Paper 3

Questions are applicable for both core and extended candidates

1   Sulfur is an element in Group VI of the Periodic Table.
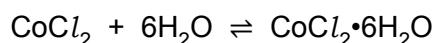
   (e) Sulfur dioxide is formed when sulfur burns in air.

   (vi) Sulfur dioxide reacts with oxygen in the presence of a catalyst to form sulfur trioxide. This is a reversible reaction.

   Complete the equation for this reaction by writing the sign for a reversible reaction in the box.

$$2SO_2 \ + \ O_2 \ \boxed{} \ 2SO_3$$ [1]

2(b) Cobalt(II) chloride can be used to test for the presence of water.

$$CoCl_2 \ + \ 6H_2O \ \rightleftharpoons \ CoCl_2 \cdot 6H_2O$$

anhydrous   hydrated
cobalt(II) chloride   cobalt(II) chloride
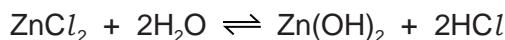
   (i) State the meaning of the symbol $\rightleftharpoons$.

   .... [1]

3   This question is about zinc and compounds of zinc.
   (d) Zinc chloride reacts with water as shown. The solution formed is acidic.

$$ZnCl_2 \ + \ 2H_2O \ \rightleftharpoons \ Zn(OH)_2 \ + \ 2HCl$$

   (i) State the meaning of the symbol $\rightleftharpoons$.

   .... [1]

Paper 4

**Questions are applicable for both core and extended candidates
unless indicated in the question**

4   The equation for the reaction between methanoic acid and ethanol in the presence of a catalyst can be represented as shown.

$$HCOOH + CH_3CH_2OH \rightleftharpoons X + H_2O \qquad \Delta H = -29.5\,kJ/mol$$

X represents the ester formed.

(c) The reaction is reversible and reaches an equilibrium within a closed system.

   (i)   State what is meant by the term closed system.   **(extended only)**

   .... [1]

   (ii) State **two** characteristics of an equilibrium.   **(extended only)**

   1 ....

   ....

   2 ....

   ....
   [2]

   (iii) Complete Table 4.1 to show the effect, if any, on the concentration of **X** at equilibrium for each change of condition.   **(extended only)**

Table 4.1

change of condition	effect on the concentration of **X** at equilibrium
temperature is decreased	
concentration of HCOOH is decreased	
concentrations of both HCOOH and CH_3CH_2OH are decreased	
the catalyst is removed	

[4]

**5**   The Haber process is used to manufacture ammonia.
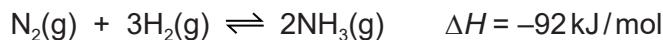
(a) State the main source of each gas used in the Haber process.   **(extended only)**

nitrogen ....

hydrogen ....

[2]

(b) The equation for the Haber process is shown.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \, kJ/mol$$

The reaction is reversible. The forward reaction is exothermic.

(i)   State what is meant by the symbol ΔH.   **(extended only)**

.... [1]

(ii) ΔH for the forward reaction is $-92 \, kJ/mol$.

State why this value shows that the forward reaction is exothermic.   **(extended only)**

.... [1]

(iii) State the typical conditions and name the catalyst used in the Haber process.

temperature .... °C   **(extended only)**

pressure .... kPa

catalyst ....

[3]

(iv) Complete Table 3.1 to show the effect, if any, when the typical conditions in the Haber process are changed. Use only the words **increases**, **decreases** or **no change**.

Table 3.1   **(extended only)**

change to typical conditions	effect on the rate of the forward reaction	effect on the concentration of $NH_3(g)$ at equilibrium
temperature increases	increases	
pressure decreases		
no catalyst	decreases	

[4]

(v) Explain in terms of collision theory why increasing the temperature increases the rate of the reaction.

....

....

....

....

.... [3]

6 This question is about sulfur and compounds of sulfur.

Sulfur is converted into sulfuric acid, H_2SO_4, by the Contact process.

The process involves four stages.

stage 1 Molten sulfur is converted into sulfur dioxide.

stage 2 Sulfur dioxide reacts with oxygen to form sulfur trioxide.
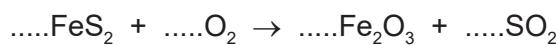
stage 3 Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4 Oleum reacts to form concentrated sulfuric acid.

(a) (i) In **stage 1**, iron pyrites, FeS_2, can be used instead of molten sulfur.
The iron pyrites is heated strongly in air.

Balance the equation for the reaction occurring when iron pyrites reacts with oxygen in the air.
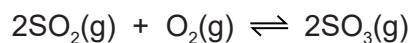
$$.....FeS_2 \ + \ .....O_2 \ \rightarrow \ .....Fe_2O_3 \ + \ .....SO_2$$ [1]

(ii) Name Fe_2O_3. Include the oxidation number of iron.

.... [1]

(b) The equation for **stage 2** is shown.

$$2SO_2(g) \ + \ O_2(g) \ \rightleftharpoons \ 2SO_3(g)$$

The forward reaction is exothermic.
The reaction is carried out at a temperature of $450\,°C$ and a pressure of $2\,atm$.

Using explanations that do **not** involve cost:

(i) explain why a temperature greater than $450\,°C$ is **not** used   **(extended only)**

....

.... [1]

(ii) explain why a pressure lower than $2\,atm$ is **not** used.   **(extended only)**

....

.... [1]

7 This question is about compounds of sulfur.

(a) Sulfuric acid, H_2SO_4, is manufactured using the Contact process. This manufacture involves four stages.

stage 1   Molten sulfur burns in air to produce sulfur dioxide.

stage 2   Sulfur dioxide reacts with oxygen to form sulfur trioxide.

stage 3   Sulfur trioxide combines with concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

stage 4   Oleum reacts to form concentrated sulfuric acid.

(i) Write a chemical equation for the reaction occurring in **stage 1**.   **(extended only)**

.... [1]

(ii) State the essential conditions that are necessary for **stage 2**. Write an equation for the chemical reaction that occurs.   **(extended only)**

....

....

....

.... [4]
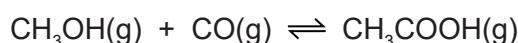
(iii) Write a chemical equation for the reaction occurring in **stage 3**.   **(extended only)**

.... [1]

(iv) Name the substance that reacts with oleum in **stage 4**.   **(extended only)**

.... [1]

8   Ethanoic acid is manufactured by the reaction of methanol with carbon monoxide.

An equilibrium mixture is produced.

$$CH_3OH(g) + CO(g) \rightleftharpoons CH_3COOH(g)$$

(a) State **two** characteristics of an equilibrium.   **(extended only)**

1 ....

2 ....

[2]

(b) The purpose of the industrial process is to produce a high yield of ethanoic acid at a high rate of reaction.

The manufacture is carried out at a temperature of 300 °C.

The forward reaction is exothermic.

Use this information to state why the manufacture is **not** carried out at temperatures:

- **below** 300 °C   **(extended only)**

....

- **above** 300 °C.   **(extended only)**

....

[2]

(c) Complete the table using only the words *increases*, *decreases* or *no change*. **(extended only)**

	effect on the rate of the forward reaction	effect on the equilibrium yield of $CH_3COOH(g)$
adding a catalyst		no change
decreasing the pressure		

[3]

(d) Suggest which of the following metals is a suitable catalyst for the reaction. Give a reason for your answer.
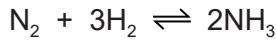
aluminium   calcium   cobalt   magnesium   potassium

suitable catalyst ....

reason ....

[2]

9   Ammonia is made in an industrial process starting with nitrogen. The equation for the reaction is shown.

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

(a) Name the industrial process used to make ammonia.   **(extended only)**

.... [1]

(b) State the raw material from which nitrogen is obtained.   **(extended only)**

.... [1]

(c) State what is meant by the symbol $\rightleftharpoons$.

.... [1]

(d) State the temperature and pressure used in this industrial process.   **(extended only)**

temperature = ... °C

pressure = ... atm
[2]

(e) Name the catalyst used in this industrial process.   **(extended only)**

.... [1]

(f) The forward reaction is exothermic.

State the effect, if any, on the position of the equilibrium when the following changes are made. Explain your answers.   **(extended only)**

temperature is reduced

....

....

pressure is reduced

....

....
[4]

(g) Explain, in terms of particles, what happens to the rate of reaction when the temperature is reduced.

....

....

....

....

.... [3]

(h) Give the formula of the compound formed when sulfuric acid reacts with ammonia.

.... [1]

[Total: 14]

10 (d) Hydrated copper(II) sulfate is a coloured compound. It exists as hydrated crystals which contain water molecules.

(i) State the term given to water molecules present in hydrated crystals.

.... [1]

(ii) State the colour of hydrated copper(II) sulfate crystals.

.... [1]

(iii) Write the formula of hydrated copper(II) sulfate.

.... [2]