WJEC EDUQAS AS CHEMISTRY · COMPONENT 2

CHEMISTRY



EXAM QUESTION PACK

2.7 ALCOHOLS AND CARBOXYLIC ACIDS

SCORE	PERCENTAGE
/105	%

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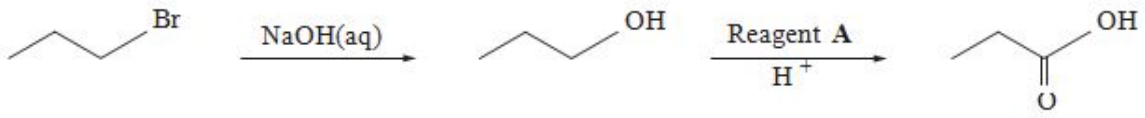
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1.

(a) 1-bromopropane can be used to prepare propanoic acid in a two-stage process shown below.



(i) Classify the reaction occurring in the first stage of this process.

[1]

(ii) The first stage uses aqueous sodium hydroxide. Under alternative conditions, 1-bromopropane produces a different product when it reacts with sodium hydroxide.

Give the alternative conditions required, and the product that would be formed from 1-bromopropane under these conditions.

[2]

(iii) For the second stage, state the **full name** of reagent **A** and classify the reaction occurring.

[2]

(iv) Reagent **A** can also be used to produce propanal from propan-1-ol. State how you would isolate propanal from this reaction

[1]

(b) (i) 1-bromopropane can also be used to prepare butanoic acid in a different two-stage process. For **each** of these two stages, give reagents and conditions required, and draw the **displayed** formula (showing all bonds) of the intermediate.

[3]

(ii) Butanoic acid is used to prepare esters used in the flavouring and perfume industries. It may be prepared from 1-bromopropane in a two-stage process as in *(b)* (i) above or from butan-1-ol or butanal in a one-stage process.

Suggest **two** factors that a scientist would consider in choosing between these different routes to produce butanoic acid on a bulk scale.

[2]

(c) Compound **B** is an isomer of formula $C_4H_8O_2$ which exists as a sweet-smelling liquid at room temperature.

(i) Elemental analysis of compound **B** shows that it has a composition of 54.5 % carbon, 9.1 % hydrogen and 36.4 % oxygen, by mass. Show that this composition is consistent with the formula above. [2]

(ii) Compound **B** shows three resonances in its H nuclear magnetic resonance spectrum.

- A triplet at 1.0 ppm with an area of 3
- A singlet at 2.1 ppm with an area of 3
- A quartet at 4.0 ppm with an area of 2

The infrared spectrum of compound **B** shows absorptions at 2981 cm^{-1} and 1750 cm^{-1}.

These are the only significant absorptions above 1500 cm^{-1}.

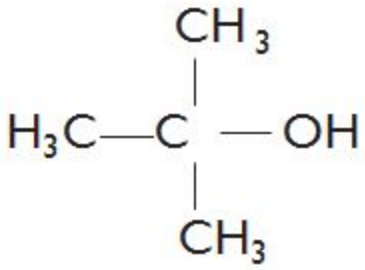
Using **all** the information supplied, deduce the structure of compound **B**. Give **reasons** in support of your answer.

[5] QWC [2]

(Total 20)

2. (a) In 2012 an off-licence in Derby was prosecuted for selling fake vodka

(i) A report in the local paper stated that this 'vodka' was contaminated by 'tertiary butanol', the formula of which is shown below.



State the **systematic** name of this compound.

[1]

(ii) Analysis showed that the total alcohol content of a bottle of the fake vodka was 35 %.

A gas-liquid chromatogram showed a mixture of alcohols to be present in the following proportions:

- Tertiary butanol 6 parts
- Methanol 8 parts
- Ethanol 86 parts

Calculate the percentage of ethanol by volume in the fake vodka.

[1]

..... %

(iii) Tertiary butanol can be dehydrated in an elimination reaction to produce 2-methylpropene. Suggest a suitable dehydrating agent for this reaction.

[1]

(Total 3)

3. *(a)* Ethanol, C_2H_5OH, is a liquid at room temperature. It is being increasingly used as a fuel.

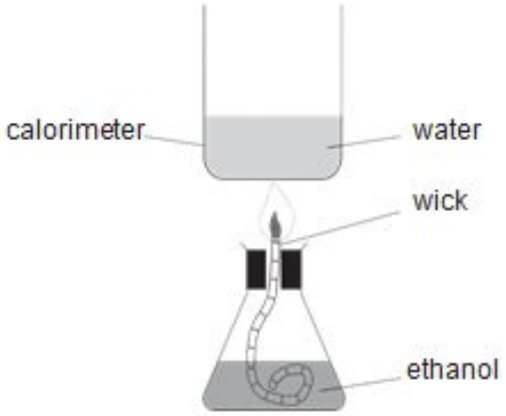
(i) Write the equation that represents the standard molar enthalpy change of formation (ΔH_f) of ethanol. [1]

(ii) Suggest why this enthalpy change cannot be measured directly. [1]

(b) Enthalpy changes of combustion can often be measured directly. The equation for the reaction which represents the enthalpy change of combustion (ΔH_c) of ethanol is as follows.

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$$

A student used the apparatus below to determine the enthalpy change of combustion of ethanol.



The student obtained the following results.

Mass of spirit burner + ethanol at start	= 72.27 g
Mass of spirit burner + ethanol after combustion	= 71.46 g
Temperature of water at start	= 21.5 °C
Temperature of water after combustion	= 75.5 °C
Volume of water in calorimeter	= 100 cm^3

The energy released in the experiment can be calculated using the formula

$$\text{energy released} = mc\Delta T$$

where m = mass of the water in grams (assume 1 cm^3 has a mass of 1 g)
c = 4.2 $Jg^{-1}°C^{-1}$
ΔT = change in temperature of the water

(i) Calculate the energy released in the experiment

[1]

Energy released = ... J

(ii) The enthalpy change of combustion of ethanol is defined as the energy change per mol of ethanol burned.

Use your answer to (i) to calculate the enthalpy change of combustion of ethanol.

Give your answer in kJ mol^{-1} and correct to **3 significant figures**. Include the sign.

[3]

(c) Another student did not carry out an experiment to find ΔH_c of ethanol. He looked up the literature value on a respected internet site.

How would you expect the numerical values obtained by the two students to differ? Explain your answer.

You may assume that both values were found under the same conditions of temperature and pressure.

[2]

(d) The students then used the apparatus from (b) to find the enthalpy change of combustion of higher relative molecular mass alcohols. They found that as the number of carbon atoms increased the value of the enthalpy change of combustion became more negative.

(i) Write the equation for the reaction which represents the enthalpy change of combustion of propanol, C_3H_7OH. [1]

(ii) In terms of bond strengths, explain why enthalpy changes of combustion are negative

[1]

(iii) Explain why the enthalpy change of combustion of propanol is more negative than that of ethanol

[1]

(e) Recent research has been carried out to find economic and environmentally friendly uses for waste straw and wood chippings.

The process of gasification involves the material being partly combusted at a temperature of about 700 °C to give a mixture consisting mainly of hydrogen and carbon monoxide but also some carbon dioxide.

Another approach has been to use enzyme catalysed reactions to change the waste material into glucose and then to ethanol.

Comment on the economic and environmental factors involved in both of these processes.

[4] QWC [2]

(Total 17)

4. Chloromethane can be produced by the chlorination of methane gas.

(a) During the initiation stage of this process, chlorine free radicals are produced.

(i) Give the condition(s) required for this initiation stage.

[1]

(ii) State what is meant by a *free radical.*

[1]

(b) Write the equation(s) for the propagation stage(s) to produce chloromethane starting with methane and chlorine free radicals

[2]

(c) Apart from chloromethane, a range of other compounds are produced in small amounts during the reaction.

(i) One of the compounds produced in the reaction is ethane. Show how this compound is produced.

[1]

(ii) Another of the compounds produced contains 24.3 % carbon, 4.1 % hydrogen and 71.6 % chlorine by mass. Calculate the **empirical** formula of this compound.

[2]

(d) Chloromethane can be converted into methanol by reaction with hydroxide ions

(i) Classify the mechanism of this reaction

[1]

(ii) The boiling temperatures of chloromethane and methanol are given in the table below.

Compound	Boiling temperature / K
chloromethane, CH_3Cl	249
methanol, CH_3OH	338

Explain why the boiling temperature of methanol is higher than the boiling temperature of chloromethane.

[3]

(iii) Methanol can then be converted to methanoic acid. Give the reagent(s) and condition(s) required for this reaction.

[2]

Reagent(s) .....

Condition(s) .....

(e) CFCs are another class of organic compounds. They contain chlorine, fluorine and carbon. These compounds once had a range of uses, however their use is now avoided due to their effect on the ozone layer which is part of the **upper** atmosphere.

The table shows the lifetime of some compounds in the **lower** atmosphere and their relative ozone depletion potential (RODP), taking CCl_3F as having a value of 1.0. The RODP is measured by mixing a compound with ozone in a laboratory experiment.

Compound	Formula	Lifetime in the lower atmosphere	Relative ozone depletion potential (RODP)
A	CHF_3	243 years	0.01
B	CCl_2F_2	20 years	0.86
C	CCl_3F	75 years	1.00
D	$CBrClF_2$	120 days	10.00

By referring to this table, explain why CFCs **B** and **C** are far more harmful than compounds **A** and **D**.

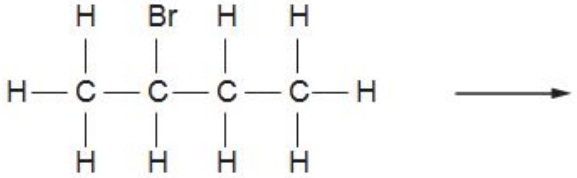
Your answer should explain how and why CFCs affect the ozone layer

[3]

(Total 16)

5. 2-Bromobutane, C_4H_9Br, is a halogenoalkane that behaves in a similar way to 1-chlorobutane.

(a) (i) Complete the diagram below to show the mechanism for the reaction between 2-bromobutane and aqueous sodium hydroxide. You should include relevant charges, dipoles, lone pairs and curly arrows to show the movement of electron pairs. [4]



(ii) What **type** of mechanism is shown in *(a)*(i)?

[1]

(iii) The reaction involves heterolytic bond fission.

What is meant by *heterolytic bond fission*?

[1]

(b) Bromoethane can be converted into ethene.

(i) Name the reagent and solvent needed to convert bromoethane into ethene.

[1]

(ii) What **type** of reaction occurs in *(b)*(i)?

[1]

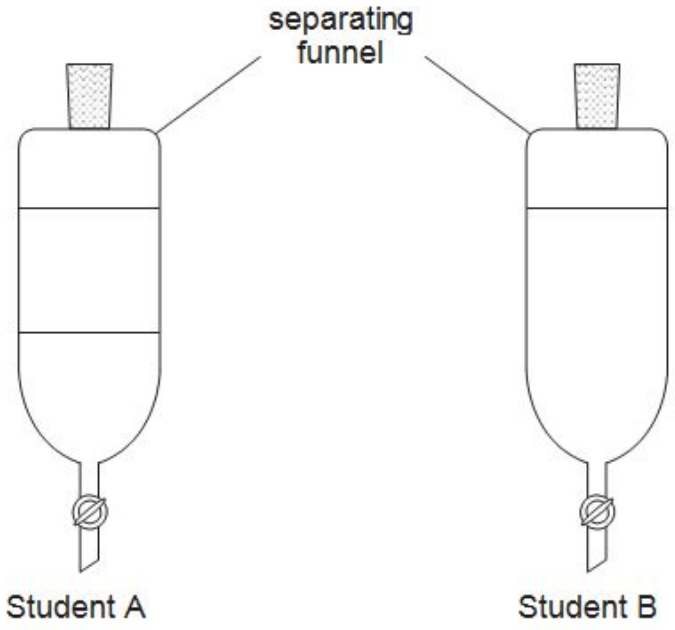
(iii) 2-Bromobutane behaves in a similar way to bromoethane in this type of reaction. When 2-bromobutane is reacted as described in *(b)*(i) two alkenes that are **structural** isomers are formed

Draw the displayed formulae of these two alkenes

[2]

(c) Two students were each given a different alcohol. They each added their alcohol to water in a separating funnel, shook the mixture and then left it to stand.

The diagrams show the results.



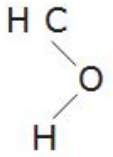
What can be deduced about the alcohols given to each student? You should explain why the alcohols behave differently in this experiment.

[5] QWC [1]

(Total 16)

6. Ethanol, C_2H_5OH, is the alcohol that is present in alcoholic drinks.

(a) Ethanol is soluble in water. Complete the diagram below to show why ethanol is soluble in water. You should include relevant lone pairs and dipoles and label the bond responsible for this solubility. [3]



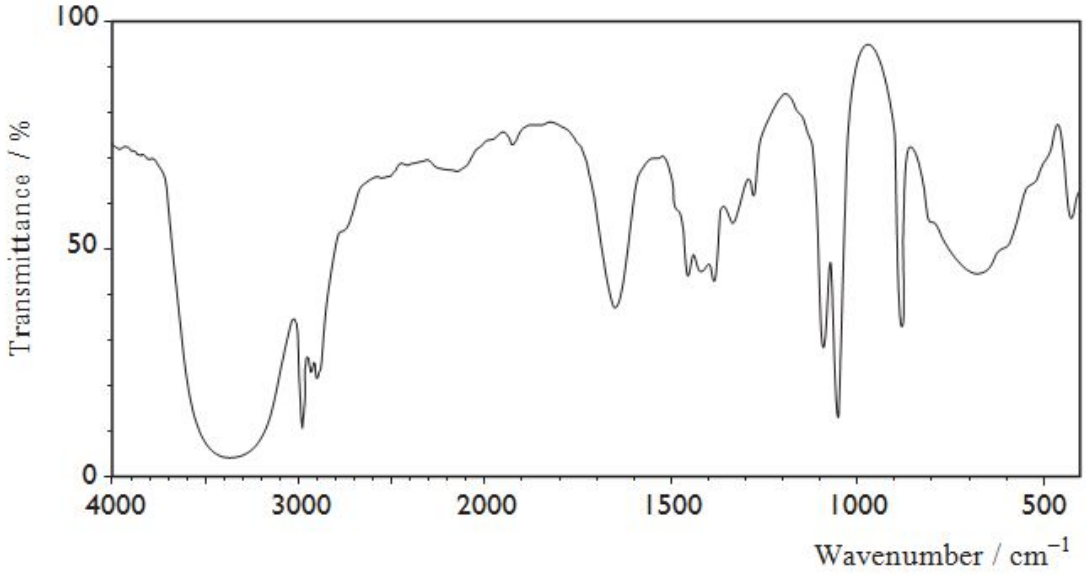
(b) If it is suspected that a driver has been drinking alcohol they can be tested in several ways.

(i) One method previously used to test for ethanol in breath involved blowing through acidified potassium dichromate(VI). A positive test was shown by the colour change from orange to green.

What type of reaction causes this colour change?

[1]

(ii) Another method uses IR spectroscopy. The IR spectrum for ethanol is shown below.



I. State which functional group is shown to be present in ethanol by the absorption at about 3350 cm^{-1}

[1]

II. A student suggested that this absorption should be used to test for the presence of ethanol in breath. Give a reason why this suggestion is not valid.

[1]

(c) If ethanol, in a drink such as wine, is left in an open bottle and exposed to air it becomes 'sour' and unpleasant to taste. This is because it forms ethanoic acid.

(i) Draw the **displayed** formula of ethanoic acid.

[1]

(ii) What significant change would be noticed if the IR spectrum of this product was compared with that of ethanol? Give the reason for this change

[2]

(Total 9)

7. State the reagent(s) used and the colour change seen when a primary alcohol is oxidised to give a carboxylic acid.

[2]

Reagent(s).....

Colour change from. . . . . *to* . . . . . .

(Total 2)

8. But-2-ene is a useful starting material for the production of synthetic rubber.

(a) But-2-ene can be produced from crude oil by fractional distillation and then cracking.

(i) Explain why fractional distillation can be used to separate molecules with different numbers of carbon atoms.

[1]

(ii) Write the equation for a cracking reaction that produces but-2-ene from decane, $C_{10}H_{22}$. [1]

(b) Bromine solution can be used to distinguish between but-2-ene and butane.

(i) Give the colour **change** that would be expected when bromine solution is added to but-2-ene.

[1]

(ii) In a similar reaction hydrogen bromide reacts with propene.

Draw the mechanism of the reaction of propene with hydrogen bromide indicating clearly all charges and the movement of electrons.

[3]

(iii) Propene can be produced from the product in part (ii) by using sodium hydroxide. Give the condition(s) required for this reaction.

[1]

(c) But-2-ene can exist as *E*- and *Z*-isomers.

(i) Explain why but-2-ene can form *E*- and *Z*-isomers whilst propene and butane cannot.

[2]

(ii) Draw the **skeletal** formula for *Z*-but-2-ene.

[1]

(d) In industry, butan-2-ol can be produced from but-2-ene. This uses the same reagent(s) and condition(s) as the production of ethanol from ethene.

(i) Give the reagent(s) and condition(s) used for this reaction

[2]

Reagent(s)

.....

Condition(s) .....

(ii) Explain how infrared spectroscopy can be used to distinguish between butan-2-ol and but-2-ene.

[1]

(Total 13)

9. During 2010 a serious leak of petroleum (crude oil) occurred in the Gulf of Mexico. This loss of millions of litres of petroleum caused an environmental and ecological disaster.

(a) Petroleum consists largely of a mixture of alkanes that do not dissolve in seawater but form a surface layer. The main reason that these alkanes cannot dissolve in water is because they are unable to hydrogen bond with water. Explain what is meant by *hydrogen bonding* and use this to explain why alkanes do not dissolve in water.

[4] QWC [1]

(b) (i) Some of the leaking oil was collected by tankers and taken to oil refineries. The petroleum was then separated into fractions by the process of fractional distillation. Describe what is meant by *fractional distillation.*

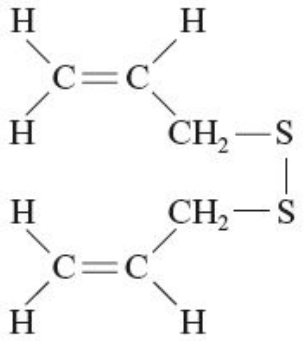
[2]

(ii) One of the fractions was then further refined into fuel for vehicles.
During refining, most of the sulfur compounds present in the fuel are removed in order to reduce the amount of oxides of sulfur released in exhaust gases.
One stage in the process is to convert unpleasant-smelling thioalcohols (R—SH) into disulfides (R—S—S—R) using copper chloride, $CuCl_2$.

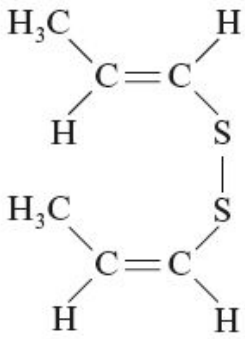
$$2R—SH + 2CuCl_2 \longrightarrow R—S—S—R + 2CuCl + 2HCl$$

Explain, using the oxidation states (numbers) of copper, why copper chloride, $CuCl_2$, is reduced in this reaction. You should assume that the oxidation state of chlorine is –1. [2]

(c) Compounds **A** and **B** are organic compounds of sulfur found naturally in some foods.



compound **A**
found in garlic



compound **B**
produced on cooking onions

(i) These two compounds are structural isomers. State what is meant by the term *structural isomer*.

[1]

(ii) Explain why only compound **B** can exist as E-Z isomers.Your answer should comment on the atoms/groups involved and the reason why these give rise to E-Z isomerism.

[2]

(iii) Compound **A** is sold by the chemical suppliers at £48.00 for 100 g. The material sold is only 73% pure but this is satisfactory for the purposes needed.
Calculate the cost of 1 mol of compound **A**, which has a molecular formula $C_6H_{10}S_2$. [2]

(Total 14)

(ii) Structure 1 mark + 4 marks for explanations.

- Product is ethyl ethanoate. (1)
- Two points from the following required for each mark– MAX 4 marks
  - Sweet-smelling = ester
  - Peak at 1.0ppm implies – CH_3
  - Peak area 3 = CH_3
  - Peak area 2 = CH_2
  - Triplet shows CH_3 is next to a CH_2 group.
  - Singlet shows CH_3 no hydrogen atoms bonded to adjacent carbon.
  - Peak at 2.1 ppm suggests this is next to C=O.
  - Quartet shows CH_2 is adjacent to a CH_3 group.
  - Peak at 4.0 ppm shows it is –O-CH_2-
  - IR Peak at 1752 cm^{-1} = C=O
  - IR Peak at 2981 cm^{-1} = C-H or O-H
  - Cannot be –OH as we know there is no –OH in NMR spectrum

[5]

QWC: selection of a form and style of writing appropriate to purpose and to complexity of subject matter. (1)

QWC: organisation of information clearly and coherently; use of specialist vocabulary where appropriate. (1) [2]

[20 marks]

2 (a) (i) (2-)Methylpropan-2-ol **[1]**

(ii) 30.1 / 30 **[1]**

(iii) (Concentrated) sulfuric acid / phosphoric acid / aluminium oxide / pumice **[1]**

3 (a) (i) $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$ (state symbols needed)

C(s) allowed as C(gr) or C(graphite) [1]

(ii) (if these elements were reacted together) other products would form/ carbon does not react with hydrogen **and** oxygen under standard conditions [1]

(b) (i) energy = $100 \times 4.2 \times 54 = 22680$ [1]

(ii) moles ethanol = 0.81/46 = 0.0176 (1)

energy change = $\frac{22.68}{0.0176}$ $\Delta H = -1290$ (1)

–ve sign and correct to 3 sf (1) [3]

(c) internet value numerically larger (1)

heat losses / incomplete combustion / thermal capacity of calorimeter ignored (1) no credit for energy loss [2]

(d) (i) $C_3H_7OH + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 4H_2O$ (ignore state symbols) [1]

(ii) negative enthalpy change means energy in bonds broken is less than that in bonds made [1]

(iii) more bonds broken and made in propanol and therefore more energy released [1]

(e) any 4 from:

both conserve carbon / non-renewable fuel sources / fossil fuels / use renewable sources

(these gas / liquid) suitable for different uses e.g. ethanol to fuel cars

atom economy gasification is less (some C lost as CO_2) / CO_2 produced in gasification is a greenhouse gas

CO is toxic

gasification at high temperature / enzymes need low temperature

enzyme approach therefore saves fuel / gasification needs more energy [4]

3 max if any reference to destruction of ozone layer

QWC [2]
The candidate has selected a form and style of writing that is appropriate to purpose and complexity of the subject matter (1)

Answer has suitable structure (1)

Total [17]

4 (a) (i) ultraviolet / sunlight [1]

(ii) A species with an unpaired electron. [1]

(b) $CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$ (1)
$CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$ (1) [2]

(c) (i) Two $CH_3\bullet$ radicals combine (in a termination reaction). [1]

(ii) $24.3 \div 12 = 2.025$ for C $4.1 \div 1.01 = 4.059$ H $71.6 \div 35.5 = 2.017$ Cl (1)
CH_2Cl (1) [2]

(d) (i) Nucleophilic substitution [1]

(ii) Methanol has hydrogen bonding between molecules (1)
Chloromethane has van der Waals forces / dipole-dipole forces between molecules (1)
Hydrogen bonding is stronger than Van der Waals/dipole-dipole (1) [3]

(iii) Acidified potassium dichromate / acidified potassium manganate(VII) (1)
Heat /warm (1) (Need correct reagent to gain heat mark) [2]

(e) Compounds B and C are stable enough to reach the ozone layer OR Compound D would not reach the ozone layer as it would decompose in the lower atmosphere. (1)

(The C-Cl forms) Cl• which will decompose the ozone. (1)

Compound A does not contain chlorine, (so it cannot form Cl•) / Compound A has a lower RODP (1)

[3]

Total [16]

5 (a) (i) δ– on Br and δ+ on C attached (1)

Arrow from lone pair on OH^- to δ+ on C (1)

Arrow from C-Br bond to Br (1)

Correct alcohol + Br^- (1) [4]

(ii) Nucleophilic substitution [1]

(iii) The bond breaks and both the electrons go to one of the bonded atoms/ the bond breaks and ions are formed. [1]

(b) (i) Sodium hydroxide in ethanol/ alcohol [1]

(ii) Elimination/ dehydrohalogenation [1]

(iii) Structural formulae for but-1-ene (1)

and but-2-ene (1) [2]

(c) A is non-miscible with water/ does not mix with water and B is miscible/ mixes with water/ is soluble in water (1)

A has a longer carbon chain/ is bigger (1)

Hydrogen bonding (1)

Between the OH in alcohol and water (1)

In large alcohols non-polar/ hydrophobic part of molecule is large / OH is less significant part of molecule (1) [5]

QWC: organisation of information clearly and coherently; use of specialist vocabulary such as intermolecular force/ hydrogen bond/ hydrophobic/ non-polar/ miscible [1]

Total [16]

6 (a) diagram completed with at least 1 water molecule and indication of interaction between O on one molecule and H on the other (1)

interaction between δ^+ on H and lone pair on O (1)

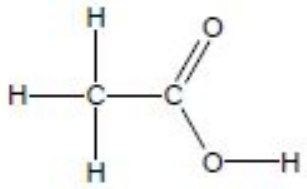
interaction labelled hydrogen bond (1) [3]

(b) (i) reduction/ redox – accept 'oxidation' [1]

(ii) I OH [1]

II OH is also present in water [1]

(c) (i) [1]



(ii) peak at 1650-1750 (1)

due to C=O (1) [2]

Total [9]

7 Reagent: acidified potassium dichromate / $Cr_2O_7^{2-}$ and H^+
or acidified manganate(VII) / MnO_4^- and H^+ (1)

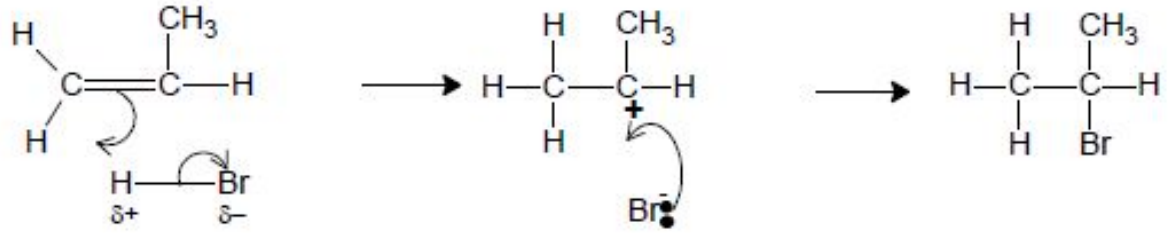
Colour change: from orange to green
or from purple to colourless (1) [2]

8 (a) (i) Molecules with different numbers of carbon atoms have different boiling points. [1]

(ii) Any suitable reaction, e.g. $C_{10}H_{22} \rightarrow C_4H_8 + C_6H_{14}$ [1]

(b) (i) Turns from orange to colourless (no credit for 'red') [1]

(ii) (1) for arrows in first diagram; (1) for arrow in second diagram; (1) for all charges.



[3]

(iii) Ethanol OR Alcohol solution / Heat - both required [1]

(c) (i) Restricted rotation about double bond in but-2-ene but not butane (1)

2 groups attached to each carbon of the double bond are different in but-2-ene but in propene one carbon has the same two groups attached (1) [2]

(ii)



Accept any valid representation [1]

(d) (i) Steam, phosphoric acid catalyst, (1) 300°C, 70 atm pressure (1) [2]

(ii) Butan-2-ol will have IR absorptions at 2500-3550 cm^{-1} / 1000 – 1300 cm^{-1} and butene will not
OR
But-2-ene will have an IR absorption at 1620-1720 and butan-2-ol will not [1]

Total [13]

9 (a) Hydrogen bonding occurs between (1) oxygen, nitrogen or fluorine (1) of one molecule and hydrogen, which is bonded to oxygen / nitrogen / fluorine of another molecule (1)
Alkanes do not contain an O-H, N-H or F-H bond and cannot therefore hydrogen bond to water molecules (1) [4]

QWC *Candidates should have use 'a selection and form of writing appropriate to purpose and to complexity of subject matter'* [1]

(b) (i) The (purified) petroleum is separated by heating (1) due to the different boiling temperatures of different fractions (1)

OR the mixture is vaporised (1) and then condensed according to boiling temperatures (1) (as at the oil refinery) [2]

(ii) $CuCl_2$ Cu +2 CuCl Cu +1 (1)

(reduction occurs when) the oxidation number becomes less positive (1) [2]

(c) (i) Same molecular formula but a different structural formula / structure [1]

(ii) Both of the carbon atoms of the double bond have different atoms / groups bonded to them (1)
There is no free rotation about the double bond (1) [2]

(iii) M_r of compound **A** is 146.3 / 146 (1)

Cost per mole is $\frac{146.3 \times 48 \times 100}{100 \times 73}$ = £96.20 (1)

(Accept £96.00 per mole if M_r of 146 has been used) [2]

Total [14]