QUESTION 5 (Start on a new page.)

5.1 The reaction between pure aluminium, Aℓ(s), and EXCESS hydrochloric acid, HCℓ(aq), is used to investigate the factors that affect the rate of a reaction.

The balanced equation for the reaction is:

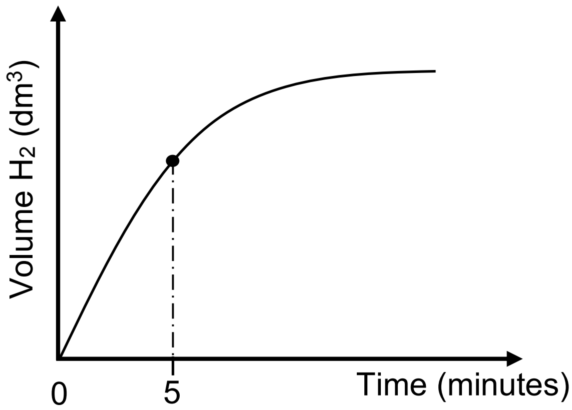
$$2A\ell(s) + 6HC\ell(aq) \rightarrow 2A\ell C\ell_3(aq) + 3H_2(g)$$

5.1.1 Define the term *reaction rate*. (2)

EXPERIMENT I

In this experiment, 1 mol·dm^{-3} HCℓ solution reacts with a 0,5 g Aℓ strip from an aluminium roll at room temperature.

The graph of volume $H_2(g)$ versus time for this experiment, not drawn to scale, is shown below.



5.1.2 For the time interval t = 0 to t = 5 minutes, the average reaction rate for the formation of $H_2(g)$ is 0,033 dm^3·min^{-1}.

Calculate the mass of Aℓ present in the container at t = 5 minutes. Take the molar gas volume as 24,5 dm^3·mol^{-1}. (6)

Assume that the concentration of the HCℓ(aq) stays constant for the duration of the reaction.

5.1.3 Use the collision theory to explain the change in the reaction rate from t = 0 to t = 5 minutes. (4)

EXPERIMENT II

Experiment I is repeated using a 2 mol·dm^{-3} HCℓ solution.

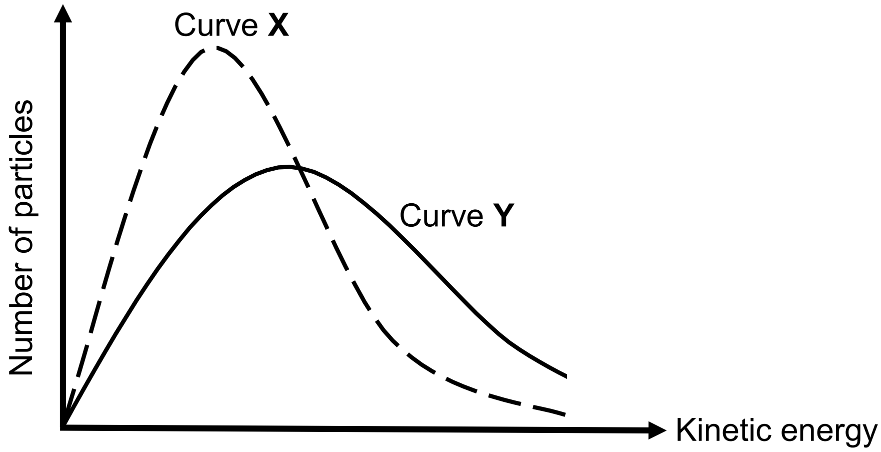
5.1.4 Redraw the above graph (NO numerical values need to be shown) in your ANSWER BOOK and label the curve **A**. On the same set of axes, draw the curve that will be obtained for Experiment II. Label this as curve **B**. (2)

EXPERIMENT III

Experiment I is repeated using 0,5 g pure powdered Aℓ.

5.1.5 How will the volume of H_2(g) produced in Experiment III compare to that in Experiment I? Choose from GREATER THAN, LESS THAN or EQUAL TO. (1)

5.2 Curve **X** is the Maxwell Boltzmann distribution curve for a reaction under a set of reaction conditions. A change was made to one of the reaction conditions to obtain curve **Y**.



5.2.1 What change was made to obtain curve **Y**? (1)

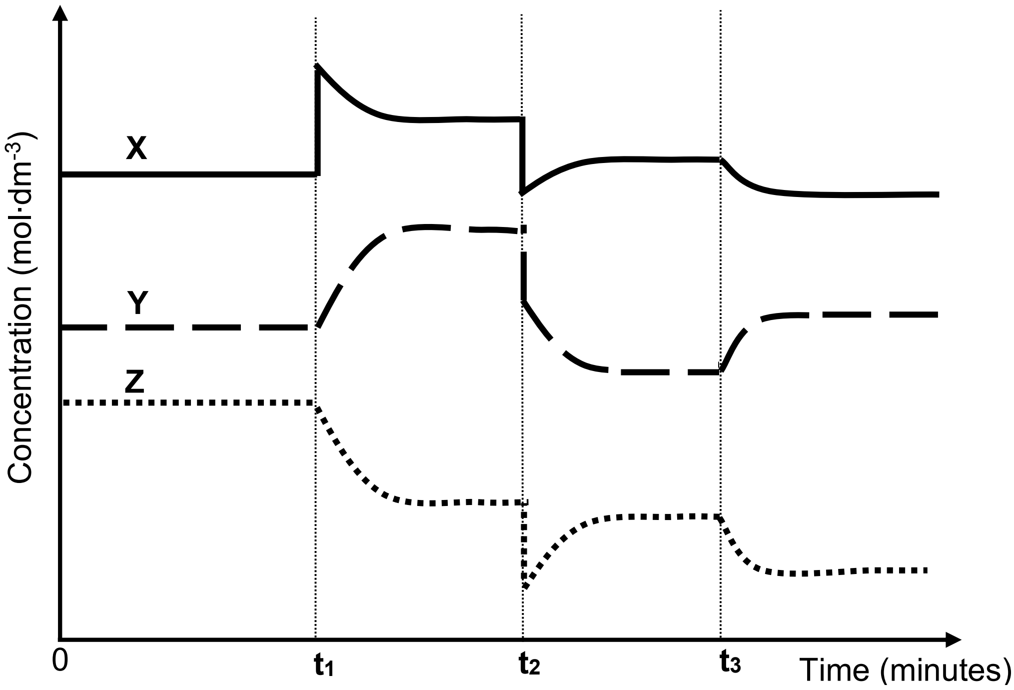
5.2.2 Give a reason for the answer to QUESTION 5.2.1. (1)
[17]

QUESTION 6 (Start on a new page.)

6.1 The reaction of carbon monoxide gas, CO(g), with oxygen gas, $O_2(g)$, is investigated. The reaction reaches equilibrium in a closed container at constant temperature T °C, according to the balanced equation:

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \quad \Delta H < 0$$

Changes to the conditions of equilibrium are made at different times. The graph shows the results obtained. **X**, **Y** and **Z** represent the gases in the above reaction.



6.1.1 Define the term *chemical equilibrium*. (2)

Use the graph to answer the questions below.

6.1.2 At t_1, oxygen, $O_2(g)$, was added to the container. Write down the letter that represents $O_2(g)$. Choose from **X**, **Y** or **Z**. (1)

6.1.3 At t_2, the pressure is adjusted by changing the volume of the container. Was the pressure INCREASED or DECREASED? (1)

6.1.4 Give a reason for the answer to QUESTION 6.1.3. (1)

6.1.5 Write down the NAME or FORMULA of the gas that is represented by the letter **Z.** (1)

6.1.6 Give a reason for the answer to QUESTION 6.1.5. (1)

6.1.7 What change in temperature is made at t_3? Choose between INCREASED or DECREASED. (1)

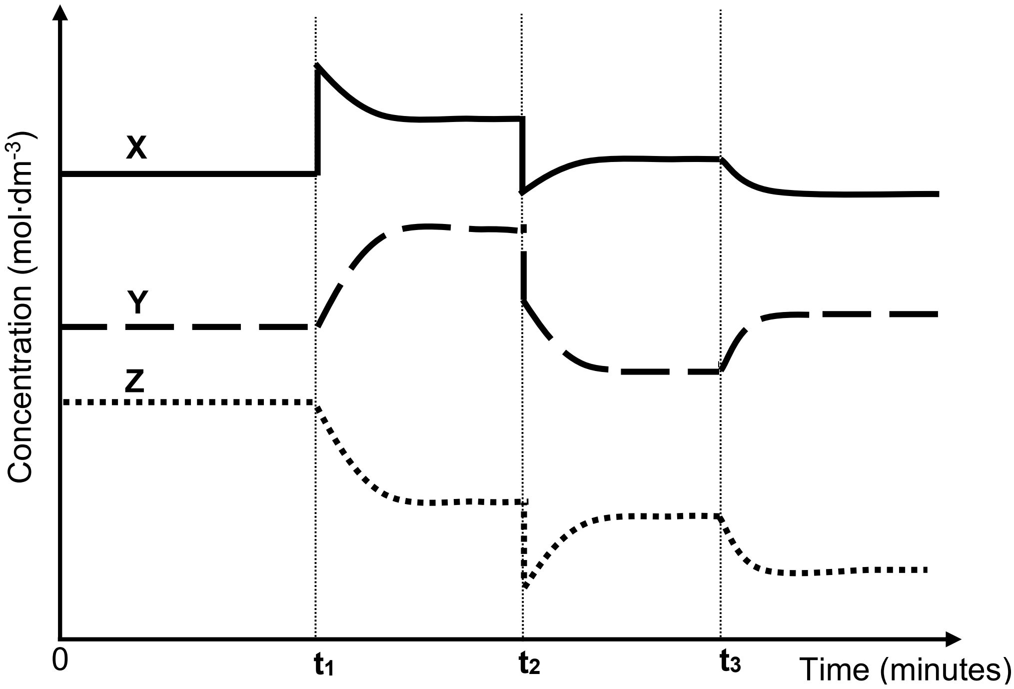
6.1.8 Use Le Chatelier's principle to explain the answer to QUESTION 6.1.7. (3)

QUESTION 6 (Start on a new page.)

6.1 The reaction of carbon monoxide gas, $CO(g)$, with oxygen gas, $O_2(g)$, is investigated. The reaction reaches equilibrium in a closed container at constant temperature T °C, according to the balanced equation:

$$2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) \quad \Delta H < 0$$

Changes to the conditions of equilibrium are made at different times. The graph shows the results obtained. **X**, **Y** and **Z** represent the gases in the above reaction.



6.1.1 Define the term *chemical equilibrium*. (2)

Use the graph to answer the questions below.

6.1.2 At t_1, oxygen, $O_2(g)$, was added to the container. Write down the letter that represents $O_2(g)$. Choose from **X**, **Y** or **Z**. (1)

6.1.3 At t_2, the pressure is adjusted by changing the volume of the container. Was the pressure INCREASED or DECREASED? (1)

6.1.4 Give a reason for the answer to QUESTION 6.1.3. (1)

6.1.5 Write down the NAME or FORMULA of the gas that is represented by the letter **Z.** (1)

6.1.6 Give a reason for the answer to QUESTION 6.1.5. (1)

6.1.7 What change in temperature is made at t_3? Choose between INCREASED or DECREASED. (1)

6.1.8 Use Le Chatelier's principle to explain the answer to QUESTION 6.1.7. (3)

6.2 Carbon monoxide gas, $CO(g)$, reacts with water vapour, $H_2O(g)$, at T °C. The reaction reaches chemical equilibrium according to the balanced equation:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

Initially, 0,6 moles of $CO(g)$, 0,6 moles of $H_2O(g)$, 0,1 moles of carbon dioxide gas, $CO_2(g)$, and 0,1 moles of hydrogen gas, $H_2(g)$, were mixed and sealed in a 2 dm^3 flask.

If the equilibrium constant, K_c, for this reaction at T °C is 4, calculate the mass of $CO(g)$ present in the flask at equilibrium. (9)

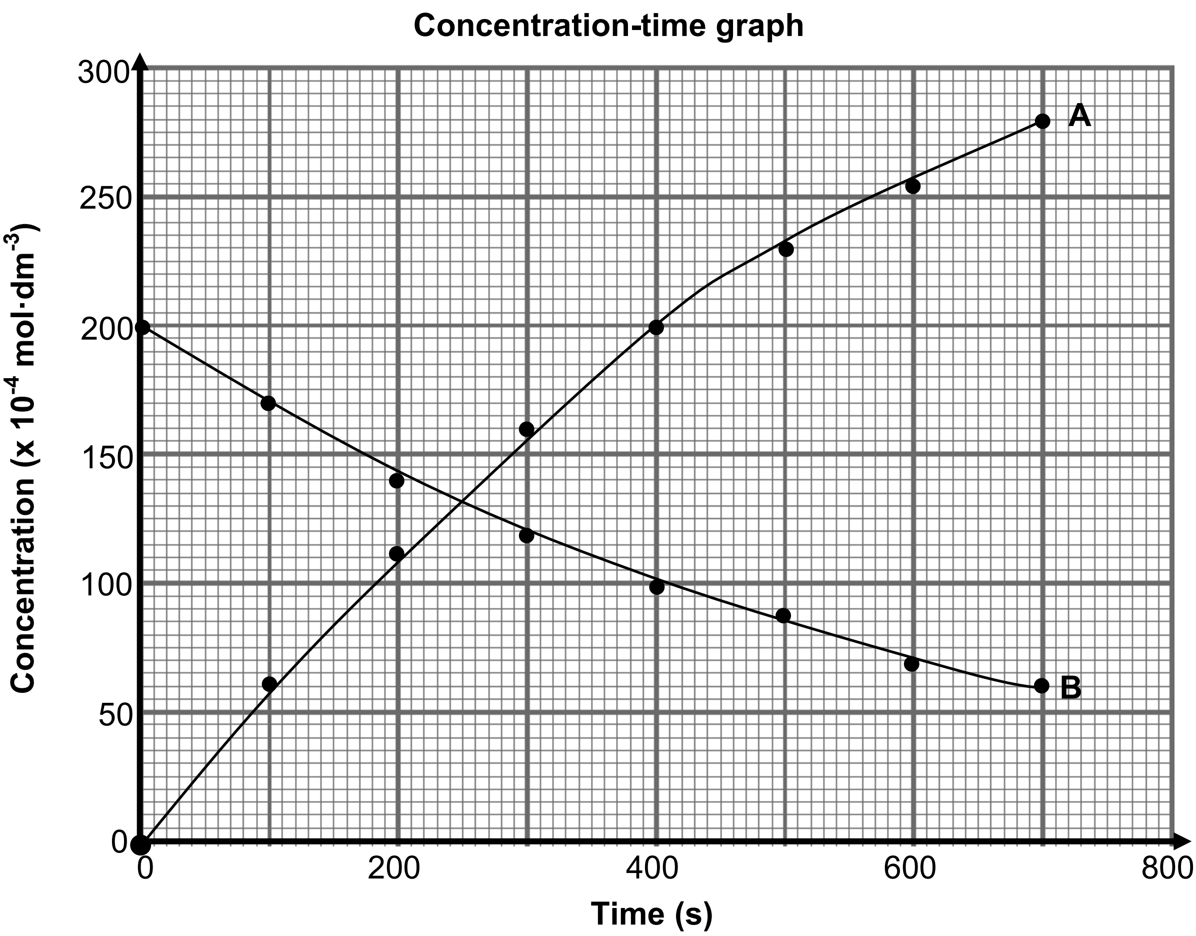
[20]

QUESTION 5 (Start on a new page.)

Consider the following decomposition reaction that takes place in a sealed 2 dm^3 container:

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

The graph below shows how the concentrations of $N_2O_5(g)$ and $NO_2(g)$ change with time.



5.1 Refer to the graph above and give a reason why curve **A** represents the change in the concentration of $NO_2(g)$. (1)

5.2 Consider the statement below:

The rate of decomposition of $N_2O_5(g)$ is half the rate of formation of $NO_2(g)$.

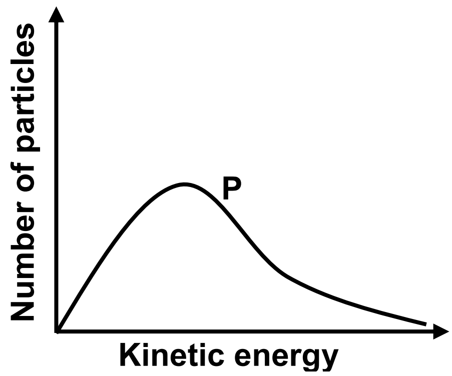
Is this statement TRUE or FALSE? Give a reason for the answer. (2)

5.3 Calculate the:

5.3.1 Mass of NO_2(g) present in the container at 400 s (4)

5.3.2 Average rate of production of O_2(g) in $mol{\cdot}dm^{-3}{\cdot}s^{-1}$ in 700 s (4)

5.4 The Maxwell-Boltzmann distribution curve for the N_2O_5(g) initially present in the container is shown below.



The initial concentration of the N_2O_5(g) is now INCREASED.

5.4.1 Redraw the distribution curve above in the ANSWER BOOK and label this curve as **P**.

On the same set of axes, sketch the curve that will be obtained for the higher concentration of N_2O_5(g). Label this curve as **Q**. (2)

5.4.2 Will the rate of decomposition of N_2O_5(g) at the higher concentration be HIGHER THAN, LOWER THAN or EQUAL TO the original rate of decomposition? Explain the answer using the collision theory. (3)

[16]

QUESTION 6 (Start on a new page.)

One mole of pure hydrogen iodide gas, HI(g), is sealed in a 1 dm^3 container at 721 K. Equilibrium is reached according to the following balanced equation:

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

It is found that 0,11 moles of $I_2(g)$ are present at equilibrium.

6.1 State Le Chatelier's principle. (2)

6.2 Determine the number of moles of EACH of the following at equilibrium:

6.2.1 $H_2(g)$ (1)

6.2.2 HI(g) (1)

6.3 The equilibrium constant, K_c, at 721 K is 0,02.

The temperature of the container is now increased to 850 K.
The equilibrium constant, K_c, at 850 K is 0,09.

6.3.1 Is the forward reaction EXOTHERMIC or ENDOTHERMIC? (1)

6.3.2 Fully explain the answer to QUESTION 6.3.1. (3)

6.3.3 Calculate the mass of HI(g) present at the new equilibrium at 850 K. (8)

[16]