Louisiana Tech University, Chemistry 102 POGIL (Process Oriented Guided Inquiry Learning) Exercises on Chapter 13 (1). Chemical Kinetics 1

Why?

Chemical kinetics is important because it provides new models, concepts, and parameters to study the rates of chemical reactions. The models, concepts, and parameters that describe chemical reaction kinetics provide chemists, chemical engineers and biologists with tools to better understand and describe chemical processes such as industrial chemical production, stratospheric ozone decomposition, food decomposition, microorganism growth, and the complex chemistry of biological systems. These models can also be used in the design or modification of chemical reactors to optimize product yield, more efficiently separate products, and eliminate environmentally harmful by-products. For, example, when catalytic cracking of heavy hydrocarbons into gasoline and light gas is carried out, kinetic models can be used to find the temperature and pressure at which the highest yield of heavy hydrocarbons into gasoline will take place.

Using the concepts of chemical kinetics we can find time-how long it will take-to complete a reaction, the effect of temperature on the rate, other substances (catalysts or inhibitors) on the reactions. Catalysts are substances that increase the rates of chemical reactions without themselves being consumed chemically. Catalysts in biological systems are called enzymes.

Learning Objectives

Understand reaction rates and rate laws

1. Define reaction rate and calculate average rates (Section 13. 1).
2. Describe the effect reactant concentrations have on reaction rate, and determine rate laws and rate constants from initial rates (Section 13.2).
3. Describe how chemical reactions are affected by the following:

a) Temperature b) Concentration c) Catalysts d) Particle size of solid reactants

Success Criteria

- **Write an expressions for rate of decomposition of reactants, rate of formation of products and the rate of a reaction from either reactants or products**
- **Graph the concentration of reactants and products as the reaction progress**

Resources

Chemistry: The Molecular Science 1st Edition, John W. Moore, Conrad L. Stanitski and Peter C. Jurs.

Prerequisites

Chemical equations, stiochiometric coefficients, Concentration (molarity= mole/ L; $moldm^{-3}$; [reactant] or [products])

Reactant - a substance that is consumed by a chemical reaction

Product - a substance that is produced by a chemical reaction.

New Concepts

Reaction Rates

Chemical reaction rates is equal to change in concentration of reactants/products per unit time divided by the stoichiometric coefficient if it is not equal to 1.

For changes in amounts of reactants and products, the units can be mol/s and time is in seconds (s) or min.. For changes in concentrations per time, the units can be one of mol/(L s).

$$2\ A \text{ ------> } 3\ B$$

Rate of disappearance:

Rate of decomposition (disappearance) of reactants:

$$\text{Rate of disappearance} = -\frac{\Delta[A]}{\Delta t}$$

rate of formation (appearance) of products:

$$\text{Rate of appearance} = \frac{\Delta[B]}{\Delta t}$$

$\Delta[A] = [A]_f - [A]_i$; $[A]_f$= final concentration; $[A]_i$ = initial concentration

$\Delta t = t_f - t_i$; t_f= final time; t_i= initial time

Note that reaction rate based on reactants have a negative (-) sign because $[A]_f - [A]_i$ is always will be negative for reactants i.e. final concentrations will be always lower than initial concentration.

The rate of a reaction is not equal to the rate of disappearance of reactants or appearance of products if the stoichiometric coefficients of the reactants and products are not equal to one (1). The rate of disappearance of reactants or appearance of products has to be divided by the stoichiometric coefficient to obtain the rate of reaction.

Rate of reaction based on reactants:

$$\text{Rate of reaction} = -\frac{1}{2}\frac{\Delta[A]}{\Delta t}$$

Rate based on products:

$$\textbf{Rate of reaction} = \frac{1}{3}\frac{\Delta[B]}{\Delta t}$$

Rate of reaction

$$\text{Rate of reaction} = -\frac{1}{2}\frac{\Delta[A]}{\Delta t} = \frac{1}{3}\frac{\Delta[B]}{\Delta t}$$

The rate reaction = change in concentration of reactants/products per unit time divided by the stoichimetric coefficient if it is not equal to 1.

Factors that are affecting rates of chemical reactions

Rates of chemical reactions are affected by the following:

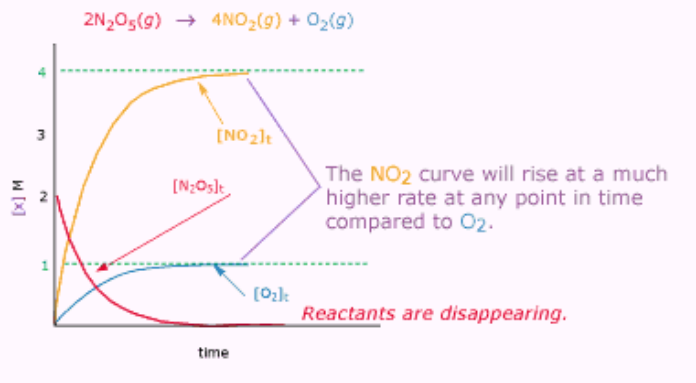
a) Temperature

b) Concentration

c) Catalysts

d) Particle size of solid reactants

Graphing concentrations of reactants and products



$2\ N_2O_5$ ----> $4\ NO_2 + O_2$

- Initial concentration: beginning concentration at time 0.
- Initial rate is obtained by the intercept to the like at time 0.
- Average rate is obtained by the change in concentration (y_2-y_1) at time t_1 and t_2 (t_2-t_1) and the slope of the of the curve at these points ($\Delta y/\Delta x$)
- Instantaneous rate is obtained by the change in concentration (y_2-y_1) at time t_1 and t_2 when t_2-t_1 approaches 0 and the slope of the of the curve at the point ($\delta y/\delta x$)

Chapter 13. Group Activity 1. **Key Questions** (relatively simple to answer using the Focus Information)

1) What is the rate of a chemical reaction? (general and in words)

2) Answer the following Given the reaction:

$2\ N_2O_5 \text{ ----> } 4\ NO_2 + O_2$

a) What's the rate of disappearance (decomposition) of N_2O_5? (equation)

b) What are the rates of appearance of NO_2 and O_2? (equations)

c) What are the rates of reaction based on N_2O_5, NO_2 , and O_2? (equations)

d) Are the rates of decomposition based on N_2O_5, and formation based on , NO_2 , and O_2 equal? (explain)

d) Are the rate of reaction based on N_2O_5, NO_2 , and O_2 equal? (equations and explain)

<u>Graphing the concentration of reactants and products</u>

3) What are the differences between average and instantaneous reaction rates? Refer to graph in new concepts.

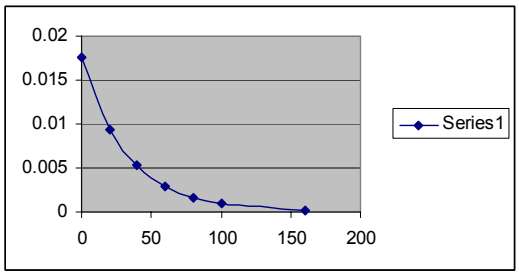
4) Why is instantaneous rates of N_2O_5 and NO_2 are negative and positive respectively?

5) At what time the reaction is complete?

6) The reaction: $2\ N_2O_5 \text{ ---> } 4\ NO_2 + O_2$

The table shows the concentration of N_2O_5 as a function of time (@45^0C);

Time / min	$[N_2O_5]$ / moldm^{-3}
0	0.01756
20	0.00933
40	0.00531
60	0.00295
80	0.00167
100	0.00094
160	0.00014



Plot this data. N2O5data.xls

What are the rates of reaction between 0-20, 20-40, 40-60, 60-80 min intervals?

Rate = 2.06 x 10^{-4} moldm^{-3}min^{-1}. That is the change in concentration from 0 to 20 minutes / 20 minutes. Now you try for the other times: (you should get 1.01 x 10^{-4}, moldm^{-3}min^{-1} etc.).

7) How does reaction rate vary with time? Consider the decomposition of N_2O_5.

8) What are the factors that affect rates of a chemical reactions?

9) In the graph below what does it mean by kinetic and equilibrium regions?