Non Sibi High School

Andover's Chem 550/580: Advanced Chemistry

Chapter 15, Review Quiz 1 Answers

1

a. Write the K_c and K_p expressions for the reaction $\frac{1}{2}I_2(s) + \frac{1}{2}Cl_2(g) \rightleftharpoons ICl(l)$.

b. If $K_c = 1.19 \times 10^3$ for this reaction, calculate the equilibrium molarity of chlorine gas.

a.

$$K_c = \frac{1}{[Cl_2]^{\frac{1}{2}}}$$

$$K_p = \frac{1}{{P_{Cl_2}}^{\frac{1}{2}}}$$

b.

$$1.19 \times 10^3 = \frac{1}{[Cl_2]^{\frac{1}{2}}}$$

$$[Cl_2] = 7.06 \times 10^{-7}\,M$$

2

For the reaction $\frac{1}{2}I_2(s) + \frac{1}{2}Cl_2(g) \rightleftharpoons ICl(l)$, the value of $K_p = 241$. Calculate the value of K_p for the following reaction:

$$2ICl(l) \rightleftharpoons I_2(s) + Cl_2(g)$$

$$K_p = \left(\frac{1}{241}\right)^2 = 1.72 \times 10^{-5}$$

3

a. Write the K_c expression for the reaction $2Cr(s) + 3Ge^{4+}(aq) \rightleftharpoons 2Cr^{3+}(aq) + 3Ge^{2+}(aq)$.

b. Solid chromium metal is added to a solution containing the initial concentrations 0.30 M Ge^{4+}, 0.86 M Cr^{3+}, and 0.73 M Ge^{2+}. When equilibrium is reached, the molarity of Cr^{3+} is found to be 0.68 M. Calculate the equilibrium molarity of Ge^{2+} and Ge^{4+} as well as K_c for the reaction.

a.

$$K_c = \frac{[Cr^{3+}]^2[Ge^{2+}]^3}{[Ge^{4+}]^3}$$

b. Molarity of Cr^{3+} decreases, so reaction goes left to reach equilibrium:

R)	2Cr(s)	+	$3Ge^{4+}$(aq)	$\rightleftharpoons$	$2Cr^{3+}$(aq)	+	$3Ge^{2+}$(aq)
I)			0.30		0.86		0.73
C)			+3x		-2x		-3x
E)			0.30+3x		0.86-2x		0.73-3x

$$[Cr^{3+}] = 0.68 = 0.86 - 2x$$
$$x = 0.090\,M$$
$$[Ge^{4+}] = 0.30 + 3(0.090) = 0.57\,M$$
$$[Ge^{2+}] = 0.73 - 3(0.090) = 0.46\,M$$
$$K_c = \frac{(0.68)^2(0.46)^3}{(0.57)^3} = 0.24$$

4

For the reaction $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$, $K_p = 7.7$. If a mixture initially contains 0.79 atm CO, 0.67 atm O_2, and 0.21 atm CO_2, calculate the equilibrium pressure of each gas and the total pressure at equilibrium.

$$Q_p = \frac{(0.21)^2}{(0.79)^2(0.67)} = 0.11 < K_p = 7.7, \text{so goes right to reach equilibrium}$$

R)	2CO(g)	+	O_2(g)	$\rightleftharpoons$	$2CO_2$(g)
I)	0.79		0.67		0.21
C)	-2x		-x		+2x
E)	0.79-2x		0.67-x		0.21+2x

$$K_p = 7.7 = \frac{(0.21 + 2x)^2}{(0.79 - 2x)^2(0.67 - x)}$$
$$x = 0.22\,atm$$
$$P_{CO} = 0.79 - 2(0.22) = 0.35\,atm$$
$$P_{O_2} = 0.67 - (0.22) = 0.45\,atm$$
$$P_{CO_2} = 0.21 + 2(0.22) = 0.65\,atm$$
$$P_{total} = 0.35 + 0.45 + 0.65 = 1.45\,atm$$

5

a. Write the K_p expression for the decomposition of liquid bromine trifluoride to form bromine gas and fluorine gas:

$$2BrF_3(l) \rightleftharpoons Br_2(g) + 3F_2(g)$$

b. After a 0.85 gram sample of liquid bromine trifluoride was placed in a 225 mL container and heated to 75°C, the total pressure at equilibrium was found to be 0.68 atm. Calculate the equilibrium pressure of each gas and K_p for this reaction.

c. Calculate the mass of liquid bromine trifluoride present at equilibrium.

a.

$$K_p = P_{Br_2} {P_{F_2}}^3$$

b.

R)	$2BrF_3(l)$	$\rightleftharpoons$	$Br_2(g)$	+	$3F_2(g)$
I)			0		0
C)			+x		+3x
E)			x		3x

$$P_{total} = 0.68 = x + 3x$$

$$x = 0.17\,atm = P_{Br_2}$$

$$P_{F_2} = 3(0.17) = 0.51\,atm$$

$$K_p = (0.17)(0.51)^3 = 0.023$$

c.

$$\frac{0.51\,atm \times \frac{225}{1000}\,L}{0.0821\,\frac{L\cdot atm}{mol\cdot K} \times (75+273)\,K} = 0.00402\,mol\,F_2 \left(\frac{2\,mol\,BrF_3}{3\,mol\,F_2}\right)\left(\frac{136.9\,g\,BrF_3}{1\,mol\,BrF_3}\right) = 0.37\,g\,BrF_3\,reacted$$

$$0.85 - 0.37 = 0.48\,g\,BrF_3\,at\,equilibrium$$

6

Consider the reaction:

$$2K(s) + Cl_2(g) + 3O_2(g) \rightleftharpoons 2KClO_3(s) \quad \Delta H < 0$$

a. State whether the amount of chlorine gas present at equilibrium will increase, decrease, or remain unchanged when each of the following occurs:

i. Helium gas is added at constant volume.

ii. Oxygen gas is removed.
iii. The volume of the container is decreased.
iv. The temperature is increased.
v. Neon gas is added at constant pressure.
vi. A catalyst is added.
vii. Solid potassium metal is added.

i. Inert gas added with no volume change = no shift = amount of chlorine gas unchanged (guideline 7a).

ii. Remove (g) reactant = shifts left = amount of chlorine gas increases (guideline 2a).

iii. Volume of container decreases = shifts to side with fewer (g) moles. There are fewer (g) moles on the right ($4 \rightleftharpoons 0$), so shifts right = amount of chlorine gas decreases (guideline 4b).

iv. Temperature increases = shifts in endothermic direction = shifts left = amount of chlorine gas increases (guideline 8a).

v. Inert gas added with no pressure change = volume increases = shifts to side with more (g) moles = shifts left = amount of chlorine gas increases (guideline 7b).

vi. Add catalyst = no shift = amount of chlorine unchanged (guideline 6).

vii. Add (s) product = no shift = amount of chlorine gas unchanged (guideline 3a).

b. Of the changes above, which will change the value of K_c and K_p, and will K_c and K_p increase or decrease?

Only a temperature change will change the value of K_c and K_p. Reaction shifts left when temperature is increased, so K_c and K_p decrease.

7

If $K_p = 0.29$ at 35°C for the reaction $NH_4HS(s) \rightleftharpoons H_2S(g) + NH_3(g)$, calculate K_c for the reaction at 35°C.

Do not include solid:

$$0.29 = K_c(0.0821 \times 308)^{(1+1)-0=2}$$

$$K_c = 4.5 \times 10^{-4}$$

8

If $K_c = 3.65 \times 10^6$ at 425°C for the reaction $O_2(g) + 2SO_2(g) \rightleftharpoons 2SO_3(g)$, calculate $\Delta G°$ for the reaction at 425°C.

$$K_p = 3.65 \times 10^6(0.0821 \times 698)^{2-(1+2)=-1} = 6.37 \times 10^4$$

$$\Delta G^\circ = -8.31\,\text{J/mol}\cdot\text{K}(698\,\text{K})\ln(6.37\times10^4) = -6.42\times10^4\,\text{J/mol} = -64.2\,\text{kJ/mol}$$

9

If $\Delta G^\circ = 14.0\,\text{kJ/mol}$ at 45°C for the reaction $PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^-(aq)$, calculate K_c for the reaction at 45°C.

$$1.40\times10^4\,\text{J/mol} = -8.31\,\text{J/mol}\cdot\text{K}(318\,\text{K})\ln K_c$$

$$K_c = 0.00500$$

10

Given that $K_p = 0.0094$ at 175°C for the reaction below, estimate K_p for the reaction at 222°C:

$$NO_2(g) \rightleftharpoons NO(g) + \frac{1}{2}O_2(g) \quad \Delta H^\circ = 57\,\text{kJ/mol}$$

$$K_{eq} = K_p$$

$$\ln\frac{(K_p)_2}{0.0094} = \frac{5.7\times10^4\,\text{J/mol}\cdot\text{K}}{8.31\,\text{J/mol}\cdot\text{K}}\left(\frac{1}{448\,\text{K}} - \frac{1}{495\,\text{K}}\right)$$

$$(K_p)_2 = 0.040\,\text{at}\,222^\circ\text{C}$$

11

The normal boiling point of acetone is 56°C. If $\Delta H^\circ_{vaporization} = 31.2$ kJ/mol for acetone, estimate the vapor pressure of acetone in mmHg at 41°C.

At normal boiling point 56°C, vapor pressure of acetone = 760 mmHg:

$$\ln\frac{P_2}{760\,\text{mmHg}} = \frac{3.12\times10^4\,\text{J/mol}\cdot\text{K}}{8.31\,\text{J/mol}\cdot\text{K}}\left(\frac{1}{329\,\text{K}} - \frac{1}{314\,\text{K}}\right)$$

$$P_2 = 441\,\text{mmHg} = \text{vapor pressure of acetone at}\,41^\circ\text{C}$$

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