Revision – rates and equilibrium

Graph analysis Part (A)

1. Consider the reaction shown below.

$A(aq) \rightleftharpoons C(aq) + 2D(aq)$ ΔH=-49 kJ

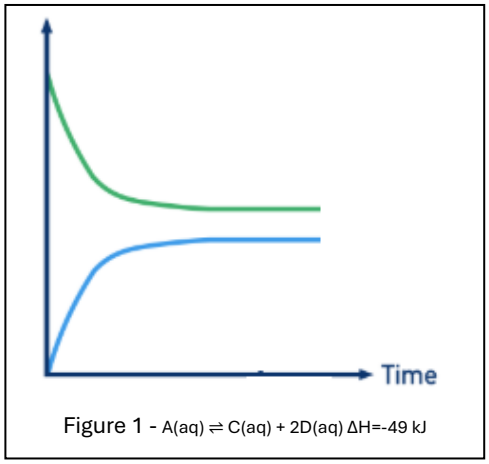

Figure 1 - $A(aq) \rightleftharpoons C(aq) + 2D(aq)$ ΔH=-49 kJ

a. Using fig 1, identify the species represented by the graphs coloured:
   - Green _____ *1 mark*
   - Blue _____ *1 mark*

b. Which of the following could be the likely units of the Y-axis? Circle the correct response/s. *1 mark*
   i. kJ
   ii. atm
   iii. [ ]
   iv. Rate
   v. mol

c. Explain your reasoning as to why you selected the options you did to question b. above and why the others were not considered.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ *5 marks*

2. Consider the reaction shown in fig. 2, showing the decomposition of ammonia .

$2NH_3(g) \rightleftharpoons 3H_2(g) + N_2(g)\ \Delta H=+92\ kJ$

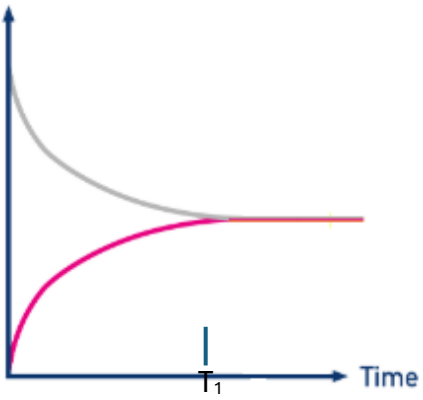

Figure 2 – graphing of a feature of the reaction

$2NH_3(aq) \rightleftharpoons 3H_2(aq) + N_2(aq)\ \Delta H=+92\ kJ$

a. Which of the following could be the likely units of the Y-axis where T_1 represents the time at which the net amount, in mol, of NH_3 and H_2 are constant? Circle the correct response/s

1 mark

i. kJ
ii. atm
ii. [ ]
iv. Rate
v. mol

b. Explain your reasoning as to why you selected the options you did to question b. above and why the others were not considered.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ *5 marks*

3. Consider the reaction shown in fig. 3, shown below of the decomposition of ammonia. The reaction takes place in a sealed vessel after the addition of an unknown amount of NH_3 gas.

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

a. In the graph in fig. 3, draw a labelled line of the $[CH_4]$ over time. *2 marks*

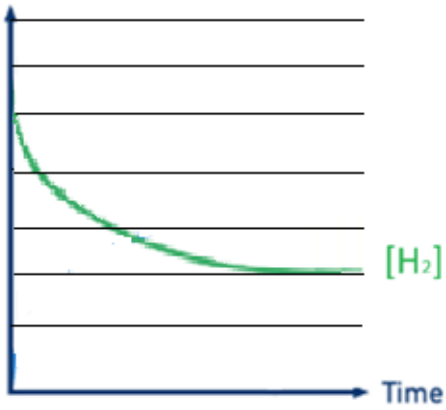

Fig 3 - $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ $\underline{\Delta H}$=-206 kJ

c. In the graph shown in fig. 4 on the right:
   - draw a labelled graph of $[H_2]$ in the presence of a catalyst. *2 marks*

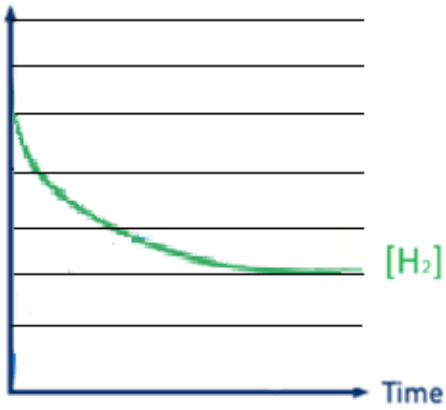

Fig 4 - $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ $\underline{\Delta H}$=-206 kJ

   - explain the factors you considered when drawing this graph and why it looks similar or different to that drawn in question a. above?

_____

_____

_____

_____

_____

_____ *3 marks*

d. The graph in fig. 5, is of the $[H_2]$ produced by the reaction shown below at 100°C.

- draw a labelled graph of $[H_2]$ if the reaction below takes place at 300°C.

2 marks

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

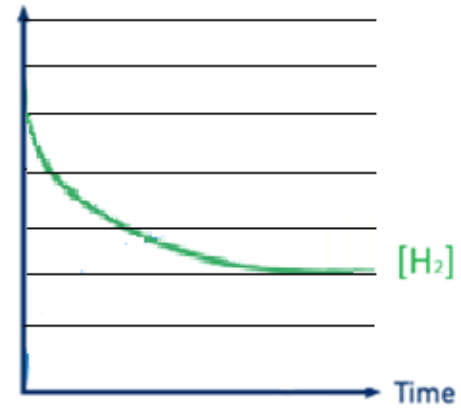

Fig 5 - $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ $\underline{\Delta H}$=-206 kJ

- explain the factors you considered when drawing this graph and why it looks similar or different to that drawn in question a. above?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ *3 marks*

4. A mixture of H_2 and Cl_2 gases was placed in a reaction vessel, at a temperature of 100 °C and allowed to reach equilibrium according to the reaction shown below.

$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $\underline{\Delta H} = +184.6$ kJ

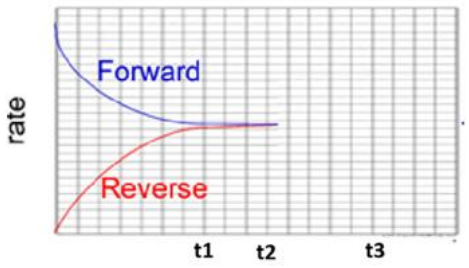

Figure 6 – rate time diagram of the reaction

$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $\underline{\Delta H} = +184.6$ kJ

a. The graph of the forward and reverse rates of reaction are shown on the right, in fig. 6. *3 marks*

i. Explain, in terms of particle theory, what is taking place in the reaction vessel between t_1 and t_2.

_____

_____

_____

_____

_____ *2 marks*

ii. At t_2 additional H_2 gas was added to the reaction equilibrium mixture. On the graph shown in fig. 6, continue the graphs of the forward and reverse reactions, clearly label each graph as reverse or forward.

2 marks

iii. Immediately after the addition of H_2, at t_2, explain how Q_P and K_P may have changed. In your response give the Q_P expression.

_____

_____

_____

_____

_____

_____

_____

_____

_____ *3 marks*

iv. At t_2 the temperature of the reaction vessel was decreased to 50°C. On the graph shown in fig. 7, continue the graphs of the forward and reverse reactions. Clearly label the two graphs as reverse or forward. *3 marks*

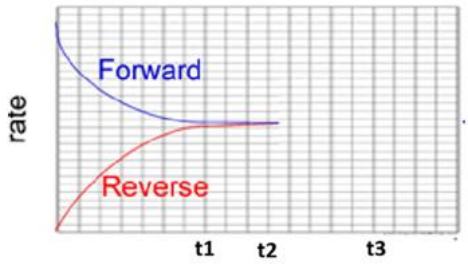

Figure 7– rate time diagram of the reaction

$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $\underline{\Delta H} = +184.6$ kJ

v. Explain the shape of each graph drawn in question iii. Above, with reference to Le Chatelier's principle how the system responds to the stress applied (ie. temperature change)

_____

_____

_____

_____

_____

_____

_____

_____ *3 marks*

vi. Explain how K_P and Q_P change as a result of the temperature drop in the system as discussed in question iii. Above.

_____

_____

_____

_____

_____

_____

_____

_____ *3 marks*

vii. At t_2 the volume of the reaction vessel was doubled. On the graph shown in fig. 8, continue the graphs of the forward and reverse reactions. Clearly label the two graphs as reverse or forward

3 marks

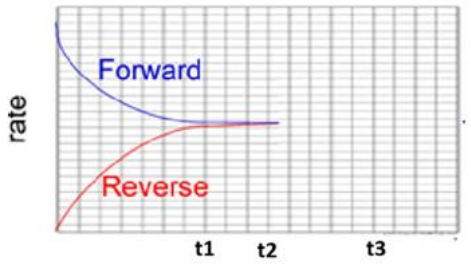

Figure 8– rate time diagram of the reaction

$2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ $\underline{\Delta H} = +184.6$ kJ

viii. Explain how the values of Q_P and K_P change when the volume is doubled. Justify your response with a simple calculation given the equilibrium partial pressure of each species as $[H_2] = 1$ atm, $[Cl_2] = 1$ atm, $[HCl] = 1$ atm.

4 marks

5. Consider the graph of concentration vs time for the equilibrium system below.

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ $\underline{\Delta H}$ = -184.6 kJ

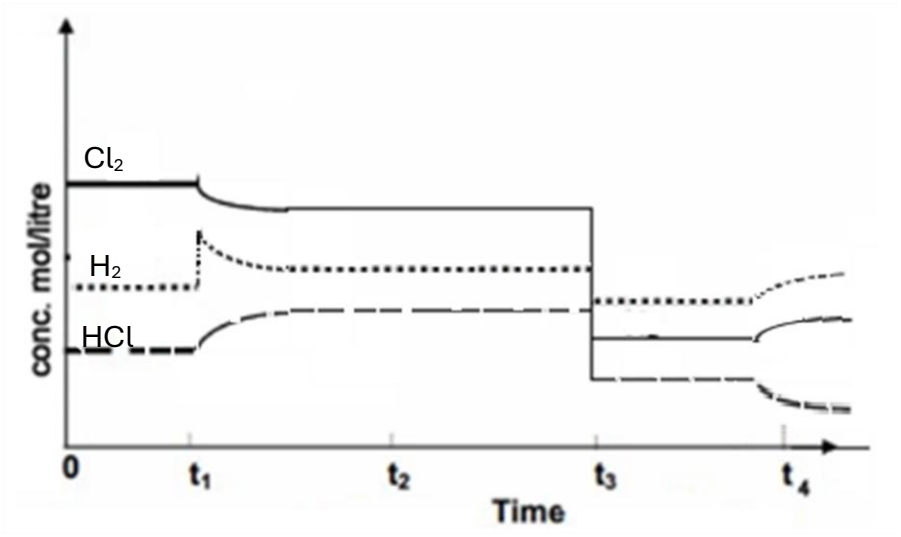

Figure 9 – concentration vs time graph of the $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

Give the possible stress applied at each time interval and justify your answer with reference to the graph.

Time t_1 _____

_____

_____

_____*2 marks*

Time t_2 _____

_____

_____

_____*2 marks*

Time t_3 _____

_____

_____

_____*2 marks*

Time t_4 _____

_____

_____

_____*2 marks*

6. A mixture of two gases nitrogen monoxide (NO) and chlorine gas (Cl_2) was introduced into a sealed vessel and allowed to reach equilibrium. The temperature of the vessel cooled as the reaction proceeded to form $NOCl_2$.
   a. Write a balanced thermochemical equation for the equilibrium system given above. The sign and units of the ΔH need only be given.

_____ *2 marks*

   b. Consider the concentration vs time graph shown below in fig 10.

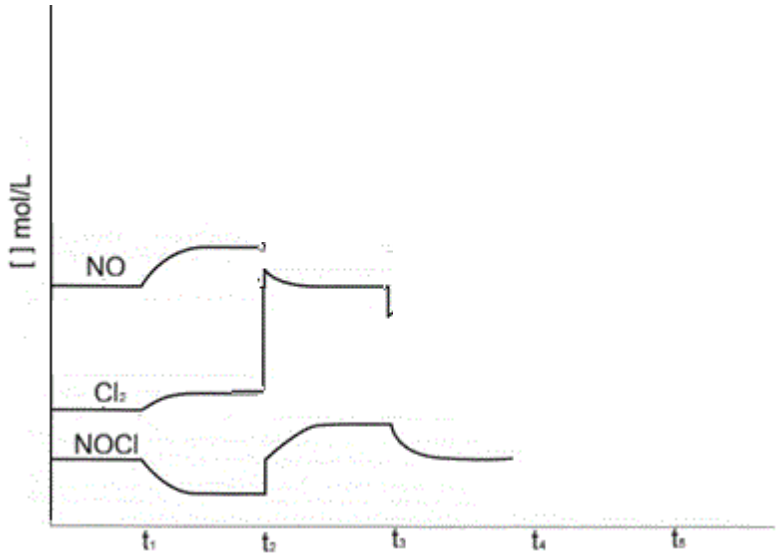

Figure 10 – Concentration vs time graph of a system

i. What is the likely stress applied to the system at t_1? Explain how this impacted the Q_c and K_c.

_____

_____

_____*2 marks*

ii. What was the change made to the system at t_2? Complete the diagram for the [NO]. *2 marks*

iii. What was the stress applied to the system at t_3? Indicate how the system responded by completing the graphs of [NO] and [Cl_2]. *3 marks*

iv. At t_4 NOCl was removed from the system. Indicate how the system responded by completing the graphs of [NO], [Cl_2] and [NOCl]. *3 marks*

7. Consider the graphs shown below when answering the following questions. A graph can be used more than once.

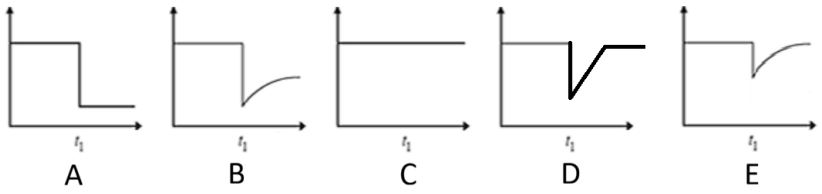

Figure 11 – Graphs representing [ ] or rate of a system after a stress at t_1.

a. A catalyst is used to conduct the reaction. When equilibrium is reached the catalyst is removed from the system at t_1. Which graph best represents the rate of the forward reaction? Justify your answer.

_____

_____

_____ *2 marks*

b. A system at equilibrium has one of its reactants reduced in concentration at t_1 whilst maintaining a constant temperature. Which graph best represents the concentration of this reactant? Justify your answer

_____

_____

_____ *2 marks*

c. The following reaction is allowed to reach equilibrium in a closed vessel.

$$A(g) + B(g) \rightleftharpoons D(g) + C(g)$$

At t_1 the volume of the reaction vessel was changed. Which graph best represents the [A]? Justify your answer

_____

_____

_____ *2 marks*

d. The system $A(g) + B(g) \rightleftharpoons D(g)$ is at equilibrium. At time t_1, the total pressure is greatly increased by injecting an inert gas. Which graph best represents the change in the partial pressure of D? Justify your answer.

_____

_____

_____ *2 marks*

Equilibrium- Application of Le Chatelier's principle (Part (B)

8. Complete the table below by circling the correct response.

Equilibrium system All systems below are at equilibrium	Stress	Response of the system right (→), left (←), unchanged (-)	What changes? Reaction quotient, Equilibrium constant
$A(aq)+X(aq) \rightleftharpoons 3D(aq)$ $\underline{\Delta H < 0}$	Product D is removed	(→) (←) (-)	K_C ↓ ↑ – Q_C ↓ ↑ –
$2A(aq)+D(aq) \rightleftharpoons 2G(aq)+Z(aq)$ $\underline{\Delta H < 0}$	Volume of reaction vessel is halved	(→) (←) (-)	K_C ↓ ↑ – Q_C ↓ ↑ –
$J(g)+3Z(g) \rightleftharpoons A(g)+D(g)$ $\underline{\Delta H > 0}$	Pressure increases considerably by adding He gas.	(→) (←) (-)	K_p ↓ ↑ – Q_p ↓ ↑ –
$J(aq)+3Z(aq) \rightleftharpoons A(aq)+D(aq)$ $\underline{\Delta H > 0}$	Catalyst added at constant temperature	(→) (←) (-)	K_C ↓ ↑ – Q_C ↓ ↑ –
$J(aq)+3Z(aq) \rightleftharpoons A(aq)+D(aq)$ $\underline{\Delta H > 0}$	Temperature increased.	(→) (←) (-)	K_C ↓ ↑ – Q_C ↓ ↑ –

9. Consider the equilibrium system given by the equation below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \underline{\Delta H} = +53 \text{ kJ}$$

A mixture of gas at equilibrium was sampled at SLC and found to contain 0.0150 mol of H_2, 0.0200 mol of I_2 and 10.05 mol of HI.

a. Calculate the equilibrium constant at SLC. *4 marks*

b. What does the magnitude of the K_C tell you about the reaction, in particular its rate and its yield at SLC.

_____

_____

_____

_____

_____*2 marks*

c. The temperature of the reaction vessel was increased to 75 °C.

i. How do you expect the K_c to change. Justify your response with a clear explanation.

_____

_____

_____

_____

_____*2 marks*

ii. How do you expect the rate of reaction to change. Justify your response with a clear explanation

_____

_____

_____

_____

_____*2 marks*

10. Consider the equilibrium shown below. $FeSCN^{2+}$ is shown in red to highlight the fact that it is red in solution whilst Fe^{3+} is yellow.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq) \quad \underline{\Delta H} = -45 \text{ kJ}$$

a. A mixture composed of 50 mL 0.1M $Fe(NO_3)_3$ and 50.0 mL of NaSCN is allowed to come to equilibrium at 25°C. The following stresses were applied to the system whilst at equilibrium. For each stress discuss how the system will visibly change in colour and offer an explanation using le Chatelier's principle.

i. The system is heated

_____

_____

_____

_____

_____*2 marks*

ii. 1 drop of 1.0 M $AgNO_3$ is placed in a slightly red coloured equilibrium mixture. AgSCN is an insoluble solid

_____

_____

_____

_____

_____*2 marks*

iii. 1 drop NaSCN is added to a somewhat reddish coloured equilibrium mixture.

_____

_____

_____

_____

_____*2 marks*

b. In 200 mL of pure water at 25.0 °C, 2.00 mol of Fe^{3+} ions were added and mixed with 2.00 mol of SCN^-. The mixture was allowed to reach equilibrium at which point the temperature of the water was recorded at 38.5°C.

i. Calculate the energy, in kJ, absorbed by the water. *2 marks*

ii. Calculate the mol of Fe^{3+} and SCN^- ions that reacted. *2 marks*

iii. Calculate the following concentrations at equilibrium. *2 marks*

$[Fe^{3+}]$

$[SCN^-]$

iv. Write the expression for the reaction quotient and calculate the value of K_c at this temperature. Include units. *4 marks*

Further revision on rates and equilibrium can be found in the past VCE exams listed below.

Rate questions	Equilibrium question
2025 VCE 2024 VCE 2023 VCE 2022 VCE 2021 VCE 2020 VCE 2019 VCE 2018 NHT 2018 VCE 2016 VCE 2014 VCE 2013 VCE 2012 VCE 2010 VCE 2009 VCE 2008 VCE 2007 VCE	2025 VCE 2024 VCE 2023 VCE 2022 VCE 2021 VCE 2020 VCE 2019 VCE 2018 NHT 2017 VCE 2016 VCE 2014 VCE 2013 VCE 2012 VCE 2011 VCE 2010 VCE 2010 HSC 2009 VCE 2009 HSC 2008 VCE 2007 VCE 2006 VCE 2005 VCE

The link below excellent revision for Le Chatelier's principle .

Equilibrium - Chemistry