B, A, C, D, C, A, B

SECTION TWO: Short Answer [41 marks]

8. Write the equilibrium constant expression for each of the following:

a) $4NO_{2(g)} + 6H_2O_{(g)} \Leftrightarrow 7O_{2(g)} + 4NH_{3(g)}$

$$K = \frac{[O_2]^7[NH_3]^4}{[NO_2]^4[H_2O]^6}$$ ✓✓

b) $2H_2O_{(l)} + 4Au_{(s)} + O_{2(g)} + 8CN^-_{(aq)} \Leftrightarrow 4Au(CN)_2^-{}_{(aq)} + 4OH^-_{(aq)}$

$$K = \frac{[Au(CN)_2^-]^4[OH^-]^4}{[O_2][CN^-]^8}$$ ✓✓ [4 marks]

9. Hydrogen chloride gas, HCl, decomposes according to the equation:
$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $K = 0.25$ at a certain temperature.

a) If a mixture of 0.050 moles each of all three gases is placed in a vessel of volume 2 L at this temperature, is the system at equilibrium? Justify your answer.

$$K = \frac{[H_2][Cl_2]}{[HCl]^2}$$ ✓

$$= \frac{0.025 \times 0.025}{(0.025)^2}$$ ✓

$$= 1$$ ✓

No not = 0.25 [3 marks]

b) If the above mixture is not at equilibrium, describe the changes that will occur as the system does move toward equilibrium?

$K = \frac{P\downarrow}{R\uparrow}$ Less H_2, Cl_2 ✓

More HCl

favours reverse ✓

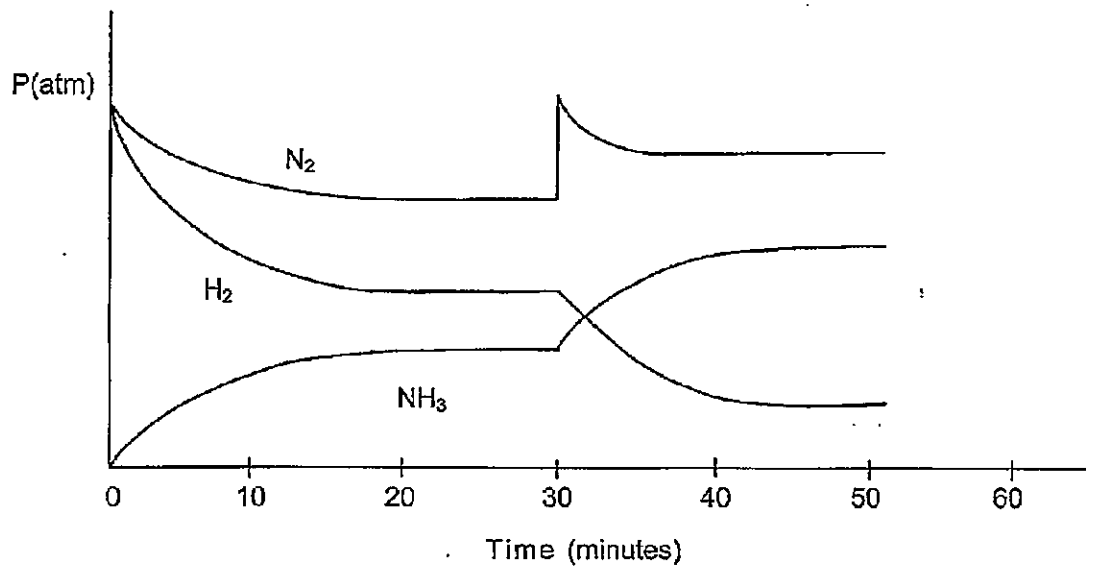
OR

FWD/RVE RXN EQUAL/OPPOSITE RATES [2 marks]

10. Ammonia is an industrially important gas produced by the Haber process, as illustrated by the reaction below:

$N_{2(g)} + 3H_{2(g)} \Leftrightarrow 2NH_{3(g)}$ $\Delta H = -92$ kJ mol^{-1} (at 25°C)

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



The reaction is catalysed by iron(III) oxide (Fe_2O_3).

The above graph shows the partial pressures of the three species involved in the reaction:

Refer to this graph to answer the following questions:

a) Why does the partial pressure of H_2 decrease more rapidly than that of the N_2 from t=0 to t=10?

$H_2 : N_2$ 3:1

[1 mark]

b) The partial pressures of each of the three species stabilises between 20 and 30 minutes. Describe what is happening during this time.

Equilibrium (OR) FWD RxN = REVERSE RxN

[1 mark]

c) What has occurred at the 30-minute mark to cause the changes shown in the graph?

↑ N_2

[1 mark]

d) By the 40-minute mark, what difference will the change in (c) have made to the rate of :

i) the forward reaction? Same ↓ Increase but

ii) the reverse reaction? Same ↓ same

[2 marks]

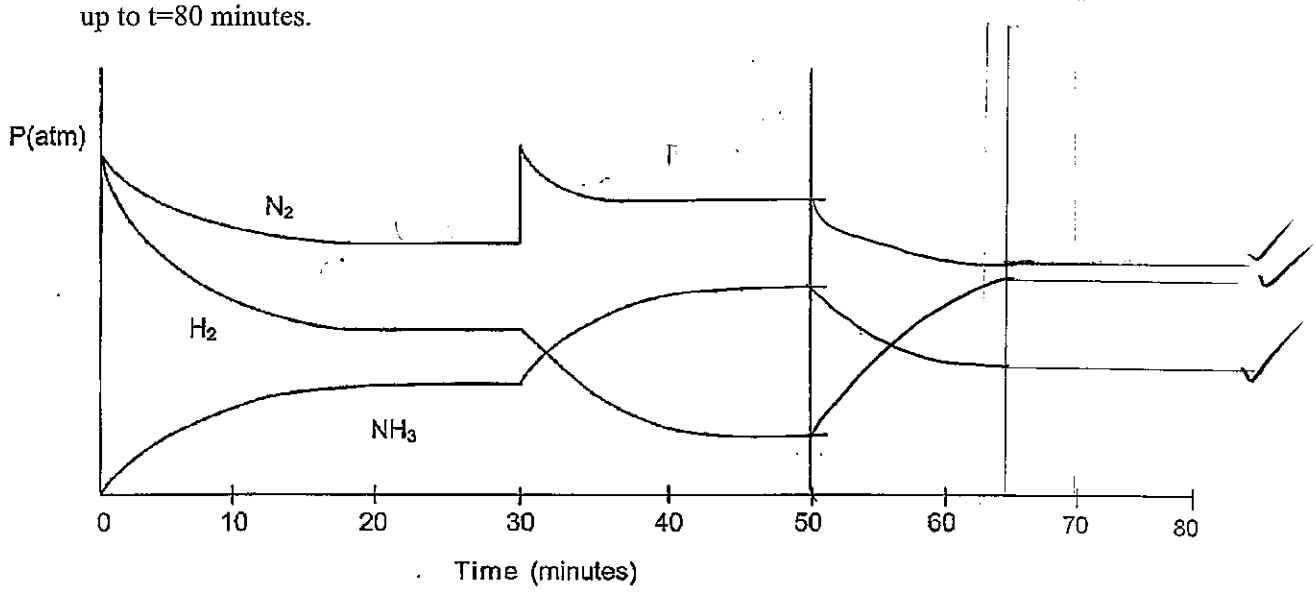
e) Using the Collision Theory, explain why the rate of the forward reaction is affected by the change that occurs at the 30-minute

↑ $[N_2]$, increases rate of fwd rxn

[2 marks]

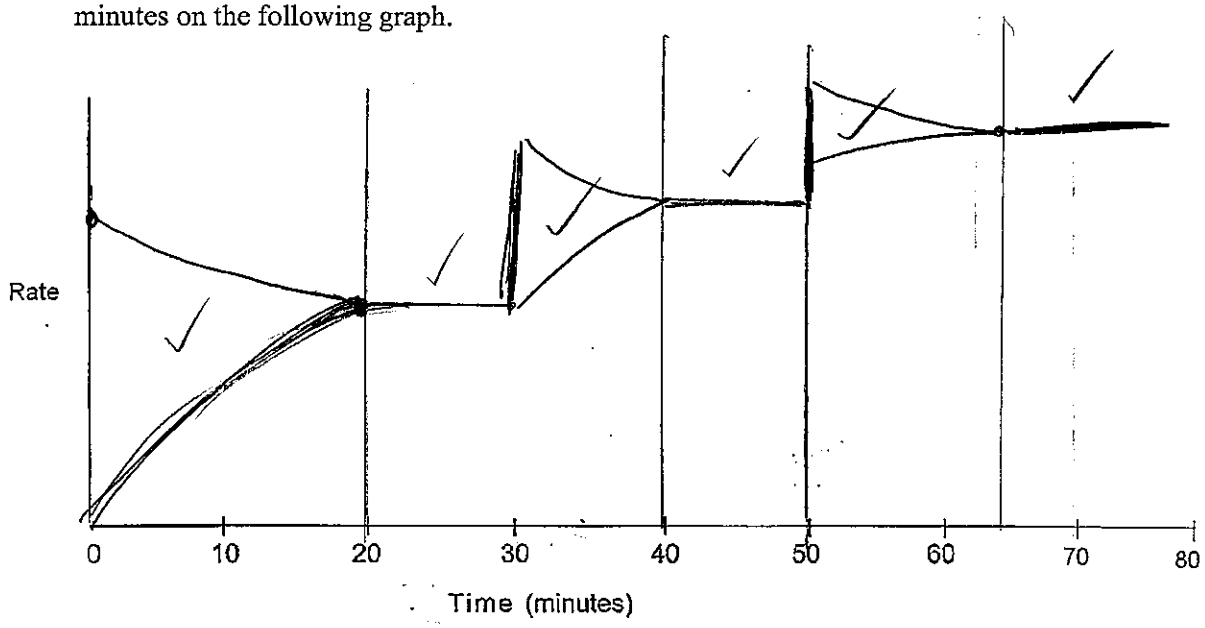
favours reverse

f) At t=50 minutes, the system was heated and equilibrium was established again at t=65 min. Estimate the equilibrium concentration of each gas to complete the concentration graph above up to t=80 minutes.



[3 marks]

g) For this process, plot the estimated rates of the forward and reverse reactions from t=0 to t=80 minutes on the following graph.



[6 marks]

11. When cobalt chloride is dissolved in dilute hydrochloric acid, the following equilibrium is set up:

$$\underset{\text{RED}}{Co(H_2O)_6^{2+}_{(aq)}} + 4Cl^-_{(aq)} \rightarrow \underset{\text{DEEP BLUE}}{CoCl_4^{2-}_{(aq)}} + 6H_2O_{(l)} \qquad \Delta H = +ve$$

Both the red and deep blue ion are present in the reaction mixture which is hence PURPLE in colour.
Three test-tubes are set up, each containing some of the purple equilibrium mixture.
Each of the test tubes is treated as described below. In each case, describe how the equilibrium will shift, and explanation and what will be observed.

What is done	How the equilibrium shifts. *Write →, ← or 'no change'*	Explanation	What is observed. Give the complete observation.
A few drops of concentrated hydrochloric acid is added to test-tube 1	→	Fwd reaction favoured to absorb extra Cl^-	More blue less red.
A few drops of concentrated silver nitrate is added to test-tube 2	←	Reverse reaction favoured to produce Cl^-	More red, less blue,
The solution in test-tube 3 is heated	→	endothermic fwd rxn favoured to absorb extra heat	more blue less red

[9 marks]

12. The first step in the production of nitric acid is summarized by the following balanced chemical equation.

$$4NH_{3(g)} + 5O_{2(g)} \Longleftrightarrow 4NO_{(g)} + 6H_2O_{(g)} \quad \Delta H = -907kJ$$

a. Write the equilibrium expression for this reaction

$$K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

b. Describe the conditions that maximize the yield of NO.

↑ conc of NH_3, O_2,
Remove NO
9 → 10, Decrease pressure
Lower temperature

c. Describe the conditions that maximize the rate of production of NO.

↑ conc of NH_3, O_2
↑ temperature
Catalysts
high pressure

d. Discuss the factors chemists must take into account when trying to determine which conditions will be used to maximise the yield at the greatest rate."

↑ temperature reduces yield
but ↑ temperature
Use catalyst at
reasonable pressure

[8 marks]