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# Level 2 Chemistry 2022

## 91166 Demonstrate understanding of chemical reactivity

Credits: Four

| Achievement | Achievement with Merit | Achievement with Excellence |
|---|---|---|
| Demonstrate understanding of chemical reactivity. | Demonstrate in-depth understanding of chemical reactivity. | Demonstrate comprehensive understanding of chemical reactivity. |

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

**You should attempt ALL the questions in this booklet.**

A periodic table is provided in the Resource Booklet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2 – 16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

## QUESTION ONE

(a) Hydrogen iodide, HI($g$), can be produced through the reaction of hydrogen gas, $H_2(g)$ with iodine gas, $I_2(g)$, as shown in the equation below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta_r H = +\ 53.0\ \text{kJ mol}^{-1}$$

(i) Write the $K_c$ expression for this reaction.

$K_c =$

(ii) At 490 °C, the equilibrium mixture has a concentration of 0.105 mol $L^{-1}$ for both $H_2(g)$ and $I_2(g)$, while the concentration of HI is 0.711 mol $L^{-1}$.

Calculate the value of $K_c$ at 490 °C.

(iii) Explain what would happen to the value of $K_c$ if the temperature of the equilibrium mixture was increased.

(b) Hydrogen iodide, HI, is a strong acid, whereas hydrofluoric acid, HF, is a weak acid.

(i) Write equations to show their reactions with water, $H_2O(\ell)$.

$HI(g) + H_2O(\ell)$

$HF(g) + H_2O(\ell)$

(ii) Solutions of both hydrogen iodide, HI(*aq*), and hydrogen fluoride, HF(*aq*), are made up to the same concentration.

Explain how the pH and electrical conductivity of the two solutions would differ.

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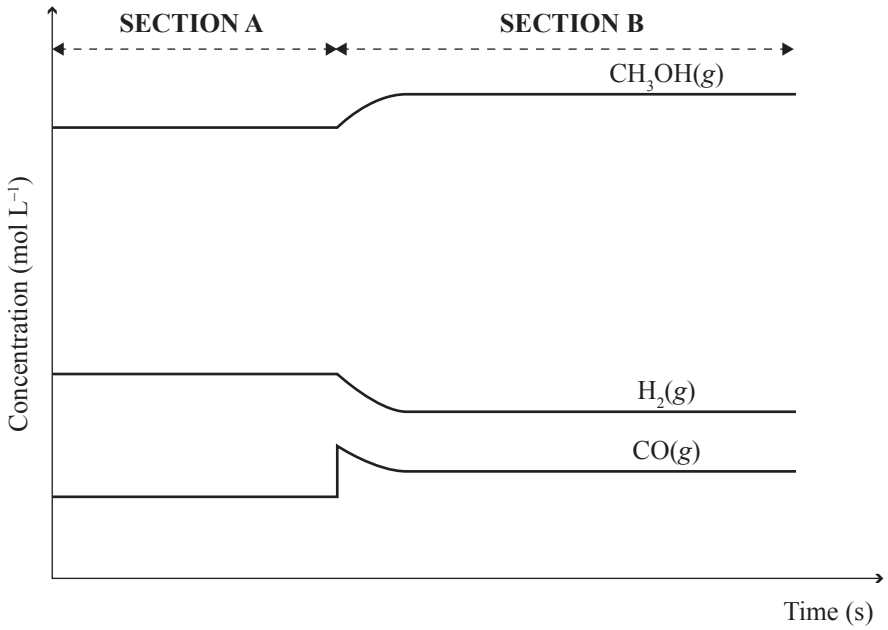
**The examination continues on the following page.**

## QUESTION TWO

(a) Methanol, $CH_3OH(g)$, is manufactured through the reaction of carbon monoxide, $CO(g)$, with hydrogen gas, $H_2(g)$. The equation for the equilibrium that is established is shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Once chemical equilibrium has been established, the concentrations of all species present in the reaction are recorded and graphed below.




(i) Explain how the graph shows the system is at equilibrium throughout **Section A**.

Refer to the rates of the forward and reverse reactions in your answer.

(ii) At the beginning of **Section B**, in the graph on the previous page, some carbon monoxide, CO(*g*), is added to the reaction vessel.

Explain, using equilibrium principles, how the system responds to restore equilibrium.

Refer to the graph in your answer.

(iii) Using equilibrium principles, explain why carrying out the reaction at high pressure is advantageous in the manufacture of methanol, $CH_3OH(g)$.

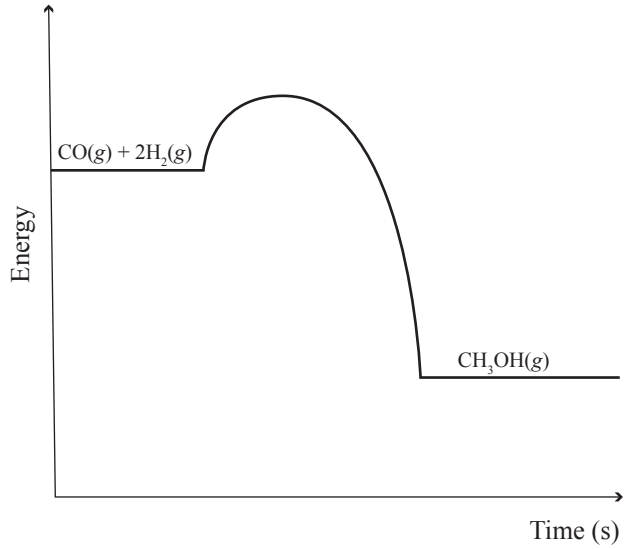
(b) The formation of methanol, $CH_3OH(g)$, from carbon monoxide, $CO(g)$, and hydrogen, $H_2(g)$, is a slow reaction. To increase the rate of reaction, a small amount of zinc oxide, $ZnO(s)$, can be added. This zinc oxide can be recovered after the reaction is complete.

(i) State the role of the zinc oxide, $ZnO(s)$, in the reaction.

(ii) An energy diagram for the reaction without the use of zinc oxide, $ZnO(s)$, is shown below.

Add a line to show how the diagram would differ when zinc oxide is added.

*If you need to redraw your response, use the graph on page 14.*



(iii) Explain how zinc oxide, ZnO(*s*), increases the rate of reaction.
Refer to collision theory and activation energy in your answer.

## QUESTION THREE

(a) (i) Calculate the concentration of hydronium ions, $H_3O^+(aq)$, in a solution of hydrochloric acid, HCl(*aq*), that has a pH of 2.4.

(ii) A solution of lithium hydroxide, LiOH(*aq*), has a concentration of 0.450 mol $L^{-1}$.

Calculate the pH.

(b) Three solutions of equal concentration, A, B, and C were known to be sodium hydroxide, NaOH(*aq*), sodium chloride, NaCl(*aq*), and sodium carbonate, $Na_2CO_3(aq)$. The pH of each solution was measured and recorded below.

| | **Solution A** | **Solution B** | **Solution C** |
|---|---|---|---|
| **pH** | 11.6 | 13.0 | 7.0 |

(i) Identify solutions A, B, and C.

A: _____ B: _____ C: _____

(ii) Fully explain how you identified solutions A, B, and C.

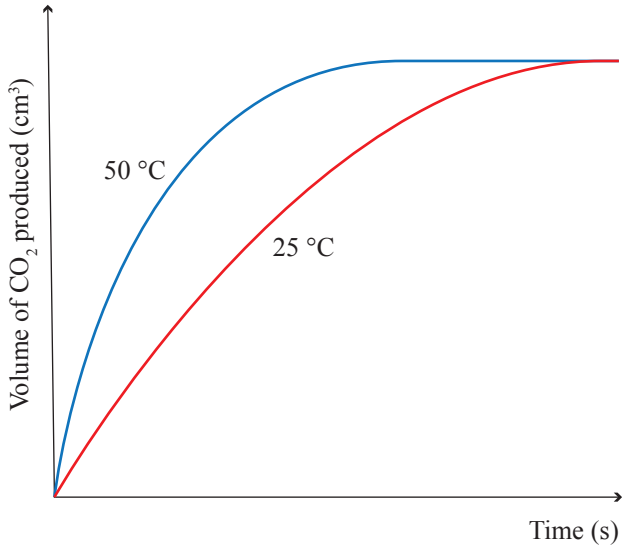
Use relevant equations to support your answer.

*Question Three continues on the next page.*

(c) Once identified, the solution of sodium carbonate, $Na_2CO_3(aq)$ was then used in a reaction with hydrochloric acid, $HCl(aq)$. The equation for the reaction is shown below.

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(\ell) + CO_2(g)$$

The reaction was carried out at both 25 °C and 50 °C, and the volume of $CO_2$ gas produced was recorded on the graph below.




In both reactions, the same concentration and volume of each solution is used.

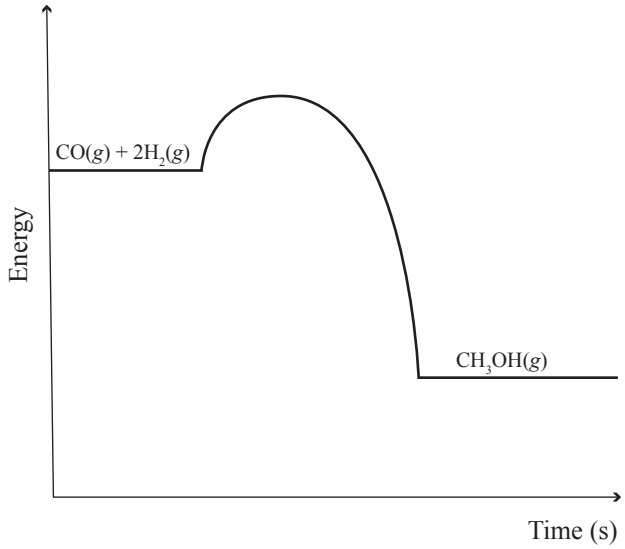
Explain the effect of increased temperature upon the rate of reaction.

In your answer you should:

- refer to collision theory
- consider both the rate of $CO_2$ production, and the total volume of $CO_2$ formed, for each reaction
- refer to the lines on the graph above.

## SPARE DIAGRAMS

If you need to redraw your response to Question Two (b)(ii), use the graph below. Make sure it is clear which answer you want marked.



**Extra space if required.**
**Write the question number(s) if applicable.**

QUESTION NUMBER

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