Cambridge IGCSE Chemistry

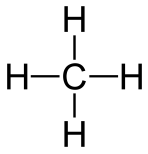
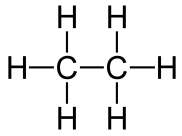
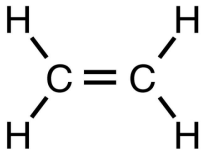
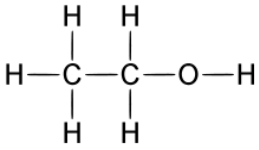
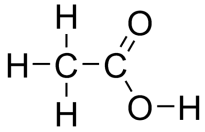
Topic 14: Organic chemistry

Names of compounds

Notes

Name and draw the structures of methane, ethane, ethene, ethanol, ethanoic acid and the products of the reactions in 14.4-14.6

- Prefixes (beginning of the name)
  - Any compound with 1 carbon has the prefix of: Meth-
  - 2 carbons: Eth-
  - 3 carbons: Prop-
  - 4 carbons: But-
  - Remember the first 4 prefixes using MEPB Monkeys Eat Peanut Butter
- The suffix of any compound refers to the functional group
  - Alkanes –ane (C-C) e.g. ethane
  - Alkenes –ene (C=C) e.g. ethene
  - Alcohols –ol (OH) e.g. ethanol
  - Carboxylic acids –anoic acid (-COOH) e.g. ethanoic acid

methane	CH_4	
ethane	C_2H_6	
ethene	C_2H_4	
ethanol	C_2H_5OH	
ethanoic acid	CH_3COOH	

(Extended only) Name and draw the structures of the unbranched alkanes, alkenes (not cis-trans), alcohols and acids containing up to four carbon atoms per molecule

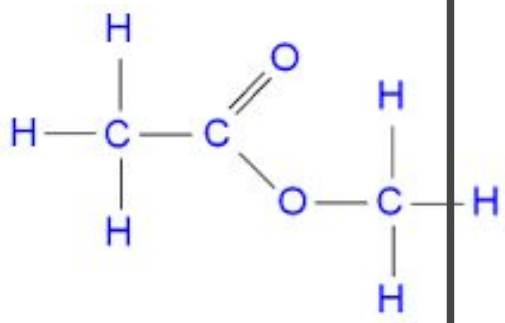
- use above information and examples given of ways to go through thinking to name compounds of alkanes, alkenes, alcohols and acids containing up to four carbon atoms per molecule

State the type of compound present, given a chemical name ending in –ane, -ene, -ol or –oic acid or a molecular structure

- -Ane : alkane
  - Functional group (same group of atoms in each molecule that makes an alkane) is C-H / C-C (NOT C=C)
- -Ene : alkene
  - Functional group is C=C
- -Ol : alcohol
  - Functional group is OH
- -Oic acid : carboxylic acid
  - Functional group is COOH

(Extended only) Name and draw the structural formulae of the esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms

- General rule
  - Alcohol + carboxylic acid -> ester + water
  - e.g. Methanol + Ethanoic acid -> Methyl Ethanoate + H2O
- How to name esters
  - (prefix of alcohol + yl) + (name of carboxylic acid minus the “oic acid” + oate)
  - E.g. Meth-yl Ethan-oate



- This ester is formed (from the example)
- the alcohol part is to the right normally with an H from the –OH functional group being lost.
- The carboxylic acid part is to the left with an OH from the –COOH functional group being lost
- H + OH ⟶ H_2O (a by-product).

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Fuels

Notes

Name the fuels:

- Coal, natural gas and petroleum

Name methane as

- The main constituent of natural gas
- methane= CH_4

Describe petroleum as…

- A mixture of hydrocarbons

… and its separation into useful fractions by fractional distillation

- different hydrocarbons have different carbon chain lengths, with longer chain carbon chains having higher boiling points
- their different boiling points means petroleum can be separated by fractional distillation:
    - a large fraction column with petroleum is heated
    - different hydrocarbons boil and rise up as gases, which can then be collected separately

Describe the properties of molecules within a fraction

- Some properties of hydrocarbons depend on the size of their molecules. These properties influence their use as fuels.
- The shorter the molecules, the lower the temperature at which that fraction evaporates or condenses – and the lower its boiling point.
- Shorter the molecules, the less viscous it is. (more runny)

Name the uses of the fractions as:

- Refinery gas for bottled gas for heating and cooking
- Gasoline fraction for fuel (petrol) in cars
- Naphtha fraction for making chemicals
- Kerosene/paraffin fraction for jet fuel
- Diesel oil/gas oil for fuel in diesel engines
- Fuel oil fraction for fuel for ships and home heating systems
- Lubricating fraction for lubricants, waxes and polishes
- Bitumen for making roads

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Topic 14: Organic chemistry

Homologous series

Notes

Describe the concept of homologous series as…

- A 'family' of similar compounds with similar chemical properties due to the presence of the same functional group

(Extended only) Describe the general characteristics of a homologous series

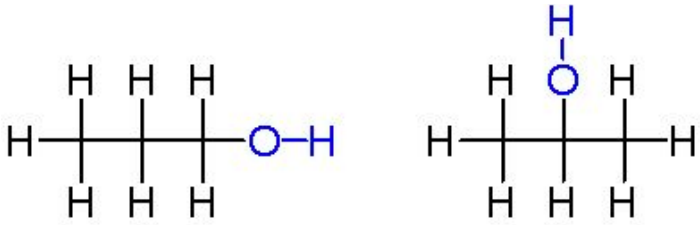
- Similar chemical properties – undergo the same chemical reactions
    - E.g. alkenes decolourise bromine water (orange to colourless) due to the C=C, whereas alkanes do not due to the lack of C=C

(Extended only) Recall that the compounds in a homologous series have…

- The same general formula
    - General formulae = a type of empirical formula that represents the composition of any member of an entire class of compounds (e.g. for ethene = C_nH_{2n})

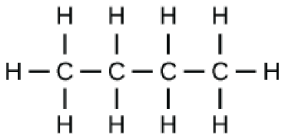
(Extended only) Describe and identify structural isomerism

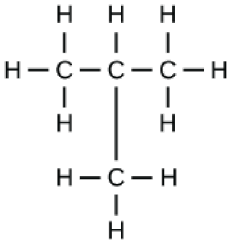
- Structural isomerism = compounds with the same molecular formula exist in different forms due to different arrangements of atoms
- Can be structural isomers due to different placement of functional groups:



- Can be structural isomers due to different functional groups but with the exact same group of atoms:

- Can be structural isomers due to branched or unbranched chains





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Topic 14: Organic chemistry

Alkanes

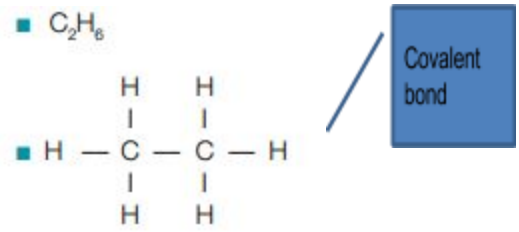
Notes

Describe the properties of alkanes (exemplified by methane) as being…

- Generally unreactive, except in terms of burning

Describe the bonding in alkanes

- Contain no C=C double bonds, therefore the carbons are saturated, because they each form 4 single bonds i.e. they form as many bonds as possible
- they have C-C and C-H single covalent bonds
- C_nH_{2n+2} is the general formula e.g. ethane is C_2H_6
- Alkane molecules can be represented in the following forms:



- The first 4 alkanes are methane, ethane, propane and butane (MEPB: Monkeys Eat Peanut Butter)

(Extended only) Describe substitution reactions of alkanes with chlorine

- Halogen + alkane –(UV)-> halogenoalkane + hydrogen halide
  - e.g. $Br_2 + C_2H_6$ -(UV)-> $C_2H_5Br + HBr$
- Must be in the presence of ultraviolet radiation (UV)

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Alkenes

Notes

Describe the manufacture of alkenes and of hydrogen by cracking

- Hydrocarbons can be cracked to produce smaller, more useful molecules. This process involved heating the hydrocarbons to vaporise them.
- The vapours are:
    - Either passed over a hot catalyst (silica or alumina)
    - Mixed with steam and heated to a very high temperature (temperature in the range of 600-700˚C) so that thermal decomposition reactions can occur.
- The products of cracking include shorter chain alkanes and alkenes (or hydrogen)

(Extended only) Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam

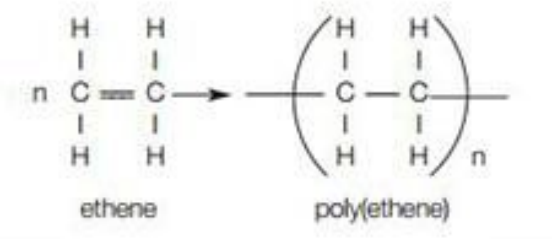
- Generally:
    - Addition reactions
    - Involves the removal of C=C double bond
    - C=C is very reactive and can easily react to form –C-C-
- reaction with bromine:
    - alkene + bromine → dibromoalkane
    - E.g. Ethene + bromine → 1,2-dibromoethane
- reaction with steam:
    - alkene + steam → alcohol
    - E.g. Ethene + steam → ethanol
- reaction with hydrogen:
    - alkene + hydrogen → alkane
    - E.g. Ethene + hydrogen → ethane

Distinguish between saturated and unsaturated hydrocarbons: from molecular structures, by reaction with aqueous bromine

- From molecular structures:
    - Unsaturated = contain one or more C=C double bonds e.g. alkenes
    - Saturated = contain no C=C double bonds e.g. alkanes
- By reaction with aqueous bromine:
    - Unsaturated hydrocarbons react with bromine in an addition reaction, decolourising it (orange to colourless) – shown above with the example of ethene reacting with bromine
    - Saturated hydrocarbons do not react with bromine and therefore the solution will remain orange

Describe the formation of poly(ethene) as an example of addition polymerisation of monomer units

- Alkenes can be used to make polymers such as poly(ethene) by addition polymerisation. In this reaction, many small molecules (monomers) join together to create very large molecules (polymers).
- The repeat unit has the same atoms as the monomer because no other molecule is formed in the reaction



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Topic 14: Organic chemistry

Alcohols

Notes

Describe the manufacture of ethanol by fermentation and by catalytic addition of steam to ethene

- Fermentation:
  - The fermentation of glucose
  - conditions: temperature of about 30˚C, anaerobic conditions (no oxygen) and using the enzymes in yeast
  - equation: glucose → ethanol + carbon dioxide
- Steam:
  - Reacting ethene with steam
  - conditions: phosphoric acid catalyst, temperature of about 300˚C and a pressure of about 60-70 atm
  - equation: ethene + steam → ethanol

(Extended only) Outline the advantages and disadvantages of these two methods of manufacturing ethanol

- Fermentation
  - Advantages
    - Renewable raw materials
    - Warm, normal pressure (inexpensive)
    - Little energy needed
  - Disadvantages
    - Batch process (stop-start)
    - A lot of workers needed
    - Slow
    - Impure – needs treatment
- Steam
  - Advantages
    - Continuous process (runs all the time)
    - Few workers needed
    - Fast
    - Pure
  - Disadvantages
    - Non-renewable raw materials
    - High temperature and pressure (expensive)
    - A lot of energy needed

Describe the properties of ethanol in terms of burning

- Burning in air or oxygen (complete combustion)
  - $CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$
  - Can be used as a fuel in this way (this reaction produces heat energy)
  - Burns in a good supply of oxygen

Name the uses of ethanol as…

- A solvent
- A fuel

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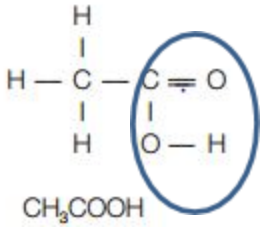
Carboxylic acids

Notes

Describe the properties of aqueous ethanoic acid

- Ethanoic acid is a member of the carboxylic acids, they have the functional group –COOH.
- First four members are: methanoic acid, ethanoic acid, propanoic acid and butanoic acid

ethanoic acid →



- Dissolves in water to produce an acidic solution

(Extended only) Describe the formation of ethanoic acid by the oxidation of ethanol by fermentation and with acidified potassium manganate(VII)

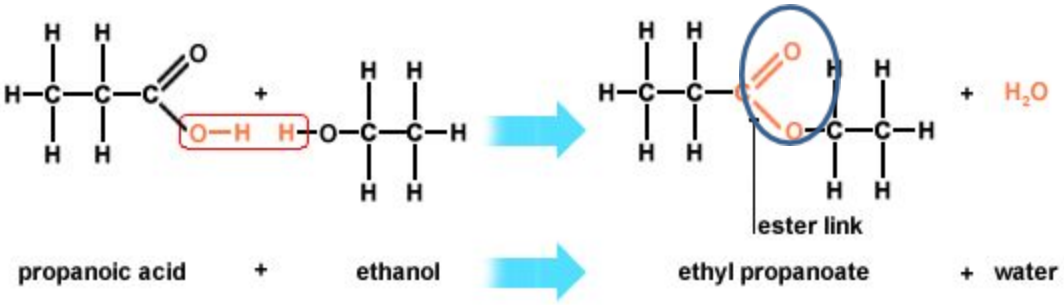
- Ethanol reacts with oxygen in the air to form ethanoic acid (microbial oxidation)
- Ethanol reacts with acidified potassium manganate(VII) to form ethanoic acid (under reflux)

(Extended only) Describe ethanoic acid as…

- A typical weak acid
- this means ethanol will release some H^+ ions in solution, but will not fully dissociate (loses the H^+ from the COOH group)

(Extended only) Describe the reaction of a carboxylic acid with an alcohol in the presence of a catalyst to give an ester

- Carboxylic acids react with alcohols in the presence of an acid catalyst to produce esters…



  - They have the functional group –COO-.

- name:
  - first part is from alcohol e.g. methanol → methyl
  - second part is from carboxylic acid e.g. butanoic acid→ butanoate

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Polymers

Notes

Define polymers as…

- Large molecules built up from small units (monomers)

Understand that different polymers have different units and/or different linkages

- Each polymer is made from a certain monomer or monomers, therefore different polymers have different units and/or different linkages (depending on how the monomer(s) join up to form the polymer)
- monomers can be different lengths or can have different groups attached
- can have a C-C linkage, ester linkage or amide linkage

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Synthetic polymers

Notes

Name some typical uses of plastics and of man-made fibres such as nylon and Terylene

- Plastics:
  - Plastic bags
  - Clingfilm
  - Buckets, other plastic tools
- Man-made fibres such as nylon and Terylene:
  - Drawn into very fine fibres and woven into cloth for clothing
  - Other natural fibres (e.g. cotton) can be mixed with nylon or polyester fibres to make a soft but hard-wearing cloth

(Extended only) Explain the differences between condensation and addition polymerisation

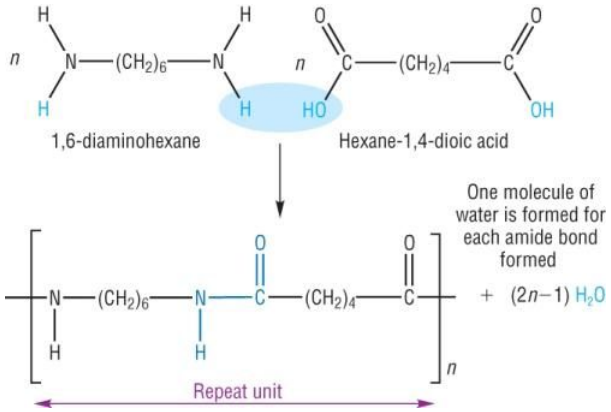
- Addition polymerisation involves the removal of a C=C double bond to form a –C-C- bond, i.e. it joins up unsaturated molecules to form a long saturated molecule
- Condensation polymerisation involves the reaction of two different functional groups to form one long molecule by the removal of a small molecule, such as water H_2O
  - This means that there can be more than one monomer used in condensation polymerisation (unlike addition which only uses one)

(Extended only) Deduce the structure of the polymer product from a given alkene and vice versa

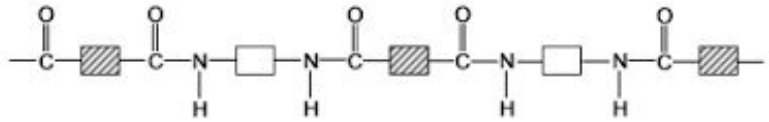
- the polymer product would be a long chain of the alkene without the C=C and instead with –C .... C- at the end, i.e. open branches

(Extended only) Describe the formation of nylon (a polyamide) and Terylene (a polyester) by condensation polymerization

Formation of nylon:

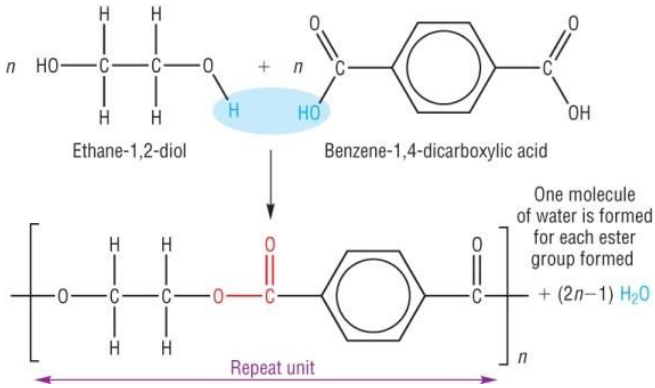


- this is the only detail you need to know the structure of nylon in:

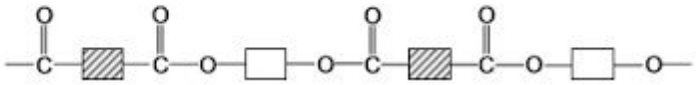


- Polyamides are condensation polymers
    - Amine and carboxylic acid functional groups react, losing a small molecule – water
- A polyamide is formed from:
    - a monomer molecule containing two carboxylic acid groups (dicarboxylic acid) reacting with a monomer molecule containing two amine groups
    - or a single monomer molecule with both carboxylic acid and amine functional groups
- -OH + -COOH -> -COO- (+H_2O removed)

Formation of Terylene: (a polyester)



- this is the only detail you need to know the structure of terylene in:



- Polyesters are condensation polymers
- A polyester is formed from:
    - a monomer molecule containing two carboxylic acid groups (dicarboxylic acid) is reacting with a monomer molecule containing two alcohol groups (diol)
    - or a single monomer molecule with both carboxylic acid and alcohol functional groups
- -OH + -COOH -> -COO- (+H_2O removed)

Describe the pollution problems caused by non-biodegradable plastics

- Unable to biodegrade, because the polymers that form these plastics are inert / unable to react therefore, microorganisms and bacteria are unable to break them down
    - *o* Thus, the landfills are bad for the environment as the plastics will remain in the ground, unable to break down/decompose
- They produce toxic gases when they are burned
    - *o* Carbon dioxide is also released – which adds to global warming

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Natural polymers

Notes

Name proteins and carbohydrates as…

- Constituents of food

(Extended only) Describe proteins as…

- Possessing the same (amide) linkages as nylon but with different units

*(Extended only) Describe the hydrolysis of proteins to amino acids (Structures and names are **not** required)*

- Hydrolysis is the splitting up of a molecule using water
- Hydrolysis of polymers results in the formation of their monomers
- In the case of proteins, when you add water to split up this natural polymer, you will get amino acids (the monomers that form the proteins)

(Extended only) Describe complex carbohydrates in terms of…

- A large number of sugar units (diols) joined together by condensation polymerisation, e.g. a polyester with –O- linkages

(Extended only) Describe the hydrolysis of complex carbohydrates (e.g. starch), by…

- Acids or enzymes to give simple sugars
- similarly to proteins, complex carbohydrates can be broken down into their monomers (simple sugars) using water with acids/enzymes

(Extended only) Describe the fermentation of simple sugars to…

- Produce ethanol (and carbon dioxide)
- sugar (glucose) → ethanol + carbon dioxide
- conditions: yeast enzyme, around 30°C, anaerobic conditions (no oxygen)

(Extended only) Describe, in outline, the usefulness of chromatography in separating and identifying the products of hydrolysis of carbohydrates and proteins

- Chromatography is used to separate a mixture of molecules, therefore when you hydrolyse large molecules (polymers) like carbohydrates and proteins, you are left with a mixture of their monomers
    - Thus, chromatography can be used to separate and identify these monomers by their Rf values
    - sugars and amino acids will not produce visible spots, so once the chromatogram is dry, you need to spray it with a locating agent (Ninhydrin produces purple spots with amino acids and resorcinol makes coloured spots with sugars)