheric pressure)

Viscosity: The "thickness" of the substance.

Vapour Pressure: The ability of the substance to evaporate from a liquid state.

Functional Groups

Class of Compound	Functional Group	General Formula	Example
halide (halocarbon)	—F (fluoro-) —Cl (chloro-) —Br (bromo-) —I (iodo-)	*R*—*X* (*X* represents any halogen)	$CH_3CHClCH_3$ 2-chloropropane
alcohol	—OH	*R*—OH	$CH_3CH_2CH_2OH$ 1-propanol
ether	—O—	*R*—O—*R′*	$CH_3OCH_2CH_3$ methyl ethyl ether
aldehyde	$-\overset{O}{\overset{\|\|}{C}}-H$	$R-\overset{O}{\overset{\|\|}{C}}-H$	$CH_3CH_2\overset{O}{\overset{\|\|}{C}}-H$ propanal
ketone	$-\overset{O}{\overset{\|\|}{C}}-$	$R-\overset{O}{\overset{\|\|}{C}}-R'$	$CH_3\overset{O}{\overset{\|\|}{C}}CH_2CH_2CH_3$ 2-pentanone
organic acid	$-\overset{O}{\overset{\|\|}{C}}-OH$	$R-\overset{O}{\overset{\|\|}{C}}-OH$	$CH_3CH_2\overset{O}{\overset{\|\|}{C}}-OH$ propanoic acid
ester	$-\overset{O}{\overset{\|\|}{C}}-O-$	$R-\overset{O}{\overset{\|\|}{C}}-O-R'$	$CH_3CH_2\overset{O}{\overset{\|\|}{C}}OCH_3$ methyl propanoate

R – Represents an alkyl branch - a carbon chain with only single C – C and C – H bonds.

IUPAC Rules

The International Union of Pure and Applied Chemists have decided to name molecules the following way.

1) Count the longest carbon chain – this forms the prefix (start of the word). This is called the backbone.
2) See if the carbon atoms are bonded using single, double or triple bonds. Select a suffix of -ane for single bonds; -ene for double bonds; -yne for triple bonds.
3) Now, if there are oxygen or nitrogen containing functional groups, the –e at the end of the name falls away and is replaced with the correct functional group (-ol, -al, -one, -oic acid, -oate, -amine or -amide).
4) Any branches or halogens can now be named and added to the front of the name. These must be mentioned in alphabetical order.

Note 1: If all the carbons and function groups are bonded directly to the same carbon chain, there are no spaces in the name.

Numbering functional groups: Rules

1) If there are oxygen/nitrogen containing groups or double/triple bonds, the backbone must be numbered from the side closest to them. The functional group that is mentioned last decides the numbering.
2) If there are none of the functional groups in Rule 1, the carbon atoms in the backbone are numbered so that the pattern of substitution has the lowest number.
3) If the numbering can't be decided by Rule 1 or Rule 2, the functional group that is alphabetically first decides the numbering (number from the side closest to it).
4) Numbering is placed in front of each functional group if the group can be in more than on place.
5) Number are separated by commas "," and from word with dashes "-".

Terminology

Molecular formula: only the symbol and number of each atom, starting with carbon eg. C_2H_5O

Empirical formula: the simplest ratio of elements in the compound. Often not the same as molecular eg. C_8H_{20} molecular is reduced to C_2H_5 by dividing by four.

Structural Formula: a formula showing all the atoms bonded by dashes to represent electron pairs.

Homologous series: a group of molecule all sharing the same functional group.

Isomer: one molecule that has the same molecular formula but different structural formula (and name).

Saturated: a molecule containing only single bonds between carbon atoms.

Unsaturated: a molecule containing double or triple bonds between carbon atoms.

Demonstration

When ether (a light organic molecule) is placed in an open dish, the liquid very quickly evaporates. This shows that it has a very high vapour pressure. The desire of the molecules to become gas is high. This because ether has very weak intermolecular forces.

When we compare ether to butan-1-ol, we can see that the vapour pressure is must lower.

These two molecules have the same molecular mass as they are isomers of one another – here is the reason for the difference:

- Butan-1-ol has an OH group (hydroxyl) and this allows for hydrogen bonding. This means that molecules require more energy to become gas. This lowers the vapour pressure and increases the boiling point of the compound.
- Diethyl ether does not have any hydrogen atoms bonded to the oxygen in the structure. This means that it cannot to hydrogen bonding and must rely on van der Waals forces. This means that the molecules are not held together strongly and can escape and become gas easily.

Questions

Question 1 (DOE March 2010 Question 7)

7.3 A group of learners know that the boiling points of straight chain hydrocarbons increase with an increase in their molecular mass.

7.3.1 Refer to intermolecular forces to explain why the boiling points of straight chain hydrocarbons increase with an increase in their molecular mass. (2)

Question 2 (DOE November 2009 Question 5)

The table below shows data collected for four organic compounds, represented by the letters A – D, during a practical investigation.

	Organic compound	Relative molecular mass	Boiling point (°C)
A	$CH_3CH_2CH_3$	44	- 42
B	CH_3CHO	44	21
C	$CH_3CH_2NH_2$	45	17
D	CH_3CH_2OH	46	78

5.1 Is compound A a saturated or an unsaturated hydrocarbon? Give a reason for your answer. (2)

5.2 To which homologous series does compound B belong? (1)

5.3 Write down the IUPAC name for each of the following compounds:

5.3.1 B (1)

5.3.2 C (1)

Links

- http://castlelearning.com/review/reference/chem%20table%20r.htm
- http://en.wikipedia.org/wiki/Organic_chemistry
- http://www.mindset.co.za/learn/xtra
- http://www.education.gov.za/Examinations/PastExamPapers/tabid/351/Default.aspx