Research Experience for Teachers (RET)
Center for Pre-College Programs
New Jersey Institute of Technology

MODULE

MODULE TOPIC: Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

RATIONALE:
Students should develop an understanding of what constitutes good evidence, be able to apply mathematical models to laboratory situations, and analyze effects of chemical reactions.

STANDARD(S) & INDICATOR(S):
(Note: This section should include all standards listed in the lessons.)
5.1.8.B1. Identify questions and make predictions that can be addressed by conducting investigations.
5.1.8.B2. Design and conduct investigations incorporating the use of a control.
5.1.8.B3. Collect, organize, and interpret the data that result from experiments.
5.6.12.B1. Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another and that the rate is affected by nature of reactants, concentration, pressure, temperature, and the presence of a catalyst.

OBJECTIVES:
(Note: This section should include all objectives listed in the lessons.)
Students will be able to:
1. Demonstrate the ability to plan and prepare a laboratory experiment with minimal prompting.
2. Interpret laboratory data.
3. Predict the effect of new conditions on expected laboratory data byextrapolating their results.
4. Evaluate the results of their predictions based on new data.

MATERIALS:
Sieves, US Standard# 5 (4.00 mm) # 10 (2.00 mm), #20 (0.85 mm), #80 (0.18mm), #100 (0.150 mm)
Zinc. reagent, mossy, shot, 20 mesh, 30 mesh, powder
Hydrochloric acid, 2 M
Standard laboratory glassware, tubing , microscopes, timers, rulers and other supplies
Personal protective equipment--gloves, lab aprons, goggles
Mac laptops, Vernier Labpro interface, pressure sensor

LIST OF HANDOUTS (attach original copies of each handout-teacher & student edition)
Student Laboratory Instructions for Design a Laboratory Experiment
Instructor Notes for Design a Laboratory Experiment
Lesson Plan overview (this sheet)
Lesson #1 description
Lesson #2 description
Outline of Expectations (Rubric)

BACKGROUND INFORMATION:

Students have had instruction in reaction types and a moderate number of open-ended laboratories, but no instruction in kinetics. This laboratory exercise is designed to introduce students to the concept that reaction rates can be affected by concentration, or, in this case, particle size (actually, surface area) of a solid reactant.

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS):

Students will develop a procedure to analyze the effects of particle size on rate of production of hydrogen gas. Methodology is left up to the students, but could be increase in gas pressure of a sealed container, flow of gas from a reaction container via tubing into an inverted water-filled graduated cylinder immersed in a container of water, or other methods. Students will then undertake their investigation after instructor approval of procedures, analyze the data, and use it to predict the rate of gas production from an unused particle size fraction outside the range that they tested. They will then test their predictions, and analyze the results.

SAMPLE QUESTIONS TO ELICIT CLASS DISCUSSION (PRELAB QUESTIONS):

1. What conditions may affect how fast a reaction occurs?
2. Which can be used to analyze the rate of a reaction: disappearance of reactants, appearance of products, both, or neither? Why?
3. 3. If size of a solid reactant affects the rate of reaction, what features related to size might be most important in affecting the rate?

HOMEWORK ACITVITY/EXERCISES/PROBLEMS:

1. Laboratory project proposal
2. Laboratory report

PARAMETERS TO EVALUATE STUDENT WORK PRODUCTS:

1. Students will produce a complete laboratory proposal, with all required sections.
2. The laboratory proposal will be a plan that is technically feasible to accomplish safely within the timeframe of a laboratory period
3. Students will identify a complete list of materials and procedures to be used in the laboratory proposal.
4. All data will be included, and presented in tables and graphs.
5. Students will produce a complete laboratory report, with all required sections.
6. Analysis of first laboratory data and prediction of effects of size are mathematically correct.
7. Analysis of second laboratory data is complete and mathematically correct.

REFERENCES:

none

Lesson #1
Design a Laboratory Experiment

Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

DESCRIPTION:
Students will plan, then use their experimental plan to determine the effect of zinc particle sizes on the rate of the reaction.

STANDARD(S) & INDICATOR(S):
5.1.8.B2. Design and conduct investigations incorporating the use of a control.
5.1.8.B3. Collect, organize, and interpret the data that result from experiments.
5.6.12.B1. Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another and that the rate is affected by nature of reactants, concentration, pressure, temperature, and the presence of a catalyst.

LEARNING OBJECTIVES: Students will be able to:
1. Develop laboratory experiment to determine the relationship between particle size and reaction rate.
2. Determine the relationship between particle size and reaction rate. and formulate a mathematical relationship between input data and laboratory results.

MATERIALS:
Student Laboratory Instructions

PROCEDURE:
1. Students will be given Student Laboratory Instructions.
2. Students will be instructed in safety, proved an oral overview of their charge, and have questions about availability of materials, equipment and supplies answered.
3. Students will plan and prepare a laboratory experiment to determine the relationship between particle size and reaction rate. They will develop and turn in a laboratory proposal with all required sections.
4. Instructor will evaluate proposed plans, and inform students of areas to modify.
5. Students will perform their proposed laboratory experiments during the second laboratory session of lesson #1
6. Students will interpret their experiment and formulate a mathematical relationship between input data and laboratory results.
7. Students will submit an initial laboratory report with results and analysis of them.

ASSESSMENT:
Students should be able to prepare and use a plan to experimentally determine the effect of particle size on reaction rate. Evaluation will include whether all required sections of both the laboratory plan and initial laboratory report are submitted, whether student can develop and use a mathematical model of their results, and use the model to predict results under new conditions.

Lesson #2
Analysis of Predictions for Reaction Rate

Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

DESCRIPTION:
Students will predict the rate of reaction of new particle size(s) on reaction rate, and then test their prediction.

STANDARD(S) & INDICATOR(S):
5.1.8.B1. Identify questions and make predictions that can be addressed by conducting investigations.
5.1.8.B2. Design and conduct investigations incorporating the use of a control.
5.1.8.B3. Collect, organize, and interpret the data that result from experiments.
5.6.12.B1. Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another and that the rate is affected by nature of reactants, concentration, pressure, temperature, and the presence of a catalyst.

LEARNING OBJECTIVES: Students will be able to
1. Predict the effect of particle sizes on reaction rates.
2. Assess experimentally the effect of particle size on reaction rates.
3. Evaluate and revise their model of the relationship between particle size and reaction rate.

MATERIALS:
1. Student Laboratory Instructions
2. 2. Sieves, US Standard# 5 (4.00 mm) # 10 (2.00 mm), #20 (0.85 mm), #80 (0.18mm), #100 (0.150 mm)
3. Zinc. reagent, mossy, shot, 20 mesh, 30 mesh, powder
4. Hydrochloric acid, 2 M
5. Standard laboratory glassware, tubing , microscopes, timers, rulers and other supplies
6. Personal protective equipment--gloves, lab aprons, goggles
7. Mac laptops, Vernier Labpro interface, pressure sensor
8. Student initial laboratory report and predictions

PROCEDURE:
1. Students will predict the results of new particle size(s) on reaction rate(s).
2. Students will plan and prepare a new set of laboratory experiments to test their predictions.
3. Students will compare their new data to their predictions, evaluate their model of the relationship between particle size and reaction rate, and revise their model of the relationship if necessary.

ASSESSMENT:
1. Students should be able to predict the effect of specific particle sizes on reaction rates based on prior data.
2. Students should be able to prepare and use a laboratory experimental procedure to assess their predictions of the effect of physical parameters on reaction rate.
3. Students should be able to evaluate and revise models of the effects of particle sizes on reaction rates.

Student Laboratory Instructions, AP Chemistry,
Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

Your objective is to propose, plan, undertake, and analyze the results of a laboratory experiment.
You are a part of a research team that has been instructed to investigate the effects of particle size on reaction rate of a new metal, cniz, with hydrochloric acid, as part of a larger project that will require a yet-to-be-determined rate of production of hydrogen gas from the reaction of acid and the metal.
You will be responsible for investigating the reaction rate, as determined by hydrogen gas production. You have available as starting materials various size fractions of cniz metal. They are shot (larger particles and you are to determine average size), 2.0-4.0 mm, 0.85-2.00 mm, and 0.18-0.85 mm. You may assume that the particle distribution within each range is uniform, and take the average diameter as the value for that size fraction. You will analyze the reaction rates, develop a mathematical expression for the relationship between particle size and rate of gas generation, predict the rate that is expected for120-100 mesh size particles (0.15-0.18 mm), and then test your prediction. A comparison of your new results and you prediction should be made, evaluating any discrepancies between them. This is important because the final production rate may be close to, but outside the range that you analyzed.

You also have such supplies as standard laboratory glassware, tubing, microscopes, rulers, various Vernier sensors and interface, laptops, personal protective equipment such as gloves, lab aprons, and goggles, and common supplies found in a chemistry laboratory. Since you will be generating a flammable gas, consider safety in all that you do and heed the safety instructions given by your teacher.

Your team should submit a research proposal in time so that it can be approved or returned by your instructor and modified by the next laboratory period. It should be in the general format of a standard laboratory write-up. That is it should include title, purpose, procedure, materials, a blank table or tables for data, a description of how the results would be calculated, a description of how the validity of the results will be analyzed, and a discussion of possible error sources (not "human error" or "incorrect measurement"), and how each type of error would affect your results.

Outline of Expectations, Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

Criteria	**3**	**2**	**1**
Prelab questions correct	Three correct questions	Two correct questions	One or no correct questions
Prepare method to evaluate gas production	Method is fully functional without revision	Method needed minor revision	Method was incomplete or needed major revision
Proposed protocol was safe	Proposed protocol had no safety revisions required	Proposal had minor safety revisions required	Proposal had major potential problems
Laboratory proposal is complete	All required sections of proposal are complete	One section of proposal was missing or more than one section incomplete or needed minor revision	Two or more sections of proposal missing, or three or more sections incomplete or needed minor revision
Mathematical model properly predicts results	Mathematical model properly predicts results	Mathematical model inadequately predicts results	Mathematical model does not predict results
Procedures in both laboratories were safe	laboratories had no safety violations	laboratories had minor, technical safety violations	laboratories had major safety violations
Initial report is complete	All required sections of report are complete	One section of report was wrong or missing or more than one section wrong, incomplete or needed minor revision	Two or more sections of report wrong or missing, or three or more sections wrong, incomplete or needed minor revision
Final report is complete	All required sections of report are complete	One section of report was wrong or missing or more than one section wrong, incomplete or needed minor revision	Two or more sections of report wrong or missing, or three or more sections wrong, incomplete or needed minor revision
Laboratory procedures were successfully used	Proposed procedures were used without revision	Proposed procedures were used with minor revision, or parts were incorrectly done	Proposed procedures were used with major revision, or major errors in application

Instructor Notes Laboratory Instructions, AP Chemistry,
Effects of Particle Size on Reaction Rates (Design a Laboratory Experiment)

Students are given a problem to solve to analyze, and extrapolate data on the rate of reaction between different particle sizes of the unknown metal, cniz (zinc) and hydrochloric acid. The students will then test their prediction and analyze the experimental results in light of their prediction. Their instructions are minimal.

The module is divided into two lessons over three laboratory sessions: 1) planning the experiment and testing using their laboratory protocol and 2) predicting, testing and evaluating their prediction in light of the new data.

Since the laboratory is generating flammable gas, and some possible procedures have the potential to generate the gas under pressure, a careful review of safety procedures is in order. This should include an analysis of possible hazards in the proposed experiments and possible deviations of the proposed protocol because of student error. Use of a laboratory fume hood during gas generation is advised, as well as a limit on the quantities of materials available to generate hydrogen, whether or not a hood is used.

A thorough discussion of safety precautions should be given at the beginning of each laboratory session.

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