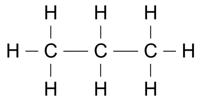
# ORGANIC CHEMISTRY

Structural formula and Physical Properties

## STRUCTURAL FORMULA

- Shows individual atoms in a molecule and uses dashes for each bond
- E.g. propane



## Condensed formula

- Shows the structure but not individual bonds
- E.g. propane

$CH_3CH_2CH_3$

## Molecular formula

- This is the simplest ratio of atoms
- It does not show any structure
- E.g. propane

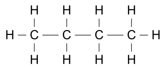
$C_3H_8$

This type of formula is only used in combustion equations for organic molecules

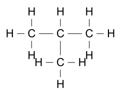
## Structural isomers

- Molecular formulae can represent different molecules
- E.g. $C_4H_{10}$

  Can be butane



Or 2-methyl propane



## PHYSICAL PROPERTIES

- Physical properties can include melting and boiling points, solubility in water or different solvents and the appearance of the substance.
- Physical properties of organic molecules are affected by the size of the molecule due to the intermolecular forces.

## Physical properties of alkanes

- Alkanes are colourless compounds.
- Alkanes have only dispersion forces as their intermolecular forces.
- All hydrocarbons are non-polar molecules because the carbon-hydrogen bond is considered non-polar.

## Boiling points

- Bigger molecules have ***more*** dispersion forces so they have higher boiling points than smaller molecules – it takes more energy to separate the molecules
- The first 4 alkanes are gases at room temperature
- Branched chain hydrocarbons don't fit together as well, so generally have lower boiling points than their non-branched isomers

## Solubility

- Alkanes do not dissolve in water because they cannot hydrogen bond to water
- Alkanes can dissolve in organic solvents
- In general for solubility, "like dissolves like", or polar dissolves polar and non-polar dissolves non-polar. Because alkanes are non-polar, they cannot dissolve in polar water.

## Flame characteristics

- Alkanes burn completely in oxygen with a hot non-luminous flame (non-luminous means it is hard to see)

## Alkene and Alkyne physical properties

- Alkenes combust incompletely so burn with a luminous smokey yellow flame
- Other physical properties are similar to the corresponding alkane
- Physical properties of alkynes are similar to those of the corresponding alkene

## Alcohols

- Boiling points for alcohols are unusually high because of the presence of the hydroxyl group and the ability to form hydrogen bonds
- Boiling point increases with increasing molecular weight within the homologous series

## Alcohols

- Low molecular weight alcohols are water soluble as they can form hydrogen bonds with water
- High molecular weight alcohols are insoluble in water because as the non-polar hydrocarbon chain gets bigger, it decreases the overall polarity of the molecule

## Alcohols

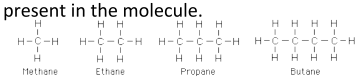
- Alcohols can be more viscous as liquids than other hydrocarbons
- Viscosity is resistance to flow
- Viscosity is influenced by hydrogen bonding
- Alcohols burn completely in oxygen with a hot non-luminous flame

# Alkanes

The saturated hydrocarbons

## Alkanes

- A family of hydrocarbons which contain only single bonds between carbon atoms.
- All alkanes have the word ending *–ane* in their names.
- The prefix identifies how many carbon atoms are present in the molecule.



# Alkanes

- General formula for alkanes is $C_nH_{2n+2}$
  - Write the formula for the alkane with 3 carbon atoms? With 20 carbon atoms?
- Alkanes are an ***homologous series*** because each successive molecule differs by $CH_2$.

# Table for some alkanes

| FORMULA | NAME | STATE | USES |
|---|---|---|---|
| $CH_4$ | Methane | Gas | LNG |
| $C_2H_6$ | Ethane | Gas | Used to make polythene |
| $C_3H_8$ | Propane | Gas | LPG, cigarette lighters |
| $C_5H_{12}$ | Pentane | Liquid | Used for making polystyrene |
| $C_6H_{14}$ | Hexane | Liquid | thermometers |

*Handout: Table of alkanes*

# Organic formulae – Molecular Formula

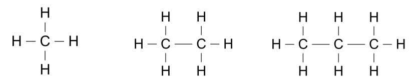
- Shows the simplest ratio of atoms present

| | | |
|---|---|---|
| methane | ethane | propane |
| $CH_4$ | $C_2H_6$ | $C_3H_8$ |

- Essentials Questions

# Organic formulae – Structural Formula

- Shows all of the atoms in a molecule and how they are arranged
- methane ethane propane



# Organic Formulae – Condensed Formula

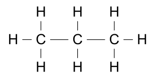
- Shows structure but not individual bonds

| | | |
|---|---|---|
| Methane | Ethane | Propane |
| $CH_4$ | $CH_3CH_3$ | $CH_3CH_2CH_3$ |

- Octane
- $CH_3(CH_2)_6CH_3$

# Alkanes……

- Alkanes are saturated hydrocarbons because there are only single bonds present in the molecules.
- Alkanes are "saturated" with hydrogen atoms as no more can be added to the molecule.



# Structural Isomers

- **Structural Isomers** are compounds which have the same number and type of atoms (same molecular formula) but a different arrangement of atoms.

- Straight chains
- e.g. butane ($C_4H_{10}$)

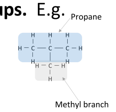
*These molecules are structural isomers.*

*They both have 4 x carbon atoms and 10 x hydrogen atoms*

- Branched chains
- e.g. 2-methyl propane ($C_4H_{10}$)

# Naming branched chain hydrocarbons (1)

- Chain branches are called **alkyl groups.** E.g.
- meth*yl* $-CH_3$
- eth*yl* $-CH_2-CH_3$
- prop*yl* $-CH_2-CH_2-CH_3$




Methyl propane

# Naming branched chain hydrocarbons (2)

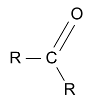
- Steps to name branched chain alkanes:

1. Identify the parent (longest chain) – name it with a suffix *–ane*
2. Identify the branch chain(s).
3. Count the number of carbons in the branch(s). Name the branch(es).
4. Identify the position of the branch by numbering from the end of the parent chain that gives the branch the lowest number.
5. If there are several identical branches on the parent chain, the position of each branch is numbered separately, and the branch names written together using the following prefixes:
   - *di* – two
   - *tri* – three
   - *tetra* - four
6. Branches are named in alphabetical order.

# Ketones

# Ketone Functional Group

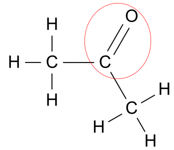
- Same as aldehyde but within the carbon chain:



- Where R is a hydrocarbon chain.

# Ketone example

- Propanone is the smallest ketone:

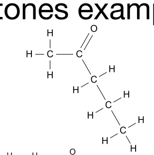


# Naming Ketones

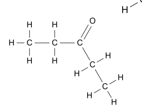
- Use the word ending "-anone"
- Use a number to indicate the position of the ketone functional group in the molecule

# Naming Ketones examples

- 2-pentanone

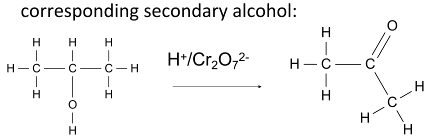


- 3-pentanone



# Formation of Ketones

- Ketones are produced by oxidation of the corresponding secondary alcohol:




# Ketones Reactions

- Ketones are generally unreactive because the carbon atom involved in the functional group is surrounded by two alkyl groups within the chain.

## Ketone Boiling Points

- Same as aldehydes

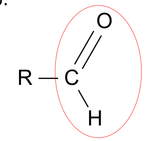
## Ketone Solubility

- Same as aldehydes

## Aldehydes

## Aldehydes

- Aldehydes contain an aldehyde functional group:

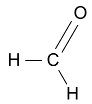


## Naming Aldehydes

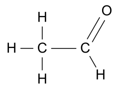
- Aldehydes have the name ending “-anal”
- Numbers are not needed to indicate the position of the functional group because it is always on carbon number 1

## example

- Methanal

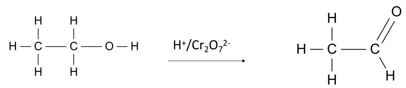


- ethanal



## Formation of Aldehydes

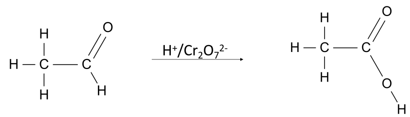
- Aldehydes are formed by the controlled oxidation of primary alcohols:




- If acidified dichromate solution is used the solution will change from orange to green

## Oxidation of Aldehydes

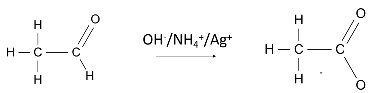
- Aldehydes can be further oxidised to the corresponding carboxylic acid:




## Distinguishing test

- Aldehydes react with Tollen’s Reagent (ammoniacal silver nitrate solution), producing a silver mirror on the inside of the reaction vessel. This is how aldehydes are distinguished from all other organic chemicals

## Tollen’s Test




- The carboxylate ion is formed because of the basic conditions, which cause the carboxylic acid to become ionised

## Aldehyde Boiling Points

- Boiling points of aldehydes increase with increasing carbon chain length, because more dispersion forces form between molecules, thus more heat is needed to separate the molecules.

## Aldehyde Boiling Points

- Aldehydes contain a polar aldehyde functional group, capable of forming dipole-dipole interactions with other aldehyde molecules
- The boiling points of aldehydes are higher than those of the corresponding hydrocarbons and less than the alcohols.

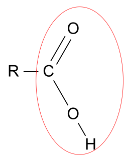
## Aldehyde Solubility

- Aldehydes can form hydrogen bonds with the oxygen atom on polar water molecules.
- Small aldehydes (<5 carbons in the chain) are soluble in water.
- Large aldehydes are insoluble in water because the ratio of polar to non-polar components in the molecule is too small.

## Carboxylic acids

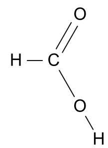
## Carboxylic Acid Functional Group

- The functional group is called a carboxyl group or a carboxylic acid group



## Methanoic acid

- Methanoic acid is the simplest carboxylic acid:

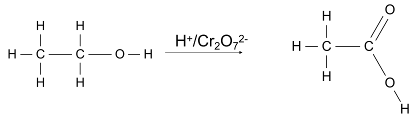


## Naming carboxylic acids

- Use the word ending “oic acid” e.g. ethanoic acid

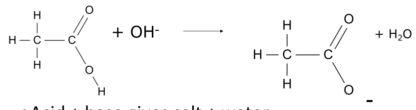
## Formation of carboxylic acids

- Carboxylic acids are produced from the complete oxidation of primary alcohols:



## Reactions of Carboxylic Acids

- Carboxylic acids are weak acids and they can ionise in basic solutions:



- Acid + base gives salt + water

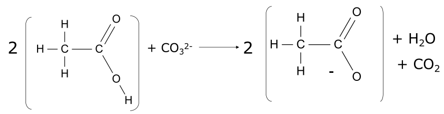
## Naming Carboxylate ions

- Use the word ending “-oate ion” e.g. ethanoate ions

## Distinguishing test

- Carboxylic acids react with carbonates or hydrogen carbonates producing carbon dioxide gas
- Bubbles or effervescence are the observation

## Equation



## Carboxylic acids boiling points

- Carboxylic acid boiling points are very high (higher than the corresponding alcohol)
- The carboxyl group is very polar and is capable of forming more hydrogen bonds which require more heat energy to separate than weaker interactions

## Boiling point trend

- As the carbon chain length increases, the boiling point increases because there are more sites for dispersion forces to form, thus more heat energy is needed to separate the molecules

## Solubility of carboxylic acids

- Carboxylic acids contain a carboxyl group capable of forming hydrogen bonds with water
- Small carboxylic acids are soluble
- Large carboxylic acids are insoluble because the non-polar hydrocarbon chain outweighs the polar functional group

## Solubility of carboxylate ions

- Carboxylate ions are infinitely soluble in water because they have a full ion charge, just like sodium ions ($Na^+$)