Announcements – Lecture XI – Thursday, Mar 1st

1. iClicker:  Pick any letter a-e

15.2 The Equilibrium Constant, K

The Relationship between K_p and K_c

The equilibrium constant, **Kc**, for the following reaction is **2.90×10^{-2} at 1260 K**. **Calculate Kp** for this reaction at this temperature.

$$2\,SO_3(g) \Leftrightarrow 2\,SO_2(g) + O_2(g)$$

$R = 0.0821\ L.atm.mol^{-1}.K^{-1}$

Kp = ?.00 (↱ 3)

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

$$\Delta n = 2 + 1 - 2 = 1$$

$$K_p = 2.90 \times 10^{-2} \times (RT)$$
$$= 2.90 \times 10^{-2} \times (0.0821 \times 1260)$$
$$= 2.99$$

15.2 The Equilibrium Constant, K

Manipulating Equilibrium Constant Expressions

a) Multiple by a constant
b) Reverse the reaction
c) Combining reactions

a) Multiple by a constant.

1. $SO_2(g) + \frac{1}{2}O_2(g) \Leftrightarrow SO_3(g)$
2. $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$

$$K_1 = \frac{[SO_3]}{[SO_2][O_2]^{1/2}} \qquad K_2 = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

2. = 2 × (1.)

$$K_2 = K_1^2$$

b) Reverse the reaction.

1. $2SO_3(g) \Leftrightarrow 2SO_2(g) + O_2(g)$
2. $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$

$$K_1 = \frac{[SO_2]^2[O_2]}{[SO_3]^2} \qquad K_2 = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

2. = −1 × (1.)

$$K_2 = K_1^{-1}$$

c) Combining reactions.

1. $C(s) + \frac{1}{2}O_2(g) \Leftrightarrow CO(g)$
2. $C(s) + \frac{1}{2}O_2(g) \Leftrightarrow CO(g)$
3. $2C(s) + O_2(g) \Leftrightarrow 2CO(g)$

$$K_1 = \frac{[CO]}{[O_2]^{1/2}} \qquad K_2 = \frac{[CO]}{[O_2]^{1/2}} \qquad K_3 = \frac{[CO]^2}{[O_2]}$$

$$K_3 = K_1 \times K_2$$

15.2 The Equilibrium Constant, K

Manipulating Equilibrium Constant Expressions

The equilibrium constant, **Kc**, for the following reaction is 0.25 at 500K

$$2\ PCl_5(g) \Leftrightarrow 2\ PCl_3(g) + 2\ Cl_2(g)$$

Calculate **Kc** at this temperature for:

$$PCl_3(g) + Cl_2(g) \Leftrightarrow PCl_5$$

Kc = ?.0 → 2

$$PCl_3(g) + Cl_2(g) \Leftrightarrow PCl_5$$

Compared to: $2\ PCl_5(g) \Leftrightarrow 2\ PCl_3(g) + 2\ Cl_2(g)$

The reaction in question is reversed and multiple by ½.

$$K_c = (0.25)^{-1 \times \frac{1}{2}}$$

$$= (0.25)^{-\frac{1}{2}}$$

$$= \frac{1}{(0.25)^{\frac{1}{2}}} = \frac{1}{\sqrt{0.25}} = 2$$

15.3 Using Equilibrium Constants in Calculations

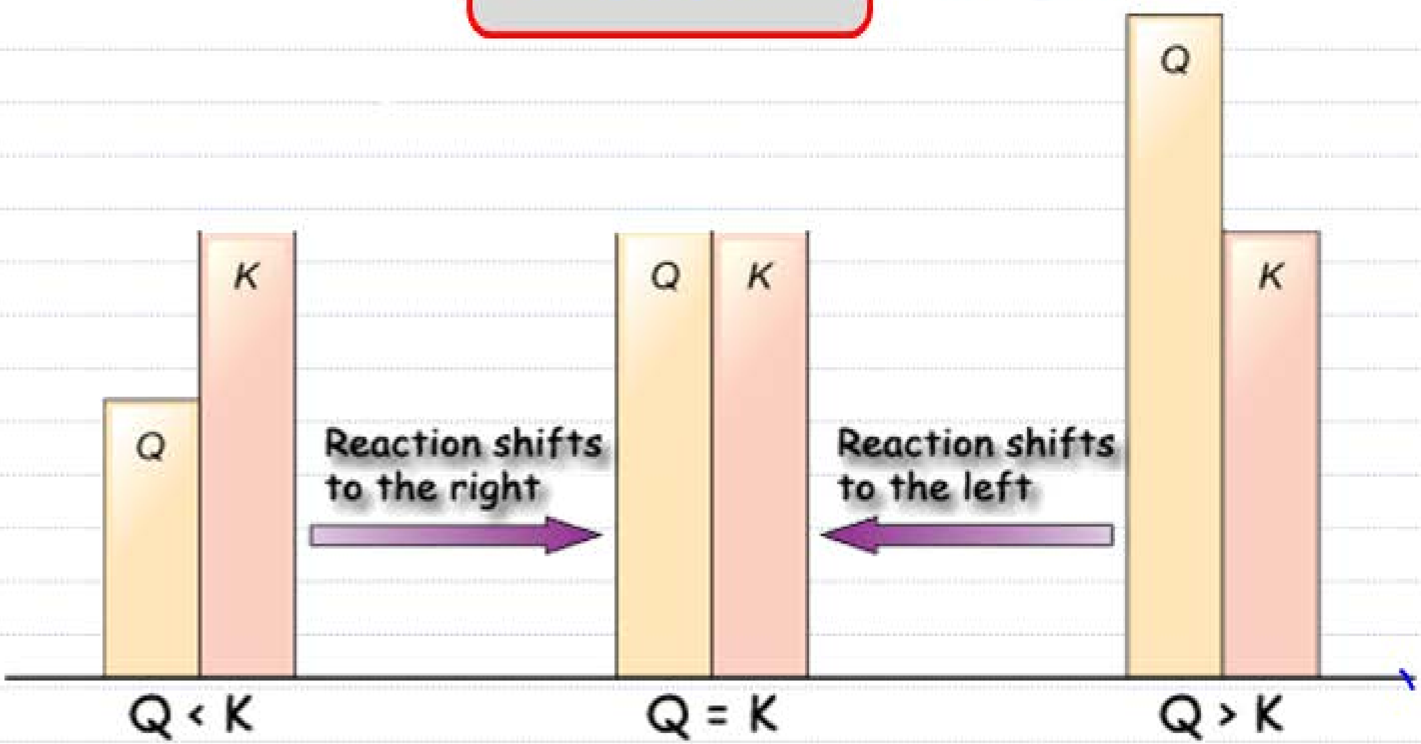
Determining Whether a System Is at Equilibrium – Q

Q = Reaction Quotient

$aA + bB \rightleftharpoons cC + dD$

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

- $Q < K$
- $Q = K$
- $Q > K$

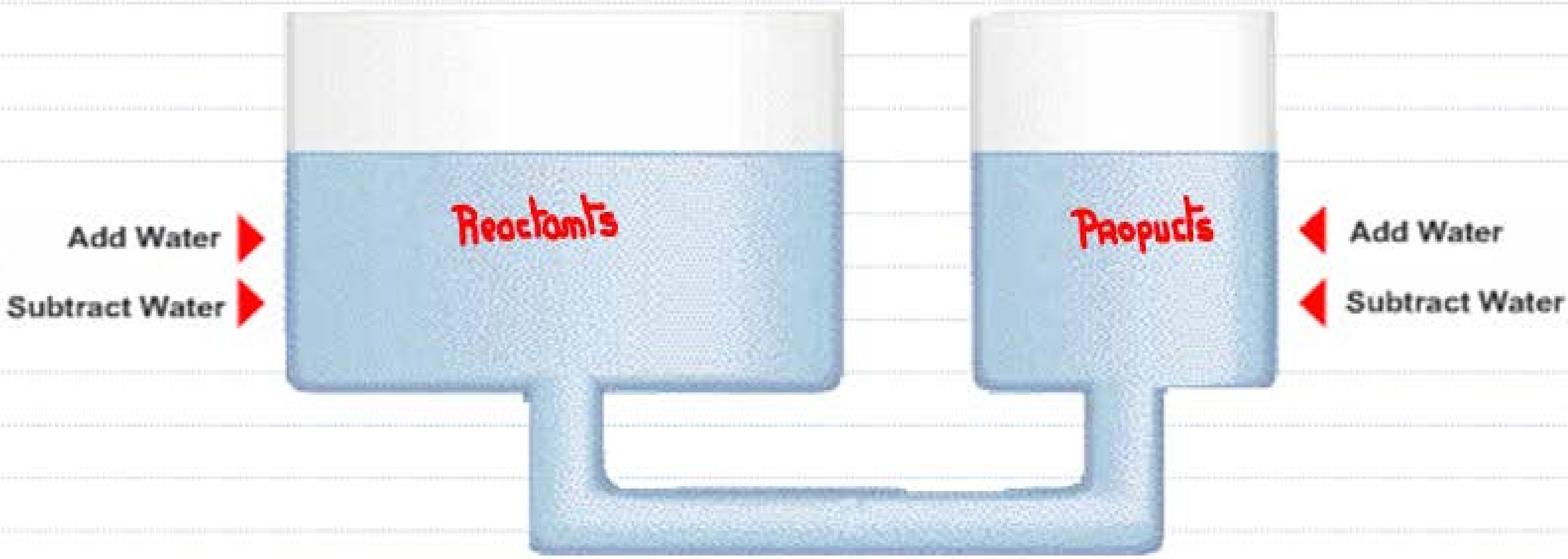


15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Addition or Removal of a Reactant or Product

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy

R ⇔ P

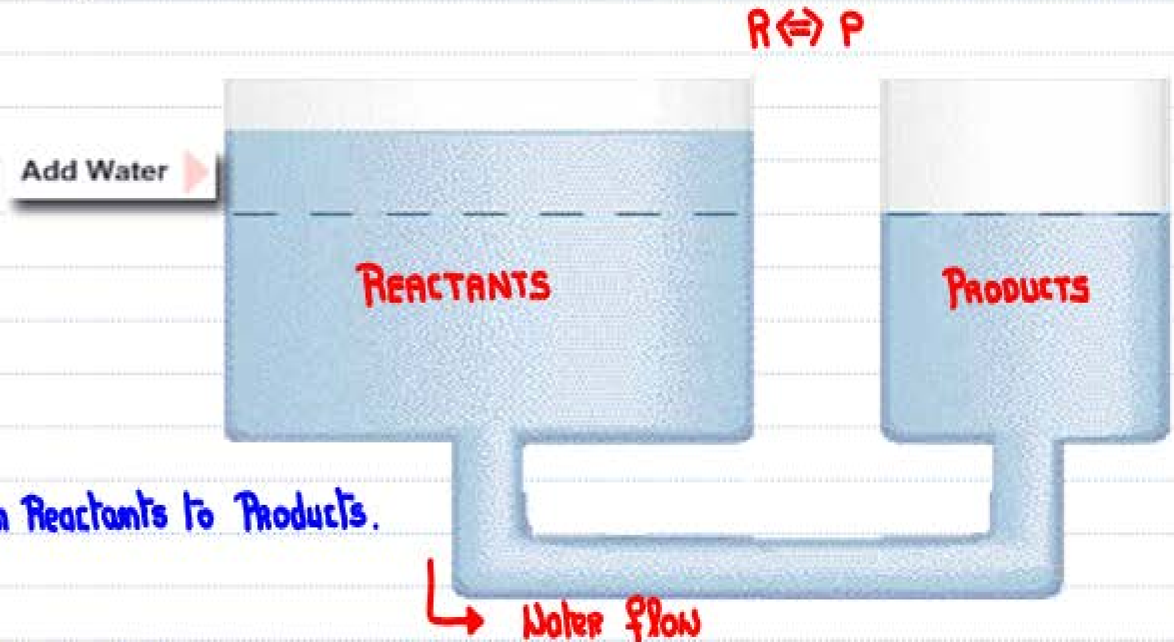


See Class Web Site.

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Addition of a Reactant.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy



Shift from Reactants to Products.

Why?

$$Q = \frac{[\text{Products}]}{[\text{Reactants}]}$$

Addition of Reactant, Q↓, thus $Q < K$

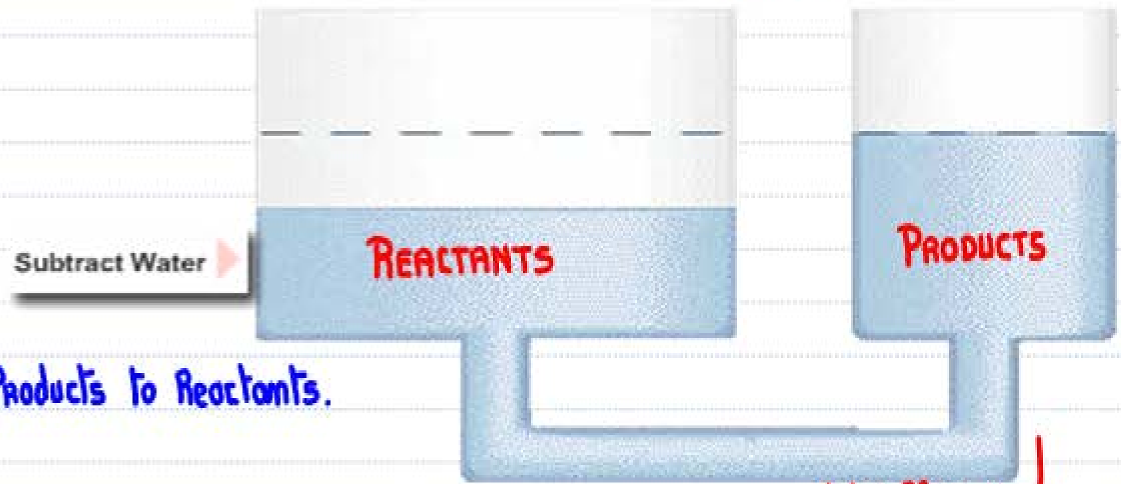
↳ Shift to the right ... Shift towards products.

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Removing an Reactant.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy

R ⇔ P



Water flow

Shift from Products to Reactants.

Why?

$$Q = \frac{[\text{PRODUCTS}]}{[\text{REACTANTS}]}$$

Removal of Reactant, Q↑, thus Q > K

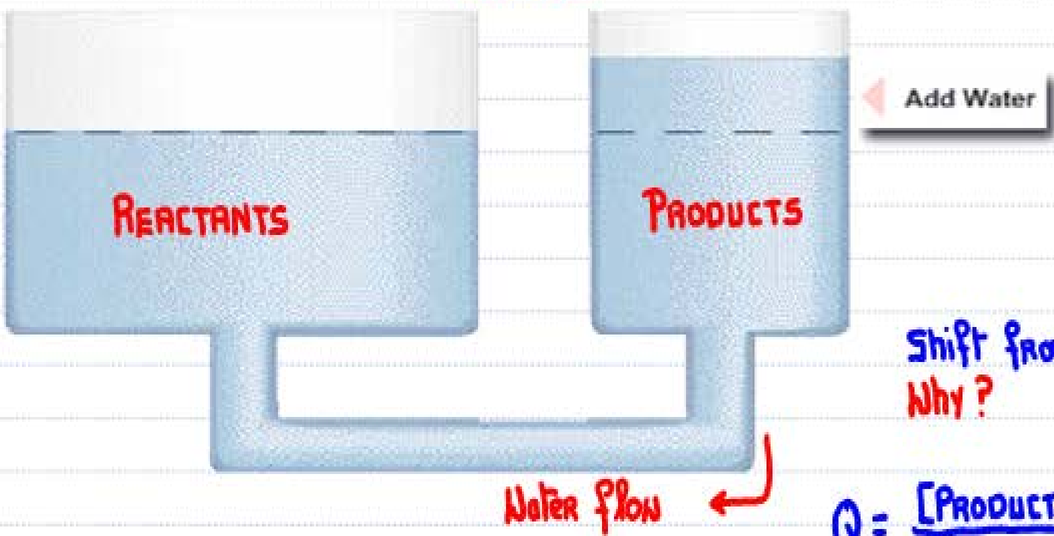
↳ Shift to the left ... Shift towards Reactants.

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Adding a Product.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy

$R \Leftrightarrow P$



Shift from Products to Reactants.
Why?

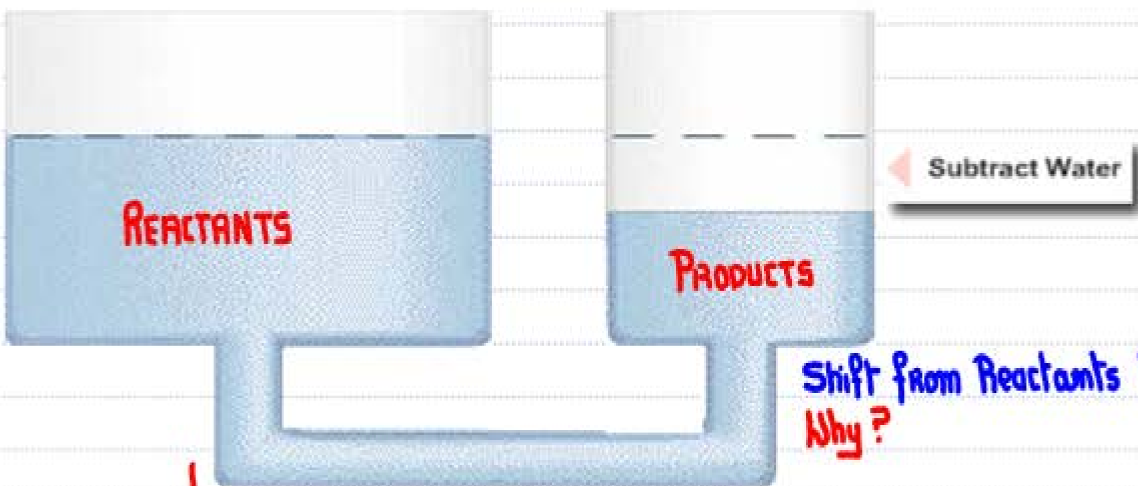
$$Q = \frac{[\text{PRODUCTS}]}{[\text{REACTANTS}]}$$

Addition of Product, Q↑, thus Q > K
↳ Shift to the left...
Shift towards Reactants.

Removing a Product.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy

R ⇔ P



↳ Water flow.

Shift from Reactants to Products.
Why?

$$Q = \frac{[\text{PRODUCTS}]}{[\text{REACTANTS}]}$$

Removal of Product, Q↓, thus Q < K
↳ Shift to the right...
Shift towards products.

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Addition or Removal of a Reactant or Product

HCN is a weak acid –

$HCN(aq) + H_2O(l) \Leftrightarrow H_3O^+ + CN^-$ $\quad Kc = 4.0x10^{-10}$ @ 25°C

Removal of H_3O^+ from this equilibrium will cause the [CN^-] to

a) Increase ✓

b) Decrease

c) Remain unchanged

d) Impossible to determine

$$Q = \frac{[Products]}{[Reactants]}$$

Removing a product, Q↓, Q < K

↳ Shift to the right.

Shift to products.

[CN^-]↑

Addition or Removal of a Reactant or Product

HCN is a weak acid –

$HCN(aq) + H_2O(l) \Leftrightarrow H_3O^+ + CN^-$ $K_c = 4.0 \times 10^{-10}$ @ 25°C

Addition of OH^- to this equilibrium will cause the $[CN^-]$ to

a) Increase ✓
b) Decrease
c) Remain unchanged
d) Impossible to determine

At first look it looks like c) as OH^- is neither a product or a reactant.

$HCN(aq) + H_2O(l) \Leftrightarrow H_3O^+ + CN^-$

$+ OH^- = 2\,H_2O$

Net result is the removal of a product...
causing a shift towards products ... $[CN^-]\uparrow$