National 5 Chemistry

Unit 2:

Nature's Chemistry

Student:

Topic 6

Consumer Products

Topics	Sections			Done	Checked
6.1 *Alkanol Family*	1.	Alkanol Molecules			
	2.	Properties of Ethanol			
	3.	Uses of Ethanol			
	4.	Properties of Alkanols			
		Self -Check Questions 1 - 3	Score: /		
6.2 *Alcohol Structures*	1.	Straight-Chain Isomers			
	2.	Branched-Chain Isomers			
	3.	Other Alcohols			
6.3 *Carboxylic Acids*	1.	Ethanoic Acid			
	2.	Properties			
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6.4 *Energy From Fuels*	1.	Alcohol Biofuels			
	2.	Specific Heat Capacity			
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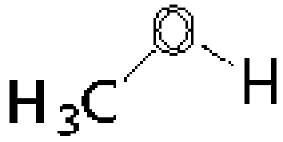
Consolidation Work		Consolidation A	Score: /		
		Consolidation B	Score: /		
		Consolidation C	Score: /		
		Consolidation D	Score: /		

End-of-Topic Assessment	Score: %	Grade:	

6.1 Alkanol Family

Alkanol Molecules

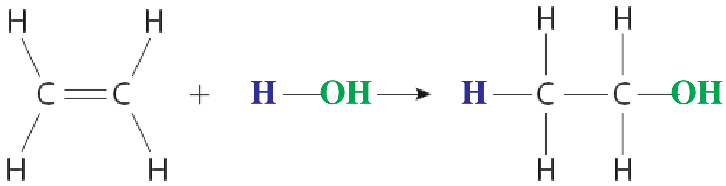


In the last Topic you learnt that ***alkanols*** can be made by the ***addition*** of a ***water molecule*** across the ***double bond*** in an ***alkene***.

The ***functional group*** in *alkanols* is the ***Hydroxyl*** *group*.

ethene + ***water*** → ***ethanol***

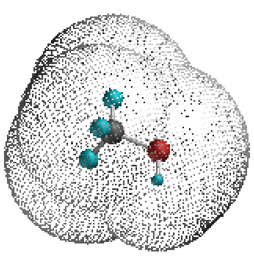
C_2H_4 + H_2O → C_2H_5OH

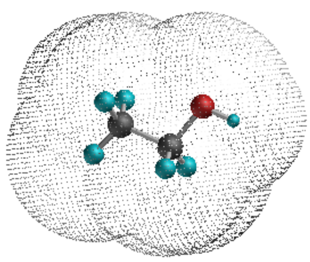


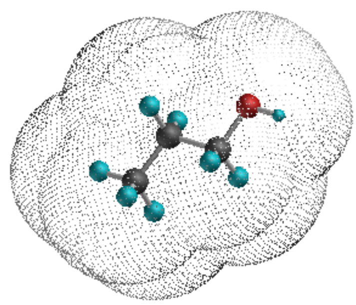
$$C_n\,H_{2n+1}\,OH$$

The ***alkanols*** can be thought of as '*substituted alkanes*' - a ***hydrocarbon*** chain with the ***hydroxyl*** *group* replacing one of the ***hydrogen*** atoms.

Name	*Functional Molecular Formula*	*Full Structural Formula*
methanol	CH_3OH	H | H – C – OH | H
ethanol	C_2H_5OH	H H | | H – C – C – OH | | H H
propan-1-ol	C_3H_7OH	H H H | | | H – C – C – C – OH | | | H H H



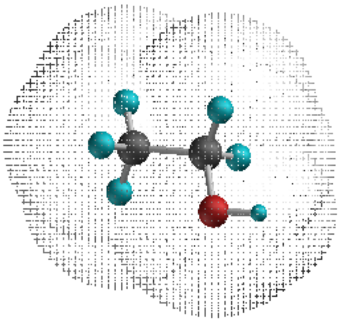




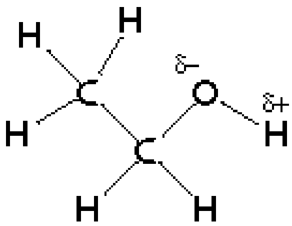
As well as sharing the same ***General formula***, the ***physical*** *properties* of the alkanols such as *melting point* (***increases***), *boiling point* (***increases***) and *solubility in water* (***decreases***) show a steady trend as the *molecular size* increases. For these reasons, the alkanols can be described as a ***homologous series***.

Properties of Ethanol

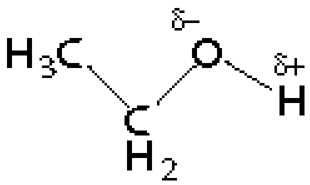
The aim of this activity is to investigate some of the properties of ethanol



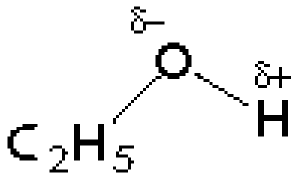
Ethanol has a short ***hydrocarbon*** chain, like an ***alkane***, with the ***hydroxyl*** *functional group* at the end.



Full Structural Formula

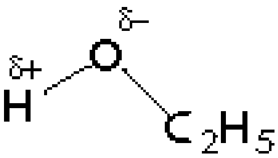


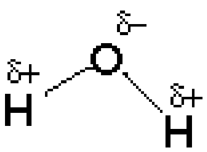
Shortened Structural Formula



Functional Molecular Formula

Property	***Result***
Appearance	***clear, colourless liquid (sickly sweet smell)***
Solubility	***very soluble in water***
pH	***universal indicator green (pH = 7, neutral)***
Conduction	***non-conductor***
Burning	***very flammable - blue flame***





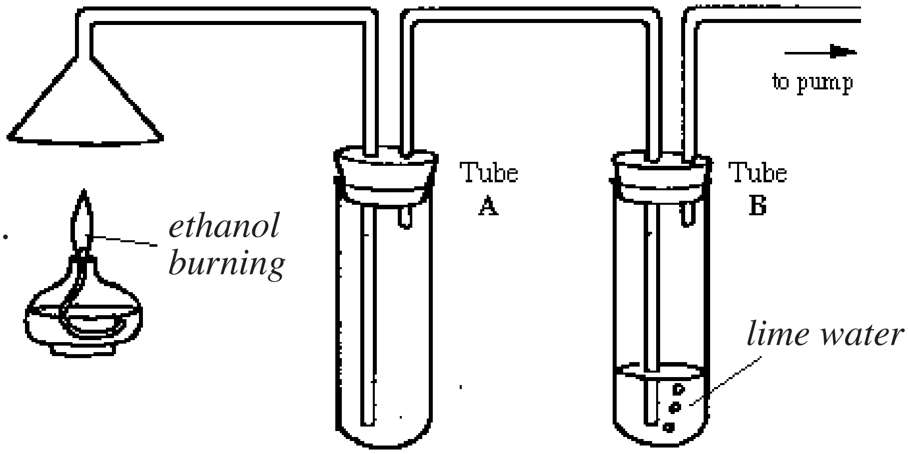
Like ***water***, *ethanol* is a ***covalent*** molecule and, as a result, is a *very poor* ***conductor*** of electricity.

Like ***water***, *ethanol* has a ***polar*** O—H bond which allows for ***stronger*** *attractions* between molecules. As a result, water and ethanol will '*dissolve*' in each other as the ***strength*** of their *attractions* are very ***similar***.

Uses of Ethanol

Historically, ***ethanol*** has often been used as a ***fuel***, often as *methylated spirits*.

It releases *more* ***energy*** (*per kg*) than ***wood*** but *less* ***energy*** than ***petrol***.



Word equation:	*ethanol*	+	*oxygen*	→	*carbon dioxide*	+	*water*
Formulae equation:	$2\ C_2H_5OH$	+	$7\ O_2$	→	$4\ CO_2$	+	$6\ H_2O$

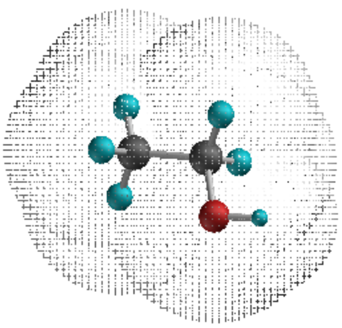
Like ***water***, ethanol is an excellent ***solvent*** able to ***dissolve*** a variety of substances.

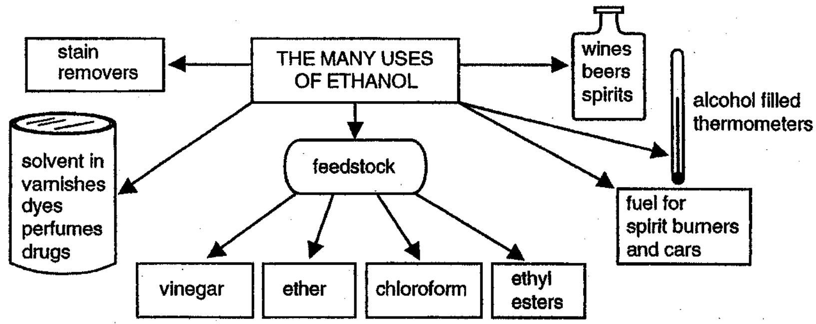
Ethanol is widely used as the ***solvent*** for many ink based pens and is, therefore, the ideal chemical to be used when attempting to remove ink stains.

In industrial and *consumer products*, ***ethanol*** is the second most important *solvent* after ***water***. Ethanol is the *least toxic* of the alcohols (it is only ***poisonous*** in large amounts), which makes it more suitable for use in *industry* and *consumer products*.

Ethanol is a ***solvent*** in:

Cosmetics such as *perfumes*.
Food colourings and ***flavourings*** such as *vanilla*.
Medicinal preparations such as *antiseptics*.
Some ***cleaning agents***.
Industry.

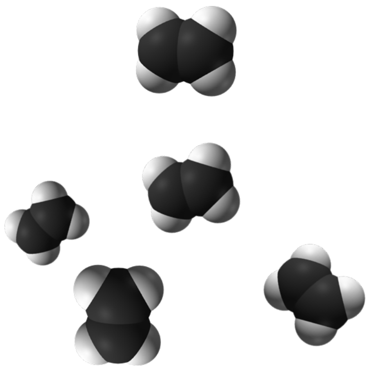




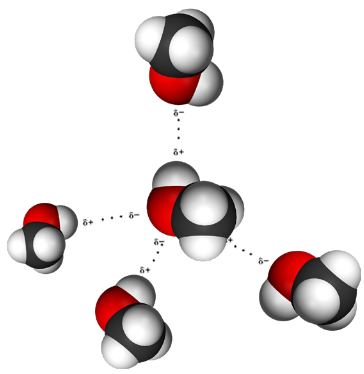
Properties of Alkanols

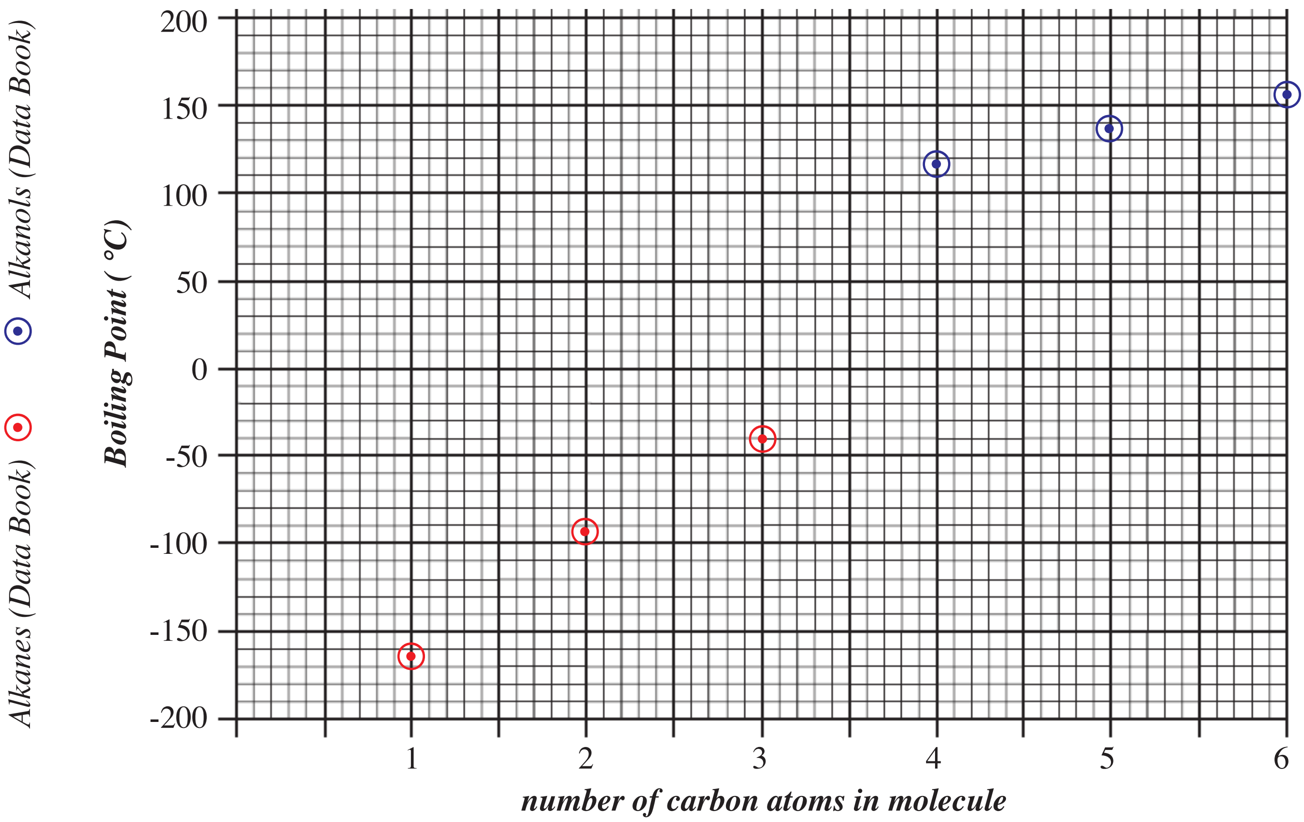
Most ***properties*** of the ***Alkanols*** are a result of the ***weak attractions*** *between* the ***molecules***.

However, there are ***significant differences*** between the ***properties*** of the ***polar alkanols*** and the ***non-polar hydrocarbons*** such as ***alkanes*** and ***alkenes***.



ethene	**name**	methanol
C_2H_4	**formula**	CH_3OH
28 amu	**mass**	32 amu
non-polar	**type**	polar
-104	**BPt (°C)**	65





Melting & Boiling Pts

as usual, the ***melting and boiling points increase*** as the *size of the molecules increase*.

Flammability

as usual, the ***flammability increases*** as the *size of the molecules decrease*.

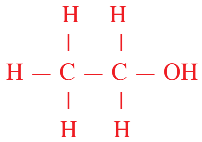
Solubility

small alkanol molecules are very ***soluble*** (***miscible***) in water, ***solubility will decrease*** as the *hydrocarbon chain gets bigger*.

Q1.

Ethanol is one member of the alkanol family.

a) Draw the full structural formula for ethanol.



b) Circle the functional group of the molecule.

c) State the name of this functional group.

*hydro**xyl** group*

d) Some people mistakenly expect ethanol to be alkaline.

i) Why would they think this?

*because the covalent hydro**xyl** group (—OH) is very similar to the hydro**xide ion** (OH^{-})*

ii) Explain why ethanol is, in fact, neutral.

*because the covalent hydro**xyl** group (—OH) is very similar to the hydro**xide ion** (OH^{-})*

Q2.

Ethanol has many different uses, for example.

A making vinegar
B burning in spirit burners
C manufacturing chloroform
D removing marker pen graffiti
E extracting chlorophyll from leaves
F an alternative to mercury in thermometers

a) In which ***two*** examples is ethanol being used as a solvent?

D & ***E***

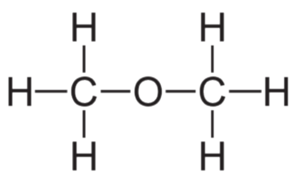
b) In which ***two*** examples is ethanol being used as a feedstock?

A & ***C***

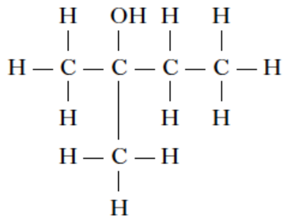
c) When pure, ethanol is a clear colourless liquid. State ***two*** other properties of ethanol.

(very) soluble in water
non-conductor
neutral (pH = 7)
(very) flammable

d) Draw the full structural formula for an isomer of ethanol that is ***not*** an alcohol

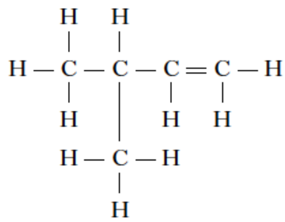


Q3. Int2

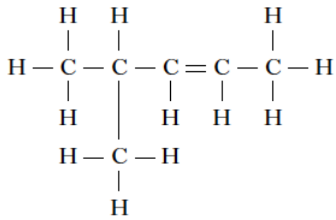


The above compound could be formed by adding water to

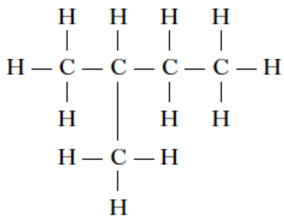
A



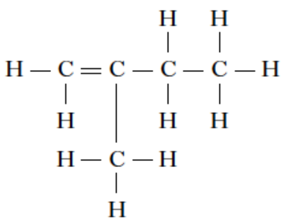
B



C



D

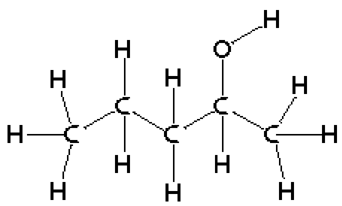


6.2 Alcohol Structures

Straight-Chain Isomers

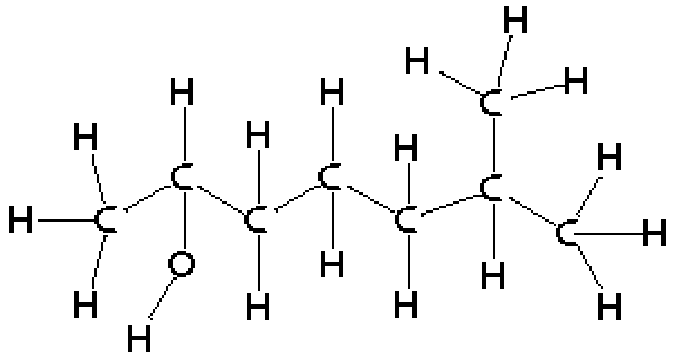
The ***position*** of the ***hydroxyl*** group can change to produce ***isomers*** without the need to introduce ***branches***.

Full Structural	H H OH | | | H — C — C — C — H | | | H H H	H OH H | | | H — C — C — C — H | | | H H H
Shortened Structural	$CH_3CH_2CH_2OH$	$CH_3CH(OH)CH_3$
Systematic Name	propan-1-ol	propan-2-ol

Straight-Chain Alkanols	
Name:	heptan-4-ol
Full Structural Formula:	H H H OH H H H | | | | | | | H — C — C — C — C — C — C — C — H | | | | | | | H H H H H H H
Shortened Structural Formula:	$CH_3CH_2CH_2CH(OH)CH_2CH_2CH_3$
Name:	pentan-2-ol
Full Structural Formula:	
Shortened Structural Formula:	$CH_3CH_2CH_2CH(OH)CH_3$
Name:	octan-1-ol
Full Structural Formula:	H H H H H H H OH | | | | | | | | H — C — C — C — C — C — C — C — C — H | | | | | | | | H H H H H H H H
Shortened Structural Formula:	$\mathbf{CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH}$

Branched-Chain Isomers

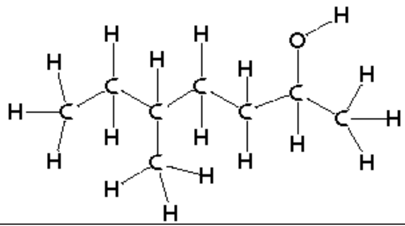
This activity considers how to use systematic names to indicate both the position of the hydroxyl group and the branch position in isomers of branched-chain alkanols



The '*longest chain*' must include the ***functional group***.

The chain is ***numbered*** from the ***end nearest the functional group***

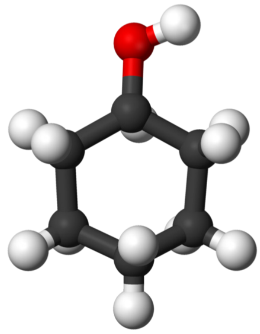
Systematic Name 6-methylheptan-2-ol

Branched-Chain Alkanols	
Name:	2-methylpentan-1-ol
Full Structural Formula:	H H H CH_3 H | | | | | H — C — C — C— C —C — OH | | | | | H H H H H
Shortened Structural Formula:	$CH_3CH_2CH_2CH(CH_3)CH_2OH$
Name:	5-methylheptan-2-ol
Full Structural Formula:	
Shortened Structural Formula:	$CH_3CH_2CH(CH_3)CH_2CH_2CH(OH)CH_3$
Name:	5-methylhexan-3-ol
Full Structural Formula:	H H OH H CH_3 H | | | | | | H — C — C — C— C —C — C — H | | | | | | H H H H H H
Shortened Structural Formula:	**OH CH_3** **| |** **$CH_3CH_2CHCH_2CHCH_3$**

Other Alcohols

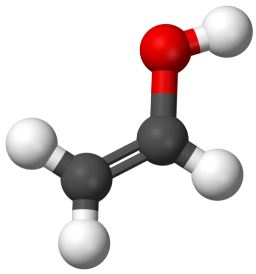
The ***alkanols*** are based on ***alkanes*** - *chains* (and *branches*) with *single carbon to carbon bonds* (**C — C**) only. There are many other possible alcohols.

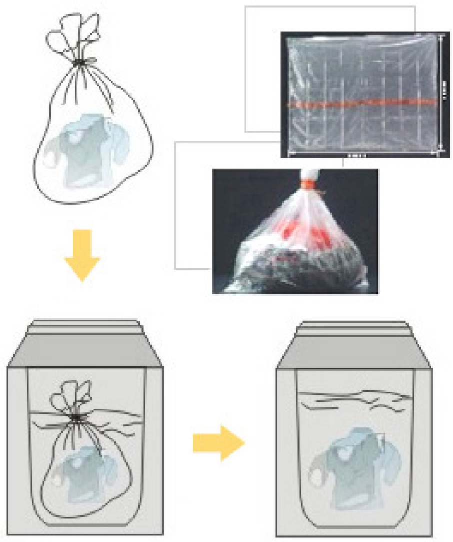
Cycloalkanols - *rings* with *single carbon to carbon bonds* (**C — C**) only.



Cyclohexanol is used in the production of *nylon*, *paints*, *plastics*, *detergents*, *textiles* and *pesticides*. It's also used as a *solvent* in some *specialist inks*.

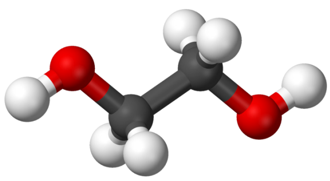
Alkenols - *chains* (and *branches*) with a *double carbon to carbon bond* (**C = C**)



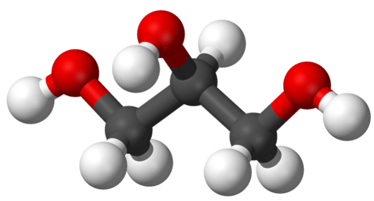


Ethenol (often called *VinylAlcohol*) is used to make a *water soluble plastic*, ***polyethenol*** (better known as *PolyVinylAlcohol* or ***PVA***) used as a *glue* but can also make *soluble sutures* (for *stitching*) and *soluble laundry bags* for use in *hospitals*.

Diols & Triols - *molecules* with *two or three hydroxyl groups* (**— OH**).



Ethane-1,2-diol (often called *ethylene glycol*) is an odorless, colourless, ***syrupy***, sweet-tasting liquid mainly used to make *polyesters* but is also an ingredient in *antifreeze*



Propane-1,2,3-triol (often called *glycerol* or *glycerine*) is an odorless, colourless, ***viscous***, sweet-tasting liquid mainly used to make *medicinal solutions* but also has many uses in *food production*.

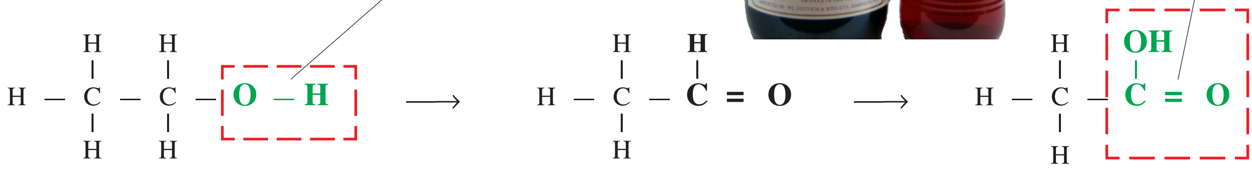
6.3 Carboxylic Acids

Ethanoic Acid

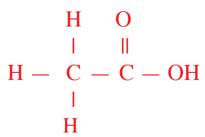
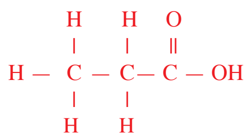
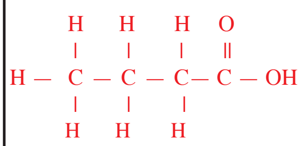
Ethanoic acid is normally manufactured from ***ethanol*** in a two-step reaction called ***oxidation***.

hydroxyl group is the *functional group* of an *alcohol*

carboxyl group is the *functional group* of an *acid*



*C_2H_5**OH*** *CH_3**COOH***

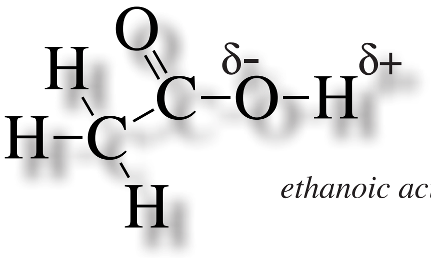
Chemical properties	***Ethanoic acid***	***Propanoic acid***	***Butanoic acid***
Molecular Formula	CH_3COOH	C_2H_5COOH	C_3H_7COOH
Structural Formula			
Smell & Appearance	'vinegary' colourless liquid	'cheesey' colourless liquid	'pukey' colourless liquid
Solubility / Universal indicator	soluble pink, pH < 7	soluble pink, pH < 7	soluble pink, pH < 7
Magnesium	'fizzes' (hydrogen gas)	'fizzes' (hydrogen gas)	'fizzes' (hydrogen gas)
Calcium carbonate	'fizzes' (CO_2 gas)	'fizzes' (CO_2 gas)	'fizzes' (CO_2 gas)

The smell of acids can be *unpleasant* (sometimes described as '*like vomit*' which is not surprising as ***fatty acids*** are formed during ***digestion***).

The ***covalent carboxyl group*** (—COOH) will ***dissociate*** in ***water*** to produce ***hydrogen ions***, $H^+_{(aq)}$ so they will have ***typical acid reactions***.

$H^{\delta+}-Cl^{\delta-}$

hydrogen chloride



ethanoic acid

$H^+ \; Cl^-{}_{(aq)}$

hydrochloric acid

acids are substances which dissolve in water to produce ***hydrogen ions, $H^+_{(aq)}$.***

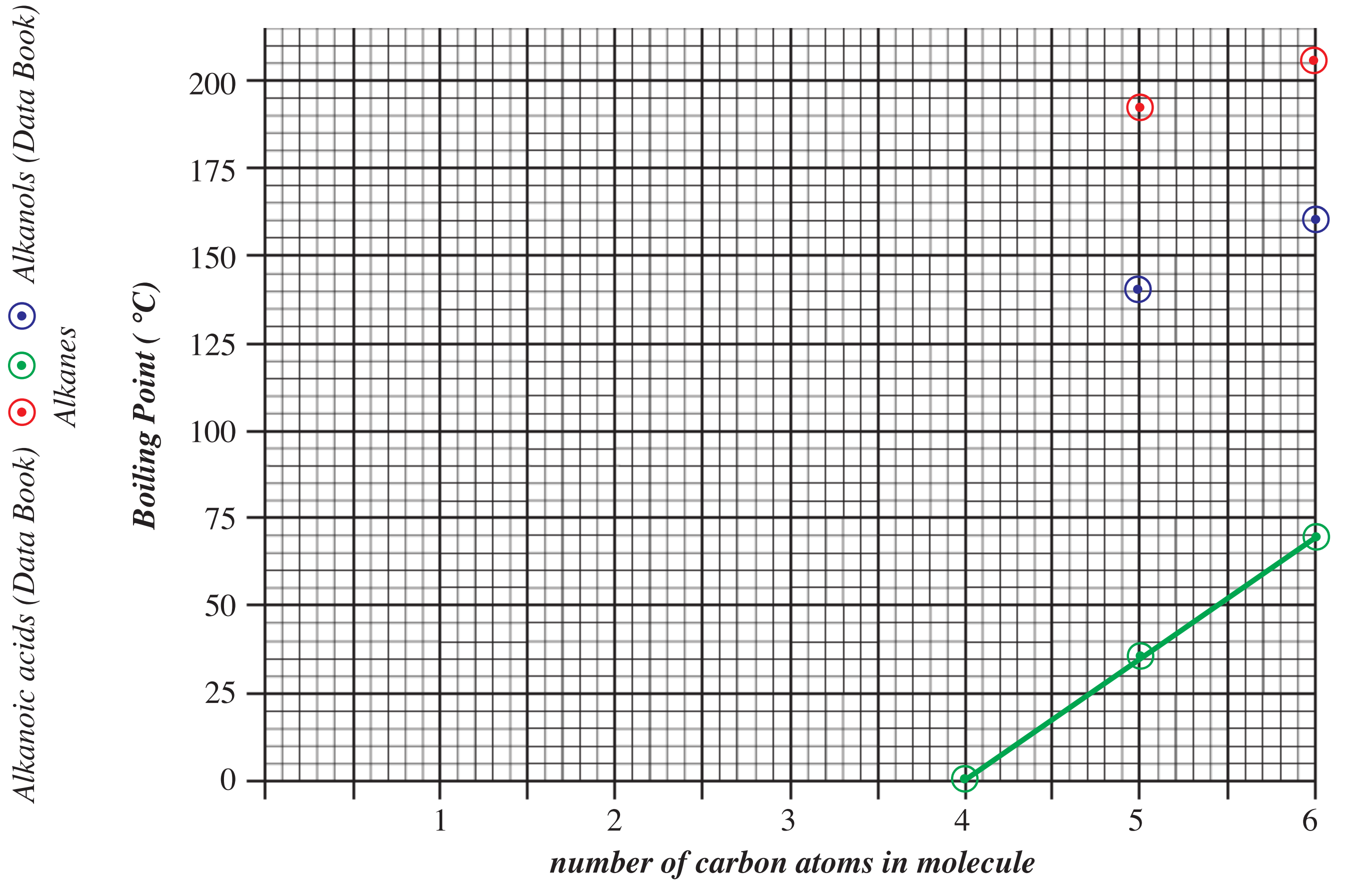
$H^+ \; CH_3COO^-{}_{(aq)}$

ethanoic acid

e.g	*magnesium*	+	*sulfuric acid*	→	*magnesium sulfate*	+	*hydrogen*
	$Mg_{(s)}$	+	$H_2SO_{4(aq)}$	→	$MgSO_{4(aq)}$	+	$H_{2(g)}$
	magnesium	+	*ethanoic acid*	→	*magnesium ethanoate*	+	*hydrogen*
	$Mg_{(s)}$	+	$CH_3COOH_{(aq)}$	→	$Mg(CH_3COO)_{2(aq)}$	+	$H_{2(g)}$

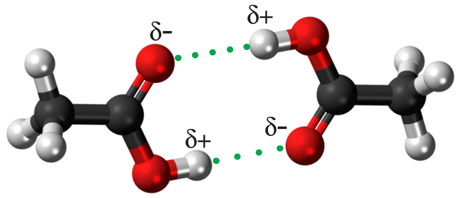
Properties

Most ***properties*** of the ***Carboxylic acids*** are a result of the ***stronger than normal attractions*** *between* the ***molecules***.

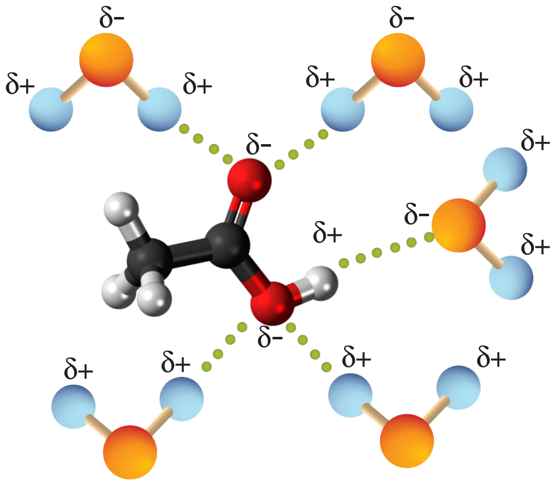


Melting & Boiling Pts

as usual, the ***melting and boiling points increase*** as the *size of the molecules increase*.



polar molecules can set up extra attractions



Solubility

small acid molecules are very ***soluble*** (***miscible***) in water, ***solubility will decrease*** as the *hydrocarbon chain gets bigger*.

Flammability

as usual, the ***flammability increases*** as the *size of the molecules decrease*.

General Formula

The ***general formula*** for the ***alkanoic acids*** is:-

$$C_nH_{2n+1}COOH$$

Notice that one of the ***carbon*** atoms is not included in the C_n '*chain*'. This is to enable the ***carboxyl functional group*** to be emphasised. ***WARNING !*** - this means that for each acid **n** is one less than you'd expect; *methanoic* **n = 0**, *ethanoic* **n = 1**, etc.

From all this it can be seen that the ***alkanoic** acids* have:

① ***similar chemical*** *properties*

② ***physical*** *properties* that show a *steady* ***trend***

and ③ a *common* ***general*** *formula*,

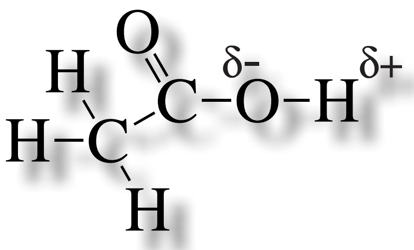
so they belong to a ***homologous*** *series*

Organic Salts

*Whenever an organic acid reacts, an **organic salt** will be produced - the molecular ion left behind when the H^+ ion reacts.*

$H^{\delta+}—Cl^{\delta-}$ ➡ $H^+ \; Cl^-_{(aq)}$ ➡ $Cl^-_{(aq)}$

hydrogen chloride — *hydrochloric acid* — *chloride ion*



➡ $H^+CH_3COO^-$ ➡ CH_3COO^-

ethanoic acid — ***ethanoate ion***

The ***acid*** name has the '*—oic*' ending replaced with an '*—oate*' ending.

'parent acid'	***salt formed***
methanoic	*methan**oate***
ethanoic	*ethanoate*
propanoic	*propanoate*
butanoic	*butanoate*

e.g *sodium oxide* + *hydrochloric acid* → *sodium chloride* + *water*

$Na_2O_{(s)} + 2\ HCl_{(aq)} \rightarrow 2\ NaCl_{(aq)} + H_2O_{(l)}$

sodium oxide + *ethanoic acid* → *sodium ethanoate* + *water*

$Na_2O_{(s)} + 2\ CH_3COOH_{(aq)} \rightarrow 2\ NaCH_3COO_{(aq)} + H_2O_{(l)}$

e.g *copper(II) carbonate* + *nitric acid* → *copper (II) nitrate* + *water* + *carbon dioxide*

$CuCO_{3\,(s)} + 2\ HNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

copper(II) carbonate + *methanoic acid* → *copper (II) methanoate* + *water* + *carbon dioxide*

$CuCO_{3\,(s)} + 2\ HCOOH_{(aq)} \rightarrow Cu(HCOO)_{2\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$

Q1. Int2

A student carefully measured the boiling points of some alcohols. The results are shown in the following table.

Alcohol	*Boiling Point (°C)*
propan-1-ol	97
propan-2-ol	81
butan-1-ol	117
butan-2-ol	100
pentan-1-ol	137
pentan-2-ol	119

a) What is the effect on the boiling point of an alkanol of moving the hydroxyl group from an end-of-chain position to the next carbon along?

moving to position 2 ***decreases*** *the Boiling Point*

b) Predict the boiling point of hexan-2-ol.

81 → 100 → 119 → ***138***

c) Give the shortened structural formula for pentan-2-ol.

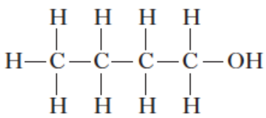
$CH_3CH_2CH_2CH_2(OH)CH_3$ or equivalent

Q2. Higher

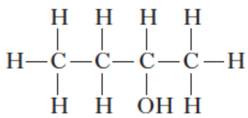
The structures for molecules of four liquids are shown below.

Which liquid will be the most viscous?

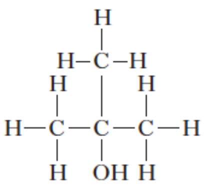
A



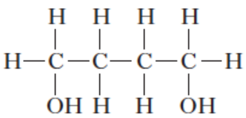
B



C



D



Q3.

Many medicines are available as tablets which dissolve readily in water.

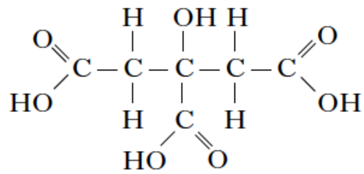
These tablets contain solid citric acid and sodium hydrogencarbonate.

a) When the tablet is added to water the citric acid reacts with the sodium hydrogencarbonate giving off a gas.

Name the gas produced.

carbon dioxide

b) The structure of citric acid is shown below.



i) Circle the functional groups responsible for the acidic nature of this molecule.

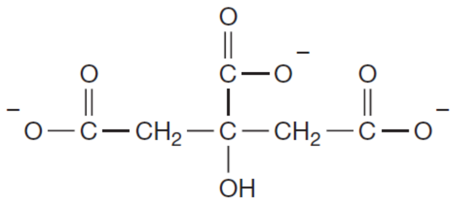
ii) Name the other functional group present.

hydroxyl

iii) Write the molecular formula for citric acid.

$C_6H_8O_7$

c) Draw the structure of the dissociated form of citric acid.



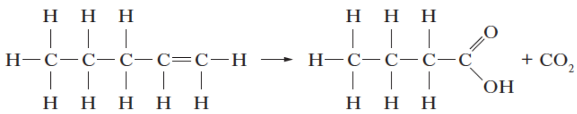
d) How many moles of NaOH would react with one mole of citric acid?

3 H^+ ions so 3 moles of NaOH (3 OH^- ions)

Q4.

Potassium permanganate can be used to convert alkenes into two molecules.

The conversion of pent-1-ene is shown.



molecule X

a) Name molecule X.

butanoic acid

b) State the test for carbon dioxide.

lime water *turns* ***cloudy/milky***

6.4 Energy From Fuels

Alcohol Biofuels

Whilst ***ethanol*** can be made from ***alkenes*** by the ***addition*** of *water* (**hydration**), it has also always been made by the ***fermentation*** of ***sugars***.

Traditionally the *microorganism* ***yeast*** has been used to make ***ethanol*** but, recently, other *microorganisms* like ***bacteria*** have been used to make *mixtures* of ***ethanol*** and ***butanol***.

Ethanol and ***butanol*** are *greener* fuels than ***petrol*** and ***diesel*** but ***butanol*** has advantages over ***ethanol*** that mean that a lot of work is going into developing ***bacterial fermentation***.

Advantages of ethanol and butanol

SCOTTISH biofuel PROGRAMME *energising business*

Can be produced sustainably and are renewable fuel sources

Adds oxygen to petrol/diesel blends – reducing greenhouse gas and unburned hydrocarbon emissions

Blend with petrol and diesel as a fuel extender

Higher octane rating than petrol/ diesel which increases engine performance

Butanol versus ethanol

Not hygroscopic (does not pick up water)

Completely miscible with diesel (separation under cold and damp conditions is a problem with ethanol-diesel blends requiring emulsifier addition)

Low vapour pressure (easier and safer to handle) means less evaporation in comparison to ethanol, highly flammable vapours are a problem with ethanol

Blend with petrol to any per cent (ethanol limited to 85%)

No engine modifications required (less corrosive than ethanol) which means it can be added to any vehicle on the road.

Can be handled & stored in current infrastructure for petrol

More similar properties to petrol and diesel therefore makes it easier to blend, it has a higher viscosity, reducing pump and injector leakage (observed with ethanol) which is important for fuel delivery in the vehicle

A longer hydrocarbon chain = more energy from its combustion compared to ethanol

Fermentation is a ***chemical*** reaction that certain ***plants*** can use to produce ***energy*** whenever the supply of ***oxygen*** is too poor to allow normal ***respiration***.

Yeast is a plant (a ***fungus***) that is particularly well suited to living in conditions where ***oxygen*** is in ***poor*** supply. Long ago, bakers and brewers learnt to use ***yeast*** for their own purposes. Bakers used the ***carbon dioxide*** gas produced during ***fermentation*** to help their dough to 'rise'.

Respiration

Glucose + oxygen → carbon dioxide + water + ***energy***

Fermentation

Glucose → carbon dioxide + ethanol + ***energy***

Almost anything, ***fruit***, ***vegetables***, ***grains*** etc, can be used for ***fermentation***, hence, the wide variety of ***alcoholic*** drinks made all around the world.

Yeast contains a ***biological catalyst***, an ***enzyme***, called *zymase*. In ***beer*** making the ***yeast*** is grown and added to the ***hops***, wheras ***grapes*** have ***yeast*** present on their skin making ***wine*** particularly easy to make. Most ***baking*** is done using 'yeast extracts' , in other words, ***zymase***.

Specific Heat Capacity

ΔH = *energy gained or lost by the water*

c = *specific heat capacity of the water*

m = *mass of the water*

ΔT = *rise or fall in temperature*

$$\Delta H = c \times m \times \Delta T$$

During ***chemical*** reactions ***energy*** is ***released*** *to the* ***surroundings***, ***exothermic***, or ***taken in*** *from the* ***surroundings***, ***endothermic***.

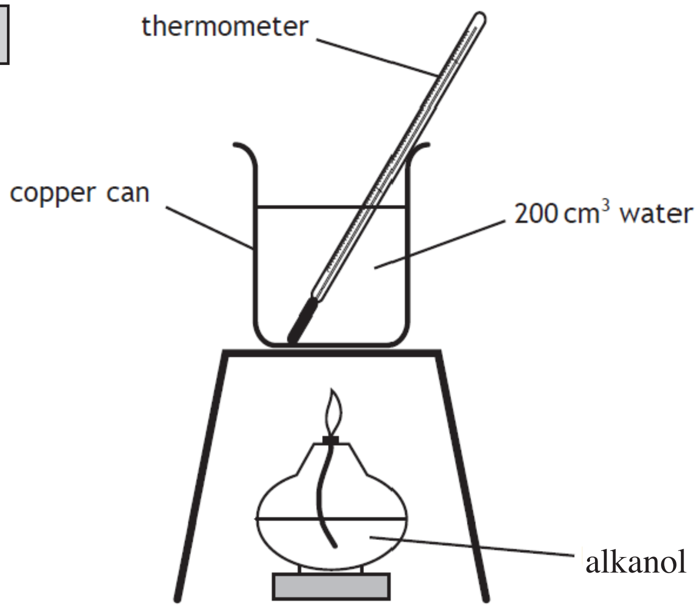
Often, the ***surroundings*** are the ***water*** that the chemicals are ***dissolved*** in or we can arrange things so that water absorbs the heat.

We know exactly ***how much energy*** it takes to heat, or cool down, ***1kg*** of water by exactly ***1°C***. This is the ***specific heat capacity***,

$c = 4.18\ kJ\ kg^{-1}\ °C^{-1}$ (***Data Book***)

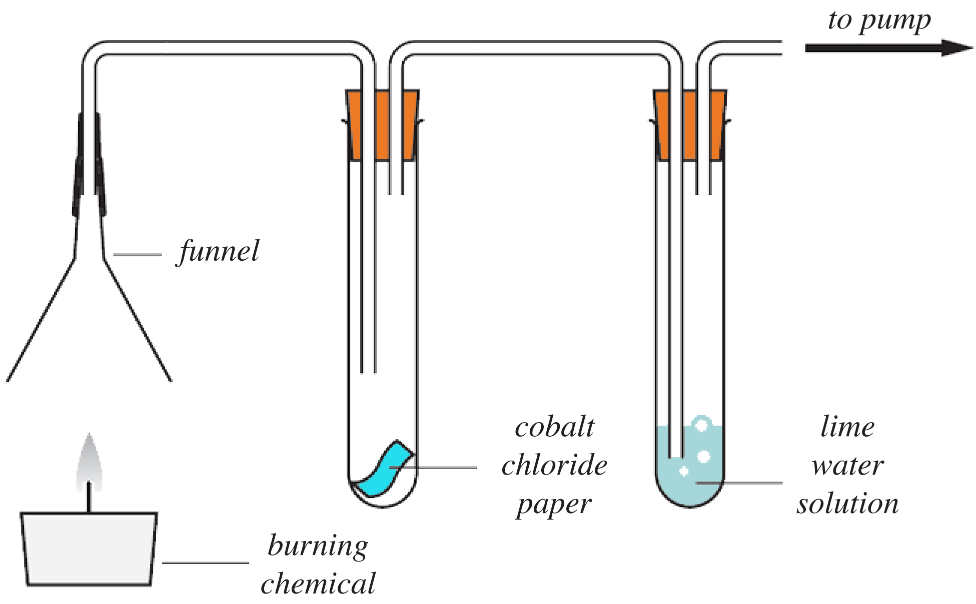
Remember: *the density of water is 1.00 g cm^{-3} and 1cm^{3} = 1ml so:-* *1ml of water = 1g*

Measuring Energy from Fuels



Combustion Equations

This reaction is effectively the same for all organic molecules including ***alcohols***, ***acids*** and ***esters***.



carbon → ***carbon dioxide***: as shown by the ***lime water*** turning ***milky / cloudy***

hydrogen → ***water***: as shown by the ***blue Cobalt Chloride*** paper turning ***pink***

methanol + ***oxygen*** → ***carbon dioxide*** + ***water***

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$$

butanoic acid + ***oxygen*** → ***carbon dioxide*** + ***water***

$$C_3H_7COOH + 5O_2 \rightarrow 4CO_2 + 4H_2O$$

octanoic acid + ***oxygen*** → ***carbon dioxide*** + ***water***

$$C_7H_{15}COOH + 12O_2 \rightarrow 8CO_2 + 8H_2O$$

organic molecule + ***oxygen*** → ***carbon dioxide*** + ***water***

*Combustion equations are particularly suitable for practising how to do '**calculations based on balanced equations**' - **Section 5 (page 8)** of your **Chemistry Calculations Booklet 1**.*

Q1. Int2

The alkanals are a homologous series of compounds that all contain the elements carbon, hydrogen and oxygen.

a) What is meant by the term homologous series?

Group/family/chemicals with same general formula

***and** same/similar (chemical) properties*

b) The combustion of alkanals releases heat energy.

Name of alkanal	Heat energy released when one mole burns (kJ)
methanal	510
ethanal	1056
propanal	1624
butanal	2304

i) Make a general statement linking the amount of heat energy released and the number of carbon atoms in the alkanal molecules.

*As **number of carbon atoms** increases*

***amount of heat energy released** increases*

ii) Predict the amount of heat energy released, when 1 mole of pentanal burns.

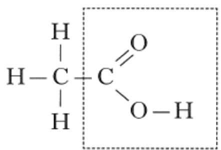
546 578 680 ***852*** ***852 + 2304***

32 102 ***172*** ***3156*** kJ

Q2. Int2

Ethanoic acid is a member of the alkanoic acid family.

a) The functional group in ethanoic acid has been highlighted.



Name this functional group.

carboxyl group

b) Ethanoic acid can be prepared by reacting methanol with carbon monoxide.

$$CH_3OH \quad + \quad CO \rightarrow CH_3COOH$$

Calculate the mass of ethanoic acid produced from 16 g of methanol.

1 mole ⟶ *1 mole*

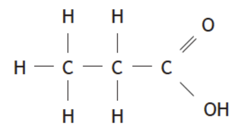
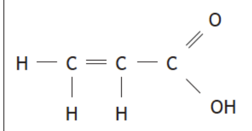
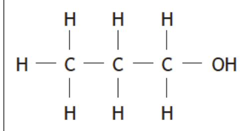
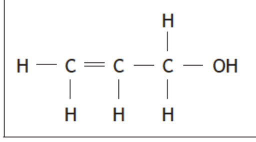
32 g ⟶ *60 g*

16 g ⟶ *60 x 16/32*

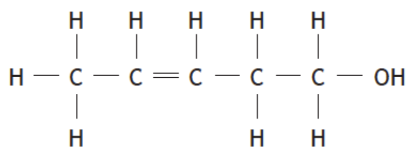
⟶ *30 g*

Q3. Int2

A student tested some compounds. The results are given in the table.

Compound	*pH of aqueous solution*	*Effect on bromine solution*
	4	no effect
	4	decolourised
	7	no effect
	7	decolourised

Which line in the table below shows the correct results for the following compound?



	pH of aqueous solution	*Effect on bromine solution*
A	4	decolourised
$\boxed{\text{B}}$	7	decolourised
C	4	no effect
D	7	no effect

Q4. Higher

When 1 mole of methanol (CH_3OH) is burnt, 727 kJ of energy is released.

What mass of methanol has to be burned to produce 72·7 kJ?

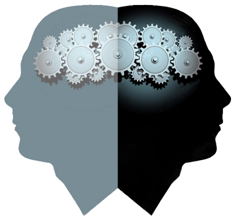
$\boxed{\textbf{A}}$ 3.2 g

B 32 g

C 72.7 g

D 727 g

N5 Knowledge Met in this Section



Homologous Series

- A homologous series is a group of compounds with:
    - ❖ similar chemical properties
    - ❖ the same general formula
    - ❖ a gradual change in physical properties such as melting and boiling point.
- Examples of homologous series include families of compounds called the ***alkanols*** and ***alkanoic acids***.

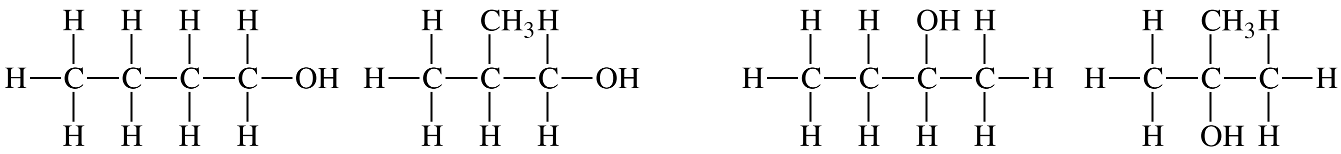
Alkanols

- The ***alkanols*** are the family of ***alcohols*** which have the ***hydroxyl group —OH*** on a chain of carbon atoms with single (C — C) bonds only

Name	*Molecular Formula*	*Shortened Structural Formula*
methanol	$CH_3OH_{(l)}$	CH_3OH
ethanol	$C_2H_5OH_{(l)}$	CH_3CH_2OH
propanol	$C_3H_7OH_{(l)}$	$CH_3CH_2CH_2OH$
butanol	$C_4H_9OH_{(l)}$	$CH_3CH_2CH_2CH_2OH$
pentanol	$C_5H_{11}OH_{(l)}$	$CH_3CH_2CH_2CH_2CH_2OH$
hexanol	$C_6H_{13}OH_{(l)}$	$CH_3CH_2CH_2CH_2CH_2CH_2OH$
heptanol	$C_7H_{15}OH_{(l)}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$
octanol	$C_8H_{17}OH_{(l)}$	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$

- The ***general formula*** for the alkanols is $C_nH_{2n+1}OH$
- Most alkanols will be made by the ***addition*** of water (***hydration***) to ***alkenes***
- Ethanol can be made by the ***yeast fermentation*** of sugars
- Other alcohols can be made by the ***bacterial fermentation*** of sugars
- The alkanols have ***weak attractions*** *between* their molecules and the early (smaller) members of the family
    - ❖ have ***very low melting & boiling points***
    - ❖ are ***volatile***, ***flammable*** and ***non-viscous*** (*runny*)
- The alkanols, however, have ***stronger attractions*** same as water so
    - ❖ the smaller members are ***soluble*** (*miscible*) in water
- The alcohols are used in a wide variety of ***consumer products***

- Alkanols can be ***straight chained*** or ***branched*** and the ***hydroxyl*** group can change position.



- Alkanols can be ***named*** systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

butan-1-ol ***2-methylpropan-1-ol*** ***butan-2-ol*** ***2-methylpropan-2-ol***

- The alkanols burn to give carbon dioxide and water on ***complete combustion***

Alkanoic acids

- The ***alkanoic acids*** are the family of ***organic acids*** which have the ***carboxyl group —COOH*** on a chain of carbon atoms with single (C — C) bonds only

Name	*Molecular Formula*	*Shortened Structural Formula*
meth***anoic acid***	$HCOOH_{(l)}$	$HCOOH$
eth***anoic acid***	$CH_3COOH_{(l)}$	CH_3COOH
prop***anoic acid***	$C_2H_5COOH_{(l)}$	CH_3CH_2COOH
hex***anoic acid***	$C_5H_{11}COOH_{(l)}$	$CH_3CH_2CH_2CH_2CH_2COOH$

- The ***general formula*** for the alk***anoic acids*** is $C_nH_{2n+1}COOH$ (n = 0, 1 etc)
- Most alkanoic acids will be made by the ***oxidation*** of an ***alkanol***
- The alkanoic acids burn to give carbon dioxide and water on ***complete combustion***
- The alkanoic acids have ***weak attractions*** *between* their molecules and the early (smaller) members of the family
    - ❖ have ***very low melting & boiling points***
    - ❖ are ***volatile***, ***flammable*** and ***non-viscous*** (*runny*)
- The alkanoic acids, however, have ***stronger attractions*** same as water so
    - ❖ the smaller members are ***soluble*** (*miscible*) in water
- The alkanoic acids ***dissociate*** in water to produce $\boldsymbol{H^+_{(aq)}}$ ***ions*** and will
    - ❖ react with ***metals*** to produce ***hydrogen gas***
    - ❖ react with ***carbonates*** to produce ***carbon dioxide gas***
    - ❖ be ***neutralised*** by the addition of ***alkali*** ($\boldsymbol{OH^-_{(aq)}}$ ***ions***)

- ***Straight chained acids*** can be ***named*** systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

  but-1-ene ***but-2-ene*** ***2-methylpropene***
- The acids burn to give carbon dioxide and water on ***complete combustion***
- The acids are used in a wide variety of ***consumer products***

Organic Salts

- Whenever an *organic acid* reacts, an ***organic salt*** will be produced.
- The salt will contain the molecular ion left behind when the H^+ ion reacts.

Acid Name	*Molecular Formula*	*Molecular Ion*	*Salt Name*
*meth**anoic acid***	$HCOOH_{(l)}$	$HCOO^-_{(aq)}$	*meth**anoate***
*eth**anoic acid***	$CH_3COOH_{(l)}$	$CH_3COO^-_{(aq)}$	*eth**anoate***
*prop**anoic acid***	$C_2H_5COOH_{(l)}$	$C_2H_5COO^-_{(aq)}$	*prop**anoate***
*but**anoic acid***	$C_3H_{11}COOH_{(l)}$	$C_3H_{11}COO^-_{(aq)}$	*but**anoate***

Energy from Fuels

- Organic molecules release energy (***exothermic***) when they burn (***combustion***)
- Alkanes and alcohols are of particular use as fuels
- Alcohol can be made from any fruit or vegetable containing starch or sugars e.g. grapes (glucose) → wine, barley (starch) → whisky, rice (starch) → saki
- The alcohol in alcoholic drinks is ***ethanol***, the second member of a family called the ***alkanols***
- Alcohol (***ethanol***) is obtained from glucose by a process called ***fermentation***
- ***Fermentation*** is the breakdown of glucose to form ethanol and carbon dioxide. An enzyme in ***yeast***, a living organism, acts as a catalyst for the reaction:

  glucose → ethanol + carbon dioxide
- $C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$
- There is a limit to the alcohol contencentration of fermented drinks because yeast cells die if the concentration rises above 12 %
- Like all enzymes, those used in fermentation have a pH and a temperature at which they work best (their optimum pH and temperature)
- Since water boils at 100 °C and ethanol boils at 78 °C, the two can be separated by ***distillation***. This enables high alcohol drinks such as whisky to be made (spirits)

CONSOLIDATION QUESTIONS A

Q1. Int2

A bottle of whisky contains 40% ethanol by volume.

Which line in the table is the correct description of the mixture?

	Solute	Solvent	Solution
A	ethanol	whisky	water
$\boxed{B}$	ethanol	water	whisky
C	water	ethanol	whisky
D	whisky	water	ethanol

Q2. Int2

When a compound is burned completely, the products are carbon dioxide and water.

From this information, it can be concluded that the compound must contain

A carbon only

B hydrogen only

$\boxed{\textbf{C}}$ carbon and hydrogen

D carbon, hydrogen and oxygen

Q3. Int2

Ethanol can be produced from sugar cane by

A oxidation

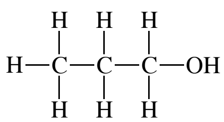
$\boxed{\textbf{B}}$ fermentation

C polymerisation

D catalytic hydration.

Q4. Int2

Propan-1-ol can be dehydrated.



Which of the following compounds is a product of the reaction?

A Propanoic acid

B Propan-2-ol

$\boxed{\textbf{C}}$ Propene

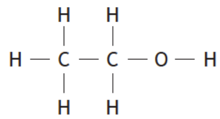
D Propane

Q6. N5

Car manufacturers have developed flexible fuel engines for vehicles.These vehicles can run on ethanol or petrol or a mixture of both.

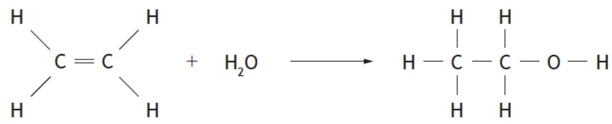
Ethanol can be produced from ethene which comes from cracking crude oil. It can also be made by fermenting glucose which is obtained from crops such as sugar cane and maize.

a) The structure of ethanol is shown opposite.



Circle the functional group in this molecule.

b) Ethanol is produced from ethene as shown.

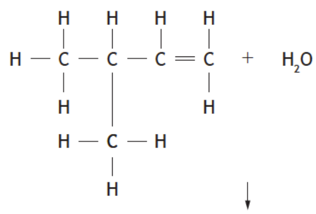


ethene ethanol

i) Name the ***type*** of chemical reaction taking place.

addition or hydration

ii) Draw a structural formula for a product of the following reaction.



c) Suggest one ***advantage*** of producing ethanol from crops.

renewable / carbon neutral / no greenhouse effect

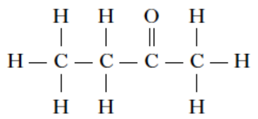
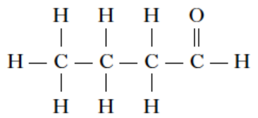
d) Suggest one ***disadvantage*** of producing ethanol from crops.

A lot of land used to make ethanol instead of crops to feed people ***or*** *low yield* ***or*** *deforestation*

CONSOLIDATION QUESTIONS B

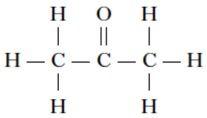
Q1. Int2

The table shows the result of heating two compounds with acidified potassium dichromate solution.

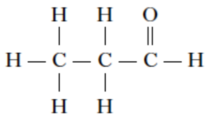
Compound	Acidified potassium dichromate solution
	stays orange
	turns green

Which of the following compounds will ***not*** turn acidified potassium dichromate solution green?

A



B



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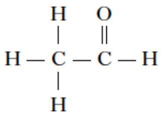

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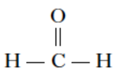
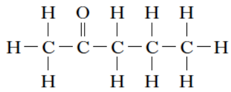


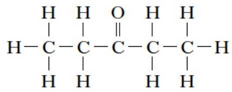
Q2. Int2

Chemicals in food provide flavour and smell. Ketones are responsible for the flavour in blue cheese.

Two examples of ketones are shown below.

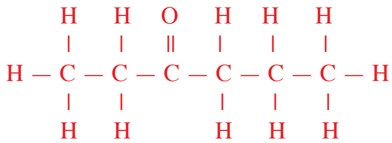


pentan-2-one

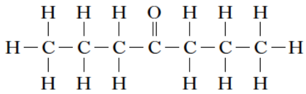


pentan-3-one

a) Draw a structure for hexan-3-one.



b) Suggest a name for the ketone shown below.



heptan-3-one

c) Information about the boiling points of four ketones is shown in the table.

Ketone	Boiling point (°C)
C_3H_6O	56
C_4H_8O	80
$C_5H_{10}O$	102
$C_6H_{12}O$	127

Predict the boiling point of $C_7H_{14}O$. *151* °C

+24 , + 22 , +25 mean value = + 23.7 (24)

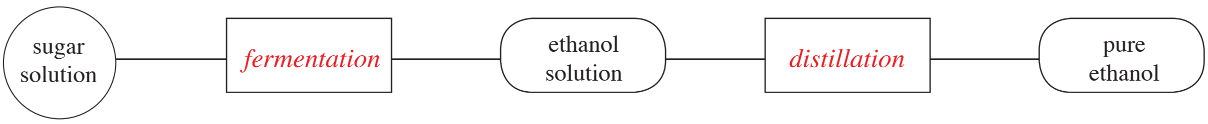
Q3. Int2

Ethanol can be manufactured in different ways from different raw materials.

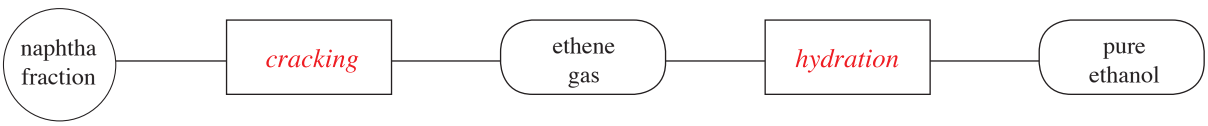
Selevt the appropriate processes from the following list to complete the two flowcharts below

fermentation *hydration* *dehydration*
cracking *distillation* *oxidation*

a)



b)



CONSOLIDATION QUESTIONS C

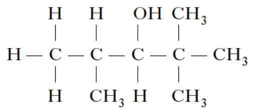
Q1. Int2

The shortened structural formula for an organic compound is

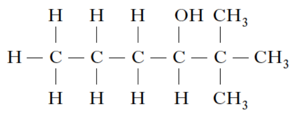
$$CH_3CH(CH_3)CH(OH)C(CH_3)_3$$

Which of the following is another way of representing this structure?

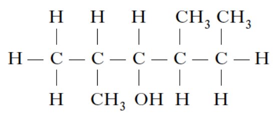
A



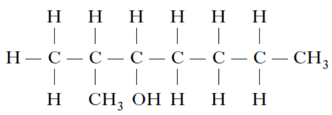
B



C



D



Q2.

Which of the following compounds fits the general formula, C_nH_{2n}, and will rapidly decolourise bromine solution?

A cyclopentane

B pentane

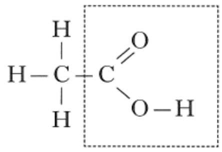
C pentene

D cyclopentene

Q3.

Ethanol can be used to produce ethanoic acid.

a) Draw a structural formula for ethanoic acid.



b) To which family of compounds does ethanoic acid belong?

*carboxylic acid **or** alkanoic acid **NOT** just acid*

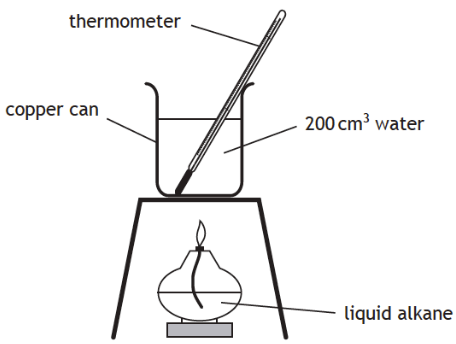
Q4. Int2

Alkanes burn, releasing energy.

a) What name is given to any chemical reaction which releases energy?

exothermic

b) A student investigated the amount of energy released when an alkane burns using the apparatus shown.



The student recorded the following data.

Mass of alkane burned	1 g
Volume of water	200 cm^3
Initial temperature of water	15 °C
Final temperature of water	55 °C
Specific heat capacity of water	4·18 kJ kg^{-1} °C^{-1}

b) contd

i) Calculate the energy released, in kJ.

You may wish to use the data booklet to help you.
Show your working clearly.

33·44 on its own = 3 marks

$E_H = cm\Delta T = 4\ 18 \times 0\ 2 \times 40 = 33\ 44$

and using concept $cm\Delta T$ with $c = 4{\cdot}18$ ***1 mark***

using data correctly ie 0·2 and 40 °C ***1 mark***

final answer ***1 mark***

ii) Suggest one improvement to the student's investigation.

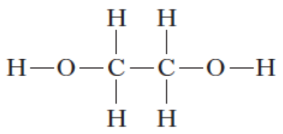
Any one from:

heat insulation
repeat to get average
move burner nearer to can
remove tripod and clamp can
stir water
thermometer not touching copper can
use clay triangle on tripod
or any reasonable answer

CONSOLIDATION QUESTIONS D

Q1. Higher

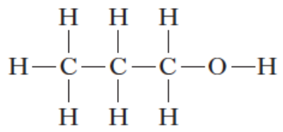
Alcohols are widely used in antifreeze and de-icers.



ethane-1,2-diol

molecular mass 62

boiling point 197 °C



propan-1-ol

molecular mass 60

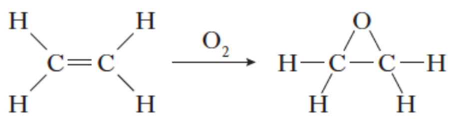
boiling point 98 °C

a) Why is the boiling point of ethane-1,2-diol much higher than the boiling point of propan-1-ol?

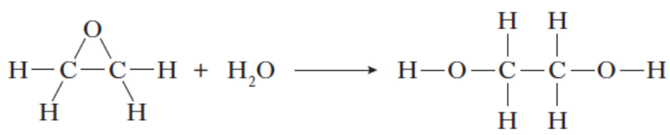
because ***two (polar) hydroxyl groups*** (—OH) will result in ***stronger attactions between molecules***

b) Ethane-1,2-diol can be produced industrially from ethene in a two stage process:

Stage one



Stage two



Name the alkene required to produce butane-2,3-diol.

but-2-ene

Q2. N5

Liquefied petroleum gas (LPG), which can be used as a fuel for heating, is a mixture of propane and butane.

a) Propane and butane are members of the homologous series of alkanes.

Tick (✓) the two boxes that correctly describe members of the same homologous series.

	Tick (✓)
They have similar chemical properties.	(✓)
They have the same molecular formula.	
They have the same general formula.	(✓)
They have the same physical properties.	
They have the same formula mass.	

b) The table gives some information about propane and butane.

Alkane	*Boiling Point (°C)*
propane	−42
butane	−1

Explain why butane has a higher boiling point than propane.

*butane has a **larger molecule** (more carbon atoms) which means*

***more (stronger) attractions** between molecules*