PEARSON EDEXCEL IGCSE CHEMISTRY · 4CH1

CHEMISTRY



EXAM QUESTION PACK

SECTION 4: ORGANIC CHEMISTRY (PACK 1)

SCORE	PERCENTAGE
/295	%

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Q1.

This question is about alcohols, carboxylic acids and esters.

(a) Ethanol can be manufactured by reacting ethene with steam in the presence of a phosphoric acid catalyst.

Which row gives the correct conditions of temperature and pressure for this reaction?

(1)

	Temperature in °C	Pressure in atmospheres
☒ **A**	35	300
☒ **B**	65	300
☒ **C**	300	65
☒ **D**	300	35

(b) Give the displayed formula of butanol.

(1)

(c) Ethanoic acid (CH_3COOH) is a carboxylic acid present in vinegar.

(i) The concentration of CH_3COOH in vinegar can be found by titration with aqueous potassium hydroxide (KOH).

The equation for the reaction is

$$CH_3COOH + KOH \rightarrow CH_3COOK + H_2O$$

In a titration, a 25.0 cm^3 sample of vinegar is neutralised by 45.00 cm^3 of KOH solution of concentration 0.400 mol/dm^3.

Calculate the concentration, in mol/dm^3, of CH3COOH in this sample of vinegar.

(2)

concentration = ... mol/dm^3

(ii) A sample of vinegar containing 0.0030 mol of CH_3COOH is poured into a flask.

Calculate the maximum volume, in cm^3, of carbon dioxide gas formed at rtp when excess sodium carbonate is added to the flask.

The equation for the reaction is

$$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$$

[Assume that the molar volume of carbon dioxide at rtp is 24 000 cm^3]

(2)

volume = ... cm^3

(d) Alcohols react with carboxylic acids to form esters.

Which alcohol could react to form the ester ethyl propanoate?

(1)

☒ **A** CH_3OH

☒ **B** C_2H_5OH

☒ **C** C_3H_7OH

☒ **D** C_4H_9OH

(e) Polyesters are formed in condensation polymerisation reactions between dicarboxylic acids and diols.

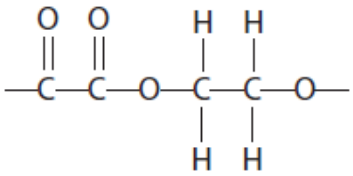
(i) State one difference between condensation polymerisation and addition polymerisation.

(1)

.....

.....

(ii) The repeat unit of a polyester is



Give the displayed formula of each of the two monomers needed to form this polyester.

(2)

(iii) Give one advantage of biopolyesters.

(1)

.....

.....

(Total for question = 11 marks)

Q2.

This question is about alcohols, carboxylic acids and esters.

(a) Ethanol can be manufactured by the fermentation of a solution of glucose.

(i) Write a word equation for this reaction.

(1)

.....

(ii) State the substance that needs to be added for the reaction to occur.

(1)

.....

(iii) State two conditions needed for this reaction.

(2)

.....

.....

(b) In the presence of an acid catalyst, ethanoic acid is heated with butanol to form an ester.

(i) Which of these is the formula of the ester?

(1)

☒ **A** $CH_3COOC_3H_7$

☒ **B** $CH_3COOC_4H_9$

☒ **C** $C_2H_5COOC_4H_9$

☒ **D** $C_3H_7COOC_2H_5$

(ii) State how you would know that an ester has formed.

(1)

.....

.....

(iii) Give one use of an ester.

(1)

.....

.....

(c) Aspirin is a compound used to reduce pain.

Aspirin contains a carboxylic acid functional group and an ester functional group.

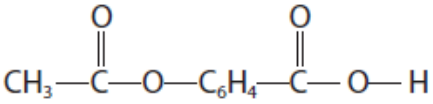
(i) State what is meant by the term **functional group**.

(1)

.....

.....

(ii) This is the structural formula of aspirin.



Draw a circle around the carboxylic acid functional group.

(1)

(iii) Aspirin has this percentage composition by mass.

C = 60.00% H = 4.44% O = 35.56 %

Show by calculation that the empirical formula of aspirin is $C_9H_8O_4$

(3)

(Total for question = 12 marks)

Q3.

This question is about alcohols, carboxylic acids and their reactions.

(a) The boxes give some information about a carboxylic acid.

Complete the boxes by giving the missing information.

(3)

structural formula	CH_3COOH
name	
	CH_2O
displayed formula	

(b) Ethanol can be oxidised to produce a carboxylic acid.

(i) Give the names of the two reagents used in this oxidation reaction.

(2)

1 .....

2 .....

(ii) Which of these colour changes occurs during the reaction?

(1)

☒ **A** green to orange

☒ **B** orange to green

☒ **C** red to yellow

☒ **D** yellow to red

(c) Alcohols and carboxylic acids can be heated together to form esters.

(i) State why it is better to heat the mixture using a water bath rather than directly with a Bunsen burner flame.

(1)

.....

.....

(ii) An ester has the structural formula $CH_3CH_2COOCH_3$

Which of these is the name of this ester?

(1)

☒ **A** ethyl methanoate

☒ **B** methyl ethanoate

☒ **C** methyl propanoate

☒ **D** propyl methanoate

(Total for question = 8 marks)

Q4.

Alcohols contain the functional group —OH

(a) Give the structural formula of the alcohol that contains one carbon atom.

(1)

.....

(b) Ethanol (C_2H_5OH) is an alcohol that can be obtained from glucose ($C_6H_{12}O_6$).

(i) Name the process that converts glucose into ethanol.

(1)

.....

(ii) Explain why this process is carried out in the absence of air and at a temperature below 40 °C.

(4)

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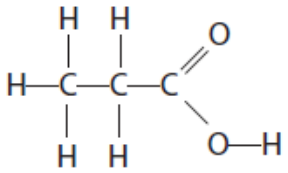
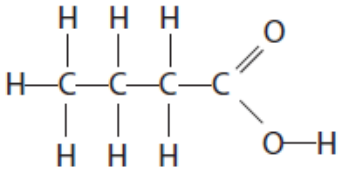
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(c) The table gives information about some organic compounds in the same homologous series.

Compound	Molecular formula	Displayed formula
ethanoic acid	$C_2H_4O_2$	
propanoic acid		
	$C_4H_8O_2$	

(i) Complete the table by giving the missing information.

(3)

(ii) Name the homologous series that contains these compounds.

(1)

.....

(d) The compounds in the table can react with alcohols to form esters.

When preparing esters, a small amount of concentrated sulfuric acid is also used.

(i) State the purpose of the acid.

(1)

.....

(ii) Draw the displayed formula of the ester that forms when propanoic acid reacts with ethanol.

(2)

(iii) Esters have particular uses that depend on their properties.

Give an example of a property and use of esters.

(2)

property .....

use .....

(Total for question = 15 marks)

Q5.

This question is about alcohols, carboxylic acids and esters.

(a) The table gives information about some alcohols.

Alcohol	Structural formula	Relative formula mass
methanol	CH_3OH	32
ethanol	C_2H_5OH	
	C_4H_9OH	74

Complete the table by giving the missing information.

(2)

(b) Ethanol can be oxidised to ethanoic acid by heating with potassium dichromate(VI) and another reagent.

(i) Name the other reagent.

(1)

.....

(ii) State the colour change that occurs during this reaction.

(1)

from ..... to .....

(c) Alcohols react with carboxylic acids to form esters.

(i) Name the ester that forms when ethanol reacts with ethanoic acid.

(1)

.....

(ii) Complete the equation for the reaction between methanol and ethanoic acid.

(2)

CH_3OH + ... → .....+ H_2O

(Total for question = 7 marks)

Q6.

This question is about alkanes.

(a) (i) Which of these is the **molecular** formula of an alkane?

(1)

☒ **A** C_2H_5

☒ **B** C_4H_{10}

☒ **C** CH_2CH_2

☒ **D** $CH_3CH_2CH_3$

(ii) Which of these has the same empirical formula and molecular formula?

(1)

☒ **A** CH_2

☒ **B** C_2H_6

☒ **C** C_3H_8

☒ **D** C_4H_{10}

(b) In the presence of ultraviolet radiation, methane reacts with bromine to form bromomethane and hydrogen bromide.

(i) State the name of this type of reaction.

(1)

.....

(ii) Give a chemical equation for this reaction.

(1)

.....

(c) One mole of an alkane burns completely in oxygen.

The equation represents the reaction.

$$\text{alkane} + x\text{O}_2 \rightarrow y\text{CO}_2 + z\text{H}_2\text{O}$$

The numbers x, y and z are used to balance the equation.

(i) The complete combustion of one mole of the alkane produces 220 g of carbon dioxide and 108 g of water.

Calculate the values of y and z.

[M_r of CO_2 = 44 M_r of H_2O = 18]

(2)

y = ...

z = ...

(ii) Determine the molecular formula of the alkane and the value of x.

(2)

molecular formula = ...

x = ...

(d) When an alkane burns in a limited supply of air, incomplete combustion occurs.

Explain why incomplete combustion of an alkane could be harmful to humans.

(2)

.....

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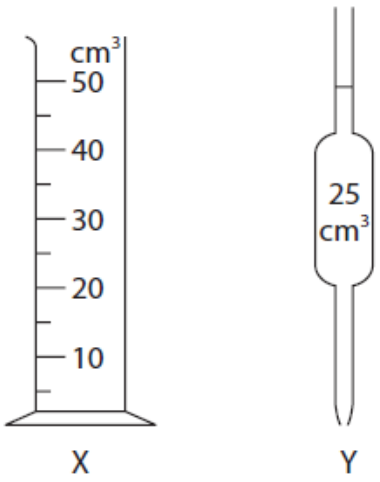
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(Total for question = 10 marks)

Q7.

(a) The diagram shows two pieces of apparatus, X and Y.



(i) Give the name of each piece of apparatus.

(2)

X = ...

Y = ...

(ii) In a titration, a student adds 25.0 cm^3 of barium hydroxide solution to a conical flask.

Give a reason why it is better to use Y rather than X.

(1)

.....

.....

(b) The student uses methyl orange indicator in the titration.

(i) State the colour of methyl orange in barium hydroxide solution.

(1)

.....

(ii) Give a reason why universal indicator is **not** suitable for use in a titration.

(1)

.....

.....

.....

(c) The student adds some dilute nitric acid to a burette and does the titration.

The equation for the reaction is

$$Ba(OH)_2 + 2HNO_3 \rightarrow Ba(NO_3)_2 + 2H_2O$$

The student finds that 21.50 cm^3 of nitric acid of concentration 0.600 mol/dm^3 neutralises 25.0 cm^3 of barium hydroxide solution.

Calculate the concentration, in mol/dm^3, of the barium hydroxide solution.

(3)

concentration = ... mol/dm^3

(d) State why sulfuric acid would not be a suitable acid to use in this titration.

(1)

.....

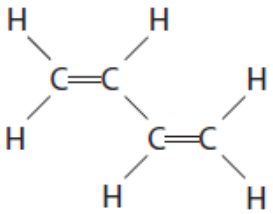
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(Total for question = 9 marks)

Q8.

The organic compound butadiene is a colourless gas used in the manufacture of synthetic rubber for tyres.

The displayed formula of butadiene is



(a) Explain why butadiene is described as an unsaturated hydrocarbon.

(3)

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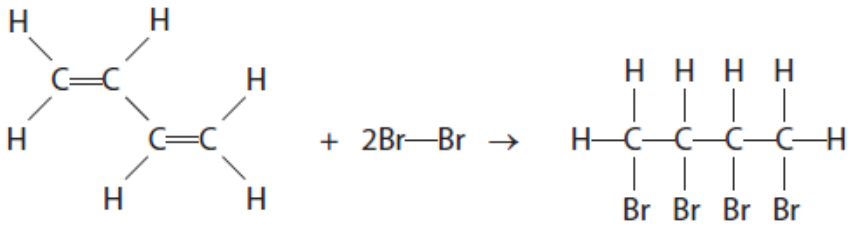
(b) (i) Butadiene reacts with bromine water.

State the colour change that occurs during this reaction.

(1)

from ..... to
.....

(ii) The equation for the reaction between butadiene and bromine can be shown using displayed formulae.



The table gives some bond energies.

Bond	C—H	C=C	Br—Br	C—C	C—Br
Bond energy in kJ/mol	412	612	193	348	276

Use this information to calculate the enthalpy change, ΔH, for the reaction.

Include a sign in your answer.

(4)

ΔH = ... kJ/mol

(c) A scientist does an investigation to find out if butadiene would be a good fuel.

He burns a sample of butadiene gas and observes that carbon forms as black soot.

(i) Complete the equation to explain the scientist's observation.

(1)

$$2C_4H_6 + 7O_2 \rightarrow .....C + 4CO + 2CO_2 + ...H_2O$$

(ii) Explain how one of the products, other than carbon, may cause a problem.

(2)

.....

.....

.....

.....

(iii) The equation for the combustion of butadiene in excess oxygen is

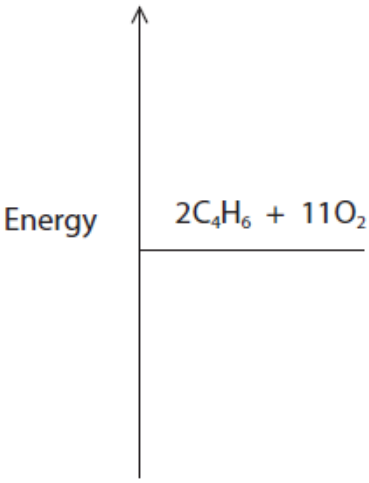
$$2C_4H_6 + 11O_2 \rightarrow 8CO_2 + 6H_2O$$

The enthalpy change for this reaction, ΔH, is – 3446 kJ/mol.

Complete the energy profile diagram for the reaction.

Label the enthalpy change for this reaction, ΔH, and the activation energy.

(4)



(Total for question = 15 marks)

Q9.

Crude oil is a mixture of hydrocarbons.

(a) This passage is about the industrial separation of crude oil.

Complete the passage by adding the missing words.

(3)

Crude oil is ..... to form vapour.

The vapour is passed through a ..... column.

The refinery gases are collected at the top of the column because they have low

....

(b) Bitumen is collected at the bottom of the column.

Give one use of bitumen.

(1)

.....

(c) One of the hydrocarbons in crude oil is an alkane with this structural formula.

$$CH_3CH_2CH_2CH_2CH_3$$

(i) Give the name of this alkane.

(1)

.....

(ii) Calculate the relative molecular mass (M_r) of this alkane.

(1)

M_r = ...

(d) Catalytic cracking is used to convert long-chain alkanes into shorter-chain alkanes.

Give the name of the catalyst and the temperature used in catalytic cracking.

(2)

catalyst
.....

temperature
.....

(e) Catalytic cracking also produces alkenes.

Decane ($C_{10}H_{22}$) can undergo cracking to give C_4H_{10} and two different alkenes.

Complete the equation for this cracking process.

(2)

$$C_{10}H_{22} \rightarrow C_4H_{10} + \text{.....} +$$
.....

Q10.

Dinitrogen tetraoxide, N_2O_4, is a colourless gas.

Nitrogen dioxide, NO_2, is a brown gas.

The two gases can exist together in dynamic equilibrium according to the equation

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

(a) Explain what is meant by the term **dynamic equilibrium**.

(2)

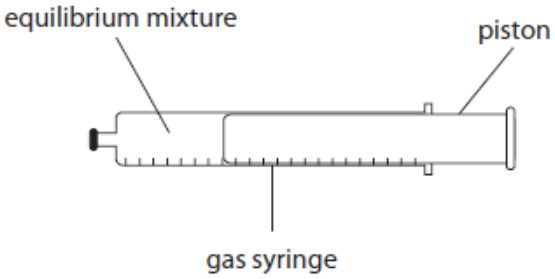
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(b) Some N_2O_4 and some NO_2 are put into a sealed gas syringe and allowed to form an equilibrium mixture.



This equilibrium mixture is brown.

(i) The pressure of the gas in the syringe is increased by pushing in the piston. The mixture is then allowed to reach a new equilibrium at the same temperature as before.

Explain why the new equilibrium mixture contains less NO_2 than the original equilibrium mixture.

(2)

.....

.....

.....

.....

.....

.....

(ii) A student suggests that the new equilibrium mixture would be lighter in colour than the original equilibrium mixture, as there is now less NO_2 present.

Suggest why the new equilibrium mixture is actually darker than the original.

(1)

.....

.....

.....

(c) Carbon monoxide, CO, and oxides of nitrogen are produced in a car engine when petrol is burned.

These oxides can be partly removed by using a catalytic converter fitted to the car's exhaust system.

(i) State how oxides of nitrogen are produced in the car engine.

(1)

.....

.....

(ii) Give a disadvantage of allowing oxides of nitrogen to escape into the atmosphere.

(1)

.....

.....

(iii) Write a chemical equation for the reaction between nitrogen monoxide, NO, and carbon monoxide to form carbon dioxide and nitrogen.

(1)

.....

(Total for question = 8 marks)

Q11.

Grapes contain glucose that can be fermented to make ethanol.



(a) The grapes are collected and crushed to produce an aqueous solution containing glucose. Yeast is added to the solution and the mixture is left to ferment at a temperature of about 30 °C in the absence of air.

(i) State why yeast is added.

(2)

.....

.....

.....

.....

(ii) Explain why another organic compound may also be formed if fermentation is carried out in the presence of air.

(2)

.....

.....

.....

.....

(iii) Explain why 30 °C is considered to be an optimum temperature for this reaction.

(2)

.....

.....

.....

.....

(b) Ethanol can also be manufactured by reacting ethene with steam.

(i) Write the chemical equation for this reaction.

(1)

.....

(ii) Name the type of reaction that occurs.

(1)

.....

(iii) State **two** conditions used for this reaction in industry.

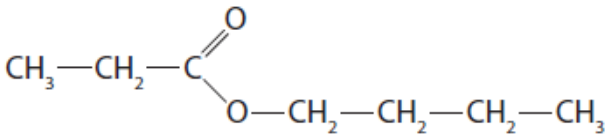
(2)

1 .....

2 .....

(c) Grapes also contain esters.

The formula of an ester is shown.



Deduce the name of the carboxylic acid and the alcohol that can react together to make this ester.

(2)

carboxylic acid .....

alcohol .....

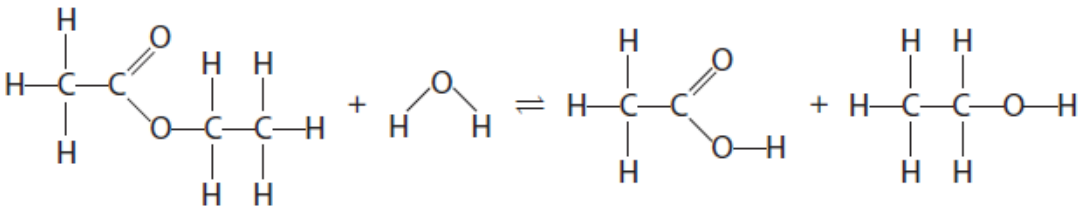
(Total for question = 12 marks)

Q12.

This question is about esters.

Ester A reacts with water to form ethanoic acid and ethanol.

The displayed formulae of the reactants and products are shown in this equation



ester A

The molar enthalpy change (ΔH) for the reaction is 0 kJ/mol.

(a) (i) Draw a ring around the functional group in ester A.

(1)

(ii) Give the name of ester A.

(1)

.....

(iii) Describe a chemical test, other than using an indicator, to show that the reaction mixture contains ethanoic acid.

(2)

.....

.....

.....

.....

(b) Explain why the molar enthalpy change (ΔH) for the reaction between ester A and water is 0 kJ/mol.

In your answer, refer to the bonds broken and the bonds formed.

(2)

.....

.....

.....

.....

(c) A mixture of ester A and water is left in a sealed container until the reaction mixture reaches dynamic equilibrium.

(i) Describe what is meant by dynamic equilibrium.

(2)

.....

.....

.....

.....

(ii) Explain why adding a catalyst does not change the position of equilibrium.

(2)

.....

.....

.....

.....

(d) The ethanoic acid produced in the reaction is completely neutralised by 22.75 cm^3 of 0.150 mol/dm^3 barium hydroxide solution.

The equation for the neutralisation reaction is

$$2CH_3COOH + Ba(OH)_2 \rightarrow Ba(CH_3COO)_2 + 2H_2O$$

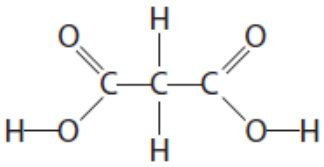
Calculate the amount, in moles, of ethanoic acid neutralised.

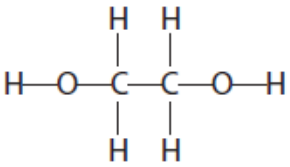
Give your answer to 3 significant figures.

(3)

amount = ... mol

(e) The structures of two organic compounds are shown.





These compounds react together to form a polymer.

Give the repeat unit of the polymer formed.

(2)

(Total for question = 15 marks)

Q13.

Ethanol, C_2H_5OH, is a member of the homologous series of alcohols.

(a) Give two characteristics of a homologous series.

(2)

1 .....

.....

2 .....

.....

(b) When ethanol is heated with potassium dichromate(VI) and one other reagent, the ethanol is oxidised to ethanoic acid,

CH_3COOH

(i) Give the formula of the other reagent.

(1)

.....

(ii) State the colour change that occurs during this oxidation reaction.

(2)

from ..... to
.....

(iii) Draw the displayed formulae for ethanol and ethanoic acid in the boxes.

(2)

ethanol	ethanoic acid

(c) Ethanol can be manufactured by two different methods.
The table gives some information about the two methods.

	Hydration of ethene	Fermentation of glucose
raw material	crude oil	sugar cane
rate of reaction	fast	slow
purity of ethanol	pure	impure
operating temperature	300 °C	30 °C
operating pressure	60 – 70 atmospheres	1 atmosphere
catalyst	phosphoric acid	enzymes in yeast

(i) Discuss the advantages and disadvantages of these two methods, using information from the table.

(6)

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(ii) The word equation for the fermentation process is

glucose → ethanol + carbon dioxide

Complete the chemical equation for this reaction.

(1)

$C_6H_{12}O_6$ → ..... +
.....

(Total for question = 14 marks)

Q14.

Ethanol, C_2H_5OH, can be manufactured from ethene and steam using a phosphoric acid catalyst.

(a) (i) State the temperature and pressure used in this manufacturing process.

(2)

temperature

.....

pressure

.....

(ii) Draw the displayed formula of ethanol.

(1)

(b) Ethanol burns in a plentiful supply of air to form carbon dioxide and water.

(i) Give the chemical equation for this reaction.

(2)

.....

(ii) When the air supply is limited, incomplete combustion occurs and carbon monoxide forms.

State why carbon monoxide is poisonous to humans.

(1)

.....

.....

(c) When ethanol reacts with ethanoic acid, an ester forms.

Give the name of this ester.

(1)

.....

(d) Butanedioic acid and ethanediol react together to form a polyester and water.

(i) Give the name of this type of polymerisation.

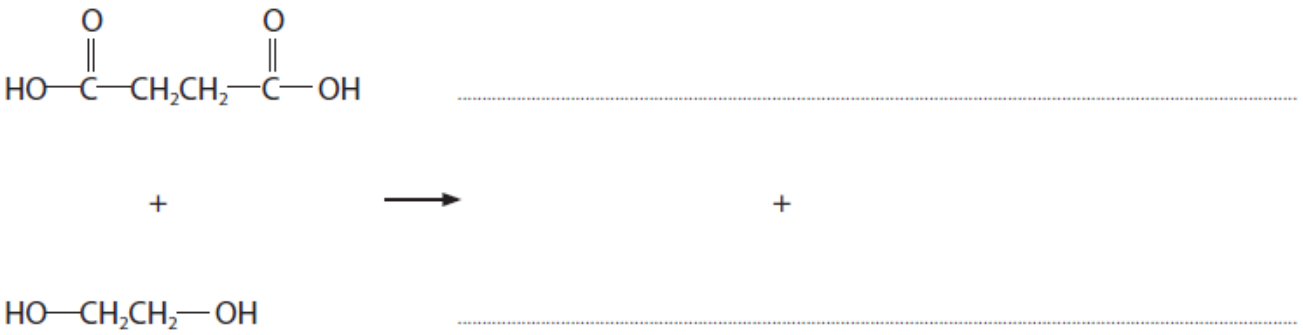
(1)

.....

(ii) Complete the equation.

Show only one repeat unit of the polyester.

(3)



(Total for question = 11 marks)

Q15.

Some cars in Brazil use ethanol, C_2H_5OH, as a fuel instead of petrol.

The ethanol is made by the fermentation of glucose which is obtained from sugar cane.

The sugar is extracted from the sugar cane and then dissolved in water to make a sugar solution.

(a) (i) Name the substance that is added to the sugar solution that causes glucose to ferment.

(1)

.....

(ii) Which temperature is the most suitable for fermentation?

(1)

☒ **A** 0°C

☒ **B** 10°C

☒ **C** 30°C

☒ **D** 80°C

(iii) Explain why fermentation is done in the absence of air.

(2)

.....

.....

.....

.....

(b) (i) State what is meant by the term **fuel**.

(1)

.....

.....

(ii) Write a chemical equation for the complete combustion of ethanol in air.

(2)

.....

(c) Ethanol is also manufactured by reacting steam with ethene, C_2H_4

The equation for this reaction is

$$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$$

State the conditions of temperature and pressure used in this process.

(2)

temperature

.....

pressure

.....

(d) When ethanol is heated with acidified potassium dichromate(VI), it is oxidised to ethanoic acid.

(i) State the colour change that occurs in the potassium dichromate(VI) during this reaction.

(1)

From ..... to .....

(ii) The structural formula of ethanoic acid is CH_3COOH

Draw the displayed formula of ethanoic acid.

(2)

(iii) Complete the equation for the reaction of ethanoic acid with sodium.

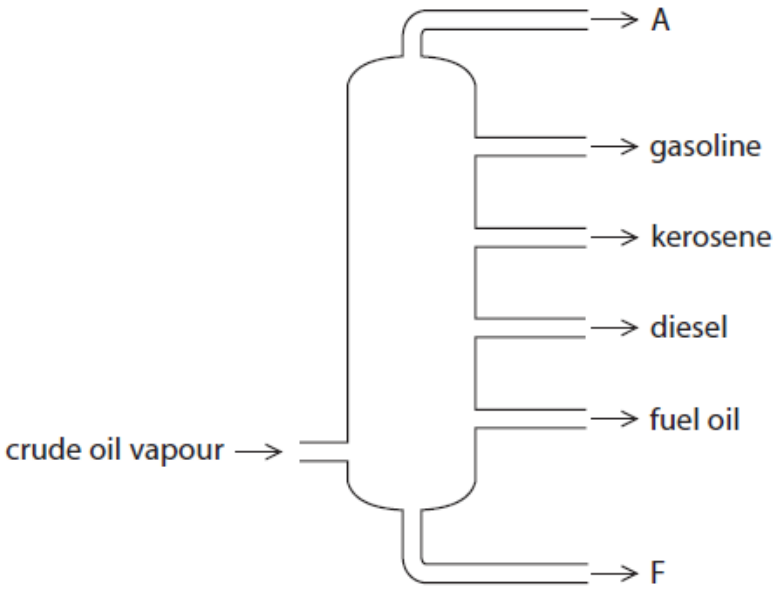
(2)

.....$CH_3COOH(aq)$ + ...$Na(s)$ → .....(aq) + ...(g)

(Total for question = 14 marks)

Q16.

The diagram shows the industrial equipment used to separate crude oil into fractions.



(a) (i) Give the name of the industrial equipment.

(1)

.....

(ii) Give one use of the fuel oil fraction.

(1)

.....

(iii) Give the names of fraction A and fraction F.

(2)

fraction A
.....

fraction F
.....

(b) One compound in the gasoline fraction is the alkane octane (C_8H_{18}) and one compound in the kerosene fraction is the
alkane dodecane ($C_{12}H_{26}$)

These two alkanes are covalently bonded and have simple molecular structures.

(i) Give the general formula for the alkanes.

(1)

.....

(ii) Explain, in terms of their structures, why $C_{12}H_{26}$ has a higher boiling point than C_8H_{18}

(3)

.....

.....

.....

.....

.....

.....

.....

.....

.....

(c) Catalytic cracking can be used to convert the alkane $C_{12}H_{26}$ into more useful products.

(i) Give the name of the catalyst used for catalytic cracking.

(1)

.....

(ii) Complete the equation for this cracking reaction.

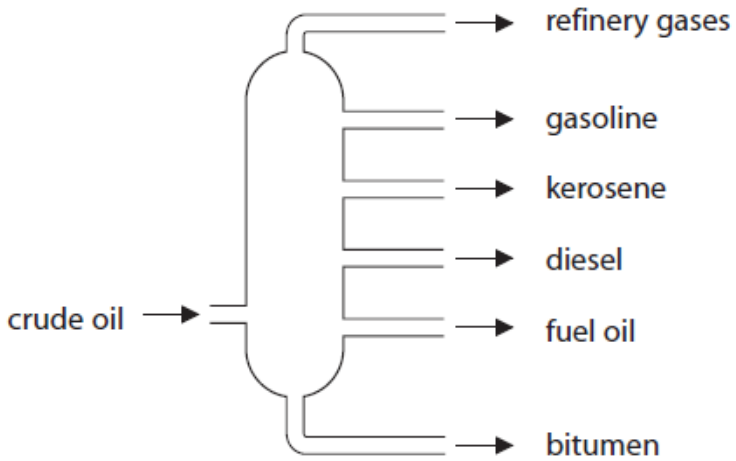
(1)

$C_{12}H_{26} \rightarrow C_9H_{20}$ + ...

(Total for question = 10 marks)

Q17.

(a) The diagram shows a fractionating column used to separate crude oil into fractions.



(i) Give a use for bitumen and a use for gasoline.

(2)

use for bitumen.....

use for gasoline.....

(ii) Explain why bitumen is collected at the bottom of the fractionating column and gasoline is collected near the top
of the fractionating column.

(2)

.....

.....

.....

.....

(b) There is a low demand for some of the fractions obtained from crude oil.

Cracking can be used to convert these fractions into more useful substances.

(i) State the conditions needed for cracking.

(2)

.....

.....

(ii) Dodecane ($C_{12}H_{26}$) can be cracked to produce an alkane and two alkenes.

Complete the equation by giving the formulae of the two alkenes.

(2)

$$C_{12}H_{26} \rightarrow C_7H_{16} + \text{.....} + \text{.....}$$

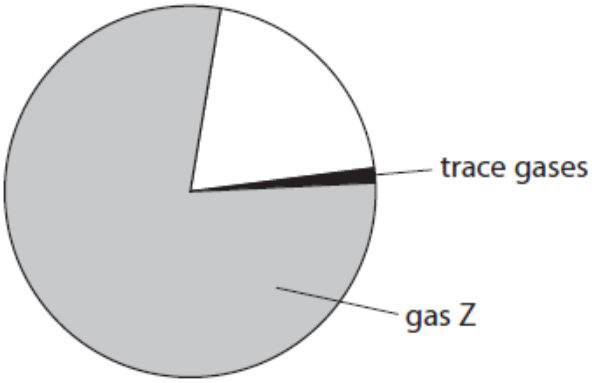
(Total for question = 8 marks)

Q18.

This question is about gases in the air.

The pie chart represents the percentages of gases in dry, unpolluted air.

Gases with percentages of less than 1% in air are called trace gases.



(a) (i) Which of these is gas Z?

(1)

☒ **A** hydrogen

☒ **B** methane

☒ **C** neon

☒ **D** nitrogen

(ii) Which of these is the approximate percentage of oxygen in dry, unpolluted air?

(1)

☒ **A** 0.04%

☒ **B** 0.9%

☒ **C** 21%

☒ **D** 35%

(b) One of the trace gases is carbon dioxide.

(i) Identify **two** reactions that produce carbon dioxide by placing a tick (✓) in two boxes.

(2)

cracking an alkane	
complete combustion of an alkane	
reaction between magnesium and hydrochloric acid	
rusting of iron	
thermal decomposition of copper(II) carbonate	

(ii) Name an environmental problem that is caused by the percentage of carbon dioxide increasing in the atmosphere.

(1)

.....

(iii) Name the trace gas with the highest percentage in dry, unpolluted air.

(1)

.....

(c) Rainwater is acidic because carbon dioxide dissolves in water to form carbonic acid.

Acid rain is more acidic than rainwater because acidic pollutant gases also dissolve in water.

(i) Give the name of the acid that forms when nitrogen dioxide dissolves in water.

(1)

.....

(ii) Name another pollutant gas that also forms acid rain.

(1)

.....

(Total for question = 8 marks)

Q19.

This question is about gases.

(a) The box gives the names of some gases.

argon	carbon dioxide	hydrogen	nitrogen	oxygen

Use gases from the box to answer these questions.

Each gas may be used once, more than once or not at all.

(i) Name the most abundant gas in the Earth's atmosphere.

(1)

.....

(ii) Name the gas that is a compound.

(1)

.....

(iii) Name the least reactive of the gases.

(1)

.....

(iv) Name the gas formed by the complete combustion of hydrocarbons.

(1)

.....

(b) Describe the test for hydrogen gas.

(1)

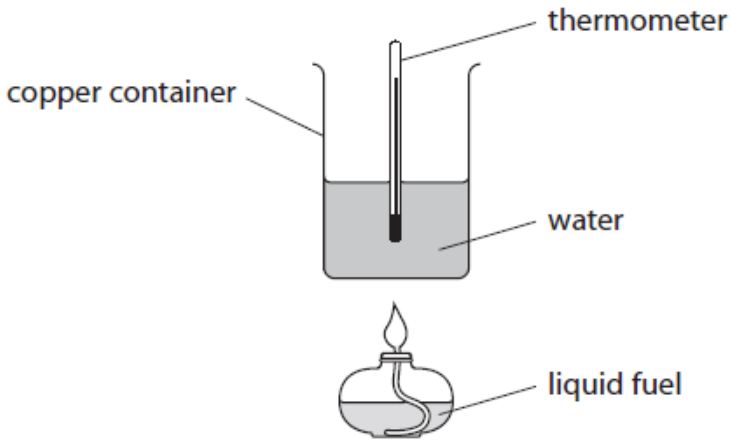
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.....

(Total for question = 5 marks)

Q20.

A student uses this apparatus to find the heat energy supplied by a liquid fuel.



The student burns some fuel to heat the water in the copper container and measures the change in temperature.

(a) The student notices that the bottom of the container turns black.

Give the name of the black substance that forms on the bottom of the container.

(1)

.....

(b) In one experiment, the student burns 0.92 g of ethanol.

The student calculates that the heat energy absorbed by the water is 18.2 kJ.

Show that the results of this experiment give an approximate value for the enthalpy of combustion of ethanol of ΔH = –900 kJ/mol.

[M_r of ethanol = 46]

(2)

(c) The data book value of ΔH for the combustion of ethanol is –1367 kJ/mol.

Give two reasons why the student's value is much lower than the data book value.

(2)

1 .....

.....

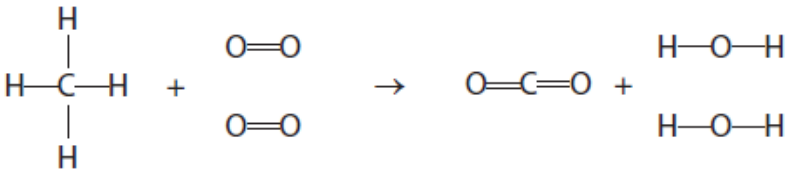
2 .....

.....

(d) The equation shows the combustion of methane.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad \Delta H = -890 \text{ kJ/mol}$$

This is the equation showing the displayed formulae.



The table shows the bond energies for O═O, C═O and O—H

Bond	O═O	C═O	O—H
Bond energy in kJ/mol	498	805	463

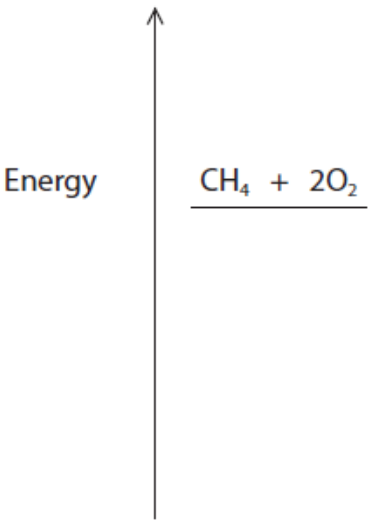
(i) Calculate the bond energy of the C—H bond, using information from the equation and the table.

(4)

C—H bond energy = ... kJ/mol

(ii) Complete the energy level diagram to show the products and ΔH.

(2)



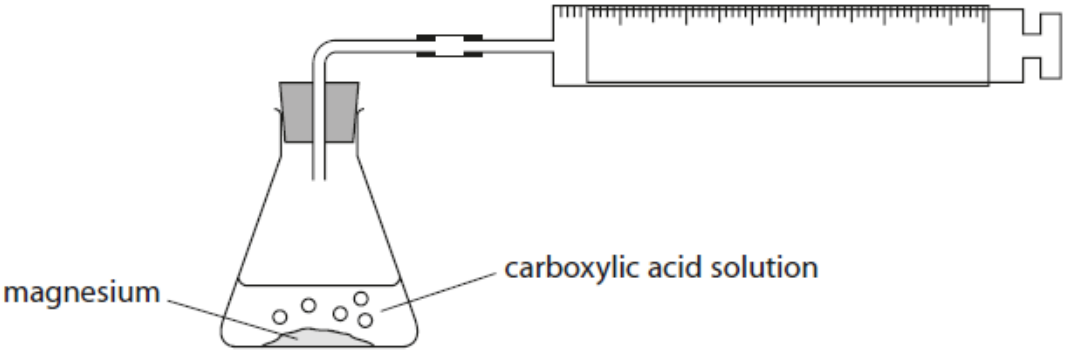
(Total for question = 11 marks)

Q21.

This question is about carboxylic acids.

Solutions of carboxylic acids react with magnesium metal to form hydrogen gas.

A student uses this apparatus to investigate the time taken to produce 10 cm^3 of hydrogen gas from different carboxylic acids.



This is the student's method.

- pour some carboxylic acid solution into a conical flask
- add some magnesium powder
- quickly connect the gas syringe and start a timer
- record the time taken to collect 10 cm^3 of hydrogen gas

The student repeats the method with three other carboxylic acids.

(a) (i) All the carboxylic acids are of the same concentration.

Give two other variables the student should control in his investigation.

(2)

1 .....

.....

2 .....

.....

(ii) Give a reason why it is important to connect the gas syringe quickly.

(1)

.....

.....

(b) The table shows the student's results.

Carboxylic acid	Formula of carboxylic acid	Time taken to produce 10 cm^3 of hydrogen in s				
		Experiment 1	Experiment 2	Experiment 3	Experiment 4	Mean time in s
Methanoic acid	HCOOH	48	50	47	49	49
Ethanoic acid	CH_3COOH	61	63	60	61	61
Propanoic acid	CH_3CH_2COOH	69	93	70	71	
Butanoic acid	$CH_3CH_2CH_2COOH$	83	85	82	81	83

(i) Calculate the mean (average) time for propanoic acid to produce 10 cm^3 of hydrogen gas.

(2)

mean time = ... s

(ii) Deduce the relationship between the number of carbon atoms in the molecule and the time taken to produce 10 cm^3 of hydrogen gas.

(1)

.....

.....

.....

(c) An ester is formed by adding ethanoic acid to ethanol in the presence of sulfuric acid.

Give the displayed formula of the ester produced when ethanoic acid reacts with ethanol.

(2)

(Total for question = 8 marks)

Q22.

This question is about three stages in the manufacture of sulfuric acid.

(a) In stage 1, sulfur is burned in oxygen to form sulfur dioxide gas.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

(i) State one environmental problem caused by the release of sulfur dioxide into the atmosphere.

(1)

.....

.....

(ii) A mass of 6.4 tonnes of sulfur is burned to produce sulfur dioxide gas.

Calculate the maximum volume, in dm^3, of sulfur dioxide gas that can be produced at rtp.

[molar volume of sulfur dioxide gas at rtp = 24 dm^3]

Give your answer in standard form.

(3)

maximum volume = ... dm^3

(b) In stage 2, sulfur dioxide is reacted with oxygen to form sulfur trioxide gas.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The yield of sulfur trioxide is approximately 98%.

(i) A catalyst is used in this reaction.

Explain how a catalyst increases the rate of a reaction.

(2)

.....

.....

.....

.....

(ii) The temperature is kept constant.

Give a reason why increasing the pressure would increase the yield of sulfur trioxide.

(1)

.....

.....

(iii) Suggest why it is not necessary to increase the pressure in stage 2.

(1)

.....

.....

.....

(c) In stage 3, the sulfur trioxide is reacted with concentrated sulfuric acid to form a liquid called oleum, $H_2S_2O_7$

The oleum is then added to water to form concentrated sulfuric acid.

Complete the chemical equations for these two reactions.

(2)

..... + ... → $H_2S_2O_7$

$H_2S_2O_7$ + ... → .....

(d) Sulfuric acid reacts with ammonia to form ammonium sulfate, $(NH_4)2SO_4$

Calculate the percentage by mass of nitrogen in ammonium sulfate.

[M_r of $(NH_4)2SO_4$ = 132]

(2)

percentage = ... %

(Total for question = 12 marks)

Q23.

A sample of a gaseous hydrocarbon, X, has a volume of 600 cm^3 at room temperature and pressure (rtp).

(a) Calculate the amount, in moles, of hydrocarbon X in the sample.

[molar volume of a gas = 24 000 cm^3 at rtp]

(2)

amount of hydrocarbon X = ... mol

(b) The mass of the sample of hydrocarbon X is 1.45 g.

Show that the relative molecular mass (M_r) of X is 58

(2)

M_r = ...

(c) Hydrocarbon X is an alkane.

Show that the molecular formula of X is C_4H_{10}

(1)

(d) Give the displayed formula of the branched-chain isomer of hydrocarbon X.

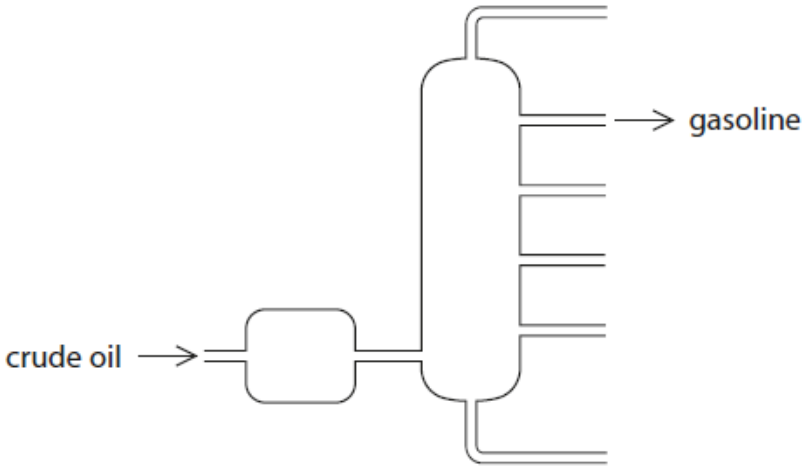
(1)

(Total for question = 6 marks)

Q24.

This question is about octane (C_8H_{18}) which is produced in the gasoline fraction during fractional distillation of crude oil.

(a) The diagram shows a fractionating column.



Describe how crude oil is separated into fractions in the fractionating column.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(b) Octane can also be produced by the process of cracking.

Give the conditions for cracking.

(2)

.....

.....

.....

.....

(c) A car is driven at constant speed for 4.00 km.

The exhaust gases are collected and their volume at room temperature and pressure (rtp) is 5.02×10^5 cm^3.

The exhaust gases include carbon dioxide and oxides of nitrogen.

The carbon dioxide is removed from the exhaust gases. The volume of the remaining gases at rtp is 2.96×10^5 cm^3.

(i) Explain how oxides of nitrogen form in a car engine.

(2)

.....

.....

.....

.....

(ii) Give a reason why oxides of nitrogen should not be released into the atmosphere.

(1)

.....

.....

(iii) Show that the car produces less than 100 g of carbon dioxide per km.

[molar volume of carbon dioxide at rtp = 24 000 cm^3]

(5)

(Total for question = 14 marks)

Q25.

(a) An organic compound has this percentage composition by mass.

C = 40% H = 6.7% O = 53.3%

(i) Show that the empirical formula of the compound is CH_2O

(2)

(ii) Draw the structural formula of a compound with the molecular formula $C_2H_4O_2$

(1)

(b) Methanoic acid (HCOOH) reacts with sodium carbonate solution to give three products.

(i) Complete the equation for this reaction.

(2)

$2HCOOH + Na_2CO_3 \rightarrow$ ..... + ... + ...

(ii) State what you would observe in this reaction.

(1)

.....

.....

(c) Methanoic acid also reacts with propanol to form an ester.

The equation for the reaction is

$$HCOOH + C_3H_7OH \leftrightarrow HCOOC_3H_7 + H_2O$$

(i) Give the name of the ester that forms.

(1)

.....

(ii) State what is meant by the ↔ symbol.

(1)

.....

(iii) When this reaction occurs in a sealed container, the reaction can reach dynamic equilibrium.

Give one characteristic of a reaction at dynamic equilibrium.

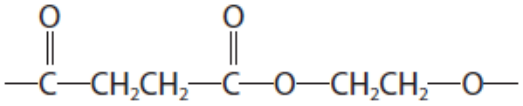
(1)

.....

.....

(d) A polyester forms when butanedioic acid reacts with ethanediol.

The diagram shows the repeat unit of the polyester that forms.



(i) Give the name of this type of polymerisation.

(1)

.....

(ii) Draw the structural formulae of the two monomers used to make this polyester.

(2)

(Total for question = 12 marks)

Q26.

(a) Ethanol, C_2H_5OH, can be oxidised to produce ethanoic acid, CH_3COOH, by heating it with potassium dichromate(VI).

(i) Name one other reactant needed for this reaction to occur.

(1)

.....

(ii) Which colour change occurs during this reaction?

(1)

☒ **A** colourless to green

☒ **B** green to orange

☒ **C** orange to colourless

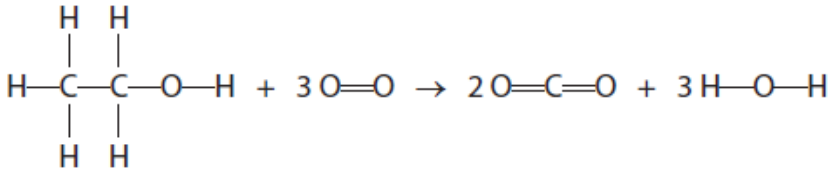
☒ **D** orange to green

(b) When ethanol is burned in air, complete combustion can occur.

The equation for this reaction is

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

This equation can also be written using displayed formulae to show all the covalent bonds in the molecules.



The table gives the bond energies for these bonds.

Bond	C—C	C—H	C—O	O—H	O═O	C═O
Bond energy in kJ/mol	346	412	358	463	496	743

(i) Use values from the table to calculate the energy needed to break all the bonds in the reactants.

(2)

energy needed ..... kJ

(ii) Use values from the table to calculate the energy released when all the bonds in the products are formed.

(2)

energy released ..... kJ

(iii) Calculate the molar enthalpy change (ΔH) in kJ/mol, for the complete combustion of ethanol.

Include a sign in your answer.

(1)

ΔH = ... kJ/mol

(c) Ethanol reacts with methanoic acid, HCOOH, in the presence of an acid catalyst to form an ester.

The equation for the reaction is

$$C_2H_5OH + HCOOH \Leftrightarrow HCOOC_2H_5 + H_2O$$

(i) Give the name of the ester that forms.

(1)

.....

(ii) Draw the displayed formula for this ester.

(2)

(iii) When this reaction takes place in a sealed container, the reaction can reach dynamic equilibrium.

Give two characteristics of a reaction at dynamic equilibrium.

(2)

1 .....

.....

2 .....

.....

(d) Methanoic acid reacts with sodium carbonate to form sodium methanoate, carbon dioxide and water.

The equation for the reaction is

$$2HCOOH + Na_2CO_3 \rightarrow 2HCOONa + CO_2 + H_2O$$

Calculate the volume, in cm^3, of carbon dioxide gas produced when 2.3 g of methanoic acid reacts completely with sodium carbonate.

[M_r of HCOOH = 46]

[molar volume of carbon dioxide at rtp = 24 dm^3]

(4)

volume of carbon dioxide = ... cm^3

(Total for question = 16 marks)

Q27.

Polymers can be classified as addition polymers or condensation polymers.

(a) An addition polymer can be formed from the monomer $CH_2=CHCl$

(i) Name this monomer.

(1)

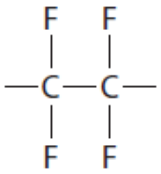
.....

(ii) Name the addition polymer formed from this monomer.

(1)

.....

(b) The diagram shows the repeat unit of a different addition polymer.

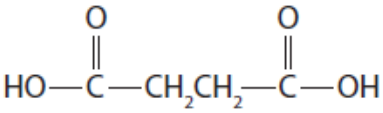


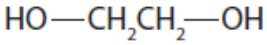
Draw the displayed formula of the monomer used to make this polymer.

(1)

(c) Polyesters are condensation polymers.

The structures of two monomers that are used to make a polyester are:





(i) Draw the structure of the repeat unit of the polyester formed from these two monomers.

(2)

(ii) Identify the small molecule formed when these two monomers form the polyester.

(1)

(Total for question = 6 marks)

Q28.

Crude oil is a mixture of hydrocarbons.

(a) Name the process used to separate crude oil into fractions.

(1)

.....

(b) Give one use of the kerosene fraction.

(1)

.....

(c) One of the hydrocarbons in the refinery gas fraction is an alkane with the structural formula $CH_3CH_2CH_2CH_3$

(i) Give the name of this alkane.

(1)

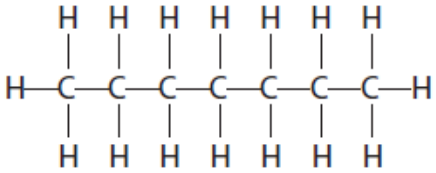
.....

(ii) Calculate the relative molecular mass (M_r) of this alkane.

(1)

M_r .....

(d) One of the alkanes in the gasoline fraction has the displayed formula



(i) Determine the molecular formula of this alkane.

(1)

.....

(ii) Give the general formula for the alkanes.

(1)

.....

(e) Catalytic cracking is used to convert long-chain alkanes into shorter-chain alkanes.

(i) Name the catalyst used in catalytic cracking.

(1)

.....

(ii) Explain why it is necessary to convert long-chain alkanes into shorter-chain alkanes.

(2)

.....

.....

.....

.....

.....

.....

(f) Catalytic cracking also produces alkenes.

$C1_1H_{24}$ can undergo cracking to give pentane (C_5H_{12}) and two different alkenes.

Complete the equation for this cracking reaction.

(2)

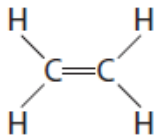
$$C_{11}H_{24} \rightarrow C_5H_{12} + \text{.....} + \text{.....}$$

(Total for question = 11 marks)

Q29.

This question is about the unsaturated hydrocarbon, ethene.

The displayed formula of ethene is



(a) (i) State the meaning of the term **hydrocarbon**.

(2)

.....

.....

.....

.....

(ii) Give the reason why ethene is described as unsaturated.

(1)

.....

.....

(b) Ethene is bubbled through bromine water until there is no further colour change.

Which of these is the appearance of the solution formed?

(1)

☒ **A** colourless

☒ **B** orange

☒ **C** purple

☒ **D** red

(c) Ethanol is produced industrially by the reaction between ethene and steam.

The equation for the reaction is

$$CH_2CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(l)$$

(i) State the temperature and pressure used in this reaction.

(2)

temperature

.....

pressure

.....

(ii) Give the **molecular** formula of ethanol.

(1)

.....

(Total for question = 7 marks)