INTRODUCTION TO NATURAL SCIENCE

CHEMISTRY HOMEWORK - SPRING - WEEK 4

Chapter 16

① (a) $K_c = \dfrac{[H_2O]_{eq}^2 [O_2]_{eq}}{[H_2O_2]_{eq}^2}$

(b) $K_c = \dfrac{[CO_2]_{eq}}{[CO]_{eq} [O_2]_{eq}^{1/2}}$

(c) $K_c = \dfrac{[CO]_{eq}^2}{[CO_2]_{eq}}$

(d) $K_c = \dfrac{[CO_2]_{eq}}{[CO]_{eq}}$

③ $I_2(g) \rightleftharpoons 2I(g)$

$$Q = \frac{[I]^2}{[I_2]} = \frac{(2.0 \times 10^{-8} M)^2}{(0.020 M)} = 2.0 \times 10^{-14} M < K$$

The reaction is <u>not</u> at equilibrium. It will proceed <u>forward</u> to reach equilibrium.

⑦ $$K = \frac{[PCl_3]_{eq} [Cl_2]_{eq}}{[PCl_5]_{eq}} = \frac{(1.3 \times 10^{-2} M)(3.9 \times 10^{-3} M)}{(4.2 \times 10^{-5} M)}$$

$$= \underline{1.21 M}$$

(9) $C(s) + CO_2(g) \rightleftharpoons 2\,CO(g)$

at equilibrium	0.20 mol	0.10 mol
volume	2.0 L	2.0 L
equilibrium concentrations	$\frac{0.20\,mol}{2.0\,L} = 0.10\,M$	$\frac{0.10\,mol}{2.0\,L} = 0.05\,M$

$$K = \frac{[CO]_{eq}^2}{[CO_2]_{eq}} = \frac{(0.05M)^2}{(0.10M)} = \underline{\underline{2.5 \times 10^{-2} M}}$$

Parts (b) and (c) are done at the end.

(11) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

initial	0.0102 M	0.00609 M	
change	$-x$	$-x$	$+x$
at equilibrium	$(0.0102 - x)$	$(0.00609 - x)$	x

$$[COCl_2]_{eq} = x = 0.00301\,M$$

$$\therefore [CO]_{eq} = 0.0102 - x = 7.19 \times 10^{-3} M$$

$$[Cl_2]_{eq} = 0.00609 - x = 3.08 \times 10^{-3} M$$

$$K = \frac{[COCl_2]_{eq}}{[CO]_{eq}[Cl_2]_{eq}} = \frac{0.00301\,M}{(7.19 \times 10^{-3} M)(3.08 \times 10^{-3} M)}$$

$$= \underline{\underline{1.36 \times 10^{2}\ M^{-1}}}$$

(15)

$$I_2(g) \rightleftharpoons 2I(g)$$

	I_2	I
initial	$\frac{0.105\,mol}{12.3\,L} = 8.54\times10^{-3}\,M$	0
change	$-x$	$+2x$
at equilibrium	$(8.54\times10^{-3}-x)$	$+2x$

$$K = \frac{[I]_{eq}^2}{[I_2]_{eq}} = \frac{(2x)^2}{(8.54\times10^{-3}-x)} = 3.76\times10^{-3}$$

$$\frac{4x^2}{8.54\times10^{-3}-x} = 3.76\times10^{-3}$$

$$4x^2 + 3.76\times10^{-3}x - 3.21\times10^{-5} = 0$$

$$x = \frac{-3.76\times10^{-3} \pm \sqrt{(3.76\times10^{-3})^2 + 4(4)(3.21\times10^{-5})}}{2(4)}$$

$$x = 2.140\times10^{-3}$$

$$[I_2]_{eq} = 8.54\times10^{-3} - x = \underline{\underline{6.14\times10^{-3}\,M}}$$

$$[I]_{eq} = 2x = \underline{\underline{4.80\times10^{-3}\,M}}$$

(22) K_1 $CO_2(g) \rightleftharpoons CO(g) + \frac{1}{2}O_2(g)$ — ①

K_2 $CO(g) + \frac{1}{2}O_2(g) \rightleftharpoons CO_2(g)$ — ②

K_3 $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$ — ③

Rn ② is the reverse of Rn ①

$\Rightarrow K_2 = K_1^{-1}$

Rn ③ is 2 × Rn ②

$\Rightarrow K_3 = K_2^2 = (K_1^{-1})^2 = K_1^{-2}$

$= (6.66 \times 10^{-12})^{-2}$

$K_3 = \underline{\underline{2.25 \times 10^{22}}}$

(23) Rn ① $H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$ $K_1 = 1.6$

Rn ② $FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)$ $K_2 = 0.67$

Reverse Rn ②

Rn ③ $Fe(s) + CO_2(g) \rightleftharpoons FeO(s) + CO(g)$ K_3

$K_3 = K_2^{-1}$

$= 1.49$

Rn ① + Rn ③ ⇒

$H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$

+

Rn (4) (the desired reaction) = Rn (1) + Rn (3)

$\therefore K_4 = K_1 \cdot K_3$

$= (1.6)(1.49) = \underline{2.4}$

(25) heat + $N_2O_3(g) \rightleftharpoons NO(g) + NO_2(g)$ $\Delta H = 40.5$ kJ/mol

(a) shift to the right (adding a reactant)

(b) shift to the left (adding a product)

(c) effectively decrease the pressure ⇒ effectively increase number of species ⇒ shift to the right

(d) shift to the left (removed a "reactant")

(28) heat + $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

<u>increase temp</u> – equilibrium shifts to the right (added a "reactant")

<u>add more NH_4HS</u> – equilibrium will <u>not</u> change since NH_4HS is a solid and does not appear in the equilibrium expression.

<u>add more NH_3</u> – equilibrium will shift to the left (added a product)

<u>H_2S is removed</u> – equilibrium will shift to the right (product has been removed)

(23) Rn ①

$SnO_2(s) + 2H_2(g) \rightleftharpoons Sn(s) + 2H_2O(g)$ $K_1 = 8.12$

Rn ② $H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $K_2 = 0.771$

Rn ③ $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$ $K_3 = K_2^{-1}$

(because Rn ③ is reverse of Rn ②) $K_3 = 1.30$

Rn ③ × 2 = Rn ④

Rn ④ $2CO(g) + 2H_2O(g) \rightleftharpoons 2H_2(g) + 2CO_2(g)$ K_4

$$K_4 = K_3^2 = 1.68$$

Rn ① + Rn ④ = Rn ⑤ 最

$SnO_2(s) + 2CO(g) \rightleftharpoons Sn(s) + 2CO_2(g)$ K_5

Rn ⑤ is the desired reaction

$$K_5 = K_1 \cdot K_4 = (8.12)(1.68) = \underline{13.66}$$

(9) (b) $[CO]_{eq} = \frac{0.10\,mol}{2L} = 0.05\,M$

$[CO_2]_{eq} = \frac{0.20\,mol}{2L} = 0.10\,M$

$$K = \frac{[CO]_{eq}^2}{[CO_2]_{eq}} = \underline{2.5 \times 10^{-2}}$$

K does not depend on the concentration of C(s)

Chapter 23

(18) (a) $^{198}_{79}Au \longrightarrow {}^{198}_{80}Hg + {}^{0}_{-1}\beta$

(b) $^{222}_{86}Rn \longrightarrow {}^{218}_{84}Po + {}^{4}_{2}He$ (or ${}^{4}_{2}\alpha$)

(c) $^{137}_{55}Cs \longrightarrow {}^{137}_{56}Ba + {}^{0}_{-1}\beta$

(d) $^{110}_{49}In \longrightarrow {}^{110}_{48}Cd + {}^{0}_{+1}\beta$ (positron)

(20) (a) $^{80}_{35}Br$ # $p = 35$ < # $n = 80 - 35 = 45$

decay by emitting ${}^{0}_{-1}\beta$ particles

$^{80}_{35}Br \longrightarrow {}^{0}_{-1}\beta + {}^{80}_{36}Kr$

(b) $^{240}_{98}Cf$ $Z > 83$ α particles are emitted

$^{240}_{98}Cf \longrightarrow {}^{4}_{2}\alpha + {}^{236}_{96}Cm$

(c) $^{61}_{27}Co$ # of $p = 27$ < # of $n = 61 - 27 = 34$

β emission

$^{61}_{27}Co \longrightarrow {}^{0}_{-1}\beta + {}^{61}_{28}Ni$

(d) $^{11}_{6}C$ # of $p = 6$ } # of $n = 11 - 6 = 5$

positron emission

$$^{11}_{6}C \longrightarrow {}^{0}_{+1}\beta + {}^{11}_{5}B$$

(24) $^{10}_{5}B$ # of $p = 5$, # of $n = 5$ } 10 nucleons

$$^{10}_{5}B \longrightarrow 5\,{}^{1}_{1}H + 5\,{}^{0}_{1}n$$

mass of nucleons $= [5(1.00783) + 5(1.00867)]$ g/mol

$= 10.0825$ g/mol

mass defect $\Delta m = (10.0825 - 10.01294)$ g/mol

$= 0.06956$ g/mol

$$E_b = (\Delta m)c^2 = \left(\frac{0.06956\ g}{mol}\right)\left(\frac{2.99\times10^{8}\ m}{s}\right)^2 \frac{kg}{10^3\ g}$$

$= 6.2187 \times 10^{12}$ J mol^{-1}

$= 6.2187 \times 10^{9}$ kJ mol^{-1}

binding energy per nucleon $= \dfrac{6.2187\times10^{9}\ kJ\ mol^{-1}}{10\ nucleons}$

$= 6.2187 \times 10^{8}$ kJ mol^{-1} nucleon^{-1}

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$$^{11}_{5}B \longrightarrow 5\,^{1}_{1}H + 6\,^{1}_{0}n \qquad 11 \text{ nucleons}$$

mass of nucleons = $[5(1.00783) + 6(1.00867)]$ g/mol

$= 11.09117$ g/mol

mass defect (Δm) = $(11.09117 - 11.00931)$ g/mol

$= 0.08186$ g/mol

$$E_b = (\Delta m)c^2 = \left(\frac{0.08186\ g}{mol}\right)\left(2.99\times10^{8}\ ms^{-1}\right)^2\left(\frac{kg}{10^3 g}\right)$$

$= 7.3184\times10^{12}\ J\ mol^{-1} = 7.3184\times10^{9}\ kJ\ mol^{-1}$

binding energy per nucleon = $\dfrac{7.3184\times10^{9}\ kJ\ mol^{-1}}{11 \text{ nucleons}}$

$= \underline{\underline{6.6531\times10^{8}\ kJ\ mol^{-1}\ nucleon^{-1}}}$