WJEC Chemistry AS-level

2.2: Rates of Reaction

Practice Questions

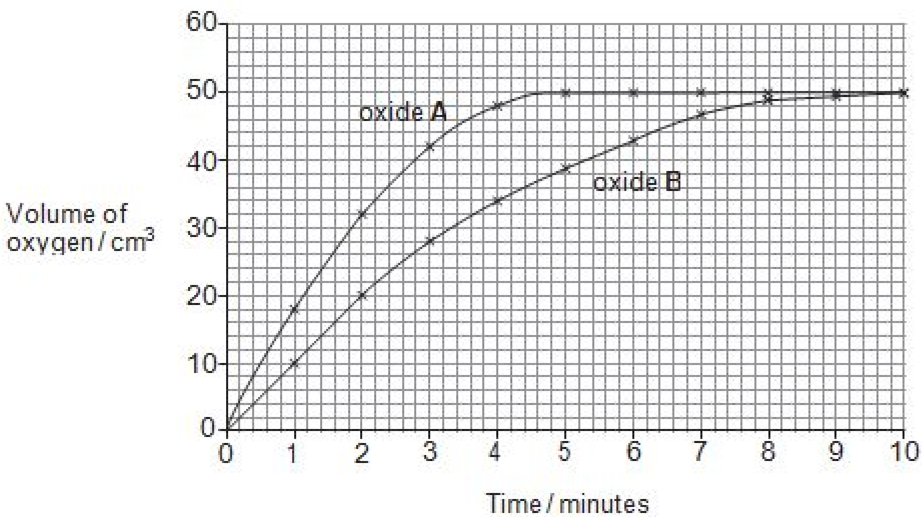
England Specification

1. Oxygen can be produced in the laboratory by the decomposition of hydrogen peroxide.

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

Trystan carried out experiments to study the effect of using two metal oxides, **A** and **B**, to catalyse the reaction. He used 0.5 g of each metal oxide and diluted 10 cm^3 of a hydrogen peroxide solution with 90 cm^3 of water in each case. Following dilution the solutions were kept at a constant temperature of 35 °C throughout the experiment.

He plotted his results on the graph shown below.



(a) Outline a suitable method, including essential apparatus, for carrying out an experiment to obtain these results. You may include a diagram if you consider it helpful.

[4]

(b) State, giving a reason, which oxide is the more efficient catalyst.

[1]

(c) In the experiment with oxide **A**, calculate the volume of oxygen evolved

(i) during the first minute,

[1]

(ii) during the third minute.

[1]

(d) Explain the difference between the answers in (c)(i) and (c)(ii).

[2]

(e) Give a reason why the total volume of oxygen obtained in the two experiments is the same.

[1]

(f) If Trystan repeated the experiment using 5 cm^3 of the original hydrogen peroxide solution diluted with 95 cm^3 of water, state the final volume of oxygen that would be evolved

[1]

(g) If he carried out the experiments at 45 °C instead of 35 °C, state what effect this would have on the time required to obtain the final volume of oxygen. Use collision theory to explain your answer.

[3] QWC [1]

(Total 15)

2.

Halogens and their compounds take part in a wide variety of reactions.

(a) Give the chemical name of a chlorine-containing compound of commercial or industrial importance. State the use made of this compound. [1]

(b) Hydrogen reacts with iodine in a reversible reaction.

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

An equilibrium was established at 300 K, in a vessel of volume 1 dm^3, and it was found that 0.311 mol of hydrogen, 0.311 mol of iodine and 0.011 mol of hydrogen iodide were present.

(i) Write the expression for the equilibrium constant in terms of concentration, K_c. [1]

(ii) Calculate the value of K_c at 300 K. [1]

K_c = ...

(iii) What are the units of K_c, if any? [1]

(iv) Equilibria of H_2, I_2 and HI were set up at 500 K and 1000 K and it was found that the numerical values of K_c were 6.25×10^{-3} and 18.5×10^{-3} respectively.

Use these data to deduce the sign of ΔH for the forward reaction. Explain your reasoning. [3]

(c) When concentrated hydrochloric acid is added to a pink aqueous solution of cobalt(II) chloride, the colour changes to blue.

Cobalt takes part in an equilibrium reaction.

$$[Co(H_2O)_6]^{2+}(aq) \quad + \quad 4Cl^-(aq) \quad \rightleftharpoons \quad [CoCl_4]^{2-}(aq) \quad + \quad 6H_2O(l)$$

(i) What is the oxidation state of cobalt in $[CoCl_4]^{2-}$? [1]

....

(ii) What type of bonding is present in $[CoCl_4]^{2-}$? [1]

....

(iii) Use the equation to identify the ions responsible for the pink and blue colours described above. Explain why the colour change occurs when concentrated hydrochloric acid is added to the pink solution. [3]

....

....

....

....

(iv) Draw diagrams to clearly show the shape of the $[Co(H_2O)_6]^{2+}$ ion and the $[CoCl_4]^{2-}$ ion. [2]

$[Co(H_2O)_6]^{2+}$ $[CoCl_4]^{2-}$

Total [14]

3. Judith carried out three experiments to study the reaction between powdered magnesium and hydrochloric acid.

She used a gas syringe to measure the volume of hydrogen evolved, at room temperature and pressure, at set intervals. In each case, the amount of acid used was sufficient to react with all the magnesium.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

The details of each experiment are shown in Table 1 below.

Experiment	Mass of magnesium / g	Volume of HCl / cm^3	Concentration of HCl / mol dm^{-3}
A	0.061	40.0	0.50
B	0.101	40.0	1.00
C	0.101	20.0	2.00

Table 1

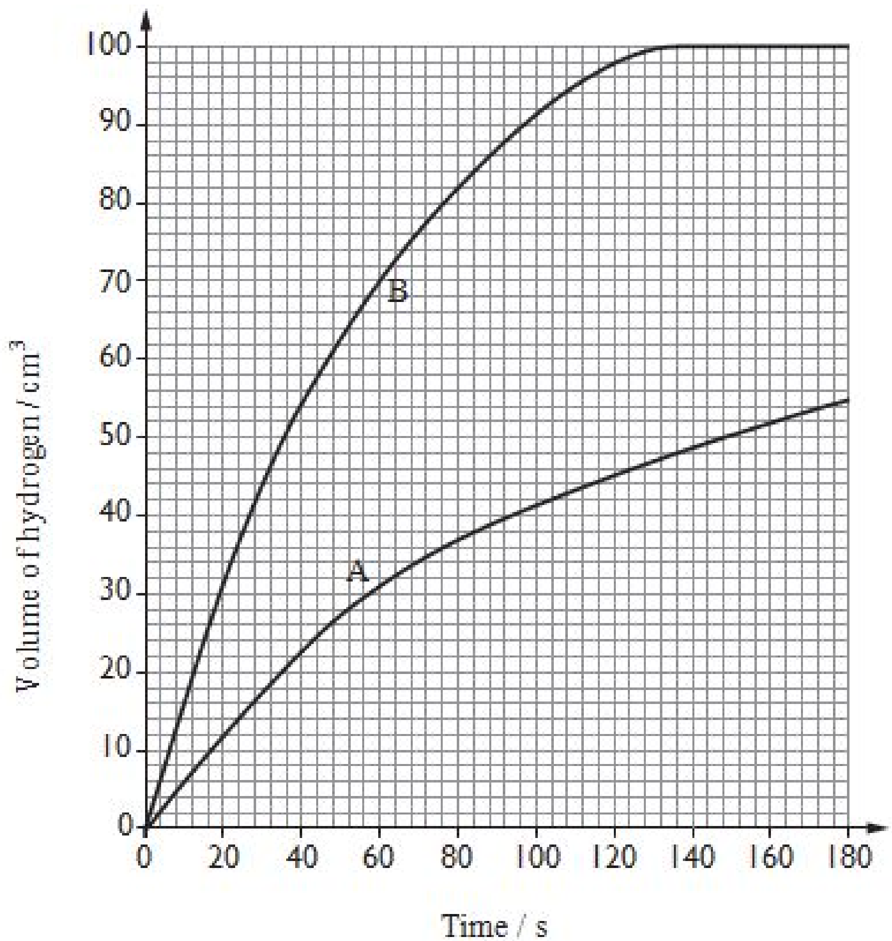
The results obtained in experiment **C** are shown in Table 2 below.

Time / s	Volume of hydrogen / cm^3
0	0
20	50
40	75
60	88
80	92
100	100
120	100

Table 2

(a) The results for experiments **A** and **B** have already been plotted on the grid below.On the same grid, plot the results for experiment **C** and draw a line of best fit.

[3]



(b)(i) State in which experiment the reaction begins most rapidly and **use the graph** to explain your choice.

[2]

(ii) By referring to Table 1 give an explanation of your answer in part (i).

[1]

(c) State the volume of hydrogen evolved after 30 seconds in experiment **B**.

[1]

(d) Using **only** the values in Table 1, show that the acid is in excess in experiment **C**.

[2]

(e)(i) In experiment **A**, 0.061 g of magnesium produces 60 cm^3 of hydrogen. If 0.122 g of magnesium were used, under the same conditions, then 120 cm^3 would be produced. Explain why using 0.610 g would not produce 600 cm^3 of hydrogen.

[1]

(ii) Calculate the volume of hydrogen produced using 0.610 g of magnesium.

(1 mole of gas molecules occupies 24 dm^3 at 25 °C)

[2]

(f) State one method of slowing down the reaction in experiment **C** and use collision theory to explain your choice. Assume that the quantities of magnesium and hydrochloric acid are the same as those in Table 1.

[3] QWC [1]

(Total 16)

4. *(a)* Nitrogen(I) oxide is a colourless gas that reacts with hydrogen to give nitrogen and water.

$$N_2O(g) + H_2(g) \longrightarrow N_2(g) + H_2O(l) \qquad \Delta H = -368\ kJ\ mol^{-1}$$

(i) State why the standard enthalpy of formation of both hydrogen and nitrogen gases is 0 $kJ\ mol^{-1}$. [1]

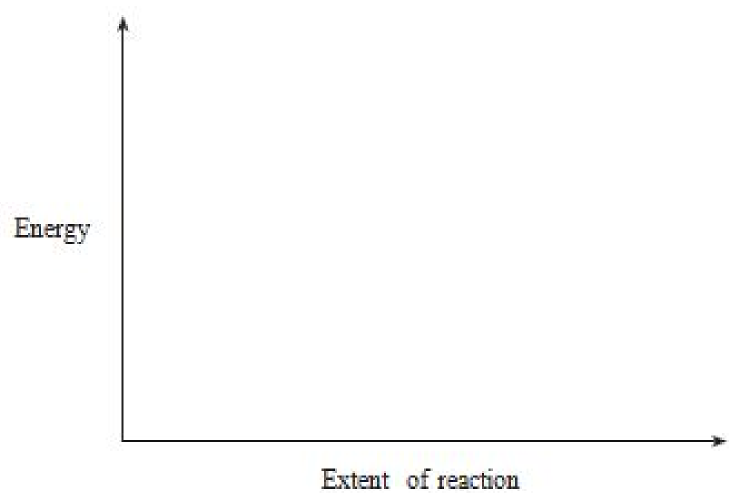
(ii) Calculate the standard enthalpy of formation of nitrogen(I) oxide in $kJ\ mol^{-1}$. (You should assume that the standard enthalpy of formation of water is $-286 kJ\ mol^{-1}$) [2]

Standard enthalpy of formation = ... $kJ\ mol^{-1}$

(b) A new method for producing phenol, C_6H_5OH, is by reacting benzene, C_6H_6, with nitrogen(I) oxide at 400 °C in the presence of a suitable catalyst.

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2 \qquad \Delta H = -286\ kJ\ mol^{-1}$$

(i) Sketch the energy profiles for the catalysed and uncatalysed reactions using the axes shown below.
Label your profiles as *catalysed* and *uncatalysed*. [2]



(ii) A pilot-scale plant used 156 kg of benzene (M_r = 78) to produce phenol (M_r = 94).

I Calculate the number of moles of benzene used. [1]

Moles of benzene = ... mol

II The yield of phenol was 95 %. Using your answer to I and the equation below (or another suitable method), calculate the mass of phenol obtained. Show your working. [3]

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2$$

Mass of phenol = ... kg

(iii) Study the short account below, which gives more detail about this process.

The process to make phenol is carried out in the gas phase and uses a solid zeolite catalyst. The operating temperature is around 400 °C.

$$C_6H_6 + N_2O \longrightarrow C_6H_5OH + N_2 \qquad \Delta H = -286 \text{ kJ mol}^{-1}$$

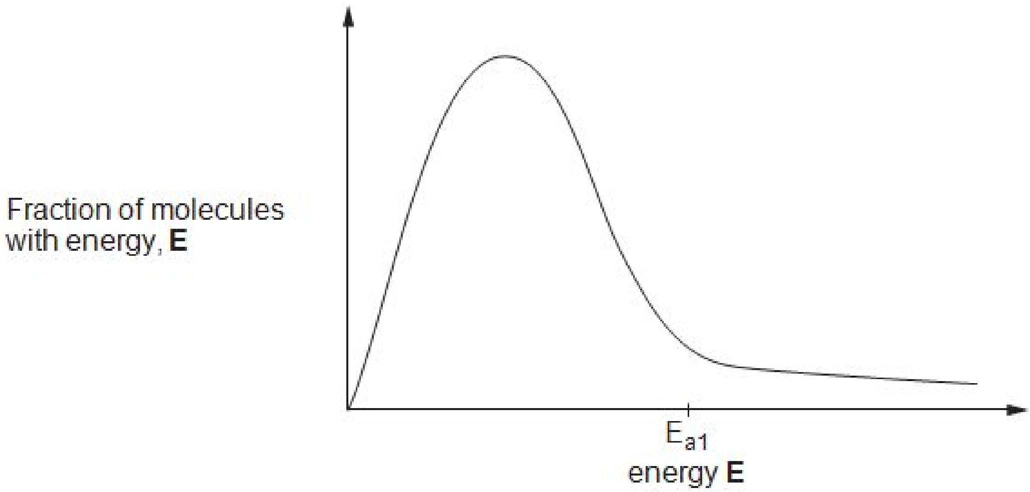
The reactants are the hydrocarbon benzene and nitrogen(I) oxide, which is a potent greenhouse gas. The nitrogen(I) oxide is obtained from another process, where it is produced as an undesirable side product.

Use the account and the equation to comment on the environmental and *Green Chemistry* advantages of this process. A reference to the yield is not required. [4]
QWC [1]

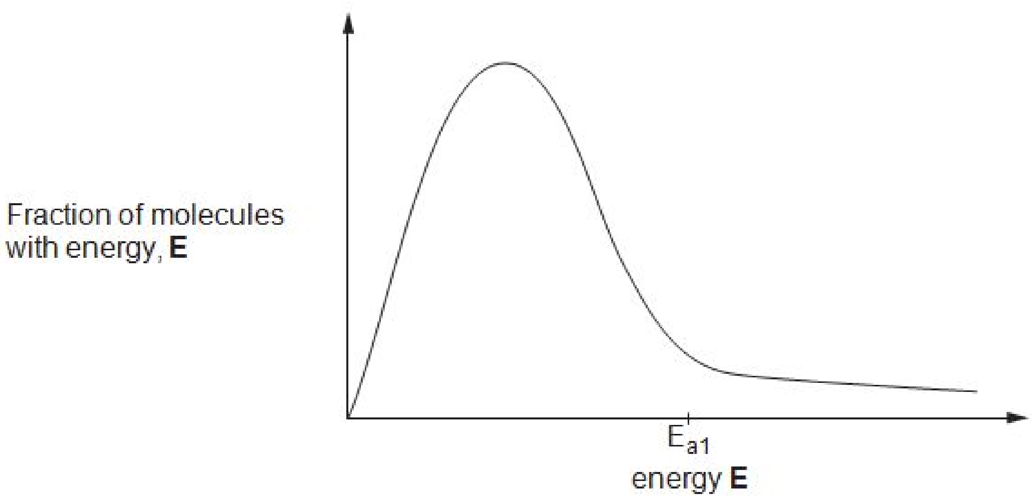
Total [14]

5. The diagrams show the energy distribution curve for gaseous molecules at a fixed temperature.

(a) On the diagram below, E_{a1} shows the activation energy of a particular reaction without a catalyst. Indicate on the diagram the fraction of molecules that react. [1]



(b) Indicate on the diagram below the activation energy, E_{a2}, and the fraction of molecules that react when the reaction proceeds with a catalyst. [1]

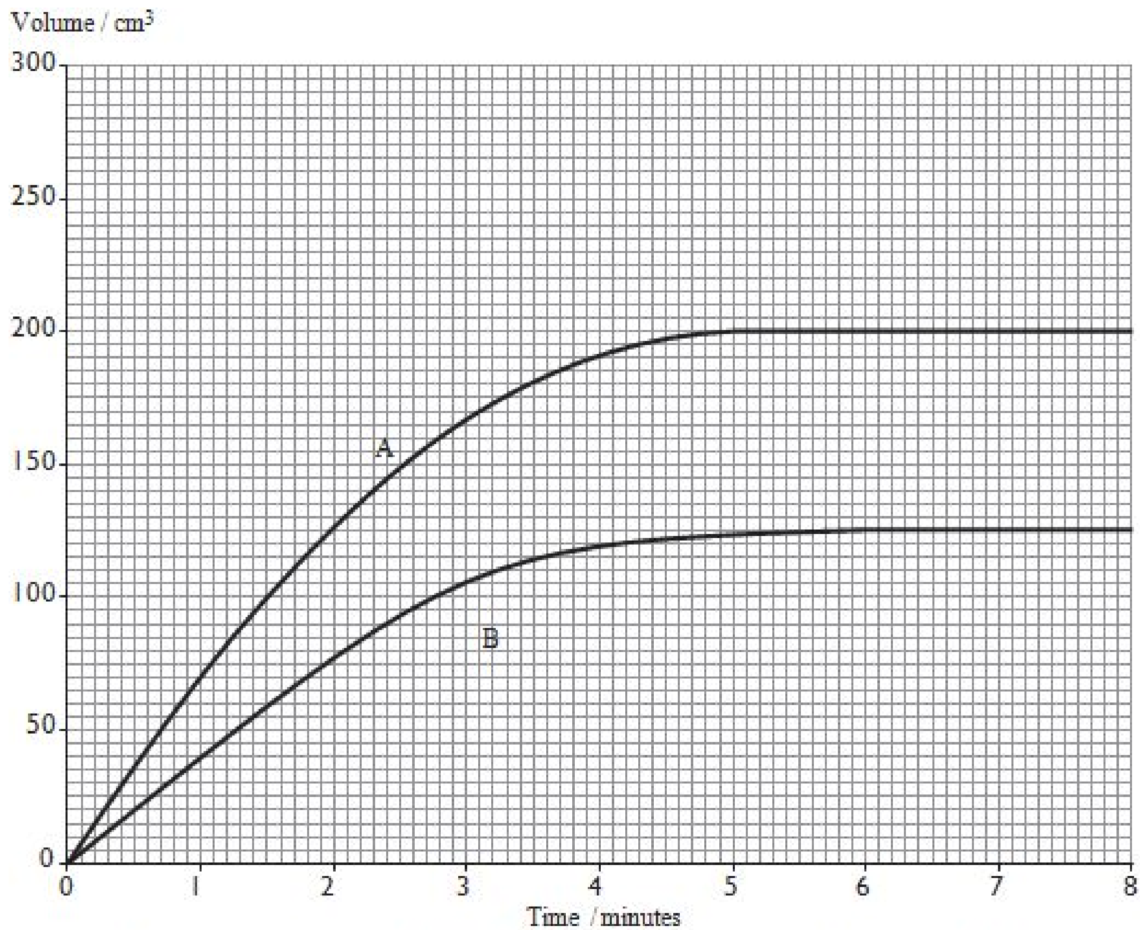


(Total 2)

6. Dolomite, $MgCO_3.CaCO_3$, is a mineral containing magnesium carbonate and calcium carbonate.

(a) Some students were asked to react samples of dolomite, each of mass 0.50 g, with an excess of dilute hydrochloric acid and to follow the rate of the reaction by measuring the volume of carbon dioxide evolved at suitable time intervals.

(i) Line **A** on the graph shows Natalie's results. Her teacher said that this was correct. David's line is labelled **B**. Although his line represents his results, the teacher said that he must have done something wrong during the experiment to obtain these results.



Suggest and explain **two** things that he might have done wrongly to obtain these results. [2]

1. ....

....

2. ....

....

(ii) Explain why, in Natalie's experiment, 0.25 g of the dolomite has reacted in 1.5 minutes but the remaining 0.25 g has taken a further 3.5 minutes to react.

[2]

(iii) Emma asked what the volume of carbon dioxide collected from the samples would be if the temperature rose from 298 K to 323 K.

The teacher explained that, if the pressure remained the same, volume V (in cm^3) and temperature T (in Kelvin) were linked by the equation:

$$V = k \times T \text{ (where k is constant)}$$

The volume of carbon dioxide evolved at 298 K is 130 cm^3. By finding the value of k, or by other means, calculate the volume of this carbon dioxide when its temperature is raised to 323 K.

[2]

Volume of carbon dioxide = **..** cm^3

(b) In another experiment 0.623 g of dolomite reacted with an excess of dilute hydrochloric acid. The total volume of carbon dioxide evolved was 162 cm^3.

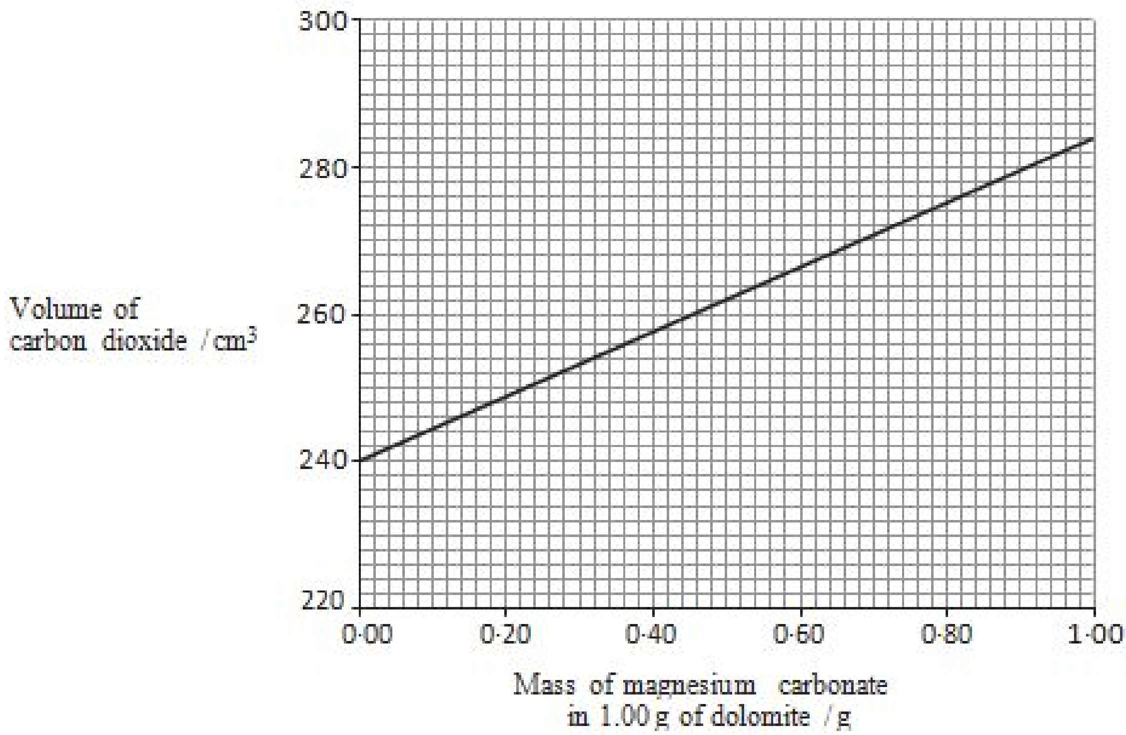
(i) Calculate the total volume of carbon dioxide that would be evolved if a sample of dolomite of mass 1.00 g was used under the same conditions.

[1]

Volume of carbon dioxide = **.............................** cm^3

(ii) Use the graph below to find the mass of magnesium carbonate present in this 1.00 g sample of dolomite.

[1]

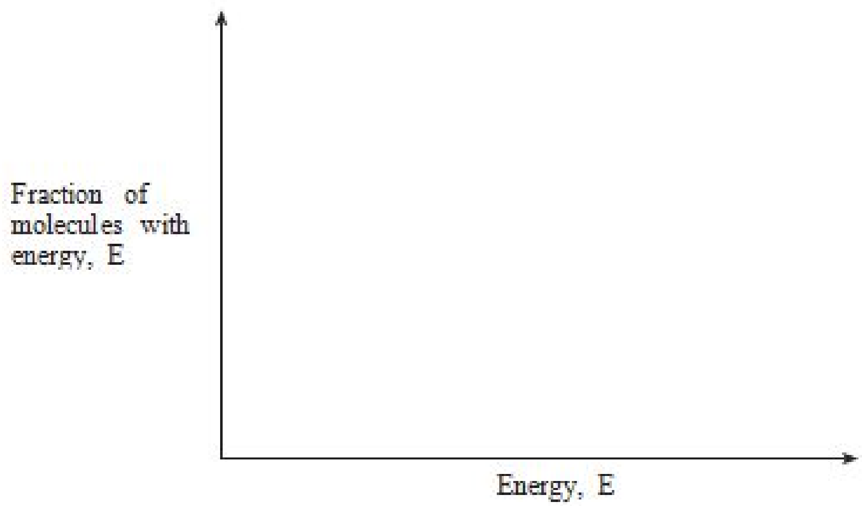


Mass of magnesium carbonate = ... g

(c) The rate of the reaction between dolomite and hydrochloric acid increases by a large amount if the temperature is increased.

Complete the following energy distribution curve diagram by drawing two lines that show the distribution of energies at two different temperatures.
Label the line at lower temperature T_1 and the line at higher temperature T_2.
Use the diagram to help you explain why the rate increases as the temperature increases. [3]

QWC [1]



(d) Briefly outline a different method of following the rate of the reaction between dolomite and hydrochloric acid.

[2]

(Total 14)

7. Many industrial processes use catalysts.

Explain how a catalyst increases the rate of a chemical reaction.

[2]

(Total 2)

8.

(a) State what is meant by the term *standard molar enthalpy change of formation*. [2]

....

....

....

(b) (i) Write an equation to represent the standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$. [1]

....

(ii) The standard molar enthalpy change of formation, $\Delta H_f^{\ominus}$, of $H_2O(g)$ is -242 kJ mol^{-1}. Using this value and the average bond enthalpies given in the table below, calculate the average bond enthalpy of the O—H bond in H_2O. [2]

Bond	Average bond enthalpy / kJ mol^{-1}
H—H	436
O=O	496

Average bond enthalpy of O—H *bond* = ... kJ mol^{-1}

(c) Hydrogen has been proposed as a possible alternative to petrol as a fuel for cars. One suggestion is to store the hydrogen in the car as solid magnesium hydride, MgH_2, and generate it as required by heating.

(i) I Give **one** advantage of using hydrogen in place of petrol as a fuel for cars. [1]

....

....

II Give **one** advantage of storing the fuel in the car in the form of magnesium hydride rather than hydrogen gas. [1]

....

(ii) One possible disadvantage of using magnesium hydride arises from its reaction with water.

$$MgH_2(s) \quad + \quad 2H_2O(l) \longrightarrow Mg(OH)_2(s) \quad + \quad 2H_2(g)$$

Suggest why magnesium hydride's reaction with water could be a problem. [1]

....

....

(iii) The fuel tank of one type of hydrogen-powered car holds 70 kg of magnesium hydride.
Calculate the volume of hydrogen gas, measured at room temperature and pressure, which would be produced if this amount of magnesium hydride reacted with water. [3]

[1 mol of gas molecules occupies 24 dm^3 at room temperature and pressure]

Volume of hydrogen gas = ... dm^3

(d) Methanol can be produced industrially by passing carbon monoxide and hydrogen over a catalyst at high temperatures and pressures.

$$CO(g) \quad + \quad 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\ kJ\ mol^{-1}$$

(i) State how the equilibrium yield of methanol is affected by an increase in temperature and in pressure.

[1]

(ii) Explain your answer to part (i).

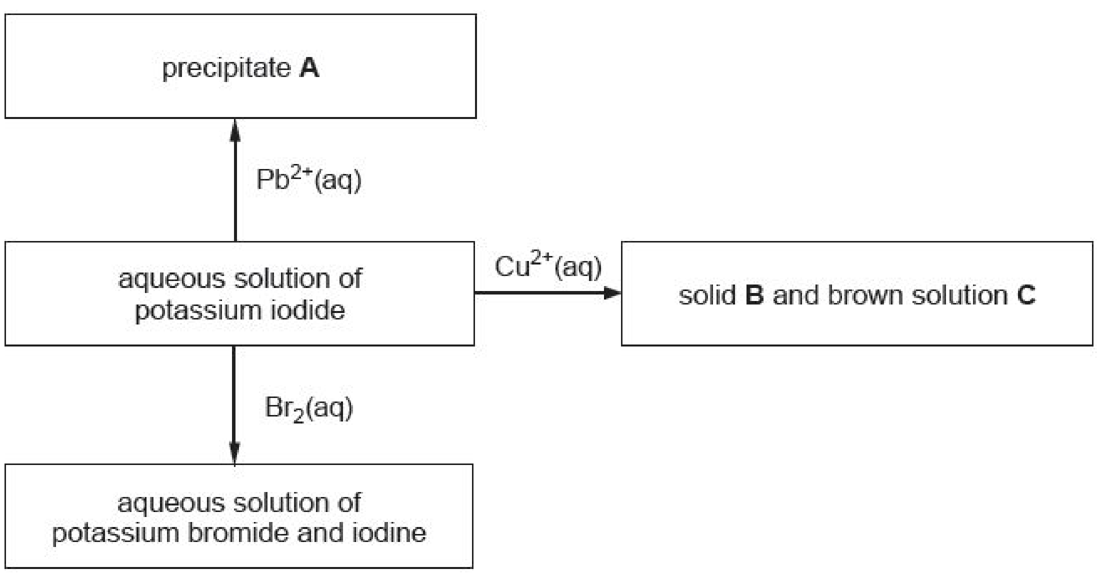
[2]

(e) Many catalysts are very expensive but their use does allow the chemical industry to operate more profitably. Explain why the use of catalysts provides economic and environmental benefits.

[3] QWC [1]

(Total 18)

9. The diagram below shows some of the reactions of potassium iodide solution.



(a) Identify precipitate **A** and give its colour. [2]

(b) Write an equation for the reaction of Cu^{2+}(aq) and I^-(aq), clearly identifying the precipitate. [2]

(c) Bromine reacts with aqueous potassium iodide as shown above, however bromine does not react with aqueous sodium chloride. Use the standard electrode potentials below to explain these observations. [3]
QWC [1]

Half-equation	E^θ/V
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54
$Br_2 + 2e^- \rightleftharpoons 2Br^-$	+1.09
$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$	+1.36

(d) Solid potassium iodide reacts with concentrated sulfuric acid in the same way as sodium iodide.

Describe the observations made during this reaction and identify the products formed.

[3]

(e) Hydrogen peroxide reacts with acidified potassium iodide according to the equation below.

$$2H^+ + 2I^- + H_2O_2 \longrightarrow I_2 + 2H_2O$$

(i) This reaction was studied using an iodine clock reaction. Describe the principles of how the rate of a clock reaction is determined. Experimental details are not required. [2]

(ii) The rate of this reaction was studied by a different method for a range of concentrations of H_2O_2(aq) and I^-(aq) and pH values. These are listed in the table below.

Experiment number	Initial concentration of H_2O_2(aq)/mol dm^{-3}	Initial concentration of I^-(aq)/mol dm^{-3}	pH	Initial rate/ mol dm^{-3} s^{-1}
1	0.0010	0.10	1	2.8×10^{-6}
2	0.0020	0.10	1	5.6×10^{-6}
3	0.0020	0.10	2	5.6×10^{-6}
4	0.0010	0.40	1	11.2×10^{-6}

I. Some experiments were undertaken at pH 1 and some at pH 2. Give the difference in the concentrations of H^+ ions in these two solutions. [1]

II. Use the data in the table to deduce the rate equation for this reaction, giving your reasoning. [3]

III. Calculate the value of the rate constant, *k*, giving its units. [2]

IV. The reaction is repeated at a higher temperature. State how the increase in temperature affects the rate equation and rate constant. [1]

Total [20]

10. The decomposition of dinitrogen(IV) oxide into nitrogen(IV) oxide is a reversible reaction that establishes a dynamic equilibrium.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +57 \text{ kJ mol}^{-1}$$

pale yellow   dark brown

(a) State the meaning of the term ***dynamic equilibrium***.

[1]

(b) The conditions applied to an equilibrium mixture of dinitrogen(IV) oxide and nitrogen(IV) oxide were changed. For each of the following, state what was **seen** and explain any change that occurred.

[5]

Temperature increased

Pressure increased

A catalyst was added

(c) Hydrazine, N2H4, is an unstable liquid that decomposes according to the following equation.

$$N_2H_4(l) \longrightarrow N_2(g) + 2H_2(g)$$

(i) Calculate the volume of gas that could be obtained from 14 kg of hydrazine.

Assume that the volume of 1 mol of gas is 24.0 dm^3

[3]

Volume of gas = ... dm^3

(ii) Use of hydrazine is as a fuel in rockets. Apart from any energy changes, state **one** feature of this reaction that suggests it would be useful in rocket propulsion.

[1]

(Total 10)