

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 $\frac{1}{2}\text{I}_2(\text{s}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightleftharpoons \text{ICl}(\text{l})$.

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

a.

$$K_c = \frac{1}{[\text{Cl}_2]^{\frac{1}{2}}}$$

$$K_p = \frac{1}{P_{\text{Cl}_2}^{\frac{1}{2}}}$$

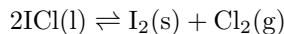
b.

$$1.19 \times 10^3 = \frac{1}{[\text{Cl}_2]^{\frac{1}{2}}}$$

$$[\text{Cl}_2] = 7.06 \times 10^{-7} \text{ M}$$

2

For the reaction $\frac{1}{2}\text{I}_2(\text{s}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightleftharpoons \text{ICl}(\text{l})$, the value of $K_p = 241$. Calculate the value of K_p for the following reaction:



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

3

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

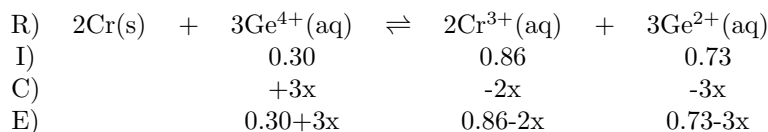
b. Solid chromium metal is added to a solution containing the initial concentrations 0.30 M Ge^{4+} , 0.86 M Cr^{3+} , and 0.73 M Ge^{2+} . When equilibrium is

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.

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

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



$$[\text{Cr}^{3+}] = 0.68 = 0.86 - 2x$$

$$x = 0.090 \text{ M}$$

$$[\text{Ge}^{4+}] = 0.30 + 3(0.090) = 0.57 \text{ M}$$

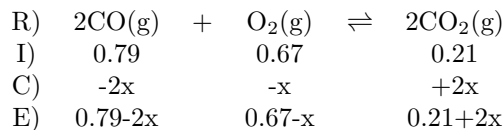
$$[\text{Ge}^{2+}] = 0.73 - 3(0.090) = 0.46 \text{ M}$$

$$K_c = \frac{(0.68)^2(0.46)^3}{(0.57)^3} = 0.24$$

4

For the reaction $2\text{CO(g)} + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}_2(\text{g})$, $K_p = 7.7$. 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.

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



$$K_p = 7.7 = \frac{(0.21 + 2x)^2}{(0.79 - 2x)^2(0.67 - x)}$$

$$x = 0.22 \text{ atm}$$

$$P_{\text{CO}} = 0.79 - 2(0.22) = 0.35 \text{ atm}$$

$$P_{\text{O}_2} = 0.67 - (0.22) = 0.45 \text{ atm}$$

$$P_{\text{CO}_2} = 0.21 + 2(0.22) = 0.65 \text{ atm}$$

$$P_{\text{total}} = 0.35 + 0.45 + 0.65 = 1.45 \text{ atm}$$

5

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



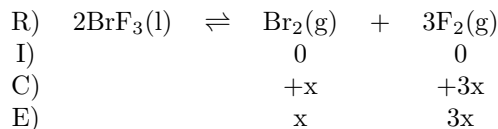
b. After a 0.85 gram sample of liquid bromine trifluoride was placed in a 225 mL container and heated to 75°C , the total pressure at equilibrium was found to be 0.68 atm. Calculate the equilibrium pressure of each gas and K_p for this reaction.

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

a.

$$K_p = P_{\text{Br}_2} P_{\text{F}_2}^3$$

b.



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

$$x = 0.17 \text{ atm} = P_{\text{Br}_2}$$

$$P_{\text{F}_2} = 3(0.17) = 0.51 \text{ atm}$$

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

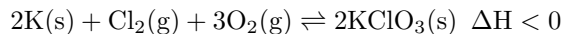
c.

$$\frac{0.51 \text{ atm} \times \frac{225}{1000} \text{ L}}{0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}} \times (75 + 273) \text{ K}} = 0.00402 \text{ mol F}_2 \left(\frac{2 \text{ mol BrF}_3}{3 \text{ mol F}_2} \right) \left(\frac{136.9 \text{ g BrF}_3}{1 \text{ mol BrF}_3} \right) = 0.37 \text{ g BrF}_3 \text{ reacted}$$

$$0.85 - 0.37 = 0.48 \text{ g BrF}_3 \text{ at equilibrium}$$

6

Consider the reaction:



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 $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{H}_2\text{S}(\text{g}) + \text{NH}_3(\text{g})$, 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 $\text{O}_2(\text{g}) + 2\text{SO}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$, calculate ΔG° for the reaction at 425°C .

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

$$\Delta G^\circ = -8.31 \text{ J/mol} \cdot \text{K}(698 \text{ K})\ln(6.37 \times 10^4) = -6.42 \times 10^4 \text{ J/mol} = -64.2 \text{ kJ/mol}$$

9

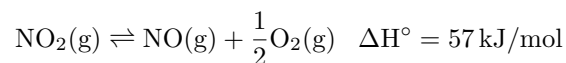
If $\Delta G^\circ = 14.0 \text{ kJ/mol}$ at 45°C for the reaction $\text{PbCl}_2(\text{s}) \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq})$, calculate K_c for the reaction at 45°C .

$$1.40 \times 10^4 \text{ J/mol} = -8.31 \text{ J/mol} \cdot \text{K}(318 \text{ K})\ln K_c$$

$$K_c = 0.00500$$

10

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



$$K_{\text{eq}} = K_p$$

$$\ln \frac{(K_p)_2}{0.0094} = \frac{5.7 \times 10^4 \text{ J/mol} \cdot \text{K}}{8.31 \text{ J/mol} \cdot \text{K}} \left(\frac{1}{448 \text{ K}} - \frac{1}{495 \text{ K}} \right)$$

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

11

The normal boiling point of acetone is 56°C . If $\Delta H^\circ_{\text{vaporization}} = 31.2 \text{ kJ/mol}$ 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:

$$\ln \frac{P_2}{760 \text{ mmHg}} = \frac{3.12 \times 10^4 \text{ J/mol} \cdot \text{K}}{8.31 \text{ J/mol} \cdot \text{K}} \left(\frac{1}{329 \text{ K}} - \frac{1}{314 \text{ K}} \right)$$

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



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