CHEMISTRY 12 – UNIT II – EQUILIBRIUM STUDY CARDS

E: Dynamic Equilibrium (Le Chatelier's Principle) *It is expected that students will be able to…*

E1: Le Chatelier's Principle - *define*

1) The oxidation of ammonia is a reversible exothermic reaction that proceeds as follows:

$$4NH_{3(g)} + 5O_{2(g)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$$

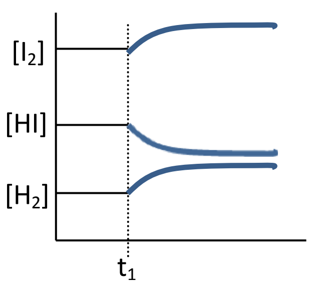
Le Chatelier's principle allows us to predict the changes that occur in an equilibrium reaction to compensate for any stress that is placed upon the system. For each situation described in the table, use **arrows** to show an **increase** or **decrease** in the concentration that is expected. *Remember, you are describing the NET effect on the concentration!*

Component	Stress	Equilibrium Concentrations			
		$[NH_3]$	$[O_2]$	$[NO]$	$[H_2O]$
NH_3	addition	⇧	⇩	⇧	⇧
	removal	⇩	⇧	⇩	⇩
NO	addition	⇧	⇧	⇧	⇩
	removal	⇩	⇩	⇩	⇧
Increases in temperature		⇧	⇧	⇩	⇩
Decrease in temperature		⇩	⇩	⇧	⇧
Increase in pressure		⇧	⇧	⇩	⇩
Decrease in pressure		⇩	⇩	⇧	⇧
Addition of a catalyst		-	-	-	-

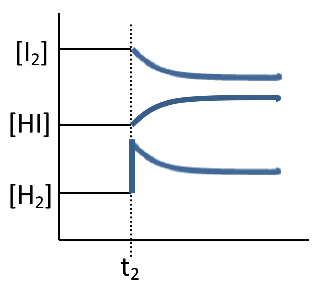
E2: Expressing Le Chatelier's Principle in graph form ([conc] vs time)

1) Using the following system at equilibrium: $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$; $\Delta H = 52kJ$
When each of the following stresses below are applied to the equilibrium, show the effect on the graph given at **time - t**:

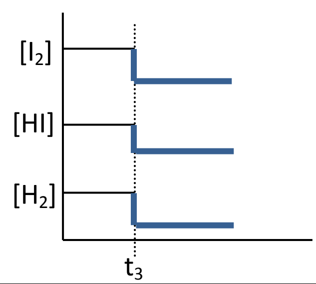
a) t_1 – the temperature is increased



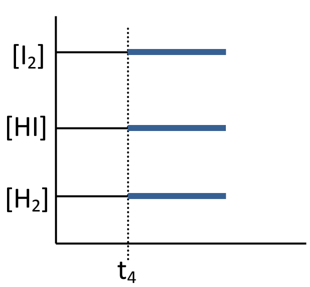
b) t_2 – some hydrogen gas is added



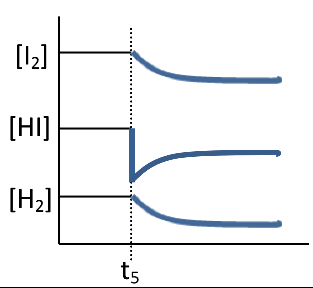
c) t_3 – the volume of the reaction vial is increased



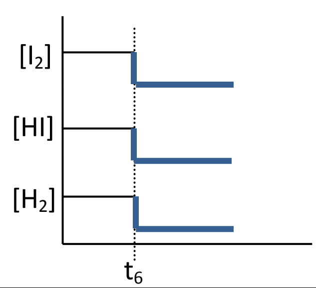
d) t_4 – an inhibitor is added



e) t_5 – some HI is removed from the system



f) t_6 – the pressure is decreased



E3: Collision Theory and Le Chatelier's Principle

1) Using the system in equilibrium: $H_{2(g)}$ + $I_{2(g)}$ $\rightleftharpoons$ $2HI_{(g)}$; ΔH = -52kJ . Using the **collision theory**, explain why the shift in equilibrium will be **favouring** the **forward reaction** as a certain amount of **iodine gas** is injected into the closed system.

When iodine gas is added to the reaction vessel, the concentration of I2 increases. This results in more frequent collisions between H2 and I2 causing the forward reaction to speed up. The forward reaction rate is greater than the reverse rate therefore hydrogen iodide is being produced more quickly than it is being consumed resulting in a shift right, to the products.

E4: Describing Reaction Rates and Le Chatelier's Principle

1) Consider the following equilibrium system: $SO_{3(g)}$ + $NO_{(g)}$ $\leftrightarrow$ $NO_{2(g)}$ + $SO_{2(g)}$ + 37kJ

a) Describe what happens to the forward and reverse reaction rate **immediately** after adding more $SO_{3(g)}$

Forward reaction rate = **INCREASES**	Reverse reaction rate = **Stays the same**

b) Describe what happens to the forward and reverse reaction rate **immediately** after removing some $NO_{2(g)}$

Forward reaction rate = **Stays the same**	Reverse reaction rate = **DECREASES**

c) Describe what happens to the forward and reverse reaction rate **immediately** after increasing the temperature

Forward reaction rate = **INCREASES**	Reverse reaction rate = **INCREASES**

d) Describe what happens to the forward and reverse reaction rate **immediately** after adding a catalyst

Forward reaction rate = **INCREASES**	Reverse reaction rate = **INCREASES**

E5: Applications of Le Chatelier's Principle

1) Ammonia (NH_3) can easily be made by combining nitrogen gas and gaseous water in the equation:

__2__ $N_{2(g)}$ + __6__ $H_2O_{(g)}$ ←→ __4__ $NH_{3(g)}$ + __3__ $O_{2(g)}$; ΔH = - 33.8 kJ

Don't forget to balance the equation!

a) Describe all the ways that you can get the highest yield of ammonia.

high pressure, maintain high concentrations of reactants (N_2 and H_2O), remove ammonia from system, low temperature

b) Look back at your answers to **a)**, is there one effect that you would probably NOT want to use for producing more ammonia? *Hint: think about reaction kinetics!!!*

A lower temperature would slow down the reaction, not ideal for an industrial process…takes too long to produce a significant amount of product.

Equilibrium Multiple Choice Practice Q's

1. Consider the following equilibrium: $N_{2(g)} + O_{2(g)} \leftrightarrow 2NO_{(g)}$
   Nitrogen gas and oxygen gas react when placed in a closed container. As the reaction proceeds towards equilibrium, the rate of the reverse reaction

   A. increases as the concentration of products decreases
   B. decreases as the concentration of products decreases
   C. increases as the concentration of products increases
   D. decreases as the concentration of products increases

2. Consider the following:

   I. Constant Temperature
   II. Equal concentrations of reactants and products
   III. Equal rates of forward and reverse reactions

   A system at equilibrium must have:
   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

3. Consider the following equilibrium: $Cl_2O_{7(g)} + 8H_{2(g)} \leftrightarrow 2HCl_{(g)} + 7H_2O_{(g)}$
   Which of the following would increase the number of moles of HCl?

   A. increase $[H_2O]$
   B. increase $[Cl_2O_7]$
   C. Increase total pressure
   D. Increase volume of the system

4. Consider the following equilibrium: $2NO_{g)} + Cl_{g)} \leftrightarrow 2NOCl_{(g)}$
   At constant temperature and volume, Cl_2 is added to the above equilibrium system.
   As equilibrium reestablishes, the

   A. [NOCl] will decrease
   B. the temperature increases
   C. [NO] will increase
   D. [NOCl] will increase

5. A 1.00L flask contains a gaseous equilibrium system: $\mathbf{A_{(g} \leftrightarrow B_{(g)}}$**.** The addition of reactants to this flask results in a

   A. shift to the left and decrease in the concentration of products
   B. shift to the left and increase in the concentration of products
   C. shift to the right and decrease in the concentration of reactants
   D. shift to the right and increase in the concentration of reactants

6. When the temperature of an equilibrium system is increased, the equilibrium always shifts to favor the

   A. exothermic reaction
   B. endothermic reaction
   C. formation of products
   D. formation of reactants

7. An equilibrium system shifts left when the

   A. rate of the forward reaction is equal to the rate of the reverse reaction
   B. rate of the forward reaction is less than the rate of the reverse reaction
   C. rate of the forward reaction is greater than the rate of the reverse reaction
   D. rate of the forward reaction and the rate of the reverse reaction are constant

8. In which of the following does entropy decrease?

   A. $NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$
   B. $4NO_{(g)} + 6H_2O_{(g)} \rightarrow 4NH_{3(g)} + O_{2(g)}$
   C. $2NaCHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$
   D. $CaCO_{3(s)} + HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

9. Consider the following equilibrium: $2NO_{2(g)} \leftrightarrow N_2O_{4(g)} + 59kJ$; For this reaction

   A. both minimum enthalpy and maximum entropy favour the products
   B. both minimum enthalpy and maximum entropy favour the reactants
   C. minimum enthalpy favours reactants and maximum entropy favours products
   D. minimum enthalpy favours products and maximum entropy favours reactants

10. Chemical systems move toward positions of

   A. minimum enthalpy and maximum entropy
   B. maximum enthalpy and minimum entropy
   C. minimum enthalpy and minimum entropy
   D. maximum enthalpy and maximum entropy

Answer Key:

1. C
2. B
3. B
4. D
5. C
6. B
7. B
8. B
9. D
10. A