Key

AP Chemistry - Unit 9 - Equilibrium

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 Back ward 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 or pressures of the reactants & products.

Q=K when the Rxn is at equilibrium

Q<K Rxn will proceed to Right to produce more products

Q>K Rxn will proceed to Left to produce more Reactants

   c. Effect of a catalyst on equilibrium

A catalyst lowers the activation energy of a Rxn by providing an alternative reaction path way or Mechanism. It has <u>No effect</u> on the equilibrium position, but it does Allow equilibrium to Be Established faster.

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

$N_{2(g)} + C_2H_{2(g)} \leftrightarrow 2HCN_{(g)}$ $K_c = 2.3 \times 10^{-4}$ at 300 °C

   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 °C is also 2.3×10^{-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.

$$\frac{1}{2}N_{2(g)} + \frac{1}{2}C_2H_{2(g)} \leftrightharpoons HCN_{(g)}$$

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

$$K_{c_1} = \sqrt{K_c}$$

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

$$K_{c_1} = 0.015$$

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

	$\frac{1}{2} N_2$	$\frac{1}{2} C_2H_2$	$\rightleftharpoons$	HCN	$K_c = 0.015$
Initial	1.0	1.0		$\emptyset$	
Change	$-x$	$-x$		$2x$	or $\frac{1}{2}x$ $\frac{1}{2}x$ x
Eq	$1.0-x$	$1.0-x$		$2x$	

$$K_c = \frac{[HCN]}{[N_2]^{1/2}[C_2H_2]^{1/2}} = \frac{2x}{(1.0-x)^{1/2}(1.0-x)^{1/2}} = \frac{2x}{(1.0-x)}$$

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

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

$$2.015x = 0.015$$

$$x = .0074$$

$$HCN = 2x$$

$$= 2(.0074)$$

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

3. Consider the following equilibrium reaction.

$4HCl_{(g)} + O_{2(g)} \leftrightarrow 2H_2O_{(g)} + 2Cl_{2(g)}$ $K_c = 885$ at 500°C

a. If 0.030 mole HCl, 0.020 mole O_2, 0.090 mol H_2O and 0.085 mole Cl_2 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

$$[HCl] = \frac{.030\ m}{1.0\ L} = 0.030\ M$$

$$[O_2] = \frac{.020\ m}{1.0\ L} = 0.020\ M$$

$$[H_2O] = \frac{.090\ m}{1.0\ L} = 0.090\ M$$

$$[Cl_2] = \frac{.085\ m}{1.0\ L} = 0.085\ M$$

$$Q = \frac{[Cl_2]^2[H_2O]^2}{[HCl]^4[O_2]} = \frac{(.085)^2(.090)^2}{(0.030)^4(0.020)}$$

$$Q = 3600$$

$$Q > K_c$$

∴ Reaction will proceed towards Reactants

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

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

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

n = products gas moles − reactant gas moles

$= 4 - 5$

$= -1$

$$\boxed{K_p = 14}$$

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4. Suppose a 1.0 L flask is filled with 0.30 atm $Br_{2(g)}$ and 0.30 atm $Cl_{2(g)}$ at 400 K. $K_p = 7.0$ for the RXN

$Br_{2(g)} + Cl_{2(g)} \leftrightarrow 2BrCl_{(g)}$ at 400K 1.0L FLASK

.30 .30

a. Find the pressures of all three gases at equilibrium

$$K_p = \frac{P_{BrCl}^2}{P_{Br_2} P_{Cl_2}}$$

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

Note: K_p is not small ∴ $.30 - x \neq 0$ can't be done

	Br_2	Cl_2	$\rightleftharpoons$	$2BrCl$
Initial	.30	.30		∅
Change	$-x$	$-x$		$+2x$
Eq	$0.30-x$	$0.30-x$		$2x$

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

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

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

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

$$.78 = 4.6x$$

$$x = .17$$

$P_{Br_2} = P_{Cl_2} = 0.30 - x = .30 - .17$

$\boxed{P_{Br_2} = P_{Cl_2} = .13 \text{ Atm}}$

$P_{BrCl} = 2x = 2(.17)$

$\boxed{P_{BrCl} = .34 \text{ Atm}}$

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

$CH_{4(g)} + 2H_2S_{(g)} \leftrightarrow CS_{2(g)} + 4H_{2(g)}$ $\longrightarrow$ which ones?

a. Decrease the concentration of dihydrogen sulfide.

cause shift to left

b. Increase the pressure on the system. 1 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?

$$2SO_{3(g)} \leftrightarrow 2SO_{2(g)} + O_{2(g)}$$

a. Sulfur dioxide is added to the system. Shift to Left to counteract ↑ 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?

$$2HgO_{(s)} \leftrightarrow Hg_{(l)} + O_{2(g)}$$

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.

0 ⇌ 1 Shift left decrease the # of moles of gas
mole g mole g

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

$$4HCl_{(g)} + O_{2(g)} \leftrightarrow 2H_2O_{(g)} + 2Cl_{2(g)}$$

5 moles ↔ 4 moles Shift to left

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

↓ volume ∴ ↑ Pressure

a. $2H_2O_{(g)} + N_{2(g)} \leftrightarrow 2H_{2(g)} + 2NO_{(g)}$ Shift Left
3 4

b. $SiO_{2(s)} + 4HF_{(g)} \leftrightarrow SiF_{4(g)} + 2H_2O_{(g)}$ Shift Right
4 3

c. $CO_{(g)} + H_{2(g)} \leftrightarrow C_{(s)} + H_2O_{(g)}$ Shift Right
2 1

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

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

a. $H_{2(g)} + Cl_{2(g)} \leftrightarrow 2HCl_{(g)} + 49.7\ kJ$ Shift to Right

b. $2NH_{3(g)} \leftrightarrow N_{2(g)} + 3H_{2(g)}$ $\Delta H = 37.2\ kJ$ Shift to left
37.2 +

c. $CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2(g)} + H_{2(g)}$ +27.6 $\Delta H = -27.6\ kJ$ Shift to Right