Topic Six: Rates and Equilibrium

Lesson	Date	Lesson Type	Topic	Text Reference	Syllabus Reference
1	2/7	Theory	Revise Energy Changes and Reaction Rates	12.1-12.5 13.3-13.4	13.10-13.13
2	2/7	Theory	Revise Factors Affecting Reaction Rates	13.1-13.2	13.10-13.13
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3	21/7	Theory	Collision Theory	13.3-13.4	3.14-3.16
4	22/7	Theory	Collision Theory	13.3-13.4	3.14-3.16
5	23/7	Theory	Equilibrium	14.1	13.17-13.18
6	23/7	Theory	Equilibrium in Physical Systems	14.2	13.18, 13.21
7	25/7	Theory	Equilibrium Constants	14.3	13.19-13.20
8	28/7	Theory	Le Chatilier's Principle	14.4	3.21
9	29/7	Prac	Expt 37		3.L.1
10-11	30/7	Prac	Expt 38		3.L.2
12	1/8	Theory	Rates and Yield	14.4	3.20 c), 3.22
13	4/8	Theory	Contact and Haber Processes	14.5	3.23, 7.13
14	5/8		Revision		
15	6/8		Topic Test		

Energy Changes

- Use chapter 12 in your textbook to revise energy changes. Write brief notes and do review exercises and questions and problems.

Reaction Rates Revision

- *Answer the following questions using chapter 13 of your textbook as a reference.*

A. Reaction Rates

1. What are the two ways reaction rate can be determined?
2. From your answer to question 1, what are the two formulae that can be used to determine reaction rate?
3. List 5 ways that reaction rate can be increased.

B. Collision Theory

1. What are the two things required for a collision to lead to a chemical reaction?
2. What is activation energy?
3. Why doesn't methane spontaneously combust, despite the abundance of oxygen in the air?
4. In terms of the collision theory, explain each of the 5 ways that reaction rate is increased

C. Energy Profile Diagrams

1. Draw an energy profile diagram for an endothermic and an exothermic reaction and explain:
    a) What is happening at each stage of the reaction
    b) The significance of E_a and ΔH for each
2. Do review exercises and questions and problems.

Equilibrium

Many reactions are _____. As the forward reaction proceeds, the concentration of _____ builds up which increases the rate of the _____ reaction. The rate of the forward reaction decreases as the concentration of _____ decreases.

Once the forward and reverse rates are _____, and the concentrations of the products and reactants are _____, a reaction is said to be in _____.

Note: The concentrations of the reactants and the products are **not** necessarily equal.

A graph showing a reaction that goes to completion (all reactants used up).

Draw graphs to show an equilibrium situation where:

a) The concentration of reactants is greater than that of products,
b) The concentration of products is greater than the concentration of reactants.

Chemical equilibrium exists only is a _____ system at _____ _____.

It is characterized by:

1.
2.

Double arrows are used to signify the equilibrium situation eg:

- Explain why an automatic swimming pool chlorinator that maintains a constant chlorine concentration in the water, is not a true equilibrium system.
- Write the equation for the equilibrium that exists between oxygen and ozone in the upper atmosphere.

Read Text 14.1 and 14.2
Do RE 14.1

Equilibrium in Physical Systems

Use your textbook to formulate notes based on the two questions below.

1. Give an example of a vapour equilibrium for a liquid in a closed system, and briefly describe what is happening in the system. Include what happens with a temperature change.

2. Give two different examples of solution equilibrium (one molecular and one ionic). Describe briefly for each what is happening in the system including what happens with a temperature change.

Do RE 14.2

Equilibrium Constants

The rate of a chemical reaction is _____ to the _____ of the reactants. In an equilibrium system, the rate of the _____ _____ is equal to the rate of the _____ _____.

The equilibrium constant (K) for the general equation:

$aA + bB \leftrightarrow cC + dD$

Is:

K =

Product concentrations are the numerator, and reactant concentrations are the denominator.

- Write the equilibrium constant expression for the production of ammonia from nitrogen and hydrogen.

- If the equilibrium constant for the formation of ammonia at 470^{o}C is 0.11, what is the equilibrium constant for the dissociation of ammonia into nitrogen and hydrogen?

Only the concentrations of species in the _____ phase or _____ are used.

The equilibrium constant is specific to a particular system and is constant for a _____.

The equilibrium constant gives an indication of the _____.

High values suggest that products are in _____ than the reactants ie. The equilibrium favors the _____.

- The K values for the ionisation of two weak acids are given:

  $CH_3COOH \leftrightarrow CH_3COO^- + H^+$ K = 1.8 x 10-5
  $HCN \leftrightarrow CN^- + H^+$ K = 6.2 x 10-10

- Which is the stronger acid?

The equilibrium constant does NOT give any information about the _____ of the reaction.

Read Text 14.3
Do RE 14.3

Le Chatilier's Principle

Le Chatelier's Principle can be stated as:

"When a change is made to a chemical system in equilibrium, the system will adjust in such a way as to partially counteract the change."

To illustrate this, we will look at the equilibrium of NO_2 and N_2O_4 gases (refer to Expt 37).

$$2\ NO_{2(g)} \leftrightarrow N_2O_{4(g)} \qquad \Delta H = -54\ kJ / mol$$

1. Temperature

The heat of reaction (ΔH) is required in order to _____ which way an equilibrium will shift after adding or subtracting _____.

Adding heat will favour the _____ reaction, in this case the _____ reaction. Taking heat out (cooling) will favour the _____ reaction.

Explain why this is the case in regards to Le Chatelier's principle.

Sketch a graph showing the concentrations of each gas when N_2O_4 is left in a closed container, and then after the mixture is heated. (NB The concentration of NO_2 is slightly higher than N_2O_4 when equilibrium has been reached at room temperature). Describe the observations at each point.

2. Pressure

If the pressure of a system at equilibrium is _____ (or the volume _____), this will favour the formation of _____ molecules. Explain why this is the case in regards to Le Chatelier's principle.

Sketch a graph as described previously, but instead showing the change when the pressure is increased after the system has reached equilibrium.

- What will happen if there are the same number of molecules on either side of the reaction?

3. Concentration Change

Describe the effect of adding the following to the equilibrium system shown below:

$$H_{2(g)} + I_{2(g)} \leftrightarrow 2\ HI_{(g)}$$

(i) Adding HI (ii) Adding I_2

For reactions that involve more than _____ species, the amount of solid or liquid added does not effect the _____, but changes in concentration of a _____ substance or amount of _____ does affect the equilibrium.

Refer to Expt 38 to see the affect of adding acid or base to some equilibrium reactions.

Exercise: Predict the effect on the equilibrium and concentration of all species in regards to the equilibrium of silver solid and iron (III) ions with silver ions and iron (II) ions when:

(i) Iron (III) chloride is added to the mixture

(ii) Iron (II) sulfate is added to the mixture

(iii) A strip of silver is added to the mixture

(iv) Silver nitrate is added to the mixture

(v) Something is added to the mixture that reacts with/absorbs the Fe (II) ions.

4. Catalyst

Explain why the addition of a catalyst will not affect a system already at equilibrium.

Read Text 14.4
Do R.E.14.4

Industrial Applications of Equilibrium

Industrial processes that involve chemical equilibrium need to maximise _____ _____ _____, but minimise the _____.

The Haber Process

This is the process for the manufacture of _____. Ammonia gas is an important substance used in the production of _____. This process is named after Fritz Haber, a German Chemist who won a nobel prize for his work in 1918.

The reaction is as follows:

The conditions of the reaction need to be carefully controlled in order to ensure that maximum _____ is attained for minimum _____.

1. **Temperature:** The reaction is exothermic, which means that _____ temperatures favour a high yield. However, this means that the rate of attainment of ammonia is quite slow. The temperature used is about _____, this ensures an acceptable _____ for a moderate _____.

2. **Pressure:** _____ pressures increase the reaction rate by increasing the _____ _____ _____. The yield is also increased as an increase in pressure shifts the equilibrium to the _____. High pressures of _____ atmospheres are used.

3. **Catalyst:** The equilibrium itself is not affected by the addition of a catalyst, however the rate of attainment of equilibrium is significantly increased. In light of this, an _____ catalyst is used along with tiny amounts of _____ and _____.

Yields of 30-40% are achieved under the above conditions. The ammonia is condensed under pressure and then separated. This removal of the ammonia also assists the forward reaction. How?

Approximately 1000 tonnes of ammonia per day can be produced. The heat released in this _____ reaction maintains the catalyst temperature. Large amounts of energy are required for the compression of the ammonia gas. This energy is obtained from the reactions used to generate _____.

** Use the table below to summarise the essential considerations of the Haber Process.

	Maximum Rate	Maximum Yield	Actual Conditions
Temperature			
Pressure			
Catalyst			
Product Removal			
Reactant Concentration			

The Contact Process

This process is almost exclusively used for the manufacture of _____.

The first step in this process involves the production of sulfur dioxide by burning liquid sulfur according the following reaction:

The sulfur dioxide is then oxidised to sulfur trioxide in the following reaction:

1. **Temperature:** **T**his reaction is _____, and so _____ temperatures favour a high yield, but this results in a slow reaction rate. The actual process is carried out at _____. At this temperature, the reaction occurs rapidly but does not go to completion. The yield is _____ by cooling the gas mixture to _____ and passing it over additional amounts of _____.

2. **Pressure:** High pressures would increase both rate and yield, but the temperature and catalyst adequately control these. Therefore the pressure is kept at approximately _____.

3. **Catalyst:** _____ is used. This provides a satisfactory rate of reaction, but does not affect the equilibrium yield.

The sulfur trioxide is then absorbed by 98% sulfuric acid to produce _____, which is effectively 99.5% sulfuric acid:

The oleum is diluted with water to produce 98% sulfuric acid:

This is the concentration of commercial concentrated sulfuric acid, which corresponds to approximately 18M.

Note: The sulfur trioxide cannot be directly added to water, as it is too difficult to handle.

** Use the table below to summarise the essential considerations of the Contact Process.

	Maximum Rate	Maximum Yield	Actual Conditions
Temperature			
Pressure			
Catalyst			
Product Removal			
Reactant Concentration			

* Read pages 291 – 295
* Do exercise 14.5

* Read pages 345-349
* Do exercise 16.4, Question 4