PEARSON EDEXCEL IGCSE CHEMISTRY · 4CH1

CHEMISTRY



EXAM QUESTION PACK

SECTION 3: PHYSICAL CHEMISTRY (PACK 1)

SCORE	PERCENTAGE
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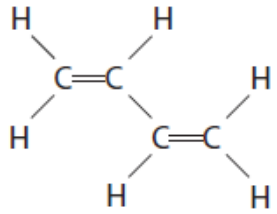
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Q1.

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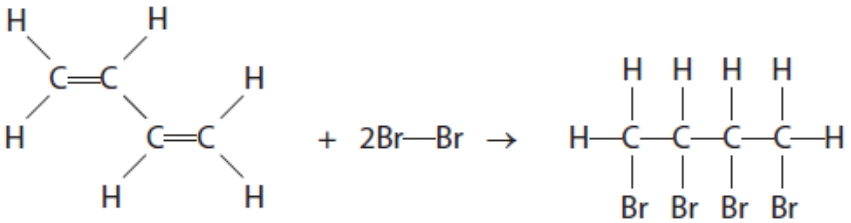
(b) (i) Butadiene reacts with bromine water.

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)

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

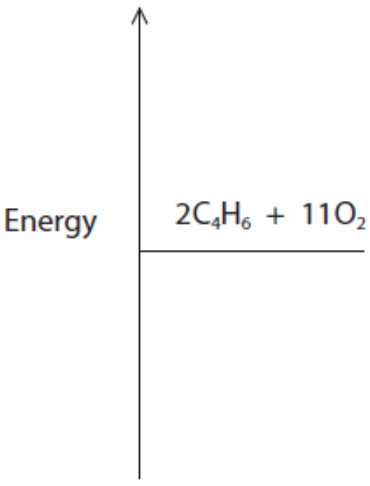
$$2C_4H_6 + 11O_2 \rightarrow 8CO_2 + 6H_2O$$

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)

Q2.

Oxygen can be prepared from hydrogen peroxide using a catalyst.

(a) Which is a correct statement about oxygen?

(1)

☒ **A** it burns with a squeaky pop

☒ **B** it relights a glowing splint

☒ **C** it turns blue litmus red

☒ **D** it turns limewater milky

(b) Explain how a catalyst increases the rate of a reaction.

(2)

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(c) The equation for the preparation of oxygen from hydrogen peroxide is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

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

$$2H{-}O{-}O{-}H \rightarrow 2H{-}O{-}H + O{=}O$$

The table gives the bond energies for these bonds.

Bond	H—O	O—O	O═O
Bond energy in kJ/mol	463	143	498

(i) Use the values in the table to calculate the enthalpy change, ΔH, for the reaction.

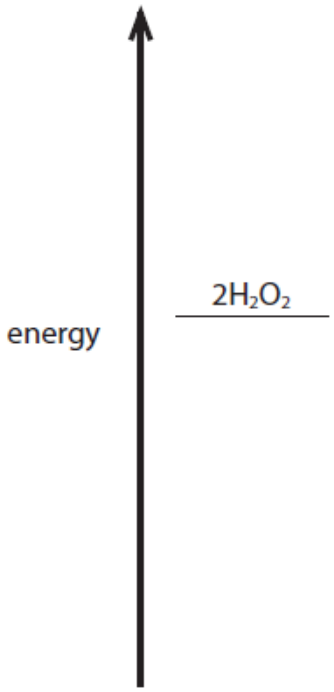
Include a sign in your answer.

(3)

ΔH = ... kJ

(ii) Complete the energy level diagram to show the position of the products and the enthalpy change, ΔH, for the reaction.

(2)



(Total for question = 8 marks)

Q3.

Hydrogen peroxide solution decomposes to give water and oxygen gas.

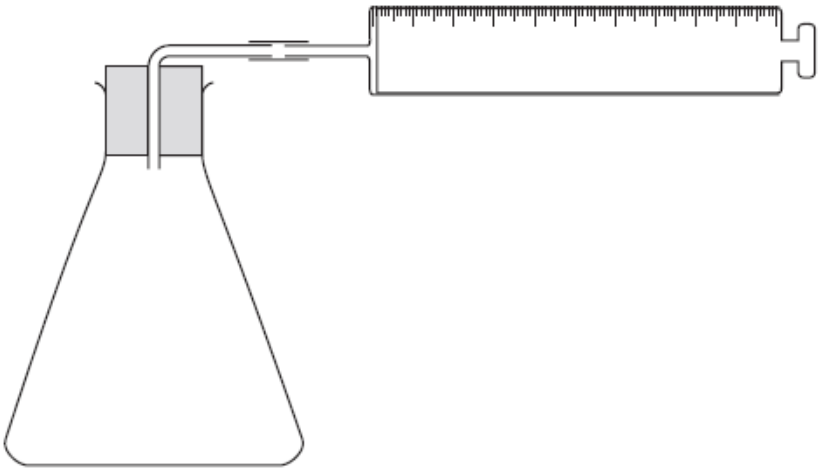
The equation for this reaction is

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

(a) Three different solids are catalysts for the decomposition of hydrogen peroxide solution.

A student is given hydrogen peroxide solution and a sample of each of the solid catalysts.

The student has a timer, a measuring cylinder, a balance and the apparatus shown in the diagram.



Describe a method the student could use to find which of the three solids is the most effective catalyst for the decomposition of hydrogen peroxide solution.

(5)

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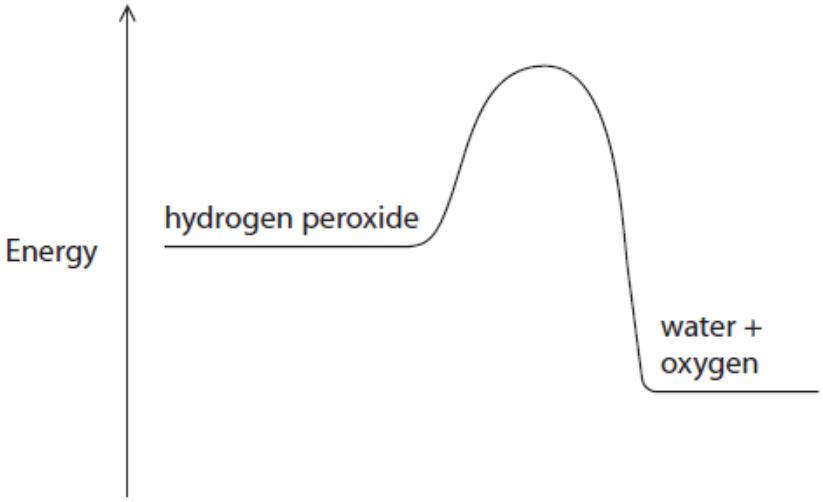
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(b) The diagram shows the reaction profile for the decomposition of hydrogen peroxide without a catalyst.



(i) Label the diagram to show the activation energy (E_a) and the enthalpy change (ΔH) for this reaction.

(2)

(ii) On the diagram, draw a curve to show the reaction profile for the same reaction when a catalyst is used.

(1)

(Total for question = 8 marks)

Q4.

Hydrogen peroxide solution decomposes slowly at room temperature to form water and oxygen.

The equation for the reaction is

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

(a) A catalyst increases the rate of this reaction.

State one other property of a catalyst.

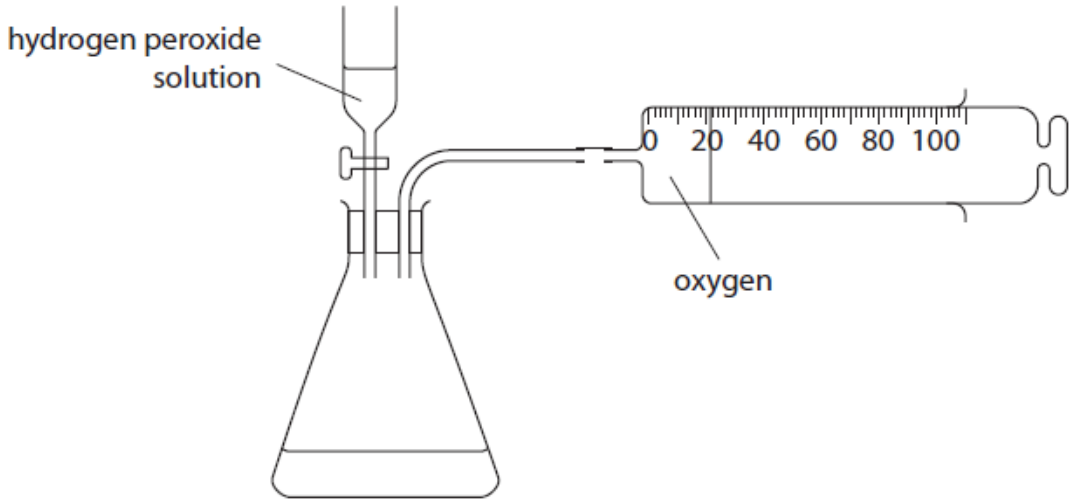
(1)

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(b) A student has samples of three solids, X, Y and Z.

The student uses this apparatus to find out which solids act as catalysts in the decomposition of hydrogen peroxide solution.



Describe the method that the student should use to find out which solids act as catalysts.

(6)

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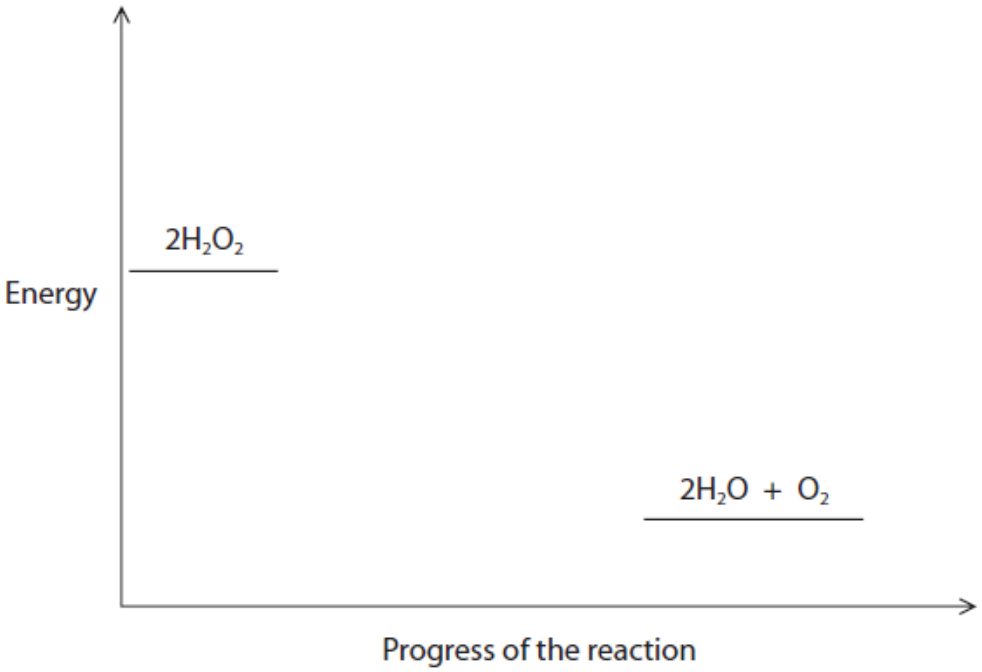
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(c) The decomposition of hydrogen peroxide solution is exothermic.

On the diagram, draw and label the reaction profiles for the reaction

- without a catalyst
- with a catalyst

(2)



(d) The equation for the reaction can be shown using displayed formulae.

$$2H{-}O{-}O{-}H \rightarrow 2H{-}O{-}H + O{=}O \qquad \Delta H = -204\,kJ$$

The table gives the bond energies for two of the bonds.

Bond	Bond energy in kJ/mol
H—O	463
O—O	146

(i) Use this information to calculate the total amount of energy needed to break all the bonds in two moles of H_2O_2

(1)

energy needed = ... kJ

(ii) Use this information to calculate the total amount of energy released when all the bonds in two moles of H_2O are formed.

(1)

energy released = ... kJ

(iii) Use the value of Δ*H* and your answers for (i) and (ii) to calculate the bond energy, in kJ/mol, for the

O═O bond.

(2)

bond energy = ... kJ/mol

(Total for question = 13 marks)

Q5.

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)

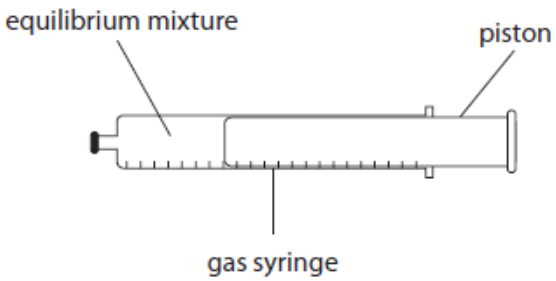
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(b) Some N_2O_4 and some NO_2 are put into a sealed gas syringe and allowed to form an equilibrium mixture.



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)

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(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)

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(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)

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

(1)

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

(1)

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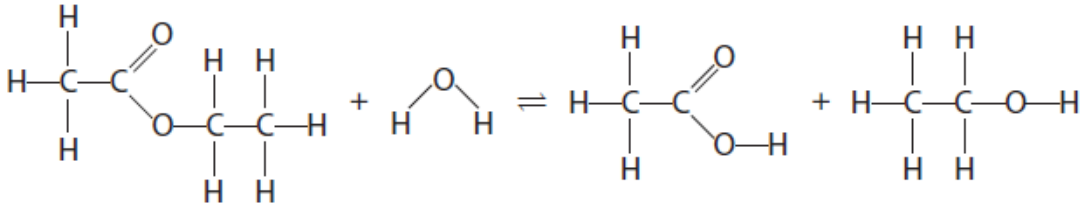
(Total for question = 8 marks)

Q6.

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)

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

(2)

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(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)

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(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)

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

(2)

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(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

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

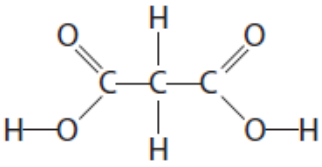
Calculate the amount, in moles, of ethanoic acid neutralised.

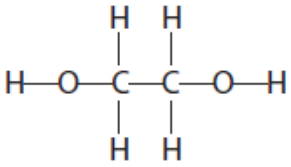
Give your answer to 3 significant figures.

(3)

amount = ... mol

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





These compounds react together to form a polymer.

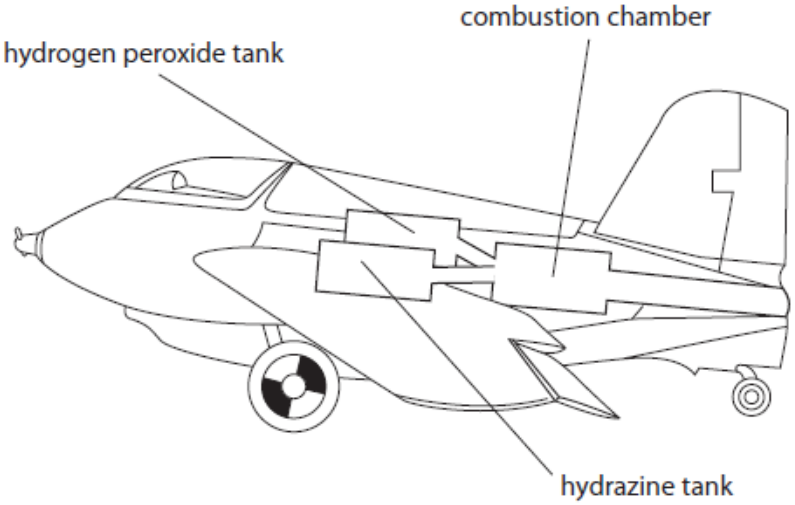
Give the repeat unit of the polymer formed.

(2)

(Total for question = 15 marks)

Q7.

During the Second World War, engineers developed a rocket-powered aircraft.



The aircraft carried these two liquids

- hydrazine, N_2H_4
- hydrogen peroxide, H_2O_2

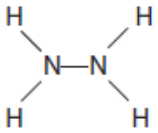
When these two liquids mix in the combustion chamber, they evaporate and then react rapidly to form nitrogen gas, N_2, and steam, H_2O

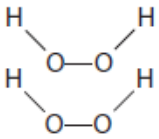
The reaction is exothermic.

The equation for the reaction is

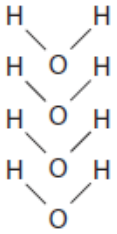
$$N_2H_4 \quad + \quad 2H_2O_2 \quad \rightarrow \quad N_2 \quad + \quad 4H_2O$$

The displayed formulae for the reactants and products are





N≡N



(a) The tables give the bond energies for the bonds broken in the reactants and the bonds made in the products.

Bonds broken	
bond	bond energy in kJ/mol
N—N	159
N—H	391
O—O	143
O—H	463

Bonds made	
bond	bond energy in kJ/mol
N≡N	945
O—H	463

(i) Use the data in the tables to calculate the total amount of energy required to break all of the bonds in the reactants.

(1)

energy required = ... kJ

(ii) Use the data in the tables to calculate the total amount of energy released when all of the bonds in the products are made.

(1)

energy released = ... kJ

(iii) Calculate the enthalpy change, ΔH, in kJ/mol, for the reaction. Include a sign in your answer.

(3)

ΔH = ... kJ/mol

(b) Explain, in terms of bonds broken and bonds made, why this reaction is exothermic.

(2)

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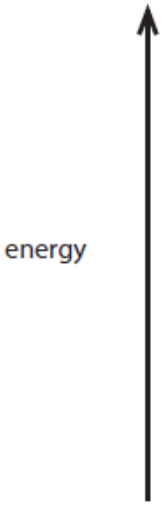
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(c) Draw an energy level diagram for the reaction between N_2H_4 and H_2O_2

(3)



(Total for question = 10 marks)

Q8.

The reaction between hydrogen and chlorine is exothermic.

This is the equation for the reaction.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \quad \Delta H = -184 \text{ kJ}$$

(a) State the meaning of the term **exothermic**.

(1)

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(b) The table gives the bond energies for the H—H and H—Cl bonds.

Bond	H—H	H—Cl
Bond energy in kJ / mol	436	431

Use the equation and information from the table to calculate the bond energy of the Cl—Cl bond.

(4)

bond energy = ... kJ / mol

(c) Explain why this reaction is exothermic.

(3)

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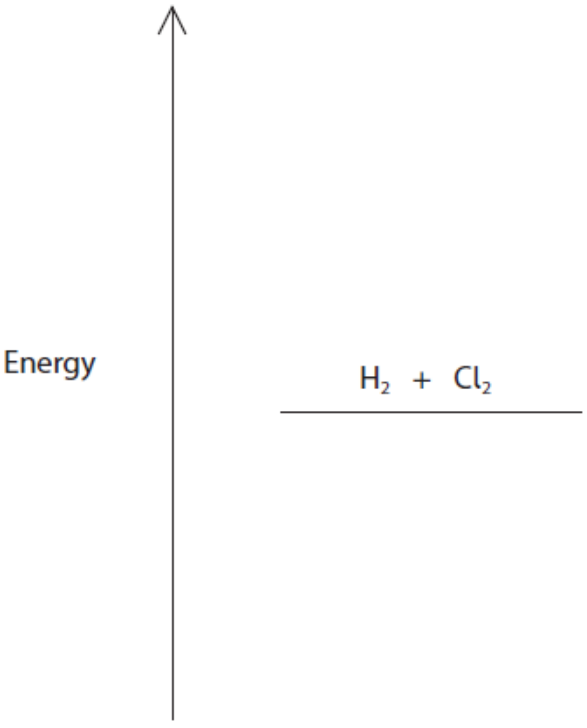
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(d) Complete the reaction profile diagram to show the position of the products, the enthalpy change (ΔH) and the activation energy (E_a) for the reaction.

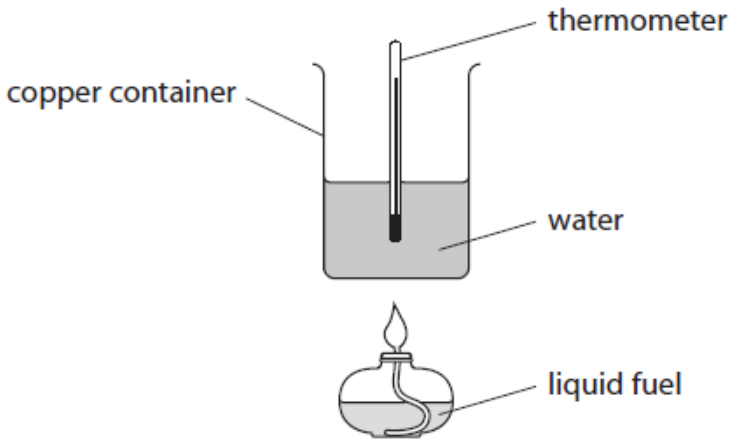
(4)



(Total for question = 12 marks)

Q9.

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)

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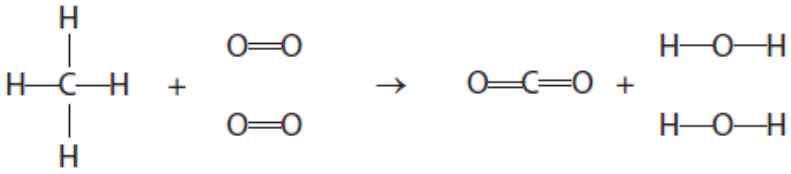
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(d) The equation shows the combustion of methane.

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

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

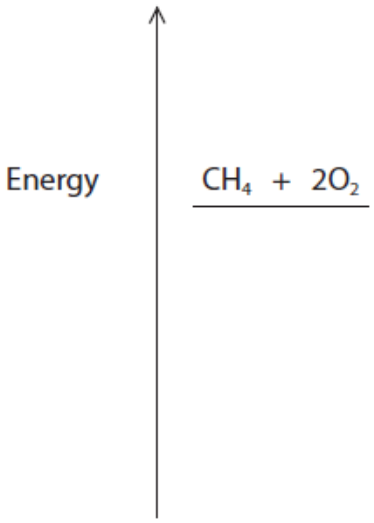
(i) Calculate the bond energy of the C—H bond, using information from the equation and the table.

(4)

C—H bond energy = ... kJ/mol

(ii) Complete the energy level diagram to show the products and Δ*H*.

(2)



(Total for question = 11 marks)

Q10.

Hydrogen gas and iodine gas react together to form hydrogen iodide gas.

$$H_2(g) + I_2(g) \leftrightarrow 2HI(g)$$

(a) (i) The pressure of an equilibrium mixture of the three gases is increased.

Predict the effect of this change on the yield of hydrogen iodide at equilibrium, giving a reason for your answer.

(2)

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(ii) A catalyst is added to an equilibrium mixture of the three gases.

Predict the effect of the catalyst on the yield of hydrogen iodide at equilibrium, giving a reason for your answer.

(2)

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(b) Hydrogen gas reacts with fluorine gas to form hydrogen fluoride gas.

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

The table gives some bond energies.

Bond	Bond energy in kJ/mol
H—H	436
F—F	158
H—F	562

Use the equation and the data in the table to calculate the enthalpy change (ΔH) in kJ/mol, for the reaction.

Include a sign in your answer.

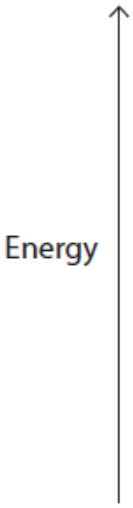
(3)

ΔH = ... kJ/mol

(c) Draw an energy level diagram for the reaction between hydrogen and fluorine.

Label the enthalpy change, ΔH.

(3)



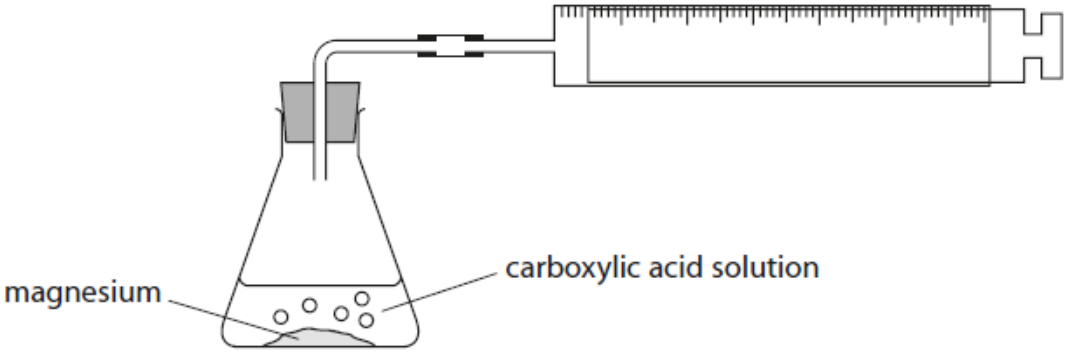
(Total for question = 10 marks)

Q11.

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 .....

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2 .....

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

(1)

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(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)

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(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)

Q12.

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)

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(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)

Q13.

In the presence of an iron catalyst, nitrogen reacts with hydrogen to form ammonia.

The reaction conditions used are a temperature of 450°C and a pressure of 200 atmospheres.

This is the equation for the reaction.

$$N_2 + 3H_2 \leftrightarrow 2NH_3 \quad \Delta H = -92 \text{ kJ/mol}$$

(a)(i) State what the symbol ↔ represents.

(1)

.....

.....

(ii) Give the reason for using a catalyst.

(1)

.....

.....

(b) (i) The reaction mixture is kept at a pressure of 200 atmospheres, but the temperature is increased to 550 °C.

Explain the effect of this change on the yield of ammonia at equilibrium.

(2)

.....

.....

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.....

(ii) The reaction mixture is kept at a temperature of 450 °C, but the pressure is increased to 300 atmospheres.

Explain the effect of this change on the yield of ammonia at equilibrium.

(2)

.....

.....

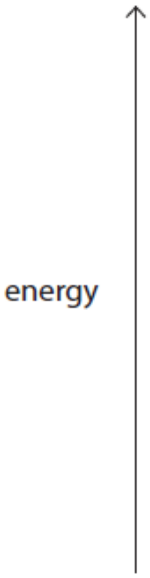
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(c) Draw an energy level diagram for the reaction between nitrogen and hydrogen.

Include the reactants, products and ΔH in your diagram.

(3)



(d) At the start of the reaction, 48 dm^3 of nitrogen is added to 120 dm^3 of hydrogen at rtp.

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

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

(i) Show by calculation that the nitrogen is in excess.

(3)

(ii) The yield of ammonia at equilibrium is 20 %.

Calculate the volume, in dm^3, of ammonia formed from 120 dm^3 of hydrogen.

(3)

volume of ammonia = ... dm^3

(Total for question = 15 marks)

Q14.

(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)

$$2HCOOH + Na_2CO_3 \rightarrow \text{.....} + \text{.....} + \text{.....}$$

(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.

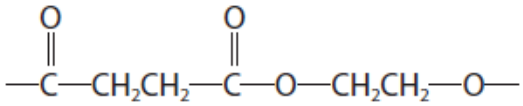
(1)

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.....

(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)

Q15.

(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

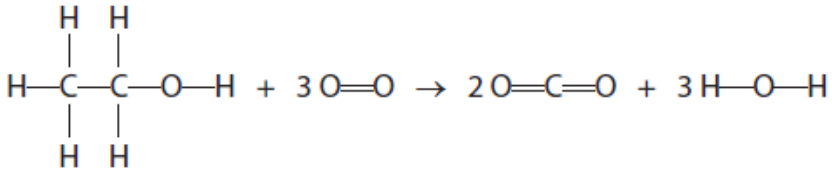
☒ **D** orange to green

(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)

Q16.

This question is about ammonia gas, NH_3

(a) Ammonia can be prepared in a laboratory from the reaction between ammonium chloride, NH_4Cl, and sodium hydroxide. The other products of the reaction are sodium chloride and water.

(i) Give a chemical equation for this reaction.

(1)

.....

(ii) Give a test for ammonia gas.

(2)

.....

.....

(b) In industry, ammonia is produced from nitrogen and hydrogen.

The equation for this reaction is

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

In a sealed container, the reaction can reach a position of dynamic equilibrium.

Explain the meaning of the term **dynamic equilibrium**.

(2)

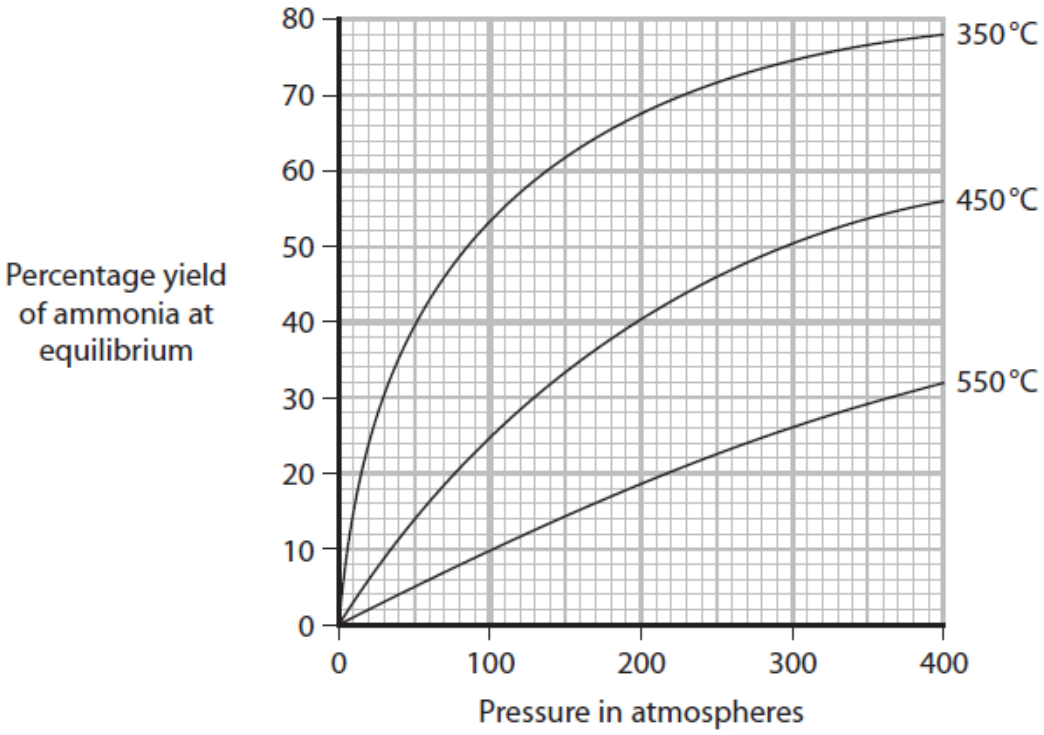
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(c) The graph shows the percentage yield of ammonia at equilibrium for different temperatures and pressures.



Using the graph, explain if the forward reaction is exothermic or endothermic.

(2)

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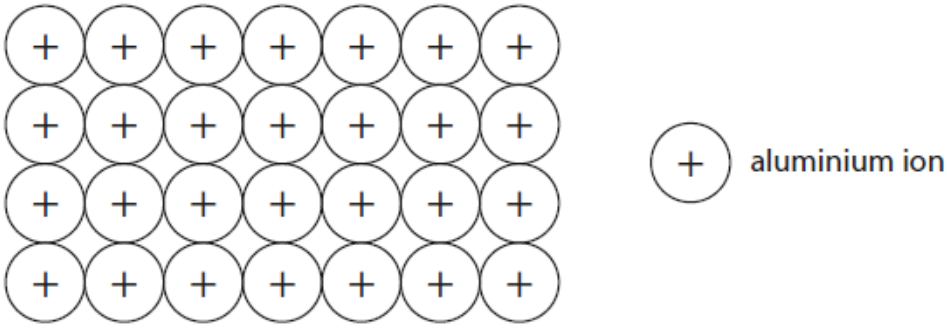
(Total for question = 7 marks)

Q17.

This question is about the metal aluminium.

(a) Aluminium is malleable and conducts electricity.

The diagram shows the arrangement of the ions in aluminium metal.



(i) Explain why aluminium is malleable.

(2)

.....

.....

.....

.....

(ii) Explain why aluminium conducts electricity.

(2)

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(b) Aluminium cannot be extracted by heating a mixture of carbon and aluminium oxide.

Give a reason why heating a mixture of aluminium oxide and carbon does not produce aluminium.

(1)

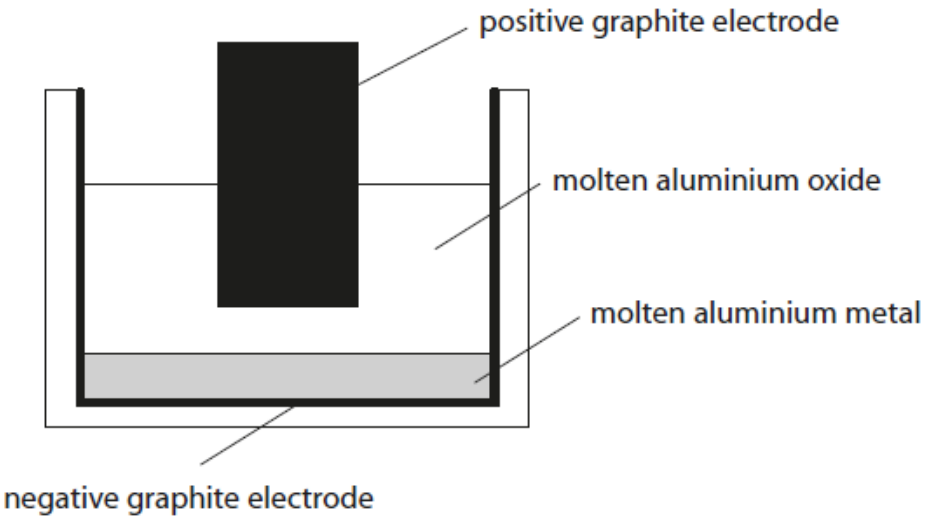
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(c) Aluminium is extracted industrially by the electrolysis of molten aluminium oxide Al_2O_3 at a temperature of about 950 °C.

Aluminium metal forms at the negative electrode and oxygen gas forms at the positive electrode. The positive and negative electrodes are made of graphite.

The diagram shows the apparatus used.



(i) Explain how aluminium metal forms at the negative electrode.

(2)

.....

.....

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.....

(ii) Write an ionic half-equation for the formation of oxygen gas at the positive electrode.

(1)

..... → .....

(iii) Suggest why carbon dioxide gas is also produced at the positive electrode.

(2)

.....

.....

.....

.....

(d) Aluminium reacts with iron(III) oxide. The reaction is exothermic.

The equation for the reaction is

$$2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe$$

(i) State how the equation shows that iron(III) oxide is reduced.

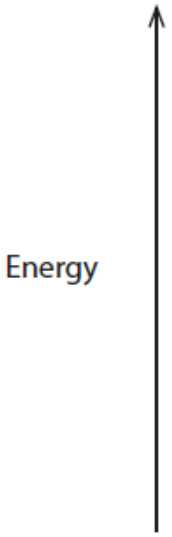
(1)

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.....

(ii) Draw an energy level diagram for the reaction between aluminium and iron(III) oxide.

(3)



(Total for question = 14 marks)

Q18.

This question is about reactions involving gases.

(a) Potassium carbonate reacts with dilute hydrochloric acid to produce carbon dioxide gas.

The equation for the reaction is

$$K_2CO_3(s) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g)$$

Calculate the volume, in cm^3, of carbon dioxide gas produced when 6.9 g of potassium carbonate reacts with excess dilute hydrochloric acid.

[*M*r of K_2CO_3 = 138]

[molar volume of CO_2 at rtp = 24 dm^3]

(3)

volume = ... cm^3

(b) This reaction involving gases is in dynamic equilibrium at a temperature of 225 °C.

$$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g) \qquad \Delta H = +41\,kJ/mol$$

(i) Predict the effect on the yield of CO(g) at equilibrium when the temperature is increased without changing the pressure.

Give a reason for your answer.

(2)

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.....

.....

.....

(ii) Predict the effect on the yield of CO(g) at equilibrium when the pressure is increased without changing the temperature.

Give a reason for your answer.

(2)

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.....

.....

(Total for question = 7 marks)

Q19.

Ammonia is manufactured on a large scale and is used to make fertilisers such as ammonium nitrate (NH_4NO_3).

(a) The first stage in the manufacture of ammonium nitrate is to react ammonia gas with oxygen gas.

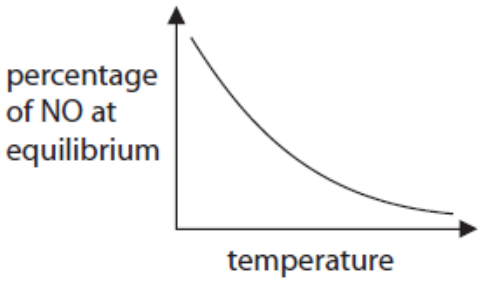
$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -907\,kJ/mol$$

The reaction is carried out at a pressure of about 10 atm and at a temperature of 800 °C, in the presence of a catalyst.

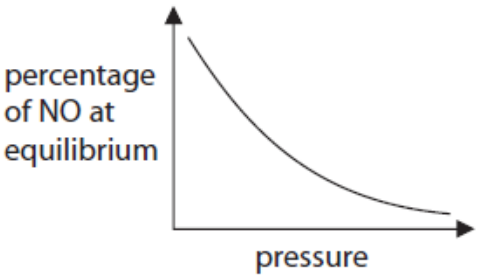
If the mixture is left for long enough in a sealed container, the reaction reaches a position of dynamic equilibrium.

Graph A shows how the percentage of nitrogen monoxide (NO) in the equilibrium mixture varies with temperature at constant pressure.

Graph B shows how the percentage of nitrogen monoxide (NO) in the equilibrium mixture varies with pressure at constant temperature.



graph A



graph B

(i) Explain why the percentage of NO at equilibrium decreases in each case.

(4)

Graph A .....

.....

.....

.....

Graph B .....

.....

.....

.....

(ii) Explain why the use of a catalyst has no effect on the position of equilibrium in a reversible reaction.

(2)

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(b) The second stage in the manufacture of ammonium nitrate is to convert the nitrogen monoxide into nitric acid. The nitric acid is then reacted with concentrated aqueous ammonia as shown in this equation.

$$HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$$

(i) State, in terms of proton transfer, why this reaction is classified as an acid-base reaction.

(1)

.....

.....

(ii) Calculate the volume of 14.8 mol / dm^3 aqueous ammonia that is required to exactly neutralise 150 dm^3 of a solution of nitric acid of concentration 15.8 mol / dm^3.

(2)

volume of aqueous ammonia = ... dm^3

(Total for question = 9 marks)