Equilibrium Scholarship Questions

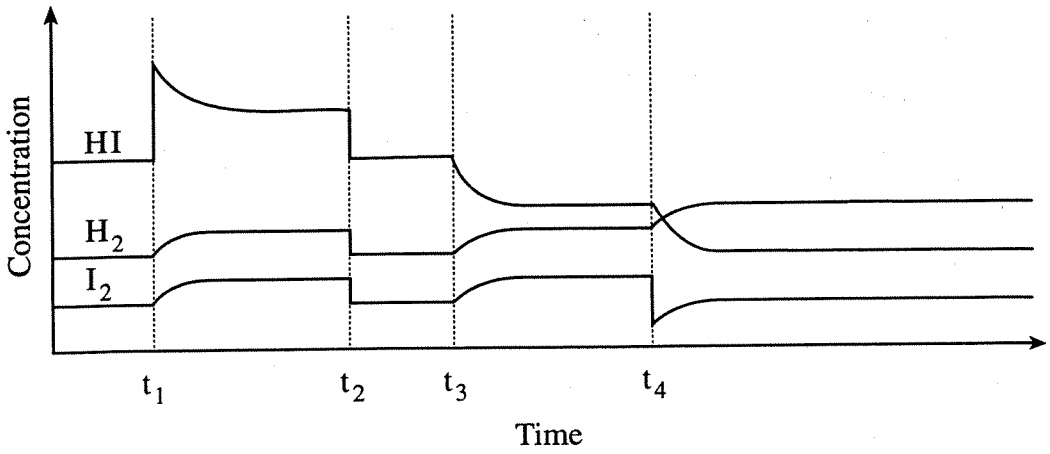
1. Consider the following equilibrium:

$$2H_2O_{(l)} + \text{heat} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)} \qquad K_w = 1.0 \times 10^{-14} \text{ at } 25°C$$

What happens to the value of K_w as temperature decreases? Explain. **(2 marks**

2. Consider the following graph for the equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} + 52\,kJ$$



Identify the imposed changes at times: **(4 marks)**

a) t_1 _____

b) t_2 _____

c) t_3 _____

d) t_4 _____

3. Equal numbers of moles of NO and O_2 are placed in a sealed flask and allowed to reach equilibrium as follows:

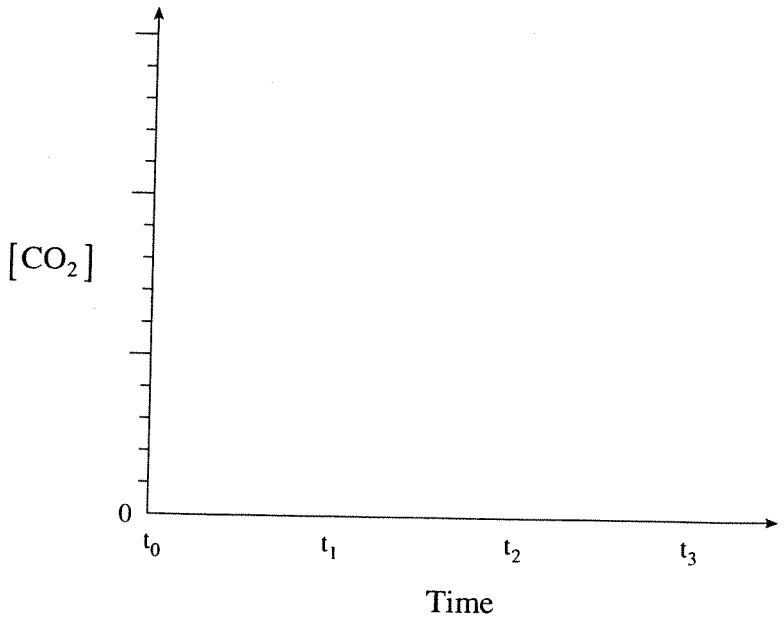
$$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$$

As the reaction proceeds towards equilibrium, what happens to the rate of the forward reaction? Explain using the collision theory. **(2 marks)**

4. Consider the following equilibrium at constant temperature:

$$CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

At time t_0, the system is at equilibrium. At time t_1, the volume of the system is suddenly decreased to one-half the original volume. At time t_2, the system reestablishes equilibrium. Sketch a graph representing the changes in the $[CO_2]$ from time t_0 to time t_3. **(2 marks)**



5. Consider the following equilibrium:

$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)} \qquad K_{eq} = 16$$

A 1.0 L flask is filled with 0.30 mol CO, 0.30 mol H_2O, 0.90 mol CO_2 and 0.90 mol H_2 at a constant temperature. Calculate the equilibrium $[CO_2]$.

(4 marks)

6. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} + \text{energy}$$

a) What happens to the $[CH_3OH]$ when the volume is decreased at constant temperature? Give **two** reasons to support your answer. **(3 marks)**

b) What happens to the $[CO]$ when a catalyst is added at constant volume and temperature? **(1 mark)**

7. Elemental tin can be prepared by reacting hydrogen gas with tin (IV) oxide as indicated by the following equilibrium equation:

$$SnO_{2(s)} + 2H_{2(g)} \rightleftarrows Sn_{(s)} + 2H_2O_{(g)} \qquad K_{eq} = 1.00 \text{ at } 500°C$$

In an experiment, 1.200 moles of SnO_2 and 0.900 moles of H_2 are placed into a 3.00 litre container at 500°C.

a) Calculate the equilibrium $[H_2]$. **(4 marks)**

b) Calculate the mass of elemental tin present in 3.00 litres of the equilibrium mixture. **(2 marks)**

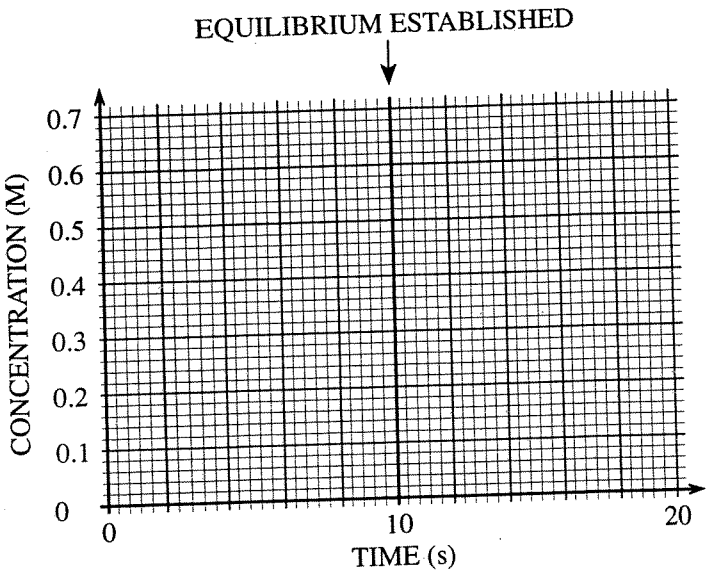
8. Consider the following equilibrium system:

$$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)} \rightleftarrows FeSCN^{2+}_{(aq)}$$

In an experiment, 25.00 mL of 0.600 M of $Fe(NO_3)_3$ is added to 25.00 mL of 0.400 M KSCN. At equilibrium, the $[FeSCN^{2+}] = 0.190$ M.

a) Calculate the K_{eq} value for the above equilibrium. **(4 marks)**

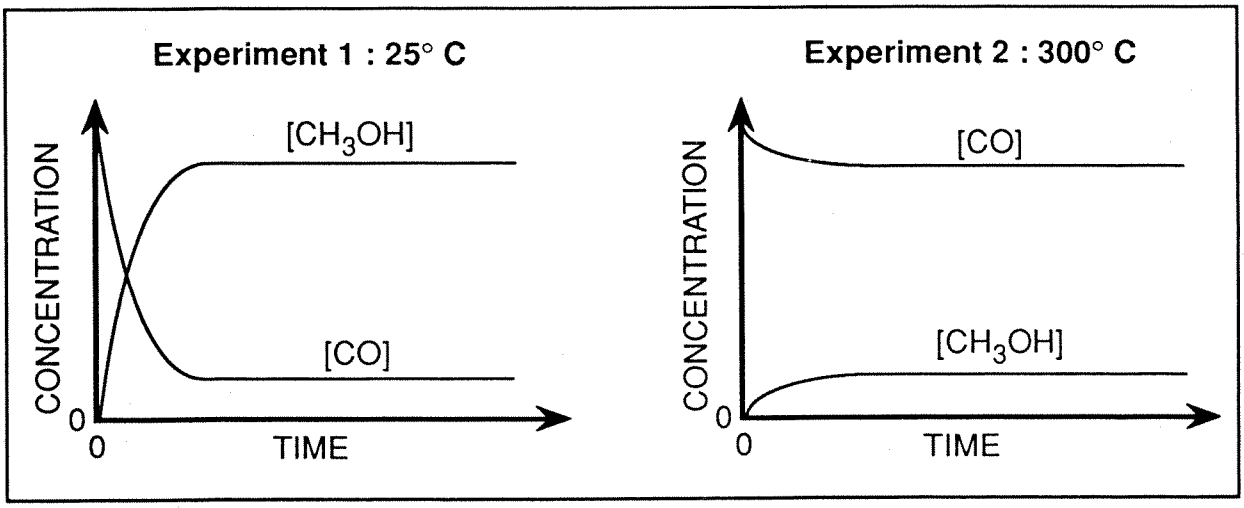
b) Graph the $[Fe^{3+}]$ from the time the reactants were combined (t = 0 seconds) to t = 20 seconds. **(2 marks)**



9. Consider this equilibrium:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)}$$

A student studying this equilibrium plotted the following graphs. These graphs use the same scale on both their x and y axis.



Based on the above data, the student concluded that the reaction as written above is endothermic. Using equilibrium principles, evaluate this conclusion, explaining why you agree or disagree with the student's interpretation. **(2 marks)**

10. A student is given a yellow solution which is known to be one of the following equilibrium systems:

<u>System One</u>

$HInd_{(aq)} \rightleftarrows H^+_{(aq)} + Ind^-_{(aq)}$

HInd is yellow, Ind^- is orange

<u>System Two</u>

$2CrO^{2-}_{4(aq)} + 2H^+_{(aq)} \rightleftarrows Cr_2O^{2-}_{7(aq)} + 2H_2O_{(l)}$

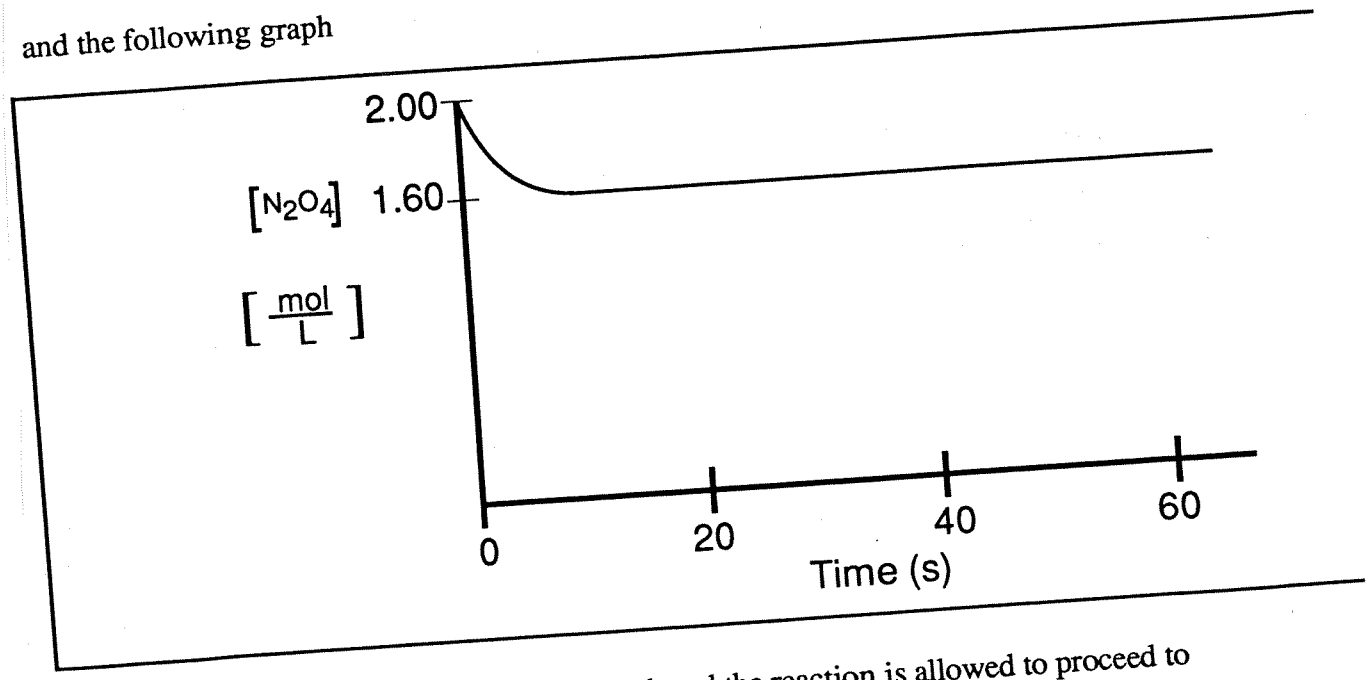
CrO^{2-}_4 is yellow, $Cr_2O^{2-}_7$ is orange

When HCl is added to the unknown equilibrium system, the colour changes from yellow to orange. On the basis of these data, identify the unknown equilibrium system. Justify your answer. **(2 marks)**

11. Given this reaction:

$$N_2O_{4(g)} \rightleftarrows 2O_{2(g)} + N_{2(g)}$$

and the following graph



2.00 mol of N_2O_4 are placed in a 1.00 L flask and the reaction is allowed to proceed to equilibrium. Using the above data, calculate the value of K_{eq} for this reaction.
(4 marks)

12. Consider the following equilibrium in a 5.00 L container:

$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$$

At equilibrium, there is 1.0 mole of CO, 3.0 moles of H_2O, 3.0 moles of CO_2, and 3.0 moles of H_2. If 2.0 moles of CO are now added, find the new equilibrium $[CO_2]$. **(5 marks)**