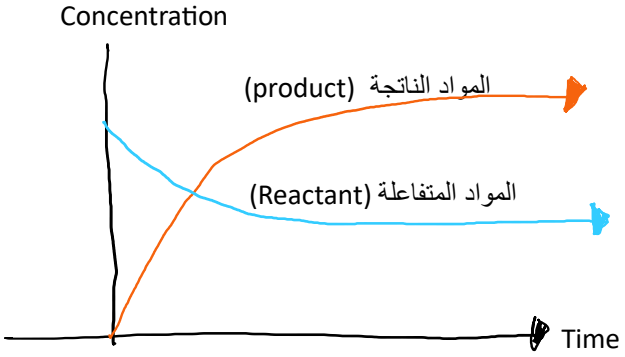
Chapter 14: *Chemical Equilibrium*

$A + B \rightleftharpoons C + D.$

T=0

T=T



Equilibrium: a state in which there are no observable changes as time.

Chemical equilibrium achieved when:
- the rates of the forward and reverse reactions are equal and
- the concentrations of the reactants and products remain Constant.

Rate of Product = Rate of Reactant
سرعة تفاعل امامي = سرعة تفاعل خلفي (عكسي)

◈The equilibrium constant (ثابت الاتزان)

$A + B \rightleftharpoons C + D$

$$Kc = \frac{[C]*[D]}{[A]*[B]}$$

❑The concentrations are expressed in (M) Molarity

$aA + bB \rightleftharpoons cC + dD$

$$Kc = \frac{[C]^c*[D]^d}{[A]^a*[B]^b}$$

Ex: Write the equilibrium constant for the Reactions:

1. $2O3 \rightleftharpoons 3O2$

2. $2No + Cl2 \rightleftharpoons 2NOCl$

Ex: $\mathbf{2NO(g) + O2\ (g) \rightleftharpoons 2NO2}$, if [NO]=0.0542M, [O2]=0.127M, [NO2]=15.5M. Calculate the equilibrium constant (Kc).

الجواب : 6.4 *10^5

The equilibrium constant (Kp)

Kp :نستخدمه بس يكون في غازات لا يمكن الضغط الجزئي نجده الا للغازات غير هيك لا يوجد ضغط جزئي

$$aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$$

$$Kp = \frac{P_C^{\,c} * P_D^{\,d}}{P_A^{\,a} * P_B^{\,b}}$$

$M = \frac{Mol}{V}$ ← Volume (L)

☐ The concentrations are expressed in (M)or in atm

Ex: What the equilibrium constant (Kp) for **$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$** , If $P(PCl_5)=0.875$, $P(PCl_3)=0.463$, $P(Cl_2)=1.98$ in atm.

الجواب : 1.05 atm

Ex: predict the Kp for the following reactions

1) $2PCl_3 + O_2 \rightleftharpoons 2POCl_3$

2) $2POCl_3 \rightleftharpoons 2PCl_3 + O_2$

3) $4\,POCl_3 \rightleftharpoons 4PCl_3 + 2O_2$

4) $PCl_3 + 1/2\,O_2 \rightleftharpoons POCl_3$

Ex: What the Kp of the reaction **$2NO_2(g) \rightleftharpoons N_2O_4(g)$**,If **$Kp = \frac{[N_2O_4]}{[NO_2]^2}$ =4.63*10^-3**

الجواب : 216

◆◆Kp: in gas only (في الغازات فقط لانه ضغط)
Kc: the concentration of **solid** and **pure liquids** are not included (تشمل كل شيء عدا مادة صلبه والسائل بدون إضافات)

Heterogenous equilibrium ⟶ **in different phases**
Homogenous equilibrium ⟶ **in the same phase.**

EX: Determine the type of equilibrium and write expressions for Kc and KP if applicable, for the following reversible reactions at equilibrium:

1. $HF(aq) + H_2O(l) \rightleftharpoons H_3O(aq) + F(aq)$

2. $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

3. $CH_3COOH(aq) + C_2H_5OH(aq) \rightleftharpoons CH_3COOC_2H_5(aq) + H_2O(l)$

4. $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

◆***Relationship between Kp,Kc***

$N_2O_4 \rightleftharpoons 2NO_2$ (g) (g)

$K_c = \frac{[NO_2]^2}{[N_2O_4]}$ $K_b = \frac{P^2_{O_2}}{P_{N_2O_4}}$

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

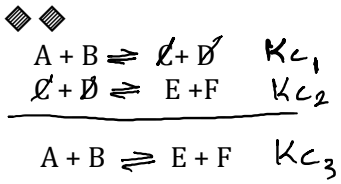
Δn = moles of gaseous products – moles of gaseous reactants

Ex: Methanol (CH_3OH) is manufactured industrially by the reaction

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

The equilibrium constant (Kc) for the reaction is 10.5 at 220°C. What is the value of KP at this temperature?

الجواب: Kp=6.41*10^-3



$$K_{c_1} = \frac{[C][D]}{[A][B]} \qquad K_{c_2} = \frac{[E][F]}{[C][D]}$$

$$K_{c_3} = \frac{[E][F]}{[A][B]}$$

$$Kc_3 = Kc_1 * Kc_2$$

Ex: If reaction **2NO + O2⇌ 2NO2** have Kc=1.5 ,and reaction **N2 +O2⇌ 2NO** have Kc=0.9 . What the final reaction and the Kc for it ?

الجواب: Kc=1.35

Determine direction of interaction:

The **reaction quotient (Qc)** عن طريق بوضعها مكان ثابت الاتزان **(Kc)** وحل على قانون ثابت الاتزان ومقارنة **Qc ب Kc** المعطاة :

IF

1. **Qc<Kc** system proceeds from left to right to reach equilibrium **(من اليسار لليمين)**
2. **Qc=Kc** The system is at equilibrium **(متساوي)**
3. **Qc>Kc** system proceeds from right to left to reach equilibrium.**(من اليمين لليسار)**

Ex: At the start of a reaction, there are 0.249 mol N2, 3.21 x 10-2 mol H2, and 6.42 x 10-4 mol NH3 in a 3.50-L reaction vessel at 375°C If the equilibrium constant (K) For the reaction is 1.2 at this temperature, decide whether the system is at equilibrium. If it is not, predict which way the net reaction will proceed.

N2(g) + 3H2 (g) ⇌ 2NH3(g)

الجواب : Qc=0.611

Calculating Equilibrium Concentrations

€€ نحسب تراكيز المواد المتفاعلة والمواد الناتجة عند التوازن

١. نعبر عن تركيزات المتوازنة لجميع عناصر التفاعل بدلالة التركيز الاولي ونضع رمز{x}الذي يمثل التغير بالتركيز.
٢. نكتب قانون ثابت التوازن (Kc) بدلالة تراكيز التوازن (وجود معلوم عند التوازن) نجد قيمة x
٣. بعد إيجاد x نحسب التركيز المتوازن لعناصر التفاعل جميعها .

Ex: A mixture of 0.500 mol H2 and 0.500 mol I2 was placed in a 1.00-L stainless-steel flask at 430°C. The equilibrium constant Kc for the reaction **H2(g) + I2(g)⇌ 2HI(g)** is 54.3 at this temperature. Calculate the concentrations of H2, I2, and HI at equilibrium.

الجواب: x=0.393M

[H2]=0.107M / [I2] =0.107M / [HI]=0.786M

Examples

Write the final reaction and Kc for **H2CO3(aq)⇌ H(ag) + HCO3(aq)** Kc=4.2*10^-7, and **HCO3(aq) ⇌ H(aq) + CO3(aq)** Kc=4.8*10^-11?

الجواب: 11.76*10^-18

What is the value of (Kp) and (Kc) for the reaction **H20(l)⇌ H2O(g)**, known that the partial pressure of H2O at 25C is 23.8 torr,R=0.0821?

الجواب: Kc=1.27*10^-3

2L flask with 4 mol NH3 as in reaction **2NH3 ⇌ N2 + 2H2** , at equilibrium it remain 1M of NH3 what is Kc ?

الجواب: Kc=1/2

10L flask is filled with 0.2mol of H2 and 0.2mol I2 at 778C ,the value of (Kc) is 49.5 for the reaction **H2 + I2 ⇌ 2HI**, what are the concentrations of I2,H2 in the flask at equilibrium?

الجواب: x=0.00156

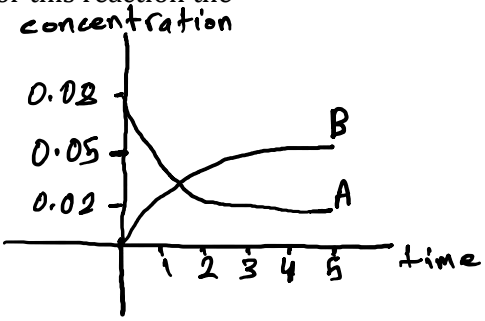
[H2] =4.5*10^-3 / [I2] =4.5*10^-3

Suppose we place with 2mol H2,1mol N2,2mol NH3 .in1L at472C. Will N2andH2 react to give NH3 Known Kc=0.105. Prediction for the reaction **N2+ 3H2 ⇌ 2NH3?**

الجواب: Qc=1/2

(س) Shown below is a concentration time for the reaction A=2B, for this reaction the value for the equilibrium constant is:

1. Kc>1
2. Kc<1
3. Kc=0
4. Kc=1



(س) **2SO2(g) +2O2(g) ⇌ 2SO3(g).** Kc= 1.7*10^-4

SO3(g) ⇌ 1/2O2(g) + SO2(g). Kc=??

1. 7.7*10^-4
2. 3.4*10^2
3. 1.6*10^-6
4. 8.5

(س) for the reaction **N2(g)+ 2O2(g)⇌ 2NO2(g)**. Kc=8.3*10^-10 at25C, what is the concentration of N2. If NO2 is twice the concentration of O2 gas?

1. 2.4*10^9M
2. 4.2*10^-10M
3. 2.1*10^-10M
4. 4.8*10^9 M

(س) 1L flask filled with 0.35 molCO and 0.4 molH2O. If you know that concentration of CO at equilibrium =0.22M calculate Kc?

CO+ H2O⇌ CO2 + H2

1.3.5
2. 1
3. 0.28
4. 5.5
5.0.75

(س). **2COF2(g) ⇌ CO2(g)+ CF4(g)**

The equilibrium constant (Kc) is 2 at 1000C for the reaction. If 0.43mol CO2 and 0.43mol CF4 are into 1L flask What will be the concentration ofCOF2 at equilibrium?

1. 0.31M
2. 0.15M
3. 0.22M
4. 1M

the equilibrium constant (Kp) for **PCl5(g) ⇌ PCl3(g) +Cl2(g),** is found to be 1.16 at 200C. If the equilibrium partial pressures of PCl5 and PCl3 are 0.254 atm and0.966 atm. What is the equilibrium partial pressure of Cl2?

الجواب : 30.5atm

Consider the following heterogeneous equilibrium:

$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

At 800°C, the pressure of CO_2 is 0.236 atm. Calculate.

(a) KP

(b) Kc for the reaction at this temperature

الجواب: a. Kb=0.236

B. Kc=2.68*10^-3

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, suppose that the initial concentrations of H_2, I_2 and HI are 0.00623M,0.00414M and0.0224M, respectively. Calculate the concentrations of these species at equilibrium.

الجواب: Kc=19.5

X=0.00156M

[H2]=0.00467M / [I2] =0.00258M / [HI]=0.0255M

(س)Which one of the following statements does not describe the equilibrium state?

1. The concentration of the reactants and products reach a constant level
2. The concentration of the reactants is equal to the concentration of products
3. The rate of the forward reaction is equal to the rate of the reverse reaction
4. Equilibrium is dynamic and there is not net conversion to reactants and products

(س) the Kc for equilibrium below is 7.52*10^-2 at 480 C, **$2Cl_2+2H_2O \rightleftharpoons 4HCl+O_2$**

What is the value of Kc at this temperature for the following reaction.

$2HCl + 1/2O_2 \rightleftharpoons Cl_2 + H_2O$

1. 1.88*10^-2
2. 3.76*10*-2
3. 7.52*10^-2
4. 0.274
5. 3.65

(س) **H2(g)+ Br2(g) ⇌ 2HBr(g)**
A mixture of 0.682 mol of H_2 and 0.440 mol of Br_2 is combined in a reaction vessel with a volume of 2L. At equilibrium at 700 K, there are 0.536 mol of H_2 present. At equilibrium, how many mol of Bry present in the reaction vessel?
1)0.146
2)0.536
3)0.00
4)0.294
5)0.440

(س)For the reaction 2NO2 (g) ⇌ 2NO (g) + O2(g) initially 0.88 atm of NO_2 was reacted. At equilibrium, the total pressure of the reaction mixture is 0.998 atm. The pressure of NO_2 at equilibrium is:
1)0.236 atm
2)0.188 torr
3)0.644 torr
4) 0.644 atm

(س)At equilibrium, the pressure of the reaction, **CaCO3(s) ⇌ CaO (s)+CO2(g)**
Is 0.125 atm at 300°C. The Ke of the reaction is ?
R= 8.3145 Pa.m/K.mol) (R=0.08206 L.atm/K. mol)
1)0.00508
2)0.00266
3)409.00
4)6.392