



H.O.T.

Science Labs
(High Order Thinking Science Labs)

CHEMISTRY



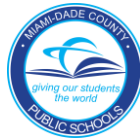
CURRICULUM AND INSTRUCTION

Division of Mathematics, Science, and Advanced Academic Programs

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Introduction

The purpose of this document is to provide Chemistry teachers with a list of basic laboratories and hands-on activities that students in a Chemistry class should experience. Each activity is aligned with the Chemistry Curriculum Pacing Guide and the Next Generation Sunshine State Standards.

All the information within this document provides the teacher an essential method of integrating the Science Next Generation Sunshine State Standards with the instructional requirements delineated by the Course Description published by the Florida Department of Education (FLDOE). The information is distributed in three parts:

- (1) A list of the course specific benchmarks as described by the FLDOE. The Nature of Science Body of Knowledge and related standards are infused throughout the activities. Specific Nature of Science benchmarks may have been explicitly cited in each activity; however, it is expected that teachers infuse them frequently in every laboratory activity.
- (2) The Interim Assessment Schedule to assist teachers with content assessed leading to the science FCAT 1.0.
- (3) Basic resources to assist with laboratory safety, organization of groups during lab activities, and scientific writing of reports.
- (4) Hands-on activities that include a teacher-friendly introduction and a student handout. The teacher introduction in each activity is designed to provide guidelines to facilitate the overall connection of the activity with course specific benchmarks through the integration of the scientific process and/or inquiry with appropriate questioning strategies addressing Norman Webb's Depth of Knowledge Levels in Science.

All the hands-on activities included in this packet were designed to cover the most important concepts found in the Chemistry course and to provide the teacher with sufficient resources to help the student develop critical thinking skills in order to reach a comprehensive understanding of the course objectives. In some cases, more than one lab was included to cover a specific standard, benchmark, or concept. In most cases, the activities were designed to be simple and without the use of advanced technological equipment to make it possible for all teachers to use. However, it is highly recommended that technology, such as *Explorelearning Gizmos* and hand-held data collection equipment from *Vernier*, *Texas Instruments*, and *Pasco*, is implemented in the science classrooms.

This document is intended to bring uniformity among the science teachers that are teaching this course so that all can work together, plan together, and rotate lab materials among classrooms. Through this practice, all students and teachers will have the same opportunities to participate in these experiences and promote discourse among learners, which are the building blocks of authentic learning communities.

Acknowledgement

M-DCPS Curriculum and Instruction Division of Mathematics, Science, and Advanced Academic Programs would like to acknowledge the efforts of the teachers who worked arduously and diligently on the preparation of this document.

Next Generation Sunshine State Standards (NGSSS)

1. **LACC.1112.RST.1.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
2. **LACC.1112.RST.1.3:** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
3. **LACC.1112.RST.2.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics.
4. **LACC.1112.RST.3.7:** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
5. **LACC.1112.RST.4.10:** By the end of grade 12, read and comprehend science/technical texts in the grades 11–12 text complexity band independently and proficiently.
6. **LACC.1112.WHST.1.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (1) Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. (2) Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. (3) Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. (4) Use precise language, domain-specific vocabulary, and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. (5) Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
7. **LACC.1112.WHST.3.9:** Draw evidence from informational texts to support analysis, reflection, and research.
8. **MACC.912.F-IF.3.7:** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (1) Graph linear and quadratic functions and show intercepts, maxima, and minima. (2) Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions. (3) Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior. (4) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior. (5) Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
9. **MACC.912.N-Q.1.1:** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

10. **MACC.912.N-Q.1.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
11. **SC.912.L.18.12:** Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.
12. **SC.912.N.1.1:** Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: (1) pose questions about the natural world, (2) conduct systematic observations, (3) examine books and other sources of information to see what is already known, (4) review what is known in light of empirical evidence, (5) plan investigations, (6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), (7) pose answers, explanations, or descriptions of events, (8) generate explanations that explicate or describe natural phenomena (inferences), (9) use appropriate evidence and reasoning to justify these explanations to others, (10) communicate results of scientific investigations, and (11) evaluate the merits of the explanations produced by others.
13. **SC.912.N.1.2:** Describe and explain what characterizes science and its methods.
14. **SC.912.N.1.4:** Identify sources of information and assess their reliability according to the strict standards of scientific investigation.
15. **SC.912.N.1.5:** Describe and provide examples of how similar investigations conducted in many parts of the world result in the same outcome.
16. **SC.912.N.1.6:** Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
17. **SC.912.N.1.7:** Recognize the role of creativity in constructing scientific questions, methods and explanations.
18. **SC.912.N.2.2:** Identify which questions can be answered through science and which questions are outside the boundaries of scientific investigation, such as questions addressed by other ways of knowing, such as art, philosophy, and religion.
19. **SC.912.N.2.4:** Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.
20. **SC.912.N.2.5:** Describe instances in which scientists' varied backgrounds, talents, interests, and goals influence the inferences and thus the explanations that they make about observations of natural phenomena and describe that competing interpretations (explanations) of scientists are a strength of science as they are a source of new, testable ideas that have the potential to add new evidence to support one or another of the explanations.
21. **SC.912.N.3.2:** Describe the role consensus plays in the historical development of a theory in any one of the disciplines of science.
22. **SC.912.N.3.3:** Explain that scientific laws are descriptions of specific relationships under given conditions in nature, but do not offer explanations for those relationships.

23. **SC.912.N.3.5:** Describe the function of models in science, and identify the wide range of models used in science.
24. **SC.912.N.4.1:** Explain how scientific knowledge and reasoning provide an empirically-based perspective to inform society's decision making.
25. **SC.912.P.8.1:** Differentiate among the four states of matter.
26. **SC.912.P.8.2:** Differentiate between physical and chemical properties and physical and chemical changes of matter.
27. **SC.912.P.8.3:** Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.
28. **SC.912.P.8.4:** Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
29. **SC.912.P.8.5:** Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.
30. **SC.912.P.8.6:** Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.
31. **SC.912.P.8.7:** Interpret formula representations of molecules and compounds in terms of composition and structure.
32. **SC.912.P.8.8:** Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.
33. **SC.912.P.8.9:** Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.
34. **SC.912.P.8.11:** Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.
35. **SC.912.P.10.1:** Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
36. **SC.912.P.10.5:** Relate temperature to the average molecular kinetic energy.
37. **SC.912.P.10.6:** Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.
38. **SC.912.P.10.7:** Distinguish between endothermic and exothermic chemical processes.
39. **SC.912.P.10.9:** Describe the quantization of energy at the atomic level.
40. **SC.912.P.10.12:** Differentiate between chemical and nuclear reactions.
41. **SC.912.P.10.18:** Explore the theory of electromagnetism by comparing and contrasting the different parts of the electromagnetic spectrum in terms of wavelength, frequency, and energy, and relate them to phenomena and applications.
42. **SC.912.P.12.10:** Interpret the behavior of ideal gases in terms of kinetic molecular theory.
43. **SC.912.P.12.11:** Describe phase transitions in terms of kinetic molecular theory.

44. **SC.912.P.12.12:** Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.
45. **SC.912.P.12.13:** Explain the concept of dynamic equilibrium in terms of reversible processes occurring at the same rates.

Resources

Materials

1. Laboratory Techniques and Safety

- Material Safety Data Sheets (online).
- 1 Petri dish
- 1 Egg
- 10 ml 1M Hydrochloric acid
- Bunsen burner or alcohol burner
- matches
- Tongs or tweezers
- 2 strips of yarn or string
- 1 can of hairspray
- Paper towels
- Strips of silk, wool and rayon
- Droppers
- Chart paper and markers

2. Cleaning Up an Oil Spill

- goggles and lab aprons
- Several translucent containers
- Water
- Kosher salt (Use of kosher salt to prepare salt water will eliminate the "clouding" that results from using regular table salt. Add 38 g of NaCl to 1 L water)
- Blue food coloring
- Graduated cylinder
- Cooking oil * other types of oil may be substituted for this experiment; however, other oils may not be environmentally safe to use or to dispose of.
- (Optional) cocoa powder
- Cleaning supplies: paper towels, fabric, coffee filters, string, sponges, scrap construction paper, various brands of detergent

3. Density

- 100-ml graduated cylinder
- 2-L graduated cylinder (plastic)
- balance (50g capacity)
- distilled water
- rubber stopper (#2 solid)
-
- can of non-diet soft drink
- can of diet soft drink
- dropper
- 2000 ml graduated cylinder (or large container)

4. Conservation of Mass during Change

- Part 1:
 - Small wad of steel wool
- Part 2:
 - Small vial and chip of ice
- Part 3:
 - Small vials
 - Solutions of calcium nitrate $\text{Ca}(\text{NO}_3)_2$ and sodium carbonate Na_2CO_3
- Part 4:
 - Small tuft of steel wool
- Part 5:
 - Crucible tongs
 - Evaporating dish
 - Bunsen burner (a lighter will also work)
- Part 6:
 - Vial with cap
 - Sugar
- Part 7:
 - Vial with cap
 - ¼ tablet of Alka-Seltzer

5. Isotopes

- 100 pennies (include a mixture of pre and post 1982 pennies)
- Zip loc bag
- Balance

6. Flame Tests

- lab goggles
- lab apron
- Bunsen burner
- nichrome wire loop
- wash bottle with distilled water
- well plate
- hydrochloric acid (HCl) 6.0 M in a dropper bottle
- solutions of metallic salts:
 - calcium nitrate ($\text{Ca}(\text{NO}_3)_2$)
 - copper nitrate ($\text{Cu}(\text{NO}_3)_2$)
 - lithium nitrate (LiNO_3)
 - potassium nitrate (KNO_3)
 - strontium nitrate ($\text{Sr}(\text{NO}_3)_2$)
 - sodium chloride (NaCl)
 - unknown solution

7. Periodic Trends

- 96 –well microplate or Playdough
- 36 plastic straws or coffee stirrers
- Scissors
- Calculator
- Ruler (cm)
- Graph paper
- Table of atomic radii and ionization energies

8. Models of Atomic Structure and Electrostatic Forces

- Roll of scotch tape
- Piece of PVC pipe (about a foot in length)
- Piece of natural fur, or wool, or a cotton tube sock
- Rubber balloon
- Small pieces of paper or confetti
- large box top
- 2 plastic cups

9. A Bagged Chemical Reaction

- Safety goggles & Lab apron
- Calcium chloride pellets (CaCl_2)
- Baking soda, sodium bicarbonate (NaHCO_3)
- Phenol red solution (acid/base indicator solution)
- Measuring cup or graduated cylinder
- 2 plastic teaspoons
- Plastic cup
- 1-gallon Ziploc-type bag
- 2 twist ties or rubber bands
- Water

10. A Mole Ratio

- Iron metal filings: 20 mesh
- Copper (II) sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
- 400-ml and 150-ml beakers
- 100-ml graduated cylinder
- weighing paper (filter paper can be used)
- balance, hot plates
- Beaker tongs, distilled water
- Stirring rod

11. Hydrated Crystals

- Hotplates
- Balance (preferably 2 decimal places)
- Hydrated $\text{MgSO}_4 \cdot n\text{H}_2\text{O}$ (Epsom salts)
- crucible
- crucible tongs
- 400-ml beaker

12. Changes of State

- Ice
- Beaker (400 ml)
- Thermometer
- Stirring rod
- Timer (s.)
- Hot plate or Bunsen burner

13. Bonding: Conductivity and Solubility

- small beakers or cups (100 ml or less)
- distilled water (~100 ml)
- wash bottle filled with distilled water
- stirring rod
- 1 cm² of Aluminum foil
- a penny
- rubbing alcohol (isopropyl alcohol – 10 ml)
- Approximately 1 g of the following:
 - sucrose (table sugar)
 - NaCl (table salt)

14. Solubility Curve of KCl

- potassium chloride (KCl)
- distilled water
- balance
- evaporating dish (or 100-ml beaker)
- 25-ml graduated cylinder
- watch glass
- 250 or 400 ml beaker
- hot plate or burner with ring stand, 2 rings & wire gauze

15. Determining the Percentage of Acetic Acid in a Vinegar Solution

- apron
- goggles
- 10 ml graduated cylinder
- 24-well plate or 3 small beakers
- 2 thin-stemmed pipets or droppers

16. Energy Content of Foods and Fuels

- Lab Pro or CBL 2 system*
- TI graphing calculator*
- Temperature probe*
- DataMate program
- 2 Food samples
- food holder (paper clip + foil)
- wooden splint

- Optional-Graphing calculator/CBL/temperature probes or any other digital hand-held device(increases accuracy and instant feedback of the changes occurring)

- [Conductivity Apparatus](#)
 - tape
 - 9-V battery
 - battery clip
 - bare wire leads
 - resistor
 - LED or buzzer
 - wood backing.(tongue depressor)
 - CaCl₂ (calcium chloride)
 - CuSO₄ (copper II sulfate)
 - Candle wax
 - SiO₂ (sand)

- test tube (18X150 mm)
- utility clamp
- glass stirring rod
- thermometer or temperature probes
- funnel
- cotton wadding
- tongs &/or hot mitts
- graph paper

- phenolphthalein indicator
- 2.0 ml standardized 0.6 M NaOH
- 2.0 ml white vinegar
- stirrer

- candle (large diameter)
- aluminum foil squares
- *thermometer (instead of probe/CBL/TI calculator)
- *graph paper (instead of probe/CBL/TI calculator)
- utility clamp and slit stopper

- 2 Stirring rods
- ring stand and 4-inch ring
- 100-ml Graduated cylinder
- soda can
- cold water

- matches
- goggles
- *thermometer and graph paper
(instead of probe/CBL/TI calculator)

17. Rates of Evaporation

- distilled water
- ethanol
- isopropyl alcohol
- acetone
- household ammonia
- droppers (5)
- small plastic cups (5)
- grease pencil or marking pen
- masking tape
- paper towel
- square of waxed paper
- stopwatch

18. Determining Reaction Rates

- Distilled water
- Graduated cylinder
- 7 Clear plastic cups
- 7 original formula effervescent Alka-Seltzer tablets
- Thermometer (extension)
- Mortar and Pestle
- Stopwatch (seconds)
- Hot water/ice cubes
- Safety goggles
- Test tube 16 X 150mm
- Cork stopper, #4

19. Boyle's Law

- safety goggles
- Boyle's law apparatus
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors

20. Half-Life

- 100 pennies (include a mixture of pre and post 1982 pennies)
- Zip loc bag
- balance
- large box top
- 2 plastic cups

21. Precipitation Reactions

- 0.1M solutions of the following in Beral pipettes or bottles with droppers
 - NiCl₂
 - Na₂S
 - Co(NO₃)₂
 - Ba(NO₃)₂
 - CuSO₄
 - NaOH
 - Na₂CO₃
 - CaCl₂
 - KI
 - K₂CrO₄
 - AgNO₃
 - Pb(NO₃)₂
 - Glass spot plate or well plate

Laboratory Safety

Rules:

- Know the primary and secondary exit routes from the classroom.
- Know the location of and how to use the safety equipment in the classroom.
- Work at your assigned seat unless obtaining equipment and chemicals.
- Do not handle equipment or chemicals without the teacher's permission.
- Follow laboratory procedures as explained and do not perform unauthorized experiments.
- Work as quietly as possible and cooperate with your lab partner.
- Wear appropriate clothing, proper footwear, and eye protection.
- Report to the teachers all accidents and possible hazards.
- Remove all unnecessary materials from the work area and completely clean up the work area after the experiment.
- Always make safety your first consideration in the laboratory.

Safety Contract:

I will:

- Follow all instructions given by the teacher.
- Protect eyes, face and hands, and body while conducting class activities.
- Carry out good housekeeping practices.
- Know where to get help fast.
- Know the location of the first aid and firefighting equipment.
- Conduct myself in a responsible manner at all times in a laboratory situation.

I, _____, have read and agree to abide by the safety regulations as set forth above and also any additional printed instructions provided by the teacher. I further agree to follow all other written and verbal instructions given in class.

Signature: _____

Date: _____

Lab Roles and Descriptions

Cooperative learning activities are made up of four parts: group accountability, positive interdependence, individual responsibility, and face-to-face interaction. The key to making cooperative learning activities work successfully in the classroom is to have clearly defined tasks for all members of the group. An individual science experiment can be transformed into a cooperative learning activity by using these lab roles and responsibilities:

Project Director (PD)

The project director is responsible for the group.

- Reads directions to the group
- Keeps group on task
- Is the only group member allowed to talk to the teacher
- Assists with conducting lab procedures Shares summary of group work and results with the class

Materials Manager (MM)

The materials manager is responsible for obtaining all necessary materials and/or equipment for the lab.

- Picks up needed materials
- Organizes materials and/or equipment in the work space
- Facilitates the use of materials during the investigation
- Assists with conducting lab procedures
- Returns all materials at the end of the lab to the designated area

Technical Manager (TM)

The technical manager is in charge of recording all data.

- Records data in tables and/or graphs
- Completes conclusions and final summaries
- Assists with conducting the lab procedures
- Assists with the cleanup

Safety Director (SD)

The safety director is responsible for enforcing all safety rules and conducting the lab.

- Assists the PD with keeping the group on-task
- Conducts lab procedures
- Reports any accident to the teacher
- Keeps track of time
- Assists the MM as needed.

When assigning lab groups, various factors need to be taken in consideration:

- Always assign the group members, preferably trying to combine in each group a variety of skills. For example, you can place an “A” student with a “B”, “C”, and a “D” and or “F” student.
- Evaluate the groups constantly and observe if they are on task and if the members of the group support each other in a positive way. Once you realize that a group is dysfunctional, re-assign the members to another group.

Writing in Science

A report is a recap of what a scientist investigated and may contain various sections and information specific to the investigation. Below is a comprehensive guideline that students can follow as they prepare their lab/activity reports. Additional writing templates can be found in the [District Science website](#).

Parts of a Lab Report: A Step-by-Step Checklist

Title (underlined and on the top center of the page)

Benchmarks Covered:

- A summary of the main concepts that you will learn by carrying out the experiment.

Problem Statement:

- Identify the research question/problem and state it clearly.

Hypothesis(es):

- State the hypothesis carefully, logically, and, if appropriate, with a calculation.
 1. Write your prediction as to how the independent variable will affect the dependent variable using an ***IF-THEN-BECAUSE*** statement:
 - i. ***If (state the independent variable) is (choose an action), then (state the dependent variable) will (choose an action), because (describe reason for event).***

Materials and activity set up:

- List and describe the equipment and the materials used. (e.g., A balance that measures with an accuracy of +/- 0.001 g)
- Provide a diagram of the activity set up describing its components (as appropriate).

Procedures:

- Do not copy the procedures from the lab manual or handout.
- Summarize the procedures that you implemented. Be sure to include critical steps.
- Give accurate and concise details about the apparatus (diagram) and materials used.

Variables and Control Test:

- Identify the variables in the experiment. There are three types of variables:
 1. Independent variable (manipulated variable): The factor that can be changed by the investigator (the cause).
 2. Dependent variable (responding variable): The observable factor of an investigation resulting from the change in the independent variable.
 3. Constant variable: The other identified independent variables in the investigation that are kept or remain the same during the investigation.
- Identify the control test. A control test is the separate experiment that serves as the standard for comparison and helps identify effects of the dependent variable

Data:

- Ensure that all observations and/or data are recorded.
 1. Use a table and write your observations clearly. (e.g., color, solubility changes, etc.)
 2. Pay particular attention to significant figures and make sure that all units are stated.

Data Analysis:

- Analyze data and specify method used.
- If graphing data to look for a common trend, be sure to properly format and label all aspects of the graph (i.e., name of axes, numerical scales, etc.)

Results:

- Ensure that you have used your data correctly to produce the required result.
- Include any errors or uncertainties that may affect the validity of your result.

Conclusion and Evaluation:

- **First Paragraph:** Introduction
- What was investigated?
 1. Describe the problem.
- Was the hypothesis supported by the data?
 1. Compare your actual result to the expected (from the literature, or hypothesis) result.
 2. Include a valid conclusion that relates to the initial problem or hypothesis.
- What were your major findings?
 1. Did the findings support (or not) the hypothesis as the solution to the problem?
 2. Calculate the percentage error from the expected value.
- **Middle Paragraphs:** Discuss the major findings of the experiment.
- How did your findings compare with other researchers?
 1. Compare your result to other students' results in the class.
 - a. The body paragraphs support the introductory paragraph by elaborating on the different pieces of information that were collected as data.
 - b. Each finding needs its own sentence and relates back to supporting or not supporting the hypothesis.
 - c. The number of body paragraphs you have will depend on how many different types of data were collected. They should always refer back to the findings in the first paragraph.
- **Last Paragraph:** Conclusion
- What possible explanations can you offer for your findings?
 1. Evaluate your method.
 2. State any assumptions that were made which may affect the result.
- What recommendations do you have for further study and for improving the experiment?
 1. Comment on the limitations of the method chosen.
 2. Suggest how the method chosen could be improved to obtain more accurate and reliable results.
- What are some possible applications of the experiment?
 1. How can this experiment or the findings of this experiment be used in the real world for the benefit of society?

Hands-on Activities

Teacher

Laboratory Techniques and Safety

NGSSS:

SC.912.N.1. Describe and explain what characterizes science and its methods.

SC.912.N.1.6 Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

(Also addresses SC.912.N.1.1, SC.912.N.2.1, SC.912.N.3.1 and SC.912.N.3.4).

Purpose of Lab/Activity:

- To practice working safely in a laboratory.
- Learn how to interpret chemical hazard labels.
- To become familiar with “Material Safety and Data Sheets.”

Prerequisite: Prior to this activity, the student should be able to:

- Identify the main safety concerns in a laboratory.
- Locate the fire safety equipment in the laboratory.
- Indicate the primary safety equipment used in laboratory.

Materials (per group/station):

- Material Safety Data Sheets (MSDS Sheets, available also online at: <http://www.ehso.com/msds.php>).
- 1 Petri dish
- 1 Egg
- 10 ml 1M Hydrochloric acid
- Bunsen burner or alcohol burner, matches
- Tongs or tweezers
- 2 strips of yarn or string
- 1 can of hairspray
- Paper towels
- Strips of silk, wool and rayon

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ol style="list-style-type: none">Outline the safety equipment in the lab with the students.Demonstrate safety procedures with some common lab reagents.Print out and distribute sample Material Safety Data Sheets.Set up as many “lab stations” as available (up to 7) through which students will rotate.Prepare materials for each lab station as follows:<ol style="list-style-type: none">Lab Station A. How is a Fume Hood Used? This station needs to be inside the fume hood. Materials: Place paper towel and tape inside the hoodLab Station B. What information is contained in a Manufacturer’s Safety Data Sheet (MSDS)? Materials: At this station print and place any 4 MSDS for students to work with.Lab Station C. How does acid affect proteins? Materials: petri dish, 1 egg per group, 1M HCL, and dropper
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Teacher

	<ol style="list-style-type: none">4. Lab Station D. How do chemicals affect fabric? Materials: Paper towels, 10 ml 1 M HCl acid, strips of silk, wool & rayon5. Lab Station E. Hairspray simulation Materials: Lighter, tongs or tweezers, 2 strips of yarn, hairspray.6. Lab Station F. Where are the fire extinguisher and the fire blanket located and how do you use them? Materials: Paper, pencil, and common sense7. Lab Station G. Chemical Toxicity and Disposal. Materials: Chart paper and markers.8. Lab Station H. Transit time and evacuation procedures. Materials: Paper and pencil
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Supervise each station to make sure the tasks for each table are being completed.b. Confirm that the safety guidelines are being followed.c. Ask the students to explain the experimental observations at the stations C, D, and E.d. Make sure the students' reports are being completed.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Review the lab stations' correct answers with the students.b. Discuss the MSDS with the studentsc. Have students list the basic safety rules of the laboratory.d. Optional 1: Distribute a sample National Fire Protection Association (NFPA) label and have students analyze the label using the "Understanding Chemical Hazard Labels and MSDS" worksheet". .e. Optional 2: Distribute "Disaster scripts" #1, #2, #3. (See Student Section, Optional Activity 2) and have students role play the scenarios and the solution to the problems described

Extension: Ask the students for homework to write down the chemical substances found in detergents at home. Then, they should look up the MSDS at <http://www.ehso.com/msds.php>. For each chemical substance they must record their toxicity and precautions in the event of ingestion.

Student

Laboratory Techniques and Safety

NGSSS:

SC.912.N.1. Describe and explain what characterizes science and its methods..

SC.912.N.1.6 Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.

(Also addresses SC.912.N.1.1, SC.912.N.2.1, SC.912.N.3.1 and SC.912.N.3.4).

Background:

Chemistry has been developed largely through experimentation. Chemistry courses use laboratory experiences to demonstrate, clarify, and develop principles of chemistry.

Behavior in the laboratory is more structured than in the classroom. Certain rules of conduct pertaining to safety and keeping a clean work environment must be followed at all times. You must also adopt correct procedures for using glassware and other pieces of equipment. General safety rules are summarized at the beginning of this lab manual. However, there often will be more specific safety rules or special procedures to follow when performing an experiment. Your teacher will provide these added instructions before you perform any lab activity. If you are unsure of any procedure, always ask your teacher before proceeding. In this activity, you will practice some laboratory techniques and apply laboratory safety rules.

Purpose or Problem Statement:

- To practice working safely in a laboratory.
- Learn how to interpret chemical hazard labels.
- To become familiar with “Material Safety and Data Sheets.”

Safety:

- There should be no eating or drinking in the lab.
- Goggles and aprons must be worn at all times.

Vocabulary: Material Safety and Data Sheets (MSDS), toxicity, hazardous

Materials (per group):

- Material Safety Data Sheets (MSDS Sheets).
- 1 Petri dish
- 1 Egg
- 10 ml 1M Hydrochloric acid
- Lighter
- Tongs or tweezers
- 2 strips of yarn or string
- 1 can of hairspray
- Paper towels
- Strips of silk, wool and rayon

Procedures:

Complete the activities in each station and investigate each of the following questions. The investigations do not need to be done in order. The write-up for each will follow this basic lab report format:

1. Purpose: What question are you trying to answer?
2. Method: What did you do?
3. Data: What did you observe?

Student

4. Results and Conclusions: Write one safety rule that follows from your observations.

Lab Station A. How is a fume hood used?

- **Materials:** paper towel, tape
- **Safety:** none
- **What to do:**
 - 1) Go to the fume hood. Examine the switches and valves to determine what each does and make a labeled diagram.
 - 2) Raise the glass door (sash) all the way to the top. Note that there is a strip of paper taped to the bottom of the glass window. Turn on the fan. Describe what happens to the paper as you lower the glass door.
 - 3) Clean up: Turn everything off, lower the glass door

Lab Station B. What information is contained in a Manufacturer's Safety Data Sheet?

- **Materials:** four different Manufacturer's Safety Data Sheets
- **Safety:** none
- **What to do:**
 - 1) List the sections that all MSDS's have in common.
 - 2) Make a table of the four chemicals with the following information: name, chemical formula, flammability, health hazards, safe disposal methods.
 - 3) Which is the most hazardous of the four chemicals? Why?
 - 4) Clean up: return all MSDS's sheets.

Lab Station C. How does acid affect protein?

- **Materials:** petri dish, 1 egg, 1 M HCl, and dropper
- **Safety:** safety goggles required 10 ml 1 M HCl acid for all; aprons are suggested
- **What to do:**
 - 1) Break an egg into the petri dish. The egg white is similar to the protein your eyes. Place a few drops of acid on the egg white and observe for a few minutes.
 - 2) Based on your results, explain to a younger student why they should wear safety goggles.
 - 3) Optional: Why should you remove contact lenses if you are wearing them?
 - 4) Clean up: discard egg in trash; wash, dry and return petri dish; wash your hands.

Lab Station D. How do chemicals affect fabric?

- **Materials:** paper towels, 10 ml 1 M HCl acid, strips of silk, wool & rayon
- **Safety:** safety goggles for all; aprons suggested
- **What to do:**
 - 1) Layout a strip of each fabric on paper towels.
 - 2) Place several drops of acid on each; wait at least 5 minutes
 - 3) Explain to a younger student why you should wear a lab apron and close shoes.
 - 4) clean up: discard of fabric & paper towel in trash, return acid to teacher, wash your hands, rinse table if needed.

Lab Station E. Hairspray simulation

- **Materials:** Lighter, tongs or tweezers, 2 strips of yarn, hairspray
- **Safety:** be careful of the fire

Student

- **What to do:**
 - 1) Cut two strips of yarn about 8 cm long. Coat one with hairspray and let it dry.
 - 2) One at a time, hold the un-covered yarn with the tong and light one end for less than 5 seconds. Repeat with the hairspray covered yarn and make observations.
 - 3) Clean up: put out the flame by smothering the fire with a lid; throw yarn in trash; return other materials to station.

Lab Station F. Where are the fire extinguisher and the fire blanket located and how do you use it?

- **Materials:** paper, pencil, and common sense
- **Safety:** none, but don't actually discharge the fire extinguisher
- **What to do:**
 - 1) Make a map that locates the fire extinguishers that are available to you.
 - 2) Take one off the wall and read the label; describe the types of fires it can put out and how to use it
 - 3) Clean up: put the fire extinguisher back

Lab Station G. Chemical Toxicity and Disposal

- **Materials:** chart paper and markers
- **Safety:** none
- **What to do:**
 - 1) Imagine that a terrorist is out to poison you. List the four ways or routes that the poison could enter your body (they must be unique; for instance, eating or drinking it are the same route).
 - 2) Suppose that you have toxic materials to dispose; trace the fate (where it ends up) of each:
 - a. a liquid—a highly infectious agent—poured down the drain
 - b. a solid--a mercury-containing battery—in the trash
 - c. a gas—the chemical warfare agent, mustard gas — released into the air
 - 3) Why should you not eat in the lab?
 - 4) Why should you wash your hands before you leave?
 - 5) Clean up: none

Lab Station H. Transit time and evacuation procedures

- **Materials:** stopwatch, paper, and pencil
- **Safety:** none
- **What to do:**
 - 1) Suppose you splash acid in your eye from the furthest part of the room and you need to go to the eye wash station. Make sure that the path is clear and walk calmly to the eyewash station; have a student use a timer to measure the transit time in seconds. Now clutter the path with backpacks, chairs, etc and measure the transit time in seconds.
 - 2) Look at the layout of the room; find the exits and make a map of the room, with arrows to indicate the safest escape route from each area of the lab. Also note the closest "safe" area to evacuate to (e.g., practice football field)
 - 3) Clean up: Unclutter the path and return the stopwatch.

Student

Optional Activity 1- Understanding Chemical Hazard Labels and MSDS Sheets

Objective: To read and interpret chemical hazard labels and MSDS.

Materials: (per student)

- How to read a Chemical Label handout
- MSDS – Acetone

Procedures: Use the documents listed above to answer the following questions.

1. Interpret the following colors on a chemical hazard label:
a. red; b. yellow; c. blue; and d. white
2. Interpret numbers on a chemical hazard label.
a. A number ____ is the most serious, and a number ____ is the least serious.
b. What does the number four on a red background indicate to the user?
c. What does the number zero on a yellow background mean?
3. Complete the following for acetone:
a. Fill in the appropriate NFPA hazard coding colors and numbers on the label above.
b. Complete the missing information on the MSDS on the back of this page.
4. What does MSDS stand for?
5. What information is found in an MSDS sheet?
6. What information do the chemical hazard label and MSDS have in common?
7. Why should an individual working with chemicals understand the hazard coding system on a chemical label?
8. What additional information provided on an MSDS might be of use to an individual working with chemicals?
9. What does the physical data include?
10. What are the Fire Hazards associated with this product?
11. Is this substance stable or reactive?
12. Can this substance be considered toxic? How?
13. Write the safety precautions for its handling.

Chemical Labels: Lay out different chemicals for students to analyze the information provided in the labels.

1. What is the information contained in a label of any chemical?
2. What does a lower number indicate? A higher number?
3. What is the storage code for your chemical?
4. Look on page 14 (p18) of the Modern Chemistry book, according to the table, what are the different grades of chemicals?

Optional Activity 2 –Disaster Scripts

Materials: Script instructions

Procedures: Distribute students in group to perform the disaster scripts for the class. Discuss what was observed and write the rules that should have been followed in each scenario.

Student

1. Acid in the Eyes Disaster Script

Props: Everyone needs goggles and aprons. The victim needs a burner, a test tube, and a test tube holder. Other actors can be using miscellaneous props to simulate a lab situation.

Acid in Eyes – Victim

About 30 seconds into this scene, put your goggles on your forehead, pretend to warm up a test tube and then smell it. Begin to yell, “Ouch, my eyes! I’ve got something in my eyes! It burns!” Keep yelling until someone comes to help. If they are speaking, stop yelling so they can be heard. When asked if you are wearing contacts, say yes. Do not resist their attempts to help you, but remember, you are in pain and cannot see. Particularly, if they try to move you to the eyewash, act like you are totally blind with your eyes clamped shut.

Acid in Eyes – Actor #2

When the victim hurts his/her eyes, run over and yell something like, “Quick! Splash your eyes with water.” Pretend to turn on the sink and try to get the victim to splash water in his/her face.

Acid in Eyes – Actor #3

After Actor #2 tries to splash the victim with water, say to the victim, “No, you need to use the eyewash.” Do NOT make any attempt to help the victim get there.

Acid in Eyes – Actor #4

The victim needs to get to the eyewash but cannot see to get there. Go to the victim, take him/her by the arm, and carefully but quickly lead the victim to the eyewash. Ask Actor #5 to help you turn on the eyewash. When prompted by Actor #5, put one hand on the victim’s forehead and the other behind his/her head. Lower the victim’s head down to the eyewash.

Acid in Eyes – Actor #5

Go with Actor #4 and the victim to the eyewash. When you get there, loudly say, “Watch his/her head!” After the victim’s head has been lowered, pretend to turn on the eyewash. Do not actually push down on the knob.

Acid in Eyes – Actor #6

When the victim’s head has been lowered to the eyewash, ask if the victim is wearing contacts.

Acid in Eyes – Actor #7

When you hear that the victim has contact lenses, say, “We need to get them out!” and call for the teacher.

Acid in the Eyes – Actor #8

You must watch the area of the accident. When they move to the eyewash, you must go to the area where the victim was working and turn off the burner. Also, put the test tube in the test tube rack, if necessary.

Student

2. Person on Fire Script

Props: Everyone needs goggles and aprons. The victim needs a burner and a beaker to reach for. Other actors can be using miscellaneous props to simulate a lab situation.

Person on Fire – Victim

After the scene starts, PRETEND that you are heating something over a burner and you accidentally reach over the flame and catch your sleeve on fire. Yell, “I’m burning!” Wave your arm around (not too wildly) and try to beat out the flames. Move away from your lab area. Do not resist any help.

Person on Fire – Actor #2

When the victim catches on fire, yell, “I know what to do! Here’s some water!” Grab a beaker or squirt bottle and pretend to throw/squirt water on the victim.

Person on Fire – Actor #3

After someone else tries to put out the fire with a beaker of water, say, “No, we need more water than that. We need to use the shower!” You go to the shower, but the victim is too frantic and is not cooperating.

Person on Fire – Actor #4

Tell the victim to “Stop, Drop, and Roll,” and get him/her to the floor. Everyone should respond as though this isn’t working.

Person on Fire – Actor #5

Once the victim is on the floor, take off your apron, run over to the victim, and say, “I’ll fix it! Hold still and I’ll beat it out!” PRETEND that you are trying to beat out the fire with your apron. Do NOT actually hit the victim.

Person on Fire – Actor #6

When beating the fire with an apron doesn’t work, say something like, “I’ll go get the fire extinguisher.” Bring the fire extinguisher to the area of the victim, but do not try to use it. Just hold it.

Person on Fire – Actor #7

After the fire extinguisher suggestion, say, “No, we can’t use that on him/her. We need the fire blanket.”

Person on Fire – Actor #8 + helper

Get the fire blanket and place it over the victim. PRETEND that you gently pat out the flames.

Person on Fire – Actor #9

You must watch the area of the accident. When the victim moves away, go over and PRETEND to turn off the burner. At some point, call for the teacher.

Student

3. Person Badly Cut Script

Props: Everyone needs goggles and aprons. The victim needs a beaker that Pretends to get “broken.” Other actors can be using miscellaneous props to simulate a lab situation.

Person Cut – Victim

You will PRETEND that you have broken a beaker and are picking up the broken pieces with your hands. The broken glass has badly cut your wrist, and blood is gushing out. Say something like, “Oh no! I broke a beaker.” Then say, “Ouch! I cut my wrist. Blood is going everywhere!” Wave it around (not too wildly). When people come to help you, take the paper towel they give you, hold it on your wound, and then **slowly** drop to the floor in a faint.

Person Cut – Actor #2

You see that the victim is badly cut. Get some paper towel and give it to the victim. Tell him/her to put it over the wound and press down firmly. You might say, “You need to apply direct pressure. Here, press down on it with this.”

Person Cut – Actor #3

You see that the victim is badly cut. After the victim faints, you ask Actor #4 to help you. You grab some paper towels and begin applying direct pressure to the wound.

Person Cut – Actor #4

You see that the victim is badly cut. After the victim faints, Actor #3 will ask you to help him/her help the victim. You must refuse to help and say something like, “No, it’s too dangerous. I don’t want to get his/her blood on me!”

Person Cut – Actor #5

You can’t stand the sight of blood. Say loudly that you don’t feel good and slowly faint.

Person Cut – Actor #6

When Actor #5 faints, go to assist him/her.

Person Cut – Actor #7 + extras

When you hear the commotion, go over and stand around so you get in the way without helping. When prompted by Actor #8, one of you should get the first aid kit and give a latex glove to Actor #3 saying, “Here, put on this glove.” Another of you should get the teacher when asked by Actor #8.

Person Cut – Actor #8

You see people milling around and the victim on the floor. Go over and take control. Point to a specific person and tell him/her to get the first aid kit. Call another student by name and tell him/her to get the teacher.

Person Cut – Actor #9

During all of the commotion, get the dust pan. Sweep up the broken glass and put it in the broken glass container so no one else gets hurt.

Teacher

Cleaning Up an Oil Spill (Replaces Alka Popper Lab)

NGSSS:

SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

(Also addresses: SC.912.N.1.2 to N.1.7, SC.912.N.2.2 and SC.912.N.2.4)

Purpose of Lab/Activity: Use scientific inquiry to explore the effectiveness of different methods to contain a simulated salt water oil spill.

Prerequisite: Prior to this activity the student should be able to

- Review the lab roles for each member of the lab group
- Describe the methodology used by scientists to solve problems.
- Explain the relative densities of oil and water.

Materials (per group):

- Safety equipment: goggles and lab aprons
- Several translucent containers
- Water
- Kosher salt (Use of kosher salt to prepare salt water will eliminate the "clouding" that results from using regular table salt. Add 38 g of NaCl to 1 L water)
- Cooking oil*, other types of oil may be substituted for this experiment, however, other types of oil may not be environmentally safe to use or to dispose of. (Optional) Adding cocoa powder to the oil will simulate the look of heavy oil. Add about 2 tsp of cocoa powder per 250 ml of oil
- Blue food coloring
- Graduated cylinder
- Cleaning supplies: paper towels, fabric, coffee filters, string, sponges, scrap construction paper, various brands of detergent

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Provide students with different scenarios of experiments and have them identify the manipulated, responding and constant variables and the experimental and control groups in each case.Introduce the purpose of today's lab and explain that they will be acting as scientists in proposing viable solutions to the problem.
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Teacher

	<ul style="list-style-type: none">c. Provide students with a copy of the handout: Power Writing and the Art of Scientific Conclusions. Discuss and clarify with the class each section of the write up.d. Divide students into groups of 4 and have them brainstorm possible methods of cleaning the simulated oil spill based on the possible materials available for the lab.e. Ask students what is the importance of including a control group? Also have students discuss why more than one trial is necessary when performing an experiment.f. Have each lab group propose a plan that includes a hypothesis, the experimental design, a detailed list of materials, and the step by step procedures. The procedure should include a method to measure the amount of oil before and after the clean up. Review each plan and clarify any errors with each lab group before they test their hypothesis.g. Provide students with a translucent container with 400 ml of the prepared simulated ocean water and access to the materials that they will need for their test.
During activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Discuss with each group the distribution of roles for the lab.b. Monitor each group as they perform their experiment.c. Review their data collection instruments and <u>ASK PROBING QUESTIONS</u> about the qualitative and quantitative observations made by each group.d. Make sure that students document any changes that they make to their original plan.
After activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Have students present their findings to the class including a summary of their plan, and any pictures and data that document their results.b. Ask students how the use of the scientific method was instrumental in helping them propose a plan to contain the simulated oil spill.c. Have students evaluate the results provided by each team and judge which would be the best method to contain the oil spill.d. Each student should write a complete report for their lab using the “<i>Power Writing Model 2009</i>”<ul style="list-style-type: none">1. In their conclusions, students should refer to the magnitude of the Exxon Valdez and the BP Gulf of Mexico oil spills and explain the advantages and limitations of using models in scientific inquiry.

Extension:

- Gizmo: [Mystery Powder Analysis](#)

Student

Cleaning Up an Oil Spill

NGSSS:

SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

(Also addresses: SC.912.N.1.2 to N.1.7, SC.912.N.2.2 and SC.912.N.2.4)

Background:

Accidental oil spills are not common; but when they occur, they can cause huge environment damage, affecting wildlife and inhabitants of the area. Two of the major oil spills are the Exxon Valdez oil spill in Prince William Sound, off the coast of Alaska in the mid 80's, and recently the BP Gulf of Mexico oil spill, off the coast of Louisiana, Alabama and Florida. As the oil spreads over the surface of the water, it forms a large oil slick which is particularly challenging to contain and clean. Generally, the process involves the physical containment of slick and then the breaking up of the large slick into clumps which are easier to clean. Natural processes such as evaporation, wave action, and biological breakdown work to clean up the oil but at a very slow rate. In this lab, you will act as scientists to test the most effective physical and chemical methods to contain remove or dissolve the oil, to prevent major damages, and restore a safe environment for all living organisms.

Purpose of activity:

- Use scientific inquiry to explore the effectiveness of different methods to contain a simulated salt water oil spill.

Safety:

- Always wear safety goggles and a lab apron.
- Do not eat or drink anything in a laboratory.
- Follow appropriate disposal of excess oil, waste oil and water mixtures, and any oil soaked materials. Do not pour down the drain.

Vocabulary: independent (manipulative) variable, dependent (responding) variable, constant variable, experimental design, experimental and control groups.

Materials (per group):

- One translucent container
- Simulated salt water
- Cooking oil, or simulated heavy oil (* 20 ml per spill).
- Blue food coloring

Student

- Graduated cylinder
- Cleaning supplies: paper towels, fabric, coffee filters, string, sponges, scrap construction paper, sand, string and various brands of detergent
- Instrument to measure: rulers (cm), pipettes, graduated cylinder.
- Optional: blank acetate or tracing paper and markers.

Procedures:

1. Brainstorm different methods for containing and cleaning an oil spill within your lab group. Propose and write up a treatment plan that includes a problem statement, hypothesis, the experimental design, a detailed list of materials, and a method to quantify the amount of oil slick before and after clean up.
2. Obtain the materials required to test your treatment plan.
3. Create your simulated oil spill using the translucent container to which you will add the ocean water prepared by your teacher and using a graduated cylinder add 20 ml of simulated oil to represent the slick.
4. Measure the initial oil slick and record in a data table.
5. Follow your proposed plan to contain and clean the slick. Record your observations in your table.
6. Measure the remaining oil slick and record in table.

Observations/Data:

1. Create a data table to record your observations and measurements for each trial of your oil containment and cleaning tests.
2. If possible, take photographs and try to visually document the size of your slick using trace paper or acetate.

Data Analysis:

1. Use data generated in all trials and compare the surface area of the initial oil slick and the oil slick after the proposed treatment.
2. Compare your group data with the data presented by other groups' containment and clean up treatment.

Results:

1. How would oil floating between the surface and the bottom or oil stuck in the ocean floor impact the method of cleanup?
2. Did time affect the oil spill?
3. Based on the results presented by each group, which cleanup treatment tested in this investigation was the most effective. Explain.
4. Did trying several treatments make a difference in the cleanup? Would combining several methods be effective?
5. What problems could be encountered in reclaiming and reusing the oil removed?
6. What effect did the detergent have on the oil spill? Hint: Research surfactants.
7. What were some of the limitations of this oil spill simulation?

Conclusion:

Write a report, using the "Power Writing Model" provided by your teacher.

Density

NGSSS:

MA.912.S.1.2 Determine appropriate and consistent standards of measurement for the data to be collected in a survey or experiment.

MA.912.S.3.2 Collects, organizes, and analyzes data sets, determine the best format for the data and present visual summaries for the following: bar graphs, line graphs, stem and leaf plots, circle graphs, histogram, box and whisker plots, scatter plots and cumulative frequency (ogive) graphs.

Purpose of Lab/Activity:

- Measure the mass and volume of several different objects.
- Calculate the density of objects by using their measured mass and volume.
- Compare the densities of various objects.
- Learn how to calculate experimental percentage error.

Prerequisite: Prior to this activity the student should be able to

- Describe the units used to measure matter in science.
- Report measurements using certainty and uncertainty readings.
- Manipulate variables in simple algebraic formulas.

Materials (individual or per group):

- | | |
|---|--|
| <ul style="list-style-type: none"> • 100-ml graduated cylinder • 2-L graduated cylinder (plastic) • balance (50g capacity) • distilled water • rubber stopper (#2 solid) | <ul style="list-style-type: none"> • can of non-diet soft drink • can of diet soft drink • dropper • 2000 ml graduated cylinder (or large container) |
|---|--|

Procedures: Day of Activity

Before activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> a. Set up all lab equipment and calculate the density of the rubber stopper with the most accurate equipment available to you. This will give students a theoretical value for them to compare their results. b. Help students differentiate between mass and weight. Compare the efforts of pushing horizontally on a block of slippery ice on a frozen pond versus lifting it. The block has the same mass but it will feel different when you try to lift it. Ask what is responsible for this? c. Students have misconceptions about volume. Measure a particular amount of water using a graduated cylinder and then pour the water into containers of different shape. Make sure that students are able to understand that the volume remains the same although the way the liquid is distributed is dependent of the shape of the container. d. Students often confuse mass and volume particularly when measuring liquids, review concepts, instruments and units. e. Make sure that students add enough water to do the graduated cylinder or container where you drop the soda or the experiment will not yield the expected results.
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Teacher

	<p>f. The following <u>misconceptions</u> relating to density have been identified by the American Institute of Physics and should be addressed throughout the activity.</p> <ol style="list-style-type: none">1. Large objects sink and small objects float.2. Objects float in water because they are lighter than water.3. Objects sink in water because they are heavier than water.4. Wood floats and metal sinks.5. All objects containing air float.6. Mass/volume/weight/heaviness/size/density may be perceived as equivalent.
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Monitor that students are using the instruments to measure mass and volume correctly. For example if using analytical balances make sure that students know how to calibrate to 0.000 g.b. Make sure students know how to read the meniscus correctly.c. As you visit each group, ask them for a definition of mass and volume and check that their understanding is accurate. It is important to reinforce this notion throughout the entire activity to minimize student misconceptions.d. Ask students to offer explanations for the differences observed in the density of the soda.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Have students share their lab group data with the whole class.b. Lead a discussion to try to explain the differences in the values reported by each group. Introduce the concept of random variation in measurements caused by different students measuring the same quantity with different equipment.c. Review the use of the formula to calculate % error. Explain to students that for this type of a lab an error below 5% is acceptable. If any group has an error that is higher, lead a discussion on measurement error and instrumental error.d. Check the student results with the following values:<ol style="list-style-type: none">1. Density of Coke- 1.01 g/cm³ (volume=376 ml (1 ml= 1 cm³), mass=380.8 g.)2. Density of Diet Coke- 0.97 g/cm³ (volume=376 ml (1 ml= 1 cm³), mass=366.6 g.)e. While two cans have the same volume, they differ in mass due to the sugar content. Sugar used in regular Coke has a mass of 39 grams while the diet version takes 100 mg of Nutra Sweet in a 12 oz diet can. Students should visualize that in the same amount of space the regular soda has more matter which translates into particles more crowded together. This enhances a preferred particle level view of density as opposed to a more common formulaic definition of mass over volume.

Extension:

- Gizmo: [Density Laboratory](#)

Student

Density

NGSSS:

MA.912.S.1.2 Determine appropriate and consistent standards of measurement for the data to be collected in a survey or experiment.

MA.912.S.3.2 Collects, organizes, and analyzes data sets, determine the best format for the data and present visual summaries for the following: bar graphs, line graphs, stem and leaf plots, circle graphs, histogram, box and whisker plots, scatter plots and cumulative frequency (ogive) graphs.

Background:

Density is a physical property of a substance and is often used to identify what the substance is. Density is a ratio that represents how much mass (amount of matter) there is in a unit of volume (amount of space something occupies) of a substance. Density can be computed by using the equation - $D = \frac{m}{V}$. Mass is usually expressed in grams and volume in milliliters (ml), which are equivalent to cubic centimeters (cm³).

Mass and volume measurements can be made in the laboratory. Mass can be determined by using a balance. If the object has a regular shape, such as a cube or a cylinder, volume can be calculated from length measurements. However, most objects have irregular shapes, and the volume must be determined indirectly. One way to measure the volume of an irregularly shaped item that does not dissolve in or react with water is by water displacement. An item that is entirely submerged in water will displace a volume of water equal to its volume. It is necessary to use the proper units when calculating the density of a substance. Densities of liquids and solids are usually expressed in terms of g/ml or g/cm³. Densities of gases are usually expressed in g/L.

The accuracy of your methods can be reported in terms of percent error. The percent error of measurements is a comparison of the differences between experimental results and theoretical or standard values, expressed as a percentage. The equation for percent error is:

$$\% \text{ error} = \frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \times 100$$

Purpose of Lab/Activity:

- Measure the mass and volume of several different objects.
- Calculate the density of objects by using their measured mass and volume.
- Compare the densities of various objects.
- Calculate percentage error

Safety:

- Always wear safety goggles and a lab apron.
- Clean up any spills immediately.
- Do not eat or drink anything in a laboratory.

Vocabulary: matter, mass, volume, density, significant digits, percent error

Student

Materials (per group):

- 100-ml graduated cylinder
- 2-L graduated cylinder (plastic)
- balance (50g capacity)
- distilled water
- rubber stopper (#2 solid)
- can of non-diet soft drink
- can of diet soft drink
- dropper
- 2000 ml graduated cylinder (or large container)

Procedures:

Part A: Density of Water

1. Find the mass of a clean, dry 100-ml graduated cylinder. Record this mass in Data Table 1.
2. Fill the cylinder with distilled water. Use a dropper to adjust the bottom of the meniscus exactly to the 100.0-ml mark.
3. Find and record the mass of the graduated cylinder and water.
4. Calculate and record the mass of the water.

Part B: Density of a Rubber Stopper

5. Find the mass of a solid #2 rubber stopper. Record this mass in Data Table 2.
6. Pour about 50 ml of tap water into the 100-ml graduated cylinder. Read and record the exact volume.
7. Place the rubber stopper into the graduated cylinder. Make sure that it is completely submerged. (If it floats, use a pencil to hold the stopper just under the surface of the water.)
8. Read and record the exact volume.

Part C: Density of a Can of Non-Diet Soft Drink

9. Find the mass of an unopened can of non-diet soft drink. Record this mass in Data Table 3.
10. Pour about 1000 ml of tap water into the 2000-ml graduated cylinder (or a large container). Record the exact volume.
11. Place the unopened can of soft drink into the graduated cylinder, making sure that it is completely submerged.
12. Read and record the exact volume.

Part D: Density of a Can of Diet Soft Drink

13. Find the mass of an unopened can of diet soft drink. Record this mass in Data Table 4.
14. Pour about 1000 ml of tap water into the 2000-ml graduated cylinder (or a large container). Record the exact volume.
15. Place the unopened can of diet soft drink into the graduated cylinder, making sure that it is completely submerged.
16. Read and record the exact volume.

Student

17. Use the mass and volume data to calculate the densities of water, the rubber stopper, a can of non-diet soft drink, and a can of diet soft drink. Show work and then record the answers in the data tables.

Observations/Data:

Data Table 1

Part A: Density of Water	
Mass of empty graduated cylinder (g)	
Mass of graduated cylinder and water (g)	
Mass of water (g)	
Volume of water (ml)	
Density of water (g/ml)	

Data Table 2

Part B: Density of Rubber Stopper	
Mass of rubber stopper (g)	
Initial volume of water in graduated cylinder (ml)	
Final volume of water in graduated cylinder (ml)	
Volume of rubber stopper (ml)	
Density of rubber stopper (g/ml)	

Data Table 3

Part C: Density of a Can of Non-Diet Soft Drink	
Mass of can of non-diet soft drink (g)	
Initial volume of water in graduated cylinder (ml)	
Final volume of water in graduated cylinder (ml)	
Volume of can of non-diet soft drink (ml)	
Density of can of non-diet soft drink (g/ml)	

Data Table 4

Part D: Density of a Can of Diet Soft Drink	
Mass of can of diet soft drink (g)	
Initial volume of water in graduated cylinder (ml)	
Final volume of water in graduated cylinder (ml)	
Volume of can of diet soft drink (ml)	
Density of can of diet soft drink (g/ml)	

Observation/Data Analysis:

1. What is the density determined for your water sample?
2. Using 1g/ml or 1 g/cm³ as the theoretical density of distilled water, calculate the percent error of your measurement (see formula in Background Information section). Show work.
3. What could you do to improve the accuracy of your measurements?
4. How does the density of the rubber stopper compare to the density of water?
5. Compare the densities of the soft drinks tested? Which soda is denser? How can you explain this result?

Student

Conclusion:

1. When you use the terms heavier or lighter to compare different objects with the same volume (such as the two soda cans), what property of the objects are you actually comparing?
2. Would you expect the densities of various fruit juices in the same container to all be the same? Explain.
3. How can the concept of density be used to differentiate between a genuine diamond and an imitation diamond?
4. Explain why a tractor-trailer can be completely filled with one type of merchandise, such as butter, but only partially filled with a second type of material, such as steel.
5. The density of aluminum is 2.70 g/cm^3 . What volume will 13.5 grams of aluminum occupy?

Teacher

Conservation of Mass during Change (Replaces Physical and Chemical Changes)

NGSSS:

SC.912.P.8.1 Differentiate among the four states of matter.

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

Purpose of Lab/Activity:

- To learn to operate a balance as a tool to measure mass.
- To establish the law of conservation of mass from experimental evidence
- To understand and represent the following changes of a system at the particle level:
 - Part 1: Expansion of matter by pulling steel wool strands apart
 - Part 2: Melting of ice
 - Part 3: Combining solutions to form a precipitate
 - Part 4: Burning steel wool which adds oxygen particles to the iron wool
 - Part 5: Dissolving sugar
 - Part 6: Dissolving Alka-Seltzer
- To be able to conclude that despite observable changes in a closed system the mass does not change. The changes occur due to a rearrangement of the atoms, but as long as the amount of atoms remains constant, so will the mass.

Prerequisites: Prior to this activity, the student should be able to:

- Provide a working definition of mass.
- Understand that all matter is composed of individual finite particles, atoms, must be established prior to this activity.
- Define mass as the amount of matter (particles, or stuff) in an object.
- Understand that a heavier object must have more mass, than a lighter object independent of their volume.

Experiment Overview: The lab activity consists of 6 parts. For every part, the students will first predict what will happen to the system as the change is performed. Then they will measure the mass of the system before and after an observable change has occurred. By using the initial and final mass, students will calculate the change of mass using the formula: $\Delta m = m_f - m_i$. The use of an analog balance is preferred but digital balances are also acceptable.

Materials (per group):

Part 1:

- Small wad of steel wool

Part 2:

- Small vial and chip of ice

Part 3:

- Small vials
- Solutions of calcium nitrate $\text{Ca}(\text{NO}_3)_2$ and sodium carbonate Na_2CO_3

Teacher

Part 4:

- Small tuft of steel wool
- Crucible tongs
- Evaporating dish
- Bunsen burner (a lighter will also work)

Part 5:

- Vial with cap
- Sugar

Part 6:

- Vial with cap
- $\frac{1}{4}$ tablet of Alka-Seltzer

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Have all materials available for all 6 partsReview with students the concept of mass. Explain to them that the idea of this lab is to see how the mass of a system is affected by an observable change.Instruct students on how to use a balanceExplain students each of the 6 parts and the overall procedureAsk them to predict how the described change will affect the system's mass. The options are, the mass will increase ($\Delta m > 0$), the mass will decrease ($\Delta m < 0$), and the mass will stay the same ($\Delta m = 0$). They should write their prediction on the data sheet for each part before the run the lab.For part 2 – Melting of ice, remind students what happens when they put a soft drink in the freezer. Water expands as it freezes and contracts as it melts. The point is to find out if the mass is affected by this change.For Part 4 – Burning steel wool, ask student what happens to the mass of an object as it is heated or burn
During activity:	What the teacher will do: <ol style="list-style-type: none">As you supervise the students engage them by asking questions on the experiments they are performing. You can ask them to state their hypothesis, state their reason for their hypothesis and to tell you about their results as they record them in their student data sheet.Make sure that all the students are conducting the experiments according to procedure in a safe manner, especially in part 4.Ask groups to show their particle level representations and ask for the reasons behind their representations. Most of the time the students will just draw a picture of what they see. This is not the point of this activity. Remind them that they are trying to draw that which they cannot see, the atoms that make up the system. This is fundamental to the success of this activity.
After activity:	What the teacher will do: <ol style="list-style-type: none">Assign each group one of the 6 experiments to present their results to the class.The students should present the experiments in the following order:

Teacher

	<ol style="list-style-type: none">1. Part 1: Pulling apart steel wool2. Part 2: Melting of ice3. Part 5: Dissolving sugar4. Part 3: Combining solutions to form a precipitate5. Part 4: Burning steel wool6. Part 6: Dissolving Alka-Seltzer <p>c. As students present, discuss with them what is happening at the particle level and how that explains what is observed at the macro level. The following is a summary of each part. Even though this is not the order in which the experiments are performed the order below is the most effective for the discussion.</p> <ol style="list-style-type: none">1. Part 1: When the steel wool is pulled, the mass is not supposed to change. Some students feel that it will become lighter because it looks more dispersed or puffier. Some students believe it should become heavier as it is bigger. Some groups will notice a decrease in mass because small parts of the steel wool will be lost as it is pulled apart..2. Part 2: Melting of the ice should not change the system's mass. The volume decreases but the mass stays the same. Students should represent the particles in a solid more structured and ordered while the liquid is more disorganized and random.3. Part 3: Forming a precipitate does not change the mass but the process is opposite to the one of sugar dissolving. In this case, the particles are coming together to form a visible solid but the total amount of particles is the same. Once again, mass is conserved.4. Part 4: When steel wool is burned, the mass is supposed to increase. Students may be very surprised as they always predict a loss of mass due to burning. Ask students why the mass increases, mass measures the amount of matter, more mass, more mater. Where does matter come from? As the iron burns, it reacts with oxygen in the air forming iron oxide. Oxygen particles are now attached to the iron making the steel wool heavier.5. Part 5: Dissolving sugar does not change the mass of the system. Mention to students that even though the sugar cannot be seen, it is still there, for it can be tasted. Ask them why particles cannot be seen now. Conclude that as the sugar dissolves, the particles separate and they are too small to be seen. The total number of particles, however, does not change.6. Part 6: If cap of vial was loose, mass should drop. If cap is screwed on tightly, mass remains constant. Students feel that bubbles are "too light" or carry no mass. Loss of mass should prove to them that there is matter inside the bubbles even though it is not visible. Have them conclude that as particles escape, mass is lost in the system but mass must be gained somewhere else. <p>d. Summarize each part and then reach overall conclusion of the lab. The mass of the system will not change if no particles are added or removed from it despite of a change in appearance. This statement is similar to the law of conservation of mass.</p>
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Student

Conservation of Mass during Change

NGSSS:

SC.912.P.8.1 Differentiate among the four states of matter.

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

Background: It is possible to imagine all matter as composed of very small particles called atoms. Mass is a property of matter which accounts for the amount of “stuff” in an object. The heavier an object, the more mass it has, which means the more matter or atoms. A balance is a piece of equipment which can measure the amount of mass, in grams, of an object.

Purpose of Lab/Activity: In this lab you will perform 6 experiments and in each one an object, called the system, will undergo a visible change. The question to be answered is how this change will affect the mass of the system.

Safety: All parts require minimal safety precautions except for part 4. In part 4 you will be working with a Bunsen burner or a lighter. Remember to wear goggles and pull all hair back while operating a burner.

Vocabulary: Mass, balance, precipitate, oxidation, solution

Materials (per group):

Part 1:

- Small wad of steel wool

Part 2:

- Small vial and chip of ice

Part 3:

- Small vials
- Solutions of calcium nitrate $\text{Ca}(\text{NO}_3)_2$ and sodium carbonate Na_2CO_3

Part 4:

- Small tuft of steel wool
- Crucible tongs
- Evaporating dish
- Bunsen burner (a lighter will also work)

Part 5:

- Vial with cap
- Sugar

Part 6:

- Vial with cap
- $\frac{1}{4}$ tablet of Alka-Seltzer

Student

Procedures:

Part 1 – Pulling Steel wool apart

1. Obtain a small wad of steel wool which is tightly rolled in a ball.
2. Measure the mass of the small tuft of steel wool
3. Separate the strands of steel wool until it reaches twice the size
4. Measure the mass of the expanded steel wool.
5. Keep the steel wool around as you will use it again in part 4
6. Calculate Δm and represent the change you observed at the particle level

Part 2 – Melting Ice

1. Obtain a small chip of ice and place in a small vial, cap the vial.
2. Measure the mass of the vial with the ice inside
3. Allow the ice to melt completely
4. Measure the mass of the vial now containing water
5. Calculate Δm and represent the change you observed at the particle level

Part 3 – Combining Solutions to Form a Precipitate

1. Obtain two vials and fill each one to 1/3 with the two solutions, calcium nitrate and sodium carbonate
2. Measure the mass of both vials and solutions together
3. Carefully pour the contents of one vial into the other
4. Measure the mass of both vials (one empty now, the other one 2/3 full)
5. Calculate Δm and represent the change you observed at the particle level

Part 4 – Burning Steel Wool

1. Measure the mass of the same piece of steel wool from part 1 again
2. Obtain crucible tongs and an evaporating dish
3. With your teacher's help, set up a Bunsen burner and ignite it
4. Hold the piece of steel wool with the crucible tongs and heat in the Bunsen burner for a minute or two. Place the evaporating dish underneath to collect any pieces of the metal that may fly away.
5. After the steel wool is cooled, measure the mass again, include any pieces of metal collected in the evaporating dish.
6. Calculate Δm and represent the change you observed at the particle level

Part 5 – Dissolving Sugar

1. Fill a vial $\frac{1}{2}$ full with water
2. Put about a $\frac{1}{4}$ tsp of sugar in the cap of the vial
3. Measure the mass of the vial with water and the cap with sugar (do not combine sugar and water)
4. Carefully put the sugar in the water and cap the vial
5. Shake vial to dissolve all the sugar
6. Measure the mass of the dissolved sugar
 - a. Calculate Δm and represent the change you observed at the particle level

Part 6 – Dissolving Alka-Seltzer

1. Fill a vial $\frac{1}{2}$ full with water
2. Put a $\frac{1}{4}$ tablet of Alka-Seltzer in the cap of the vial

Student

3. Measure the mass of the vial with water and the cap with the Alka-Seltzer
4. Place the Alka-Seltzer in the water and wait until it all dissolves and stops bubbling
5. Measure the mass of the dissolved Alka-Seltzer and cap
6. Calculate Δm and represent the change you observed at the particle level

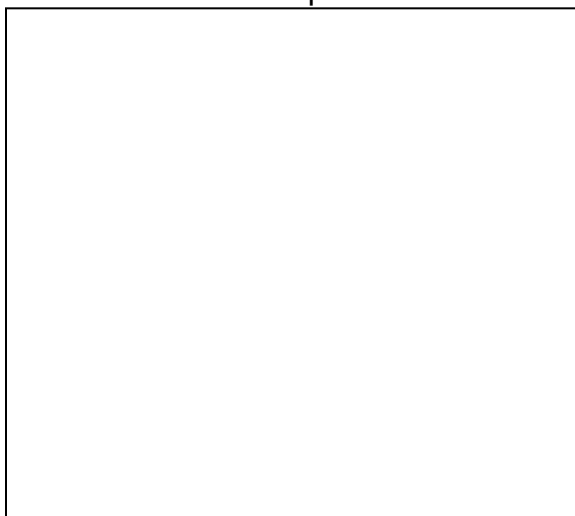
Observations/Data Analysis:

Answer the following questions on a separate sheet for each of the six parts:

1. Explain this experiment and predict how the mass of the system will be affected by the change you perform?

Mass of system before change (g)	
Mass of system after change (g)	
Δm (g)	

2. Particle Level Representation



Before change



After change

Results/Conclusion:

1. How do your results compare to your predictions? Why?
2. From the post-lab class discussion, what is the understanding you have gained from this experiment?

Teacher

Isotopes

NGSSS:

SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.

SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.

Purpose of Lab/Activity:

- To determine the isotopic composition of 100 pennies
- To apply the lessons of the penny-isotope analogy to isotopic data.

Prerequisite: Prior to this activity, the student should be able to:

- Describe how the periodic table of elements is arranged.
- Identify the parts of an atom and describe its basic structure.
- Explain the role of the electrons, protons and neutrons in determining the properties of matter.

Materials (individual or per group):

- 100 pennies* (include a mixture of pre and post 1982 pennies)
- Zip loc bag
- balance
- large box top
- 2 plastic cups

*This activity can be done with a smaller amount of pennies as long as the amount used by all groups is consistent. Also, to facilitate obtaining the pennies, teachers should ask students to bring pennies from home the day before the activity.

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ol style="list-style-type: none">Prepare the data collection materials. Prepare one zip loc bag for each lab group containing the 100 pennies. Make sure that each bag contains pre and post 1982 pennies.Review the basic structure of atoms.Show students a sample of beans or nuts and ask them if they are all the same or how are they different. Lead students to discuss how this is an analogy for atoms of the same element.Dalton's theory states that all atoms of an element are identical, have students evaluate this statement. How are theories changed in science?Have students discuss the distribution of natural isotopes for different elements. Provide diagrams of ^1H, ^2H and ^3H, also ^{12}C, ^{13}C and ^{14}C. Have them compare these to the atomic mass listed in the Periodic table. Have students predict which of these elements is most common (stable in nature).
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Teacher

	<ul style="list-style-type: none">f. How is the “average” atomic mass of an element derived from its relative isotopes?g. Model deriving the weighted average value of 4 quarters, 5 dimes, and 9 pennies. (In a weighted average, the value of each type of item is multiplied by the number of that type of item. The products are added, and the sum is divided by the total number of items). Have the students describe the steps and calculate their answers.h. Have students read the entire laboratory activity and make a flow chart of the procedure the students will follow.
During activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Ensure that students are completing the data tables correctly.b. Probe the thinking behind the experimental design: “Why are we using 100 pennies for this activity?” Have you noticed any differences in the mass of the pennies? Why are these differences found?c. Ask the students, what further analogies can they describe in the experiment?d. Have students brainstorm the parts of the experiment that may not mimic the natural properties of isotopes.
After activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Ask the students, “How are the different types of pennies analogous to the isotopes of an element?”b. How could the design of this experiment be improved?c. Which step of the calculations is analogous to the relative mass of an isotope?d. Which step of the calculations is analogous to the relative weighted mass of an isotope?e. Have students explain which calculation is comparable to the average weighted mass of the element, in this case an imaginary element called “Pennium”

Extension: Ask students to research online the existence, properties, and use of naturally occurring and man-made isotopes of various elements.

Student

Isotopes

NGSSS:

SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.

SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.

Background:

The defining characteristic of an atom of a chemical element is the number of protons in its nucleus. A given element may have a natural of different isotopes, which are nuclei with the same numbers of protons but different numbers of neutrons. For example, ^{12}C and ^{14}C are two isotopes of carbon. The nuclei of both isotopes contain six protons. However, ^{12}C has six neutrons, whereas ^{14}C has eight neutrons. In general, it is the number of protons and electrons that determines chemical properties of an element. Thus, the different isotopes of an element are usually chemically indistinguishable. These isotopes, however, have different masses.

Between 1962 and 1982, pennies were made of brass, which is an alloy composed of 95% copper and 5% zinc. In 1982, the rising price of copper led to a change in the composition of the penny. Beginning in 1982, pennies have been made of zinc plated with copper. These pennies contain 2.5% copper and 97.5% zinc. In this experiment, the two different types of pennies will represent two isotopes of an element.

Purpose of Lab/Activity:

- To determine the isotopic composition of 100 pennies
- To apply the lessons of the penny-isotope analogy to isotopic data.

Safety: Always wear safety goggles and a lab apron in the lab.

Vocabulary: “Average” atomic mass, relative and weighted atomic mass, Isotopes

Materials (individual or per group):

- Zip loc bag with pennies prepared by your teachers
- balance
- large box top
- 2 plastic cups

Procedures:

1. Use the plastic cups and large box top to contain pennies so they do not get lost.
2. Measure the mass of ten pre-1982 pennies to the nearest 0.01 g. Record your measurement in Data Table 1. Repeat for post-1982 pennies.
3. Using your data from step 1, calculate the average mass of one pre-1982 penny. Record this average mass in Data Table 1. Repeat for a post-1982 penny.
4. Obtain 100 pennies. Find the mass of the sample to the nearest 0.01 g. Record your measurement in Data Table 2.

Student

5. Divide the sample of 100 pennies into pre-1982 and post-1982 pennies. Record the numbers of each in Data Table 2.
6. Cleanup and Disposal- Follow your teacher's instructions for returning the coins.

Observations/Data:

Data Table 1

Mass of Pennies (g)	
Pennies	Mass (g)
10 pre-1982	
10 post-1982	
Avg. pre-1982 penny	
Avg. post-1982 penny	

Data Table 2

Data for 100-penny sample	
Mass of 100 pennies (g)	
Number of pre-1982 pennies in 100-penny sample	
Number of post-1982 pennies in 100-penny sample	
Ave mass of a penny in 100-penny sample (g)	

Data Analysis/Results:

1. In procedure step 1, why did you measure the mass of 10 pennies instead of the mass of 1 penny?
2. Using the mass of pre-1982 and post-1982 pennies from data table 1 and the number of each type of penny calculate the relative mass (RM) of each type of penny and list as average pre-1982 and post-1982 mass.
3. Calculate the relative abundance (RA) for each type of penny by dividing the amount of each type of penny by the total amount of pennies.
4. Derive the relative weighted mass (RWM) of each penny by multiplying the relative abundance by the relative mass for each type of penny.
5. Derive the weighted average mass (WAM) of Pennium by adding the two values from the previous step.

$$\text{WAM} = (\text{RM}_{\text{pre-1982}} \times \text{RA}_{\text{pre-1982}}) + (\text{RM}_{\text{post-1982}} \times \text{RA}_{\text{post-1982}})$$

Conclusions:

1. The density of copper is 8.96 g/cm^3 , and that of zinc is 7.13 g/cm^3 . Using the compositions given in the introduction, the density of a pre-1982 penny is $(0.95)(8.96 \text{ g/cm}^3) + (0.05)(7.13 \text{ g/cm}^3) = 8.87 \text{ g/cm}^3$. Calculate the density of a post-1982 penny.

Student

- A typical penny has a diameter of 1.905 cm and a thickness of 0.124 cm. What is the volume in cm^3 of a typical penny? Hint: $V = (\pi \times r^2)(\text{thickness of penny})$.
- Using the density and volume values from questions 1 and 2, calculate the theoretical mass of a pre-1982 penny and the mass of a post-1982 penny.
- Data Table 3 shows the isotopic mass and relative abundance for the most common isotopes of copper and zinc.
 - How many protons and neutrons are there in a ^{64}Cu nucleus?
 - How many protons and neutrons are there in a nucleus of ^{64}Zn ?

Data Table 3

Isotope	Atomic number	Mass number	Isotopic mass (amu)	Relative abundance (%)
Copper-63	29	63	62.9298	69.09
Copper-64	29	64	64.9278	30.91
Zinc-64	30	64	63.9291	48.89
Zinc-66	30	66	65.9260	27.81
Zinc-67	30	67	66.9271	4.73
Zinc-68	30	68	67.9249	18.57

- Use the data in table 3 to answer the following questions:
 - Calculate the atomic mass of copper.
 - Calculate the atomic mass of zinc.
- Use the values from the Table 1 and the answers from question 5 to calculate:
 - How many atoms of copper are in a pre-1982 penny (Hint: use Avogadro's number).
 - How many atoms of zinc are in a pre-1982 penny?
 - How many total atoms of Cu and Zn are in a pre-1982 penny?
 - How many total atoms of Cu and Zn are in a post-1982 penny?
- A nuclear power plant that generates 1000 MegaWatts of power uses 3.20 kg per day of U-235. Naturally occurring uranium contains 0.7% of U-235 and 99.3% U-238. What mass of natural uranium is required to keep the generator running for a day?

Flame Tests

NGSSS:

SC.912.P.10.9 Describe the quantization of energy at the atomic level.

SC.912.P.10.18 Explore the theory of electromagnetism by comparing and contrasting the different parts of the electromagnetic spectrum in terms of wavelength, frequency, and energy, and relate them to phenomena and applications.

Purpose of Lab/Activity:

- Observe the spectra emitted by different ions.
- Identify the metallic ions by the color emitted

Prerequisite: Prior to this activity the student should be able to:

- Know precautions to take when working with an open flame?
- Understand the basic structure of the atom.
- Describe the changes to atomic theory prior
- List the colors of the visible spectrum in order of increasing wavelength.

Materials (per group):

- lab goggles
- lab apron
- Bunsen burner
- nichrome wire loop
- wash bottle with distilled water
- well plate
- hydrochloric acid (HCl) 6.0 M in a dropper bottle
- solutions of metallic salts:
 - calcium nitrate ($\text{Ca}(\text{NO}_3)_2$)
 - copper nitrate ($\text{Cu}(\text{NO}_3)_2$)
 - lithium nitrate (LiNO_3)
 - potassium nitrate (KNO_3)
 - strontium nitrate ($\text{Sr}(\text{NO}_3)_2$)
 - sodium chloride (NaCl)
 - unknown solution (prepared by teacher)

Procedures: Day of Activity

Before activity:	<p>What the teacher will do:</p> <p>a. Review with students the electromagnetic spectrum. Make sure that they know that all electromagnetic waves travel at the speed of light 3.00×10^8 m/s.</p> <p>b. If available, provide prisms to the students and have them observe sunlight (indirectly). Ask students to describe the colors that they are able to see and have them locate this region on the electromagnetic spectrum. Emphasize that visible light is a small portion of the electromagnetic spectrum and that we use certain instruments (ex. Infrared devices) to extend our view of the spectrum</p> <p>c. Prepare 0.5M solutions of metallic salts. If nitrates are not available you can</p>
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Teacher

	<p>substitute with chlorides.</p> <p>d. Review procedures for using a Bunsen burner, emphasize fire safety.</p> <p>e. Prepare the unknown solutions with any of the metallic salts used. Make sure you record which salt is contained in the unknown given to each group.</p>
During activity:	<p>What the teacher will do:</p> <p>a. Monitor that safety procedures are being followed.</p> <p>b. Remind students to clean the nichrome wire correctly to prevent contamination. After cleaning the wire in the HCl acid, they should hold the nichrome wire in the burner till the wire imparts no color to the flame.</p> <p>c. The students should allow the wire to cool down before it is inserted in the salt solution.</p> <p>d. Talk to the students about the parts of the flame and ask them: In which part of the flame should the wire be inserted?</p> <p>e. Ask each lab group how they will determine the identity of the unknown. They may have to repeat their flame tests several times to be certain of the color observed.</p> <p>f. If possible provide pieces of cobalt glass which will allow for separation of colors that may obscure another.</p>
After activity:	<p>What the teacher will do:</p> <p>a. Discuss with students the results obtained from their lab. Have groups compare the colors that they observed.</p> <p>b. Lead students to understand that atoms give off light as they are subjected to energy.</p> <p>c. Discuss “ground state”, “excited state”, and photons.</p> <p>d. From their results, students should conclude that atoms of each element emit only select frequencies of light which can be used to identify that element.</p> <p>e. Lead the students to understand the relationship between wavelength and frequencies emitted and differences in energy between ground state and excited state</p> <p>f. Ask students to describe the difference between a line spectra and the continuous spectrum that they observed with the prism. Emphasize the discreteness of the lines from atoms in the gaseous state and make sure that they understand that in a solid lamp filament (incandescent lamp) the energy levels interact producing a smudged distribution of frequencies. Use the analogy of the tone of bells when struck together in a box, vs. the tone produced by each bell separate from another.</p>

Extension:

- Gizmo: [Star Spectra](#)
- Using Planck's equation : Energy = Planck's constant (h) X frequency (ν), ask the students to calculate the energy of one photon or one packet of energy.

Student

Flame Tests

NGSSS:

SC.912.P.10.9 Describe the quantization of energy at the atomic level.

SC.912.P.10.18 Explore the theory of electromagnetism by comparing and contrasting the different parts of the electromagnetic spectrum in terms of wavelength, frequency, and energy, and relate them to phenomena and applications.

Background:

Flame tests provide a way to test for the presence of specific metallic ions. The heat of the flame excites the loosely-held electrons in the metal ion prompting the electrons to jump from a ground level to a higher energy level in the atom. As the electrons fall back to their ground state, energy is released from the excited electrons and can be seen as a colored flame. The color is a combination of the wavelengths of each transition and can be used to determine the identity of an unknown ion. Although white light produces a continuous spectrum in which all wavelengths of visible light are present (400-700nm), an excited electron produces one or more specific lines in the spectrum. This unique spectrum corresponds to an element's distinct electron configuration.

Purpose of Lab/Activity:

- Observe the spectra emitted by different ions.
- Identify the metallic ions by the color emitted

Safety:

- Always wear safety goggles and a lab apron in the lab.
- Tie back hair and secure loose bulky clothing while working near a flame.
- All of the salt solutions (except NaCl) are toxic, if any of the solutions splash on your skin, wash affected area with large amounts of water and notify your teacher.
- Handle carefully the heated nichrome wire. Make sure to hold only from the handle.
- Hydrochloric acid is corrosive to the skin and clothing and the vapors are irritating to the lungs and the eyes. Avoid contact with the solution and inhalation of its vapors. If acid splashes on your skin or clothing wash immediately with soap and plenty of water and notify your teacher.

Vocabulary: atoms, electrons protons, continuous spectra, emission spectra, line spectra, wave length, frequency, energy, ground state (or level), excited state (or level).

Materials (per group):

- lab goggles
- lab apron
- Bunsen burner
- nichrome wire loop
- wash bottle with distilled water
- well plate
- hydrochloric acid (HCl) 6.0 M in a dropper bottle
- solutions of metallic salts:
 - calcium nitrate ($\text{Ca}(\text{NO}_3)_2$)

Student

- copper nitrate ($\text{Cu}(\text{NO}_3)_2$)
- lithium nitrate (LiNO_3)
- potassium nitrate (KNO_3)
- strontium nitrate ($\text{Sr}(\text{NO}_3)_2$)
- sodium chloride (NaCl)
- unknown solution

Procedures:

1. Put on your goggles and lab apron, and secure your hair.
2. Obtain a well plate and place it on a white sheet of paper. Label each well with the name of the solutions to be tested including a well for the unknown solution. Put a dropperful of each known solution into its corresponding well.
3. Clean the nichrome wire before testing each solution. Rinse the loop with distilled water followed by rinsing with the 6.0 M HCl. Place the loop into the flame for about a minute.
4. Following your teacher's discussion, make sure that the wire is inserted in the appropriate region of the flame.
5. Observe the color of the clean nichrome wire in the flame; this is the color you should see after you clean the wire for each new test. Briefly allow the wire to briefly cool down between tests.
6. Dip the nichrome wire into the well with the calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) solution and immediately place the loop into the flame. Observe and record the color of the flame in the Data Table. Repeat each test 2 or 3 times before trying a new solution. Clean the nichrome wire between each test (see step 3). Continue testing and recording the flame colors produced by the metallic ions of each solution.
7. Sodium has a very strong color which could affect the color results of your other tests. To prevent this from happening follow proper nichrome wire cleaning procedure and leave the sodium test for last.
8. Obtain an unknown from your teacher and repeat steps 3 and 4.

Observations/Data:

Compound in Solution	Ion	Flame Color
calcium nitrate ($\text{Ca}(\text{NO}_3)_2$)	Ca^{2+}	
copper nitrate ($\text{Cu}(\text{NO}_3)_2$)	Cu^{2+}	
lithium nitrate (LiNO_3)	Li^{1+}	
potassium nitrate (KNO_3)	K^{1+}	
strontium nitrate ($\text{Sr}(\text{NO}_3)_2$)	Sr^{2+}	
sodium chloride (NaCl)	Na^{1+}	
unknown solution		

Data Analysis/Results:

1. Is the color of the flame, a chemical or a physical property of these metals? Explain.

Student

2. What particles are found in the chemicals that may be responsible for the production of colored light in the metallic salts you tested?
3. What color did your unknown produce in the flame? What is your unknown?
4. What would have been another way of exciting the electrons without using a Bunsen burner?

Conclusion:

1. Why do different metals have different characteristic flame test colors?
2. The majority of the known compounds tested contain nitrate, yet the colors of the flames were different. What effect would you expect on the flame colors if these compounds were chlorides instead of nitrates?
3. A firework contains copper chloride and strontium sulfate. What colors would you expect to be produced?
4. When a pan of milk boils over onto the stove the flame turns red-orange. Explain why.

Extension for Advanced Students:

1. Describe the relationship between frequency and wavelength
2. Calculate the wavelength of the yellow light emitted by a sodium lamp, in meters, if the frequency of the radiation is $5.10 \times 10^{14}/\text{sec}$.
3. What is the energy of a photon of green light whose frequency is $6.85 \times 10^{14}/\text{sec}$?
4. The spectrum of lithium has a red line of 670.8 nanometers. (Hint: 1 meter = $1 \times 10^9 \text{nm}$).
 - a. Convert the nanometers, using dimensional analysis to meters.
 - b. Calculate the frequency of the wave.
 - c. Calculate the energy of a photon with this wavelength.
5. How is spectrometry used to determine the composition of stars?

Teacher

Periodic Trends

NGSSS:

SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

Purpose of Lab/Activity:

- Determine the periodic trends per group of main elements.
- Relate the reactivity of elements to their electron structure.

Prerequisite: Prior to this activity the student should be able to:

- Understand the structure of the atom.
- Determine the number of valence electrons for the main group elements.
- Relate how ions are formed when valence electrons are donated or received.
- Locate the Main Group elements on the Periodic Table labeled as 1, 2 and 3-18.

Materials (per group):

- 96 –well microplate or Playdough
- 36 plastic straws or coffee stirrers
- Scissors
- Calculator
- Ruler (cm)
- Graph paper
- Table of atomic radii and ionization energies

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Ask students which are the various ways that elements might be listed in a single vertical column.Ask students which are some of the properties of elements that could be used to organize the elements in the Periodic Table.Have students infer how groups and periods are used to organize elements with similarities.Review with students the use of a scale to do conversions. In this case, students should consider the length of the straw in cm. to propose a scale to convert Angstroms to centimeters.
During activity:	What the teacher will do: <u>Part 1- Atomic radius</u> <ol style="list-style-type: none">Discuss with students the tables provided that highlight the atomic radii and the Ionization energy data per element.Review students' proposed scale, make sure they can convert from Angstroms to centimeters (e.g., 2 cm = 1 Å)<ol style="list-style-type: none">Example: Li has an atomic radius of 1.52 Å. To create a model using the scale above, students must do the following: $1.52 \text{ Å} \times 2 \text{ cm} / 1 \text{ Å} = 3.04 \text{ cm}$. Therefore, the scaled radius of lithium will need a straw cut at the rounded value of 3.00 cm.Monitor that students use the scaled value to measure first and then cut the straws in centimeters.Straws should be placed all the way into the well plates or into the Play

Teacher

	<p>Dough. The 3D model should include the elements' symbol that they represent and the scale used.</p> <p><u>Part 2- Ionization Energy</u></p> <p>d. Make sure that students are graphing the ionization energy in the y axis and the atomic number in the x axis.</p>
After activity:	<p>What the teacher will do:</p> <p>a. Make sure students answer the analysis and conclusion questions before taking their 3D model apart. If possible have them attach a photo or a hand drawn picture of their model to their lab.</p> <p>b. Have students predict what they think will happen with the 2nd and 3rd ionization energies.</p>

Extension:

- Gizmo: [Element Builder](#), [Electron Configuration](#)

Student

Periodic Trends

NGSSS:

SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

Background:

Elements within the same family in the Periodic Table have similar properties and in many cases, one element can be replaced by another element with similar properties. This knowledge is presently being widely used in medicine with radioactive tracers that are being used more frequently to locate tumors in the body and deliver medications for their treatment. This knowledge is also being widely studied in external pollutants and contaminants that replace essential elements within the human body, such as the replacement of calcium in bones by radioactive strontium

Purpose or Problem Statement:

- Determine the periodic trends per group of main elements.
- Relate the reactivity of elements to their electron structure.

Safety: Non-applicable

Vocabulary: periodic trends, ionization energy and atomic radius.

Materials (per group):

- 96 –well microplate or Play dough
- 36 plastic straws or coffee stirrers
- Scissors
- Calculator
- Ruler (cm)
- Graph paper
- Color pencils or markers

Procedures:

Part 1- Making a 3D Model of Atomic Radius

1. Copy the values of Atomic Radii in Angstroms given in the first column of Table 1 into your Periodic Table. Describe any patterns you find as you from top to bottom and from left to right.
2. To create a 3-D model of the Atomic Radius trend, first measure a plastic straw to find the total length in cm.
3. Choose a conversion factor to change the radius of the first 35 elements listed in Table 1 from Angstroms into centimeters (Add the conversion factor to column 3 of Table 1) . Using the conversion factor, estimate the centimeters for each of the 35 elements, round each value to the nearest tenth and fill in the fourth column of Table 1.

Student

- Using the derived centimeters measure a straw for each element and cut and place each straw securely into the 96-well microplate to model the arrangement of the first 35 elements found in the Periodic Table.

Table 1- Conversion of Atomic Radii from Angstrom to Centimeter

Element	Radius in Angstroms	Conversion factor (X _____)	Derived centimeters (cm)
Li	1.52		
Be	1.11		
B	0.80		
C	0.77		
N	0.71		
O	0.66		
F	0.64		
Na	1.86		
Mg	1.60		
Al	1.43		
Si	1.18		
P	1.09		
S	1.03		
Cl	0.99		
K	2.27		
Ca	1.97		
Ga	1.22		
Ge	1.23		
As	1.21		
Se	1.40		
Br	1.14		
Rb	2.48		
Sr	2.15		
In	1.63		
Sn	1.62		
Sb	1.41		
Te	1.38		
I	1.33		
Ce	2.65		
Ba	2.17		
Tl	1.70		
Pb	1.75		
Bi	1.46		
Po	1.67		
At	1.40		

Student

Part 2- Graphing the First Ionization Energy

1. Analyze the information provided in Table 2-Ionization Energy which shows the energy necessary to remove the first electron (first ionization energy) from several elements and their corresponding atomic number (Z).

Table 2- Ionization Energy

Element	Z	First Ionization Energy (eV)
He	2	24.60
Li	3	5.40
Be	4	9.30
F	9	17.40
Ne	10	21.50
Na	11	5.10
Mg	12	7.60
Cl	17	13.00
Ar	18	15.70
K	19	4.30
Ca	20	6.10
Br	35	11.80
Kr	36	14.00
Rb	37	4.20
Sr	38	5.70

2. Plot the points of the ionization energy (y axis) vs. the atomic number (x axis) and label each point with the element symbol in the graph provided below.
3. Connect with different color lines the points corresponding to the elements within the same family or group.

Observations/Data Analysis:

1. For Part 1, analyze the 3-D model you created for the atomic radii for the first 35 elements. What pattern does this data show?
2. For Part 2, analyze your graph, what pattern does your graph show?

Conclusion:

1. Provide an explanation for the pattern of the elements as you go across a group? Provide an explanation for the pattern of the elements as you go down the group
2. Which group has the least reactive elements? How does this relate to their electronic structure?
3. Which group of elements are the most reactive? Where are they found in the periodic table?
4. Would you predict the second ionization energy to be higher or lower than the first? Explain.
5. What patterns would you expect for reactivity of the Transition elements? Explain.
6. Provide students with a blank Periodic Table and have them summarize the pattern found for both Atomic Radii and for Ionization energy.
7. Which elements are most likely to lose electrons? Explain.

Student

8. Which elements are most likely to gain electrons? Explain.
9. Electron affinity is the energy change when an electron is added to an isolated gaseous atom, how would the pattern of the ionization energy relate to the pattern of electron affinity? Explain.

Teacher

Models of Atomic Structure and Electrostatic Forces

NGSSS:

SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.

SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.

Purpose of Lab/Activity: To investigate the behavior of electrically charged objects and to create a model of atomic structure to account for the observed behavior.

Prerequisite:

- Students should have a solid understanding that matter is composed of tiny particles called atoms. It is not necessary for students to know that these particles have internal structure.
- One of the goals of this activity is for them to develop a model which includes oppositely charged particles as the atomic constituents.
- Students should also recognize that there is some natural force of attraction which keeps particles of a solid together and that make atoms stick to form compounds.

Materials (per group):

- Roll of scotch tape
- Piece of PVC pipe (about a foot in length)
- Piece of natural fur, or wool, or a cotton tube sock
- Rubber balloon
- Small pieces of paper or confetti

Procedures: Day of Activity

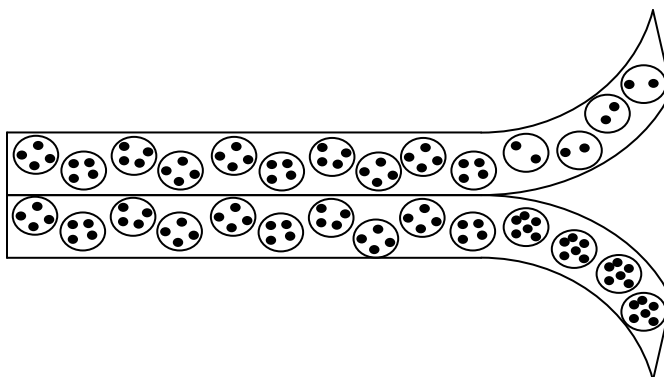
Before activity:	What the teacher will do: <ol style="list-style-type: none">a. Have the students work in pairs preferably. Groups of three will work fine also.b. Begin the activity with a simple demonstration of electrostatic forces. Inflate a balloon and rub it against your hair (without any hair styling products). The balloon is now charged and it will easily stick to the wall or another vertical flat surface. Then rub the balloon against your hair again and put it near some small pieces of paper or confetti. The paper will fly to the balloon. Ask the students what is it about the atoms of the balloon that once rubbed they behave in this way. Bring up the fact that this force must be stronger than gravity if it is able to make the small pieces of paper fly up. To show that this force is not just happening with balloons, rub a PVC pipe with natural fur, wool, or a tube sock and show them that it is also able to pick up the small paper pieces. Even more impressive is to open a water faucet so that a thin continuous stream of water flows out and approach the charged PVC pipe near it. The water stream will bend as it is attracted to the PVC pipe. Tell them that they are to perform an activity to investigate
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Teacher

	<p>the nature of this force.</p> <ol style="list-style-type: none">Demonstrate how to set up the tools for this investigation, specifically the tapes. Demonstrate that pulling two pieces of tape apart (see student procedure steps 1-5) produces tapes that can interact with an electrical force. Guide students in a discussion of how to investigate interactions with the other materials supplied.After showing how to create usable strips of tape, the students should be challenged to explore all possible two-strip interactions as well as interactions between the strips and other student-chosen objects (such as pens, notebooks, themselves, etc.).
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">As students set up the tapes supervise that they are following the correct procedure or their results will not be correctIt is sometimes difficult for students to see repulsion when two like tapes are brought together. If this is the case, the students need to recharge the tapes by putting them on the base tape and separating them again (see student procedure for detailed explanation).Encourage students to use terms such as attraction or repulsion to describe the effect of the tapes on other objectsStudents should check what happens when opposite tapes (attract) and when two equivalent tapes (repel) are brought together. They should also test the charged PVC rod with the tapes (it should attract the top tape and repel the bottom tape)
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">After students gather their results bring the students together for whole class discussion.Ask students what they think is happening to the atoms of the tapes as they are separated that transform their propertiesThe idea is to realize that when the tapes separate or the rod is rubbed with fur, electrons are transferred from one of the objects to the other.By definition, the plastic rod is considered to have a negative charge after being rubbed with a piece of fur or wool. Lead students to realize that the bottom tape is like the rod; so, it is also negative. The top tape has the opposite properties so it is positive.Ask students what happened when they brought both tapes close to common objects around the room. They should conclude that both bottom and top tapes attracted these objects. Lead students to understand that most objects are both positive and negative and therefore they show attraction to both tapes but there is no attraction or repulsion between the neutral objects.Students should realize that sub atomic particles (electrons) carry the negative charge in an atom while opposite sub atomic particles (protons) carry the positive charges. For most substances the amount of protons and electrons is equal making the substance neutral. Electrons are able to travel while protons remain in the atom.Energy from rubbing the fur or from separating the tapes is able to make electrons migrate creating an unequal number of protons and electrons that result in a charged object.

Teacher

- h. In the student version there is a diagram of tapes being pulled apart for them to add dots to represent electrons. An ideal representation is presented below:



The bottom tape has gained electrons from the top and is now negative. The top tape lost electrons and it is now positive. This diagram assumes that having 4 electrons (dots) makes the atom neutral which is the case when the tapes are stuck together.

- i. It is now possible to relate this activity with electricity. Students are familiar with the shock they feel when they walk on a carpet wearing socks and touch a grounded object. Make sure students understand that this movement of electrons is called electricity. If you have a Van de Graaff generator it is possible to show students a series of fun demonstrations of electricity in action.
- j. Students should also connect their newly developed model of the atom to the forces which holds solids together and that make atoms stick as compounds. This atomic glue is called electrostatic force.
- k. Conclusion questions address everyday instances where students experience static electricity. One important hazard students must be aware of is static spark hazard at gas stations. This link <http://www.esdjournal.com/static/refuelfr.htm> has a video of a girl inadvertently starting a fire while pumping gas. Instruct students that they should touch the car before nearing the gas pump to discharge themselves and prevent a hazardous spark.

Extension:

- Gizmo: [Pith Ball Lab](#), [Coulomb Force \(Static\)](#)

Student

Models of Atomic Structure and Electrostatic Forces

NGSSS:

SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.

SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.

Background: A solid is able to hold its shape because the particles that make it up are strongly attracted to each other. Also a chemical compound such as water is composed of separate atoms, H_2O . There is a force which holds the hydrogens to the oxygens so that they form a molecule. Some property inside the atom is responsible for the existence of this force.

Purpose or Problem Statement: To investigate the behavior of electrically charged objects and to create a model of atomic structure to account for the observed behavior.

Safety: Basic laboratory safety should be observed during this lab.

Vocabulary: Electrostatic force, electricity, electrons, attraction, repulsion.

Materials:

- Roll of scotch tape (shared between two groups)
- Piece of PVC pipe (about a foot in length)
- Piece of natural fur, or wool, or a cotton tube sock

Procedures:

Part 1 - Preparing the tapes

1. Take a 15 cm piece of transparent tape and make a handle on the end by folding under the first cm of tape, sticky side to sticky side. Place this tape on the lab table. This is the base tape.
2. Take a second 15 cm piece of transparent tape, make a handle as before, and place this tape on top of the base tape. Label this tape "B" for bottom.
3. Attach a third similarly prepared strip of tape onto the bottom tape. Label this tape "T" for top.



4. Repeat steps 1 through 3 above. You now have two sets of 3-layer tapes.

Student

Part 2 - Examining the behavior of the tapes

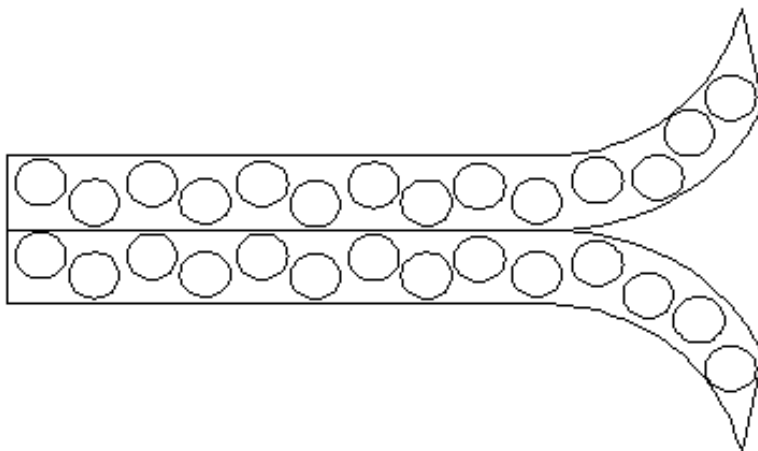
1. Peel one set of T and B tapes from its base tape, keeping the T and B tapes together. Run your finger down the non-sticky side, then quickly peel them apart.
2. As one student holds the freshly peeled top and bottom tapes on each hand, another student repeats the process with the other set of tapes.
3. Approach the two top tapes together, then the two bottom tapes and then all combinations of top and bottom tape. Record your observations.
4. Take a PVC rod and rub it with fur, wool, or any other cloth provided by your teacher. Approach the rubbed PVC pipe to freshly separated tapes. Record your observation.
5. Use a freshly separated top and bottom tape and approach it to objects around the room, it is your choice. Record your observations.
6. You may need to “recharge” you tapes after using them for a while. Just repeat steps 2-5. If after recharging, the tapes still don’t behave as expected, use new strips of tape.

Observations/Data:

1. What happens when you bring two top tapes near each other?
2. What happens when you bring two bottom tapes near each other?
3. What happens when you bring a top and a bottom tape near each other?
4. What happens when you bring the tapes near a recently rubbed PVC rod?
5. List the behavior of the tapes as you approach them to three objects of your choice.

Conclusion:

1. You should have noticed that when the tapes were in the roll there was no difference between them but after they were separated they behaved differently. Similarly, before rubbing the plastic rod, the rod is not able to attract anything but after rubbing, the rod becomes attractive. Based on a number of observations scientists have assigned the label of negative (–) to the charge of a rubber or plastic rod rubbed with fur or wool. The fur or wool becomes positively charged (+). Based on your observations from using the rod, label the T and B tapes as either a (+) or (–). Explain your reasoning.
2. Below you will find a diagram of two tapes being pulled apart. The circles in the tape represent atoms of the tape. Based on your observations and class discussion, draw electrons inside of the atoms (as black dots) to show the difference between the top tape and bottom tape before and after the tapes were separated. Explain your reasoning for each case.



Student

3. Both bottom and top tapes are able to attract a piece of paper. Knowing that objects of opposite charge attract each other, is the piece of paper negative or positive? Explain your reasoning
4. On a dry day you walk on carpet wearing socks. As you grab the door knob to open the door you feel a small shock. Explain what is happening at the particle level
5. Many gas stations have a warning for spark hazard. It is possible to ignite a dangerous fire at a gas station just by getting in and out of your car once you start fueling. Why does this occur and how can you prevent it?

Teacher

A Bagged Chemical Reaction

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

SC.912.P.8.8 Characterize types of chemical reaction, for example: redox, acid-base, synthesis and single and double replacement reaction.

Purpose of Lab/Activity:

- Observe the changes associated with a chemical reaction including heat changes, changes in an indicator, bubble of gas released.
- Determine which compounds are reactants and which are products through the use of a chemical equation.
- Use indicators in order to identify whether a solution is acidic or basic.

Prerequisite: Prior to this activity the student should be able to:

- Identify the reactants and the products of a chemical reaction
- Describe the changes that can evidence that a reaction has taken place.

Materials (individual or per group):

- Safety goggles & Lab apron
- Plastic cup
- Calcium chloride pellets (CaCl_2)
- Baking soda, sodium bicarbonate (NaHCO_3)
- Water
- Phenol red solution (acid/base indicator solution)
- Measuring cup or graduated cylinder
- 2 plastic teaspoons
- 1-gallon Ziploc-type bag
- 2 twist ties or rubber bands

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Lead students to acknowledge that when a chemical reaction takes place new substances are formed as particles are rearranged.Guide a class discussion on identifying types of evidence that a chemical reaction has taken place.Verify that students distinguish between endothermic and exothermic. Clarify misconceptions; many students think that all chemical reactions are exothermic.
During activity:	What the teacher will do: <ol style="list-style-type: none">Ensure the students shake the bag away from their faces and clothes. Once bags get tightly filled with gas, release the CO_2. Bags may explode!Ask students about the role that water has in this experiment. What would happen if the reaction was attempted just with dry products? Students should answer that without water the reaction would take very long. Refer them to the Conductivity and Solubility Lab to remind them that since the reactants are ionic, they dissociate or break apart in water.If the bag does explode, all the products are non-toxic and can be washed off.

Teacher

After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> Discuss the evidence that the students saw of a chemical reaction as a class. Students should find that in the first 2 bags a physical change took place even if heat was generated in the bag with CaCl_2 and water. The students should observe the bubbling/fizzing and the filling up of the bag with CO_2 to denote the production of this gas. A burning splint can be introduced to verify the presence of this gas in the third bag. Note: Phenol red is flammable In the fourth bag where phenol red (acid base indicator is added), the color changes from red to yellow to demonstrates that this reaction is acidic. Make sure that students understand that the increase of temperature in the third and fourth bag correspond to the release of energy from chemical bonds that are broken. Try to have the students draw the reaction at the particulate level. They should account for the kinetic energy of the water molecules bumping the ions from the reactants into each other (collision theory). As H ions bump into the oxygen ions they bond covalently to form water. In a similar fashion, the carbon and the oxygen ions form the carbon dioxide (can be identified by the bubbles) and the calcium carbonate also forms. Some of the calcium carbonate dissolves and the rest is a solid. The sodium and chloride ions remain in solution. With help, they should be able to write out the chemical equation for the reaction as shown here: $2\text{NaHCO}_3(\text{s}) + \text{CaCl}_2(\text{s}) \rightarrow \text{CaCO}_3(\text{s}) + 2\text{NaCl}(\text{aq}) + \text{HCl}(\text{aq})$ $\text{NaHCO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) + \text{NaCl}(\text{aq})$ <p>Students may recognize CaCO_3 (calcium carbonate) as a main component of chalk. Also, they may identify NaCl and H_2O as a mixture of salt water in the bag. Lastly, the gas in the bag is carbon dioxide, which is exhaled from our bodies and then taken in by plants, so they can generate oxygen.</p> Review the completion of the data table with students (see answers below)
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Table 1 - Answer Key

	Physical or Chemical change	Production of gas	Color change	Temperature change
NaHCO_3 in water + indicator	physical	no	Bright pink (pH>8.2 basic)	cold
CaCl_2 in water	physical	no	no	warm
NaHCO_3 + CaCl_2 in water	chemical	Yes (CO_2)	no	final- warm
NaHCO_3 + CaCl_2 with water + indicator solution	chemical	Gas (CO_2)	Yellow (pH<6.8 acidic)	final-warm

Teacher

Extension:

- Gizmo: [Limiting Reactants](#)

Student

A Bagged Chemical Reaction

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

SC.912.P.8.8 Characterize types of chemical reaction, for example: redox, acid-base, synthesis and single and double replacement reaction.

Background:

Chemical reactions occur when molecules come together to form new products. In our bodies and environments, chemical reactions occur continuously to help run our lives. During a reaction, chemical bonds are broken and remade. Usually, color changes, gases being released, changes in temperature, and/or formation of solute characterize chemical reactions. These events describe changes in energy or solubility of the compound, meaning new products were produced.

Chemical reactions can be defined by a chemical equation in which reactants and products are characterized by chemical symbols. All chemical reactions are accompanied by a change in energy. Some reactions release energy to their surroundings (usually in the form of heat) and are called **exothermic**. For example, sodium and chlorine react so violently that flames can be seen as the exothermic reaction gives off heat. On the other hand, some reactions need to absorb heat from their surroundings to proceed. These reactions are called **endothermic**. A good example of an endothermic reaction is that which takes place inside of an instant "cold pack." Commercial cold packs usually consist of two compounds - urea and ammonium chloride in separate containers within a plastic bag. When the bag is bent and the inside containers are broken, the two compounds mix together and begin to react. Because the reaction is endothermic, it absorbs heat from the surrounding environment and the bag gets cold.

Purpose of Lab/Activity:

- Observe the changes associated with a chemical reaction including heat changes, changes in an indicator, bubble of gas released.
- Determine which compounds are reactants and which are products through the use of a chemical equation.
- Use indicators in order to identify whether a solution is acidic or basic.

Safety:

- Remind students that there is **NO** eating or drinking during the lab.
- CO₂ is produced in the bags. Make sure the area is well-ventilated before releasing all the gas.
- Do not let students ingest baking soda or calcium chloride. Avoid contact with eyes or mouth. If ingested in small amounts neither compounds are toxic, but if ingested in larger amounts give student a full glass of water and contact a medical facility.
- Watch for bags exploding. Ensure the students shake the bag away from their faces and clothes.
- Once bags get tightly filled with gas, release the CO₂. If the bag does explode, all the products are non-toxic and can be washed off.
- The bags can be disposed of in the trash because all products are non-toxic.

Student

Vocabulary: chemical reaction, reactants, products, exothermic, endothermic

Materials (individual or per group):

- Safety goggles & Lab apron
- 4 tbsps Calcium chloride pellets (CaCl_2)
- 2 tbsp Baking soda, sodium bicarbonate (NaHCO_3)
- Phenol red solution
- Measuring cup or graduated cylinder
- 2 plastic teaspoons
- Plastic cup
- 4 1-gallon Ziploc-type bag
- 2 twist ties or rubber bands
- Water

Procedures:

1. In a Ziploc type of bag, place 2 tablespoons of sodium bicarbonate (sodium hydrogen carbonate) and a film-canister or vial (1/3 full of water or 30 ml) with 3 drops of the phenol red indicator added to the water. Place canister/vial in the bag in the upright position. Squeeze the excess air and seal the bag. Spill the water into the bag and record observations. Record observations in Table 1.
2. To a second Ziploc type bag add 1 tablespoon of calcium chloride and add the same amount of water as in the previous step but without the phenol red indicator. Repeat procedure in step 1. Record observations in Table 1.
3. To a third Ziploc bag, add 2 tablespoons of calcium chloride into one corner of the bag, twist off the corner to separate chemical from the rest of the bag and tie with a rubber band or twist tie.
4. Into the opposite corner of the third bag, add 2 tablespoons of sodium bicarbonate and twist off the corner to separate from the rest of the bag and tie with a rubber band or twist tie.
5. Place the canister/vial with 30 ml of water in the middle of the bag in the upright position.
6. Squeeze the excess air and seal the bag.
7. Carefully untwist the 2 corners (if using rubber bands, use scissors to cut them careful not to cut the bag) while the partner holds both corners apart.
8. Release both corners and allow all three chemicals to mix. Quickly observe any immediate changes in the corners. Record all your observations in Table 1.
9. In a fourth bag repeat steps #3-8 but this time with 3 drops of the phenol red indicator to the water. Record all your observations in Table 1.

Student

Observations/Data

Table 1- Physical and Chemical Changes

	Physical or Chemical change	Production Of gas	Color change	Temperature change
NaHCO ₃ in water + indicator				
CaCl ₂ in water				
NaHCO ₃ + CaCl ₂ in water				
NaHCO ₃ + CaCl ₂ with water + indicator solution				

Observation/Data Analysis:

1. Which steps could be characterized as physical or chemical change? Justify your reasoning
2. What observations confirm the presence of a chemical change?
3. Which process(es) would you characterize as exothermic? Explain.
4. Which process(es) would you characterize as endothermic? Explain.

Conclusion:

1. What was the function of the phenol red in the experiment?
2. During this reaction, baking soda (NaHCO₃) is combined with calcium chloride (CaCl₂) in water. Write the balanced chemical equation for the reaction that occurred.
3. Give the names of all the compounds present in the chemical reaction you observed.
4. What type of gas is in your bags? How can you verify?
5. Propose an explanation for where the energy change originated.
6. Which general chemical principles or laws can you confirm in this investigation?

Teacher

A Mole Ratio

NGSSS:

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Purpose of Lab/Activity:

- To examine the qualitative properties of chemical processes.
- To relate macroscopic observations to changes on an atomic scale.
- To quantify the amount of mass and moles of chemical species
- To determine % yield and limiting reactants.
- To develop a sound model for oxidation reduction reactions

Prerequisite: Prior to this activity, the student should be able to:

- Understand the differences between chemical and physical processes.
- Describe the basic structure of an atom.
- Relate the subatomic particles to the properties of an atom.
- Distinguish between compounds, elements and mixtures.
- Understand clearly that the number of valence electrons determines the difference between ions and elements. It must be clear that elements have a zero charge due to the same number of electrons and protons while ions can be positive or negative due to the unequal number of protons and electrons.
- Convert from grams to moles and vice versa.

Materials (individual or per group):

- Iron metal filings: 20 mesh
- Copper (II) sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
- 400-ml and 150-ml beakers
- 100-ml graduated cylinder
- weighing paper (filter paper can be used)
- balance, hot plates
- Beaker tongs, distilled water
- Stirring rod

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ol style="list-style-type: none">Prepare the required chemical reagents.Summarize the procedure to students. Emphasize the fact that they will be combining a solution (CuSO_4) with a metal in its elemental form (Iron)Have students describe at the particle level the state of the reactants. The goal is for them to visualize that the copper and sulfate are charged ions which have been separated by the water in the aqueous state while the iron is elemental with zero charge.After establishing the nature and charge of the reactants, ask students to predict the products. Allow them to be creative but limit them to the
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Teacher

	<p>reactants used. They should not incorporate extraneous substances. Resist giving them the answer.</p> <p>e. Review safety procedures before student work on activity</p>
During activity:	<p>What the teacher will do:</p> <p>e. Direct the students to describe the physical properties being observed such as color change or appearance of a new substance.</p> <p>f. As soon as students add the iron to the copper sulfate they will observe the reaction occur right away. Ask students to consider possible reasons for their observations.</p> <p>g. Students should soon realize that a new “orange” substance is appearing. Once the reaction is finished and the product is isolated, ask them what they think this new substance is. Many students believe it is “rust”, remind them that rust is iron oxide and point to the properties of the new substance such as its orange color and shininess. The idea is for them to realize that the substance is pure elemental copper.</p> <p>h. Point to students that the color of the supernatant solution has changed. This is a very important clue for them to understand the chemical process.</p> <p>i. Have students reason on how to conclude when the process is complete.</p> <p>j. What is the purpose of heating the solution initially?</p>
After activity:	<p>What the teacher will do:</p> <p>a. After cleaning and disposal, students should work in groups to complete analysis questions in their procedure.</p> <p>b. Bring students together for whole class discussion. The discussion has two main parts, qualitative and quantitative. Depending on the amount of class time, these could be done in different days.</p> <p>c. The objective in the qualitative discussion is for students to have a clear understanding of the oxidation reduction process. One of the clues you should give your students is that the iron disappears from view. Point to them also that copper was in aqueous ionic form before the reaction and after the reaction it became elemental neutral copper. Copper went from the 2+ state to the zero state. The only way for this to happen is for the copper to gain electrons. Lead students to realize that copper removed the electrons from the iron filings and that the iron went from zero state to some ion state (2+ or 3+).</p> <p>d. Introduce the terms oxidation and reduction. Use a mnemonic device such as LEO says GER (Lose Electrons Oxidation, Gaining Electrons Reduction) to help student memorize the newly acquired concepts.</p> <p>e. Ask students to explain the role of the sulfate ions. Lead them to see that they do not participate in the reaction. The state and properties of sulfate do not change in the reaction. They are called spectator ions and they do not participate in the reaction.</p> <p>f. Direct the students to construct a chemical equation for the process. Because iron could turn into Fe^{2+} or Fe^{3+} there are two possible equations. This is the bridge to the quantitative discussion that will ensue.</p> <p>g. Ask student to propose quantitative ways to determine if iron (II) or iron (III) was produced. They should conclude that the coefficients in the balanced equations are different and that a mole ratio analysis could determine the correct product.</p>

Teacher

	<p>h. Help students identify which reactant “ran out” first. They should observe that no iron remains. Introduce the concept of limiting and excess reagent.</p> <p>i. Discuss the process of calculating theoretical, actual and percent yield.</p> <p>j. A few enrichment questions that could be addressed at the end of this activity include:</p> <ol style="list-style-type: none">1. Could the reaction be forced backwards? Why or why not?2. What are the factors that affect the percentage yield?3. Is there a way to increase the yield in the reaction?4. What do the color change of the supernatant solution tells you?5. What other reactions follow this same pattern?
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Extension:

- Gizmo: [Chemical Equations](#)

Student

A Mole Ratio

NGSSS:

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Background:

Chemicals react with each other in fixed proportions based on various bonding principles. The valence electrons in the reacting atoms are responsible for the nature of these reactions. For these reactions to occur, the atoms must collide in the appropriate set of conditions. In this

Purpose or Problem Statement:

- To examine the qualitative properties of chemical processes.
- To relate macroscopic observations to changes on an atomic scale.
- To quantify the amount mass and moles of chemical species
- To determine % yield and limiting reactants.

Safety:

- Safety goggles and aprons must always be worn!
- No eating or drinking
- Hot objects will not appear to be hot
- Do not handle or heat broken, chipped, or cracked glassware
- Turn off the hot plate when not in use.

Vocabulary: Chemical reactions, moles, limiting reagent, excess reagent, actual, theoretical and percentage yield, valence electrons, compounds, ions, atoms, molecules, elements, oxidation-reduction, spectator ions.

Materials (per group):

- Iron metal filings: 20 mesh
- Copper (II) pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)
- 400-ml and 150-ml beakers
- 100-ml graduated cylinder
- Weighing paper (filter paper can be used)
- Balance, hot plates, beaker tongs, distilled water
- Stirring rods.

Procedures:

1. Measure and record the mass of a clean, dry 150-ml beaker.
2. Place approximately 12.00-grams of copper (II) pentahydrate into the 150-ml beaker and measure and record the combined mass.
3. Add 50.00-ml of distilled water to the copper (II) pentahydrate and heat the mixture on the hot plate at a medium setting. Stir until the solid is dissolved, but do not boil. Using tongs, remove the beaker from the hot plate.
4. Measure approximately 2.00-grams of iron metal filings onto a piece of weighing paper. Measure and record the exact mass of the filings.

Student

5. While stirring, slowly add the iron filings to the hot copper (II) sulfate solution.
6. Allow the reaction mixture to stand, without stirring, for 5 minutes to ensure complete reaction. A new solid product will settle to the bottom of the beaker.
7. Use the stirring rod to decant (pour off) the liquid into a 400-ml beaker. Be careful to decant only the liquid.
8. Add 15.00-ml of distilled water to the solid and carefully swirl the beaker to wash the product. Decant the liquid into the 400-ml beaker.
9. Repeat step 8 two more times.
10. Place the 150-ml beaker containing the wet solid on the hot plate. Use low heat to dry the solid.
11. Remove the beaker from the hot plate and allow it to cool.
12. Measure and record the mass of the cooled 150-ml beaker and the solid.
13. Cleanup and Disposal:
 - a. Make sure the hot plate is off and cool.
 - b. The dry solid can be placed in a waste container. Wet any residue that sticks to the beaker and wipe it out using a paper towel. Pour the supernatant solution into a large beaker in the fume hood.
 - c. Return all lab equipment to its proper place.
 - d. Wash your hands thoroughly after all lab work and cleanup is complete.

Observations/Data:

Data Table

Mass of empty 150-ml beaker (g)	
Mass of 150-ml beaker + $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (g)	
Mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (g)	
Mass of iron filings (g)	
Mass of 150-ml beaker and dried product (g)	
Mass of dried product (g)	
Observations:	

Student

Data Analysis/Results:

1. List all the observations that serve as evidence that a chemical reaction occurred?
2. From your data, determine the mass of the copper produced.
3. Use the mass of copper to calculate the moles of copper produced.
4. Calculate the moles of iron used in the reaction.
5. Determine the whole number ratio of moles of iron to the moles of copper from your data in steps 3 and 4.
6. Based on your result from part 5, write a chemical equation for the reaction that took place.
7. Use the balanced chemical equation to calculate the mass of copper that should have been produced from the sample of iron used: theoretical yield.
8. Use this number and the mass of copper you actually obtained (actual yield) to calculate the percentage yield.
9. What was the source of any deviation from the mole ratio calculated?
10. How could the yield have been improved?

Conclusions:

1. Using mole ratios, determine the expected yield of copper metal if all the $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ had been consumed.
2. Use this answer and that of #7 to explain what reagent was the limiting reagent.
3. Using the terms oxidation and reduction to explain at the particle level the process that occurred in the reaction.
4. How could reactions which involve the spontaneous transfer of electrons be used in a practical way?
5. An internal combustion engine relies primarily on the efficient production of energy by the combination of oxygen (O_2) and gasoline (assume this is primarily octane, C_8H_{18}). Write the chemical equation for this reaction and derive the exact ratio of oxygen to octane for 100% efficiency.
6. Automobile air bags inflate on impact because a series of gas-producing chemical reactions are triggered. To be effective in saving lives, the bags must not overinflate or underinflate. What factors must automotive engineers take into account in the design of air bags?

Teacher

Hydrated Crystals

NGSSS:

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Purpose of Lab/Activity:

- To evaluate the relationship between mass and chemical change.
- To derive the empirical formula of a hydrated salt using gravimetric analysis.

Prerequisite: Prior to this activity, the student should be able to:

- Quantify the relationship between mass and moles.
- Write chemical formulas using the basic principle of chemical bonding.
- Understand the differences between chemical and physical processes.
- Understand the basic principle of the 1st law of thermodynamics.
- Be able to compare briefly endothermic and exothermic changes.

Materials (per group):

- Hotplates
- Balance (preferably 2 decimal places)
- Hydrated $\text{MgSO}_4 \cdot n\text{H}_2\text{O}$ (Epsom salts)
- crucible
- crucible tongs
- 400-ml beaker

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ol style="list-style-type: none">Review the principles of chemical bonding with the students.Explain the differences between ionic and covalent bondingHelp students to visualize how water molecules are bonded to an ionic solid to form a hydrate.Have the students describe the “phase” of the water in the hydrate- Is it a solid or liquid? Why or why not?Introduce the coordinate covalent bonding briefly between the unit of the salt and the molecules of water.Demonstrate the safe and proper use of the hot plates, crucible and crucible tongs.Review the steps in measuring/calculating the mass and moles of the water and the salt.Explain how the data will be used to derive the empirical formula of the hydrate.
During activity:	What the teacher will do: <ol style="list-style-type: none">Supervise the safety precautions in handling the hot plates, crucibles and proper use of the crucible tongs.Ask students if they observe any evidence of water leaving the hydrate

Teacher

	<ol style="list-style-type: none">c. Ask students to explain, “What is the phase of the water molecules being lost”?d. What part of the process is chemical? What part is physical?e. Help the students evaluate and minimize the sources of error as they are conducting the experiment.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Have students work in groups to answers the analysis questions.b. Supervise the mathematical manipulations of data to ensure that students understand the steps.c. Help the students relate their observations to the calculated results.d. As a whole class discussion format discuss all the analysis questions in the student results.e. Have students describe the energy changes taking place between the atoms during the experiment.

Extension:

- Gizmo: [Stoichiometry](#)

Student

Hydrated Crystals

NGSSS:

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Background:

Hydrates are crystalline compounds with water molecules incorporated in their structure. The ratio of moles of water to one mole of the compound is a whole number which can be determined experimentally by heating the hydrate to remove the water. For example, in the hydrated compound copper (II) sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), the ratio is 5:1. There are 5 molecules of water for each formula unit of copper (II) sulfate. Once the water has been removed from a hydrated compound, it has become anhydrous. The ions in the compound are associated via ionic bonding. The atoms in water molecules are associated covalently. The ionic compound and the covalent compound are associated by a coordinate covalent bond. The overall structure can be viewed as an ionic compound. It can be thought that water is trapped inside the ionic crystal lattice and heating the substance can provide the energy necessary to liberate the water molecules.

The percentage error between the experimental and theoretical percentages of water in a hydrate can be calculated using the following equation:

$$\% \text{ Error} = \frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \times 100$$

Purpose or Problem Statement:

- To evaluate the relationship between mass and chemical change.
- To derive the empirical formula of a hydrated salt using gravimetric analysis.

Safety:

- Always wear safety goggles and a lab apron
- Hot objects will not appear to be hot.

Vocabulary: hydrates, anhydrous, gravimetric analysis, coordinate covalent bond, endothermic, exothermic

Materials (individual or per group):

- Hot plate
- Balance (preferably 2 decimal places)
- Hydrated $\text{MgSO}_4 \cdot n\text{H}_2\text{O}$ (Epsom salts)
- Crucible
- Crucible tongs
- 400 ml beaker

Student

Procedure:

1. Allow hot plate to warm up on the high setting.
2. Measure to the nearest 0.01 g the mass of a clean, dry crucible and record.
3. Add provided hydrated MgSO_4 to the crucible and measure the mass of the crucible plus hydrate to the nearest 0.01 g. Record the mass.
4. Observe and describe the properties of the solid hydrate before heating
5. Place the crucible with hydrate on the hot plate and cover with the large beaker.
6. After a few minutes write down what you observe happening inside the large beaker, and then carefully remove the large beaker while wearing a hot mitt or with beaker tongs.
7. Continue heating the crucible and contents for a total of about 10 minutes.
8. Use the crucible tongs to remove the crucible from the hot plate, allow it to cool, and determine the mass of crucible plus the anhydrous contents. Record this mass.
9. Reheat the crucible and contents for about 5 minutes, cool, and mass it again.
10. If these last two masses do not agree within 0.02g, you should reheat the crucible and contents a third time.
11. Dispose of the MgSO_4 according to your teacher's directions, and then clean the beakers and crucible.

Observations/Data:

Table 1

	Observations
Solid Hydrated MgSO_4	
Large beaker during initial heating	
Solid Anhydrous MgSO_4	

Table 2

	Mass Data
Mass of crucible	
Mass of crucible + MgSO_4 hydrate	
Mass MgSO_4 hydrate	
Mass of crucible + anhydrous MgSO_4	
Mass anhydrous MgSO_4	
Mass of water in MgSO_4 hydrate	

Data Analysis/Results:

Percentage of Water

1. Calculate the percentage of water in the hydrated crystals of MgSO_4 using your experimental data.
2. Assuming that the correct formula for the hydrate is $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, calculate the theoretical percentage of water in the hydrated crystals.

Student

3. Calculate your percentage error by comparing your experimental and theoretical percentages of water in the hydrate.

Hydrate Formula

1. Calculate the moles of anhydrous MgSO_4 .
2. Calculate the moles of water removed from the hydrate by heating.
3. Determine the ratio of moles of water to moles of anhydrous MgSO_4 .
4. Using this ratio, give the experimentally determined, predicted formula for hydrated MgSO_4 .

Conclusions:

1. Compare your observations of the hydrated and anhydrous crystals.
2. The method used in this experiment is not suitable for determining the percentage of water in all hydrates. Explain why this may be so.
3. What might you observe if the anhydrous crystals were left uncovered overnight?
4. If you were to repeat this experiment, what would you change in order to decrease your % error?
5. What if the hydrate was added to water, would this be a physical or chemical change? Explain and represent the change in an equation.
6. If energy was added (endothermic change) to remove the water from the salt, then what would happen energetically if water was added to the anhydrous salt? Explain.
7. Packets of the anhydrous form of a hydrate are sometimes used to keep cellars from being damp. Is there a limit to how long a packet could be used?
8. Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is a mineral used for making wallboard for construction. The mineral is stripped of three-quarters of its water of hydration in a process called calcining. Then, after mixing with water, it hardens to a white substance called plaster of Paris. Infer what happens as calcined gypsum becomes plaster of Paris.
9. How could the energetic processes involving a hydrate be used in a heat exchange process?

Changes of State

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

Purpose of Lab/Activity:

- Determine how the temperature changes as water changes state.
- Understand the role of energy as an agent of change at the particle level.
- Given a heating/ cooling curve for a substance, name each phase corresponding to the curve.

Prerequisite: Prior to this activity the student should be able to:

- Represent with a particle level model the difference between solid, liquid and gas, and the vocabulary used to describe those changes.
- Understand that temperature is determined by the movement of particles (kinetic or more specific thermal energy)
- Understand how energy is transferred through conduction.

Materials (per group):

- Ice
- Beaker (400 ml)
- Thermometer
- Stirring rod
- Timer (s.)
- Hot plate or Bunsen burner
- Optional-Graphing calculator/CBL/temperature probes or any other digital hand-held device(increases accuracy and instant feedback of the changes occurring)

Procedures: Day of Activity

Before activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> Review particle diagrams for each phase of matter. Discuss how the pattern of the particle diagrams corresponds to the properties of matter at the macroscopic level. Ask students what explains the rigidity of solids, and the fluidity of liquids and gases. Lead students to infer the “stickiness” or forces of attraction between the particles for each model. Review student prior knowledge on terminology used for changes of state of matter (i.e., condensation, evaporation, fusion, deposition, etc.) Introduce the purpose of the lab activity, to measure the temperature as it changes from solid to liquid to gas. Have the students predict the shape of the line in a temperature vs. time graph.
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Teacher

During activity:	What the teacher will do: <ol style="list-style-type: none">Monitor data collection and engage each group by probing their understanding of what is occurring at the particle level.Ensure that students are completing the guiding questions provided in the “Student Lab Guide” as they are collecting data. Focus on their particle diagram for accurate modeling. Students tend to draw at the macroscopic level, remind them to draw what they cannot see (microscopic level) but they infer.If students are working with a Bunsen burner make sure that proper safety procedures are followed. If hot plates are used, maintain a low temperature during the melting phase after this phase change the temperature can then be increased.Remind students that stirring is needed only during the melting phase.
After activity:	What the teacher will do: <ol style="list-style-type: none">Make sure that each student has a heating curve completed.Discuss how their final graph compares to their initial predictions.Have the students divide their graphs into regions as follows:<ol style="list-style-type: none">a low temperature plateaua region of temperature changea high temperature plateauUse probing questions below to have students analyze what is occurring at each region of the graph.<ol style="list-style-type: none">During the melting phase, why is the temperature not changing even though the beaker is on the hot plate? Have students explain what is happening at the particle level in this region; are the particles moving faster?After establishing that the particles are not changing their average speed and observing that temperature remains constant, ask: How is the energy being used? The idea is to have students conclude that the energy is acting to overcome the attractive forces thus leading to the melting process.Have students look at the next region of the graph and relate the temperature change to the behavior of the particles and the increase in kinetic energy.Have the students compare and contrast the two plateaus in their graph. Ask students which process would be expected to require more energy, solid to liquid or liquid to vapor, and provide explanations for their answers.Have students extend (extrapolate) on their graph the regions when water is all in the solid state and all in gaseous state. Students can use $\Delta T = 0$ or $\Delta T > 0$ for the different regions of their graph.Note: A good rule for students to remember is that when you have 2 phases present, the temperature is constant, but when you have only 1 phase the temperature could be changing.

Extension:

- Gizmo: [Phase Changes](#)

Student

Changes of State

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

Background: Matter can be found in three different states, solids, liquids, and gases. (There are other states of matter that will not be addressed in this lab). In a solid, the particles are attracted to each other strongly which makes them keep their shape and be rigid. In a liquid, particles are attracted more loosely and this allows them to move past one another and be fluid. In a gas, the attraction between particles is very small and particles move around bouncing into one another and into the walls of the container. Temperature is a measure of the kinetic energy of the particles in a system. The higher the temperature, the more energy of motion the particles have.

Purpose of Lab/Activity:

- Determine how the temperature changes as water changes state.
- Understand the role of energy as an agent of change at the particle level.
- Given a heating/ cooling curve for a substance name each phase corresponding to the curve.

Safety:

- Always wear safety goggles and a lab apron.
- Use hot mitts to handle hot plates.
- Do not eat or drink anything in a laboratory.

Vocabulary: temperature, states of matter, kinetic energy, potential energy, melting (fusion), freezing, evaporation, condensation, temperature change (ΔT), heating/cooling curve

Materials (individual or per group):

- Ice
- Beaker (400 ml)
- Thermometer
- Stirring rod
- Timer (sec)
- Hot plate or Bunsen burner
- Optional-Graphing calculator/CBL/temperature probes or any other electronic hand-held device (increases accuracy and instant feedback of the changes occurring)

Procedures:

1. Turn your hot plate to medium setting (or as recommended by your teacher) and allow a few minutes for the plate to heat up.
2. Add ice (preferably crushed) to the 400ml beaker (half filled is enough).
3. Measure the initial temperature of the water in $^{\circ}\text{C}$ and record in Table 1.

Student

4. Place the beaker on the hot plate and record the temperature every 30s. Carefully stir the ice 5 seconds before taking temperature readings. Do not allow the thermometer to touch the bottom of the beaker when recording the temperature.
5. When the water starts boiling, continue recording the temperature every 30 seconds for an additional three minutes. Extend Table 1 as needed to record your data.

Observations/Data Analysis: As you perform the experiment, make your observations and analyze your data completing the “Student Lab Guide”.

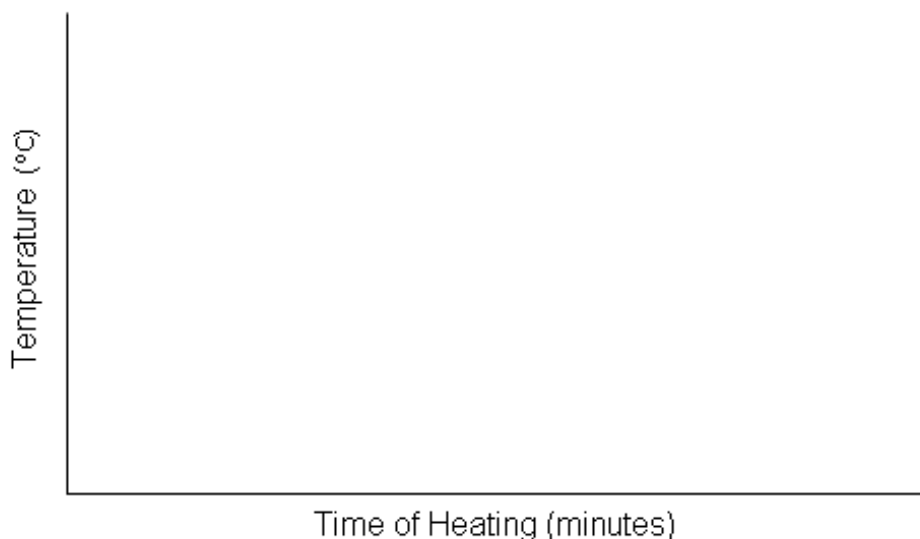
Conclusion: Summarize the scientific principles that you discovered in this lab using the following terms:

- temperature
- states of matter
- kinetic energy
- potential energy
- melting (fusion)
- freezing
- evaporation
- condensation
- temperature change (ΔT)
- heating/cooling curve

Student

Changes of State Lab – Student Lab Guide

1. In the following graph sketch your prediction of what will happen to the temperature of the system as you start heating it. Include any relevant temperatures.



2. Explain your reasoning behind your prediction:
3. Keep track of your data using a table similar to the one below:

Table 1- Temperature vs. Time

Time (s)	Temperature (°C)
Initial	
30 s	
60 s	
90 s	

4. Start heating the beaker. As you heat the beaker while stirring constantly, what is happening to the temperature of the system?
5. What phase(s) are present in the beaker?
6. Using the boxes below, draw at the particle level the changes occurring as the ice melts



ice and a little water
Temperature:

Time:



half ice and half water
Temperature:

Time:



all water
Temperature:

Time:

Student

7. What happens to the kinetic energy of the system as the ice is melting? Why?
8. When all the ice has melted, what happens to the temperature of the system? What phase (s) is (are) present in the beaker?
9. Using the boxes below, draw at the particle level the changes occurring as the water heats up



ice just melted

Temperature:

Time:



water at room temperature

Temperature:

Time:



hot water

Temperature:

Time:

10. What happens to the kinetic energy of the system as the water is heating? Why?
11. When the water starts boiling, what happens to the temperature of the system? What phase (s) is (are) present in the beaker?
12. Using the boxes below, draw at the particle level the changes occurring as the water boils



water starts boiling

Temperature:

Time:



water boiling (+ 1 min)

Temperature:

Time:



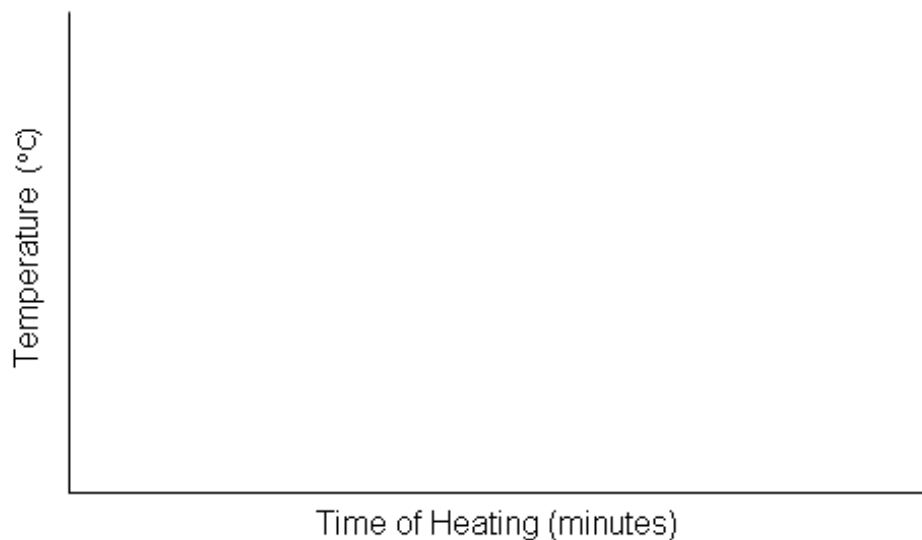
water boiling (+ 3 min)

Temperature:

Time:

13. What happens to the kinetic energy of the system as the water is boiling? Why?
14. After 4 minutes of boiling, sketch the graph that you obtained as you collected data.

Student



15. How is the curve you obtained different from your prediction?

16. On the graph above, divide your heating curve into three sections. For each section, of the graph, state what phases were present in:

- a. a low temperature plateau?
- b. an area of temperature change?
- c. a high temperature plateau?

Conclusion: Summarize the scientific principles that you discovered in this lab using the following terms:

- temperature
- states of matter
- kinetic energy
- potential energy
- melting (fusion)
- freezing
- evaporation
- condensation
- temperature change (ΔT)
- heating/cooling curve

Teacher

Bonding: Conductivity and Solubility

NGSSS:

SC.912.L.18.12 Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.

SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

Purpose of Lab/Activity:

- Identify the types of bonding (ionic, covalent, metallic) by investigating conductivity and solubility of substances.
- Visualize how atoms, ions and molecules interact with each other at the particle level to account for the behavior at the macro level.

Prerequisite:

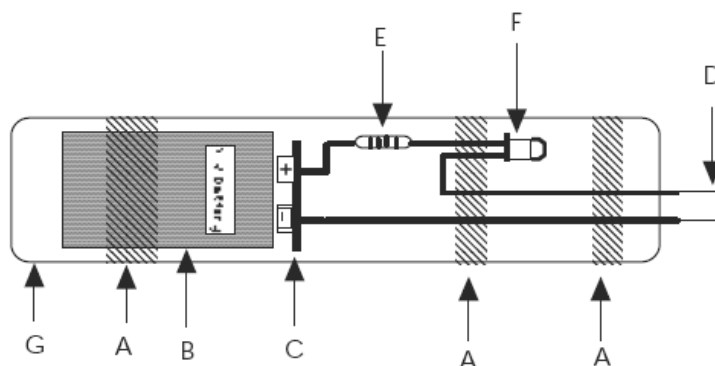
- Students should have a basic model of atomic structure which includes the electrical nature of atoms. The existence of a negative mobile particle, the electron, and a positive stationary particle, the proton, is necessary for this activity. When the amount of protons and electrons is equal, the atom is neutral.
- Students should be able to visualize that there is a force of attraction between unlike charges and repulsion between like charges.
- Students know that electricity is the flow of the mobile negative particles through a medium which will allow this flow.
- Students should have a view of the dissolving process such as water being able separate the molecules of a solid by overcoming the attractions the molecules feel towards each other

Materials:

- small beakers or cups (100 ml or less)
- distilled water (~100 ml)
- wash bottle filled with distilled water
- stirring rod
- 1 cm² of Aluminum foil
- a penny
- rubbing alcohol (isopropyl alcohol - 10ml)
- **Approximately 1 g of the following:**
 - sucrose (table sugar)
 - NaCl (table salt)
 - SiO₂ (sand)
 - Candle wax
 - CaCl₂ (calcium chloride)
 - CuSO₄ (copper II sulfate)

Teacher

- Conductivity Apparatus: From Sciencenter -



<http://www.sciencenter.org/chemistry/d/carryingcharges.pdf>

- tape
- 9-V battery
- battery clip
- bare wire leads
- resistor
- LED or buzzer
- wood backing.(tongue depressor)

Additional Materials Needed to build Apparatus:

- Scissors
- Wire stripper
- Tape solder
- 1 nail
- Candle wax or soldering iron
- Pliers
- Matches

Note: Teacher may opt to use commercially available conductivity testers. Materials for construction of student-made apparatus can be obtained at local hobby/electrical supply stores.

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">a. You can choose to build the conductivity tester in advanced or have students build them using the materials listed. These testers can be used in subsequent years once built.b. Begin the activity by reviewing some of the prerequisites for the activity mentioned above. Remind students that solids keep their shape due to the attractions that the atoms or molecules feel towards each other. This attraction comes from the internal structure of the atom and the charge associated with protons and electrons. When a solid dissolves the particles are separated by the solvent making them too small to see. Also remind students that electricity occurs when electrons are able to flow freely through a medium.
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Teacher

	<ul style="list-style-type: none">c. Pose the question to students if they think that electricity can flow through a liquid. Most of them are aware that it is dangerous to be in water when electrical equipment is around. However, pure water is actually a poor conductor. Tap water on the other hand is a better conductor due to the presence of dissolved solids.d. Tell students that they will be testing solubility and conductivity of different materials and writing down their observations.e. Give each group a set of materials, a conductivity tester and tell them to test for solubility and conductivity. The solids should be tested for conductivity before and after dissolving them.f. Review the data table students are to complete and answer any questions students may have on the procedure
During activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Supervise students as they perform their investigation. As you visit separate groups, engage their thinking with some of the following questions: (Resist giving them the answer until the whole class discussion at the end of the lab)<ul style="list-style-type: none">1. why they think that some solids dissolve and some do not.2. why some substances conduct electricity once they dissolve but not when solid3. why some substances do not conduct as a solid or in solutionb. Make sure students collect data and fill out their data table correctly
After activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Once students have collected all their data, bring the class together for class discussionb. Address the fact that substances that are not soluble in water have particles which are attracting to each other so strongly that water cannot break them apart. In this experiment, the only substances that will do this are the two metals (Al and Cu), the sand and the wax.c. Distinguish the wax and sand from the metals with the conductivity test. The wax and sand do not conduct while the metals do. Conclude that metals are insoluble (strong bonds) and conduct electricity. They are also shiny and good conductors of heat. These are the characteristics of metallic bonding. Because metals can conduct it implies that the atoms allow electrons to flow through them easily. Explain to the class that metals tend to have high melting and boiling points thanks to the strength of the metallic bonds.d. Sugar, salt, copper sulfate, and calcium chloride all dissolved which means that water is able to break their structure apart. After testing the conductivity, sugar does not conduct while the three other do. In the conductivity tester there are electrons on one lead trying to flow to the other lead (forced by the difference in potential in the battery). Copper sulfate, calcium chloride and sodium chloride are able to “ferry” the electrons from one lead to the other. This happens because these solids break up into oppositely charged particles or ions. These substances are considered ionic. In the solid state these substances do not conduct because the ions are locked in place in the crystal lattice. In solution, the ions can flow freely and take electrons back and forth. Sugar is not able to conduct electricity

Teacher

	<p>because when sugar dissolves it breaks into neutral clusters of atoms named molecules. These neutral clusters are not able to transport electrons because they have equal attraction and repulsion to these electrons. Within the molecules they exhibit covalent bonding.</p> <ul style="list-style-type: none">e. Have students notice that most ionic substances are composed of a metal and non-metal atom. Most molecular compounds are composed of non-metals only.f. Tell them that covalent compounds have very strong intramolecular forces and weak intermolecular forcesg. Define each one of the types of bonding based on properties, give examples of other substances which exhibit the same characteristics.
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Extension:

- Gizmo: [Solubility and Temperature](#)

Student

Bonding: Conductivity and Solubility

NGSSS:

SC.912.L.18.12 Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.

SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

Background: Recall that solids are able to keep their shape due to the force of attraction between the particles that compose it. This attraction comes from the internal structure of the atom which includes positive protons and negative electrons. Opposite charges attract and like charges repel. Electricity occurs when electrons are able to flow through a substance. Materials which allow electrons to flow are called conductors and those that do not insulators. If a solid can dissolve in water it is said to be soluble and this occurs because the solvent (water in this case) can separate the particles of the solid.

Purpose:

- To classify substances based on their properties of solubility and conductivity.
- To develop a particle level model to account for the differences in properties of solubility and conductivity.

Safety:

- Always wear safety goggles.
- Use conductivity tester only for described activities.

Vocabulary: Conductivity, solubility, insulator, electrolyte, non-electrolyte, ions, metallic bonding, covalent bonding, ionic bonding, covalent network.

Materials (per group):

- Conductivity apparatus
- small beakers or cups (100 ml or less)
- distilled water (~100 ml)
- wash bottle filled with distilled water
- stirring rod
- 1 cm² of Al foil
- a penny
- rubbing alcohol (isopropyl) (10ml)
- **Approximately 0.5 g of the following:**
 - sucrose (table sugar)
 - NaCl (table salt)
 - SiO₂ (sand)
 - Candle wax
 - CaCl₂ (calcium chloride)
 - CuSO₄ (copper (II) sulfate)

Procedure:

1. **Conductivity-** Use conductivity apparatus to test the conductivity of all substances before making any solutions. Be sure to keep the wire test probes apart. Record your

Student

results in the second column of Table 1. Rinse and dry the paper clip probes with distilled water between each test.

2. **Solubility**- Take ~1 g of each solid substance, place it in the small beaker or cup and try to dissolve it with ~10 ml of distilled water. Record your results in the third column of Table 1.
3. **Conducts when dissolved**- If the substance dissolves in water, test the solution with the conductivity apparatus. Make sure to keep the probes apart. Enter your results in the final column of Table 1. If a substance did not dissolve enter NO in this column.

Observations/Data:

Table 1: Test Results

Substances	Original substance conducts? Yes/No	Substance dissolves? Yes/No	Solution conducts? Yes/No
Al (s) - Aluminum foil			
$C_{12}H_{22}O_{11}(s)$ Sucrose (sugar)			
$C_{20}H_{42}(s)$ candle (wax)			
$C_3H_8O(l)$ isopropyl alcohol			
$CaCl_2(s)$ calcium chloride			
Cu (s) -- Copper			
$CuSO_4(s)$ -- Copper sulfate			
$H_2O(l)$ -- Distilled water		N/A	N/A
$NaCl(s)$ salt -- Sodium chloride			
$SiO_2(s)$, sand -- Silicon dioxide			

Data Analysis/Results:

1. Group the substances that have the same characteristics. Which groups did you form?
2. From each group that you assembled, look at the similarities and differences between atoms that make up the substances. Describe the similarities and differences that you detected.

Conclusion:

1. Explain at the particle level why some substances dissolve in water while others do not.
2. Some substances dissolved and conducted electricity while others dissolved but did not conduct electricity. What are solutions that conduct electricity called?

Student

3. Explain at the particle level how some solutions can conduct electricity while others cannot.
4. Based on the 3 types of bonding discussed (metallic, ionic, covalent) assign the appropriate one to each substance tested.
5. Using a 3 column chart, compare and contrast ionic, covalent and metallic bonding.
6. What is a covalent network? What substance in this experiment is considered a covalent network? Name at least another substance that exhibits this type of arrangement.

Teacher

Solubility Curve of KCl

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Purpose of Lab/Activity:

- To study the effect of temperature on solubility
- To understand the process of solubility and saturation at the particle level
- To experimentally construct a solubility curve
- To use a solubility curve to find the solubility of a solute at different temperatures

Prerequisite: Students should have clear model on how the solution process works. Most important is for them to realize that solids dissolve and disappear from view as the particles of the solid are separated by the solvent. Students should also know that temperature is a measure of the kinetic energy of the particles in a system. Basic laboratory safety and techniques are expected due to the nature of this experiment.

Materials (per group):

- potassium chloride (KCl)
- distilled water
- balance
- evaporating dish (or 100-ml beaker)
- 25-ml graduated cylinder
- watch glass
- 250 or 400 ml beaker
- hot plate or burner with ring stand, 2 rings & wire gauze
- test tube (18X150 mm)
- utility clamp
- glass stirring rod
- thermometer or temperature probes
- funnel
- cotton wadding
- tongs &/or hot mitts
- graph paper

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Gather all materials and set up the students into groupsAsk students about their experience with solutions. Sugar in lemonade or iced tea is usually an event most students are familiar with.Introduce the difference in solubility at different temperatures by asking whether more sugar will dissolve in hot tea or iced tea.Explain the procedure to studentsAssign a different temperature to each group (i.e., room temperature, 30 °C, 40 °C, 50 °C, 60 °C, 70 °C, 80 °C, and 90 °C). Adjust temperature assignment according to the number of groups. Warn students not to allow the water bath to boil.
During activity:	What the teacher will do: <ol style="list-style-type: none">Make sure students are working safely and diligently.

Teacher

	<ul style="list-style-type: none">b. The most difficult part of this lab is to keep the temperature of the water bath constant. Assist students with this task and make sure that they are reading the thermometers correctly.c. Visit each group individually and ask them questions about what steps they are completing and why.d. Point out to students that given the initial amount of KCl added (about 10 grams) they should not expect all the salt to ever dissolve. Ask them if they expect the amount of solute dissolved in the solvent to be constant at different temperatures and why.e. Set up a space in the room for groups to post their results. The quality of the graph will depend on the individual group results so great care must be taken if good results are desired.
After activity:	<p>What the teacher will do:</p> <ul style="list-style-type: none">a. Students should gather data from the whole class and construct their solubility curveb. After all groups build their graph, bring them together for a whole class discussion and analysis of resultsc. The class discussion should have two main goals: First, to help students develop a particle level model of solubility and how temperature affects it. Second, for students to know how to read their chart and answer questions such as the ones in the conclusion section of the student procedure.d. Have students explain orally how water dissolves KCl. They should say that in the solid state, the ions of potassium and chlorine are attracting each other in a crystal lattice structure. All the ions together amount to a visible quantity of salt. When water is added the water molecules surround the ions and separate them from the lattice. Now the ions are in the aqueous state and invisible.e. Once this is established, ask why temperature affects this process. Lead students to see that at higher temperatures the water molecules have more energy and are moving faster. At the same time, the potassium chloride lattice has more energy as well. The extra energy makes it easier for the water molecules to separate the potassium and chloride ions. Therefore, fewer water molecules are needed to separate the particles and the amount of solute dissolved increases.f. Turn now to the analysis of the solubility curve that the students produced. Ask students what the solubility line represents. This is the combination of temperature and amount of solute at saturation. Below the line the solution is unsaturated. Above the line the solution is saturated and there are visible undissolved solids. One of the conclusion questions addresses extrapolation of the curve by asking students for solubility at temperatures outside of the range of data collected. Students may have difficulty understanding how the units in the vertical axis in the chart. The units are grams of solute (KCl) per 100 grams of solvent (water). A question in the student section addresses this understanding by checking on other amounts of solvent. Another question in the conclusion section addresses calculating how much solute precipitates if a solution is cooled down. Feel free to add more questions such as this which enforce graphical analysis.g. Two extension questions are given at the end for students to apply their

Teacher

	<p>understanding of the situation to real life applications. One deals with the solubility of gases - carbon dioxide in soda. The question begins by telling students that the opposite trend is observed when dealing with the solubility of gases. Explain to students that gases would rather escape the liquid and they are lightly attracted to the solvent particles. Increasing the temperature will help the particles escape the attraction and leave the liquid phase.</p>
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Extension:

- Gizmo: [Solubility and Temperature](#)

Student

Solubility Curve of KCl

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Background: A homogeneous mixture of a solute in a solvent is called a solution. If the solute is originally a solid, the solvent is able to separate the particles of the solid to the point that the solid disappears from view. An unsaturated solution is capable of dissolving additional solute for a given amount of solvent because there are free solvent molecules available to do the dissolving. Molecules of the solvent surround particles of the solute as they separate them. When all the solvent particles are “busy” surrounding solute particles no more solute can dissolve. This is called a saturated solution. Any additional solute added to a saturated solution will collect on the bottom of the container and remain undissolved. Think of adding sugar to lemonade. At the beginning all the sugar will dissolve but at some point no more sugar will dissolve and the extra sugar just sits in the bottom. The amount of solute that can be dissolved in a given amount of solvent at a specific temperature and pressure is defined as the solubility of the solute. Solubility is dependent upon temperature. You can dissolve more sugar in hot lemonade than in cold lemonade. In this activity, you will determine the solubility of a salt at different temperatures and will plot a solubility curve for the solute.

Purpose of Lab/Activity:

- To determine the solubility of a solute, potassium chloride (KCl), in water as the temperature of the solution is changed.

Safety:

- Always wear safety goggles and a lab apron.
- Never taste any substance used in the lab.
- Test tube and evaporating dish may cause burns
- Use caution around hot items.

Vocabulary: Solubility, solution, saturated, unsaturated, homogeneous, solubility curve, supersaturated.

Materials (per group):

- | | | |
|---------------------------------------|---------------------------------------|------------------------|
| • potassium chloride (KCl) | • watch glass | • utility clamp |
| • distilled water | • 250 or 400 ml beaker | • glass stirring rod |
| • balance | • hot plate or burner | • thermometer |
| • evaporating dish (or 100-ml beaker) | with ring stand, 2 rings & wire gauze | • funnel |
| • 25-ml graduated cylinder | • test tube (18X150 mm) | • cotton wadding |
| | | • tongs &/or hot mitts |
| | | • graph paper |

Student

Procedures:

1. Your teacher will assign your group a temperature between 20°C and 90°C.
2. Determine the mass of a clean, dry evaporating dish (or 100 ml beaker) with watch glass cover. Set aside.
3. Fill the large 250 or 400 ml beaker with water $\frac{1}{2}$ way and place on hot plate to heat.
4. Put 15 ml of distilled water in the test tube and add about 10 g of KCl. Immerse the test tube in the large (250 ml) beaker.
5. Place the thermometer in the large beaker and heat the water until it reaches your assigned temperature. Maintain this temperature for 10 minutes, stirring every few minutes and rechecking the temperature.
6. Set up a funnel for filtering the solution, using a small wad of cotton instead of filter paper, placing the previously weighed evaporating dish (or 100 ml beaker) below the funnel.
7. Remove the test tube from the water bath, being careful that any solid at the bottom of the test tube is undisturbed. Decant about half of the solution into the funnel.
8. Weigh the evaporating dish, watch glass, cover and contents when filtering is complete.
9. Evaporate the water from the solution by heating rapidly at first and then more slowly. Start the evaporation without the watch glass and then cover the evaporating dish with the watch glass to prevent loss of KCl by spattering.
10. After the evaporating dish has cooled, measure the mass again. Reheat until the mass changes by less than 0.02 g.
11. Cleanup and Disposal:
 - a. Turn off the hot plate and allow it to cool.
 - b. Make sure all glassware is cool before emptying the contents.
 - c. Dissolve all the KCl with plenty of water and flush down the drain
 - d. Return all lab equipment to its proper place.
 - e. Clean up your work area.

Observations/Data:

1. Record your data calculation answers in Table 1.
2. Record class data in Table 2
3. Make a line graph of the solubility of KCl in grams KCl/100 g water (Y-axis) versus the temperature in °C (X-axis).

Table 1 - Individual Group Data

Assigned Temperature	
Mass of evaporating dish and cover	
Mass of evaporating dish and cover plus KCl solution	
Mass of KCl solution	
Mass of evaporating dish and cover plus dry KCl	
Mass of dry KCl	
Mass of water that was in solution	
Grams KCl in one g water	
Grams KCl in 100 g water	

Student

Table 2 - Class Data

Temperature (°C)	Mass of KCl per 100 g water

Conclusion:

1. Describe your findings on the effect of temperature on the solubility of KCl.
2. Explain, at the particle level, why changes in temperature affect solubility?
3. Using the plot you made, predict the solubility of KCl in water at 15°C and 95°C
4. A saturated solution of potassium chloride in 50 g of water at 70°C is cooled to 30°C. How much solute will precipitate out of the solution?
5. If you wish to fully dissolve 500 grams of KCl in a liter of water, at what temperature should the solution be?
6. In a dishwasher, the temperature of the water is very hot. Explain why it is better to use hot water in a dishwasher rather than cold water.
7. Unlike solids for which solubility in a liquid generally increases with increasing temperature, the solubility of a gas in a liquid usually decreases as the temperature increases. Knowing this, explain why you should never heat a can containing a carbonated soft drink.

Teacher

Determining the Percentage of Acetic Acid in a Vinegar Solution

NGSSS:

SC.912.P.8.8 Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.

SC.912.P.8.11 Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.

Purpose of Lab/Activity

- Determine the end point of an acid-base titration
- Calculate the molarity of acetic acid in vinegar
- Calculate the percentage of acetic acid in vinegar.

Prerequisite: Prior to this activity, the student should be able to

- Use the pH scale.
- Identify and list some common acids and bases.
- Explain the properties of acids and bases.

Materials (individual or per group):

- apron
- goggles
- 10 ml graduated cylinder
- 24-well plate or 3 small beakers
- 2 thin-stemmed pipets or droppers
- phenolphthalein indicator
- 2.0 ml standardized 0.6 M NaOH
- 2.0 ml white vinegar
- stirrer

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ol style="list-style-type: none">Review the pH scale with the students.Manipulate some examples of concentration and derivation of pH.Use the expression $M_a V_a \propto M_b V_b$ to derive the unknown volumes or concentrations.Have students list some common bases and acids.Review the relationships between volume, mass, density, moles, and molarity.Review the relationship between solute, solvent, and solution.
During activity:	What the teacher will do <ol style="list-style-type: none">Monitor the proper technique for calibrating the pipets.Make sure the students are not cross contaminating their instruments.Ensure the students are keeping a track of their calculations as they complete their titrations.Make sure the students are following proper safety techniques for handling chemicals.

Teacher

After activity:	What the teacher will do: <ol style="list-style-type: none">Ask the students, "How was the end point determined in the chemical reaction?"Discuss the errors associated with the end pointHave students discuss the differences between the equivalence point and the end point.Evaluate the sources of error in the calibration of the pipets and the subsequent titration.
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Extension:

- Gizmo: [pH Analysis](#), [pH Analysis: Quad Color Indicator](#)

Student

Determining the Percentage of Acetic Acid in a Vinegar Solution

NGSSS:

SC.912.P.8.8 Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.

SC.912.P.8.11 Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.

Background Information:

Vinegar, which is naturally produced from the fermentation of apple cider in the absence of oxygen, contains acetic acid (CH_3COOH) at a concentration 4.0 to 5.5 %. The exact concentration of acetic acid can be determined by titration with a standard base such as sodium hydroxide. This can be done on a microscale as described below by counting drops of base needed to neutralize the acid in vinegar, or on a larger scale with a standard 50 ml buret setup.

Purpose of Lab/Activity

- Determine the end point of an acid-base titration
- Calculate the molarity of acetic acid in vinegar
- Calculate the percentage of acetic acid in vinegar.

Safety Precautions:

- Wear safety goggles and a lab apron.
- Do not touch chemicals

Vocabulary: titration, concentration, molarity, mol per liter, solution, solvent, solute, acid, base, pH scale, hydronium and hydroxide ions.

Materials (individual or per group):

- apron
- goggles
- 10 ml graduated cylinder
- 24-well plate or 3 small beakers
- 2 thin-stemmed pipets or droppers
- phenolphthalein indicator
- 2.0 ml standardized 0.6 M NaOH
- 2.0 ml white vinegar
- stirrer

Procedures:

Calibrate pipet droppers:

1. Put about 5 ml of water in the 10 ml graduated cylinder and read the exact volume. Record this reading in Data Table 1- Calibration Data.
2. Fill the pipet with water. Holding the pipet in a **vertical position**, transfer exactly 20 drops of water to the graduated cylinder. Record the new volume in the graduated cylinder as the final volume for trial 1.
3. The final volume for trial 1 will then be the Initial volume for trial 2 as 20 more drops are added to the graduated cylinder.
4. Record the new final volume and repeat for a third trial.

Student

5. Mark this pipet as "Acid".
6. Repeat steps 1 to 4 and mark the second pipet as "Base".
7. Fill in the Data Table 1- Calibration Data with the Average Volume of 20 Drops and the Average Volume Per Drop for both pipets.

Data Table 1 - Calibration Data

Trial	Acid Pipet			Base Pipet		
	Initial	Final	ml added	Initial	Final	ml added
1						
2						
3						
Average Volume of 20 Drops	--	--		--	--	
Average Volume Per Drop	--	--		--	--	

Titration:

1. Drain the water from the Acid pipet, rinse the Acid pipet with vinegar, and discard this vinegar. Then fill the pipet with fresh vinegar.
2. Hold the pipet vertically and add 20 drops of vinegar and 1 drop of phenolphthalein to 3 wells of the well plate or to the 3 small beakers.
3. Drain the water from the Base pipet, rinse the Base pipet with NaOH solution, and discard this rinse solution. Then fill the pipet with fresh NaOH solution.
4. Hold the Base pipet vertically and add NaOH solution drop by drop to one well or beaker with gentle swirling after each drop is added. Continue adding drops of NaOH solution until the pink phenolphthalein color remains for 30 s. Record the number of drops of NaOH added in the Titration Data Table.
5. Repeat step 4 with the 2 other 20-drop vinegar samples refilling the NaOH pipet if necessary. Record the observed number of drops in the Data Table 2- Titration.
6. Cleanup: Clean all equipment used and dispose of the chemicals as directed by your teacher. Wash your hands.

Data Table 2 - Titration

Trial	Number of Drops Added		Volume Added (ml)	
	Vinegar	NaOH	Vinegar	NaOH
1				
2				
3				

Data Analysis/Results:

1. Calculate the volumes of vinegar and NaOH for each trial and record in Data Table 2- Titration. Show your calculations.

Student

2. From the molarity of the standardized NaOH solution (provided by your teacher) calculate the number of moles of NaOH used to neutralize the acetic acid in each trial. Show work.
3. Write the balanced equation for the neutralization of acetic acid by sodium hydroxide.
4. From the calculations in steps 2 and 3, and the mole ratio from the balanced equation of #3 above, calculate the number of moles of acetic acid neutralized by NaOH each trial. Show work.
5. From the moles of acetic acid calculated in #4 and the volumes of vinegar used in each trial, calculate the molarities of acetic acid in each trial, then average your results.
6. Calculate the molar mass of acetic acid, CH₃COOH.
7. Using your average molarity of acetic acid in vinegar (#5), calculate the mass of acetic acid in 100 ml (0.100 L) of vinegar. Hint: Find the mass of acetic acid in 1L and then the mass in 100 ml.
8. Assume that the density of vinegar is close to 1.00 g/ml, so that the mass of 100 ml of vinegar will be 100.g. Determine the percentage of acetic acid in your sample of vinegar.

Conclusion:

1. Why was phenolphthalein used in each titration? Could you have done your titrations without phenolphthalein?
2. How could the end point have been determined more accurately?
3. Why does the titrated mixture have to be stirred vigorously to ensure greater accuracy?
4. Why were you instructed to hold the pipets in a vertical position when you used them?
5. What if the pipet was not rinsed with the standard, NaOH before it was used to titrate the acid solution, what effect would it have had on the % by volume?
6. How does a company producing vinegar solution ensure that the concentration is accurate enough?
7. How does fermentation of apple cider result in the production of an acid?
8. Describe some other fermentation processes that are useful biochemically?

Teacher

Energy Content of Foods and Fuels

NGSSS:

SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.

SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.

SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Purpose of Lab/Activity:

- Determine the energy content of foods and fuels and compare to standard values.
- Understand how energy is produced from chemical reactions that take place all around us.
- To evaluate the efficacy of experimental set ups for energy measurements

Prerequisite: Prior to this activity, the student should be able to:

- Distinguish between potential and kinetic energy.
- Be able to relate the energy stored to the interactions between atoms.
- Relate the law of conservation of energy and matter to metabolic processes in living matter.
- Be familiar with the units used for energy and to apply basic heating calculations
- Be able to discuss that combustion reactions occur between organic compounds and oxygen.
- Be able to write balanced chemical equations for various chemical processes.

Materials (individual or per group):

- Lab Pro or CBL 2 system*
- TI graphing calculator*
- Temperature probe*
- DataMate program
- 2 Food samples
- food holder (paper clip + foil)
- wooden splint
- candle (large diameter)
- aluminum foil squares
- *thermometer (instead of probe/CBL/TI calculator)
- *graph paper (instead of probe/CBL/TI calculator)
- utility clamp and slit stopper
- 2 Stirring rods
- ring stand and 4-inch ring
- 100-ml Graduated cylinder
- soda can
- cold water
- matches
- goggles

*thermometer and graph paper (instead of probe/CBL/TI calculator)

Procedures: Day of Activity:

Before activity:	What the teacher will do: a. Bring up the concept of energy with the students. In previous activities energy is defined as a quantity which is responsible for change in a system. Bring relevance to the concept by explaining that the human body also needs energy to function and change. Ask students where the energy they eat comes from. The easily connect that this energy comes from the food
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Teacher

	<p>they eat.</p> <ol style="list-style-type: none">Ask the class how the energy is stored in food. They should conclude that energy is stored as chemical potential in the molecules of food. Bring to their attention that a chemical reaction needs to occur for that energy to become useful in our bodies. Remind them that a chemical reaction means a rearranging of the atoms of reactants to form products.Ask students what the food we eat react with in our bodies? The idea is for them to realize that the oxygen we breathe is also use in this process of respiration. If the food reacts with oxygen in our bodies, it can also react with oxygen outside. Demonstrate how food can catch on fire and release energy.Have students briefly distinguish the caloric differences between various food groups.Familiarize the students with the proper use of the technology used for this lab and with the overall procedure.
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">Monitor the proper use of the technologySupervise the construction of the food holder and the set up used.Ask the students to discuss the change in potential energy and kinetic energy and how they are related to each other.Ask students if they feel that all the energy of the reaction is going into heating the water or if some is going somewhere else.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">Summarize the differences between the fuel values of the various chemical groups.Make sure the students have manipulated their calculations correctly.Help the students interpret their data properlyStudents should compare the values obtained from their experiment with the values in the food labels. They should be greatly smaller. This is because of the low quality of the experimental setup which allows for a high percentage of the energy to be dissipated. Discuss with them how the results are going to be tied to how much energy is received by the water in the can. Ask students to come up with ideas on how this problem can be eliminated. If no good ideas come up, explain to them the concept of a bomb calorimeter which submerges the reaction in water so that all the energy released goes into the water as opposed to the air around it.

Extension:

- Gizmo: [Calorimetry Lab](#)

Student

Energy Content of Food and Fuels

NGSSS:

SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.

SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.

SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Background: All human activity requires “burning” food and fuel for energy. The energy is originally stored in the food as chemical potential energy. This energy is released when atoms rearrange in chemical reactions. In this experiment, you will determine the energy released (in kJ/g) as various foods and fuels burn such as cashews, marshmallows, peanuts, popcorn, paraffin wax, and ethanol. You will look for patterns in the amounts of energy released during burning of the different foods and fuels.

Purpose of Lab/Activity:

- Determine the energy content of foods and fuels and compare to standard values.
- Understand how energy is produced from chemical reactions that take place all around us.

Safety:

- Always wear safety goggles and a lab apron.
- Do not eat or drink anything in a laboratory.
- Tie back hair and secure loose bulky clothing while working near a flame.
Note: If anyone is allergic to nuts, you can substitute with potato chips or other snack food

Vocabulary: Exothermic and endothermic processes, enthalpy change diagrams, chemical potential energy, kinetic energy. Fuel value and caloric content.

Materials (individual or per group):

- Lab Pro or CBL 2 system*
- TI graphing calculator*
- Temperature probe*
- DataMate program
- 2 Food samples
- food holder (paper clip + foil)
- wooden splint
- candle (large diameter)
- aluminum foil squares
- utility clamp and slit stopper
- 2 Stirring rods
- ring stand and 4-inch ring
- 100-ml Graduated cylinder
- soda can
- cold water
- matches
- goggles

*thermometer and graph paper (instead of probe/CBL/TI calculator)

Student

Part A: Energy Content of Foods

Procedures:

1. Obtain and wear goggles and a lab apron. Tie back long hair and secure loose fitting clothes.
2. The following procedure will focus on the use of a temperature sensor and CBL or LabPro interface.
Note: A low-tech approach using a thermometer and a stop watch is also possible using this procedure. However, students will have to record the data by hand directly from the thermometer.
3. Plug the Temperature Probe into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
4. Turn on the calculator and start the DATAMATE program. Press to reset the program.
5. Set up the calculator and interface for the Temperature Probe.
 - a. Select SETUP from the main screen.
 - b. If the calculator displays a Temperature Probe in CH 1, proceed directly to Step 5. If it does not, continue with this step to set up your sensor manually.
 - c. Press to select CH 1.
 - d. Select TEMPERATURE from the SELECT SENSOR menu.
 - e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
6. Set up the data-collection mode.
 - a. To select MODE, press once and press .
 - b. Select TIME GRAPH from the SELECT MODE menu.
 - c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
 - d. Enter "6" as the time between samples in seconds.
 - e. Enter "100" as the number of samples. The length of the data collection will be 10 minutes.
 - f. Select OK to return to the setup screen.
 - g. Select OK again to return to the main screen.
7. Obtain a piece of one of the two foods assigned to you and a food holder. To make the food holder shape the paper clips into a small tripod and place on a piece of aluminum foil. Find and record in Data Table 1 the initial mass of the food sample and food holder.
8. Determine and record the mass of an empty can. Add 50 ml of cold water to the can. Determine and record in the mass of the can and water.
9. Set up the apparatus as shown in Figure 1. Use a ring and stirring rod to suspend the can about 2.5 cm (1 inch) above the food sample. Use a utility clamp to suspend the Temperature Probe (or thermometer) in the water. The probe (or thermometer) should not touch the bottom of the can. Remember: The Temperature Probe must be in the water for at least 30 seconds before you do Step 10.
10. Select START to begin collecting data. Record the initial temperature of the water, T_1 , in your data table (round to the nearest 0.1°C). Note: You can monitor temperature in the upper-right corner of the real-time graph displayed on the calculator screen. Remove the food sample from under the can and use a wooden splint to light it. Quickly place the burning food sample directly under the center of the can. Allow the water to be heated until the food sample stops burning. CAUTION: Keep hair and clothing away from open flames.

Student

11. If using a thermometer, record a temperature every 15 seconds. At first, the temperature will increase until it reaches a maximum and then it will decrease. The most important data points are the initial (T_1) and highest temperature (T_2)
12. Continue stirring the water until the temperature stops rising. Record this maximum temperature, T_2 . Data collection will stop after 10 minutes (or press the **STO** key to stop before 10 minutes has elapsed).
13. Determine and record the final mass of the food sample and food holder.
14. To confirm the initial (T_1) and final (T_2) values you recorded earlier, examine the data points along the curve on the displayed graph. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph.
15. Press **ENTER** to return to the main screen. Select START to repeat the data collection for the second food sample. Use a new 50-ml portion of cold water. Repeat Steps 7-14.
16. When you are done, place burned food, used matches, and partially-burned wooden splints in the container provided by the teacher.

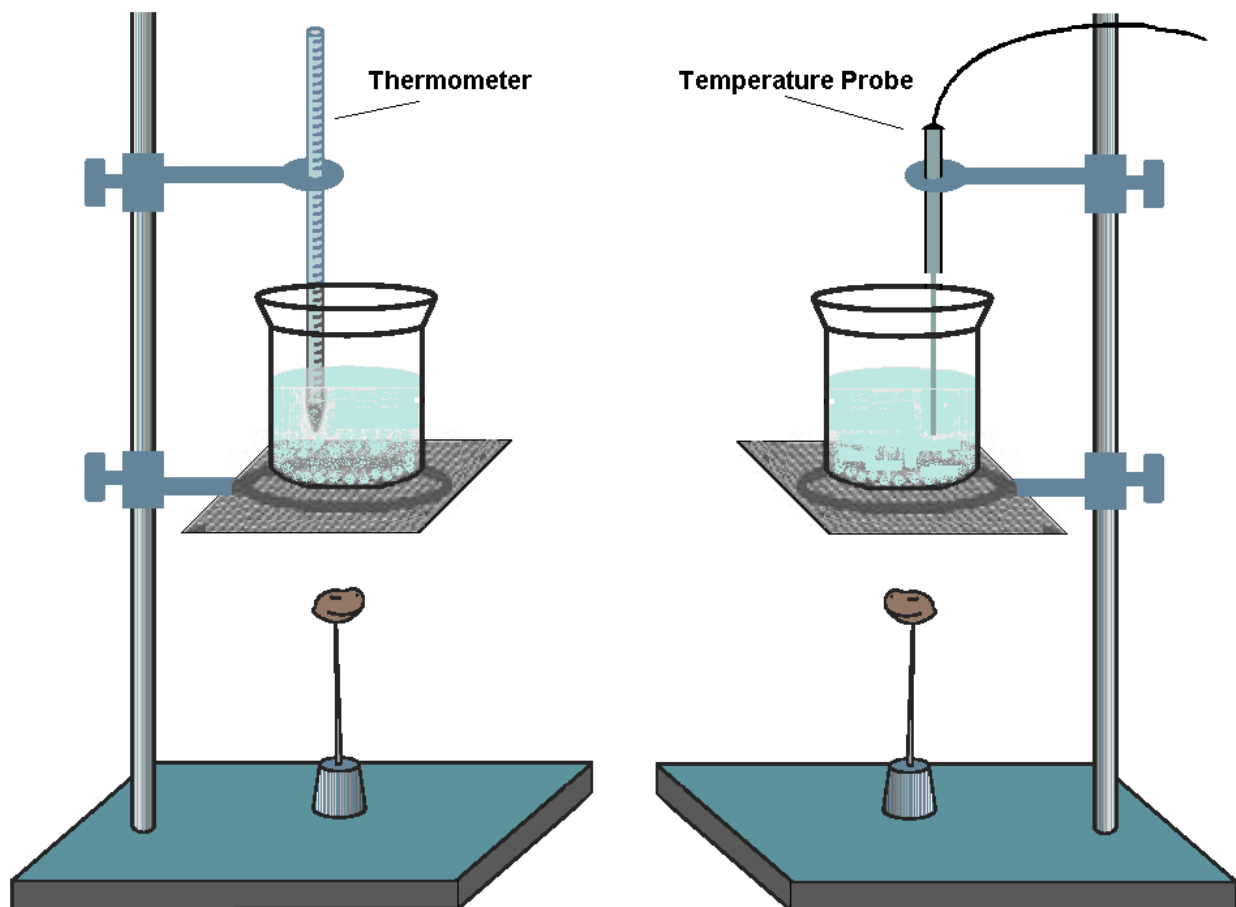


Figure 1

Observations/Data:

1. Find the mass of water heated for each sample and record in Data Table 1.
2. Find the change in temperature of the water, ΔT , for each sample and record in Data Table 1.

Student**Data Table 1 - Group Results**

Food type	Amounts	
	Initial mass of food and holder	g
Final mass of food and holder	g	g
Mass of food burned	g	g
Mass of can and water	g	g
Mass of empty can	g	g
Mass of water heated	g	g
Final temperature, T_2	°C	°C
Initial temperature, T_1	°C	°C
Temperature change, ΔT	°C	°C
Heat, q	kJ	kJ
Energy content in kJ/g	kJ/g	kJ/g

Data Analysis/Results:

1. Calculate the heat absorbed by the water, q , using the equation $q = C_p \cdot m \cdot \Delta t$ where q is heat, C_p is the specific heat capacity, m is the mass of water, and ΔT is the change in temperature. For water, C_p is 4.18 J/g °C. Change your final answer to kJ.
2. Find the mass (in g) of each food sample burned.
3. Use the results of Steps 3 and 4 to calculate the energy content (in kJ/g) of each food sample.
4. Record your results and the results of other groups in Data Table 2.

Data Table 2 - Class Results

Marshmallows	Peanuts	Cashews	Popcorn
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g
kJ/g	kJ/g	kJ/g	kJ/g

Average Results for each food type:

Marshmallows	Peanuts	Cashews	Popcorn
kJ/g	kJ/g	kJ/g	kJ/g

Student

Conclusion:

1. Which food had the highest energy content? The lowest energy content?
2. Food energy is often expressed in a unit called a Calorie. There are 4.18 kJ in one Calorie. Based on the class average for peanuts, calculate the number of Calories in a 50-g package of peanuts.
3. Using the food label determine the caloric content of each food and compare with your results. Explain what factors in the experimental design account for this difference.
4. Two of the foods in the experiment have a high fat content (peanuts and cashews) and two have high carbohydrate content (marshmallows and popcorn). From your results, what generalization can you make about the relative energy content of fats and carbohydrates?

Part B: Energy Content of Fuels

Procedures:

1. Obtain and wear goggles.
2. The following procedure will focus on the use of a temperature sensor and CBL or LabPro interface. A low-tech approach using a thermometer and a stop watch is also possible using this procedure. However, students will have to record the data by hand directly from the thermometer.
3. Plug the Temperature Probe into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
4. Turn on the calculator and start the DATAMATE program. Press to reset the program.
5. Set up the calculator and interface for the Temperature Probe.
 - a. Select SETUP from the main screen.
 - b. If the calculator displays a Temperature Probe in CH 1, proceed directly to Step 5. If it does not, continue with this step to set up your sensor manually.
 - c. Press to select CH 1.
 - d. Select TEMPERATURE from the SELECT SENSOR menu.
 - e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
6. Set up the data-collection mode.
 - a. To select MODE, press once and press .
 - b. Select TIME GRAPH from the SELECT MODE menu.
 - c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
 - d. Enter "6" as the time between samples in seconds.
 - e. Enter "100" as the number of samples. The length of the data collection will be 10 minutes.
 - f. Select OK to return to the setup screen.
 - g. Select OK again to return to the main screen.
7. Set the candle on a piece of aluminum foil or any type of candle holder. Wider based candles (ex. 1 inch diameter) are preferable because they do not tip over.
8. Find and record in Table 1 Part 1 the combined mass of the candle and aluminum foil
9. Determine and record the mass of an empty can. Add 100 ml of chilled water to the can. Determine and record the mass of the can and water.
10. Set up the apparatus as shown in Figure 2. Use a ring and stirring rod to suspend the can about 5 cm above the wick. Use a utility clamp to suspend the Temperature Probe (or thermometer) in the water. The probe/thermometer should not touch the bottom of the

Student

can. Remember: The Temperature Probe must be in the water for at least 30 seconds before you do Step 11.

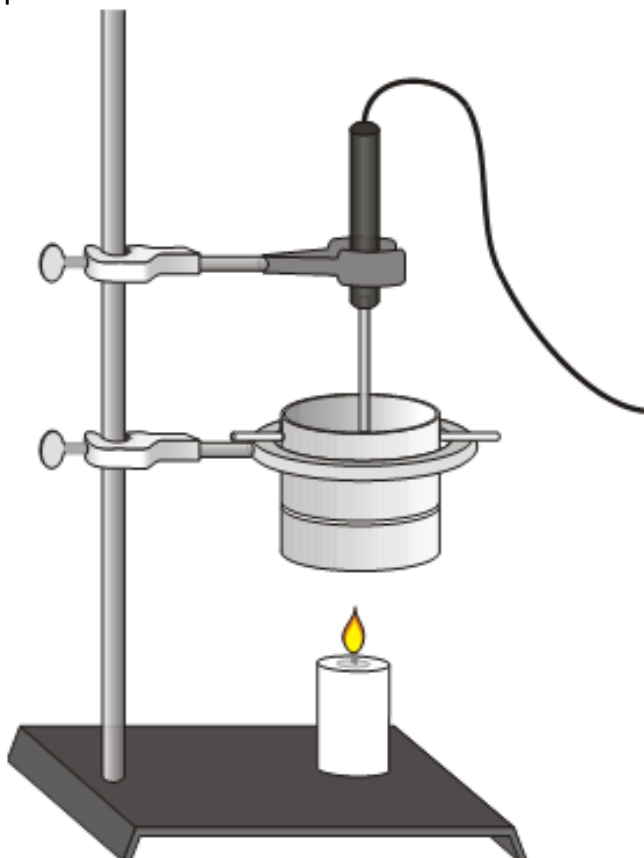


Figure 2

11. Select START on the calculator to begin collecting data. Monitor temperature (in °C) on the calculator screen for about 30 seconds and record the initial temperature of the water, t_1 , in your data table. Light the candle and heat the water until its temperature reaches 40°C and then extinguish the flame. CAUTION: Keep hair and clothing away from an open flame.
12. If using a thermometer, record a temperature every 15 seconds. At first, the temperature will increase until it reaches a maximum and then it will decrease. The most important data points are the initial (T_1) and highest temperature (T_2)
13. Continue stirring the water until the temperature stops rising. Record this maximum temperature, T_2 . Data collection will stop after 10 minutes (or press the **STO▶** key to stop before 10 minutes has elapsed).
14. Determine and record in Table 1 Part 1, the final mass of the cooled candle and foil, including all drippings.
15. To confirm the initial (T_1) and final (T_2) values you recorded earlier, examine the data points along the curve on the displayed graph. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph.
16. Press **ENTER** to return to the main screen. Select START to repeat the data collection using ethanol in an alcohol burner. Repeat Steps 8-15. Be sure to use 200 ml of chilled water in Step 9.

Student

Observations/Data:

1. Find the mass of water heated.
2. Find the change in temperature of the water, ΔT .

Data Analysis/Results:

1. Calculate the heat absorbed by the water, q , using the formula in the introduction of this experiment. For water, C_p is $4.18 \text{ J/g}^\circ\text{C}$. Change your final answer to kJ.
2. Calculate the heat absorbed by the water, q , using the equation $q = C_p \cdot m \cdot \Delta T$, where q is heat, C_p is the specific heat capacity, m is the mass of water, and Δt is the change in temperature. For water, C_p is $4.18 \text{ J/g}^\circ\text{C}$. Change your final answer to kJ.
3. Find the mass of paraffin burned.
4. Calculate the heat of combustion for paraffin in kJ/g. Use your Step 3 and Step 4 answers.
5. Calculate the % efficiency in both trials of the experiment. Divide your experimental value (in kJ/g) by the accepted value, and multiply the answer by 100. The accepted heat of combustion of paraffin is 41.5 kJ/g , and for ethanol the value is 30.0 kJ/g . Record in Data Table 2.

Data Table 3 - Paraffin Fuel

	Amount
Initial mass of fuel + container	g
Final mass of fuel + container	g
Mass of fuel burned	g
Mass of can and water	g
Mass of empty can	g
Mass of water heated	g
Final temperature, t_2	$^\circ\text{C}$
Initial temperature, t_1	$^\circ\text{C}$
Temperature change, Δt	$^\circ\text{C}$

Data Table 4 - Heat

Heat, q	kJ
Heat of combustion, in kJ/g	kJ/g paraffin
% efficiency	%

Conclusion:

1. Based on your results, which fuel produces more energy per gram burned? Give an explanation for the difference. (Hint: Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is an *oxygenated* molecule; paraffin, $\text{C}_{25}\text{H}_{52}$, does not contain oxygen.)
2. Suggest some advantages of using ethanol (or paraffin) as a fuel.
3. Discuss heat loss factors that contribute to the inefficiency of the experiment.

Student

Student Independent Research:

1. How does the energy from the sun become stored in foods and fuels?
2. How does this energy flow through biological systems and through the processes that shape the Earth?

Teacher

Rates of Evaporation

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

Purpose of Lab/Activity:

- Measure and compare the rates of evaporation for different liquids.
- Classify liquids based on their rates of evaporation.

Prerequisite: Prior to this activity the student should be able to:

- Explain the process of evaporation and the energy involved.
- Describe phase changes in terms of the kinetic molecular model.
- Relate the collision theory to the kinetic molecular model.

Materials (individual or per group):

- distilled water
- ethanol
- isopropyl alcohol
- acetone
- household ammonia
- droppers (5)
- small plastic cups (5)
- grease pencil or marking pen
- masking tape
- paper towel
- square of waxed paper
- stopwatch

Procedures: Day of Activity

Before activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">a. Review with students the kinetic molecular model asking them to represent water using the particle model for each state of matter.<ol style="list-style-type: none">1. Ask students what forces are holding the molecules together in each case.b. Using a spray bottle with water squirt a student volunteer and have them make observations after a couple of minutes. Discuss what is happening with the water and have students describe what is occurring at the particle level. Have them also note any temperature changes they may feel.c. Now use 2 spray bottles one with alcohol and the other with water, spray several volunteer students on their forearm and have them compare and describe what they feel with their classmates. Try to involve students in relating what is happening at the particle level to energy changes and to complete a drawing to represent this.d. Show students a container with ping pong balls and ask them to describe what needs to occur for evaporation to take place. They should identify the balls at the surface as the ones that escape or evaporate. Have them relate this model to kinetic energy.e. In order to help them visualize the intermolecular forces you can use Velcro pieces to hold the balls together. Ask students what would happen
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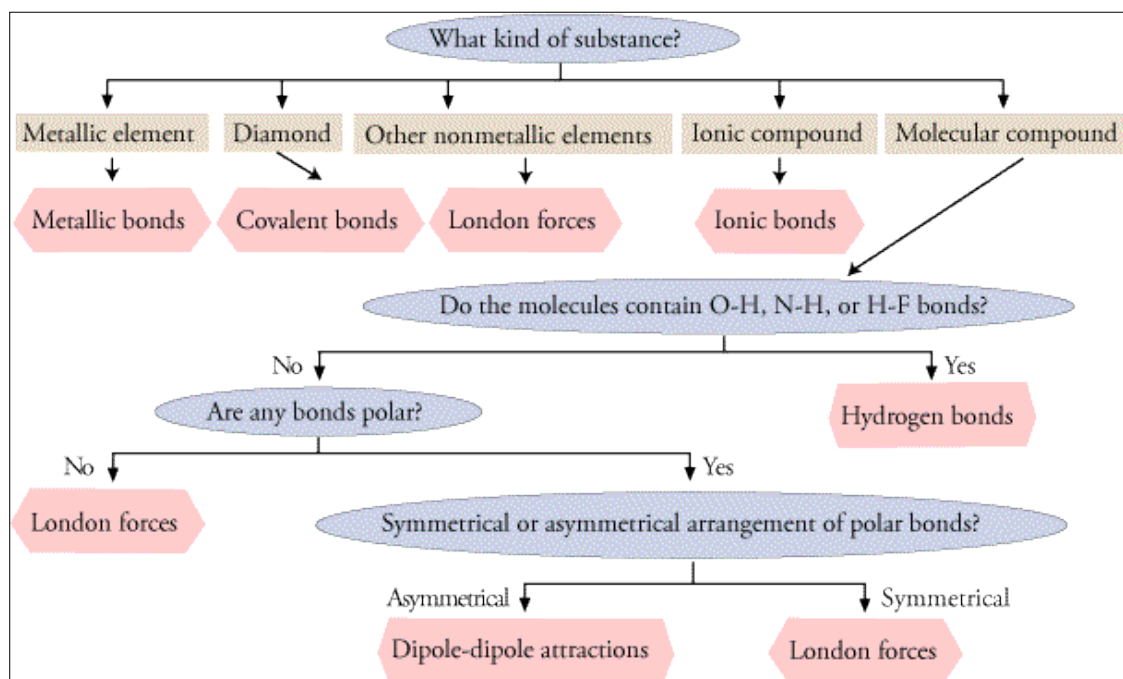
Teacher

	<p>if you used heavier balls such as baseballs, which balls would require more energy to evaporate or escape from the surface. (Note: make sure students do not isolate these factors as attractive forces and molecular weight occurs simultaneously).</p> <p>f. Have students predict which factors could affect the evaporation rate of different substances.</p> <p>g. Make sure students understand that the rate of evaporation of a substance is always compared to the rate of vaporization of a specific known material and hence it is stated as a ratio. For this reason, there are no units for rate of evaporation. You may wish to tell them that the general reference material for evaporation rates is <i>n</i>-butyl acetate (commonly abbreviated BuAc) which has a relative evaporation rate of 1.0.</p> <p>h. Explain to the students that during this lab, the rate of evaporation will be defined as the time in seconds for the drop to evaporate assuming that the volume of the drop is comparable in each case.</p>
During activity:	<p>What the teacher will do:</p> <p>a. Review with students the basic lab procedures and data collection that should take place during the experiment. They should discuss how they will identify when the liquid has completely evaporated and how to standardize this observation.</p> <p>b. Make sure that students draw the shape of the drop. Try to get them to express the direction of the attractions using arrows. Also if possible urge them to use the terms cohesion and adhesion.</p>
After activity:	<p>What the teacher will do:</p> <p>a. Review with students their results. Refer back to the Changes of State lab to discuss energy changes that took place as the substance evaporated. They should explain that thermal energy must be sufficient to overcome the surface tension or the cohesion of the liquid in order to evaporate.</p> <p>b. For advanced students provide the boiling and melting points of the substances tested. Have students identify the pattern and compare these trends with evaporation rate.</p> <p>c. You may want to copy the diagrams from the following pages to review with students the differences between intra and intermolecular forces.</p>

Extension:

- Gizmo: [Phase Changes](#)

Teacher



Intermolecular and Intramolecular Forces

Force	Model	Basis of Attraction	Energy (kJ/mol)	Example
Intramolecular				
Ionic		Opposite charges	4000 – 400	NaCl
Covalent		Nuclei – shared e ⁻ pair	1100 – 150	H - H
Metallic		Metal cations and delocalized electrons	1000 – 75	Au
Intermolecular				
Ion-dipole		Ion and polar molecule	600 – 40	Na ⁺ & H ₂ O
Dipole-dipole		Partial charges of polar molecules	25 – 5	HCl & HCl
Hydrogen bond		H bonded to N, O, or F, and another N, O, or F	40 – 10	H ₂ O & NH ₃
London dispersion		Induced dipoles of polarizable molecules	40 – 0.05	Xe & Xe

Student

Rates of Evaporation

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

Background:

A puddle of water formed after it rains, will evaporate after some time. The process of evaporation describes how liquids change to gases as the molecular kinetic energy is increased allowing some of the molecules to separate from the liquid. Several factors determine how fast a sample of liquid evaporates. The volume of the sample is a key factor. A drop of water takes less time to evaporate than a liter of water. The amount of energy supplied to the sample is another factor.

In order to understand the process of evaporation you need to be familiar with properties of liquids such as viscosity, surface tension, and polarity. The ability of a substance to resist flowing is called viscosity. Highly viscous liquids have strong intermolecular forces that hold the liquid from flowing freely. Surface tension refers to the force on the molecules at the surface of the liquid. Substances with high surface tension have stronger forces of attraction between molecules. Polarity is a property that refers to a molecule with one end slightly positive and the other slightly negative. The attraction of polar molecules to other polar molecules occurs through dipole-dipole forces. The attraction of nonpolar molecules to other nonpolar molecules occurs through London dispersion forces.

Purpose of Lab/Activity:

- Measure and compare the rates of evaporation for different liquids.
- Classify liquids based on their rates of evaporation.
- Predict which intermolecular forces exist between the particles of each liquid.

Safety:

- Always wear safety goggles and a lab apron.
- Wear gloves because some of the liquids can dry out your skin.
- Avoid inhaling any of the vapors, especially ammonia.
- There should be no open flames in the lab; some of the liquids are flammable.

Vocabulary:

Intermolecular forces of attraction, viscosity, evaporation, surface tension, polarity, volatile substances, cohesive and adhesive

Materials (individual or per group):

- distilled water
- ethanol
- isopropyl alcohol
- acetone

Student

- household
- ammonia
- droppers (5)
- small plastic cups (5)
- grease pencil or marking pen
- masking tape
- paper towel
- square of waxed paper
- stopwatch

Procedures:

1. Use a grease pencil or masking tape to label each of five small plastic cups. Use A for distilled water, B for ethanol, C for isopropyl alcohol, D for acetone, and E for household ammonia.
2. Place the plastic cups on a paper towel.
3. Use a dropper to collect about 1 ml of distilled water and add to cup labeled A.
4. Place the dropper on the paper towel directly in front of the cup. Repeat with the other liquids.
5. Place a square of waxed paper on your lab surface.
6. Plan where on the waxed paper you will place each of the 5 drops that you will test. The drops must be as far apart as possible to avoid mixing.
7. Have your stopwatch ready. Collect some water in your water dropper and place a single drop on the waxed paper. Begin timing. Time how long it takes for the drop to completely evaporate. While you wait, calculate the molecular weight for each substance and record your answer in Table 1 along with the time for the liquid to evaporate. Also while you are waiting make two drawings of each drop, the first should show the shape of the drop as viewed from above and the second should be a side view at eye level. If possible use arrows to show attraction of molecules to each other or to the paper and try to label with the terms: "cohesion and adhesion".
8. Note: If drops take longer than 5 min to evaporate, record 300 s in your data table.
9. Repeat step 5 with the four other liquids.
10. Use the above procedure to design an experiment in which you can observe the effect of temperature on the rate of evaporation of ethanol. Your teacher will provide a sample of warm ethanol. Record your observations.

Observations/Data:

Data Table 1- Evaporation Rate

Liquid	Formula	Molecular Weight	Evaporation time (s)
Distilled water	H ₂ O		
Ethanol	C ₂ H ₅ OH		
Isopropyl alcohol (2-propanol)	C ₃ H ₈ O		
Acetone	(CH ₃) ₂ CO		
Household ammonia	NH ₃		

Student**Table 2- Drawing of Drops**

Liquid	Top View	Side Eye-level View
Distilled water		
Ethanol		
Isopropyl alcohol (2-propanol)		
Acetone		
Household ammonia		

Student

Data Analysis/Results:

1. Which liquids evaporated quickly? Rate them in order of speed of evaporation.
2. Based on your data, in which liquid(s) are the attractive forces between molecules most likely to be solely dispersion forces?
3. Make a generalization about the molecular weight and the evaporation rate of the liquid.
4. What is the relationship between surface tension and the shape of a liquid drop? What are the attractive forces that increase surface tension?
5. Which liquid is more efficient (water ethanol, alcohol, acetone, or ammonia) at cooling down an object as a result of evaporation? Is there a relationship between the rate of evaporation and the cooling effect that a liquid exhibits? Explain.
6. The isopropyl alcohol you used is a mixture of isopropyl alcohol and water. Would pure isopropyl alcohol evaporate more quickly or more slowly compared to the alcohol and water mixture? Give a reason for your answer.
7. Household ammonia is a mixture of ammonia and water. Based on the data you collected, is there more ammonia or more water in the mixture? Use what you learned about the relative strengths of the attractive forces in ammonia and water to support your conclusion.

Conclusion:

1. Should rate of evaporation be directly or inversely related to the strength of intermolecular attraction? Give clear reasons for your choice.
2. Make a generalization about the shape of a liquid drop and the evaporation rate of the liquid.
3. The vapor phases of liquids such as acetone and alcohol are more flammable than their liquid phases. For flammable liquids, what is the relationship between evaporation rate and the likelihood that the liquid will burn?
4. Suggest why a person who has a higher than normal temperature might be given a rubdown with rubbing alcohol (70% isopropyl alcohol).
5. Table salt can be collected from salt water by evaporation. The water is placed in large, shallow containers. What advantage do these shallow containers have over deep containers with the same overall volumes?
6. Is there a relationship between the boiling point of these liquids and their rate of evaporation?
7. How does the rate of evaporation of warm ethanol compare to ethanol at room temperature? Use kinetic-molecular theory to explain your observations.

Teacher

Determining Reaction Rates

NGSSS:

SC.912.P.12.12 Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.

SC.912.P.10.6 Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.

SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Purpose of Lab/Activity:

- To determine the factors that affect the rate of a chemical reaction {e.g., temperature, pH, concentration (pressure), and catalyst.}
- To determine the percentage yield and limiting reagent in chemical process.
- To evaluate Le Chatelier's principle. (for advanced students)
- To quantify the enthalpy change of a process (for advanced students)

Prerequisite: Prior to this activity, the student should be able to:

- Understand and express the particle meaning of concentration, pressure and temperature
- Describe the collision theory as it relates to the movement of particles.
- Explain how energy is related to the changes in chemical structure.
- To list and briefly describe the main factors that affect reaction rates.
- For teachers of Honors and/or AP Chemistry students, the following should also be considered:
 - Be familiar with the relationship between moles, mass, volume (of liquid phases or gases)
 - To discuss the idea of limiting reactants and excess reactants.
 - To derive and compare the theoretical and actual yield.

Materials (individual or per group):

- Safety goggles
- Stopwatch (seconds)
- Thermometer (extension)
- Distilled water
- Graduated cylinder
- 7 Clear plastic cups
- 7 original formula effervescent Alka-Seltzer tablets
- Hot water/ice cubes
- Mortar and Pestle
- Test tube 16 X 150mm
- Cork stopper, #4

Procedures: Day of Activity:

Before activity:	What the teacher will do: <ul style="list-style-type: none">g. Guide the students through a modeling discussion of the kinetic molecular theory.h. Have students explain how the kinetic molecular theory relates to temperature.i. Have students discuss how the 4 main factors (temperature, surface area, concentration, and amount of activation energy as it relates to the catalyst) that affect rates of reactions relate to the collision theory.j. Guide the students through a construction and comprehension of enthalpy change diagrams (Optional-for advanced students)
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Teacher

	<p>k. For the extended version: Review stoichiometry, percentage yield, limiting reagents.</p> <p>l. Discuss the principles of enthalpy change in physical and chemical processes (Note: Changes in state can bring about changes in temperature. When this happens at constant pressure we call it enthalpy. Another word for the enthalpy of a chemical reaction is the heat of reaction. Knowing the heat capacity of the system the enthalpy of the can be calculated - $(T_f - T_i) \times C_p = \Delta H$.)</p> <p>m. Clarify the difference between the process of dissolving the Alka Seltzer and the subsequent chemical change. A common misconception is that dissolving is a chemical change.</p>
During activity:	<p>What the teacher will do:</p> <p>a. Guide the students through the interpretation of data as it relates to the kinetic molecular theory.</p> <p>b. Instruct students to analyze their results and relate them to the collision theory, for example: 1) Ask the students, 'How does temperature affect the movement of the particles? 2) How does concentration affect the collisions of the particles?</p> <p>c. For the extended version with advanced students ask: 1) What does the pressure represent? 2) How is the pressure changing and why? 3) What is the effect of pressure on the reaction direction and why? 4) Where is the 'energy change' originating?</p>
After activity:	<p>What the teacher will do:</p> <p>a. Summarize how the observations in the experiment confirm the collision theory.</p> <p>b. Ask the students to relate how the different trials of the reactions relate to the collision theory?</p> <p>c. Relate the specific factors examined experimentally: concentration (pressure), temperature, surface area relate to the rates of reactions.</p> <p>d. Review students' comprehension of the limiting reagent.</p> <p>e. Review the effect of the limiting reagent on the results of chemical reactions.</p> <p>f. Review actual yield, theoretical yield, percentage yield and discuss specific factors that affect the percentage yield.</p> <p>g. Direct the students to clarify and evaluate the relationship between concentration and pressure as it relates to gases.</p> <p>h. Summarize the experimental observations that confirm Le Chatelier's principle.</p>

Answer Key Experiment V:

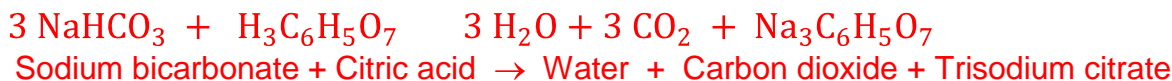
Determining the percentage yield, limiting reagent and the molar enthalpy of the reaction

Observations/Data Analysis :

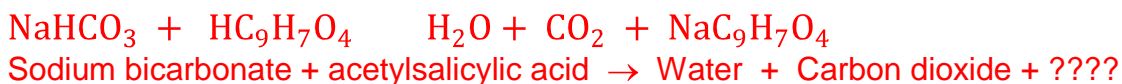
1. Active Ingredients from package of "original formula" fast relief Antacid and pain medicine-Alka-Seltzer:
 - 325 mg of Aspirin, Acetylsalicylic acid, or 2-acetoxybenzoic acid ($C_9H_8O_4$)
 - 1000 mg of Citric acid ($H_3C_6H_5O_7$)
 - 1916 mg of sodium bicarbonate ($NaHCO_3$)

Teacher

2. obtain from experimental data in Data Table 5A
3. obtain from experimental data in Data Table 5A
4. The balanced reaction with citric acid:



5. The balanced reaction with acetylsalicylic acid:



6. Baking Soda and Citric Acid



To simplify calculations use mmols (the ratio in g/mol is equivalent to mg/mmols, make sure that students understand that all you are doing is working in a smaller unit which will keep the numbers larger and easier to manipulate) see example below:



The millimoles of citric acid are given by: $\frac{1000}{192.124} = 5.205 \text{ mmol}$

If you do not want to use millimoles the alternative calculation in moles is as follows:

$$1000 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mole}}{192.124 \text{ g}} = 0.005205 \text{ moles}$$

Using the mole ratio then, $5.205 \times \frac{3 \text{ moles of HCO}_3^-}{1 \text{ mole H}_3\text{C}_6\text{H}_5\text{O}_7} = 15.615 \text{ mmol}$ of baking soda is needed.

Baking Soda and acetylsalicylic acid



The millimoles of acetylsalicylic acid are given by: $\frac{325 \text{ mg}}{180.16 \frac{\text{mg}}{\text{mmol}}} = 1.804 \text{ mmol}$.

Then, $1.804 \text{ mmol} \times \frac{1}{1} = 1.804 \text{ mmol}$ of baking soda is used.

The millimoles of baking soda are given by: $\frac{1916 \text{ mg}}{84.01 \frac{\text{mg}}{\text{mmol}}} = 22.81 \text{ mmol}$.

Teacher

Then, $22.81 \text{ mmol} \times \frac{1}{3} = 7.603 \text{ mmol}$ of citric acid needed L.R. (not enough, refer to actual amount of 5.205 mmol calculated previously)

Then $5.305 \text{ mmol} \times \frac{3}{1} = 15.615 \text{ mmol}$ of baking soda is used and

$22.81 \text{ mmol} \times \frac{1}{1} = 22.81 \text{ mmol}$ of acid needed; L.R. (not enough, refer to actual amount of 1.804 mmol calculated previously)

To find the excess mass of baking soda left over:

$22.81 \text{ mmol} - (15.65 + 1.804) \times 84.01 \text{ g/mol} \times \frac{1}{1000} = 0.4529 \text{ g}$ of baking soda left over*.

This value is given to the student in step 3 of Observation Experiment V.

Expected mass of CO₂ produced:

$1.804 \text{ mmols acetylsalicylic acid (LR)} \times \frac{1}{1} \times 44.01 \text{ g/mol CO} \times \frac{1}{1000 \text{ mg}} \times = 0.07939 \text{ g CO}_2$

$5.205 \text{ mmols citric acid} \times \frac{3}{1} \times 44.01 \text{ g/mol CO}_2 \times \frac{1}{1000 \text{ mg}} = 0.06872 \text{ g CO}_2$

Then, the total theoretical yield would be $0.07939 \text{ g CO}_2 + 0.06872 \text{ g CO}_2 = 0.14811 \text{ g}$

To find the percentage yield use the data generated in the experiment. (A typical percent yield could be approximately 83.0%). Note: this value could be affected by binders, sugar, food coloring (not applicable here) and human error (most likely).

Extension:

- Gizmo: [Limiting Reactants](#), [Collision Theory](#)

Student

Determining Reaction Rates

NGSSS:

SC.912.P.12.12 Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.

SC.912.P.10.6 Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.

SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Background: Students must be very familiar with the kinetic molecular theory and how it relates to the collision theory. The idea of concentration, pressure, temperature, kinetic energy must be discussed. The role of catalysts and their properties must be reviewed and perhaps related to the biological role of enzymes. The rate of a chemical reaction depends on the frequency of the collisions between the atoms or ions of the reactants. The concentration or pressure has an effect on the frequency of the collisions of the particles. The manipulation of concentration, temperature and/or pressure/volume can also affect direction of a reaction. Temperature will “drive” the extent of a reaction in either direction.

Purpose of Lab/Activity:

- To examine the factors that affect the rates of reactions.
- Extended: To quantify the energy change of the process.
- Extended: To determine the percentage yield of the chemical process.
- Extended to examine Le Chatelier’s principle as it relates to the yield in a chemical process

Safety:

- Safety goggles,
- Aprons.
- No eating or drinking

Vocabulary: reaction rates, reaction order, rate constant, temperature, kinetic energy, catalysts, pressure, concentration, surface area, collision theory, frequency of collisions enzymes. For those considering the extended part of the lab these should also be presented: moles as it relates to mass, volume of liquid and gas phases, limiting reactant, excess reactant, theoretical and actual yield, the percentage yield, molar enthalpy change, endothermic and exothermic reactions. Le Chatelier’s principle.

Materials (individual or per group):

- Safety goggles
- Stopwatch (seconds)
- Thermometer (extension)
- Distilled water
- Graduated cylinder
- 7 Clear plastic cups
- 7 original formula effervescent Alka-Seltzer tablets
- Hot water/ice cubes
- Mortar and Pestle
- Test tube 16 X 150mm
- Cork stopper, #4

Experiment I: Effect of temperature on reaction rates

Procedures:

1. Use one whole tablet for each trial

Student

- Use 250 milliliters of water for each trial
- Different temperatures could be: 0 °C (ice), water at room temperature (about 20 °C), heated water (about 60 °C). Make sure to record temperatures in Table 1.
- Add the tablet to each temperature trial and start the stopwatch immediately!
- Stop the time when the tablet has dissolved completely and be consistent. **Pay Attention!** Record the time in Table 1 in seconds.

Observations/Data:

Data Table 1

Trials #	Time (seconds) for dissolving tablet.	Temperature (degrees Celsius)
#1		
#2		
#3		

Data Analysis/Results:

- Graph the Water Temperature vs Time for Tablet to Dissolve.
- Using the hot water, the rate was how many times faster than at 0 degrees Celsius?
- Estimate the time it would take to dissolve an Alka-Seltzer tablet at 10 °C.
- What if the temperature is doubled from 20 to 40 °C, by how much will the reaction rate change?

Experiment II: Effect of surface area on reaction rates

Procedures:

- For each trial use a whole tablet, one broken into 8 equal pieces, and a crushed tablet
- Use 250 ml of water at room temperature (or lukewarm water) for each trial. Be consistent.
- Crush one tablet completely in the mortar and pestle
- Except for the trials with the whole and 8-piece tablets, the crushed tablet must be transferred to the clear plastic cup before adding the measured water. Start timing immediately until completely dissolved! Record the time in Table 2.
- Be sure to be consistent when recording the time for completely dissolving each tablet.

Observations/Data:

Data Table 2

Trial #	Time (seconds) for dissolving tablet.	Tablet
#1		"Whole" tablet
#2		"8-piece" tablet
#3		"Crushed" tablet

Data Analysis/Results:

- What is the effect of particle size on the rate of the reaction?

Student

2. The rate of the reaction for the crushed tablet was how many times faster than that of the whole tablet?
3. As the particle size decreases, what is the effect on the total surface area and the probability of interactions between atoms/ions/rate of the reactions?
4. Compare the results of particle size to the effect of temperature on the rate of the reaction (Hint: Use data from Experiment 1.) Explain.

Experiment III: Effect of a lower pH on the reaction rate

Procedures:

1. Prepare two slightly acidic solutions by diluting a 2-Molar solution of HCl (strong acid) , the first one with 125 ml of water to 125 ml of the acid and the second weakly acidic solution by measuring 250 ml of commercial vinegar.
2. Add a tablet to each acidic solution and record the time for the tablet to dissolve under trials #2 and #3 of Data Table 3.
3. The data from Trial#1 of Data Table #2 can be used as Trial #1 for this experiment. Transfer the value from Table 2 to Table 3.

Observations/Data:

Data Table 3

Trials #	Time (sec.) for dissolving tablet	pH of solution
#1 (from Data Table 2)		Neutral H ₂ O pH = 7
#2		Slightly acidic 5% by Vol. Vinegar pH = 3
#3		Strongly acidic 1.00 Molar HCl pH = 0

Data Analysis/Results:

1. Compare the results and analyze the pH difference in the 3 trials and its effect on the rate of the reaction.
2. Evaluate the effect of a decreased pH on the rate of the dissolving process; does it increase or decrease the rate of the reaction?
3. What if the pH was increased? What effect would this have on the rate of the reaction? Explain.

Student

Optional-Extension for Advanced Students

Experiment IV: Evaluating the effect of pressure: Le Chatelier's principle

Procedures:

Part A: Rate of Reaction at normal pressure.

1. Fill a 16 X 150 mm test tube $\frac{1}{2}$ full of water at room temperature.
2. Break an Alka-Seltzer tablet in half and drop the pieces into the test tube.
3. Measure the time required for the reaction/dissolving of the Alka-Seltzer in water. Record the time.

Part B: Rate of Reaction under increased pressure.

1. Repeat steps 1 and 2 from part A
2. Immediately insert the cork stopper in the end of the test tube just enough to slow down the escape of carbon dioxide gas. Do not insert the cork completely because the pressure from the contents will break the test tube. The pressure being exerted upon the system (test tube and contents) is equal to the pressure you feel being exerted against the cork.
3. Important: To avoid a total "blow-out" of the liquid from the tube, release the gas by lifting the cork slightly. This will allow the gas and liquid "to squeeze" its way past the cork, in controlled amounts.
4. When the gas bubbles are no longer visible in the liquid the reaction will be at equilibrium. Observe and record the time of the reaction in Table 4.
5. Slightly release the pressure on the cork once more. Record your observations in question #3 of the results section of this lab.

Observations/Data:

Data Table 4

Trial #	Time (seconds) for dissolving tablet.	Pressure (atm)
Part A		Normal sea level pressure (1 atm)
Part B		Increased pressure

Data Analysis/Results:

1. How does the increased pressure affect the time for the production of the gas?
2. When the gas bubbles are no longer visible in the liquid the reaction will be at equilibrium (at equal rates represented by 2 arrows of the same size but in opposite direction). What other factors could have been used to shift the direction of the arrows toward the product besides the pressure?
3. In step 8 you were asked to again slightly release the pressure on the cork once. What did you observe? Propose an explanation what occurred.

Extended discussion:

A known process in chemistry is the Bon-Haber process for synthesizing ammonia which is widely used in the production of fertilizers and explosives. Research this process in the following sites and answer the following questions.

Student

Consider the need to optimize the % yield in the process for (the precursor for producing fertilizers and explosives!) under ideal circumstances.

1. Write the balanced chemical reaction for the process.
2. Is the reaction exothermic or endothermic? Use thermodynamic tables found in different sources (for example Appendix C Chemistry the Central Science by Brown and Lemay).
3. Is the entropy increasing or decreasing? Explain the entropy change qualitatively and derive it quantitatively: Use thermodynamic tables (for example Appendix C Chemistry the Central Science by Brown and Lemay).
4. Is this process spontaneous at room temperature? Use the free energy expression: $\Delta G = \Delta H - T\Delta S$.
5. As temperature increases how will the rate be affected? What about the percentage yield? (Le Chatelier's principle)
6. How will an increased pressure affect the percentage yield? Explain.
7. Propose a solution to "optimize" the production of ammonia under ideal conditions.

Student

Experiment V: Determining the percentage yield, limiting reagent, and the molar enthalpy of the reaction

Procedures:

1. Obtain the mass of an Alka-Seltzer tablet.
2. Obtain the mass of an empty clear plastic cup.
3. Using a graduated cylinder measure 250 ml of the water and add to the cup.
4. Measure the initial temperature (T_i) of the water in degree Celsius.
5. Add the tablet to the water.
6. After the tablet completely dissolves, record the final temperature (T_f) in degree Celsius.
7. Mass the cup of water and "reacted" tablet at the end of the process.

Observations/Data:

Data Table 5A

	Measurements
Initial Mass of Alka- Seltzer tablet	g
Mass of Empty Cup	g
Volume of water	ml
Initial Total mass of tablet, water and cup	g
Final Mass of water, cup and reacted tablet	g
Mass of gas produced	g
Initial temp of Water	°C
Final temp of Solution	°C
ΔT of Solution	°C

Data Analysis:

1. Record the mass and the type of active ingredients from the package of an original formula Alka-Seltzer (bright blue packet).
2. To find the mass of gas produced, subtract the initial mass of tablet, water and cup from the final mass of water, cup and reacted tablet and record in the corresponding space in Data Table 5A and in 5B (under mass of CO_2).
3. The answer in step 2 is the mass of the gas evolved but the tablet includes additional substances such as excess baking soda which must be considered in the calculations. To find the actual mass of the CO_2 gas, complete the following calculation:
 - a. Answer from #2 – 0.4529g of baking soda* = CO_2 gas
4. Write the balanced chemical equation between the baking soda and the citric acid.
5. Write the balanced equation between the baking soda and the acetylsalicylic acid
6. Derive the molar masses for each reactant and product and derive the moles of each of the reactants and record in Table 5B.

Data Table 5B

Chemical substances	Molar masses	Actual Mass	# of Mols
Aspirin			
Baking Soda			
Citric Acid			
Water			
Carbon dioxide			

Student

Results:

1. Determine the limiting reagent. Show all your work
2. Determine the expected or theoretical mass of the gas evolved.
3. Calculate the excess mass of the reactant left over (already given in Experiment V step 3) but you need to show the work of how this value was derived.
4. Derive the percentage yield of the reactions. Hint: use CO₂ answer from Data Table 5A divided by the answer in step 2 above X 100.
5. Derive the enthalpy of the "solution" and the "reaction" in kilojoules per mol of reaction by the following: $[Q = mc\Delta T]$ / limiting reagent in moles; where the m is given by the Final Mass of water + cup + reacted tablet, C is the specific heat capacity of water: 4.184J/g-K, and ΔT is the final temperature minus the initial temperature in Celsius or Kelvin.

Data Table 5C

Initial Temperature (T _i)	°C
Final Temperature (T _f)	°C
Mass of system (m)	g
Specific heat (C)	J/g-K
Energy (Q) - {Q = m C ΔT}	J
Energy "gained" by the reaction/dissolution process	kJ
moles of limiting reactant (citric acid)	mol

To calculate the Molar Enthalpy (ΔH) of reaction:

$$\Delta H = Q \text{ (heat in kilojoules)}/n \text{ (moles of limiting reagent)} = \text{_____ kJ/mol}$$

Conclusions:

1. Explain the role of aspirin, baking soda and citric acid chemically?
2. Why was the baking soda "chosen" to be the excess reagent?
3. Evaluate the sources of error in deriving the enthalpy of the reaction. Outline the specific effects of the errors identified.

Boyle's Law

NGSSS:

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

SC.912.P.12.10 Interpret the behavior of ideal gases in terms of kinetic molecular theory.

SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Purpose of Lab/Activity: To examine the idea of pressure and its relationship to volume.

Prerequisite: Prior to this activity, the student should be able to:

- State Boyle's law in their own words.
- Use the kinetic molecular theory to describe how particle behavior is related to Boyle's law.
- Describe the change of pressure with respect to elevation.
- Give all the units for pressure and explain their origins.
- Explain pressure in terms of force and area.
- Derive the standard units for force, area and volume.
- Compare the use of a barometer to a manometer.

Materials (individual or per group):

- safety goggles
- Boyle's law apparatus
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors

Procedures: Day of Activity:

Before activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> a. Review the basic principles of the kinetic molecular theory. b. Derive the standard units for pressure, force, and area. c. Explain the use of a barometer and the principle underlying the measurement of pressure. d. Relate pressure to elevation and its subsequent implications. e. Review the use of graphs in evaluating variables as a basic tool of the scientific method. f. Review the use of a piston as a measurement of PV work g. Discuss the chemical composition of air.
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> a. Supervise the safe use of the piston b. Provide directions for reading the syringes accurately. c. Confirm the dependent variable is assigned as the volume. d. Ask the students, "why is the pressure considered the independent variable for this experiment?"
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> a. Have the students construct the mathematical relationship between pressure and volume. b. Have students discuss the behavior of the particles using the kinetic molecular theory.

Teacher

	<ul style="list-style-type: none">c. Discuss the shape of the graphs and compare to initial predictions.d. Have students calculate the PV constant for the piston using the appropriate units.e. Have students establish Boyle's law in their own words based on their experimental observations.
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Extension:

- Interactive [Boyle's Law Apparatus](#)
- Gizmo: [Boyle's Law and Charles' Law](#)

Student

Boyle's Law

NGSSS:

SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.

SC.912.P.12.10 Interpret the behavior of ideal gases in terms of kinetic molecular theory.

SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Background Information:

In this investigation, you will observe the behavior of a gas, using a device called a Boyle's law apparatus. The apparatus consists of a graduated syringe with a movable piston. Initially, the syringe is adjusted to trap a volume of gas at the same pressure as its surroundings. The piston then does not move because the pressure exerted by the gas in the syringe equals the pressure of the atmosphere pushing on the piston. If the piston is pushed downward, it compresses the gas trapped in the syringe. If the pressure on the piston is then decreased, the pressure of the trapped gas will push the piston up.

In order to read the volume of trapped gas correctly, you must always read the measurement on the side of the piston that is in contact with the gas. Because air is a mixture of gases-mostly nitrogen and oxygen-that behaves physically as a single gas, the data from this lab can be treated as data for a single gas. As the pressure of the air changes, you will monitor and collect data on the resulting changes in volume. You can then use your data to find the atmospheric pressure and determine how closely your results agree with Boyle's law

Purpose of Lab/Activity: Determine the relationship between pressure and volume.

Safety Precautions:

- Wear appropriate safety goggles.
- Don't let the students aim the pressurized syringe at anyone as the syringe tip cap could shoot off.
- Note: *The increasing load of books on the piston may become unsteady. Falling books can injure the person measuring the gas volumes and damage the Boyle's law apparatus. Steady the books by resting them slightly against the ring or by nudging them into balance as you would with wooden building blocks.*

Vocabulary: Force, area, pressure, barometer, manometer, gases, altitude, elevation, density, torr, psi (pounds per square inch- lbs/in²), N/m², mmHg, atm, volume

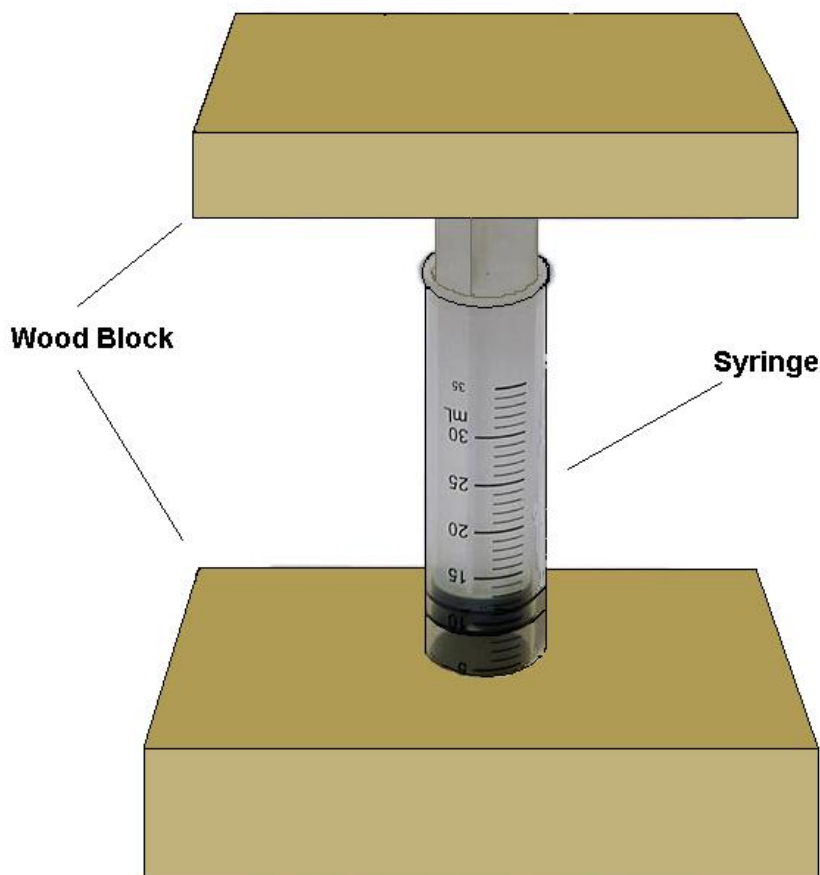
Materials (individual or per group):

- safety goggles.
- Boyle's law apparatus.
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors.

Student

Procedures:

1. Work with a partner so that one person operates the apparatus (see figure below) while the other steadies the books and keeps track of the procedural steps.
2. Put on your safety goggles. Secure the Boyle's law apparatus with a ring stand and clamp. Adjust the initial volume (about 30 ml) to atmospheric pressure as directed by your teacher.
3. Test the apparatus by pushing down on the piston with your hand slowly and steadily until the volume of the trapped gas is reduced to 15 ml. Release the piston and note whether it returns to initial volume. If not, check and adjust the seal at the syringe opening. (Note: if red tip seals are too loose try replacing it with a small rubber stop with a small indentation).
4. Place the apparatus on a flat, steady surface, such as a sturdy table or the floor. Record the initial volume at 0 books of pressure in the data table.
5. Place one book on the piston and record the resulting volume of trapped gas in the data table. Add a second book and record the gas volume. Continue adding books and recording the resulting volumes until all 5 books are resting on the piston. Remember to steady the books, especially when the apparatus is being read.
6. Remove all the books from the piston and reset the apparatus to the initial volume recorded in Step 2.
7. Repeat Step 5 and 6 two more times, remembering to reset the apparatus between sets of trials.
8. Clean up your work area.



Student

Observations/Data:

Data Table 1- Volume and Pressure Relationship

Pressure (#books)	V ₁ (ml)	V ₂ (ml)	V ₃ (ml)	V _{avg} (ml)	1/V _{avg} (ml ⁻¹)	P _{atm}	P _{total}	(P _{total}) x (V _{avg})

Data Analysis and Results:

1. Find the average of each set of three volumes and record these averages in the data table.
2. For Graph #1 plot the pressure (in books) on the horizontal axis, and the average volume, V_{avg} on the vertical axis. Draw a smooth line through the points. Make sure the graphs are titled, axes clearly labeled with units, and scales properly sequenced.
3. According to Boyle's law, pressure and volume have an inversely proportional relationship. If this idea is correct, you should obtain a linear relationship (straight line) when you plot pressure versus the corresponding inverse of the average volume. Calculate the inverse, 1/V_{avg}, of each volume and record these values in the appropriate column of the data table.
4. For Graph #2, plot the corresponding 1/V_{avg} values versus pressures in units of "books" on the horizontal axis. Note: the graph of Pressure vs 1/V_{avg} is also "linear", yielding a slope of $m = PV$; furthermore the $y = mx + b$ equation will confirm that the *y-intercept* is the initial atmospheric pressure when 1/V = 0 (no books initially present).
5. The line obtained for the second plot crosses the vertical axis of the graph above the origin, which tells you that there is pressure on the gas even when there are no books on the piston. Consider that 1/V = 0 only when the total pressure on the gas is zero (and the volume is infinitely large). The additional pressure is the atmospheric pressure. To find this pressure in units of books, extend the plot of 1/V_{avg} versus Pressure_{books} on Graph #2 to the point where it intersects the horizontal axis. At this point, 1/V_{avg} = 0. The scale distance from this point to the origin is the atmospheric pressure measured in books. Using your graph, determine this value (See Sample Graph 2 below).
6. Record the value of P_{atm} in each row of the table in the proper column.
7. Add the value you found for atmospheric pressure (P_{atm}) to pressure in books (P_{books}) for each trial and record these values of P_{total} in the table.

$$P_{\text{total}} = P_{\text{books}} + P_{\text{atm}}$$

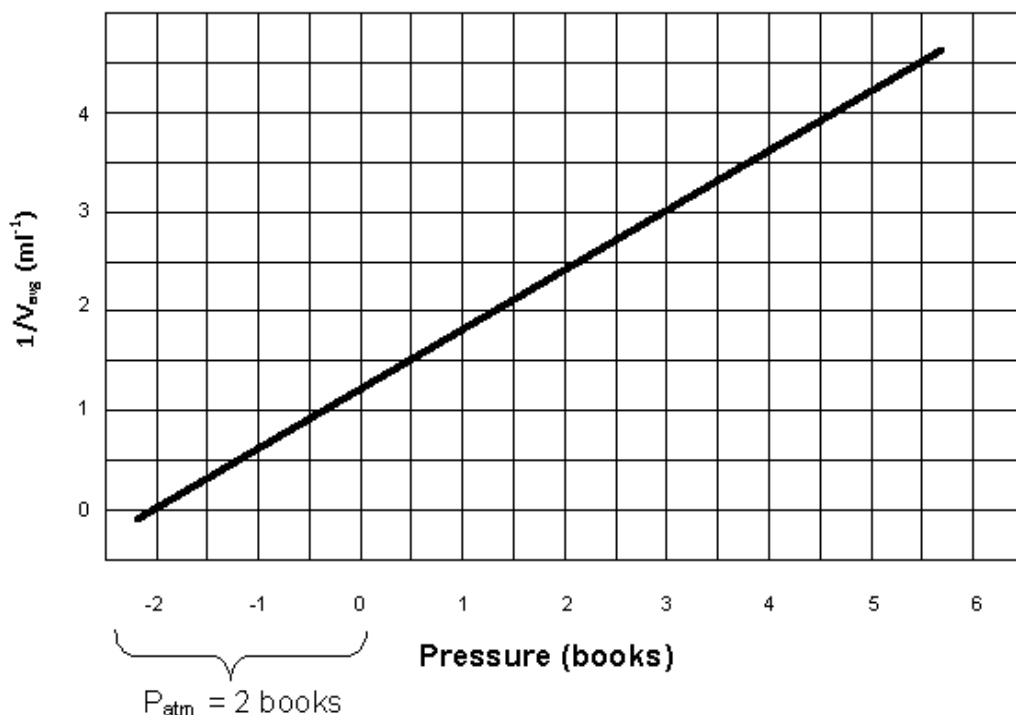
8. Calculate the product of P_{total} x V_{avg} for each trial and record these values in the data table.

Student

Conclusions:

1. What is the benefit of repeating the measurements 3 times?
2. Explain the relationship between pressure and volume shown in Graph#1.
3. Describe the results shown in Graph #2.
4. Look at the values you calculated in the last column of the data table. How do they compare?
5. State Boyle's Law.
6. How do the pressure and volume values relate in terms of Boyle's law?
7. Will this pressure/volume relationship hold true for solids and liquids? Why or why not?
8. When the plunger was compressed, it got more and more difficult to push the plunger in. Explain, using the kinetic molecular theory, why this happens.
9. Solve the following problems: 1) For an initial volume of 5.20-L and a pressure of 103 kilopascals, at what pressure in atmospheres will the volume of the gas expand to 12.00-L? 2) A gas at 700.0 millimeters mercury occupies volume of 200.0 milliliters, at how many atmospheres will it occupy 0.950-Liter?

Sample Graph



Extension for Advanced Students:

1. If the gas had behaved non ideally, what would have been the effect on the results of the experiment? (Hint: There will be a negative and a positive deviation away from the expected behavior- research the molecular origin of these effects).
2. When you use a bicycle pump to inflate a tire you push on the pump and air moves into the tire. In order for the pump to work, air pressure must be greater in the pump than in the bicycle tire. The air will move from the pump to the tire, causing inflation. How does the principle of Boyle's law come into effect in the operation of bicycle pump?

Half-Life

NGSSS:

SC.912.P.10.10 Compare the magnitude and range of the four fundamental forces (gravitational, electromagnetic, weak nuclear, strong nuclear).

SC.912.P.10.11 Explain and compare nuclear reactions (radioactive decay, fission and fusion), the energy changes associated with them and their associated safety issues.

SC.912.P.10.12 Differentiate between chemical and nuclear reactions.

Purpose of Lab/Activity:

- To graph and interpret data of the isotope's half-life.
- To model the half-life of an imaginary isotope.

Prerequisite: Prior to this activity, the student should be able to:

- Describe the basic structure of an atom
- Explain the general role of the sub atomic particles
- Explain the role of isotopes and their natural occurrence.
- Describe the implications of the law of conservation of energy and matter.

Materials (individual or per group):

- 100 pennies
- Plastic cup
- Container with lid such as a shoebox
- Timer or clock with second hand.

Procedures: Day of Activity:

Before activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> Review the model of the atom, making sure that students identify the properties of the nucleus. Have students review how the subatomic particles determine the properties of the atom. Ask students, what determines the degree to which an atom is unstable? Ask students, how the stability relates to the time it takes for a particle to disintegrate? Ask students, what 2 forces are related to the disintegration of the nucleus. You should introduce a general idea of strong and weak nuclear forces are acting on the atom. Discuss the law of conservation of energy and matter. Introduce the main purpose of the activity. On the board, set-up Table 2.Group Data (from the Student Section); so, that once the groups complete the experiment and calculations, one person from each group reports their group data on the board
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none"> Ask students how the heads and tails analogy relates to parent and daughter isotopes as you are studying radioactive decay Does the data obtained from the 2 trials describe the behavior of natural

Teacher

	<p>isotopes? Explain.</p> <ol style="list-style-type: none">As students collect data, ask them to describe patterns that are emerging and what is the meaning of those patterns?Direct the students to write their group data on the Group Data Table displayed on the board.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">Ask student to explain why two trials of tossing the coins are needed and how the calculated average minimizes any statistical deviations?Looking at Table 2. Group Data on the board, ask the students: How does each group's data compare to the class average data? Explain the discrepancies.How does this experimental design model the natural occurrence of isotopes?What are the limitations of this model?

Extension:

- Gizmo: [Half-life](#)

Student

Half-Life

NGSSS:

SC.912.P.10.10 Compare the magnitude and range of the four fundamental forces (gravitational, electromagnetic, weak nuclear, strong nuclear).

SC.912.P.10.11 Explain and compare nuclear reactions (radioactive decay, fission and fusion), the energy changes associated with them and their associated safety issues.

SC.912.P.10.12 Differentiate between chemical and nuclear reactions.

Background:

Isotopes are atoms of the same element with different atomic masses. These different masses are a result of having different numbers of neutrons in their nuclei. Isotopes can be stable or unstable (radioactive). Radioactive isotopes have unstable nuclei that break down in a process called radioactive decay. During this process, the radioactive isotope is transformed into another, usually more stable, element. The amount of time it takes half the atoms of a radioactive isotope in a particular sample to change into another element is its half-life. A half-life can be a fraction of a second for one isotope or more than a billion years for another isotope, but it is always the same for any particular isotope.

Purpose of Lab/Activity:

- To graph and interpret data of the isotope's half-life.
- To model the half-life of an imaginary isotope.

Safety: Do not eat or drink or eat in lab.

Vocabulary: Spontaneous decay, radioactivity, alpha, beta, gamma emission, half-life, protons, neutrons, electrons, nucleus, energy, potential energy, stability, elements, atom.

Materials (individual or per group):

- 100 pennies
- Plastic cup
- Container with lid such as a shoebox
- Timer or clock with second hand.

Procedures:

1. Place 100 pennies, each head-side up, into the container. Each penny represents an atom (parent nuclei) of an unstable isotope.
2. Place the lid securely on the container. Holding the container level, shake it vigorously for 20 seconds.
3. Set the container on the table and remove the lid. Remove only pennies that are now in a tails-up position (decayed nuclei or daughter nuclei).
4. Count the pennies you removed and record this number in Table 1 under Trial 1. Also record the number of heads-up pennies that are left (undecayed parent nuclei).
5. Repeat steps 2 through 4 until there are no pennies left in the container.
6. Repeat steps 1 through 5 and record your data in Table 1 under Trial 2.

Student

Observations/Data:

1. Calculate the averages for each time period and record these numbers in Table 1. The first row is done for you.
2. Graph the average data from Table 1. Graph the number of heads-up pennies remaining on the Y-axis (undecayed atoms or nuclei) against time in seconds (on X-axis) using a symbol such as X, O, Δ, or different colors to represent the trials and the average values.
3. Record the averages for each time trial per group in your class in Table 2. The first row is done for you.
4. Determine the totals and then the averages for the combined data from all groups and record in Table 2.
5. Create a second graph for the average class data for undecayed nuclei. Use a different symbol or color for each group and the class' average in the same way as you graphed your individual group's data.
6. Be sure to include a symbol key for each graph.

Data Analysis:

Table 1 - Group Data

	Trial 1		Trial 2		Averages	
	A	B	C	D	Columns A and C (H)	Columns B and D (T)
Shaking Time	Number of Heads-up Remaining	Number of Tails-up Removed	Number of Heads-up Remaining	Number of Tails-up Removed		
At 0 s	100	0	100	0	100	0
After 20 s						
After 40 s						
After 60 s						
After 80 s						
After 100 s						
After 120 s						
After 140 s						

Student**Table 2 - Class Data**

	Group	I	II	III	IV	V	VI	VII	VIII	Total	Average
0 s	H	100	100	100	100	100	100	100	100	800	100
	T	0	0	0	0	0	0	0	0	0	0
20 s	H										
	T										
40 s	H										
	T										
60 s	H										
	T										
80 s	H										
	T										
100 s	H										
	T										
120 s	H										
	T										
140 s	H										
	T										

H = Heads; T = Tails

Results:

1. In this model, what represented the process of radioactive decay?
2. Which side of the penny represented the decayed isotope? Which side represented the undecayed atoms?
3. In this model, what was the half-life of the pennies? Explain
4. Why were more accurate results obtained when the data from all groups was combined and graphed?

Conclusions:

1. What can you conclude about the total number of atoms that decay during any half-life period of the pennies?
2. If your half-life model had decayed perfectly, how many atoms of the radioactive isotope should have been left after 80 seconds of shaking? (Hint: extrapolate the graph).
3. If you started with 256 radioactive pennies, how many would have remained undecayed after 60 seconds of shaking? (Hint: interpolate the graph).

Teacher

Extra Lab -Precipitation Reactions Activity (Replaces Activities of Metals Lab)

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.8 Characterize types of chemical reaction, for example: redox, acid-base, synthesis and single and double replacement reaction.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Purpose of Lab/Activity:

- To introduce students to precipitation reactions, a type of double displacement reactions
- To practice nomenclature of ionic compounds and formula writing
- To create a particle level model to explain precipitation reactions
- To identify the parts of a chemical equation and the state subscripts

Prerequisite: Students should already be familiar with ionic compounds and electrolytes. They should have a clear model of how a solid dissolves in a solvent to produce an aqueous solution. They should also be aware of basic nomenclature of ionic compounds including polyatomic ions.

Materials:

0.1M solutions of the following in Beral pipettes or bottles with droppers

- NiCl₂
- Na₂S
- Co(NO₃)₂
- Ba(NO₃)₂
- CuSO₄
- NaOH
- Na₂CO₃
- CaCl₂
- KI
- K₂CrO₄
- AgNO₃
- Pb(NO₃)₂
- Glass spot plate or well plate

Procedures: Day of Activity

Before activity:	What the teacher will do: <ol style="list-style-type: none">Prepare all solutions. Bottles with droppers work well and can be used for many groups and years to follow. Upside down beral pipettes work well too. Label the bottles or pipettes with the formula of the compound only to make students practice nomenclature.Ask students how soluble solids dissolve when placed in a solvent such as water. Review the particle level model that explains this situation. Stress that water molecules separate the ions in the solid until they become invisible. There is a force that allows the water molecules to overcome the attraction between the ions in the solid.Show students the containers of the solids that you used to make the solutions. The nickel chloride and potassium chromate are both colorful
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Teacher

	<p>enough for them to see what the chemical looks like in the solid state and then show them the solutions they will be using.</p> <ol style="list-style-type: none">Explain students the procedure and stress that they don't use more than two drops of reactant. Some of these chemicals such as the chromates and lead salts are toxic and harmful for the environment. So to reduce waste the amounts must be small.Warn students not to mix anything other than what is described in the activity.This activity works best when students work in pairs.Groups can work in any order they prefer. If all groups work in order they will all need the same bottles at the same time. Working out of order will minimize this delay. Another solution is to make enough solutions for every group.
During activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">Students will be very surprised to see what happens when they start combining the solutions. Some precipitates are white and others are black or colored. Therefore, student should have a white piece of paper under the glass spot plate and a dark surface to see the colors well.Students may not realize that the color change occurs because a solid is forming. You may need to point out that at the bottom they can see some flecks of solid collecting as the mixture settles.Ask the students what they think it is happening or where the solid is coming from.Watch students write some of the formulas for the products and reactants. Correct mistakes in nomenclature as you observe themFollow appropriate disposal procedure for the chemicals used in this experiment.
After activity:	<p>What the teacher will do:</p> <ol style="list-style-type: none">Bring the students together for class discussion.Ask students to explain what they think is happening at the particle level that makes a solid form out of two clear solutionsLead students to conclude that each solution has an ion that when they finally combine they attach to each other very strongly and water cannot break the lattice apart.Ask students what is the role of the ions that do not precipitate. Introduce the concept of spectator ions. These ions do not participate in the reaction, they just watch as spectators in a show do.This time you can choose to cover the concept of total ionic equations and net ionic equations if you deem this appropriate for your course. Also you can introduce solubility rules.Mention that this type of reactions is called precipitation reactions and they are also part of the type of reaction called double displacement.Discuss the conclusion questions in the student procedure after students have had time to work through them.

Extension:

- Gizmo: [Limiting Reactants](#), [Collision Theory](#)

Student

Precipitation Reactions Activity

NGSSS:

SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.

SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.

SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.

SC.912.P.8.8 Characterize types of chemical reaction, for example: redox, acid-base, synthesis and single and double replacement reaction.

SC.912.P.8.9 Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions.

Background: It is common to see a solid in water dissolve until it disappears. The water molecules are able to dismantle the lattice structure of the solid and separate it into ions too small to see. In this case, the force between the water and the ions is stronger than the forces between the ions and dissolution occurs. Is it possible for this process to happen in reverse? The following activity will answer that question.

Purpose or Problem Statement: In the following activity you will combine solutions of ionic compounds to form precipitates. You will learn how these precipitates form at the particle level.

Safety:

- Use only the amount of chemical described in the procedure
- Use goggles at all times
- You will be handling small amounts of toxic chemicals. Do not touch or ingest the chemicals in any way.
- Dispose the chemicals as instructed by your teacher

Vocabulary: Precipitate, Lattice, solution, ions, solute, solvent, precipitation reactions, double displacement reactions, spectator ions.

Materials (individual or per group):

0.1M solutions of the following in Beral pipettes or bottles with droppers

- | | | |
|-------------------------------------|-----------------------------------|-------------------------------------|
| • NiCl ₂ | • NaOH | • AgNO ₃ |
| • Na ₂ S | • Na ₂ CO ₃ | • Pb(NO ₃) ₂ |
| • Co(NO ₃) ₂ | • CaCl ₂ | • Glass spot plate or well plate |
| • Ba(NO ₃) ₂ | • KI | |
| • CuSO ₄ | • K ₂ CrO ₄ | |

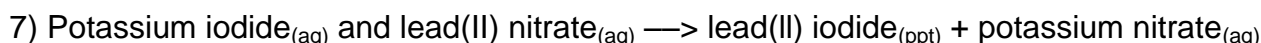
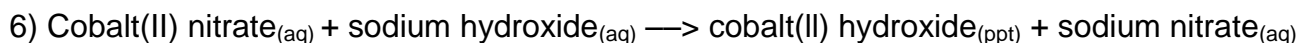
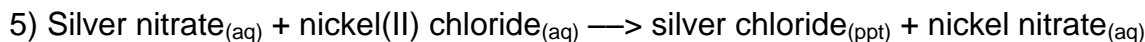
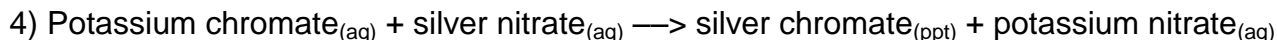
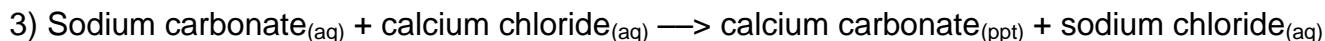
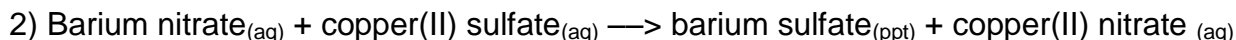
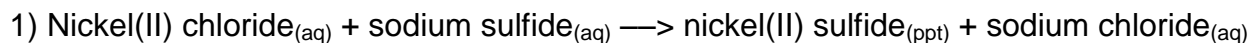
Procedures:

Using the following chemical reactions:

1. Combine two drops of each reactant (left of the arrow, —>) on the glass plate. The products are right of the arrow. [(ppt) means precipitate, flecks of solid formed and (aq) means aqueous, or in solution, no solid formed.
2. Write the chemical formula for each compound in the reaction.

Student

3. Under the chemical formula for the precipitate (ppt), write the **color** of the precipitate.



4. Disposal and cleaning: Follow your teacher's instructions for the cleaning and disposal. Do not flush the chemicals down the drain. This lab involves heavy metals such as lead, barium, and silver which are toxic and harmful to the environment. These chemicals should be disposed the appropriate way.

Conclusion:

1. In your own words, define precipitate
2. Explain how precipitation reactions occur at the particle level
3. What are spectator ions?
4. Tap water involves many dissolved solids including calcium and magnesium. In some areas of high mineral concentration pipes clog overtime just from the water running through them. Based on your knowledge of precipitation reactions, explain how the pipes clog.
5. Based on the reactions that you produced above, what chemical could you add to a solution containing chloride ions if you wish to separate the chloride out of the solution?
6. Heavy metals such as lead, silver, and barium are toxic and sometimes present in the water. Based on your knowledge of precipitation reactions, how can water treatment plants get rid of these toxic ions?
7. Kidney stones, a very painful condition, are composed of solid calcium oxalate. Provide an explanation on how these stones can originate in your body.

ANTI-DISCRIMINATION POLICY

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Title VI of the Civil Rights Act of 1964 - prohibits discrimination on the basis of race, color, religion, or national origin.

Title VII of the Civil Rights Act of 1964, as amended - prohibits discrimination in employment on the basis of race, color, religion, gender, or national origin.

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