



# **Chemistry Support Documents 2004 Curriculum**

**Public Schools of North Carolina**

# **Curriculum Support for the 2004 revision of the *North Carolina Standard Course of Study for Chemistry***

## **Acknowledgements**

A group of dedicated and talented science teachers sent many hours developing these materials. The result is this resource that will facilitate the implementation of the North Carolina Science Curriculum.

A special thanks to the authors of these materials:

Kelly Allen	Misti Anderson
Thomas Bartik	Ken Carter
Myra Halpin	Bud Harrelson
Brian Herndon	Sharron Huffman
Sandra Hylton	Mike Jones
Nicole Murry	Anu Palit
Dee Dee Whitaker	

And to the many other teachers and scientists who provided helpful comments.

We would like to extend a special thanks to Sam Houston, The North Carolina Science, Mathematics and Technology Education Center, the Teacher Link Fellows and The Burroughs Wellcome Fund for their generous support during the development of these materials.

We make every effort to keep these materials accurate and up to date. Check the Department of Public Instruction's website <http://www.ncpublicschools.org/curriculum/science/scos/> for current versions.

Please send comments and corrections on these materials to:

Ragan Spain M.A.Ed., NBCT  
Secondary Division Science Consultant  
North Carolina Department of Public Instruction  
Email: [rspain@dpi.state.nc.us](mailto:rspain@dpi.state.nc.us)

# Chemistry Curriculum Support

For 2004 revision of the *NC Standard Course of Study in Chemistry*

## Table of Contents

<a href="#">Introduction</a> .....	3
<a href="#">Goals</a> .....	3
<a href="#">Unifying Concepts</a> .....	4
<a href="#">The Strands</a> .....	5
<a href="#">Laboratory Safety</a> .....	13
<a href="#">Detailed Description of Content</a> .....	18
<a href="#">What is an Atom?</a> .....	33
<a href="#">An Investigation of Density</a> .....	38
<a href="#">Boyle's Law: <i>Pressure-Volume Relationship in Gases</i></a> .....	41
<a href="#">The Bond-Type Triangles</a> .....	50
<a href="#">Heat of Fusion</a> .....	54
<a href="#">Electron Spectroscopy</a> .....	56
<a href="#">Observations-Copper Chloride and Aluminum</a> .....	60
<a href="#">Construction of Air Bags</a> .....	62
<a href="#">Limiting Factors: Copper Chloride and Aluminum Single Reaction</a> .....	64
<a href="#">Heat of Solution</a> .....	67
<a href="#">Decomposition of Sodium Hydrogen Carbonate</a> .....	72
<a href="#">HONORS CHEMISTRY Resources</a> .....	79
<a href="#">CHEMISTRY Reference Tables</a> .....	115

## Introduction

This support document is designed to support implementation of the 2004 revision of the North Carolina Standard Course of Study for Chemistry. It includes each objective with a detailed content description, a list of enrichment topics, suggested laboratory materials, information about the North Carolina Total Science Safety program and a collection of laboratory investigations, classroom activities and other resources.

The particular laboratory investigations and classroom activities in the support document are not required but if these activities are not done then similar laboratory investigations should be substituted. The chemistry course is intended to be a laboratory course.

The detailed content description should serve as a minimum and not a maximum for Chemistry. Teachers should differentiate instruction according to the needs and interests of their students.

Goal 1 was added to emphasize the importance of science as inquiry. Students should be provided many opportunities throughout the course to design and carry out investigations and to analyze and evaluate data. They should be required to present their data and explain their conclusions.

## Goals

The Chemistry course encourages students to continue their investigations of the structure of matter along with chemical reactions and the conservation of matter and energy in those reactions. Inquiry is applied to the study of the composition, structure, properties and transformation of substances. The course focuses on basic chemical concepts and incorporates investigations to build understanding of these concepts. The unifying concepts and program strands provide a context for teaching content and process skill goals. All goals should focus on the unifying concepts:

- Systems, Order and Organization
- Evidence, Models, and Explanation
- Constancy, Change, and Measurement
- Evolution and Equilibrium
- Form and Function.

**Strands:** The strands are: Nature of Science, Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives. They provide the context for teaching of the content Goals and Objectives.

## Unifying Concepts

Unifying Concepts should unite the study of various chemical topics across grade levels. Focus on the unifying concepts of science will also help students to understand the constant nature of science across disciplines and time even as scientific knowledge, understanding and procedures change.

- Systems, Order and Organization.
- Evidence, Models, and Explanation.
- Constancy, Change, and Measurement.
- Evolution and Equilibrium.
- Form and Function.

An excellent discussion of developing understanding of the unifying concepts in chemistry is found in “Chapter 3: The Unifying Concepts” of *Chemistry in the National Science Education Standards* (American Chemical Society, 1997) available on line at: [http://chemistry.org/portal/resources/ACS/ACSContent/education/chemistry\\_standards.pdf](http://chemistry.org/portal/resources/ACS/ACSContent/education/chemistry_standards.pdf)

Below is a brief summary of chemistry topics to help teachers develop this understanding. Making connections and comparisons across the scientific disciplines will help students see these concepts in the larger context of science beyond chemistry.

Unifying Concepts	Chemistry topics which demonstrate these concepts
Systems, Order and Organization	<ul style="list-style-type: none"> <li>• Periodic Table</li> <li>• Systems in discussion of energy flow and thermodynamics</li> <li>• Chemical reactions</li> <li>• Entropy</li> </ul>
Evidence, Models, and Explanation	<ul style="list-style-type: none"> <li>• How do we know what we know? What constitutes evidence in a laboratory investigation?</li> <li>• Atomic theory – historical development of models of the atom and evidence these models are based on.</li> </ul>
Constancy, Change, and Measurement	<ul style="list-style-type: none"> <li>• Conservation laws</li> <li>• Measurement of physical and chemical changes</li> </ul>
Evolution and Equilibrium	<ul style="list-style-type: none"> <li>• Radioactivity and chemical evolution of elements in the universe</li> <li>• Properties of solutions</li> </ul>
Form and Function	<ul style="list-style-type: none"> <li>• Equipment design</li> <li>• Atomic and molecular structure related to physical and chemical processes.</li> </ul>

**STRANDS**

North Carolina's science curriculum has strands which provide a context for teaching the goals and objectives in the Standard Course of Study. The strands are: Nature of Science, Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives.

<b>Strands</b>	<b>Ideas for integrating the Strands</b>
<p><b>Nature of Science</b></p> <p>This strand includes the following sections: Science as a Human Endeavor, Historical Perspectives, and the Nature of Scientific Knowledge. These sections are designed to help students understand the human dimensions of science, the nature of scientific thought, and the role of science in society.</p> <p><b><i>Science as a Human Endeavor</i></b></p> <p>Intellectual honesty and an ethical tradition are hallmarks of the practice of science. The practice is rooted in accurate data reporting, peer review, and making findings public. This aspect of the nature of science can be taught by designing instruction that encourages students to work in groups, design investigations, formulate hypotheses, collect data, reach conclusions, and present their findings to their classmates.</p> <p>The content studied in chemistry provides an opportunity to present science as the basis for engineering, ecology, computer science, health sciences and the technical trades. The diversity of chemistry content allows for looking at science as a vocation. Scientist, artist, and technician are just a few of the many careers in which a chemistry background is necessary.</p> <p>Perhaps the most important aspect of this strand is that science is an integral part of society and is therefore relevant to students' lives.</p>	<ul style="list-style-type: none"> <li>• Demonstrate using newspaper and magazine articles the importance of understanding Chemistry.</li>   <li>• Include examples of both individual and team contributions to the field of chemistry.</li>   <li>• Design inquiry activities in which all students to collect data and report their finding to their peers for review.</li>   <li>• Debate whether scientific peer review process is adequate to trust scientists' information in making policy decisions.</li>   <li>• Assign students to investigate the chemistry knowledge needed for diverse occupations.</li>   <li>• Invite speakers from local industries and services to discuss the use of chemistry principles in their work. (Waste management, water and air quality, biotechnology, pharmaceuticals, forensics, etc)</li> </ul>

Strands	Ideas for integrating the Strands
<p><b><i>Historical Perspectives</i></b></p> <p>Most scientific knowledge and technological advances develop incrementally from the labors of scientists and inventors. Although science history includes accounts of serendipitous scientific discoveries, most development of scientific concepts and technological innovation occurs in response to a specific problem or conflict. Both great advances and gradual knowledge building in science and technology have profound effects on society. Students should appreciate the scientific thought and effort of the individuals who contributed to these advances.</p> <p>A historical view from the philosophical perspective of Democritus (who produced no experimental evidence) to the genius of Dalton's inferences from his observation of gases, make chemistry come alive. In other examples, the history of Aristotle's philosophy of matter, and of Dalton's and Bohr's models of atomic theory, emphasize the value of a scientific model in enabling researchers to explore an unseen entity by starting with certain assumptions posited by the model.</p>	<ul style="list-style-type: none"> <li>• Be sure to include examples of both male and female scientists from diverse backgrounds and cultures.</li> <li>• Study the contributions of key scientists</li> <li>• Emphasize how the understanding of the atom and atomic structure has changed over time.</li> </ul>
<p><b><i>Nature of Scientific Knowledge</i></b></p> <p>Much of what is understood about the nature of science must be addressed explicitly.</p> <ul style="list-style-type: none"> <li>• All scientific knowledge is tentative, although many ideas have stood the test of time and are reliable for our use.</li> <li>• Theories "explain" phenomena that we observe. They are never proved; rather, they represent the most</li> </ul>	<ul style="list-style-type: none"> <li>• Encourage students to explore the difference between a theory and a law.</li> <li>• Remind students how scientific explanations undergo rigorous scrutiny.</li> </ul>

<b>Strands</b>	<b>Ideas for integrating the Strands</b>
<p>logical explanation based on currently available evidence. Theories become stronger as more supporting evidence is gathered. They provide a context for further research and give us a basis for prediction. For example, atomic theory is an explanation for the behavior of matter based on the existence of tiny particles. Kinetic molecular theory explains, among other things, the expansion and contraction of gases.</p> <ul style="list-style-type: none"> <li>• Laws are fundamentally different from theories. They are universal generalizations based on observations we have made of the natural world, such as the nature of gravity, the relationship of forces and motion, and the nature of planetary movement.</li> <li>• Scientists, in their quest for the best explanations of natural phenomena, employ rigorous methods. Scientific explanations must adhere to the rules of evidence, make predictions, be logical, and be consistent with observations and conclusions. "Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific." (National Science Education Standards, 1996, p. 201)</li> </ul>	
<p><b>Science as Inquiry</b></p> <p>Inquiry should be the central theme in chemistry. It is an integral part of the learning experience and may be used in both traditional class problems and laboratory work.</p>	<ul style="list-style-type: none"> <li>• Because of the importance of science as inquiry this aspect has been integrated into Goal 1: The learner will develop abilities necessary to do and understand scientific inquiry.</li> </ul>

Strands	Ideas for integrating the Strands
<p>Because of the unique safety issues that arise in the chemistry lab, students must be given well-supervised experience in basic laboratory techniques, including safe use of materials and equipment. However, the essence of the inquiry process is to ask questions that stimulate students to think critically and to formulate their own questions. Observing, classifying, using numbers, plotting graphs, measuring, inferring, predicting, formulating models, interpreting data, hypothesizing, and experimenting help students build knowledge and communicate what they have learned.</p> <p>Inquiry applies creative thinking to new and unfamiliar situations. Students should learn to design solutions to problems that interest them. This may be accomplished in a variety of ways, but situations that present a discrepant event or ones that challenge students' intuition have been successful. Classical experiments confirming well-accepted scientific principles may be necessary to reinforce constructed understandings and to teach safe and proper use of laboratory techniques and instruments, but they should not be the whole laboratory experience. Instead, laboratory experience should be a foundation for exploring new questions. Experiments such as measurement of physical properties, decomposition of compounds, and observation of the behavior of gases should be preliminary to open-ended investigations in which students are charged with posing questions, designing experiments, recording and displaying data, and communicating. For example, after measuring physical properties, students might investigate the relationship between the density of certain liquids and their boiling points. Although original research</p>	<ul style="list-style-type: none"> <li>• This idea should be integrated into the entire course and not just taught as a separate “lab introduction” unit.</li> </ul>

Strands	Ideas for integrating the Strands
<p>by students traditionally has been relegated to a yearly science fair project, ongoing student involvement in this process contributes to their understanding of scientific enterprise and to their problem-solving abilities.</p> <p>A solid conceptual base of scientific principles, as well as knowledge of science safety, is necessary for inquiry. Students should be given a supportive learning environment based on how scientists and engineers work. Adherence to all science safety criteria and guidelines for classroom, field, and laboratory experiences is imperative. Contact the Science Section at DPI for information and professional development opportunities regarding North Carolina specific Science Safety laws, codes, and standards. The Science Section is spearheading a statewide initiative entitled NC-The Total Science Safety System.</p>	
<p><b><i>Science and Technology</i></b></p> <p>Science and Technology It is impossible to learn science without developing some appreciation of technology. Therefore, this strand has a dual purpose: (a) developing students' knowledge and skills in technological design, and (b) enhancing their understanding of science and technology.</p> <p>The methods of scientific inquiry and technological design share many common elements - objectivity, clear definition of the problem, identification of goals, careful collection of observations and data, data analysis, replication of results, and peer review. Technological design differs from inquiry in that it must operate within the limitations of materials, scientific laws, economics, and the demands of society. Together, science and technology present</p>	<ul style="list-style-type: none"> <li>• Provide opportunities for students to utilize technology to collect and analyze data in laboratory settings.</li> <li>• Allow students to brainstorm ways that technology can be used to enhance scientific study in the future.</li> <li>• Discuss the limitation of technology in scientific study</li> </ul>

Strands	Ideas for integrating the Strands
<p>many solutions to problems of survival and enhance the quality of life.</p> <p>The relationship between science and technology is easily seen in the discipline of chemistry. Technological design plays an important role in building chemistry knowledge. For example, electron microscopes, super-colliders, personal computers, and spectrometers have changed our lives, increased our knowledge of chemistry, and improved our understanding of the universe. As students explore chemistry from a historical perspective, they can easily investigate the technology that contributed to knowledge in specialized areas. A relevant assignment might ask students to identify the technology used by researchers in exploring the atom and the relationships of the technology to the sophistication of the knowledge gained. Another assignment might be for students to compare the relative simplicity of Rutherford's gold foil apparatus to the spaceage technology of modern super-colliders. Interviews with scientists and technicians in all areas of chemistry could provide a rich listing of the newest research instruments and the kinds of questions they seek to answer.</p>	
<p><b><i>Science in Personal and Social Perspectives</i></b></p> <p>This strand is designed to help students formulate basic understandings and implied actions for many current issues facing our society. Many examples of chemistry affecting personal and social issues can be found to help students understand the importance and applications of chemical knowledge.</p>	<ul style="list-style-type: none"> <li>• Design scientific resolutions for local or global challenges.</li> <li>• Encourage debate about these resolutions and their consequences.</li> <li>• Research how science has helped create new and improved products for public use, such as NASA developments.</li> </ul>

Strands	Ideas for integrating the Strands
<p><b><i>Environmental Quality</i></b></p> <p>Studies indicate that the general public associates "chemicals" with materials that may harm humans and/or the environment. For that reason, it is particularly important to lead students to approach such issues scientifically. There are, obviously, both negative and positive impacts from man-made chemicals, and students can gain much from conducting cost/benefit analyses of selected uses.</p> <p>Such tasks emphasize the use of evidence in decision making, a skill that transfers to every aspect of students' lives.</p> <p>There are many available resources that promote one point of view or another about the use of chemicals. Having students analyze such materials for accuracy, possible bias, and misleading statements equips them to make decisions as consumers and voters. Scientists from local industries or colleges and universities can provide excellent help in evaluating such publications and, at the same time, provide information about careers in chemistry.</p> <p><b>Science and Technology in Local, National, and Global Challenges</b></p> <p>This aspect of the science in personal and social, perspectives strand encourages examination of the - involvement of human decisions in the application of scientific and technological knowledge.</p> <p>"Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national, or global challenges." "Students should understand the appropriateness and value of basic</p>	

<b>Strands</b>	<b>Ideas for integrating the Strands</b>
<p>questions 'What can happen?' - 'What are the Odds?'- and, 'How do scientists and engineers know what will happen?'" (NSES, p. 199). The NSES emphasizes that students should understand the causes and extent of science-related challenges. They should become familiar with the advances and improvements that proper application of scientific principles and products has brought to environmental enhancement, wise energy use, reduced vehicle emissions, and improved human health.</p>	

## Safety in the Science Classroom and Laboratory

### Chemical Management:

*In North Carolina, it is the responsibility of the Superintendent of a school system to appoint a qualified chemical hygiene officer to direct the development of and compliance with the chemical hygiene plan for the school system. This plan must include protocols and processes for chemical management for science laboratories and preparation rooms, as well as, professional development for science teachers and administrators. Because laws, codes and standards change, the plan must be reviewed and updated annually or more often as necessary.*

### Instruction, Supervision, and Maintenance of a Safe Learning Environment:

In North Carolina, it is the teacher's responsibility to address safety in planning instructional activities, laboratory investigations, and to supervise students so that all activities and investigations are carried out in a safe manner. The teacher is responsible for adhering to professional standards, NC laws and codes when assessing the learning environment. Ongoing professional development is an essential part of ensuring laboratory safety.

It is the principal's responsibility to provide personal protective equipment and resources to ensure science teachers can teach the North Carolina's science curriculum safely. All *North Carolina Standard Course of Study* Science classes are designed to be laboratory courses and must include a laboratory component.

The suggestions and resources for science safety and resources included here are in no way comprehensive but may serve as a quick reference for a few common safety issues.

- 1) Chemicals:
  - a. Order only the amounts you will use for one year. Do as much microchemistry as possible to minimize hazards
  - b. Be sure you have an appropriate storage system for chemicals.
  - c. You must have the MSDS available for all chemicals in your classroom/prep room (including kitchen/grocery store chemicals). You should go over the MSDS information with students each time they will be using a chemical. Document this in your lesson plan book.
  - d. Use the smallest amounts and weakest/most dilute concentrations of chemicals that you can and still have a viable investigation/demonstration.
  - e. Be sure you have appropriate disposal arranged before using a chemical.
  - f. Avoid the use of toxic chemicals.
  - g. Sulfur is a common allergen. Reactions that use or produce sulfur compounds should be performed under a working hood.

## Safety in the Science Classroom and Laboratory

- h. Go over all hazards and safety precautions with students prior to each laboratory investigation/activity and document in your lesson plan book and with student work samples (i.e. quizzes or prelab assignments).
  - i. Be aware of latex allergies that some students have. Alternative types of gloves must be provided when students need gloves.
- 2) Be sure goggles are appropriate and meet standards for the planned investigation. Goggles designed for impact are different than those designed to protect against fluid splashing. Chemical splash goggles are required anytime students are using fluids. Be sure contact lens wearers have non-vented chemical splash goggles. Visor-type goggles are NOT appropriate or safe for activities using fluids.

**DISCLAIMER:** Mention of any company or product does not constitute endorsement by the NCDPI. In addition the inclusion of links to websites is not intended to reflect endorsement by DPI, nor is it intended to endorse any views expressed or products or services offered by the author of the reference or organization operating the server on which the reference is maintained. Also, suggestions for activities do not mean that these are the only way to conduct an experiment or activity.

### Resources and References for Science Safety:

**NCDPI Total Science Safety Program:** Contact Benita Tipton, Science Consultant, [btipton@dpi.state.nc.us](mailto:btipton@dpi.state.nc.us). (919) 807-3933.

**NCDPI School Insurance** <http://www.ncpublicschools.org/fbs/insurance/>

This office will help you with risk control, safe facilities, and fire safety issues. Their website has several pages that address science safety issues and has links to websites with federal and state laws and codes.

### NCDPI Publications

NCDPI has a variety of science safety posters – currently available: Science Safety Signs, Goggles: It's the Law, and a Science Chemicals Poster which provides a chart for the teacher to enter the title and date of a lab exercise along with information about specific chemicals, including the NFPA Hazards Rating, Personal Protective Equipment and the Waste Disposal Method.

The NCDPI **School Science Facilities Planner** is available to download as a PDF file <http://www.schoolclearinghouse.org/pubs/SCIENCE.PDF>

**Other Resources**

**American Chemical Society**

*American Chemical Society Safety Guidelines*

*Chemical Safety for Teachers and Their Supervisors: Grades 7-12*

*Safety Audit/Inspection Manual*

Teachers can order single copies by calling ACS at 1-800-227-5558.

29 CFR 1910 OSHA

General Industry Regulations

[www.oshacfr.com](http://www.oshacfr.com)

*CRC Handbook of Laboratory Safety*

5<sup>th</sup> edition

A. Keith Furr

[www.crcpress.com](http://www.crcpress.com)

*2000 Emergency Response Guidebook*

U.S. Dept of Transportation

Research and special Programs Administration

<http://hazmat.dot.gov/guidebook.htm>

*A Guide to Working With Corrosive Substances*

Harry E. Payne, Jr

North Carolina Occupational Safety and Health Standards for General Industry

NC Department of Labor

Division of Occupational Safety and Health

4 West Edenton Street

Raleigh, NC 27601-1092

*Handbook of Chemical Health and Safety*

Robert J Alalmo, editor

Learning by Accident

Edited: Fariba Mojtabai & James Kaufman

Volume # 2

The Laboratory safety Institute

192 Worchester Road

Natick, MA 01760

*It's Elementary... and Beyond*

[www.chemed.org](http://www.chemed.org)

**MSDS Sheets for Chemicals (Material Safety Data Sheets)**

Numerous sources – here are some links

[www.flinnsci.com/homepage/cindex.html](http://www.flinnsci.com/homepage/cindex.html)

## Safety in the Science Classroom and Laboratory

[www.uvm.edu/uvmsafety/labsafety/chemsafety/netmsds.html](http://www.uvm.edu/uvmsafety/labsafety/chemsafety/netmsds.html) (grocery/kitchen chemicals)

[www.msds.pdc.cornell.edu/msdsrch.asp](http://www.msds.pdc.cornell.edu/msdsrch.asp)

[www.fishersci.com](http://www.fishersci.com)

[www.osha.gov](http://www.osha.gov)

[www.cdc.gov/niosh](http://www.cdc.gov/niosh)

**National Science Teachers Association** [www.nsta.org](http://www.nsta.org)

Click on *Publications* and *Position Statements*.

Numerous NSTA position statements on Safety, Field Trips, Class Size, etc.

NSTA Safety Publications:

*Exploring Safely: A Guide for Elementary Teachers*- Terry Kwan & Juliana Texley

*Inquiring Safely: A Guide for Middle School Teachers*- Terry Kwan & Juliana Texley

*Investigating Safely: A Guide for High School Teachers*- Juliana Texley, Terry Kwan, & John Summers

*The OSHA Answer Book (7<sup>th</sup> Edition)*

Mark Moran

*Right-To Know Pocket Guide for school & University Employees*

*National Fire Rating System Reference Guide*

Lab Safety Supply

PO Box 1368

Janesville, WI 53547-1368

1-800-356-0783

Safetycertified.com

1536 Kingsley Ave

Suite 126

Orange Park, FL 3207

1-800-597-2040

*Safety in Academic Chemistry Laboratories*

Volume 2

Accident Prevention for Faculty and Administrators 7<sup>th</sup> ed

(also have student version)

American Chemical Society

1155 16<sup>th</sup> St, NW

Washington, DC 20036

*Safety in the Elementary (K-6) Science Classroom*

Second Edition

Committee on Chemical Safety

1155 Sixteenth St, NW

Washington, DC 20036

Chemistry.org

## Safety in the Science Classroom and Laboratory

### *Safety in High School and College Laboratories*

Fisher Science Education

1 800 955 1177

1 800 955 0740 (f)

[www.fisheredu.com](http://www.fisheredu.com)

### *Science Classroom Safety and the Law*

Flinn Scientific Inc.

P.O. Box 219

Batavia, IL60510

E-mail: [flinn@flinnsci.com](mailto:flinn@flinnsci.com)

Website: [www.flinnsci.com](http://www.flinnsci.com)

### *Science Laboratory Safety Manual*

Linda M. Stroud, Ph.D.

[www.sciencesafetyconsulting.com](http://www.sciencesafetyconsulting.com)

**Other safety resources are available from several science supply catalogs.**

Detailed Description of Content		
Goals and objectives	Content – What are students expected to know and be able to do?	A = Recommended Activities O = Optional Enrichment
<b>COMPETENCY GOAL 1: The learner will develop abilities necessary to do and understand scientific inquiry.</b>		
1.01 Design, conduct and analyze investigations to answer questions related to chemistry. <ul style="list-style-type: none"> <li>Identify questions and suggest hypotheses.</li> <li>Identify variables.</li> <li>Use a control when appropriate.</li> <li>Select and use appropriate measurement tools.</li> <li>Collect and organize data in tables, charts and graphs.</li> <li>Analyze and interpret data.</li> <li>Explain observations.</li> <li>Make inferences and predictions.</li> <li>Explain the relationship between evidence and explanation.</li> <li>Identify how scientists share findings.</li> </ul>	This goal and these objectives are an <i>integral</i> part of <i>each of the other goals</i> . In order to measure and investigate scientific phenomena, students must be given the opportunity to design and conduct their own investigations in a safe laboratory. The students should use questions and models to formulate the relationship identified in their investigations and then report and share those finding with others <b>Students will be able to:</b> <ul style="list-style-type: none"> <li>Identify questions and suggest hypotheses.</li> <li>Identify variables.</li> <li>Use a control when appropriate.</li> <li>Select and use appropriate measurement tools.</li> <li>Collect and organize data in tables, charts and graphs.</li> <li>Analyze and interpret data.</li> <li>Explain observations.</li> <li>Make inferences and predictions.</li> <li>Use questions and models to determine the relationships between variables in investigations.</li> <li>Identify how scientists share findings.</li> </ul>	Activities and Labs listed below are <b>suggested</b> resources only. This list is not inclusive and only reflects labs and activities recommended by the Chemistry Curriculum Committee. Teachers should substitute other labs appropriate to the equipment available in their school. Effort should be made in each course to provide students opportunities to practice the skills of a chemist.  <b>A:</b> Students should be given numerous opportunities to design and conduct experiments within the context of the entire course.
1.02 Evaluate reports of scientific investigations from an informed scientifically-literate viewpoint including considerations of: <ul style="list-style-type: none"> <li>Appropriate sample.</li> <li>Adequacy of experimental controls.</li> <li>Replication of findings.</li> <li>Alternative interpretations of the data</li> </ul>	<b>Students will be able to:</b> Analyze reports of scientific investigations from an informed scientifically-literate viewpoint including considerations of: appropriate sample, adequacy of experimental controls, replication of findings, alternative interpretations of the data.	<b>A:</b> Integrate follow-up questions for lab activities and experiment summaries which focus on experiment design and appropriate conclusions.
1.03 Evaluate experimental designs with regard to safety and use safe procedures in laboratory investigations: <ul style="list-style-type: none"> <li>Identify and avoid potential safety</li> </ul>	<b>Students will be able to:</b> <ul style="list-style-type: none"> <li>Identify and avoid potential safety hazards given a scenario.</li> <li>Differentiate between safe and unsafe procedures.</li> </ul>	<b>A:</b> Data sets and experimental outcomes should be presented to students for analysis within the context of the entire course. Each lab activity should include safety

## Detailed Description of Content

<p>hazards given a scenario.</p> <ul style="list-style-type: none"> <li>Differentiate between safe and unsafe procedures.</li> <li>Use information from the MSDS (Material Safety Data Sheets) to assess chemical hazards.</li> </ul>	<ul style="list-style-type: none"> <li>Use information from the MSDS (Material Safety Data Sheets) to assess chemical hazards.</li> </ul>	<p>hazards and MSDS data as appropriate.</p>
<p><b>COMPETENCY GOAL 2: The learner will build an understanding of the structure and properties of matter. (34%)</b></p>		
<p>2.01 Analyze the historical development of the current atomic theory.</p> <ul style="list-style-type: none"> <li>Early contributions: Democritus and Dalton.</li> <li>The discovery of the electron: Thomson and Millikan.</li> <li>The discovery of the nucleus, proton and neutron: Rutherford and Chadwick.</li> <li>The Bohr model.</li> <li>The quantum mechanical model.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Describe the composition of the atom and the experiments that led to that knowledge.</li> <li>Describe how Rutherford predicted the nucleus.</li> <li>Understand the inverse relationship between wavelength and frequency, and the direct relationship between energy and frequency.</li> <li>Analyze diagrams related to the Bohr model of the hydrogen atom in terms of allowed, discrete energy levels in the emission spectrum.</li> <li>Describe the electron cloud of the atom in terms of a probability model.</li> </ul>	<p><b>A: Animations from <a href="http://www.dlt.ncssm.edu/TIGER">www.dlt.ncssm.edu/TIGER</a></b> (Click on chemistry by topic and go to atomic structure.)</p> <p><b>O:</b> Calculations of energies and wavelengths in Bohr atom using <math>c=f\lambda</math>, <math>E=hc/\lambda</math>, and <math>E=-R_h(1/n^2)</math>.</p>
<p>2.02 Examine the nature of atomic structure</p> <ul style="list-style-type: none"> <li>Subatomic particles: protons, neutrons, and electrons.</li> <li>Mass number.</li> <li>Atomic number.</li> <li>Isotopes.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Characterize the protons, neutrons, electrons: location, relative charge, relative mass (<math>p=1</math>, <math>n=1</math>, <math>e=1/2000</math>).</li> <li>Use symbols: <math>A</math>= mass number, <math>Z</math>=atomic number</li> <li>Use notation for writing isotope symbols:        or U-235</li> <li>Identify isotope using mass number and atomic number and relate to number of protons, neutrons and electrons.</li> <li>Have a conceptual awareness of the nature of average atomic mass. (Relative abundance of each isotope determines the average- no calculations).</li> </ul>	<p><b>A: <a href="#">The Atom Activity</a></b> “What is an Atom?” curriculum support activity</p> <p><b>O:</b> Calculating average atomic mass of atoms from relative abundance (%) and actual isotopic mass. Mass defect and <math>E=mc^2</math></p>

## Detailed Description of Content

<p>2.03 Apply the language and symbols of chemistry.</p> <ul style="list-style-type: none"> <li>Name compounds using the IUPAC conventions.</li> <li>Write formulas of simple compounds from their names.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Use the state of matter symbols: (s), (l), (g), (aq)</li> <li>Write binary compounds of two nonmetals: use Greek prefixes (di-, tri-, tetra-, ...)</li> <li>Write binary compounds of metal/nonmetal*</li> <li>Write ternary compounds (polyatomic ions)*</li> <li>Write, with charges, these polyatomic ions: nitrate, sulfate, carbonate, acetate, and ammonium.</li> <li>Know names and formulas for these common laboratory acids: HCl, HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>, (CH<sub>3</sub>COOH)</li> </ul> <p><i>*The Stock system is the correct IUPAC convention for inorganic nomenclature.</i></p>	<p><b>O:</b> “-ic/-ous” method for copper, iron, manganese, mercury, tin, etc. “-ite/-ate”, “hypo-/per-” with names of polyatomic ions Names and formulas for other acids Organic nomenclature</p>
<p>2.04 Identify substances using their physical properties:</p> <ul style="list-style-type: none"> <li>Melting points.</li> <li>Boiling points.</li> <li>Density.</li> <li>Solubility.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Apply information (BP, MP, density) from the reference tables to identify an unknown.</li> <li>Calculate density. (<math>D=m/V</math>)</li> <li>Apply the solubility rules.</li> <li>Use graph of solubility vs. temperature to identify a substance based on solubility at a particular temperature. Use graph to relate the degree of saturation of solutions to temperature. Use graph to make simple calculations about solutions.</li> </ul>	<p><b>A:</b> <a href="#">Density Lab</a> curriculum support activity. Density Activity Unknown Liquid Lab</p>
<p>2.05 Analyze the basic assumptions of kinetic molecular theory and its applications:</p> <ul style="list-style-type: none"> <li>Ideal Gas Equation.</li> <li>Combined Gas Law.</li> <li>Dalton’s Law of Partial Pressures.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Know characteristics of ideal gases</li> <li>Apply general gas solubility characteristics</li> </ul> <p><b>Students should be able to use the following formulas and concepts of kinetic molecular theory.</b></p> <ul style="list-style-type: none"> <li>1 mole of any gas at STP=22.4 L</li> <li>Ideal gas equation (<math>PV=nRT</math>),</li> <li>Combined gas law (<math>P_1V_1/T_1 = P_2V_2/T_2</math>) and applications holding one variable constant             <ul style="list-style-type: none"> <li><math>(PV=k)</math>, <math>P_1V_1 = P_2V_2</math> <i>Boyle’s Law</i></li> <li><math>(V/T=k)</math>, <math>V_1/T_1 = V_2/T_2</math> <i>Charles’ Law</i></li> <li><math>(P/T=k)</math>, <math>P_1/T_1 = P_2/T_2</math> <i>Gay-Lussac’s Law</i></li> </ul> </li> </ul> <p><i>(Note: Students should be able to derive and use these gas laws, but are not necessarily expected to memorize their names.)</i></p> <ul style="list-style-type: none"> <li>Avogadro’s Law (<math>n/V=k</math>), <math>n_1/V_1 = n_2/V_2</math></li> </ul>	<p><b>A:</b> <a href="#">Boyle’s Law Lab</a> uses CBL/LabPro Technology Dalton’s Law Demonstration Mg-HCl - Drying a Gas</p> <p><b>O:</b> Graham’s Law Calculate MW from effusion of gases Calculation of KE of gas molecules Distribution of speeds as a function of temperature Real gases and the van der Waals equation Differentiate between ideal gas and real gas (conceptually, no calculations) Density/MW variation of Ideal Gas equation calculations</p>

## Detailed Description of Content

	<ul style="list-style-type: none"> <li>• Dalton's Law (<math>P_T = P_1 + P_2 + P_3 \dots</math>)</li> <li>• Vapor pressure of water as a function of temperature (conceptually)</li> </ul>	equation calculations
2.06 Assess bonding in metals and ionic compounds as related to chemical and physical properties.	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>• Describe how ions are formed and which arrangements are stable (filled d-level, or half-filled d-level).</li> <li>• Appropriately use the term cation as a positively charged ion and anion as negatively charged ion.</li> <li>• Predict ionic charges for representative elements based on valence electrons.</li> <li>• Describe ionic bond's intermolecular attraction as electrostatic attraction.</li> <li>• Determine that a bond is predominately ionic by the location of the atoms on the Periodic Table (metals combined with nonmetals) or when <math>\Delta EN &gt; 1.7</math>.</li> <li>• Explain how ionic bonding in compounds determines their characteristics: high MP, high BP, brittle, and high electrical conductivity either in molten state or in aqueous solution.</li> <li>• Explain how covalent bonding in compounds determines their characteristics: low MP, low BP, poor electrical conductivity, polar nature, etc.</li> <li>• Describe metallic bonds: "metal ions plus 'sea' of mobile electrons".</li> <li>• Explain how metallic bonding determines the characteristics of metals: high MP, high BP, high conductivity, malleability, ductility, and luster.</li> </ul>	<p><b>A:</b> <a href="#">Bonding- Type Triangle</a></p> <p><b>O:</b> Coulomb's Law (<math>F = kq_1q_2/r^2</math>)</p> <p>Crystal shapes</p> <p>Lattice energies</p>
2.07 Assess covalent bonding in molecular compounds as related to molecular geometry and chemical and physical properties. <ul style="list-style-type: none"> <li>• Molecular.</li> <li>• Macromolecular.</li> <li>• Hydrogen bonding and other intermolecular forces (dipole/dipole interaction, dispersion).</li> <li>• VSEPR theory.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>• Apply the concept that sharing electrons form a covalent compound that is a stable (inert gas) arrangement.</li> <li>• Determine that a bond is predominately covalent by the location of the atoms on the Periodic Table (nonmetals combined with nonmetals) or when <math>\Delta EN &lt; 1.7</math>.</li> <li>• Know that the diatomic elements have single,</li> </ul>	<p><b>A:</b> Molecular and Intermolecular Bonds</p> <p>Lab</p> <p><a href="#">Bond-Type Triangle Activity</a></p> <p><b>O:</b> Molecular geometries (VSEPR) expanded octet</p> <p>Valence bond theory: hybrid orbitals</p> <p>sigma and pi bonds</p> <p>Molecular orbital theory</p>

## Detailed Description of Content

	<p>double, or triple bonds (For example: F<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>).</p> <ul style="list-style-type: none"> <li>• Describe carbon bonds as either single, double or triple bonds.</li> <li>• Apply the relationship between bond energy and length of single, double, and triple bonds (conceptual, no numbers).</li> <li>• Draw Lewis (dot diagram) structures for simple compounds with one central atom.</li> <li>• Apply Valence Shell Electron Pair Repulsion Theory (VSEPR) for these electron pair geometries and molecular geometries, and bond angles.             <ul style="list-style-type: none"> <li>• Electron pair - Molecular (bond angle)</li> <li>• Linear framework – linear</li> <li>• Trigonal planar framework– trigonal planar, bent</li> <li>• Tetrahedral framework– tetrahedral, trigonal pyramidal, bent</li> <li>• Bond angles (include distorting effect of lone pair electrons – no specific angles, conceptually only)</li> </ul> </li> <li>• Describe bond polarity. Polar/nonpolar molecules (relate to symmetry) ; relate polarity to solubility—“like dissolves like”</li> <li>• Describe macromolecules and network solids: water (ice), graphite/diamond, polymers (PVC, nylon), proteins (hair, DNA) intermolecular structure as a class of molecules with unique properties.</li> <li>• Describe intermolecular forces for molecular compounds.             <ul style="list-style-type: none"> <li>• H-bond as attraction between molecules when H is bonded to O, N, or F. Dipole-dipole attractions between polar molecules.</li> <li>• London dispersion forces (electrons of one molecule attracted to nucleus of another molecule) – i.e. liquefied inert gases.</li> <li>• Relative strengths (H&gt;dipole&gt;London/van</li> </ul> </li> </ul>	<p>Formal charge calculations            Additional macromolecules            Dipole moment – conceptual</p>
--	---	--

## Detailed Description of Content

	der Waals).	
2.08 Assess the dynamics of physical equilibria. <ul style="list-style-type: none"> <li>• Interpret phase diagrams.</li> <li>• Factors that affect phase changes.</li> </ul>	<b>Students should be able to:</b> <ul style="list-style-type: none"> <li>• Describe physical equilibrium: liquid water-water vapor. Vapor pressure depends on temperature and concentration of particles in solution. (conceptual only – no calculations)</li> <li>• Draw phase diagrams of water and carbon dioxide (shows how sublimation occurs). Identify regions, phases and phase changes using a phase diagram.</li> <li>• Know that phase changes occur with changes in temperature and/or pressure. Relate change of phase to heating and cooling curves.</li> </ul>	A: <a href="#">Heat of Fusion</a> “Ice Cream Lab” O: Calculations with Raoult’s law
<b>COMPETENCY GOAL 3: The learner will build an understanding of regularities in chemistry.</b>		
3.01 Analyze periodic trends in chemical properties and use the periodic table to predict properties of elements. <ul style="list-style-type: none"> <li>• Groups (families).</li> <li>• Periods.</li> <li>• Representative elements (main group) and transition elements.</li> <li>• Electron configuration and energy levels.</li> <li>• Ionization energy.</li> <li>• Atomic and ionic radii.</li> <li>• Electronegativity.</li> </ul>	<b>Using the Periodic Table, students should be able to:</b>  <b>Groups (families)</b> <ul style="list-style-type: none"> <li>• Identify groups as vertical columns on the periodic table.</li> <li>• Know that main group elements in the same group have similar properties, the same number of valence electrons, and the same oxidation number.</li> <li>• Understand that reactivity increases as you go down within a group for metals and decreases for nonmetals.</li> </ul> <b>Periods</b> <ul style="list-style-type: none"> <li>• Identify periods as horizontal rows on the periodic table.</li> </ul> <b>Representative elements (main group) and transition elements</b> <ul style="list-style-type: none"> <li>• Identify representative (main group) elements as A groups <u>or</u> as groups 1, 2, 13-18.</li> <li>• Identify alkali metals, alkaline earth metals,</li> </ul>	A: “Periodic Table Mystery” “Building and Using a 3-D Periodic Table” <a href="#">Photoelectron Spectroscopy</a> activity  O: Electron affinity Examine shapes of orbitals

	<p>halogens, and noble gases based on location on periodic table.</p> <ul style="list-style-type: none"> <li>Identify transition elements as B groups <u>or</u> as groups 3-12.</li> </ul> <p><b>Electron configuration and energy levels</b></p> <ul style="list-style-type: none"> <li>Write electron configurations, including noble gas abbreviations (no exceptions to the general rules). Included here are extended arrangements showing electrons in orbitals.</li> <li>Identify s, p, d, and f blocks on Periodic Table.</li> <li>Identify an element based on its electron configuration. (Students should be able to identify elements which follow the general rules, not necessarily those which are exceptions.)</li> <li>Determine the number of valence electrons from electron configurations.</li> <li>Predict the number of electrons lost or gained and the oxidation number based on the electron configuration of an atom.</li> </ul> <p><b>PERIODIC TRENDS, including...</b></p> <p><b>Ionization energy</b></p> <ul style="list-style-type: none"> <li>Define ionization energy.</li> <li>Know group and period general trends for ionization energy.</li> <li>Apply trends to arrange elements in order of increasing or decreasing ionization energy.</li> <li>Explain the reasoning behind the trend.</li> </ul> <p><b>Atomic and ionic radii</b></p> <ul style="list-style-type: none"> <li>Define atomic radius and ionic radius.</li> <li>Know group and period general trends for atomic radius.</li> <li>Apply trends to arrange elements in order of increasing or decreasing atomic radius.</li> <li>Compare cation radius to neutral atom. Compare anion radius to neutral atom.</li> <li>Explain the reasoning behind the trend.</li> </ul>	
--	---	--

	<p><b>Electronegativity</b></p> <ul style="list-style-type: none"> <li>• Define electronegativity.</li> <li>• Know group and period general trends for electronegativity.</li> <li>• Apply trends to arrange elements in order of increasing or decreasing electronegativity.</li> <li>• Explain the reasoning behind the trend.</li> <li>• Use differences in electronegativity to predict bond type (ionic, polar covalent, and nonpolar covalent).</li> </ul>	
<p>3.02 Apply the mole concept, Avogadro's number and conversion factors to chemical calculations:</p> <ul style="list-style-type: none"> <li>• Particles to moles.</li> <li>• Mass to moles.</li> <li>• Volume of a gas to moles.</li> <li>• Molarity of solutions.</li> <li>• Empirical and molecular formula.</li> <li>• Percent composition.</li> </ul>	<p><b>Students should be able to:</b> <b>Calculate formula mass.</b></p> <p><b>Particles to moles</b></p> <ul style="list-style-type: none"> <li>• Convert representative particles to moles and moles to representative particles. (Representative particles are atoms, molecules, formula units, and ions.)</li> </ul> <p><b>Mass to moles</b></p> <ul style="list-style-type: none"> <li>• Convert mass of atoms, molecules, and compounds to moles and moles of atoms, molecules, and compounds to mass.</li> <li>• Convert representative particles to mass and mass to representative particles.</li> </ul> <p><b>Volume of a gas to moles</b></p> <ul style="list-style-type: none"> <li>• Convert moles to volume and volume to moles at STP.</li> </ul> <p><b>Molarity of a solution</b></p> <ul style="list-style-type: none"> <li>• Calculate molarity given mass of solute and volume of solution.</li> <li>• Calculate mass of solute needed to create a solution of a given molarity and volume.</li> <li>• Solve dilution problems: <math>M_1V_1 = M_2V_2</math>.</li> </ul> <p><b>Empirical and molecular formula</b></p>	<p><b>A: <a href="#">Observations</a> Copper Chloride and Aluminum Lab</b></p> <p><b>O: Molality</b> Write formulas for and name hydrates.</p>

## Detailed Description of Content

	<ul style="list-style-type: none"> <li>Calculate empirical formula from mass or percent using experimental data.</li> <li>Calculate molecular formula from empirical formula given molecular weight.</li> </ul> <p><b>Percent composition</b></p> <ul style="list-style-type: none"> <li>Determine percentage composition by mass of a given compound.</li> <li>Perform calculations based on percent composition.</li> <li>Calculate using hydrates.</li> </ul>	
<p>3.03 Calculate quantitative relationships in chemical reactions (stoichiometry):</p> <ul style="list-style-type: none"> <li>Moles of each species in a reaction.</li> <li>Mass of each species in a reaction.</li> <li>Volumes of gaseous species in a reaction.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Interpret coefficients of a balanced equation as mole ratios.</li> <li>Use mole ratios from the balanced equation to calculate the quantity of one substance in a reaction given the quantity of another substance in the reaction. (given moles, particles, mass, or volume and ending with moles, particles, mass, or volume of the desired substance)</li> </ul>	<p><b>A:</b> Investigation involving quantitative mole relationships</p> <p><a href="#">Construction of Air Bags</a></p> <p><b>Observations: Copper Chloride and Aluminum</b></p> <p><b>O:</b> Limiting reactant problems Percent yield</p>
<p><b>COMPETENCY GOAL 4: The learner will build an understanding of energy changes in chemistry.</b></p>		

- 4.01 Analyze the Bohr model in terms of electron energies in the hydrogen atom.
- The spectrum of electromagnetic energy.
  - Emission and absorption of electromagnetic energy as electrons change energy levels.

**A student should be able to:**

- Understand that energy exists in discrete units called quanta.
- Describe the concepts of
  - an atom being “excited” above its ground state by the addition of energy, resulting in the electron(s) moving to a higher energy level.
  - when the atom returns to its ground state, the electron(s) releases that energy gained as electromagnetic radiation (emissions spectrum).
- Articulate that this electromagnetic radiation is given off as a photon(s). This photon represents the physical difference between ground state and excited state.
- Use the “Bohr Model for Hydrogen Atom” and “Electromagnetic Spectrum” diagrams from the Reference Tables to relate color, frequency, and wavelength of the light emitted to the energy of the photon.
- Explain that Niels Bohr produced a model of the hydrogen atom based on experimental observations. This model indicated that:
  - an electron circles the nucleus only in fixed energy ranges called orbits;
  - an electron can neither gain or lose energy inside this orbit, but could move up or down to another orbit;
  - and that the lowest energy orbit is closest to the nucleus.
- Recognize the historical contribution that this model gave to our modern theory of the structure of the atom; however, also realize the limitations of this model (applicable only to the hydrogen atom).
- Describe the wave/particle duality of electrons.

**A: Spectrum Lab**

**O:** Calculations of wavelengths and energies in Bohr atom using  $c=f\lambda$ ,  $E=hc/\lambda$ , and  $E=-R_h(1/n^2)$

## Detailed Description of Content

<p>4.02 Analyze the law of conservation of energy, energy transformation, and various forms of energy involved in chemical and physical processes.</p> <ul style="list-style-type: none"> <li>Differentiate between heat and temperature.</li> <li>Analyze heating and cooling curves.</li> <li>Calorimetry, heat of fusion and heat of vaporization calculations.</li> <li>Endothermic and exothermic processes including interpretation of potential energy.</li> <li>Diagrams (energy vs reaction pathway), enthalpy and activation energy.</li> </ul>	<p><b>A student should be able to:</b></p> <ul style="list-style-type: none"> <li>Recognize that, for a closed system, energy is neither lost nor gained during normal chemical activity.</li> <li>Explain that the total useful energy of an open system is constantly declining due to entropy.</li> <li>Define and use the terms and/or symbols for: enthalpy, entropy, specific heat capacity, temperature, joule, endothermic reactions, exothermic reactions, and catalyst.</li> <li>Interpret the following: <ul style="list-style-type: none"> <li>heating and cooling curves (noting both significance of plateaus and the physical states of each segment)</li> <li>Phase diagrams for H<sub>2</sub>O and CO<sub>2</sub></li> <li>Energy vs reaction pathway diagrams for both positive and negative values of <math>\Delta H</math> (including activation energy).</li> </ul> </li> <li>Complete calculations of: <math>q = mC_p\Delta T</math>, <math>q = mH_f</math>, <math>q = mH_v</math>, and <math>q_{\text{lost}} = (-q_{\text{gain}})</math> in water, including phase changes.</li> <li>Contrast heat and temperature, including temperature as a measure of average kinetic energy, and appropriately use the units Joule, Celsius, and Kelvin.</li> </ul>	<p><b>A:</b> <a href="#">Heat of Solution Lab</a></p> <p><b>O:</b> Hess's Law calculations (multistep) Heats of formation Stoichiometric calculations with heat</p>
<p>4.03 Analyze the relationship between entropy and disorder in the universe.</p>	<p><b>A student should:</b></p> <ul style="list-style-type: none"> <li>Understand entropy as a measure of disorder.</li> <li>Recognize that the entropy of the universe is increasing.</li> <li>Explain that, along with a tendency for systems to proceed toward the lowest energy level, they also move in the direction of the greatest entropy. (Increasing Entropy: solid → liquid → gas; Ionic compounds → ions in solution)</li> </ul>	<p><b>A: Phase Change Demonstration</b></p> <p><b>O:</b> Understand Gibbs free energy and how it is used to predict spontaneity. calculations with <math>\Delta G = \Delta H - T\Delta S</math></p>
<p>4.04 Analyze nuclear energy.</p> <ul style="list-style-type: none"> <li>Radioactivity: characteristics of</li> </ul>	<p><b>A student should be able to:</b></p> <ul style="list-style-type: none"> <li>Use the symbols for and distinguish between</li> </ul>	<p><b>A: "Penny's Lab or M &amp; M Lab"</b></p>

## Detailed Description of Content

<p>alpha, beta and gamma radiation.</p> <ul style="list-style-type: none"> <li>Decay equations for alpha and beta emission.</li> <li>Half-life.</li> <li>Fission and fusion.</li> </ul>	<p>alpha (<math>{}^4_2\text{He}</math>), and beta (<math>{}^0_{-1}\text{e}</math>) nuclear particles, and gamma (<math>\gamma</math>) radiation include relative mass).</p> <ul style="list-style-type: none"> <li>Use shorthand notation of particles involved in nuclear equations to balance and solve for unknowns. Example: The neutron is represented as (<math>{}^1_0\text{n}</math>).</li> <li>Discuss the penetrating ability of alpha, beta, and gamma radiation.</li> <li>Conceptually describe nuclear decay, including:             <ul style="list-style-type: none"> <li>Decay as a random event, independent of other energy influences</li> <li>Using symbols to represent simple balanced decay equations</li> <li>Half-life (including simple calculations)</li> </ul> </li> <li>Contrast fission and fusion.</li> <li>Cite illustrations of the uses of nuclear energy, including, but not limited to: electricity, Carbon-14 dating, and radioisotopes for medicine (tracers, ionizing radiation, gamma sterilization, etc).</li> </ul>	<p><b>O:</b> Calculations with <math>A=A_0e^{-kt}</math>            Complex calculations with half-life  <b>O:</b> Transmutation</p>
<p><b>COMPETENCY GOAL 5: The learner will develop an understanding of chemical reactions.</b></p>		
<p>5.01 Evaluate various types of chemical reactions</p> <ul style="list-style-type: none"> <li>Analyze reactions by types: single replacement, double replacement (including acid-base neutralization), decomposition, synthesis, and combustion of simple hydrocarbons.</li> <li>Predict products.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>Identify a reaction by type.</li> <li>Predict product(s) in a reaction using the reference tables.</li> <li>Identify acid-base neutralization as double replacement.</li> <li>Write and balance ionic equations.</li> <li>Write and balance net ionic equations for double replacement reactions.</li> <li>Recognize that hydrocarbons (C,H molecule) and other molecules containing C, H, and O burn completely in oxygen to produce CO<sub>2</sub> and water vapor.</li> </ul>	<p><b>A: “Reaction Types Demonstration”</b>  <b>“Solubility Rule Activity”</b></p>

## Detailed Description of Content

	<ul style="list-style-type: none"> <li>Use reference table rules to predict products for all types of reactions to show the conservation of mass.</li> <li>Use activity series to predict whether a single replacement reaction will take place.</li> <li>Use the solubility rules to determine the precipitate in a double replacement reaction if a reaction occurs.</li> </ul>	
5.02 Evaluate the law of conservation of matter to the balancing of chemical equations. <ul style="list-style-type: none"> <li>Write and balance formulas and equations</li> <li>Write net ionic equations.</li> </ul>	<b>Students should be able to:</b> <ul style="list-style-type: none"> <li>Write and balance chemical equations.</li> <li>Write net ionic reactions.</li> <li>Predict and write formulas using the reference tables.</li> </ul>	<b>O:</b> Balancing REDOX reactions by half-reaction method or electron transfer method.  <b>A:</b> “Solubility Rule Activity” write equations for reactions observed
5.03 Identify and predict the indicators of chemical change: <ul style="list-style-type: none"> <li>Formation of a precipitate.</li> <li>Evolution of a gas.</li> <li>Color change.</li> <li>Absorption or release of heat.</li> </ul>	<b>Students should be able to determine if a chemical reaction has occurred based on the following criteria:</b> <ul style="list-style-type: none"> <li>Precipitate Tie to solubility rules (Goals 2.04 and 5.01).</li> <li>Product testing - Know the tests for some common products such as oxygen, water, hydrogen and carbon dioxide. (tests to know: burning splint for Oxygen, Hydrogen and Carbon Dioxide (include knowledge of safety precautions) lime water for Carbon Dioxide).</li> <li>Color Change – Distinguish between color change as a result of chemical reaction, and a change in color intensity as a result of dilution.</li> <li>Temperature change – Tie to endothermic/exothermic reaction. Express <math>\Delta H</math> as (+) for endothermic and (–) for exothermic.</li> </ul>	<b>O:</b> Calculate heat of reaction - $\Delta H$  <b>A:</b> <a href="#">Decomposition of NaHCO<sub>3</sub></a>  <b>Test for reaction products</b>
5.04 Assess the physical and chemical properties of acids and bases. <ul style="list-style-type: none"> <li>General properties of acids and bases.</li> <li>Concentration and dilution of acids and bases.</li> </ul>	<b>Students should be able to</b> <ul style="list-style-type: none"> <li>Distinguish between acids and bases based on formula and chemical properties.</li> <li>Distinguish between Arrhenius acids and bases and Bronsted-Lowry acids and bases.</li> </ul>	<b>O:</b> Acid-base equilibria; $K_a$ , $K_b$ , $K_w$ Lewis theory. Weak acids and weak bases in titrations. Buffer systems

## Detailed Description of Content




<ul style="list-style-type: none"> <li>• Ionization and the degree of dissociation (strengths) of acids and bases.</li> <li>• Indicators.</li> <li>• Acid-base titration.</li> <li>• pH and pOH.</li> </ul>	<ul style="list-style-type: none"> <li>• Compute concentration (molarity) of acids and bases in moles per liter (3.02).</li> <li>• Solve dilution problems: <math>M_1V_1 = M_2V_2</math>.</li> <li>• Differentiate between concentration (molarity) and strength (degree of dissociation). No calculation involved.</li> <li>• Use pH scale to identify acids and bases.</li> <li>• Interpret pH scale in terms of the exponential nature of pH values in terms of concentrations.</li> <li>• Relate the color of indicator to pH using pH ranges provided in a table. Range should involve various values of pH (for example: 3.3 or 10.8).</li> <li>• Determine the concentration of an acid or base using titration. Interpret titration curve for strong acid/strong base.</li> <li>• Compute pH, pOH, <math>[H^+]</math>, and <math>[OH^-]</math>. Calculations will involve only whole number values (for example: pH or pOH values such as 3, 5, 8, and <math>[H^+]</math> and <math>[OH^-]</math> values such as <math>1 \times 10^{-4}</math> or <math>1 \times 10^{-10}</math>).</li> </ul>	<p>Henderson-Hasselbalch equation</p> <p><b>A:</b> an Acid Base Titration Lab</p>
<p>5.05 Analyze oxidation/reduction reactions with regard to the transfer of electrons.</p> <ul style="list-style-type: none"> <li>• Assign oxidation numbers to elements in REDOX reactions</li> <li>• Identify the elements oxidized and reduced.</li> <li>• Write simple half reactions.</li> <li>• Assess the practical applications of oxidation and reduction reactions.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>• Determine oxidation number of each element in a REDOX reaction, including peroxides.</li> <li>• Determine elements oxidized and reduced.</li> <li>• Write half reactions indicating gain or loss of electrons and identify the reaction as either reduction or oxidation.</li> <li>• Students should be aware of some practical applications of oxidation/reduction reactions. Some examples include: simple wet cell, dry cell, bleaching, and electroplating.</li> </ul>	<p><b>O:</b> Oxidizing agents, reducing agents Balancing REDOX reactions by half-reaction method or electron transfer method Determine anode and cathode Cell potential calculations</p> <p><b>A:</b> “Electrochemistry Law”</p>
<p>5.06 Analyze the factors that affect the rates of chemical reactions.</p> <ul style="list-style-type: none"> <li>• The nature of the reactants.</li> <li>• Temperature.</li> <li>• Concentration.</li> </ul>	<p><b>Students should be able to:</b></p> <ul style="list-style-type: none"> <li>• Explain collision theory – molecules must collide in order to react, and they must collide in the correct or appropriate orientation and with sufficient energy to equal or exceed the</li> </ul>	<p><b>O:</b> Rate from concentration vs. time graphs Order of reaction and graphs used to determine order: <math>[x]</math> vs. time, <math>\ln[x]</math> vs. time, <math>1/[x]</math> vs. time Rate law, rate constant, overall order</p>

## Detailed Description of Content

<ul style="list-style-type: none"><li>• Surface area.</li><li>• Catalyst.</li></ul>	<p>activation energy. (Goal 4.02)</p> <ul style="list-style-type: none"><li>• Understand qualitatively that reaction rate is proportional to number of effective collisions.</li><li>• Explain that nature of reactants can refer to their complexity and the number of bonds that must be broken and reformed in the course of reaction.</li><li>• Interpret potential energy diagrams.</li><li>• Explain how temperature (kinetic energy), concentration, and/or pressure affects number of collisions.</li><li>• Explain how increased surface area increases number of collisions.</li><li>• Explain how a catalyst lowers the activation energy, so that at a given temperature, more molecules will have energy equal to or greater than the activation energy.</li></ul>	<p>Determine mechanisms from rate law Rate determining step</p> <p><b>A:</b> “Reaction Rates Lab – Mr. Potato Inquires”</p>
---	---	---

## What is an Atom?

Data collected from selected atoms.

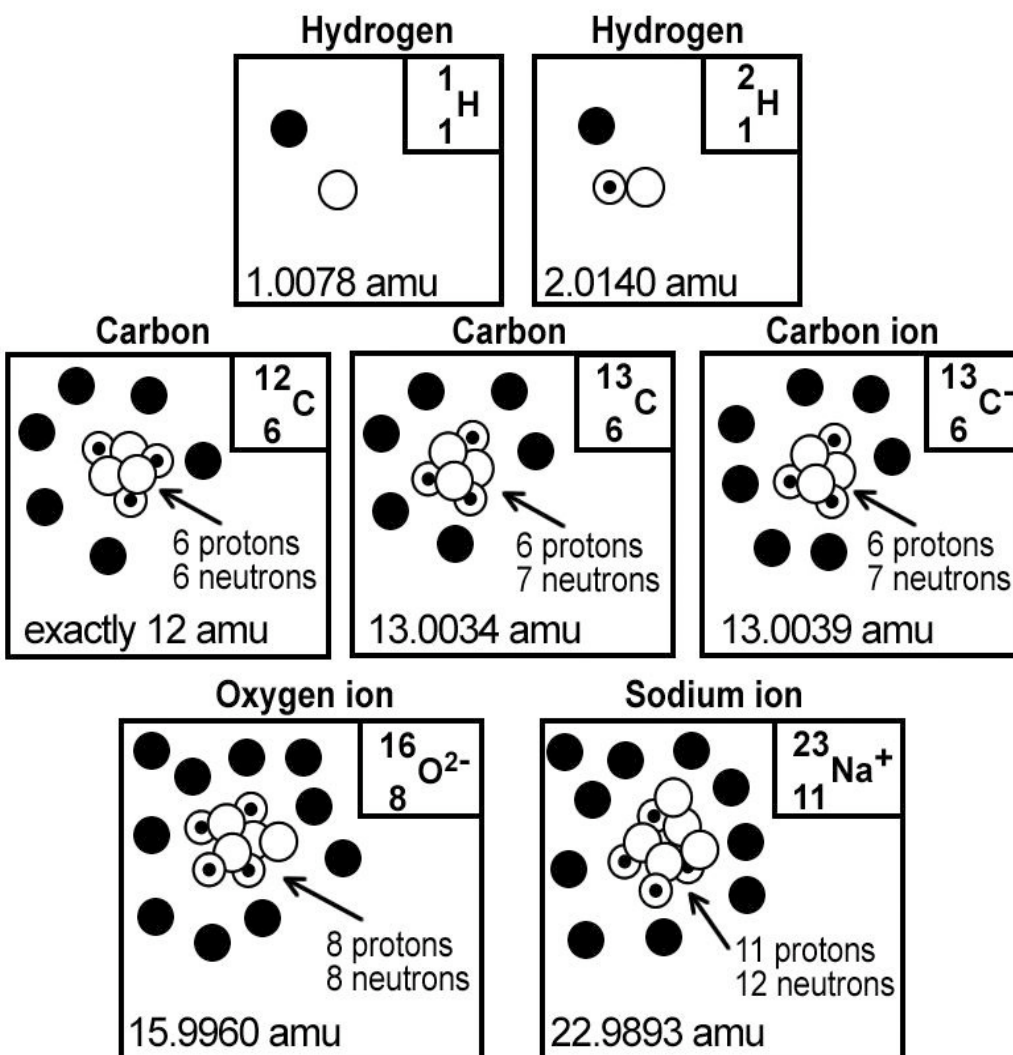
	Electron (-)
	Proton (+)
	Neutron (neutral)

$$1 \text{ amu} = 1.6606 \times 10^{-24} \text{ g}$$

A is the mass number

Z is the atomic number

## What is an atom?



The nucleus of an atom contains the protons and the neutrons.

${}^1\text{H}$  and  ${}^2\text{H}$  are isotopes of hydrogen.

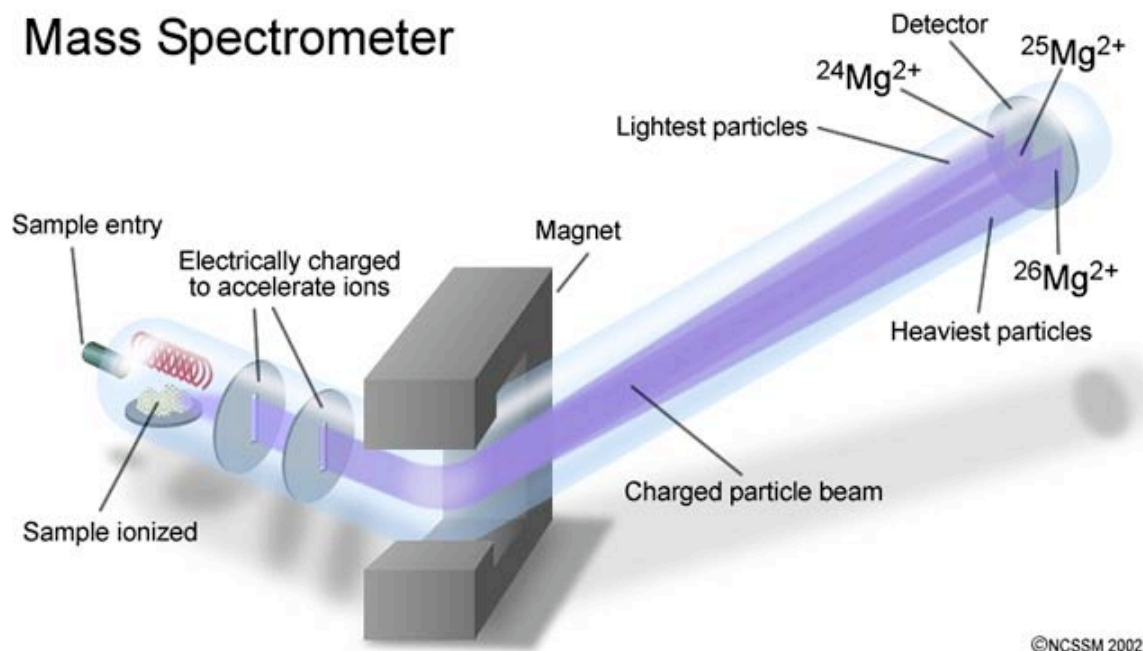
${}^{12}\text{C}$  and  ${}^{13}\text{C}$  are isotopes of carbon.

An ion is a charged particle,  $\text{O}^{2-}$  and  $\text{Na}^+$  are ions.

*You can't see all the neutron and protons in the nucleus in the diagrams*

Chemists identify isotopes by using a mass spectrometer. The separation is possible because each isotope has a different mass. Lighter masses will bend more as they pass through the magnet field.

## Mass Spectrometer



### Critical Thinking Questions

- How many protons are found in  $^{12}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}^-$ ? \_\_\_\_\_
- How many neutrons are found in  $^{12}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}^-$ ? \_\_\_\_\_
- How many electrons are found in  $^{12}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}$ ? \_\_\_\_\_  $^{13}\text{C}^-$ ? \_\_\_\_\_
- Based on the data presented above,
  - What do all carbon atoms (and ions) have in common?
  - What do all hydrogen atoms (and ions) have in common?
- What is the significance of the atomic number,  $Z$ ? Where will you find it on the periodic table?
- Look at a periodic table, what do all nickel (Ni) atoms have in common?
- How is the mass number,  $A$ , determined?
- What structural feature is different in isotopes of a particular element?
- What feature distinguishes a neutral atom from an ion?

## What is an atom?

10. Where is most of the mass of an atom, within the nucleus or outside of the nucleus? Explain your reasoning.

11. Complete the chart below:

Isotope	Atomic Number Z	Mass Number A	Number of Electrons
$^{31}\text{P}$	15		
$^{18}\text{O}$			8
	19	39	18
$^{58}\text{Ni}^{2+}$		58	

12. What is the mass (in grams) of

- a. one  $^1\text{H}$  atom? \_\_\_\_\_  
 b. one  $^{12}\text{C}$  atom? \_\_\_\_\_

13. What is the mass (in grams) of  $4.35 \times 10^6$  atoms of  $^{12}\text{C}$ ?

14. What is the mass (in grams) of one molecule of carbon dioxide which has one  $^{12}\text{C}$  atom and two  $^{16}\text{O}$  atoms?

15. Define mass number

16. Define atomic number.

17. How many electrons, protons, and neutrons are found in each of the following?

Atom or ion	Electrons	Protons	neutrons
$^{24}\text{Mg}$			
$^{23}\text{Na}^+$			
$^{35}\text{Cl}$			
$^{35}\text{Cl}^-$			
$^{56}\text{Fe}^{3+}$			
$^{15}\text{N}$			
$^{16}\text{O}^{2-}$			
$^{27}\text{Al}^{3+}$			

## What is an atom?

18. Estimate the mass of one  $^{14}\text{C}$  atoms (in amu) as precisely as you can from the data given here. Explain your answer.

19. Use the data given to estimate the values (in amu) of

- a. An electron
- b. A proton
- c. A neutron

20. The mass values calculated in #18 are only approximate because when atoms (up through iron) are made (mainly in stars) from protons, neutrons, and electrons, energy is released. Einstein's equation  $E = mc^2$  enables us to relate the energy released to the mass loss in the formation of atoms. Use the known values for the mass of a proton, 1.0073 amu, mass of a neutron, 1.0087, and the mass of an electron,  $5.486 \times 10^{-4}$  amu, to show that the mass of a  $^{12}\text{C}$  atom is less than the sum of the masses of the constituent particles.

Summary of Activity: Describe an atom.

*An Investigation of Density*

**Learning Objectives:** Students will investigate density and discover if their existing knowledge of density is correct.

**Standards:** 1.01, 2.04

**Skills:** Measurement, and the appropriate use of significant figures

**Strand:**

**Safety Precautions:** none

**Science Concepts:** Significant figures, Mass, Volume, and Density

**Materials:** electronic balance, gram cubes (Fischer), metric rulers

**Procedure:**

1. Complete the prelab activity provided by your teacher.
2. Using your centimeter ruler, measure the length, width and height of a single cube. Record these measurements in your data table using the correct number of significant figures.
3. Measure and record the mass of this cube using the correct number of significant figures.
4. Build a cube that is 2 blocks x 2 blocks x 2 blocks on each side. Measure the length, width and height and mass of this cube as you did for the first one.
5. Repeat step 4 for a cube that is 3 blocks x 3 blocks x 3 blocks on each side.
6. Now that your raw data is recorded, calculate the volume for each cube. Record the volumes in your data table with the correct number of significant figures.
7. Using your data so far, calculate the density for each cube. Record the densities in your data table with the correct number of significant figures.
8. On your lab follow-up sheet, prepare a graph of your mass-volume data. Plot the volume on the x-axis and the mass on the y-axis.
9. Draw a best-fit line through your data points.
10. Determine the slope of the best-fit line.

**Teacher notes:**

- Alternative methods: Because the gram cubes are 1cm x 1 cm x 1 cm the lengths, widths and heights of the cubes do not have to be measured. But be cautious of significant digits.
- Expected densities for the 3 cubes are  $\sim 0.95 \text{ g/cm}^3$ . Because each cube is made of the same substance, each of the 3 densities should be the same. Some students will get all three densities to be the same. Some may get densities that differ by  $0.01 \text{ g/cm}^3$  and they come to the conclusion that the densities of the cubes are different. Spend some time talking about experimental error. This is also a good time to talk about the purpose and significance of a best-fit line.

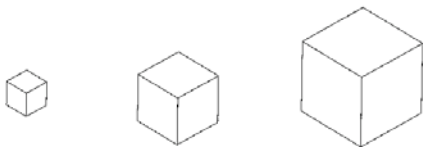
**References:**

**Prelab Activity**  
**Density Lab**

Name \_\_\_\_\_

1. Read the entire procedure and in the space below, make a data table to record data to be collected. Label each column and row with the appropriate title and units.

2. Formulate a hypothesis about the following question. Each of the cubes below is made of the same material. Which cube would you predict to have the greatest density?

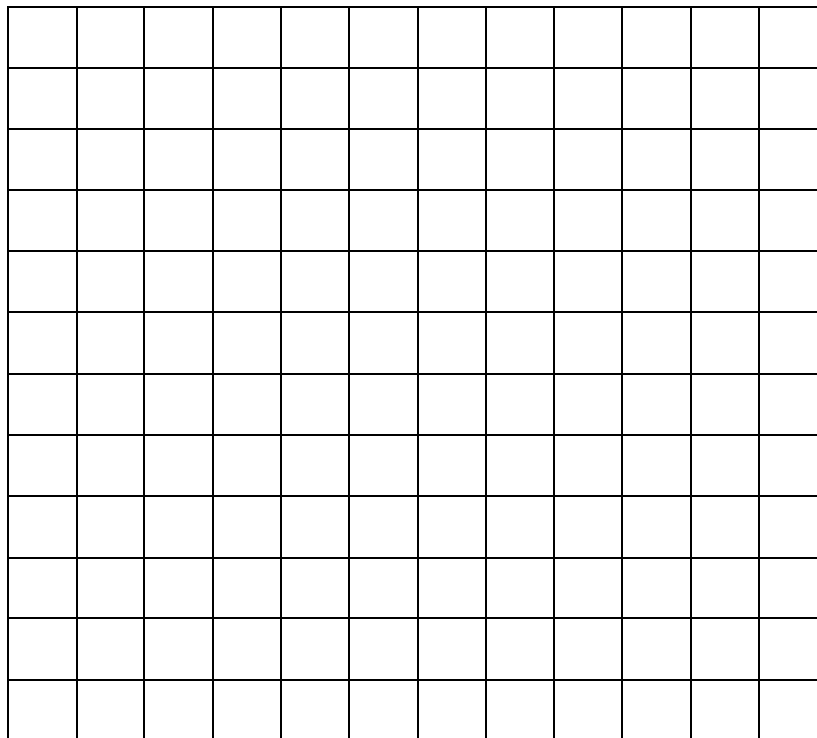


3. What is the formula to calculate the volume of a cube?
4. Define the term Density.
5. What is the formula for Density?

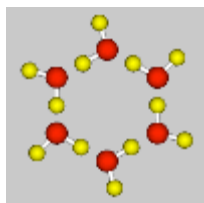
**Lab Follow-Up Questions**  
**Density Lab**

Name \_\_\_\_\_

1. Draw your graph here:



2. Is there a relationship between the calculated slope and the calculated densities of your 3 cubes? If so, describe the relationship.
3. Write a concluding statement about this experiment. Be sure to refer back to your hypothesis. Support your conclusion with appropriate data, calculated results and graphical results.



***Boyle's Law:***  
***Pressure-Volume Relationship in Gases***

**Learning Objectives:**

To determine the relationship between the pressure and volume of a confined gas.

**Standards:** 1.01, 2.05

**Skills:** Calculations, Graphical data analysis

**Strand:**

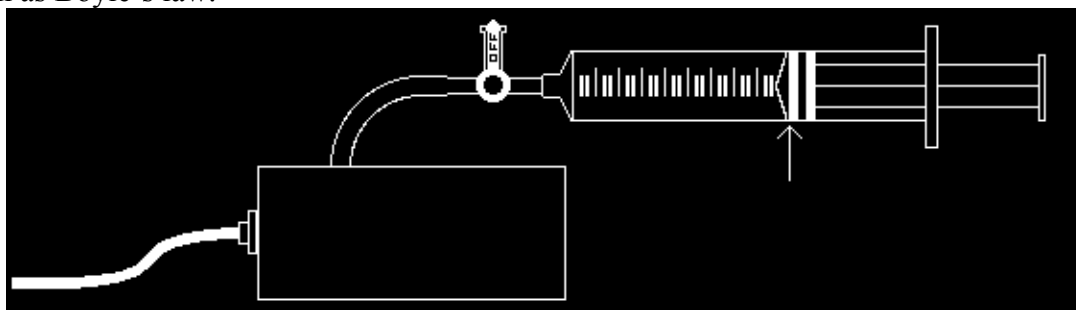
**Safety Precautions:** none

**Science Concepts:** the relationship between pressure and volume for gases

**Materials:** TI-83+ calculator, CBL, CBL pressure sensor with syringe

**Procedure:**

The primary objective of this experiment is to determine the relationship between the pressure and volume of a confined gas. The gas we use will be air, and it will be confined in a syringe connected to a pressure sensor (see Figure 1). When the volume of the syringe is changed by moving the piston, the pressure exerted by the confined gas changes. This pressure change will be monitored using a pressure sensor interfaced to a CBL. It is assumed that temperature will be constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. From the data and graph, you should be able to determine the mathematical relationship that exists between the pressure and volume of the confined gas. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.



**Figure 1**

1. Prepare the pressure sensor.
  - a. Plug the pressure sensor into Channel 1 of the CBL using the DIN adapter.
  - b. Attach the 20-mL syringe to the valve of the Pressure Sensor as shown in Figure 1.
  - c. Connect the CBL System to the TI-83+ calculator using the link cable. Be sure it is firmly plugged in at both ends. Attach the AC adapter to the CBL.
2. Turn on the CBL unit and calculator. Press [APPS] and select CHEMBIO. Press [ENTER]. "PRGM CHEMBIO" appears. Press [ENTER] " Vernier Software-Biology and Chemistry with

the CBL” appears. Press [ENTER] to go to the MAIN MENU. If the CBL and the calculator are not turned on and the link cable pushed in firmly at both ends, the message “Link Error” will appear. Be sure that the link cable is firmly pushed into the CBL and calculator and press the On button on the CBL.

3. Set up the calculator and CBL for a pressure sensor and calibration (in atmospheres).
  - a. Select **SET UP PROBES** from the **MAIN MENU**. Press [ENTER].
  - b. Enter “1” as the number of probes. Press [ENTER].
  - c. Select **PRESSURE** from the **SELECT PROBE** menu. Press [ENTER].
  - d. Enter “1” as the channel number. Press [ENTER].
  - e. Select **USE STORED** from the **CALIBRATION** menu. Press [ENTER].
  - f. Select **ATM** from the **PRESSURE UNITS** menu. Press [ENTER].
4. To collect pressure versus volume data:
  - a. It is best for one person to take care of the gas syringe and for another to operate the calculator.
  - b. Open the syringe to the atmosphere by turning the blue knob away from the syringe (so the arrow points toward black interface box). Move the piston so that the front edge of the black ring is lined up with the 20.0 mL line on the syringe. Turn the blue knob to the position shown in Figure 1 so the side arm is closed and the syringe is open to the pressure sensor.
5. Set up the calculator and CBL for data collection.
  - a. Select **COLLECT DATA** from the **MAIN MENU**. Press [ENTER].
  - b. Select **TRIGGER/PROMPT** from the **DATA COLLECTION** menu. Press [ENTER].
  - c. When the pressure reading has stabilized, press [TRIGGER] on the CBL. When prompted to “Enter Value”, type in the volume reading at the front edge of the black ring (20.0 mL for the first point). Press the [ENTER] key to store this pressure-volume data pair.
6. Select **MORE DATA** from the **DATA COLLECTION** menu to collect another data pair. Move the piston to 18.0, when the pressure reading has stabilized, press [TRIGGER] on the CBL. Type in the gas volume (in mL) on the calculator. Press the [ENTER] key to store this pressure-volume data pair. Repeat for volumes of 16.0, 15.0, 12.0, 10 , 8.0, 6.0 and 5.0 mL.
7. Select **STOP AND GRAPH** from the **DATA COLLECTION** menu when you have finished collecting data. Use right arrow key to examine the data points along the displayed graph of pressure vs. volume. As you move the cursor right or left, the volume (X) and pressure (Y) values of each data point are displayed below the graph.
8. Press [ENTER] to exit the graph.
9. Select **NO** which returns you to the **Main Menu**. Press [ENTER]. Select **Quit**. Press [ENTER].

### Analyzing the DATA

Your task in this investigation is to describe the relationship and devise an equation for calculating the pressure of a specific volume of gas assuming that the temperature does not change. The volume data is in L1 and the pressure data is in L2.

1. Press **MODE**.
2. Highlight **NORMAL**. Press [ENTER].
3. Highlight **3** for the number of decimal places. Press [ENTER].
4. Press [QUIT] to return to the main screen.

### Method of Analysis 1

1. From your graph, is pressure versus volume a linear relationship? If not, to see if an inverse relationship exists between pressure and volume, a graph of pressure vs. *reciprocal of volume*

(1/volume or volume<sup>-1</sup>) should be plotted. To do this using your TI-83+ calculator, it is necessary to create a new data list, the reciprocal of original volume data.

- To clear any previous regression equation and curve, press [Y=] and [CLEAR]. Press [QUIT], then press [CLEAR] to clear the calculator screen.
  - Create a list of *1/volume* values in L3 by pressing [STAT] Select **EDIT** and press [ENTER]. Highlight the column heading of L3 and press [L1] [X<sup>-1</sup>] and [ENTER]. L1 is volume, L2 is pressure, and L3 is 1/volume. Record these values in the data table.
  - To plot a graph of pressure vs. 1/volume, press [STATPLOT], then select **Plot1**. Press [ENTER]. Use the arrow keys to position the cursor on each of the following Plot1 settings. Press [ENTER] to select any of the settings you change: Plot1 = On, Type = Scatter (1st type), Xlist = L3 Ylist = L2 and Mark = square. Press [GRAPH] , then [ZOOM], select **ZoomStat** and press [ENTER].
2. Follow this procedure to calculate and display a linear regression line on your graph of pressure vs. 1/volume:
- Press [STAT]. Arrow right to display the **CALC** menu. Select **LinReg(ax+b)**.
  - To identify the lists that correspond to the two variables, press [L3] [,] [L2]. Press [ENTER]. The statistics are displayed for the equation in the form:

$$y = ax + b$$

where  $x$  is 1/volume,  $y$  is pressure,  $a$  is a proportionality constant ( the slope of the line), and  $b$  is the y-intercept, and  $r$  is the correlation factor. The closer the absolute value of  $r$  is to one the better the data correlates to a straight line. Record these values in the data table. On the TI-83+ If the  $r$  value does not appear on the screen, press [CATALOG]. Arrow down to **Diagnostic On** and press [ENTER] twice. The screen should show Diagnostic On and Done. Run the linear regression analysis again.

- To display a best-fit regression line on the graph of pressure vs. 1/volume, first press [Y=], then [VARS]. Select **STATISTICS**, then press the right arrow key to display the **EQ** menu. Select **RegEQ** to copy the linear regression equation to Y1=. Press [ENTER]
- Press [WINDOW] and then set Xmin = 0 and Ymin = 0 (so both axes are scaled from 0).
- Press [GRAPH] to view the graph of pressure vs. 1/volume with a best-fit regression line.

If the relationship between P and V is an inverse relationship, the plot of P versus 1/V should be linear and pass through (or near) the origin. Examine your graph to see if this is true for your data. Write an equation for this line.

### Method of Analysis 2

- To clear the previous regression equation and curve, press [Y=] and [CLEAR]. Press [QUIT], then press [CLEAR] to clear the calculator screen.
- To plot a graph of pressure vs. volume, press [STAT PLOT], then select **Plot1**. Press [ENTER]. Use the arrow keys to position the cursor on each of the following Plot1 settings. Press [ENTER] to select any of the settings you change: Plot1 = On, Type = Scatter(1st type), Xlist = L1 Ylist = L2, and Mark = square. Continue with step 3a below.
- Based on the graph of pressure vs. volume, decide what kind of mathematical relationship you think exists between these two variables, direct or inverse. To see if you made the right choice:
  - Press [GRAPH], then [ZOOM], select **ZoomStat** and press [ENTER] to see the graph.
  - Press [STAT] and arrow right to display the **CALC** menu. Use the down-arrow key to scroll down the menu and select **PwrReg**. Press [ENTER].

- c. Press [L1] [,] [L2] [ENTER]. The power-regression statistics for these two lists are displayed for the equation in the form:

$$y = a*x^b.$$

where  $x$  is volume,  $y$  is pressure,  $a$  is a proportionality constant, and  $b$  is the exponent of  $x$  (volume) in this equation. Note: The relationship between pressure and volume can be determined from the value and sign of the exponent,  $b$ . The closer  $b$  is to  $-1$ , the better the data fit an inverse relationship. An inverse relationship may be expressed in several forms. Here it is expressed as  $y=ax^{-1}$ . This is mathematically equivalent to  $y=a/x$  which indicates an inverse relationship since  $y$  decreases if  $x$  increases. This is also mathematically equivalent to  $yx=a$  which indicates an inverse relationship since  $y$  must decrease if  $x$  increases if the product of  $y$  times  $x$  is a constant.

The closer the absolute value of  $r$ , the correlation factor, is to one the better the data fit the power function above. Record these values in the data table.

- d. To display the power-regression curve on the graph of pressure vs. volume, first press [Y=]. Press [CLEAR] to clear the  $Y_1=$  equation, then press [VARS]. Select STATISTICS and press the right arrow key to display the EQ menu. Select RegEQ to copy the power regression equation to  $Y_1=$ .
- e. Press [WINDOW] and then set  $X_{min} = 0$  and  $Y_{min} = 0$  (so both axes are scaled from 0).
- f. Press [GRAPH] to plot pressure vs. volume with the power-regression curve for your data. If you have correctly determined the mathematical relationship, the power regression line should very nearly *fit* the points on the graph (that is, pass through or near the plotted points).
- g. Write an equation for the determining of the volume of a gas given the pressure at a constant temperature.

#### To Store Data as a Program and automatically write to lists when program is run.

You will want to store L1 (volume), L2 (pressure), and L3 (1/volume) for use in analyzing the data later and to have the data available to transfer to Graphical Analysis.

1. Assume the data that you want to store is in a list or several lists in STAT on your calculator. For this example assume data is in list L1.
2. Press [PRGM] on the calculator.
3. Arrow over to NEW. Select Create New. Press [ENTER].
4. In put a name that you will remember later. The first character must to be a letter and the name can only have 8 characters. Press [ENTER].
5. Press [RCL] [L1].  
(L1 is the location of the list you want to store.) This command shows at the bottom of the calculator screen. When you press ENTER the list of entries in L1 are displayed. Do **not** press another ENTER.
6. Press [STO] [L1] followed by [ENTER]. This command names the list that the data will be written to when the program is run.
7. Press [ENTER] and repeat steps 5 and 6 for each list you want to store, modifying step 5 and 6 to store each list in a different location ( i.e. L2 and L3).
8. Press [QUIT] to leave the programming mode.

#### Teacher notes:

What you will need for each lab group:

CBL units with Din adapters and link cables, TI-83+ calculators, CBL AC adapters, and Pressure sensors with syringes

## Boyle's Law

1. Calibration: The factor calibration is usually adequate to establish the relationship between pressure and volume.

2. If this lab is done as a demonstration, it would be a good idea to use the TI-View Screen projection calculator to collect the data for the class. The data could be transferred to the individual student calculators using the link cable and the students could do the data analysis themselves.

3. Sample Data:

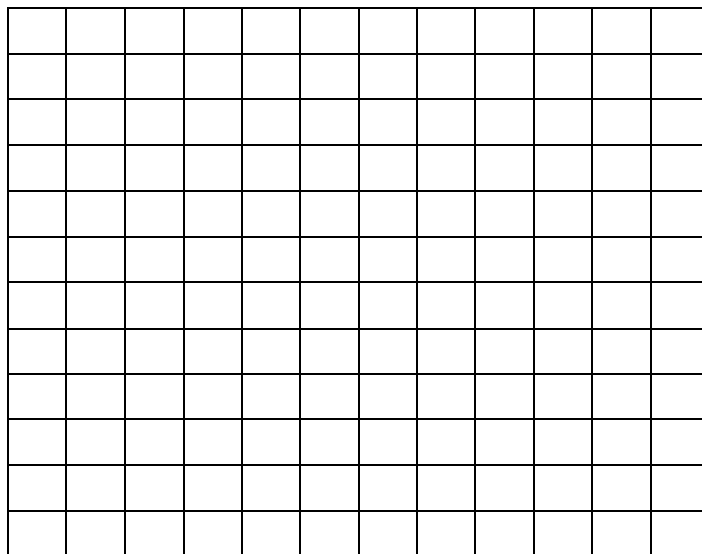
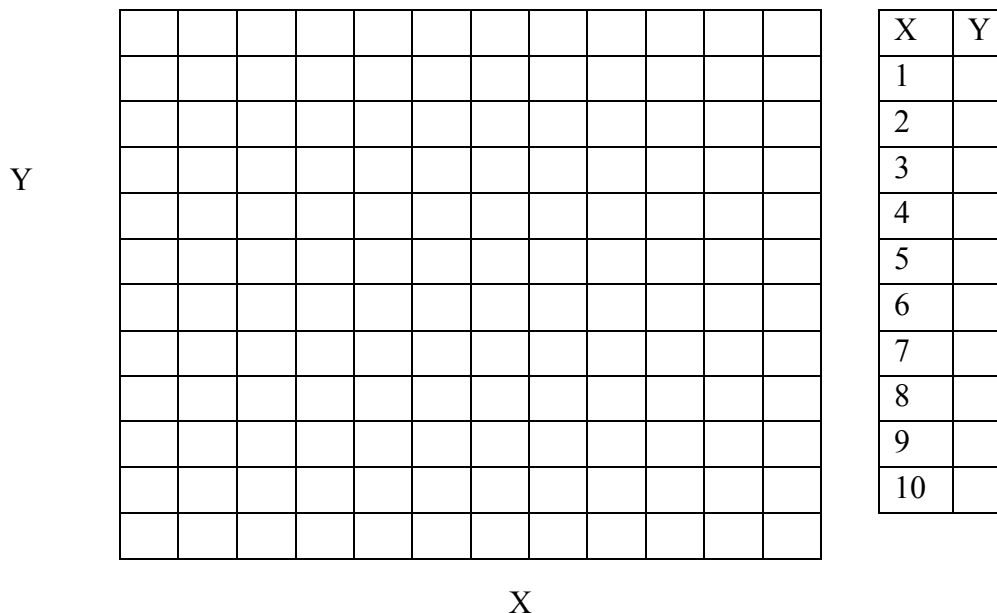
Volume (mL)	Pressure (atm)	1/Volume (mL <sup>-1</sup> )	Pressure x Volume ( mL x atm )	Pressure/Volume ( atm/ mL )
20.0	.986	.050	19.73	.049
18.0	1.17	.056	21.09	.065
16.0	1.42	.063	22.69	.089
15.0	1.55	.067	23.31	.104
12.0	2.11	.083	25.03	.176
10.0	2.63	.100	26.27	.263
8.0	3.26	.125	26.04	.407
6.0	4.49	.167	26.93	.748
5.0	5.32	.200	26.57	1.06

4. Another way to decide the relationship between pressure and volume by completed the last two columns in the table. If pressure and volume are inversely related then pressure times volume should be constant ( $PV=k$ ). If pressure and volume are directly related then pressure/volume should be constant ( $P/V=k$ ). Since pressure times volume is essentially constant, they are inversely related.

**Prelab Activity**  
**Boyle's Law Lab**

Name \_\_\_\_\_

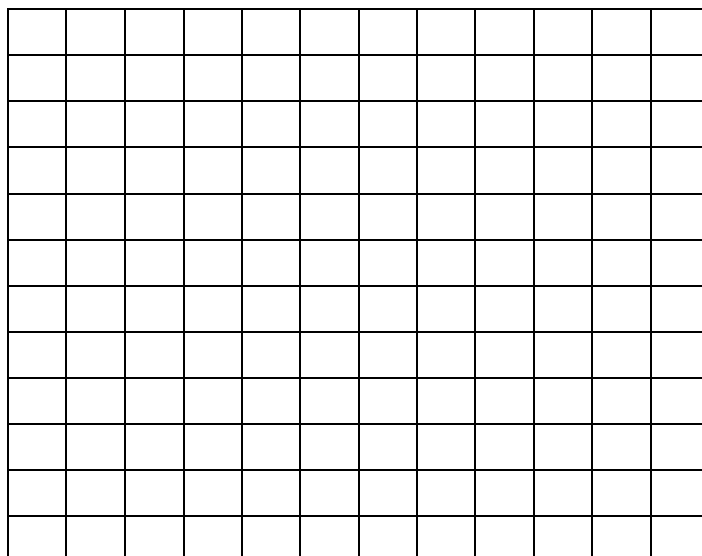
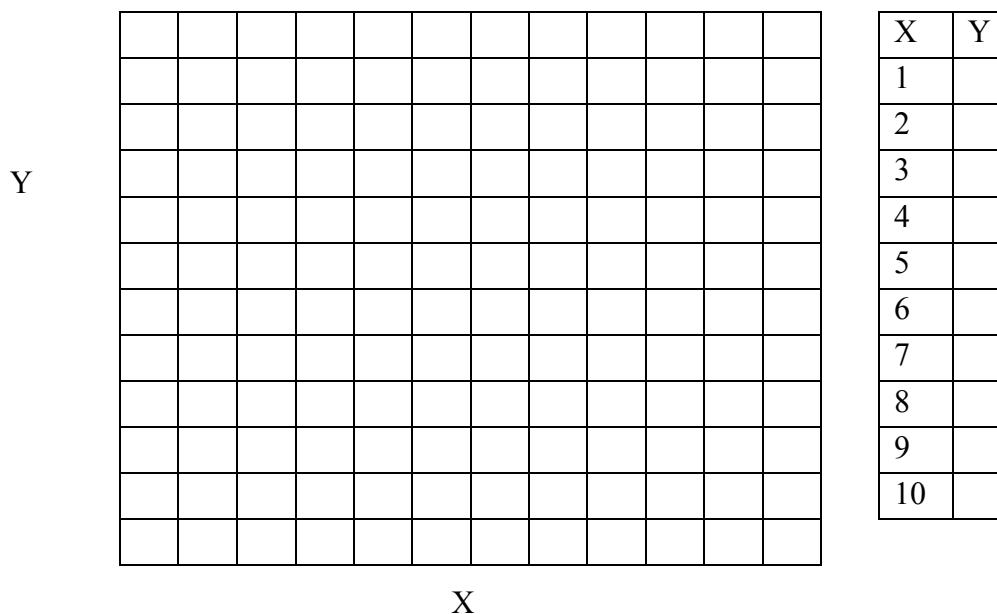
1. On the graph below, plot the relationship  $XY = 10$  using integer values of X from 1 to 10. Label the scale on the axes and record the values in the table.



X

In chemistry, this graph is termed an *inverse* relationship.

2. On the graph below, plot the relationship  $\frac{Y}{X} = 10$  using integer values of X from 1 to 10. Label the scale on the axes and record the values in the table.

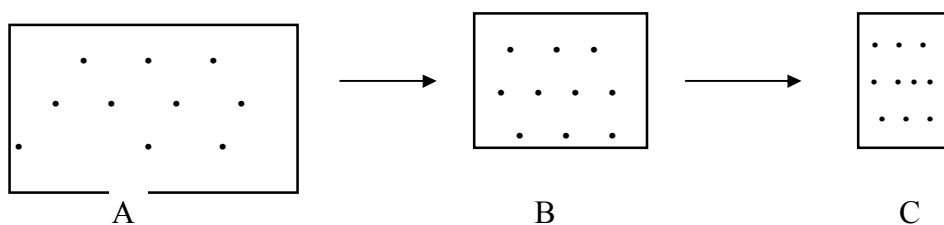


X

In chemistry, this graph is termed a *direct or linear* relationship.

3. If the function  $XY=100$  were plotted,
- how would the shape of the graph compare to that in number 1?
  - how would the position of the graph on the axes compare to that in number 1?

4. You have 10 molecules of gas in container A. The size of container A is reduced by one-half to give "B", then reduced by one-half again to give "C".



If this process is repeated ten times and the data is graphed, what type of relationship would you expect to see in a graph of P versus V?

Make a hypothesis for the relationship between the pressure and volume of a gas.  
Hypothesis:

**Lab Follow-Up Questions**  
**Boyle's Law Lab**

Name \_\_\_\_\_

Data Table  
 Attach graphs to this follow-up sheet.

Volume (mL)	Pressure (atm)	1/Volume (mL <sup>-1</sup> )	Pressure x Volume (mL x atm)	Pressure/Volume (atm/ mL)

Using Method of Analysis 1, write an equation for your graph:

a = \_\_\_\_ b = \_\_\_\_ r = \_\_\_\_ Pressure and volume are (directly or inversely) related.

Using Method of Analysis 2, write an equation for your graph:

a = \_\_\_\_ b = \_\_\_\_ r = \_\_\_\_ Pressure and volume are (directly or inversely) related.

**Follow-Up Questions**

- One way to determine if a relationship is inverse or direct is to find a proportionality constant,  $k$ , from the data. For a direct relationship,  $P/V = k$ . For an inverse relationship,  $P \times V = k$ . Calculate  $k$  for the seven ordered pairs in your data table for both types of relationships. Show the answers in the fourth and fifth columns of the data table.
  - Pressure times volume can be generated in L4 by pressing [STAT]. Select **EDIT** and press [ENTER]. Highlight the column heading L4 and press [L1] [x] [L2] and [ENTER]. L4 is pressure times volume. Record the values in the data table.
  - Pressure/ volume can be generated in L5 by one of two methods:
    - Press [STAT]. Select **EDIT** and press [ENTER]
    - Highlight the column heading L5 and press [L2] [+ ] [L1] and [ENTER].
    - Highlight the column heading L5 and press [L2] [x] [L3] and [ENTER].
 L5 is pressure/ volume. Record the values in the data table.
- For which column ( $P/V$  or  $P \cdot V$ ), were the values relatively constant? Good data may show some minor variation, but the values for  $k$  should be relatively constant. Is the relationship between pressure and volume direct or inverse?

## Boyle's Law

- Using  $P$ ,  $V$ , and  $k$ , write an equation representing Boyle's law. Write a verbal statement that correctly expresses Boyle's law.
- If the volume is *doubled* from 5.0 mL to 10.0 mL, what does your data show happens to the pressure?
- If the volume is *halved* from 20.0 mL to 10.0 mL, what does your data show happens to the pressure?
- If the volume is *tripled* from 5.0 mL to 15.0 mL, what does your data show happened to the pressure?
- From your answers to the first three questions *and* the shape of the curve in the plot of pressure versus volume, do you think the relationship between the pressure and volume of a confined gas is direct or inverse? Explain your answer.
- Based on your data, what pressure (in atm) would you expect if the volume of the syringe was increased to 40.0 mL. Explain or show work to support your answer.
- Based on your data, what pressure (in atm) would you expect if the volume of the syringe was decreased to 2.5 mL. Explain or show work to support your answer.
- What experimental factors are assumed to be constant in this experiment?

## The Bond-Type Triangles - Class Activity

### Information Part I:

Properties of Compounds with Ionic Bonding:

High melting points (usually  $>500^{\circ}\text{C}$ )

Hard and brittle as solids

Do not conduct electricity as solids; conduct electricity when molten

Properties of Metals:

Good conductors of electricity as solids

Malleable and ductile as solids

Melting points can be low (Hg,  $-30^{\circ}\text{C}$ ) or high (W,  $3410^{\circ}\text{C}$ )

Properties of Compounds with Covalent Bonding:

Melting points can be low ( $\text{H}_2$ ,  $< -252^{\circ}\text{C}$ ) or high (C, diamond,  $<3000^{\circ}\text{C}$ )

Variable hardness

Do not conduct electricity as solids or when molten

**Table 1. Electronegativity, EN, parameters and melting points for selected compounds.**

Compound or Metal	EN		$\overline{\text{EN}}$	$\Delta\text{EN}$	Melting Point ( $^{\circ}\text{C}$ )	Type of Bonding
	first atom	second atom				
CsF(s)	0.66	4.19	2.42	3.53	682	ionic
NaCl(s)	0.87	2.87	1.87	2.00	801	ionic
NaI(s)	0.87	2.36	1.62	1.49	661	ionic
Cs(s)	0.66	0.66	0.66	0	28	metallic
Na(s)	0.87	0.87	0.87	0	98	metallic
CuZn(s;brass)	1.8	1.6	1.7	0.2	932	metallic
F <sub>2</sub> (g)	4.19	4.19	4.19	0	-220	covalent
O <sub>2</sub> (g)	3.61	3.61	3.61	0	-218	covalent
HI(g)	2.30	2.36	2.33	0.06	-51	covalent
C(s; diamond)	2.54	2.54	2.54	0	>3000	covalent
CH <sub>4</sub> (g)	2.54	2.30	2.42	0.24	-182	
GaAs(s)	1.76	2.21	1.99	0.45	1238	
Si(s)	1.92	1.92	1.92	0	1410	

$\overline{\text{EN}}$  is the average electronegativity of the two elements.

$\Delta\text{EN}$  is the difference in electronegativity (absolute) between the two elements.

### Critical Thinking Questions

1. Based on the data in Table 1, what combination of  $\Delta$  EN values and average EN values lead to metallic bonding?
2. Based on the data in Table 1, what combination of  $\Delta$  EN values and average EN values lead to ionic bonding?
3. Based on the data in Table 1, what combination of  $\Delta$ EN values and average EN values lead to covalent bonding?
4. Verify the  $\Delta$  EN value and the average EN value for methane, CH<sub>4</sub>, given in Table 1. Is it possible to classify methane as metallic, ionic, or covalent bonding? Explain your reasoning.
5. Verify the  $\Delta$  EN value and the average EN value for GaAs, given in Table 1. Is it possible to classify methane as metallic, ionic, or covalent bonding? Explain your reasoning.

### Information Part II:

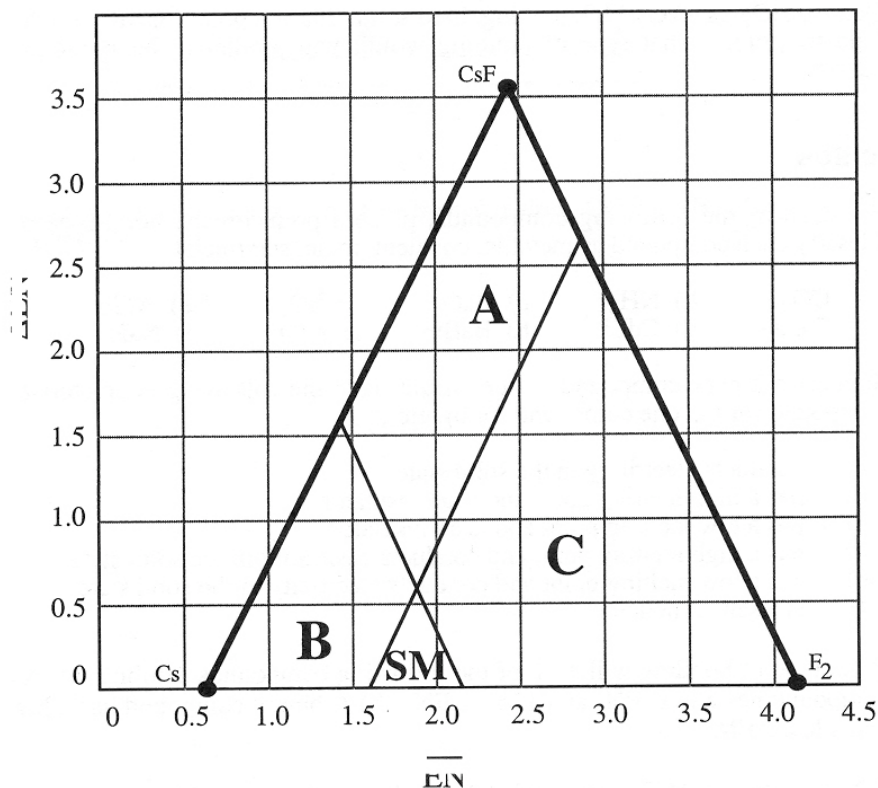
Many compounds have properties that are intermediate between the three bond types: metallic, covalent, and ionic. Si, for example, is known as a semiconductor; this compound has properties which are intermediate between metallic and covalent.

A bond-type triangle is a chart that enables us to predict the properties of a compound based on the electronegativities of the elements that comprise the compound. The data for CsF, F<sub>2</sub>, and Cs from Table 1 have been used to generate three points at the corners of the bond-type triangle shown in Figure 1.

Additional electronegativities you will need for the next activity.

N 3.066	Ba 0.88	S 2.589
Al 1.6113	Sb 1.984	Cd 1.52
Li .912	Br 2.685	Zn 1.59

## The Bond-Type Triangle



### Critical Thinking Questions Part II:

1. Verify that the points for CsF, F<sub>2</sub>, and Cs are at the appropriate positions on the bond-type triangle.
2. Place a point on the chart for sodium chloride, a compound with ionic bonding; for sodium, a metal; for hydrogen iodide, a compound with covalent bonding; for Si, a semiconductor.

### Information:

The bond-type triangle can be divided into regions, which indicate the predominant type of bonding present in compounds. The dividing lines between regions are not absolute, but they give a general idea of the boundaries between different types of bonding.

### Critical thinking Questions:

Associate the regions (A, B, C) with bond types (metallic, covalent, ionic). This “SM” region is sometimes called semimetals.

Quartz, SiO<sub>2</sub>, is a very high melting, hard solid. Place a point for SiO<sub>2</sub> on the bond-type triangle. What type of bonding would you predict to be predominant in quartz?

## The Bond-Type Triangle

### Exercises:

For each of the following compounds, place a point on the bond-type triangle. Classify each compound as metallic, covalent, ionic, semimetal.

- a) CO<sub>2</sub>   b) NH<sub>3</sub>   c) BaO   d) SO<sub>2</sub>   e) AlSb  
f) GaAs   g) CdLi   h) BaBr<sub>2</sub>   i) ZnO   j) NaH

Suggest a binary compound which would have the following characteristic [one compound from a), one compound for b), etc.]:

conducts electricity in the solid state

has a high melting point and is an insulator

has a low melting point and is an insulator

has a high melting point and conducts electricity in the solid state

has a low melting point and conducts electricity in the solid state is a semiconductor

What type of bonding will each of the following compounds exhibit?

a) A binary compound has a low average EN and a low  $\Delta$  EN.

b) A binary compound has a high average EN and a low  $\Delta$  EN.

## *Heat of Fusion*

### Learning Objectives:

To experimentally determine the heat of fusion of water.

**Standards:** 1.01, 4.02

**Skills:** Use of the calorimeter, quantitative measurement

**Strand:**

### Safety Precautions:

Safety goggles should be worn at all times during this lab. Wash your hands thoroughly before leaving lab.

**Science Concepts:** Heat transfer, calorimetry, and heat of fusion

### Materials:

coffee cup calorimeter, thermometer, ice, distilled water, and electronic balance

### Procedure:

When a chemical process such as melting or freezing (“fusion”) occurring in an aqueous environment is carried out in a calorimeter, the substance involved (ice) in the process is considered to be the “system.” In this case we are looking for the amount of heat energy that must be transferred from liquid water at a given temperature to ice in order to completely melt the ice at the melting temperature (0.0°C); this is the energy required for the phase change, also called the heat of fusion. Both the water containing the substance and the calorimeter itself are considered to be the “surroundings.” We will assume that the amount of heat absorbed by the calorimeter itself is negligible. Therefore, the heat change for the surroundings can be calculated from the mass of the water in the calorimeter ( $m$ ), the heat capacity of the water ( $s$ ), and the change in temperature of the water ( $\Delta T$ ) by the following equation:  $q_{\text{surroundings}} = ms\Delta T$

Remember that the heat change for the system (the ice) must be equal in magnitude but opposite

in sign to that for the surroundings (the water):  $q_{\text{system}} = -q_{\text{surroundings}}$

In other words, **the heat that is lost by the system must be gained by the surroundings**, or of course if the system takes in heat energy, it must be taken from the surroundings.

- a. By measuring the temperature change of a known mass of water (and ice) in a calorimeter, you should be able to make a data table and calculate the heat of fusion of water based on the following series of calculations: Total volume of water (including the ice that melted); Mass of ice melted; Change in temperature of the warm water; and the amount of energy released as the warm water was cooled through the temperature change (The specific heat of water in

## Heat of Fusion

its liquid state is  $4.184 \text{ J/g}^\circ\text{C}$ ). Make and complete a data table on the back of this sheet. Show all calculations in addition to your final result. Use correct significant figures!

- b. Calculate the energy released per gram of ice melted and the kilojoules required to melt one mole of ice (this will be the molar heat of fusion).
- c. The theoretical value for the heat of fusion of water is  $6.01 \text{ kJ/mol}$ . Calculate your % error. Describe and explain your sources of error.

### **Teacher notes:**

Each lab group should have one coffee cup calorimeter consisting of two Styrofoam coffee cups (one inside the other) with a lid that has a hole for a thermometer. The lid can be made with a third Styrofoam coffee cup, cut to a height of around 2" or so and turned upside down.

### **References:**

This experiment is based on one presented in the following lab manual:

Anderson, Misti Ault and Todd E. Woerner. General Chemistry Laboratory Manual: Chemistry 22L. Hayden McNeil Publishing, Inc., Plymouth, MI. 2003

## **Electron Spectroscopy**

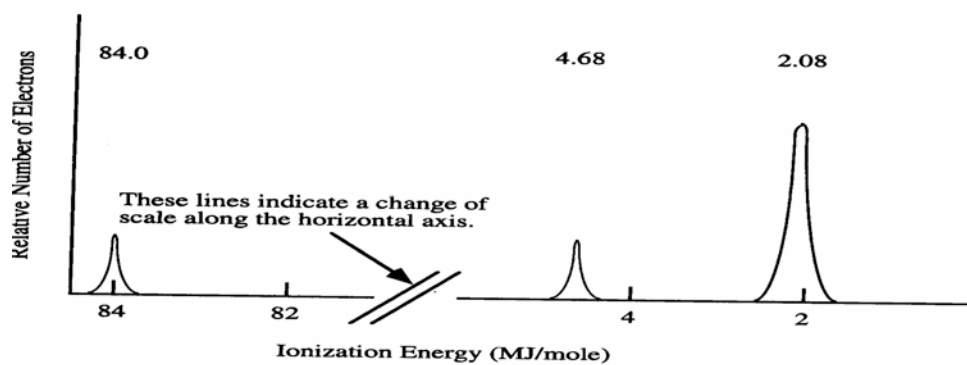
### **Where is the electron?**

### **How many electrons are there in an orbital?**

Earlier atomic models proposed electrons in orbitals around the nucleus, some further away from the nucleus than others. If an electron is said to occupy an energy level in an atom then each electron must be in an orbital at a particular distance from the nucleus and the energy levels corresponding to these orbitals have a certain energy level.

The next step in the location of the electron required Photoelectron Spectroscopy. This is a process of bombarding the atoms with energy. A spectroscopic technique that measures the kinetic energy of electrons emitted upon the ionization of the substance by high energy monochromatic photons.

The spectrum is a plot of the number of electrons emitted versus their kinetic energy. In the diagram below the "X" axis is labeled high to low energies so that you think about the XY intersect being the nucleus.



**The Periodic Table of the Elements**  
**Electronic Structure**

H																	He																												
Li	Be											B	C	N	O	F	Ne																												
Na	Mg											Al	Si	P	S	Cl	Ar																												
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr																												
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe																												
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn																												
Fr	Ra	Ac	Rf	Ha	Sg																																								
<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <tr> <td style="background-color: green;">Ce</td> <td style="background-color: green;">Pr</td> <td style="background-color: green;">Nd</td> <td style="background-color: green;">Pm</td> <td style="background-color: green;">Sm</td> <td style="background-color: green;">Eu</td> <td style="background-color: green;">Gd</td> <td style="background-color: green;">Tb</td> <td style="background-color: green;">Dy</td> <td style="background-color: green;">Ho</td> <td style="background-color: green;">Er</td> <td style="background-color: green;">Tm</td> <td style="background-color: green;">Yb</td> <td style="background-color: green;">Lu</td> </tr> <tr> <td style="background-color: green;">Th</td> <td style="background-color: green;">Pa</td> <td style="background-color: green;">U</td> <td style="background-color: green;">Np</td> <td style="background-color: green;">Pu</td> <td style="background-color: green;">Am</td> <td style="background-color: green;">Cm</td> <td style="background-color: green;">Bk</td> <td style="background-color: green;">Cf</td> <td style="background-color: green;">Es</td> <td style="background-color: green;">Fm</td> <td style="background-color: green;">Md</td> <td style="background-color: green;">No</td> <td style="background-color: green;">Lr</td> </tr> </table>																		Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu																																
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																																
" S " Orbitals																	" P " Orbitals																												
" d " Orbitals																	" f " Orbitals																												

Figure 1. Simulated photoelectron spectrum of potassium.

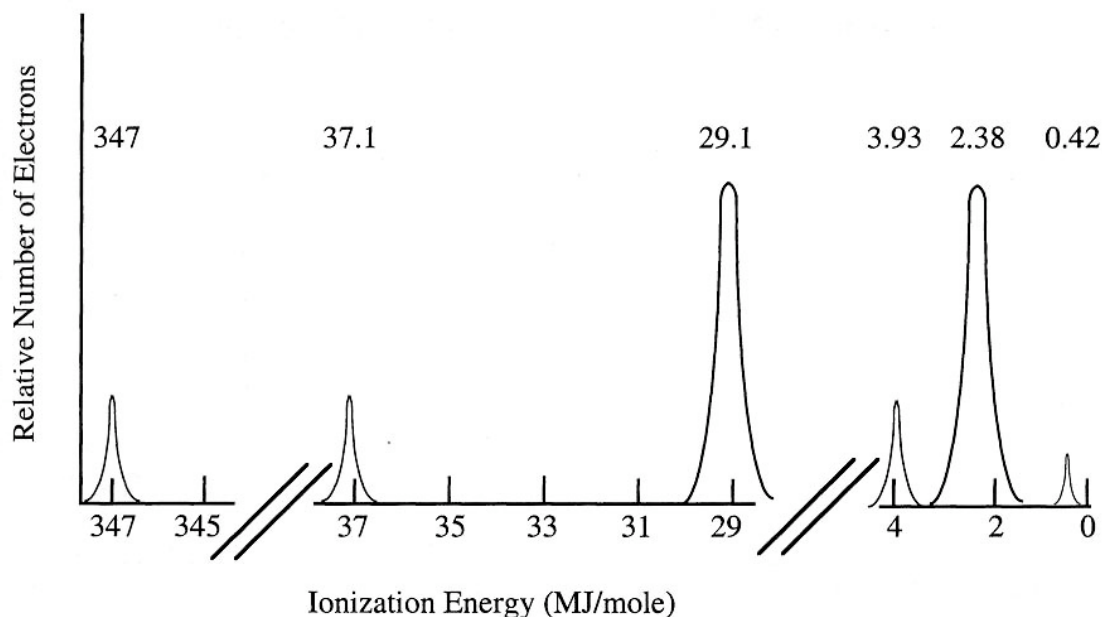


Table 1. Ionization energies (MJ/mole) for selected elements.

Element	1s	2s	2p	3s	3p	3d	4s
K	347	37.1	29.1	3.93	2.38		0.42
Ca	390	42.7	34.0	4.65	2.90		0.59
Sc	433	48.5	39.2	5.44	3.24	0.77	0.63

**Orbital names s, p, d, and f stand for names given to groups of lines in the spectra of the alkali metals. Early chemists called the line groups sharp, principal, diffuse, and fundamental.**

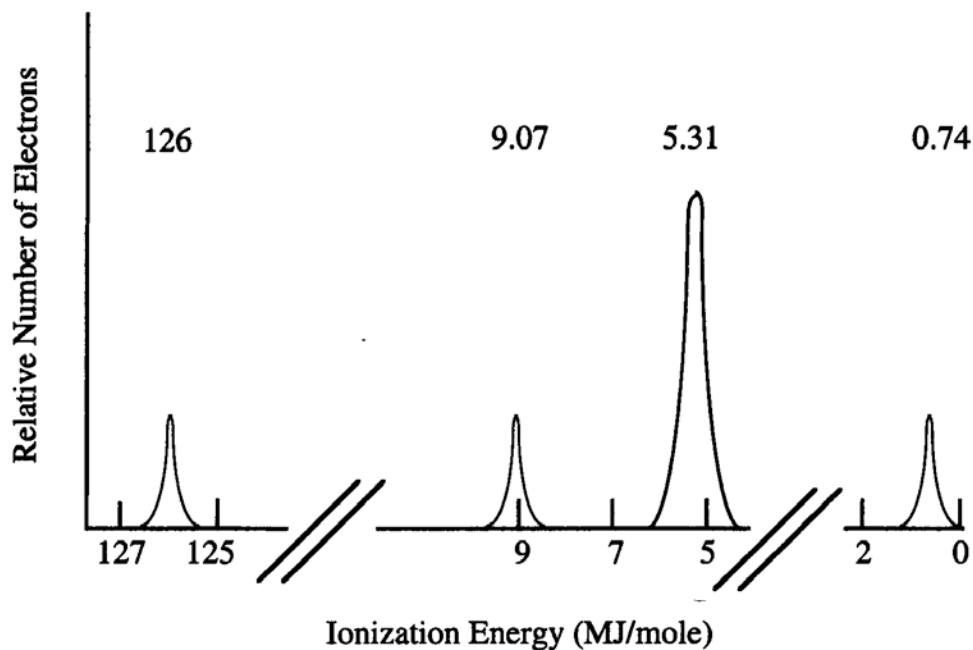
### Discussion:

1. There are no labels on the y axis in the tables above. Using the data provided above put numbers on the y axis.
2. Label each peak on the graphs above with s, p, d, or f.
3. Sketch a photoelectric spectrum of calcium. (Don't try to make it to scale)
4. Draw a photoelectric spectrum of Sc. (Don't try to make it to scale)
5. Potassium loses one electron when forming an ion. Which electron is mostly to be removed to for  $K^+$ ? \_\_\_\_\_

6. Scandium loses two electrons when forming  $\text{Sc}^{2+}$ . Which electrons are mostly to be removed? \_\_\_\_\_.

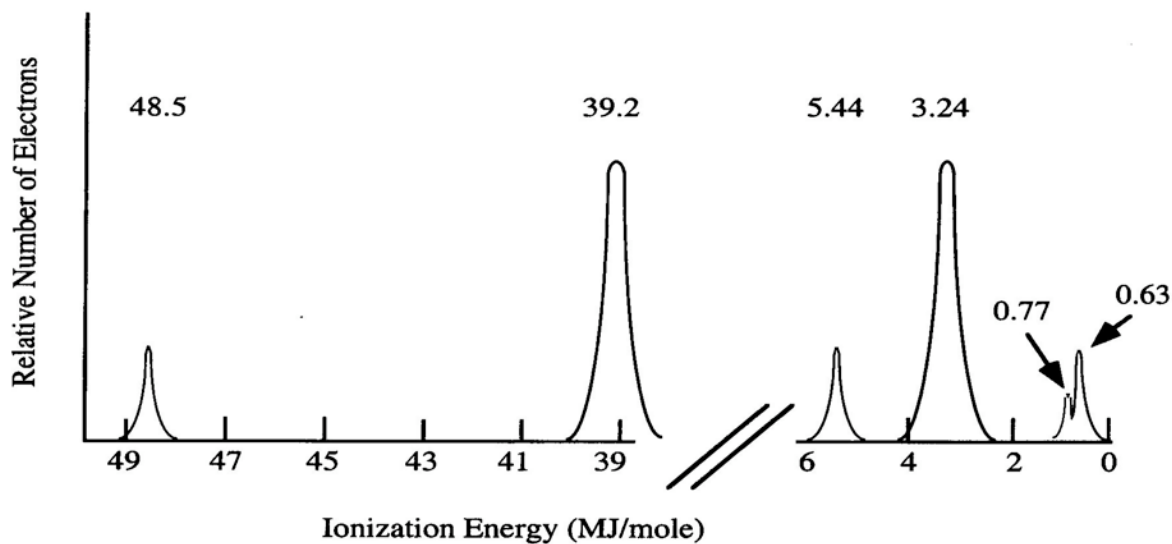
Explain the logic for your answer. \_\_\_\_\_

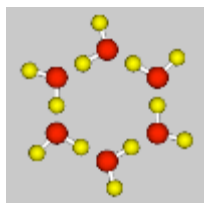
7. What element could have the following spectrum? \_\_\_\_\_



8. What element spectrum is this \_\_\_\_\_

Figure 2. Simulated photoelectron spectrum of scandium. The 1s peak occurs at 433 MJ/mole and is not shown in this spectrum.





*Observations: Copper Chloride and Aluminum*

**Learning Objectives:**

To conduct the reaction between copper chloride and aluminum in order to learn and sharpen students' skill in scientific observation. To observe the indicators of a chemical reaction.

**Standards:** 1.01, 503

**Skills:** Observation

**Strand:**

**Safety Precautions:** Safety goggles should be worn at all times during this lab. Wash your hands thoroughly before leaving lab.

**Science Concepts:** Indicators of a chemical change

**Materials:** Squares of Al foil, 250 mL beaker, 100.0 mL 0.100 M  $\text{CuCl}_2$  solution, 100 mL graduated cylinder, stirring rod, water

**Procedure:**

1. Tear a square of Al foil into smaller pieces.
2. Measure out and pour 100.0 mL of 0.100 M  $\text{CuCl}_2$  solution into your 250 mL beaker.
3. Add the Al foil pieces to the solution in the beaker. Stir and record your observations. Observe by sight (what do you see happening?), by touch (feel the outside of the beaker), by smell (waft some air above the beaker towards you nose, do you smell anything?) and by sound (do you hear anything as the reaction proceeds?). Note that you may or may not notice changes by all of these avenues, but it is important that you learn to observe using all four of these senses. Remember never to taste anything in the lab!

**Teacher notes:**

Cut squares of Al foil that have an approximate mass of 0.25 g. The exact mass is not important, but you will want the squares to be the same size.

You will need 100 mL of each  $\text{CuCl}_2$  solution per lab station, make up some extra to account for spills.

**References:**

## Observations: Copper Chloride and Aluminum

### Lab Follow-up Questions Observations: $\text{CuCl}_2 + \text{Al}$

Name \_\_\_\_\_

1. Record your observations below.

Sight:

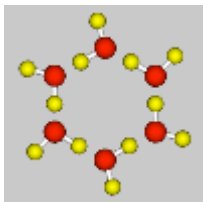
Touch:

Smell:

Sound:

2. What is the new solid that forms as a result of the reaction?
3. Knowing what solid is formed, what solution must be left still dissolved in the water?
4. Complete the following chemical equation for the reaction occurring in the beaker.





## Construction of Air Bags

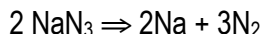
**Learning Objective(s):** You will use your knowledge of gas laws and stoichiometry to design, construct, and test your plan for a simulated automobile air bag.

**Standards, Skills, and Strand:** - 1.01, 2.05, 3.02, 3.03, 5.03

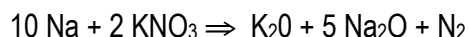
**Safety Precautions:** Safety glasses are required

**Science Concepts:** In most cars today you will find an air bag. The air bag has 3 main parts. First the bag, which is made of a thin nylon fabric, holds the chemicals and sensors and folds into the steering wheel or the dashboard. The electron components contain a sensor that detects a collision force equal to running into a brick wall at about 10-15 mph and an igniter that detonated the first chemical reaction. The third component contains  $\text{NaN}_3$ ,  $\text{KNO}_3$ , and  $\text{SiO}_2$ .

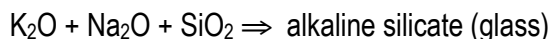
The chemical component in the airbag is a mixture sodium azide ( $\text{NaN}_3$ ) together with  $\text{KNO}_3$  and  $\text{SiO}_2$ . The first reaction has a high activation energy and an electrical impulse is require to start the reaction. This reaction liberates a large volume of nitrogen gas, which fills the air bag.



The sodium by-product of reaction 1, and the potassium nitrate generate additional nitrogen for the airbag in a second reaction



These two reactions leave potassium oxide and sodium oxide to react with the third compound of the mixture, silicon dioxide, forming alkaline silicate ("glass"), which is a safe, stable, and won't produce a fire.



The nylon bag actually has small holes in it and will deflate soon after inflating to allow the passenger to escape the accident.

**Materials:** Zip lock bag, balance, graduated cylinder, weigh boat, baking soda ( $\text{NaHCO}_3$ ), vinegar (0.09 M  $\text{HC}_2\text{H}_3\text{O}_2$ ), and if you need additional materials ask your teachers.

**Procedure:** Each group designs their own procedure.

**Challenge:** Your task is to simulate the construction of an air bag using a ziplock bag, baking soda ( $\text{NaHCO}_3$ ), and vinegar ( $\sim 0.09 \text{ M HC}_2\text{H}_3\text{O}_2$ ). You may use a balance, weigh boat, and a graduated cylinder.

## Construction of Air Bags

Your task is to mix the reagents in the bag to inflate but **not** burst the bag. The best design will be one that fills the bag with enough gas so that you can not pinch the bag in the middle and have both side touch. When you are ready to test your bag, consult your teacher.

### Things to include in your procedure:

How will you get both reagents in side the bag without loosing gas? If you need other materials for your procedure, check with your teacher. Write your plan showing all calculations and have it initialized by your teacher before beginning. You may do some preliminary testing but you must write them up and have the teacher initialize. The teacher's initials mean that it is safe, not that it is the correct method.

### Paper Work

Your notebook should include a well-designed plan, changes you made after the first trial, and results. Include a discussion of your experiences.

### Teacher note:

Students should have learned stoichiometry and gas laws before being expected to conduct this lab.

It is always interesting to add extra materials to stations to see what students may elect to do with them.

### Follow-up questions for discussion:

Did you have one reagent in excess? If so, which reagent and why did you select that one?

How did you find the volume of the bag to do your calculations?

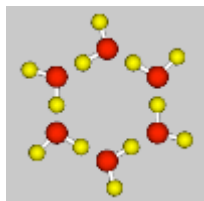
Did you consider the volume displaced by the reagents? Does that make much difference?

Was the reaction endothermic or exothermic? Did you consider the temperature? What effect did that have?

How did you get both reagents inside the bag before the reaction started?

### HONORS

- If your have one reagent in excess, determine the limiting factor in your reaction and explain why you elected to have that reagent in excess.
- Baking soda costs 39 cents a box and the vinegar was \$1.49 a quart. Write up a procedure for the most cost effective airbag.
- You may add Standard Thermodynamic Data to determine the amount of energy involved in these reactions to include more concepts in this test. (it is endothermic which usually surprises students)



***Limiting Factors: Copper Chloride and Aluminum Single Replacement Reaction***

**Learning Objectives:**

To revisit the  $\text{CuCl}_2 + \text{Al}$  reaction observed in an earlier demonstration in order to reinforce the students' understanding of limiting factors in a chemical reaction.

**Standards:** 1.01, 3.03

**Skills:** Quantitative measurement, data recording, stoichiometric calculations

**Strand:**

**Safety Precautions:** Safety goggles should be worn at all times during this lab. Wash your hands thoroughly before leaving lab.

**Science Concepts:** single replacement reactions, limiting factors

**Materials:** Squares of Al foil (of approx. 0.27g mass), 2-250 mL beakers, 100.0 mL 0.100 M  $\text{CuCl}_2$  solution, 100.0 mL 0.200 M  $\text{CuCl}_2$  solution, balance, 100 mL graduated cylinder, stirring rod, water

**Procedure:**

4. Mass 2 pieces of aluminum foil each having a mass of 0.27 grams. Record the exact mass of each piece.
5. Label a 250 mL "A" and a second beaker "B".
6. In beaker "A" pour 100.0 mL of 0.200 M  $\text{CuCl}_2$  solution.
7. In beaker "B" pour 100.0 mL of 0.100 M  $\text{CuCl}_2$  solution.
8. Tear one piece of the foil in small pieces and place in beaker "A". Stir and record your observations. Take your time and feel the outside of the beaker. Describe color changes. What does the final product look like?
9. Add the second piece of Al foil (also torn into pieces) to beaker "B" and record your observations as you did for step 5.

**Teacher notes:**

The mass of the Al foil squares need only be approximate. Once you have one with a mass of approximately 0.27g, cut others to be the same size (you need not mass them all). You will need 100 mL of each  $\text{CuCl}_2$  solution per lab station, make up some extra to account for spills. If students don't start with balanced equations they may think Al and  $\text{CuCl}_2$  are the same in the 0.1M solution.

### References:

### Lab Follow-up Questions

Name \_\_\_\_\_

### Limiting Factors: CuCl<sub>2</sub> + Al Single Replacement Rxn

5. Write a paragraph describing how the two reactions results are different. Why do you think the resulting mixture looks different?)
  
  
  
  
  
  
  
  
  
  
6. Write a balanced **ionic** equation for the reaction between aluminum and copper chloride solution.
  
  
  
  
  
  
  
  
  
  
7. If you used 0.2500 g of aluminum and 100 mL of 0.2000 M CuCl<sub>2</sub>, what is the limiting factor? (answer this questions 2 ways – one , what would you expect to visually observe and secondly by calculations)
  
  
  
  
  
  
  
  
  
  
8. If you used 0.250g of aluminum and 100 mL of 0.100 M CuCl<sub>2</sub>, what is the limiting factor? (answer this questions 2 ways – one by visual observations and secondly by calculations)



## *Heat of Solution*

**Learning Objectives:**

To learn the theory and practice of calorimetry, investigate the thermochemistry of dilute salt solutions, and experimentally determine the heats of solution for various salts

**Standards:** 1.01, 4.02

**Skills:** Use of the calorimeter, quantitative measurement

**Strand:**

**Safety Precautions:** Safety goggles should be worn at all times during this lab. Wash your hands thoroughly before leaving lab.

**Science Concepts:** Heat transfer, calorimetry, and heat of solution

**Materials:**

Balance, Weigh boats, Spatula, Coffee cup calorimeter, Thermometer, Pipet bulbs, Beaker(s), Erlenmeyer flask(s), Volumetric flask(s), Graduated cylinder(s), Pipet(s), Hot Plate, Deionized water, Ice,  $\text{NH}_4\text{Cl}$ ,  $\text{NH}_4\text{NO}_3$ ,  $\text{KC}_2\text{H}_3\text{O}_2$ ,  $\text{KCl}$ ,  $\text{KI}$ ,  $\text{LiCl}$ ,  $\text{NaC}_2\text{H}_3\text{O}_2$ , and  $\text{NaC}_2\text{H}_3\text{O}_2 \cdot 3\text{H}_2\text{O}$ .

**Procedure:**

In the study of thermodynamics a number of different types of "heat" are discussed. Heats of solution, heats of formation, heats of fusion and heats of vaporization are just a few of the types of energy transfers that are studied. In this experiment your research team will use calorimetry to investigate the heats of solution of various salts. In a later experiment, your team will use the data from this experiment to design, with marketability in mind, a hot or cold pack using the heats of solution determined in the first half of this experiment.

By surrounding the "system" being studied (the substance that is dissolving) in the water, we can indirectly measure how much energy the dissolving substance either gives off or takes in. If the dissolving substance gives off energy, then the temperature of the surrounding water should increase, but if the dissolving substance takes in energy then the temperature of the surrounding water should decrease.

When a chemical process such as dissolution occurring in an aqueous environment is carried out in a calorimeter, the substance dissolving is considered to be the "system." Both the water containing the substance and the calorimeter itself are considered to be the "surroundings." For the purposes of this lab, we will assume that the amount of heat absorbed by the calorimeter itself is negligible. Therefore, the heat change for the surroundings can be calculated from the mass of the solution in the calorimeter ( $m$ ), the heat capacity of the solution ( $s$ ), and the change in temperature of the solution ( $\Delta T$ ) by the following equation:  $q_{\text{surroundings}} = ms\Delta T$

## Heat of Solution

Remember that the heat change for the system must be equal in magnitude but opposite in sign to that for the surroundings:  $q_{\text{system}} = -q_{\text{surroundings}}$

In other words, **the heat that is lost by the system must be gained by the surroundings**, or of course if the system takes in heat energy, it must be taken from the surroundings. Assume that the specific heat of the solution is the same as pure water,  $4.184 \text{ J/g}^\circ\text{C}$

Design and carry out an experiment to determine the **molar heat of solution** (the amount of energy that is released/absorbed when one mole of a salt dissolves in water) for one of the salts listed in the materials section. Your teacher will assign your salt. Use no more than 0.5 g of salt per trial! After your group has determined the molar heat of solution for your salt, enter the average value for your salt into the class data table for later use.

### Analysis:

1. Describe in detail the experiment that your group conducted to determine the molar heat of solution of your assigned salt. What were the resulting values that you found? How do they compare to the other experimental values entered into the class data table?

### Teacher notes:

Each lab group should have one coffee cup calorimeter consisting of two Styrofoam coffee cups (one inside the other) with a lid that has a hole for a thermometer. The lid can be made with a third Styrofoam coffee cup, cut to a height of around 2" or so and turned upside down.

### References:

This experiment is based on one presented in the following lab manual:  
Anderson, Misti Ault and Todd E. Woerner. General Chemistry Laboratory Manual: Chemistry 22L.  
Hayden McNeil Publishing, Inc., Plymouth, MI. 2003

**Extension for honors classes:**

Develop a method to determine the calorimeter constant,  $W$ . *Every calorimeter has a unique  $W$  value so it is important that you determine the  $W$  for your calorimeter each day.*

If the temperature of the solution inside the calorimeter increases, some heat will be absorbed by the calorimeter; while it is an effective insulator, it is not perfect. The amount of heat absorbed by the calorimeter can be determined by finding the calorimeter constant,  $W$ .

Consider mixing two quantities (known volumes) of water that are at different, but known, temperatures. Since you will be looking for any heat lost to the container, consider starting with water in the calorimeter that is at the same temperature as the calorimeter itself and then adding water at a higher temperature.

If the heat lost from the hot water [ $m_2s(T_2-T_e)$ ] is exactly equal to the heat gained by the cold water [ $m_1s(T_e-T_1)$ ] then the calorimeter constant would be zero since all energy would be accounted for. But if the calorimeter absorbs some heat then:

$$W = \frac{m_2s(T_2-T_e) - m_1s(T_e-T_1)}{(T_e-T_1)} \quad \begin{array}{l} \text{(difference between heat lost and heat gained)} \\ \text{(}\Delta T \text{ of cool water)} \end{array}$$

Where  $m_2$  = mass of hot water,  $s$  = specific heat of water,  $T_2$  = temperature of hot water,  $T_e$  = equilibrium temperature,  $m_1$  = mass of cold water,  $T_1$  = temp of cold water. Keep in mind that your calorimeter constant ( $W$ ) should be positive.

When choosing the temperature for your the hot water, keep in mind that you don't want it to be too much higher than the room temp or you "heat-up" your calorimeter for the remaining experiments. If you do, you will need to allow the calorimeter to return to room temperature before proceeding.

**Phase change Demonstration**

**Solid**



**Liquid**



**Gas**



**Mixture**



Solids have regular arrangements and molecules are close together.

Add energy by shaking the box and the molecules bounce around and are further apart.

If you add even more energy and molecules will bounce out of the box if you don't have a top on the box.

To illustrate distillation, color some of the balls and make them heavier (I used a syringe and add water). When you add energy by shaking the box more of the white balls will 'evaporate' leaving more dark molecules in the box. However, some dark balls will 'evaporate' illustrating that it is very difficult to get a pure separation.

## ***Decomposition of Sodium Hydrogen Carbonate***

**Learning Objectives:** Students will design an experiment to investigate the changes that take place when sodium hydrogen carbonate is heated and to identify its decomposition products. This is a **qualitative** laboratory activity, meaning students will identify the products, not determine how much of each product is produced.

**Standards:** 1.01 (Design, conduct & analyze investigations to answer chemistry questions)  
5.01 (Identify various types of chemical reactions)  
5.03 (Identify the indicators of chemical change)

**Skills:** Developing testable hypotheses, experimental design, the use of identifying chemical tests, writing and balancing equations

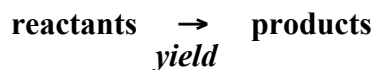
**Strand:** Science as Inquiry

**Safety Precautions:** Take care to avoid burns from the Bunsen burner.

### **Teacher Background Information:**

This lab may be used as an open inquiry lab or an example research. If it is used as a research project, students should do the prelab and have some discussions regarding hypothesis testing. If used as inquiry, remove some of the outline and give students the lists of tests and research question.

One of the characteristics of a chemical change is that new and different substances are formed having chemical characteristics different than the starting materials. Equations can be written for the chemical change, usually in the form:



Some reactions take place spontaneously while others require energy to take place (i.e. heat, light, or electrical energy). Many substances decompose upon heating. Decomposition may yield two or more smaller molecules. These molecules may be gases, liquids, or solids. As heat is absorbed, the substance becomes increasingly unstable and at some temperature the bonding forces are overcome and decomposition occurs. The temperature required for decomposition depends on the stability of the substance. An example you are familiar with is the decomposition of sugar. Heating sugar (sucrose) in the presence of oxygen causes it to decompose.

Sodium hydrogen carbonate (sodium bicarbonate), commonly known as baking soda, will decompose when heated. This decomposition may yield two or more smaller molecules and will result in new solids, liquids, and/or gases. Complete decomposition of the entire sample requires continued heating.

**Research question:** What are the decomposition products formed by heating sodium hydrogen carbonate?

**Hypothesis:** A hypothesis is a guide for the research. Each hypothesis should be a testable statement such as, "The decomposition of sodium hydrogen carbonate will yield oxygen." You should formulate as many hypotheses that are necessary to write a complete equation for the decomposition of sodium hydrogen carbonate.

**Materials:**

Bunsen burner, 500-mL beaker, large test-tube with stoppers/glass tube/rubber hose, 3 small test tubes, test tube rack, test tube clamp, wooden splints, lime water, cobalt chloride paper, 1. M HCl, 0.3M barium chloride, and NaHCO<sub>3</sub>

**Procedure:** Design an experiment to test each hypothesis. Consult your lab notebook for methods of identifying compounds. The Pre-lab questions provide strong hints as to which test you may wish to perform. You should begin with approximately 3 cm of sodium hydrogen carbonate in a test tube. See the video tape to familiarize yourself with proper methods of conducting each test. Water displacement is the best method of collecting gases for analysis. See the video for instructions on how to collect gases by water displacement. If the neck of your test tube is cool, water may condense on the glass. That would be the best source of water to test. If it isn't cool use the cold mirror test. You may wish to bubble the gas directly into the lime water when you test for carbon dioxide.

**Conclusions:** For each hypothesis you should have a conclusion. The only acceptable conclusions are: "data support the hypothesis that .....", "data reject the hypothesis that .....", or "the data are inclusive to support or reject the hypothesis ....."

In your discussion you should address your errors, ways to improve your method, and the overall equation of the decomposition of sodium hydrogen carbonate.

**Teacher notes:**

Place on each table straws, limewater, beakers, cooled test tubes, and cobalt chloride paper. When students breathe into a test tube water will condense on the sides. Test this condensation with cobalt chloride paper.

Teacher Directed tests:

Take the solid product and test for CO<sub>3</sub><sup>2-</sup> - discuss the problem of incomplete decomposition. The pH of the final residue can be compared to that of pure NaHCO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, and Na<sub>2</sub>O.

Set-Up

10 - 500 mL beakers  
10 - large test-tube with stoppers/glass tube/rubber hose  
30 small test tubes  
10 test tube racks  
10 test tube clamps  
3 green capped bottles labeled NaHCO<sub>3</sub>  
3 beakers with wooden splints  
3 reagent bottle labeled lime water  
Dessicator containing cobalt chloride paper  
3 dropper bottles of 1. M HCl  
3 dropper bottles of Barium Chloride .3M solution

**References:** list any/all references for this experiment

**Prelab Activity**

**Name** \_\_\_\_\_

**Decomposition of  $\text{NaHCO}_3$  Lab**

1. Make a list of the chemical formulas for **all** the possible products you think might possibly result when  $\text{NaHCO}_3$  is decomposed by heating. These may be solids, liquids, or gases. By each product specify if it will be solid, liquid, or gas at room temperature.
  
2. List the molecule(s) or ion(s) that you might test for. Use the reactions described in your notebook, "Identification Test for Chemical Compounds", to help you.

**TEST CHEMICAL**

**TEST FOR**

Lime Water

\_\_\_\_\_

Wood Splint

\_\_\_\_\_ & \_\_\_\_\_

Cobalt Chloride Paper

\_\_\_\_\_

Barium Chloride

\_\_\_\_\_

Hydrochloric Acid

\_\_\_\_\_

## **Prelab Activity - Decomposition of NaHCO<sub>3</sub>**

When a chemical reaction occurs new products are formed. These products may be solid, liquids, or gases. You are given a list of tests that chemist use to identify some substances. Your task today is to identify the gases that you exhale. Use the materials on your table to identify at least two gases you exhale.

### **IDENTIFICATION TEST FOR CHEMICAL COMPOUNDS**

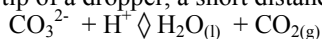
#### **SOLIDS**

##### ***Dissolving your sample***

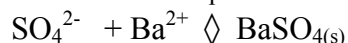
First try dissolving your sample in cold then hot water. If your sample does not dissolve try a 6 M acid solution. Observe closely to determine if the sample is dissolving or reacting. Make sure you note the formula for the acid you use. (If you use sulfuric then you will get a positive test for sulfates etc.)

#### **ANIONS**

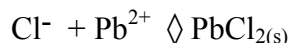
**Carbonates** react with acids to evolve CO<sub>2</sub> gas. To confirm the gas as CO<sub>2</sub> react with Ba(OH)<sub>2</sub> solution to form a white precipitate of BaCO<sub>3</sub>. Test the escaping gas by holding a drop of barium hydroxide solution, suspended from the tip of a dropper, a short distance from the escaping gas.



**Sulfate ion** – Make a solution of your salt. If it doesn't appear to be soluble try dissolving in a swater acidify with 6 M HCl. Add a drop of 0.2 M BaCl<sub>2</sub>. A white precipitate indicates the presence of sulfate.



**Chloride ion** - to a near neutral solution of your sample add a few drops of 1 M Pb(NO<sub>3</sub>)<sub>2</sub>. A yellow precipitate indicates presence of chloride ions.



**Phosphate ion** - place a sample of the solid in a test tube, add about 1 mL of distilled water, and stir to dissolve the sample. Add 1 mL of 6 M NH<sub>3</sub> and 1 mL of MgCl<sub>2</sub>/NH<sub>4</sub>Cl reagent. Stir. A positive test is the formation of a white precipitate of MgNH<sub>4</sub>PO<sub>4</sub>

**Nitrate** - place a sample of the solid in a test tube, add about 1 mL of distilled wter, and stir to dissolve the sample. Add 2 drops of 3 M H<sub>2</sub>SO<sub>4</sub> and 5 drops of FeSO<sub>4</sub>. Stir. Lay the test tube in a small beaker at a 45° angle. Slowly add 10 drops of **concentrated** H<sub>2</sub>SO<sub>4</sub> **\*\*Caution\*\***. Allow the drops to run down the side of the tube so as to form a separate layer below the aqueous layer. A faint brown ring at the interface indicates the presence of nitrate. (Nitrites also give this result)

#### **CATIONS**

##### **Aluminum**

Dissolve the sample and add a few drops of aluminon to the solution. A red color indicates the presence of aluminum.

##### **Calcium**

Dissolve sample. If you had to use acid to dissolve the sample add 5M  $\text{NH}_4\text{OH}$ , carefully, until it is slightly basic. Add 1 drop of 0.20 M  $(\text{NH}_4)_2\text{C}_2\text{O}_4$  (ammonium oxalate). Formation of a white precipitate ( $\text{CaC}_2\text{O}_4$ ) indicates calcium is present. Save the decantate for the Magnesium test. More evidence - dissolve the precipitate in 6M HCl and run a flame test. A orange red flame further confirms the presence of calcium

### Lead

Dissolve sample in hot water. Add several drops of 1.0 M of KI to the decantate. A yellow precipitate,  $\text{PbI}_2$ , indicates the presence of lead.

### Magnesium

Dissolve your sample. To the decantate add 1 drop of 5 M aqueous  $\text{NH}_3$  and 4 drops of 0.2 M  $\text{NaHPO}_4$ , mix well, warm gently and allow to stand for 1 minute. A white precipitate ( $\text{MgNH}_4\text{PO}_4$ ) indicates the presence of magnesium.

More evidence - Wash the precipitate 3 times with hot water, dissolve in 2-3 drops of 2 M HCl, and add 3 - 4 drops of magnesium reagent\*, Then add 8 M NaOH, with constant mixing, until the solution is distinctly alkaline and centrifuge, but do not decant. A blue lake proves the presence of magnesium.

\* magnesium reagent - dissolve 0.1 g of p-nitrobenzeneazoresorcinol [also called 4 p-(nitrophenylazo)resorcinol or 2,4 dihydroxy-4-nitroazobenzene] in 1000 mL of 0.025 M NaOH.

### Iron

Dissolve a small sample of the sample in 10 - 15 drops of 6 M HCl. Add 1 or 2 drops of 0.2 M KSCN. A blood red solution due to  $\text{Fe}(\text{SCN})_6^{3-}$  indicates the presence of iron.

Other evidence:

Add a few drops of  $\text{K}_4\text{Fe}(\text{CN})_6^{4-}$  to a solution of your sample. A dark blue precipitate indicates  $\text{Fe}^{3+}$ .

add a few drops of  $\text{K}_3\text{Fe}(\text{CN})_6^{3-}$  to a solution of your sample. A dark blue precipitate indicates  $\text{Fe}^{2+}$ .

### Flame Tests

Barium - yellowish green

Calcium - Yellowish Red (greenish through blue glass, green through green)

Lithium - Carmine Red (violet through blue glass, invisible through green)

Potassium -Violet (purple red through blue glass, blue-green through green)

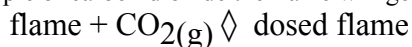
Sodium - Yellow (invisible through blue glass)

Strontium - Scarlet Red (violet through blue glass, yellow through green)

## GASES

### Carbon Dioxide

When you are testing gases, the wooden splint test is the quickest test to conduct. If you stick a burning splint into a sample of carbon dioxide the flame will go out.



This does **not** confirm carbon dioxide only indicates oxygen and hydrogen are not present. You must test for the presence of carbon dioxide.

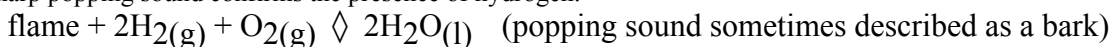
If  $\text{CO}_2(\text{g})$  is added to a sample of water the following series of reactions will take place to produce some  $\text{CO}_3^{2-}$  ions. As a result, aqueous solutions having dissolved  $\text{CO}_2(\text{g})$  and  $\text{Ca}^{+2}$  ions will react in the following way.

- $\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \diamond \text{H}_2\text{CO}_3(\text{aq})$
- $\text{H}_2\text{CO}_3(\text{aq}) \diamond \text{H}^+(\text{aq}) + \text{HCO}_3^{-1}(\text{aq})$
- $\text{HCO}_3^{-1}(\text{aq}) \diamond \text{H}^+(\text{aq}) + \text{CO}_3^{-2}(\text{aq})$
- $\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \diamond \text{CaCO}_3(\text{s})$  (a white solid)

To test for carbon dioxide, bubble the gas through a saturated lime water [Ca(OH)<sub>2</sub>] solution. The formation of a white precipitate confirms that the gas is carbon dioxide. A variation of this test is to hold a drop of either Ca(OH)<sub>2</sub> or BaCl<sub>2</sub> solution just above the opening where the gas is effusing. The drop of solution will become cloudy if the gas is carbon dioxide.

### Hydrogen

Hydrogen reacts with the oxygen in the air and produces a popping sound. To test for hydrogen, collect a small test tube of hydrogen by water displacement. Remove the test tube from the water. Hold the test tube inverted until you have a lighted wooden splint in your hand. While the wooden splint is still flaming, stick the splint into the test tube. A sharp popping sound confirms the presence of hydrogen.



### Oxygen

Oxygen promotes burning of a wooden splint. To test for oxygen, collect the gas by water displacement. Light a wooden splint. Blow out the flame of the splint and quickly stick the smoldering splint into the test tube containing the gas. If the splint ignites again, oxygen is present in the gas.



### Liquid

#### Water

Cobalt chloride paper will turn from blue to pink indicating the presence of water. To test for water, touch the tip of the cobalt chloride paper to the liquid sample. If the blue paper turns pink, water is present. (You can make your own test paper by soaking strips of filter paper in CoCl<sub>2</sub> solution, dry in an oven and keep in a desiccator)



(blue)

(pink)





# **Honors Chemistry Support Documents 2004 Curriculum**

**Public Schools of North Carolina**

**Curriculum Support**  
**for the 2004 revision of the**  
***North Carolina Standard Course of Study for***  
**Honors Chemistry**

**Acknowledgements**

This document was developed in response to the expressed needs of the honors chemistry science teachers for materials to enhance the teaching of the revised North Carolina Standard Course of Study for Science. The materials provide a guide for translating the goals and objectives of the chemistry science curriculum into good instructional design.

A group of dedicated and talented science teachers spent many hours developing these materials. The result is this resource that will facilitate the implementation of the North Carolina Science Curriculum.

A special thanks to the authors of these materials:

*Leslie Benson – Newton-Conover High School*

*Rod Bost – Alleghany High School*

*Dayne Chester – Alexander Central High School*

*Connie Johnson – Vance County*

*Jeffrey LaCosse, Ph.D. – South Granville School of Health and Life Science*

*Mike Leonowicz, Ph. D. – Teacher Link*

*Mike Luther – A.L. Brown High School*

*Thea Sinclair – St. Stephens High School*

*Ralph Smith – Wayne County*

We would like to extend a special thanks to Sam Houston, The North Carolina Science, Mathematics and Technology Education Center, the Teacher Link Fellows and The Burroughs Wellcome Fund for their generous support during the development of these materials.

We would also like to thank the many other people who contributed to this document by attending meetings and commenting on these documents.

We make every effort to keep these materials accurate and up to date. Check the Department of Public Instruction's website <http://www.ncpublicschools.org/curriculum/science/scos/> for current versions.

**Honors Chemistry Curriculum Support**  
**For 2004 revision of the *NC Standard Course of Study* in Chemistry**

**Table of Contents**

<a href="#">Honors Science Courses</a> .....	82
<a href="#">Honors Chemistry</a> .....	85
<a href="#">Honors Chemistry Objectives</a> .....	86
Activities and Labs	
<a href="#">Accident at Snow Creek Bridge</a> .....	88
<a href="#">Additional Teacher Background Information</a> .....	92
<a href="#">Lab Report Grade Sheet</a> .....	94
<a href="#">Lab Investigation Rubric</a> .....	95
<a href="#">Exhibit A</a> .....	97
<a href="#">Exhibit B</a> .....	98
<a href="#">Turning Iron Into Copper</a> .....	100
<a href="#">Why Stuff Happens</a> .....	106

## Honors Courses in North Carolina: Science

### Honors Science Courses

Course descriptions for the following high school science honors courses: Honors Biology, Honors Chemistry, Honors Earth/Environmental Science, Honors Physical Science and Honors Physics are included in this document. Local school districts may also develop local honors versions of such courses as Anatomy and Physiology or Molecular Genetics. All of the honors science courses share the following characteristics and assumptions:

- Students enrolled in honors courses will learn the material in the standard course of study for the course at greater depth than in the standard level version of the course. The support documents for the course include appropriate honors extensions by objective.
- Students enrolled in the honors version of the course will take the same EOC as students enrolled in the standard level version of the course.
- Students who choose an honors science course are expected to work more independently than students in standard level courses.
- Because students can be expected to cover the standard level material more independently there will be time for more enrichment topics as specified in the course descriptions for specific honors courses.
- Students who choose an honors science course will be expected to complete more independent in-depth scientific investigations and to report on them using a more formal scientific laboratory report format.
- Students who choose an honors science course will be expected to read and present orally and in writing recent scientific findings.

Many of the materials and activities suggested for honors courses will also be appropriate for some students enrolled in standard level versions of the course. The difference may be in the level of independence expected of students and the amount of time activities may take. All students, not just those in honors courses, should experience challenging work and some level of independent inquiry in their science courses. Teachers should include some of the enrichment topics for all students.

### Definition of Honors Science Courses

Honors science courses are designed to demand more challenging involvement than standard science courses. They must be demonstrably more challenging than standard courses and provide multiple opportunities for students to take greater responsibility for their learning. Honors science courses should be distinguished by a difference in the quality of the work expected rather than merely by the quantity of the work required.

### Purposes of Honors Science Courses

Honors science courses should be designed for students who have demonstrated an advanced level of interest and achievement in a given subject area. The rationale for honors courses is not to provide a means to attract students to enroll in classes for additional credit, but rather to offer challenging, higher level courses for students who aspire to an advanced level of learning. Furthermore, students and parents should be

informed that honors science courses are more demanding and have requirements beyond those of standard science courses.

Honors courses should be developed as an integral component of a differentiated program of study that provides an array of opportunities for all students based on their aptitudes, affinities, and interests. A well developed science program will have both standard and honors courses.

### Characteristics of Honors Science Courses

Honors science courses will address the same goals and objectives as the corresponding *NC Standard Course of Study*; however, they should address the content with greater complexity, novelty, acceleration, and/or pacing. Honors science courses should reflect a differentiation of curriculum, both in breadth and depth of study. Honors science courses should exemplify the following characteristics:

- Require a higher level of cognition and quality of work than the standard course
- Enable students to become actively involved in classroom and laboratory learning experiences
- Involve students in exploratory, experimental, and open-ended learning experiences

Honors science courses should provide opportunities for the following:

- Problem-seeking and problem-solving
- Participation in scholarly and creative processes
- Use of imagination
- Critical analysis and application
- Personalized learning experiences
- Learning to express/defend ideas
- Learning to accept constructive criticism
- Becoming a reflective thinker
- Becoming an initiator of learning

### Essential Questions

Essential questions are designed to focus attention on main ideas. They are used in honors courses to prompt thinking and spark discussion of key elements within a larger context. Essential questions are helpful in working through the steps in problem-solving, planning, and decision making processes.

Essential questions reflect the most historically important issues, problems and debates in a field of study. In the sciences, essential questions should be used to help students make connections across particular disciplines such as biology and chemistry to the larger unifying concepts of science as well as to focus on essential questions within disciplines. For example, How do genes and the environment interact to produce a phenotype? and How does the periodic table help us to predict physical and chemical properties of an element? Are essential questions within their particular disciplines? What other explanations could account for this data. and How can we measure that? are essential questions that are in all of the sciences. By examining such questions, students engage in higher order thinking. Essential questions are open-ended with no single, correct answer.

## Honors Science Courses

They are meant to stimulate inquiry, debate and further questions, and can be reexamined over time. They are designed to be thought provoking to students, engaging them in sustained, focused inquiries, culminating in meaningful performances (McTighe & Wiggins, 2004).

Instructors of honors science courses are expected not only to pose essential questions to the students, but also to guide students in generating their own essential questions. The Honors Science Portfolio should include a list of essential questions with specific indications of how these essential questions are to be used in the honors class. Examples of essential questions appear in the Science Examples Section.

### Honors Chemistry

Honors Chemistry is an accelerated comprehensive laboratory course designed to give the students a more conceptual and in-depth understanding of the concepts in the *North Carolina Standard Course of Study* in Chemistry. In Honors Chemistry students are expected to work independently on a variety of assignments and accept greater responsibility for their learning. The course will include the additional Honors objectives and an in-depth study of at least two of the listed enrichment topics. Students will design and complete at least one in depth independent study of chemistry directed questions. The curriculum will integrate inquiry and technology to explore the world of chemistry.

Honors Chemistry is intended to be a tenth or eleventh grade course for students accelerated in mathematics. Success in Honors Chemistry will require the student to: 1) operate with algebraic expressions to solve problems using direct, inverse, combined, and joint variation, 2) use logarithms and exponents to solve problems, and 3) describe graphically, algebraically and verbally real-world phenomena as functions and identify the independent and dependent variables.

The *North Carolina End-of-Course Test of Chemistry* is required to receive credit for this class. Students may not take Honors Chemistry in addition to standard level *Standard Course of Study* Chemistry.

**Enrichment topics:** In depth study of **at least two** of the following eight enrichment topics is required in addition to the extended objectives listed below.

1. Crystal structure
2. Environmental Chemistry
3. Organic Chemistry
4. Nuclear medicine
5. Textile chemicals
6. Polymers
7. Forensics
8. Chemistry of computers

## Honors Chemistry Objectives

**Honors Objectives:** The following objectives are extensions of those in the 2004 revision of the *Standard Course of Study* for Chemistry. The numbers are to show placement in the *Standard Course of Study*.

<b>1.02-1 H</b>	Design, conduct and evaluate independent scientific investigations. <ul style="list-style-type: none"> <li>⊖ Evaluate student-generated hypotheses related to questions in chemistry by designing and carrying out independent investigations.</li> <li>⊖ Relate the investigation(s) to current issues in chemistry (or research)</li> <li>⊖ Prepare formal written lab reports with extensive analysis of data and sources of error.</li> <li>⊖ Present findings to members of the community.</li> <li>⊖ Develop creative approaches to chemistry topics.</li> </ul>	<a href="#"><u>Accident at Snow Creek Bridge</u></a>
<b>2.01-1 H</b>	Apply quantum numbers to electron configurations.	
<b>2.02-1 H</b>	Analyze (calculate) average atomic mass from relative abundance and actual isotopic mass.	
<b>3.03-1 H</b>	Evaluate reactions to determine limiting reactant and percent yield.	<a href="#"><u>Turning Iron into Copper</u></a>
<b>4.02-1 H</b>	Summarize energy changes within a reaction to determine heats of reaction.	
<b>4.03-1 H</b>	Predict spontaneity by the use of Gibbs Free Energy.	<a href="#"><u>Why Stuff Happens</u></a>
<b>5.05-1 H</b>	Analyze redox reactions by balancing via half reaction method or electron transfer method.	

**NOTE: Objective 1.02-1 H**

**What does independent mean when the honors science document says students should do "independent investigations"?**

**Answer:** Independent does **NOT** mean unsupervised!!!! Teachers must still provide appropriate supervision at all stages. Teachers should give choices of topics or have a process in place for topic review and approval. Teachers may need to provide some assistance to students in finding appropriate sources for background reading. Teachers should always review experimental design carefully for safety reasons and to be sure the experiment will provide an appropriate learning experience. Actual laboratory work

## **Honors Chemistry Objectives**

should also be supervised. Younger and less experienced students will need more scaffolding to make this a productive learning experience.

## “Accident at Snow Creek Bridge”

### Targeted Standard Course of Study Goals and Objectives:

- 1.02-1H: Design, conduct and evaluate independent scientific investigations.
- Evaluate student-generated hypotheses related to questions in chemistry by designing and carrying out independent investigations.
  - Relate the investigation(s) to current issues in chemistry (or research)
  - Prepare formal written lab reports with extensive analysis of data and sources of error.
  - Present findings to members of the community.
  - Develop creative approaches to chemistry topics.
- 1.03: Evaluate experimental designs with regard to safety and use safe procedures in laboratory investigations:
- Identify and avoid potential safety hazards given a scenario.
  - Differentiate between safe and unsafe procedures.
  - Use information from the MSDS (Material Safety Data Sheets) to assess chemical hazards.
- 5.04: Assess the physical and chemical properties of acids and bases.
- General properties of acids and bases.
  - Concentration and dilution of acids and bases.
  - Ionization and the degree of dissociation (strengths) of acids and bases.
  - Indicators.
  - Acid-base titration.
  - pH and pOH.

### Essential Questions:

- 1) How much water is needed to raise the pH of a strong acid by one pH unit?
- 2) What is the impact of pH on various organisms and life?
- 3) Does pH have an affect on man-made materials?
- 4) How are organisms used as “bioindicators”?

### Introduction to Teacher:

#### Position in Pacing Guide

Acids and bases are studied near the end of the course in Honors Chemistry. Due to the long-term nature of this investigation, the placement must allow for at least a full week of data gathering after the problem has been presented, ideas generated and evaluated and the plan (experiment) designed.

## Honors Chemistry Support *Accident at Snow Creek Bridge*

Students should have a 90- minute class learning about the properties of acids and bases and theories of Arrhenius, Bronsted-Lowry and Lewis.

This plan requires four 90-minute classes, and then about 15 minutes for 5 more days to collect data. Students will write the report at home, and an additional 20-30 minutes are required for a final discussion/resolution.

### **Teacher Material**

Accident at Snow Creek Bridge—A lesson in Creative Problem Solving

**Day 1:** *Teacher presents the following scenario to the class—Modify for your particular county/waterway.*

You are the Director for Emergency Services for Catawba County. It is 6 AM, December 6, and the phone rings. You are told “Come to the bridge over Snow Creek on Snow Creek Road. There is a major accident and you are needed.”

Quickly you dress and get to the site of the accident. As you approach the bridge, you see an overturned tanker truck that has crashed through the metal guard rail. The cab



is wrapped around a tree, and on the rear of the truck you see the symbol

There is a gash on the side of the tank and a clear liquid is running from the gash down the side of the truck, into the road and down the bank into the creek. Firemen, sheriff deputies and emergency rescue workers are at the scene. They are all wearing coveralls and masks. The rescue squad is putting the unconscious driver of the truck into a stretcher. Everyone seems hurried and anxious. A deputy hands you a soggy shipping manifest found on the front seat of the cab (Exhibit A)

*The teacher will put up the following overhead and students will generate ideas by calling out items for columns on the “Need to Know” chart.*

What do we know?	What do we need to know?	How can we find it out?
------------------	--------------------------	-------------------------

**Homework**—Answer questions under what we need to know. Use the Internet, your text, other materials and bring the answers to class tomorrow. (Some topics that must be addressed are the MSDS information for hydrochloric acid, wind patterns, flow rate of Snow Creek, distance to Lake Hickory from accident site, volume of Snow Creek, water volume of Lake Hickory, importance of Lake Hickory for drinking water, rare or endangered organisms in the area).

**Day 2: Part 1-** Have students report on the information they found overnight, shifting the questions from “What we need to know” to “What do we know?”

*Questions teacher might ask*

- What questions are answered by the new information?
- What questions do we still need to answer?
- What new questions do you have?
- What are the effects of acid on aquatic plants? Aquatic animals? Manmade materials like steel and concrete?
- Where does Snow Creek flow? How fast does it flow?

**Honors Chemistry Support**  
***Accident at Snow Creek Bridge***

- Is the problem different today than it was yesterday?
- What are things we still need to know to solve the problem?
- What strategies should we use?

***Web Resources (Locate web resources pertinent to your area.)***

<http://www.hickorygov.com/publicdocs/masterplans/Woolpertfinal/appendix.htm>

[http://www.ncfloodmaps.com/pubdocs/catawba\\_basin\\_plan\\_fact\\_sheet.pdf](http://www.ncfloodmaps.com/pubdocs/catawba_basin_plan_fact_sheet.pdf)

<http://www.dukepower.com/community/lakes/cw/library/plans/Terrestrial%2001%20Wetland%20Mapping%20and%20Characterization%20Draft%20Report.pdf>

**Day 2:Part 2**—*Demonstrate how to use a burette. Use pH probe software to determine the pH of a solution. Show how much water is needed to raise the pH of a strong acid by one pH unit.*

**Lab—Neutralization of an acid:** Students will learn to use a burette to perform a titration. Given an unknown concentration of hydrochloric acid, students will titrate it with a strong base until an endpoint is reached. Students will perform 3 titrations and find the average molarity of the HCl.

*(Two possible solutions to the problem can be inferred from the demonstration and lab. One is diluting the acid to raise the pH and the other is adding an alkaline substance such as lime to raise the pH.)*

**Day 3:** Distribute copies of the email from the Friends of the Catawba River (Exhibit B). List what possible effects HCl could have on plants, animals, humans and manmade materials.

Brainstorm what the Department of Emergency Services could do to prevent harm to the drinking water in Lake Hickory. How could the Department discover if acid could harm the Catawba arrow lily and Catawba crayfish ostracod?

Accept all ideas, then have small groups discuss and choose the three best strategies. Finally, have lab groups design an experiment that would answer one of these questions. *(Listed below are possible questions that students will generate.)*

- Does a low pH (2-3) affect seed germination?
- Does an acid pH affect small aquatic invertebrates such as ostracods?
- Does acid affect manmade materials such as concrete?

*The teacher will need a supply of seeds, a culture of an aquatic invertebrate such as Daphnia (water flea) and pieces of concrete block for student projects, as well as HCl, pH sensors, burettes, glassware and other lab equipment. The teacher should circulate as students design the experiment and guide students to design a lab that has controls, constants, collects data that address the question, and follows safety precautions. By the end of class, each lab group will leave a detailed list of needed materials and outline of specific procedures in a project proposal format.*

**Day 4:** Students will have project proposals returned and materials available. The groups will begin the experiments and collect initial data. Systems will remain set up over the weekend.

**Honors Chemistry Support**  
*Accident at Snow Creek Bridge*

**Day 5-9:** Students will collect data each day.

**Day 9 Homework:** Students will write formal lab report for homework. They will include hypothesis, materials, actual procedure followed, data tables, discussion of data, sources of error, questions for further research, conclusions.

**Day 10:** Students turn in lab reports. Each group will report briefly the question they investigated and conclusion made. Class as a group will reach consensus as to what is the best possible solution to the problem.

**Additional Teacher Background Information, Accident at Snow  
Creek Bridge**

Table A-12 Rare and Aquatic Animals in the Catawba River Basin

Major Taxon	Common Name	Scientific Name	State Status	Federal Status
fish	Highfin carpsucker	<i>Carpionodes velifer</i>	SC	
fish	Santee chub - piedmont population	<i>Cyprinella zanema pop 1</i>	SR	
fish	Carolina darter	<i>Etheostoma collis</i>	SC	
fish	Redeye bass	<i>Micropterus coosae</i>	SR	
mollusk	Brook floater	<i>Alasmidonta varicosa</i>	T	FSC
mollusk	Carolina heelsplitter	<i>Lasmigona decorata</i>	E	E
mollusk	Seep mudalia	<i>Leptoxis dilatata</i>	T	
mollusk	Notched rainbow	<i>Villosa constricta</i>	SR	
mollusk	Eastern creekshell	<i>Villosa delumbis</i>	SR	
mollusk	Carolina creekshell	<i>Villosa vaughaniana</i>	SC	
crustacean	Bennett's mill cave water slater	<i>Caecidotea carolinensis</i>	SR	FSC
crustacean	French broad crayfish	<i>Cambarus reburus</i>	SR	FSC
crustacean	Catawba crayfish ostracod	<i>Dactylocythere isabelae</i>	SR	FSC
dragonfly	Edmund's snaketail	<i>Ophiogomphus edundo</i>	SR	FSC
dragonfly	Pygmy snaketail	<i>Ophiogomphus howei</i>	SR	FSC
<b>Rare Wetland-Dwelling Animals in the Catawba River Basin</b>				
amphibian	Bog turtle	<i>Clemmys muhlenbergii</i>	T	T(S/A)
mammal	Star-nosed mole - coastal plain population	<i>Condylura cristata pop 1</i>	SC	
mammal	Southern water shrew	<i>Sorex palustris punctulatus</i>	SC	FSC

**Rare Species Listing Criteria**

E = Endangered (those species in danger of becoming extinct)  
T = Threatened (considered likely to become endangered within the foreseeable future)  
SC = Special Concern (have limited numbers and vulnerable populations in need of monitoring)  
FSC = Federal Species of Concern (formerly considered Category 2 candidates for listing)  
SR = Significantly Rare (those whose numbers are small and whose populations need monitoring)

Changes in pH to surface waters is primarily through point source discharges. However, changes can also occur with the introduction of substances in the form of spills to a water body and through acid deposition.

## **Honors Chemistry Support Accident at Snow Creek Bridge**

*As the pH of water decreases, metals are more bioavailable within the water column and are therefore more toxic to the aquatic organisms. As the pH increases, metals are precipitated out of the water column and less toxic to aquatic organisms. If surface water has had chronic introductions of metals and the pH gradually or dramatically decreases, the metals in the substrate will become more soluble and be readily available in the water column. While lower pH values may not be toxic to the aquatic organisms, the lower values can have chronic effects on the community structure of macroinvertebrates, fish, and phytoplankton. Macroinvertebrates will show a shift from tolerant species to intolerant species and have less community diversity.*

The NC standard for pH in surface waters is 6.0 to 9.0. Trout will not survive in waters with pH values below 5.5.

Chlorine is a commonly used disinfectant at NPDES discharge facilities which have a domestic (i.e., human) waste component. These discharges are a major source of chlorine in the State's surface waters. Chlorine dissipates fairly rapidly once it enters the water, but its toxic effects can have a significant impact on sensitive aquatic life such as trout and mussels. At this time, no standard exists for chlorine in waters supplementally classified as trout waters and an action level of 17 milligrams per liter (mg/l) for chlorine has been established for all other waters. A standard for all waters may be adopted in the future. All new and expanding dischargers are required to dechlorinate their effluent if chlorine is used for disinfection. If a chlorine standard is developed for North Carolina, chlorine limits may be assigned to all dischargers in the State that use chlorine for disinfection.

**Honors Chemistry Support**  
***Accident at Snow Creek Bridge***

Lab Report Grade Sheet  
**DUE \_\_\_\_\_**

Purpose/Hypothesis:

\_\_\_\_\_ Clear, concise and meaningful. What are you trying to accomplish? How are you going to do it? Why will your procedure enable you to accomplish your goal? (5 pts)

Procedure:

\_\_\_\_\_ Clear, concise; complete; repeatable; accurately represents EXACTLY what was done in the lab. (5 pts)

Materials:

\_\_\_\_\_ Complete. (5 pts)

Safety Notes:

\_\_\_\_\_ Thoughtful, meaningful, easy to understand (5 pts)

Data and Observations:

\_\_\_\_\_ Easy to read; complete; graphs and tables are accurate and appropriate; graphs titled and labeled (5 pts)

\_\_\_\_\_ Correct number of sig figs are reported for each measuring device; (5 pts)

Calculations:

\_\_\_\_\_ All work is shown and answers are rounded to the correct number of sig figs; (5 pts)

\_\_\_\_\_ Steps are clearly labeled and *process* is communicated; (5 pts)

\_\_\_\_\_ Student's thought process and understanding is evident. (5 pts)

Error Discussion:

\_\_\_\_\_ Percent error is correctly calculated; work is shown; (5 pts)

\_\_\_\_\_ Sources of error are discussed; discussion is comprehensive (10 pts)

Conclusion:

\_\_\_\_\_ Meaningful; understanding of the purpose of the lab is apparent (5 pts)

\_\_\_\_\_ Discussion includes a connection between student's measured results and expected results (5 pts)

\_\_\_\_\_ Section provides a CONCLUSION to the whole process (5 pts)

Expectations:

\_\_\_\_\_ Lab write-up is professional (typed, subscripts, grammar, spelling) (10 pts)

\_\_\_\_\_ Outcome is scientifically reasonable (10 pts)

\_\_\_\_\_ **TOTAL (100 pts)**

## Laboratory Investigation Rubric

CATEGORY	4 – Excellent	3 - Good	2 - Satisfactory	1 – Needs Improvement	Score
<b>Question/ Purpose</b>	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.	
<b>Experimental Hypothesis</b>	Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied.	Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations.	Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic.	No hypothesis has been stated.	
<b>Procedure</b>	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment.	
<b>Safety</b>	Lab is carried out with full attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual.	Lab is generally carried out with attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but one safety procedure needs to be reviewed.	Lab is carried out with some attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but several safety procedures need to be reviewed.	Safety procedures were ignored and/or some aspect of the experiment posed a threat to the safety of the student or others.	
<b>Data</b>	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.	

**Honors Chemistry Support**  
*Accident at Snow Creek Bridge*

CATEGORY	4 – Excellent	3 - Good	2 - Satisfactory	1 – Needs Improvement	Score
<b>Calculations</b>	All calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.	
<b>Analysis</b>	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.	
<b>Error Analysis</b>	Experimental errors, their possible effects, and ways to reduce errors are discussed.	Experimental errors and their possible effects are discussed.	Experimental errors are mentioned.	There is no discussion of errors.	
<b>Scientific Concepts</b>	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.	
<b>Conclusion</b>	Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.	Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.	Conclusion includes what was learned from the experiment.	No conclusion was included in the report OR shows little effort and reflection.	

**EXHIBIT A**

Shipping Manifest

**Veckridge Chemicals Company, Inc.**

**Address:** 60-70 Central Avenue, South Kearny, NJ 07032, USA

**Phone:** 201-344-1818 **Fax:** 201-690-5938

**Hydrochloric Acid CAS 7647-01-0**

Account #344561	Sold by VCC	Reference # 2284	Ship Via UPS DOT Class B Corrosive	Terms Net 30	Date 12-05-05
Qty. Ordered	Qty. Shipped	Item #	Description	Unit Price	Total Price
10,000 gal	10,000 gal	AJ 36407	Hydrochloric Acid, 35-37%	\$12.00	\$120,000.00
			Sale Amount		\$120,000.00
			Sales Tax		\$840.00
			Freight		\$1,000.00
			Total		\$121,840.00

**EXHIBIT B**

Email from Friends of the Catawba River

To: Director of Emergency Services, Catawba County

From: Friends of the Catawba River, December 6, 11 AM

It has come to our attention that a major hazardous material spill has occurred in Snow Creek. We are very concerned about the implications of this spill for several reasons. First, as you know, the drinking water for the City of Hickory and several nearby communities comes from the Catawba River, of which Snow Creek is a tributary. Secondly, the only known location of the Catawba arrow lily is Snow Creek, just downstream of the spill site. This flowering plant flowers in the fall and the seeds germinate in the creek bed during the month of December. If the seeds fail to germinate, the population of arrow lilies would be decimated, perhaps even go extinct. Finally, the Catawba crayfish ostracod, a federal species of concern, is endemic to North Carolina and only known in some streams of Catawba County. Again, destruction of the population in Snow Creek would add to its endangered status. We are mobilizing a community awareness campaign of this problem, and expect swift action from your department.

**Honors Chemistry Support**  
***Accident at Snow Creek Bridge***

**Differentiation from Standard-level:**

- 1) Research utilizing the Internet and other available sources.
- 2) Has student-generated hypotheses and design of independent investigations.
- 3) Application of pH, acids and bases concepts to solve environmental problems.

**Safety/Special Considerations:**

Students must wear OSHA approved goggles, gloves, and aprons when performing laboratory activities with acids and bases. Students must wear gloves when collecting water samples from a stream.

**References:**

<http://www.hickorygov.com/publicdocs/masterplans/Woolpertfinal/appendix.htm>  
[http://www.ncfloodmaps.com/pubdocs/catawba\\_basin\\_plan\\_fact\\_sheet.pdf](http://www.ncfloodmaps.com/pubdocs/catawba_basin_plan_fact_sheet.pdf)  
<http://www.dukepower.com/community/lakes/cw/library/plans/Terrestrial%2001%20Wetland%20Mapping%20and%20Characterization%20Draft%20Report.pdf>

*Activity designed by Thea Sinclair, St. Stephens HS, Catawba County Schools*

## Turning Iron into Copper

### Background Information

#### Targeted Standard Course of Study Goals and Objectives:

3.03-1 H: Evaluate reactions to determine limiting reactant and percent yield.

#### Essential Question(s):

How do you determine the limiting reactant and the percent yield of a chemical reaction?

#### Introduction to teacher (background information):

Iron replaces copper from copper (II) sulfate solution to produce copper and iron(II) sulfate solution. ( $\text{Fe} + \text{CuSO}_4 \rightarrow \text{Cu} + \text{FeSO}_4$ ) 10.0 grams of  $\text{CuSO}_4$  dissolved in 50 mL of distilled water to make a 0.80 M solution. This is a convenient concentration to use with 2.0g of iron filings to cause iron to be the limiting reactant. The theoretical yield is determined by calculating the moles of iron ( $2.0/56$ ) and changing this to grams of copper ( $0.0357 * 63.45$ ) = 2.3 g. The actual yield (result of weighing dried copper) divided by  $2.3 \times 100\%$  gives the % yield.

\*\*\*Zinc can also be used instead of iron as an alternative.\*\*\*

#### Differentiation from Standard-level:

- ♣ Solutions should be made for the standard level student. The honors students should determine how to prepare the solution and proceed by preparing the solution.
- ♣ The honors student should work more independent (less guidance) of the teacher during the lab activity and in performing calculations.
- ♣ Extension: The honors student may be asked questions regarding redox reactions and balancing redox reactions (5.05—1H)

#### Safety/Special Considerations:

Observe all lab safety precautions.

**Targeted Standard Course of Study Goals and Objectives:**

3.03-1 H Evaluate reactions to determine limiting reactant and percent yield.

**Essential Question(s):**

- ♣ What happens to a reaction between two reactants when one of the reactants is completely used up?
- ♣ (What is the limiting reactant in ~2.0g of Fe reacts with 50 mL of 0.8M CuSO<sub>4</sub>? What is your percent yield?)

**Introduction (purpose with background information):**

A chemical reaction stops when one of the reactants is used up or runs out. The substance that runs out is known as the limiting reactant. When chemicals react, it is often possible to see which chemical disappears first. In this activity, you will determine whether iron or copper sulfate is the limiting reactant. By measuring the reactants, you can predict how much product should be created. This is called the theoretical yield. The amount that is actually produced is called the actual yield. By measuring the amount of the chemical produced, you will be able to determine the % yield – a ratio of actual yield to theoretical yield.

***Complete the pre-lab before beginning the lab activity.***

**Materials:**

Fe filings  
CuSO<sub>4</sub>·5H<sub>2</sub>O  
Hot plate  
Beaker (100 mL)  
Balance  
Funnel  
Filter paper  
Stirring rod

**Procedure:**

1. Determine mass of iron filings.
2. Prepare a solution by adding 5.0 g of CuSO<sub>4</sub>·5H<sub>2</sub>O to 50 mL of solution to make a 0.4M solution.
3. Combine Fe with CuSO<sub>4</sub> solution.
4. Stir gently.
5. Heat beaker gently to increase reaction time. Do not allow to boil.
6. Observe to determine when no more iron remains.
7. Filter.
8. Wash thoroughly.
9. Allow to dry.
10. Mass precipitate.

**Safety:**

- ~ Use goggles.
- ~ Dispose of FeSO<sub>4</sub> according to MSDS.
- ~ Keep CuSO<sub>4</sub> away from eyes.

**Questions to Guide Analysis:**

Was there a color change?

What happened to the solid iron?

What is the “new” product formed?

How do you know when the reaction is complete?

What’s REALLY happening here?

**Rubric: See below**

## Lab Investigation Rubric

<b>CATEGORY</b>	<b>4 – Excellent</b>	<b>3 - Good</b>	<b>2 - Satisfactory</b>	<b>1 – Needs Improvement</b>	<b>Score</b>
<b>Question/Purpose</b>	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.	
<b>Experimental Hypothesis</b>	Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied.	Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations.	Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic.	No hypothesis has been stated.	
<b>Procedure</b>	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment.	
<b>Safety</b>	Lab is carried out with full attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual.	Lab is generally carried out with attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but one safety procedure needs to be reviewed.	Lab is carried out with some attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but several safety procedures need to be reviewed.	Safety procedures were ignored and/or some aspect of the experiment posed a threat to the safety of the student or others.	
<b>Data</b>	Professional-looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.	
<b>Calculations</b>	All calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.	

**Honors Chemistry Support**  
*Turning Iron into Copper*

<b>CATEGORY</b>	<b>4 – Excellent</b>	<b>3 - Good</b>	<b>2 - Satisfactory</b>	<b>1 – Needs Improvement</b>	<b>Score</b>
<b>Analysis</b>	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.	
<b>Error Analysis</b>	Experimental errors, their possible effects, and ways to reduce errors are discussed.	Experimental errors and their possible effects are discussed.	Experimental errors are mentioned.	There is no discussion of errors.	
<b>Scientific Concepts</b>	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.	
<b>Conclusion</b>	Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.	Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.	Conclusion includes what was learned from the experiment.	No conclusion was included in the report OR shows little effort and reflection.	

Lab Data Sheet: **Turning Iron into Copper**

**Pre-Lab:**

1. Write a balanced equation for the reaction.
2. What type of reaction will be performed in the lab activity?
3. Calculate the theoretical yield for the product(s).  
(HINT: You will need the mass of your iron sample to do this)
4. What is the limiting reactant? (Show your calculations.)
5. Show your calculations for the preparation of the  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  solution.

**Data:**

Mass of Iron	
Mass of Precipitate	

**Analysis:**

Calculate the percent yield.

**Questions:**

1. Was there a color change? If so, describe.
2. What happened to the solid iron?
3. What is the “new” solid product formed?
4. How do you know when the reaction is complete?
5. Calculate the amount of excess reactant that remains.

## Why Stuff Happens

### Background Information

#### Targeted *Standard Course of Study* Goals and Objectives:

4.03-1 H Predict spontaneity by the use of Gibbs Free Energy.

#### Essential Question(s):

What controls whether a change (e.g., chemical reaction, change of state, etc.) will spontaneously happen, and how it can be manipulated?

#### Introduction to Teacher (Background Information):

The purpose of this activity is to explore the factors that control whether a reaction (or anything else, for that matter) will spontaneously happen. Under the usual lab conditions - constant temperature (T) and pressure (P) – the thermodynamic property that determines spontaneity is the change in the Gibbs free energy -  $\Delta G$  – of the system.

If  $\Delta G < 0$  the change will spontaneously occur  
 $\Delta G > 0$  it will not (the reverse reaction will be spontaneous)  
 $\Delta G = 0$  nothing happens (the system is at equilibrium)

$\Delta G$  is related to two more familiar thermodynamic properties, the change in heat (enthalpy) -  $\Delta H$  – and the change in disorder -  $\Delta S$  – of the system through the relation

$$\Delta G = \Delta H - T \Delta S$$

where T is the temperature in Kelvin.

Because there are two terms whose relative sizes affect whether a given change will occur, different types of reactions will possess differing behaviors. In particular,

If  $\Delta H < 0$  (exothermic) and  $\Delta S > 0$  ( $\rightarrow$  more disorder) then will go at all T's  
 $\Delta H > 0$  (endothermic) and  $\Delta S < 0$  ( $\rightarrow$  less disorder) then won't go at any T  
 $\Delta H < 0$  (exothermic) and  $\Delta S < 0$  ( $\rightarrow$  less disorder) then ?  
 $\Delta H > 0$  (endothermic) and  $\Delta S > 0$  ( $\rightarrow$  more disorder) then ?

The last case is particularly useful for demonstrating the interaction between heat and disorder on whether the reaction occurs, and under what conditions.

The demonstration reactions are simple ones: dissolving salts in water. Three spontaneous reactions –

one exothermic (e.g., LiCl)

one endothermic (e.g., urea; not a salt but conveniently available, safe to use and one with a relatively large endotherm)  
one with  $\Delta H \approx 0$  (e.g., NaCl) -

will be used to open the discussion on why things dissolve, and to demonstrate that the heat released cannot be the sole factor determining whether dissolution occurs. This should lead to a discussion of entropy and the concept that a solution of salt in water is more disordered than solid salt and water separately. Since the Second Law states that the universe moves spontaneously towards more a more disordered state, that would seem to be what is controlling the dissolution reaction.

With that point apparently settled, why don't all salts dissolve in water in very large amounts, for example  $\text{KNO}_3$ ,  $\text{KClO}_3$  and  $\text{KClO}_4$ ? Why do relative small amounts of these salts dissolve in water, if the heat evolved doesn't matter and the solution is obviously more disordered than the solid and pure water?

The dissolution -  $\Delta S > 0$  - of these three potassium salts in water are endothermic -  $\Delta H > 0$  - reactions, but the different in the magnitude of the enthalpy and entropy terms is small enough that the relatively-small temperature changes easily accessible in the lab can change the sign of  $\Delta G$  for the reaction, and hence whether it will occur or not. This can be seen from the reported solubility data:

	Cold Water (g / 100 ml)	Hot Water (g / 100 ml)	$\Delta H_{\text{soln}}$ (kcal/mole)
$\text{KNO}_3$	13.3 @ 0°C 35 @ 20°C	247 @ 100°C	8.34
$\text{KClO}_3$	7.1 @ 20°C	57 @ 100°C	9.89
$\text{KClO}_4$	0.75 @ 0°C	21.8 @ 100°	12.2

Potassium nitrate (saltpetre) looks particularly attractive; it's cheap, available, relatively- harmless, and it exhibits a very large change in solubility with temperature. If a large amount is placed in a flask with water, relatively little will dissolve; the chlorate or perchlorate might be better choices, since they are less soluble in cold water. Nonetheless, the question arises: "Why didn't the rest go in?" Gentle heating will dissolve the rest (the final temperature will depend on the amounts of salt and water), thus demonstrating the role of temperature – and hence the role played by the relative magnitudes of  $\Delta H$  and  $\Delta S$  – in determining spontaneity. To illustrate that this dissolution is not a kinetic phenomenon, chilling the solution will precipitate the salt in large amounts, demonstrating that the spontaneity of the reaction, not the reaction rate, is changing.

### Differentiation from Standard-Level:

These experiments require a quantitative understanding of the roles that evolved heat and disorder play in affecting spontaneity. It also demonstrates the role the temperature can play in affecting whether some reactions will occur or not.

### Safety/Special Considerations:

Some salts (e.g., chlorates, perchlorates) are poisonous if ingested. Read MSDS's for special precautions. Normal laboratory procedures, hygiene and safety rules must be observed. Dispose of waste materials properly.

**References:**

Handbook of Chemistry and Physics, 49<sup>th</sup> Edition, Chemical Rubber Company, 1968.

**Other Useful Data:**

	Cold Water (g / 100 ml)	Hot Water (g / 100 ml)	$\Delta H_{\text{soln}}$ (kcal/mole)
LiCl	63.7 @ 0°C	130 @ 95°	-8.85
Urea	119 @ 25°C		endothermic
NaCl	35.7 @ 0°C	39.12 @ 100°C	0.928

## Why Stuff Happens

### Targeted *Standard Course of Study* Goals and Objectives:

4.03-1 H Predict spontaneity by the use of Gibbs Free Energy.

### Essential Question(s):

What controls whether a salt will spontaneously dissolve in water, and can that be changed?

### Introduction (purpose with background information):

The experiments are divided in to four parts:

- (1) Dissolution of LiCl, urea, and NaCl in water; observe changes in temperature
- (2) “Non-dissolution” of potassium salt in water
- (3) Heating potassium salt “solution to cause the solid to dissolve
- (4) Cooling of hot potassium salt solution to precipitate solid

Experiment (1) demonstrates that heat evolution (exothermicity) is not the sole factor controlling the spontaneity of this reaction: salt + water → solution.

Experiment (2) poses the question: “Why doesn’t this stuff dissolve?”

Experiment (3) demonstrates the role of temperature ( and hence the interplay between  $\Delta H$  and  $\Delta S$ ) in determining spontaneity.

Experiment (4) demonstrates that the change results from thermodynamics, not kinetics.

### Materials:

LiCl, solid  
NaCl, solid  
Urea, solid  
KNO<sub>3</sub> or KClO<sub>3</sub> or KClO<sub>4</sub>, solid  
Water  
Erlenmeyer (or similar) flasks  
Hot plate or Bunsen burner  
Stirring rods  
Magnetic stirrer and bars (optional)  
Thermometers, or temperature probe and meter  
Balance  
Ice bath

**Procedure:** (using potassium perchlorate)

**Experiment 1:**

- a) Dissolve 10 g of LiCl in 100 ml H<sub>2</sub>O; record change in temperature.
- b) Dissolve 10 g of urea in 100 ml H<sub>2</sub>O; record change in temperature.
- c) Dissolve 10 g of NaCl in 100 ml H<sub>2</sub>O; record change in temperature.

**Experiment 2:**

Add 10 g KClO<sub>4</sub> to 100 ml H<sub>2</sub>O and stir; record change in temperature.

\*Note that very little salt dissolves.

**Experiment 3:**

Heat KClO<sub>4</sub>/water slurry until solid dissolves; note temperature.

**Experiment 4:**

Cool hot KClO<sub>4</sub> solution, causing solid to precipitate.

**Safety:**

Some salts (e.g., chlorates, perchlorates) are poisonous if ingested. Chlorates and perchlorates are strong oxidizing agents; be careful! Read MSDS's for special precautions. Normal laboratory procedures, hygiene and safety rules must be observed. Dispose of waste materials properly.

**Questions to Guide Analysis:**

“Why do some reactions occur, and others don't?”

“Is it because systems, if possible, spontaneously shed energy as heat, like a burning candle, or gasoline in an engine?”

**Do Experiment 1a:**

**The solid dissolves and the temperature of the solution will be measurably higher.**

“Makes sense. The solid dissolved and the solution got warmer.”

**Do Experiment 1b:**

*The solid dissolves and the temperature of the solution will measurably lower.*

“How do you explain that? The solid dissolved and the solution got colder!”

**Do Experiment 1c:**

**The solid dissolves and the temperature of the solution will be (virtually) unchanged.**

“Another mystery! The solid dissolved and the temperature didn’t change at all.”

“Maybe heat has nothing to do with it. Maybe it’s something else – disorder.”

**Discuss disorder, the concept of entropy and the Second Law of Thermodynamics: the entropy of the universe must constantly increase. Discuss the degrees of order in the solid, pure water, and a solution of the solid dissolved in water. This should eventually lead to the conclusion that the final state of the system (the solution) is more disordered than the initial state (the solid and water separately). Thus entropy has increased in this spontaneous reaction, in agreement with the Second Law.**

All is right with the world.

**Do Experiment 2:**

**The solid does not dissolve in the water.**

“What’s wrong? Why didn’t the solid dissolve, since the solution would clearly be a more disordered state than the solid and water separately?”

**Introduce the concept of the change in Gibbs free energy -  $\Delta G$  - as the indicator of spontaneity, and its relationship to both the heat -  $\Delta H$  - and the disorder -  $\Delta S$  - of the reaction:  $\Delta G = \Delta H - T \Delta S$ . Discuss the types of reactions, their spontaneity, and the role of temperature in certain kinds of reactions, as given in the Background Information.**

*Deduce the type of reaction ( $\Delta G$ ,  $\Delta H$ ,  $\Delta S$ ) in Experiment 2 from the observations.*

- 1.  $\Delta S$  must be positive ( $>0$ ), because a solution is more disordered than the solid and pure water*
- 2.  $\Delta G$  must be positive ( $>0$ ), since the solid didn’t dissolve*
- 3. Therefore,  $\Delta H$  must be positive (endothermic,  $>0$ ), since, in the rearranged equation,  $\Delta H = \Delta G + T \Delta S$ , both terms on the right are  $> 0$ .*

*“With  $\Delta H$  and  $\Delta S$  both positive, could anything be changed to make  $\Delta G$  negative and hence cause the reaction to go?”*

$\Delta G = \Delta H - T \Delta S$ ? Yes. Raise the temperature high enough to make the  $T \Delta S$  term larger than  $\Delta H$ , and hence force  $\Delta G$  to be  $< 0$ , and the reaction will spontaneously go.

**Do Experiment 3:**

**Upon heating sufficiently, the solid dissolves. “Voila”**

“But how do we know that the dissolution just wasn’t slow and heating it caused the solid to dissolve much more rapidly?”

*Discuss kinetics versus thermodynamics.*

**Do Experiment 4:**

**The solid precipitates, showing the cause is thermodynamics, not kinetics.**

Finish up with a review of the interplay between enthalpy and entropy in determining the spontaneity of a reaction at constant T and P.

**References (for further research):**

A clever thinker might reason that, once  $\Delta G$  is negative, there is no apparent reason for more solid to dissolve and no apparent reason for there to be a limit to how much will go in. Yet all solids have solubility limits, where, by definition, the  $\Delta G$  for the dissolution must be zero.

How does your clever student explain that?

Also, since the Second Law connects spontaneity with increases in the entropy of the universe, why do we use the change in Gibbs free energy as a measure of whether a reaction will go, or not?

## Lab Investigation Rubric

CATEGORY	4 – Excellent	3 - Good	2 - Satisfactory	1 – Needs Improvement	Score
<b>Question/ Purpose</b>	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.	
<b>Experimental Hypothesis</b>	Hypothesized relationship between the variables and the predicted results is clear and reasonable based on what has been studied.	Hypothesized relationship between the variables and the predicted results is reasonable based on general knowledge and observations.	Hypothesized relationship between the variables and the predicted results has been stated, but appears to be based on flawed logic.	No hypothesis has been stated.	
<b>Procedure</b>	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment.	
<b>Safety</b>	Lab is carried out with full attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual.	Lab is generally carried out with attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but one safety procedure needs to be reviewed.	Lab is carried out with some attention to relevant safety procedures. The set-up, experiment, and tear-down posed no safety threat to any individual, but several safety procedures need to be reviewed.	Safety procedures were ignored and/or some aspect of the experiment posed a threat to the safety of the student or others.	
<b>Data</b>	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.	

## Lab Investigation Rubric

<b>CATEGORY</b>	<b>4 – Excellent</b>	<b>3 - Good</b>	<b>2 - Satisfactory</b>	<b>1 – Needs Improvement</b>	<b>Score</b>
<b>Analysis</b>	The relationship between the variables is discussed and trends/patterns logically analyzed. Predictions are made about what might happen if part of the lab were changed or how the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.	The relationship between the variables is not discussed.	
<b>Scientific Concepts</b>	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.	
<b>Conclusion</b>	Conclusion includes whether the findings supported the hypothesis, possible sources of error, and what was learned from the experiment.	Conclusion includes whether the findings supported the hypothesis and what was learned from the experiment.	Conclusion includes what was learned from the experiment.	No conclusion was included in the report OR shows little effort and reflection.	

## Chemistry Reference Tables

The Reference Tables for the 2004 North Carolina Standard Course of Study in Chemistry are now in print. A valuable resource for both students and classroom teachers, this compendium of information is the same as the reference tables that will be used on the North Carolina End-of-Course Test of Chemistry beginning with the 2007-2008 school year.

It is recommended that teachers make use of this set of reference tables with their students throughout the Chemistry course. Teachers may modify the tables to their own liking for classroom instruction and assessment; however, the tables used for End-of-Course Testing will be in the included format ONLY.

In the hard copy printed version of this support document, the Reference Tables will follow this page. In the CD/electronic version, the PDF version of the Reference Tables will be located in a separate, appropriately named folder.