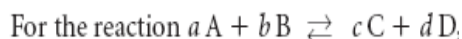


**Part 2 - K<sub>c</sub> - the Equilibrium Constant** - pgs 684-687

- From repeating experiments on a chemical system, chemists discovered that there always exists a mathematical relationship between the amount concentrations (mol/L) of the products and the reactants at equilibrium

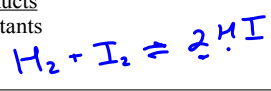
- This relationship always provides a **constant** value for a specific chemical system

- This constant value is called the **equilibrium constant, K<sub>c</sub>**



the equilibrium law expression is  $K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$

\*\*Note that this is  $\frac{\text{products}}{\text{reactants}}$



**Table 1** The Hydrogen-Iodine System at 448 °C

System	Initial system concentrations (mmol/L)			Equilibrium system concentrations (mmol/L)			K <sub>c</sub>
	H <sub>2</sub> (g)	I <sub>2</sub> (g)	HI(g)	H <sub>2</sub> (g)	I <sub>2</sub> (g)	HI(g)	
1	5.00	5.00	0	1.10	1.10	7.80	50.3
2	0.50	0.50	1.70	0.30	0.30	2.10	49.0
3	0	0	3.20	0.35	0.35	2.5	51.0

$K_c = \frac{[HI]^2}{[H_2][I_2]}$

**Example:** Write the equilibrium law expression for the reaction of nitrogen monoxide gas with oxygen gas to form nitrogen dioxide gas.



$K_c = \frac{[NO_2]^2}{[NO]^2 [O_2]}$

- Experiments have shown that the value of the equilibrium constant depends on **temp.**

- The equilibrium constant provides only a measure of the equilibrium position of the reaction; it does not provide any information on the **rate** of the reaction  
*speed*

- Substances in a gaseous or dissolved (aqueous) state have *variable* concentrations, and must *always* be shown in an equilibrium law expression

- Substances in liquid or solid state have fixed concentrations and are not shown in an equilibrium law expression

**Example:** Write the equilibrium law expression for the decomposition of solid ammonium chloride to gaseous ammonia and gaseous hydrogen chloride.



$K_c = [NH_3][HCl]$

## Calculating $K_c$ and Using $K_c$ to calculate equilibrium concentrations

### Example:

Phosphorus pentachloride gas can be decomposed into phosphorus trichloride gas and chlorine gas.



a) Write the equilibrium law expression for this reaction.

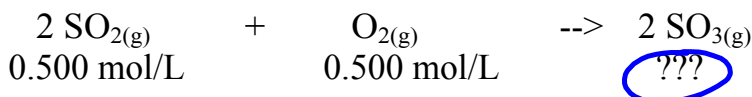
$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$$

b) If the  $[\text{PCl}_{5(g)}] = 4.3 \times 10^{-4} \text{ mol/L}$ , the  $[\text{PCl}_{3(g)}] = 0.014 \text{ mol/L}$  and the  $[\text{Cl}_{2(g)}] = 0.014 \text{ mol/L}$  then calculate  $K_c$ .

$$K_c = \frac{(0.014 \text{ mol/L})(0.014 \text{ mol/L})}{(4.3 \times 10^{-4} \text{ mol/L})} = \boxed{0.46}$$

### Example

Find the  $[\text{SO}_{3(g)}]$  for the following reaction if  $K_c = 85.0$  at  $25.0^\circ\text{C}$ . The concentrations given are the concentrations at equilibrium.



$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$$

$$85.0 = \frac{[\text{SO}_3]^2}{(0.500 \text{ mol/L})^2 (0.500)}$$

$$\boxed{[\text{SO}_3] = 3.26 \text{ mol/L}}$$

## Using ICE table to calculate equilibrium concentrations

- An ICE table is used when we are missing one or more equilibrium concentrations

- We can't calculate  $K_c$  without equilibrium concentrations

- ICE stands for

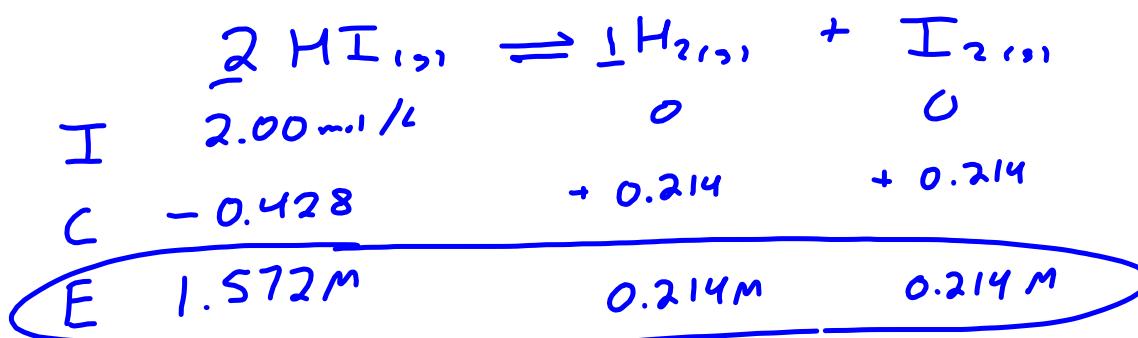
Initial – the initial conditions we started with in the system

Change – the change in concentration between initial and equilibrium conditions

Equilibrium – the concentrations at equilibrium

### Example

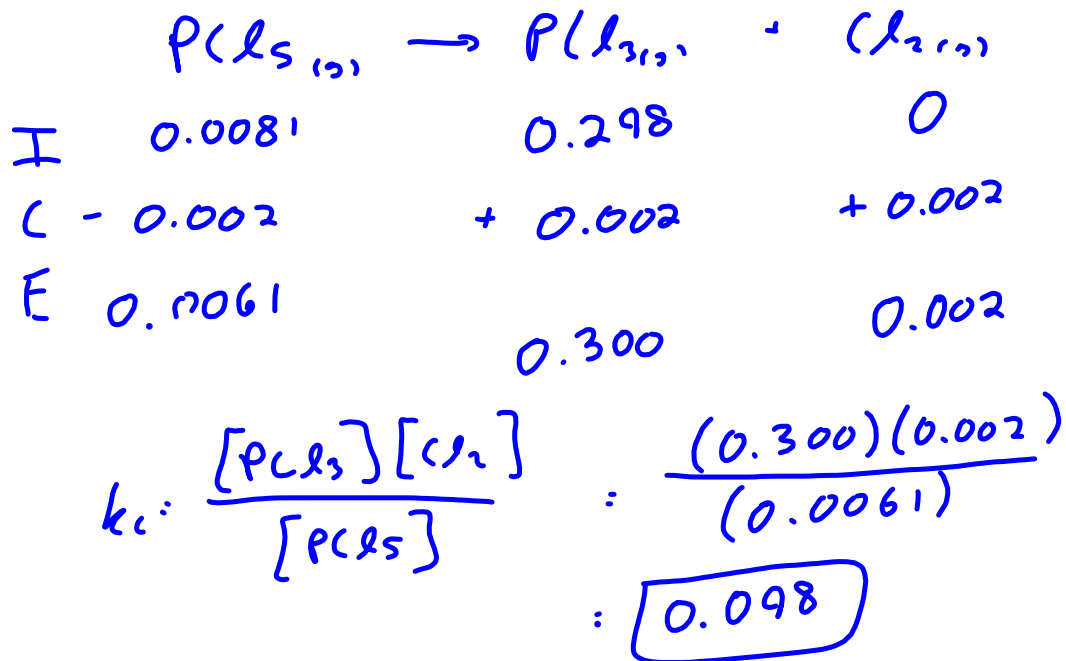
In the decomposition of hydrogen iodide, we start with 2.00 mol/L of  $\text{HI}_{(g)}$ . At equilibrium  $[\text{H}_{2(g)}] = [\text{I}_{2(g)}] = 0.214 \text{ mol/L}$ . Find the value for  $K_c$



$$K_c = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2} = \frac{(0.214 \text{ M})^2}{(1.572 \text{ M})^2} = \boxed{0.0185}$$

**Example:**

Phosphorus pentachloride gas decomposes into phosphorus trichloride gas and chlorine gas. If the  $[PCl_{5(g)}]_i = 8.1 \times 10^{-3} \text{ mol/L}$  and the  $[PCl_{3(g)}]_i = 0.298 \text{ mol/L}$ , and the  $[Cl_{2(g)}]_{eq} = 2.00 \times 10^{-3} \text{ mol/L}$ . Calculate the unknown equilibrium [ ] and the  $K_c$ .



**What do  $K_c$  values tell us??**

- A  $K_c$  value is essentially a ratio of products:reactants @ equilibrium
- So this tells us where the equilibrium lies (reactants favored or products favored)
  - >1, then this means that the products are favored
  - < 1, then this means that the reactants are favored