

## AP Chemistry - Unit 9 - Equilibrium

Key

## Wkst: Equilibrium

1. Briefly describe the following ideas or phenomena

- a. Dynamic equilibrium

A reaction at equilibrium has not stopped - the Rate of the forward reaction is equal to the Rate of the Backward Reaction

- b. The difference between Q and K

K is the equilibrium constant. For a particular reaction it is dependent on the temperatures only.

Q is the reaction quotient. It can be calculated from the concentrations & pressures of the reactants & products.

$Q = K$  when the Rxn is at equilibrium

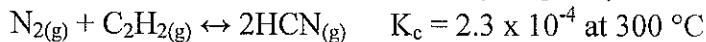
$Q < K$  Rxn will proceed to right to produce more products

- c. Effect of a catalyst on equilibrium

A catalyst lowers the activation energy of a Rxn by providing an alternative reaction pathway or mechanism. It has no effect on the equilibrium position, but it does allow equilibrium to be established faster.

$Q > K$  Rxn will proceed to left to produce more Reactants

2. Nitrogen and acetylene gases react to form hydrogen cyanide according to the reaction



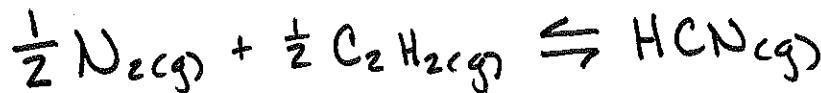
- a. Write out the equilibrium constant expression for  $K_c$  for this reaction as shown

$$K_c = \frac{[HCN]^2}{[N_2][C_2H_2]}$$

- b. The value of  $K_p$  for this reaction at  $300^\circ C$  is also  $2.3 \times 10^{-4}$ . Why are the values of  $K_p$  and  $K_c$  the same for this reaction?

The number of moles of gas remains constant during the Rxn,  
2 moles of gas react to give 2 mol of product gas

- c. Write a balanced equation and calculate the value of equilibrium constant  $K_c$  for the formation of 1.0 mole of hydrogen cyanide gas from nitrogen and acetylene gas.



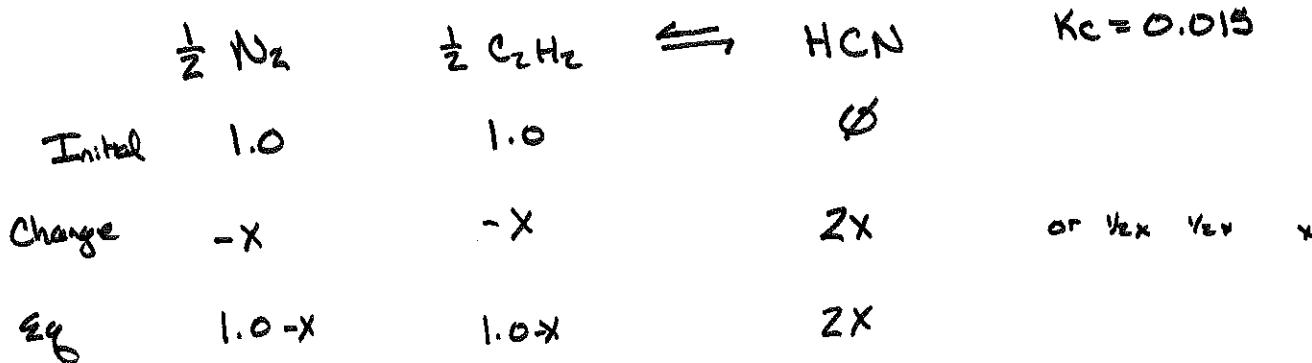
$$K_{c_1} = \frac{[HCN]}{[N_2]^{1/2} [C_2H_2]^{1/2}}$$

$$K_{c_1} = \sqrt{K_c} \\ = \sqrt{2.3 \times 10^{-4}}$$

$$K_{c_1} = 0.015$$

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- d. What is the equilibrium concentration of  $\text{HCN}_{(\text{g})}$  if nitrogen and acetylene are mixed so that both are starting concentrations of 1.0 M?



$$K_c = \frac{[\text{HCN}]}{[\text{N}_2]^{1/2} [\text{C}_2\text{H}_2]^{1/2}} = \frac{2x}{(1.0-x)^{1/2} (1.0-x)^{1/2}} = \frac{2x}{(1.0-x)}$$

$$0.015 = \frac{2x}{1.0-x}$$

$$0.015(1.0-x) = 2x$$

$$2.015x = 0.015$$

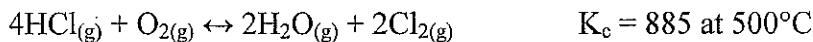
$$x = .0074$$

$$\text{HCN} = 2x$$

$$= 2(.0074)$$

$$\boxed{\text{HCN} = .015 \text{ M}}$$

3. Consider the following equilibrium reaction.



- a. If 0.030 mole HCl, 0.020 mole O<sub>2</sub>, 0.090 mol H<sub>2</sub>O and 0.085 mole Cl<sub>2</sub> are mixed in a 1.0 L container at 500°C, in what direction will the reaction proceed?

All gases in 1.0 L container      Concentration = moles/L

$$[\text{HCl}] = \frac{.030 \text{ mol}}{1.0 \text{ L}} = 0.030 \text{ M} \quad Q = \frac{[\text{Cl}_2]^2 [\text{H}_2\text{O}]^2}{[\text{HCl}]^4 [\text{O}_2]} = \frac{(0.085)^2 (0.090)^2}{(0.030)^4 (0.020)}$$

$$[\text{O}_2] = \frac{.020 \text{ mol}}{1.0 \text{ L}} = 0.020 \text{ M}$$

$$[\text{H}_2\text{O}] = \frac{.090 \text{ mol}}{1.0 \text{ L}} = 0.090 \text{ M}$$

$$[\text{Cl}_2] = \frac{.085 \text{ mol}}{1.0 \text{ L}} = 0.085 \text{ M}$$

$$Q = 3600$$

$$Q > K_c$$

$\therefore$  Reaction will proceed towards Reactants

- b. What is the value of  $K_p$  for the reaction at 500°C?

$$K_p = K_c (RT)^{\Delta n}$$

$$\Delta n = \text{products gas moles} - \text{reactant gas moles}$$

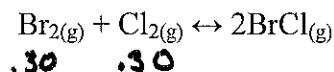
$$= (885) [0.08206(500+273)]^{-1} = 4 - 5 = -1$$

$$\boxed{K_p = 14}$$

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4. Suppose a 1.0 L flask is filled with 0.30 atm  $\text{Br}_{2(g)}$  and 0.30 atm  $\text{Cl}_{2(g)}$  at 400 K.

$K_p = 7.0$  for the reaction



at 400K

1.0L FLASK

- a. Find the pressures of all three gases at equilibrium

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

$$K_p = \frac{(2x)^2}{(.30-x)(.30-x)}$$

Note:  $K_p$  is not small  $\therefore .30 - x \approx 0$   
Can't Be done

	$\text{Br}_2$	$\text{Cl}_2$	$\rightleftharpoons$	$2\text{BrCl}$
Initial	.30	.30		$\emptyset$
Change	$-x$	$-x$		$+2x$
Eq	$0.30-x$	$0.30-x$		$2x$

$$7 = \frac{(2x)^2}{(0.30-x)^2}$$

$$\sqrt{7} = \frac{2x}{0.30-x}$$

$$2.6(0.30-x) = 2x$$

$$.78 - 2.6x = 2x$$

$$.78 = 4.6x$$

$$x = .17$$

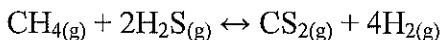
$$P_{\text{Br}_2} = P_{\text{Cl}_2} = 0.30 - x = .30 - .17$$

$$P_{\text{Br}_2} = P_{\text{Cl}_2} = .13 \text{ Atm}$$

$$P_{\text{Br-Cl}} = 2x = 2(.17)$$

$$P_{\text{Br-Cl}} = .34 \text{ Atm}$$

5. For the reaction below, which change would cause the equilibrium to shift to the right?



→ which ones?

- a. Decrease the concentration of dihydrogen sulfide.

cause shift to left

- b. Increase the pressure on the system. ↑ mole → 5

Shift Left

- c. Increase the temperature of the system.

Shift to Right

- d. Increase the concentration of carbon disulfide.

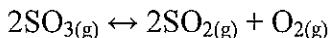
Shift to Left

- e. Decrease the concentration of methane.

Shift to Left

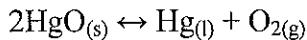
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6. What would happen to the position of the equilibrium when the following changes are made to the equilibrium system below?



- a. Sulfur dioxide is added to the system. Shift to Left to counteract  $\uparrow \text{SO}_2$
- b. Sulfur trioxide is removed from the system. Shift to left
- c. Oxygen is added to the system. Shift to Left

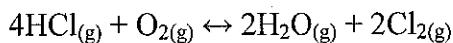
7. What would happen to the position of the equilibrium when the following changes are made to the reaction below?



- a. HgO is added to the system. No shift, Because pure liquids + solids have no effect on the equilibrium position
- b. The pressure on the system increases.

$\text{O} \xrightarrow{\text{mole g}} 1 \xrightarrow{\text{mole g}}$  Shift left decrease the # of moles of gts

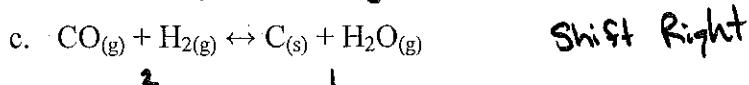
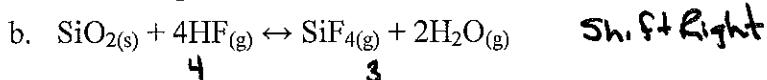
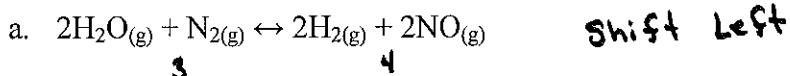
8. When the volume of the following mixture of gases is increased, what will be the effect on the equilibrium position?



5 moles  $\leftrightarrow$  4 moles Shift to left

9. Predict the effect of decreasing the volume of the container for each equilibrium.

$\downarrow$  Volume  $\therefore \uparrow$  Pressure



10. Predict the effect of decreasing the temperature on the position of the following equilibria.

$\downarrow$  Temp

(write in heat treat it)  
 as a "Reactant"

