Quiz (Equilibrium Constant and Reaction Quotient)

1. The following equilibrium was established in a 1 dm^3 sealed container at a certain temperature.

   $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $\quad K_c = 4.16 \times 10^{-2}$ mol dm^{-3}

   However, the equilibrium has been disturbed and there are now 0.45 mol of $PCl_5(g)$, 0.15 mol of $PCl_3(g)$ and 0.15 mol of $Cl_2(g)$.

   (a) Explain what would happen to the position of equilibrium in terms of the value of reaction quotient.
   (b) Calculate the equilibrium concentrations when a new state of equilibrium was established.

2. Consider the dissociation of water:

   $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

   The values of equilibrium constant is 1.00×10^{-14} at 25°C $mol^2\ dm^{-6}$ and 2.95×10^{-14} $mol^2\ dm^{-6}$ at 40°C. Calculate the neutral pH at 25 °C and 40 °C.

Suggested Answer

1. (a) $Q_c = (0.15)(0.15) / 0.45$
$= 0.05$ mol dm^{-3}

As $Q_c > K_c$, there is net Backward Reaction, the equilibrium position shifts to the left.

(b) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
$0.45 + x \quad 0.15 - x \quad 0.15 - x$

$K_c = 0.0416 = (0.15 - x)^2 / (0.45 + x)$
$x^2 - 0.3416\,x + 0.00378 = 0$
$x = 0.01145$ or $x = 0.3302$ (reject)

$[PCl_3] = 0.15 - 0.01145 = 0.1386$ mol dm^{-3}
$[Cl_2] = 0.15 - 0.01145 = 0.1386$ mol dm^{-3}
$[PCl_5] = 0.45 + 0.01145 = 0.4615$ mol dm^{-3}

2. **Neutral: $[H^+] = [OH^-]$**

At 25°C, $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
$1 - x \quad x \quad x$

$x^2 / (1 - x) = 1 \times 10^{-14}$
$\Rightarrow x = 1 \times 10^{-7}$
$\Rightarrow [H^+] = 1 \times 10^{-7}$ mol dm^{-3}

$pH = -\log [H^+] = 7$

At 40°C, $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
$1 - y \quad y \quad y$

$y^2 / (1 - y) = 2.95 \times 10^{-14}$
$\Rightarrow y = 1.718 \times 10^{-7}$
$\Rightarrow [H^+] = 1.718 \times 10^{-7}$ mol dm^{-3}

$pH = -\log [H^+] = 6.77$