Chemistry Lesson to Prepare
for UIL Science Contest

Lesson Plan Title: Chemical Kinetics: A Laboratory Investigation of Rate Laws

Goal of Lesson: To use actual laboratory data to determine a rate law, rate constant, and activation energy through application of the related mathematical relationships studied in class.

Subject/Grade Level: chemistry (preAP/AP)

TEKS Addressed:

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

> (A) demonstrate safe practices during laboratory and field investigations, including the appropriate use of safety showers, eyewash fountains, safety goggles, and fire extinguishers;
>
> (B) know specific hazards of chemical substances such as flammability, corrosiveness, and radioactivity as summarized on the Material Safety Data Sheets (MSDS); and
>
> (C) demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses scientific methods to solve investigative questions. The student is expected to:

> (E) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology, including graphing calculators, computers and probes, sufficient scientific glassware such as beakers, Erlenmeyer flasks, pipettes, graduated cylinders, volumetric flasks, safety goggles, and burettes, electronic balances, and an adequate supply of consumable chemicals;
>
> (F) collect data and make measurements with accuracy and precision;
>
> (G) express and manipulate chemical quantities using scientific conventions and mathematical procedures, including dimensional analysis, scientific notation, and significant figures;
>
> (H) organize, analyze, evaluate, make inferences, and predict trends from data; and
>
> (I) communicate valid conclusions supported by the data through methods such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports.

(10) Science concepts. The student understands and can apply the factors that influence the behavior of solutions. The student is expected to:

> (C) calculate the concentration of solutions in units of molarity;
>
> (D) use molarity to calculate the dilutions of solutions.

Overview of Lesson:

Students will determine the rate law, rate constant, and activation energy for the iodination of acetone through laboratory experiment.

Materials Needed:

1. Laboratory supplies for the attached investigation
2. Scientific or graphing calculator
3. Textbook or internet resources on chemical kinetics

Procedures and Activities:

The teacher will -

- present a lesson cycle on chemical kinetics including rate laws, orders of reaction, rate constants, and the Arrhenius equation prior to this activity.
- provide students problem solving practice and feedback on chemical kinetics.
- prepare necessary solutions and equipment for the lab procedure. (The iodination of acetone lab is found in many college lab manuals as well as on numerous internet sites. One version of this lab is attached.)
- review students on the concept of molarity and finding molarity by dilution as this is necessary for determining the starting concentrations of reactants in this experiment.

Independent Practice:

The student will –

- complete the laboratory investigation
- prepare a formal lab report

Assessment:

Teacher evaluation of lab report.

IODINATION OF ACETONE

The rate at which a chemical reaction occurs depends on several factors: the nature of the reaction, the concentrations of the reactants, the temperature, the surface area (particle size) of solid reactants, and the presence of possible catalysts or inhibitors.

This experiment involves a study of the kinetics of the reaction between iodine and acetone:

$$CH_3COCH_3 + I_2 \rightarrow CH_3COCH_2I + H^+ + I^-$$

The reaction rate is rather slow for a pH range of 4 to 8, but the rate is rather rapid for a pH less than 3 or greater than 8. The rate of this reaction is therefore dependent on the concentration of hydrogen ion in the solution as well as presumably on the concentration of the two reactants, acetone and iodine. The generic rate law for this reaction can be written:

$$\text{Rate} = k[\text{acetone}]^m[I_2]^n[H^+]^p$$

Where m, n, and p are the orders of the reaction with respect to acetone, iodine, and hydrogen ion, respectively, and k is the rate constant for the reaction.

This reaction is rather easy to study because the reactant iodine has a distinctive pigment while the iodide ion produced is colorless. The rate of this reaction can be expressed as the change in the concentration of iodine over time, or simply, the starting concentration of iodine in the solution divided by the amount of time it takes for the iodine to “disappear” and the solution turn colorless. It is also known that the rate is independent of the concentration of iodine as long as iodine is present, or zero order in iodine.

The procedure is designed to have iodine as a limiting reactant, with both the hydrogen ion and the acetone at much higher concentrations so that their own concentrations do not change appreciably during the course of the reaction. The rate of the reaction will then be:

$$\text{rate} = \frac{-\Delta[I_2]}{\Delta t} = \frac{[I_2]_0}{t}$$

The orders of reaction with respect to hydrogen ion and acetone can be analyzed by varying their concentrations and determining the rate of reaction. In a second part of the experiment, the reactant temperature will be changed while keeping the reactant concentrations constant. Measuring the rate will then permit calculation of the activation energy of the reaction using the Arrhenius equation.

EXPERIMENTAL PROCEDURE:

Be sure to wear apron and safety goggles throughout the experiment and follow all disposal procedures set by your instructor.

A. <u>Determine the rate law</u>

Using either a graduated cylinder or measuring pipet, accurately measure out 10.0 mL of 4.0 M acetone into a clean, dry 100-mL beaker. Using a different graduated cylinder or pipet, measure out 10.0 mL of 1.0 M HCl and add it to the acetone in the beaker. Add 20.0 mL of distilled water to the beaker and mix.

Using a different graduated cylinder or pipet, measure out 10.0 mL of the 0.005 M I_2 solution. Have a stopwatch ready and begin timing as soon as the iodine solution is added to the 100-mL beaker. Quickly swirl the solution to mix the reactants. The mixture will appear yellow due to the iodine present. The color will fade as the iodine is reacting and becoming iodide ion. Stop timing when the color of the iodine just disappears. Repeat the experiment.

Perform the experiment three more times (two trials for each), following the chart provided in data table A. Note that each experiment has varying volumes of reactants.

Data Table A

Experiment	4.0 M acetone (mL)	1.0 M HCl (mL)	0.0050 M iodine (mL)	Distilled water (mL)	Time – trial A (s)	Time – trial B (s)	Average Time (s)
1	10.0	10.0	10.0	20.0			
2	20.0	10.0	10.0	10.0			
3	10.0	20.0	10.0	10.0			
4	10.0	10.0	20.0	10.0			

Calculations Part A

Find the concentration of each reactant for each experiment. Remember that the total volume of the reaction mixture is 50.0 mL.

Find the rate of each experiment using $[I_2]_o/t$.

Determine the rate law for the reaction.

B. <u>Determine the Activation Energy</u>

Using clean graduated cylinders or pipets for each solution, combine 10.0 mL distilled water, 5.0 mL 4.0 M acetone, and 5.0 mL 1.0 M HCl in a large test tube. Measure out 5.0 mL of 0.005 M I_2 into a separate test tube. Place a thermometer into the large test tube measure the temperature of the reaction mixture. Prepare a stop watch and begin timing when the iodine is added to the large test tube reaction mixture. Record the time when the color just disappears.

Repeat the process an additional temperature by placing the test tubes into a water bath and letting them reach the desired temperature before starting the reaction. (Recommend about 15 C to about 35 C range)

Data Table B

Temperature	Time (s)

Calculations Part B

Find the concentration of each reactant for this experiment. Remember that the total volume of the reaction mixture is 25.0 mL and that the concentrations are constant for both temperatures.

Find the rate of each experiment using $[I_2]_o/t$. (The rates should be different for each temperature.)

Using the rate law determined in part A, determine the rate constant (k) for each temperature.

Determine the activation energy using the Arrhenius Equation.

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Lesson Plan Title: Modeling Molecular Geometry

Goal of Lesson: To apply the VSEPR theory of molecular geometry.

Subject/Grade Level: chemistry (esp. Pre-AP & AP)

TEKS Addressed:

(6) Science concepts. The student knows and understands the historical development of atomic theory. The student is expected to: (E) express the arrangement of electrons in atoms through electron configurations and Lewis valence electron dot structures.

(7) Science concepts. The student knows how atoms form ionic, metallic, and covalent bonds. The student is expected to: (E) predict molecular structure for molecules with linear, trigonal planar, or tetrahedral electron pair geometries using Valence Shell Electron Pair Repulsion (VSEPR) theory.

Overview of Lesson:

The student will construct a model of a molecule using the VSEPR theory to determine correct bond angles about each atom.

Materials Needed:

1. Textbook or internet resources to select appropriate molecules to build as well as locate information on the VSEPR theory.
2. Materials to build models such as pipe cleaners, toothpicks, Styrofoam balls, molecular model kits, etc.

Procedures and Activities:

The teacher will -

- present a lesson cycle on VSEPR theory including electronic and molecular geometry, bond types (sigma and pi), predicted bond angles, and hybridization.
- provide students practice and feedback on VSEPR theory application.
- select a molecule for each student (or student group) to build.
- outline the required elements for each model and provide an appropriate rubric for assessment.

Independent Practice:

The student will –

- design and build a three-dimensional model of a molecule assigned by the instructor using the VSEPR theory to demonstrate correct bond angles between all atoms in the molecule.
- provide a key for the model that outlines the type of bonds, predicted bond angles, hybridization of each atom, and the electronic geometry about each atom of the molecule.

Assessment:

Teacher evaluation of each model and key using a rubric. (Sample rubric attached)

Modeling Molecular Geometry Name ______________________

Molecule name (3 pt)	Chemical formula (3 pt)	Structural formula (3 pt)

MODEL	3 pt	2 pt	1 pt	0 pt
Overall structure of model	All atoms in molecule are correctly connected to each other	Only one error in the correct connection of atoms	Two errors in the connection of atoms	More than two errors connecting atoms
Overall appearance of model	Model is neat, all atoms are clearly and correctly identified as to element type and model is structurally sound	Atoms are clearly labeled as to element type but lacks some neatness	Atoms are mostly labeled and/or model has significant weakness and is not neatly done	Atoms are not labeled correctly
VSEPR	All bond angles used in model are correct	One error in bond angle	Two errors in bond angle	More than two errors in bond angle

KEY	3 pt	2 pt	1 pt	0 pt
Bond type	All bonds correctly identified as sigma or pi	One error in bond type	Two errors in bond type	More than two errors in bond type
Hybridization	All atoms correctly identified as to type of hybridization	One error in hybridization	Two errors in hybridization	More than two errors in hybridization
Electronic Geometry	All atoms correctly identified as to type of structural geometry	One error	Two errors	More than two errors
Bond Angles	All bond angles correctly identified	One error	Two errors	More than two errors