Quiz (Equilibrium Constant II)

1. Consider the following equilibrium reaction:
   $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
   If the value of the equilibrium constant for the reaction is 0.105 mol^{-2} dm^6 at 50°C, what is the value of the equilibrium constant at the same temperature for the reaction: $\frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g) \rightleftharpoons NH_3(g)$?

2. At 460°C, the equilibrium constant, K_c, for the following reaction is 48.
   $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

   In an experiment, 2.0 g of $H_2(g)$ was mixed with 508 g of $I_2(g)$ in a 5.0 dm^3 container and the mixture was allowed to reach equilibrium.
   (a) Calculate the initial number of moles of $H_2(g)$ and $I_2(g)$ respectively.
   (Relative atomic masses: H = 1.0, I = 126.9)

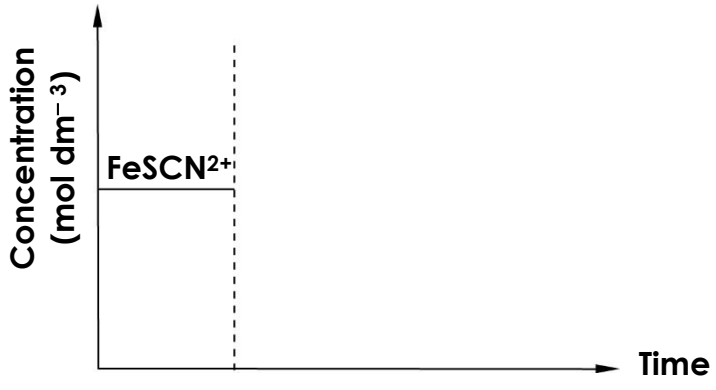
   (b) Calculate the equilibrium concentrations of $H_2(g)$, $I_2(g)$ and HI(g) in the mixture.

   (c) If 0.50 mol of HI(g) is injected into the container and the mixture was allowed to reach equilibrium again.
   Calculate the new equilibrium concentrations of $H_2(g)$, $I_2(g)$ and HI(g) in the mixture.

3. Consider the following equilibrium reaction:
   $Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$ $\quad \Delta H < 0$
   yellow colourless red

   A student mixed 50.0 cm^3 of 0.020 M $Fe(NO_3)_3(aq)$ and 50.0 cm^3 of 0.020 M KSCN(aq) in a conical flask at room temperature, and equilibrium was established.
   (a) The equilibrium concentration of $Fe^{3+}(aq)$ was 0.0026 M. Calculate the equilibrium constant for the reaction at room temperature.

   (b) A few drops of silver nitrate solution are added to the equilibrium mixture.
   (i) Given that AgSCN is insoluble in water, suggest the colour change of the mixture. Explain your answer.
   (ii) In the graph below, sketch the change of the concentration of $FeSCN^{2+}(aq)$ until a new equilibrium is established.



Suggested Answer

1. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
   $K_c = [NH_3(g)]^2 / [N_2(g)]\,[H_2(g)]^3$
   $= 0.105\ mol^{-2}\ dm^6$

   $\frac{1}{2}N_2(g) + 1\frac{1}{2}H_2(g) \rightleftharpoons NH_3(g)$
   $K_c' = [NH_3(g)] / [N_2(g)]^{\frac{1}{2}}\,[H_2(g)]^{1\frac{1}{2}}$
   $= K_c^{\frac{1}{2}}$
   $= (0.105)^{\frac{1}{2}}$
   $= 0.324\ mol^{-1}\ dm^3$

2. (a) Number of moles of $H_2(g) = 2.0 / (1.0 \times 2) = 1.0$ mol
   Number of moles of $I_2(g) = 508 / (126.9 \times 2) = 2.0$ mol

   (b) Let x mol dm^{-3} be the change in concentration of $H_2(g)$.

Concentration (mol dm^{-3})	$H_2(g)$	+ $I_2(g)$	$\rightleftharpoons$ 2HI(g)
Initial	1.0 / 5.0 = 0.2	2.0 / 5.0 = 0.4	0
Change	–x	–x	+2x
Equilibrium	0.2 – x	0.4 – x	2x

   $K_c = [HI(g)]^2 / [H_2(g)][I_2(g)]$
   $48 = (2x)^2 / (0.2 - x)(0.4 - x)$
   $48(0.08 - 0.6x + x^2) = 4x^2$
   $x = 0.186$ or 0.468 (rejected)

   $[H_2(g)]_{eqm} = (0.2 - 0.186)\ mol\ dm^{-3} = 0.014\ mol\ dm^{-3}$
   $[I_2(g)]_{eqm} = (0.4 - 0.186)\ mol\ dm^{-3} = 0.214\ mol\ dm^{-3}$
   $[HI(g)]_{eqm} = 2 \times 0.186\ mol\ dm^{-3} = 0.372\ mol\ dm^{-3}$

   (c) Let y mol dm^{-3} be the change in concentration of $H_2(g)$.

Concentration (mol dm^{-3})	$H_2(g)$	+ $I_2(g)$	$\rightleftharpoons$ 2HI(g)
Initial	0.014	0.214	0.372 + 0.50 / 5.0 = 0.472
Change	+y	+y	-2y
Equilibrium	0.014 + y	0.214 + y	0.472 – 2y

   $48 = (0.472 - 2y)^2 / (0.014 + y)(0.214 + y)$
   $44\ y^2 + 12.832\ y - 0.078976 = 0$
   $y = 0.060$ or – 0.2977 (rejected)

   $[H_2(g)]_{eqm} = (0.014 + 0.006)\ mol\ dm^{-3} = 0.020\ mol\ dm^{-3}$
   $[I_2(g)]_{eqm} = (0.214 + 0.006)\ mol\ dm^{-3} = 0.220\ mol\ dm^{-3}$
   $[HI(g)]_{eqm} = (0.472 - 2(0.006))\ mol\ dm^{-3} = 0.460\ mol\ dm^{-3}$

3. (a)

Concentration (mol dm^{-3})	$Fe^{3+}(aq)$ + $SCN^{-}(aq)$ ⇌ $FeSCN^{2+}(aq)$		
Initial	0.020 x (50/50+50) = 0.010	0.020 x (50/50+50) = 0.010	0
Change	0.010 – 0.0026 = –0.0074	–0.0074	+0.0074
Equilibrium	0.0026	0.0026	0.0074

K_c = $[FeSCN^{2+}(aq)] / [Fe^{3+}(aq)][SCN^{-}(aq)]$
= (0.0074) / (0.0026)(0.0026)
= 1095 mol^{-1} dm^3

(b) (i) The colour of the mixture becomes paler.
The removal of $SCN^{-}(aq)$ by precipitation with $Ag^{+}(aq)$ shifts the equilibrium position to the left.

(ii)