Name of the Student:_____

Max. Marks : 22 Marks **Time : 22 Minutes**

Q1.

When an aqueous solution of ethanoic acid reacts with magnesium, the progress of reaction can be followed using the equipment shown in **Figure 1** to measure the volume of hydrogen produced.

Figure 1

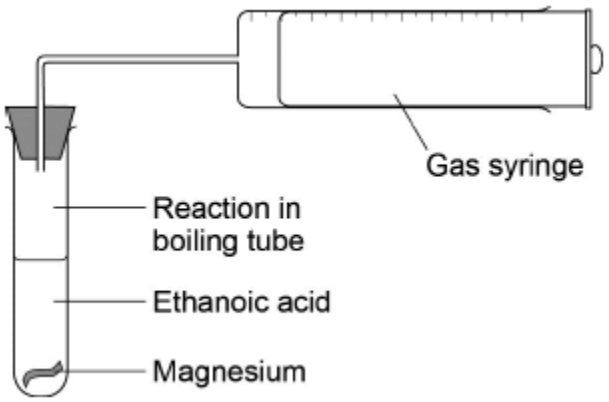
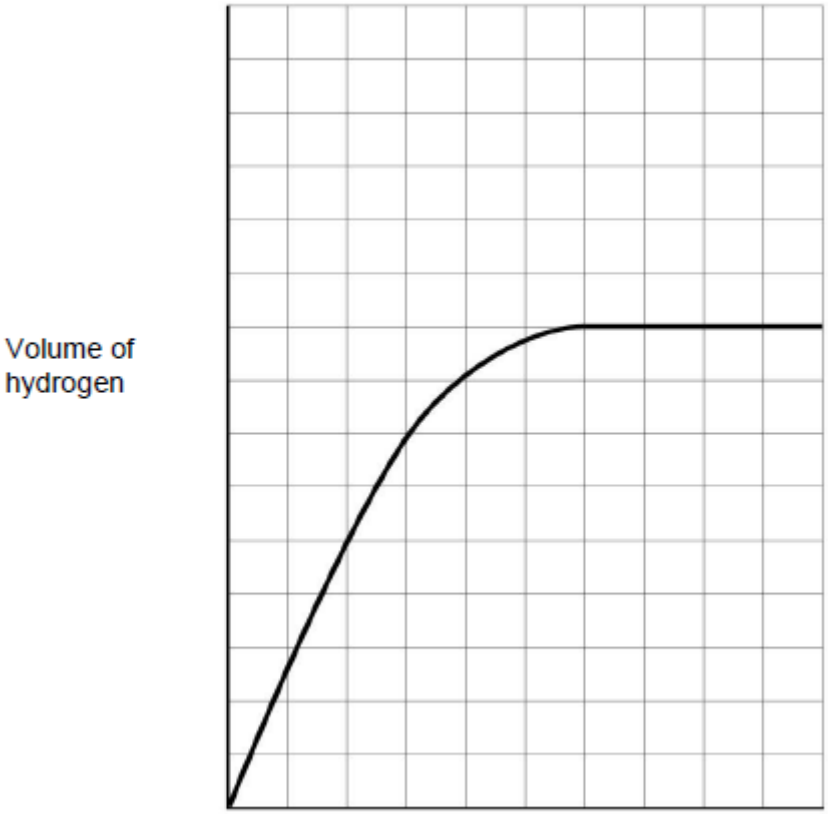


Figure 2 shows how the volume of hydrogen produced varies with time when 396 mg of magnesium are added to 30.0 cm^3 of 0.600 mol dm^{-3} ethanoic acid.

Figure 2



(a) The equation for the reaction between ethanoic acid and magnesium is shown.

$$2CH_3COOH(aq) + Mg(s) \longrightarrow (CH_3COO)_2Mg(aq) + H_2(g)$$

With the aid of calculations, show that the magnesium is in excess in this reaction.

(3)

(b) The reaction was repeated using 20 cm^3 of 0.800 mol dm^{-3} of ethanoic acid solution with all other conditions the same. The magnesium was still in excess.

Sketch a line on **Figure 2** to show how the volume of hydrogen produced varies with time in this second experiment.

Space for working.

(2)
(Total 5 marks)

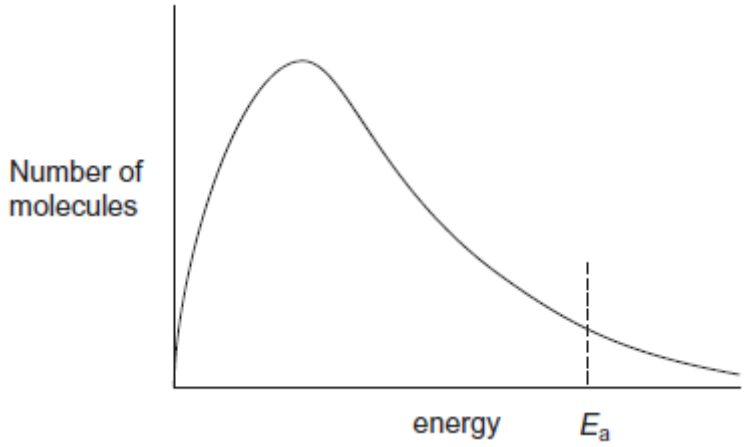
Q2.

Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically carried out at 300 °C and 3×10^7 Pa, in the presence of a catalyst.

(a) The graph shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 °C.



(i) Sketch a second curve on the graph to show the distribution of molecular energies in this mixture at a higher temperature.

(1)

(ii) Explain with reference to both curves on the graph how a small change in temperature leads to a large change in the rate of reaction.

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(2)

(b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

(i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

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(3)

(ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 °C rather than at a higher temperature.

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(2)

(Total 8 marks)

Q3.

Hydrogen is produced in industry from methane and steam in a two-stage process.

(a) In the first stage, carbon monoxide and hydrogen are formed.
The equation for this reaction is

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206 \text{ kJ mol}^{-1}$

(i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage.
Explain your answer.

Temperature _____

Explanation _____

_____

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(3)

(ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

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(2)

(iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

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(2)

(b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -41$ kJ mol^{-1}

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

Effect _____

Explanation _____

_____

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(2)

(Total 9 marks)