Announcements – Lecture XVI – Thursday, Nov 3rd

1. Fourth Lab – Saturday, November 5th … 1-4pm … ISB 155/160 (A-E)

   a) *Print lab prior to coming to lab -- use the 'Print Friendly Version' located on the top left hand side of the page – this is the version that contains the 'Data Sheet' that you will hand in upon completing the lab.*

   b) *Third set of Lab Owls will appear in Owl after this lab. There are a total of 4 sets of Lab Owls and they are worth 25% of the Lab Grade.*

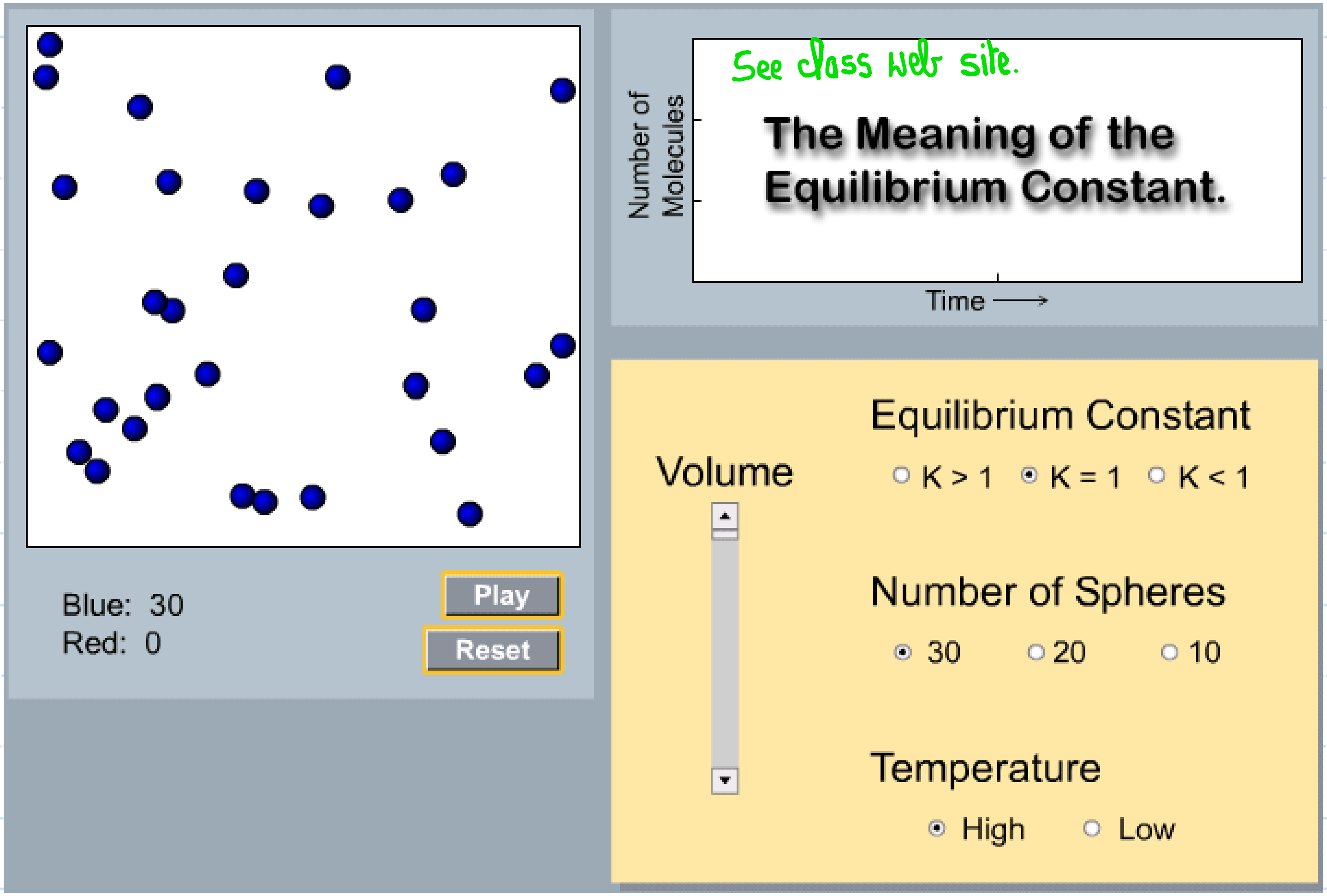
2. Exam II: Tuesday, November 8th, 1:00-2:15, In Class

3. 

   iClicker:
   Choose any letter: A-E

7.6 What is an Equilibrium Constant and How Do We Use It?

The Significance of the Magnitude of K



7.6 What is an Equilibrium Constant and How Do We Use It?

The Significance of the Magnitude of K

1) $K \gg 1$: At equilibrium the reaction favors products.
2) $K \ll 1$: At equilibrium the reaction favors reactants.
3) $K \sim 1$: At equilibrium significant quantities of products and reactants present.

1) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$K = 3.5 \times 10^8$ @ 25°C

$K \gg 1$: Product favored at equilibrium.

2) $HF(aq) + H_2O(l) \rightleftharpoons H_3O^+ + F^-$

$K = 7.6 \times 10^{-5}$ @ 25°C

$K \ll 1$: Reactant favored at equilibrium.

3) $Hb + O_2 \rightleftharpoons HbO_2$

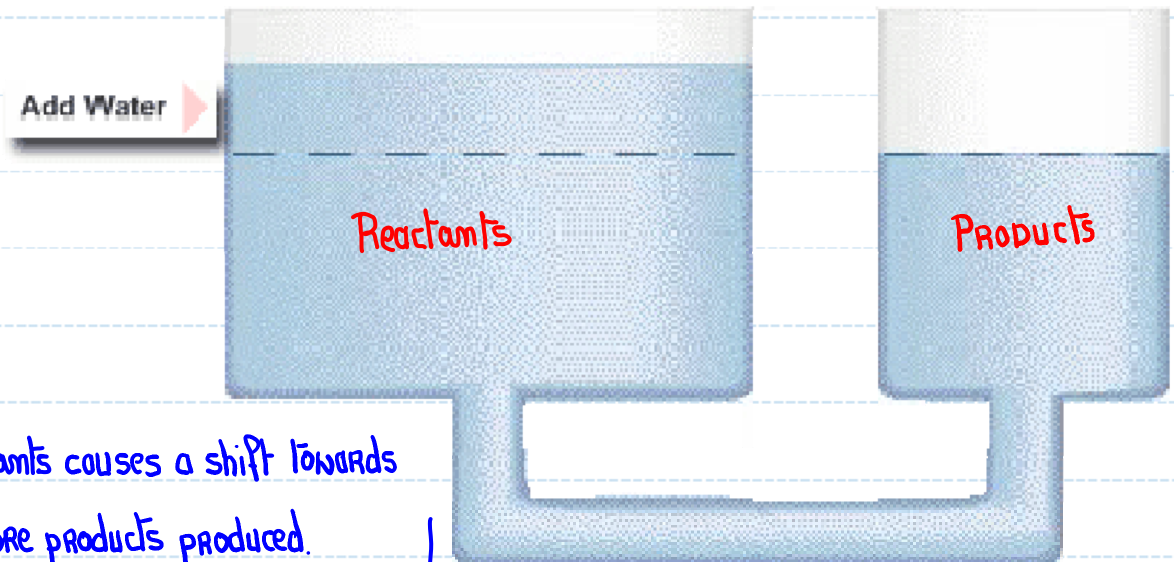
$K \approx 12$ @ 25°C

$K \sim 1$: Significant quantities of reactants and products present at equilibrium.

7.7 What Is Le Chatelier's Principle

Adding Reactants.

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



Adding Reactants causes a shift towards products ... more products produced.

↳ flow towards products

$R \rightleftharpoons P$

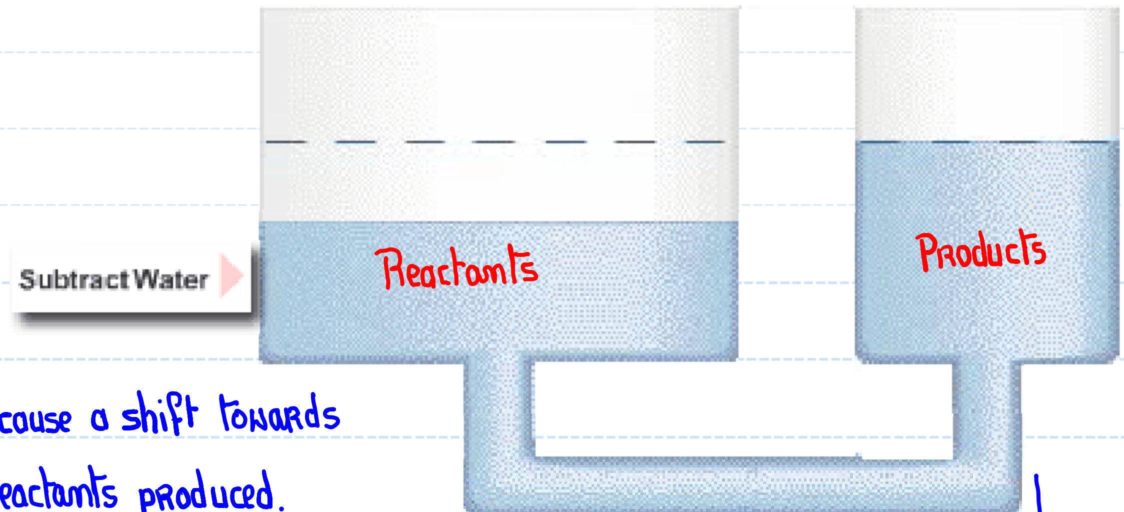
$K = \frac{[P]}{[R]}$

Adding R changes the value of $\frac{[P]}{[R]}$ ... Reaction wants to return to the original value of $\frac{[P]}{[R]}$ ... ie back to K.

7.7 What Is Le Chatelier's Principle

Removing Reactants.

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



$R \Leftrightarrow P$

$K = \frac{[P]}{[R]}$

Removing Reactants cause a shift towards Reactants ... more Reactants produced.

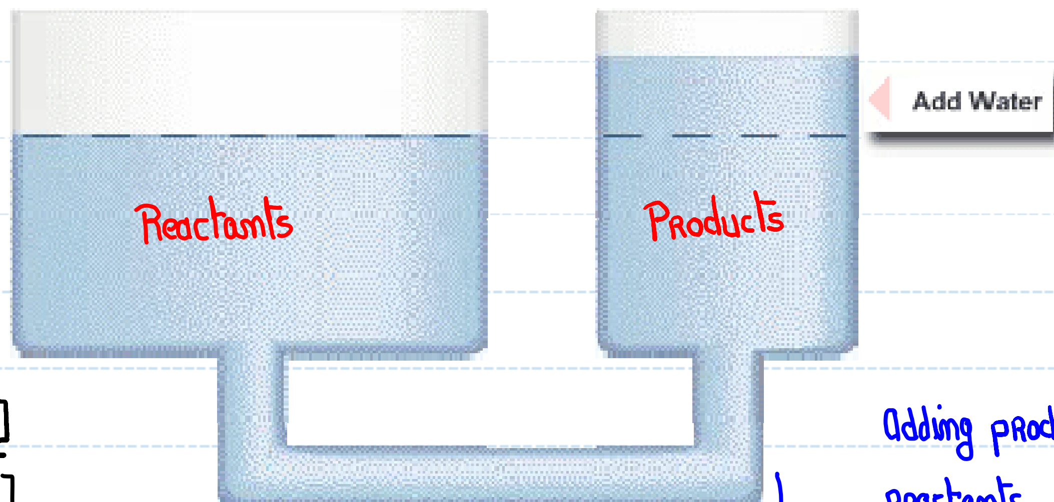
Flow towards Reactants.

Removing R changes the value of $\frac{[P]}{[R]}$ ... Reaction wants to return to the original value of $\frac{[P]}{[R]}$ ... ie back to K.

7.7 What Is Le Chatelier's Principle

Adding Products .

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



$R \rightleftharpoons P$

$K = \frac{[P]}{[R]}$

Adding products causes a shift towards reactants ... more reactants produced.

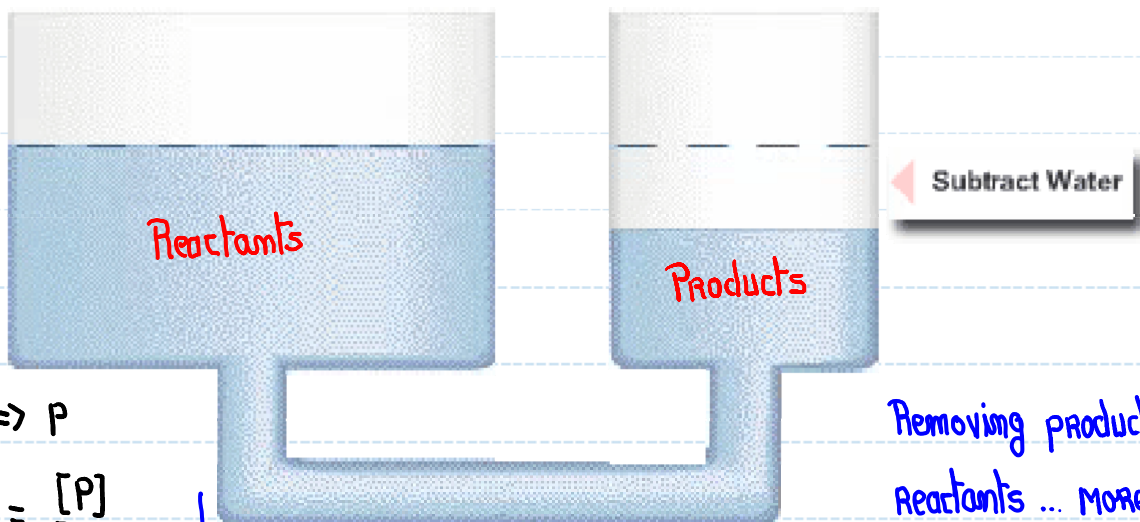
flow towards reactants.

Adding P changes the value of $\frac{[P]}{[R]}$ ... Reaction wants to return to the original value of $\frac{[P]}{[R]}$ ... ie back to K.

What Is Le Chatelier's Principle

Removing Products .

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



A ⇐⇒ P

$K = \frac{[P]}{[R]}$

↳ Flow towards products.

Removing products causes a shift towards reactants ... more reactants produced.

Removing P changes the value of $\frac{[P]}{[R]}$ ... Reaction wants to return to the original value of $\frac{[P]}{[R]}$ ... ie back to K.

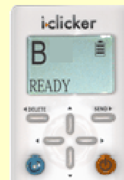
7.7 What Is Le Chatelier's Principle
Adding/Removing Reactant and Products

HCN is a weak acid –

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

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

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



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

↳ Remove H_3O^+ ... Removing P

↳ shift towards P ... $[CN^-]\uparrow$

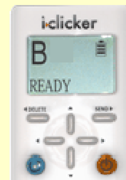
Adding/Removing Reactant and Products

HCN is a weak acid –

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

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

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



At first glance you might think c), since OH^- is neither a product or a reactant ... but!

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

$$+ OH^- = 2\,H_2O(l)$$

Adding OH^- removes H_3O^+, a product.

shift towards products ... $[CN^-]\uparrow$

7.7 What Is Le Chatelier's Principle

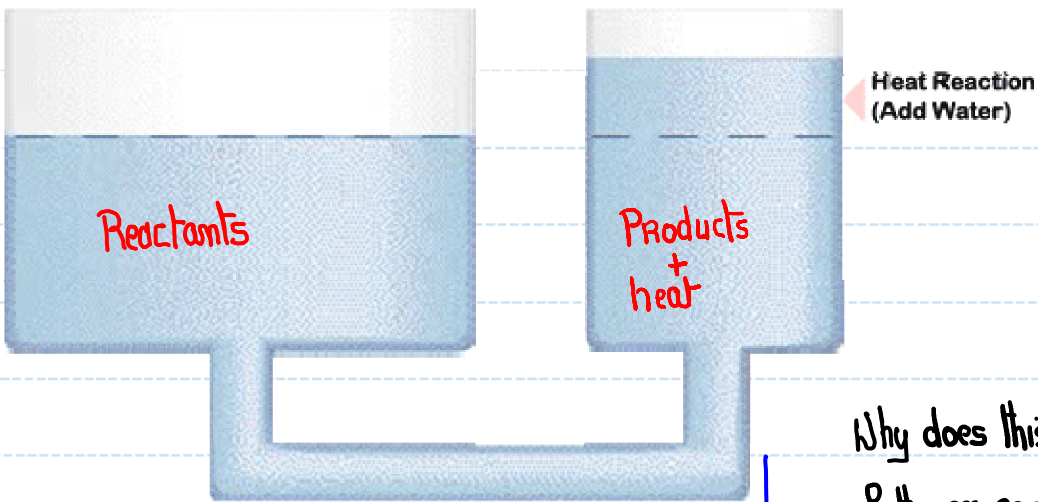
Changing the Temperature – Exothermic

↳ Reaction that gives off heat.

'Heat is a product'

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

R ⇌ P + heat



Shift towards Reactants

If we heat this reaction ... the equivalent of adding a product ... Reaction shifts towards Reactants.

Why does this happen? $K = \frac{[P]}{[R]}$. Heat is not part of the expression! The water tank does correctly predict what happens. [R]↑, [P]↓ thus K must ↓

K is dependant on T, in an endothermic reaction as T↑, K↓ ... conversely T↓, K↑

7.7 What Is Le Chatelier's Principle

Changing the Temperature – Endothermic

↳ Reaction that requires heat.
'Heat is a Reactant'

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

R + heat ⇌ P

If we heat this reaction ... the equivalent of adding a reactant ... reaction shifts towards products.

↳ Shift towards products.

Why does this happen? $K = \frac{[P]}{[R]}$. Heat is not part of the expression! The water tank does correctly predict what happens. [P]↑, [R]↓, thus K must ↑.

K is dependant on T, in an exothermic reaction as T↑, K↑ — conversely if T↓, K↓

7.7 What Is Le Chatelier's Principle

Changing the Temperature – Summary

Action	Equilibrium Shift	Why
1) Exothermic: $R \rightleftharpoons P + heat$		
Add heat (heat the RXN)	Shift towards reactants	K↓
Remove heat (cool the RXN)	Shift towards products	K↑
2) Endothermic: $R + heat \rightleftharpoons P$		
Add heat (heat the RXN)	Shift towards products	K↑
Remove heat (cool the RXN)	Shift towards reactants	K↓

1) Adding and removing reactants and products does not change the value of K.
2) Heating or cooling a reaction, changes the value of K. Whether K increases or decreases depends on whether the reaction is exothermic or endothermic.

7.7 What Is Le Chatelier's Principle

Changing the Temperature

The production of ammonia is an exothermic process –

$$N_2(g) + 3\,H_2(g) \Leftrightarrow 2\,NH_3(g)$$

To maximize the $[NH_3]$ at equilibrium it is best to

a) Heat the reaction
b) Cool the reaction ✓
c) Leave it as is!

$$N_2(g) + 3\,H_2(g) \Leftrightarrow 2\,NH_3(g) + heat$$

↳ Want a shift towards products.

Cool the reaction ... Removes heat ...

Removes a product ... shift towards

product ... $[NH_3(g)]\uparrow$