

17 Effective Activities for New Chemistry Teachers

Fun and easy to run chemistry labs
for high school students

Ian Guch

Cavalcade Publishing
Alexandria, Virginia
www.cavalcadepublishing.com

17 Effective Activities for New Chemistry Teachers

Fun and easy to run chemistry labs
for high school students

By Ian Guch

Copyright © 2001, 2002 by Ian Guch

Cavalcade Publishing
Alexandria, Virginia
www.cavalcadepublishing.com
ISBN 0-9676509-6-8

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage system without written permission from the author, except for the inclusion of brief quotations in a review. Teachers who purchase or are given this book have the limited right to photocopy any activity for use in their classrooms but may not reproduce any part of the book for any other reason unless written permission is obtained. Replicas of this work (in full or part) may not be given to any person for any reason except as indicated above.

The author and Cavalcade Publishing shall have neither liability nor responsibility to any person or entity with respect to any loss or damage caused, or alleged to be caused, directly or indirectly by the information contained in this work. It is expected that chemistry teachers will fully inform themselves of any laboratory hazards, will follow all appropriate safety guidelines at all times, and will assume all risk with respect to performing the labs in this book. If you do not wish to be bound by the above, you may return this book to the publisher for a full refund. For more information, please contact the author via electronic mail at "misterguch@chemfiesta.com" or the publisher via electronic mail at "support@cavalcadepublishing.com".

Made in the USA by Cavalcade Publishing
PO Box 7163
Alexandria, VA 22307
<http://www.cavalcadepublishing.com>

Table of Contents

Introduction	5
Acknowledgements	7
Chapter 1: Unit Conversion Lab	9
Chapter 2: Graphing Lab	13
Chapter 3: Chemical and Physical Changes Lab	17
Chapter 4: Density Lab	21
Chapter 5: Making a Solution Lab	25
Chapter 6: Dilutions Lab	29
Chapter 7: Titration Lab	33
Chapter 8: Making an Indicator Lab	37
Chapter 9: It's Haiku Time!	39
Chapter 10: Average Atomic Mass Lab	41
Chapter 11: Energy Research Project	45
Chapter 12: Colligative Properties Lab	49
Chapter 13: Mole Calculation Lab	53
Chapter 14: The Hissing Gas Tank Lab	55
Chapter 15: Molecular Motion Lab	59
Chapter 16: Chemistry Races	63
Chapter 17: Creative Homework	65
Appendix 1: Laboratory Safety	70
Appendix 2: Everyday Metric System	74
Appendix 3: Student Reference Sheet	77
Appendix 4: Suggested Teacher References	79
Appendix 5: Unusual Atomic Symbols	81
Appendix 6: Laboratory Maintenance	82
Appendix 7: Keeping Students Interested	84
About the HOT Program	87

The most incomprehensible thing about the world is that it is comprehensible.

- Albert Einstein

When the going gets weird, the weird turn pro.

- Hunter S. Thompson

Introduction

One day in late August 2001 my wife and I were simultaneously talking about ways to make the world a better place and griping about how books for teachers are too expensive. After some discussion we decided to put together a short book of labs and give it away to new teachers and teachers in underfunded schools. The book we discussed is the one you're holding in your hand. The reason, incidentally, that it's exactly 90 pages is because that's the maximum number of pages we can get at the cheapest rate from our printer. Since we're funding this project out of our own pockets (actually, this is where the profits from my other books go), we're trying to get maximum bang for the buck. We're calling it the Helping Other Teachers (HOT) Program, and we're excited to see it come to fruition.

This book offers much more information per page than others I've written. The teacher materials still contain everything you need to get the job done, but the student handout assumes your kids have lab notebooks to write their observations and results in. In each of the spaces that would normally be blank in a textbook, I've included text boxes containing information that new teachers may find useful ("Handy tips for new teachers").

If you'd like to help us distribute this book to other teachers, have them visit our site on the web at www.cavalcadepublishing.com or take a look at page 87 for more information. I feel strongly that this book will help new teachers and hope that if you have a little extra money, mailing supplies, or blank CD-R discs, you will consider donating them to this cause. That's what the HOT program is about – getting people in our "community" of teachers to help each other.

How each chapter is laid out:

When appropriate, each chapter contains the following sections. Some chapters omit one or more of these sections if they are not relevant to the activity at hand, so you won't see a "Clean up" section for activities that don't involve the use of chemicals.

- Overview: An introduction to each activity and an explanation of how it fits into the chemistry curriculum.
- Estimated time to complete this lab: A general idea of how much class time the activity will require.
- Equipment: A complete list of equipment for doing the activity with one class.
- About the lab: Everything you need to know to run the activity smoothly. This section provides a summary for the activity and gives suggestions for ways to make it more instructional for your students.

- Safety: Your students need to wear goggles whenever they do a lab. Aside from this assumption, these are the safety tips needed to keep your students out of harm's way. However, if after reading these tips you still don't feel comfortable with a lab, *don't do it!*
- Clean up: Instructions for safely disposing of chemical waste generated during the activity.
- What can go wrong: If something can go wrong or is frequently the source of confusion among students, I'll mention it here.
- Answer key: The solutions for questions posed in the activity.

Some final words:

I'm excited about the Helping Other Teachers project and about this book. Like many teachers, I sometimes feel my contributions to society are undervalued. Fortunately, I get enough positive feedback through my website (www.chemfiesta.com) to know that what I do is appreciated. I hope that by receiving this book you feel the same way.

Your friend,

Ian Guch
September 2001 – April 2002

Acknowledgements

This book would never have happened without the help and support of a lot of people. I don't really feel like I wrote the book. I feel more as if I stuck a bunch of random words on paper and let other people make them into something special.

Of course, the most important person in the making of this book was my wife, Ingrid. When I wondered if it was a good idea to write another book, she gave me the encouragement I needed to get started. When I asked her if giving away thousands of copies of a book was really a good idea given our financial situation, she told me that it was as good a way to spend money as she could think of. Not only did she support the idea of the Helping Other Teachers program, but she also proofed this book until it made sense to somebody other than me. The phrase "my better half" isn't nearly strong enough to describe Ingrid.

Thanks to my parents for helping proof this book and for supporting the idea of the HOT program. There are a lot of people in the world who feel it's unwise to follow one's dreams. Thankfully, my parents gave me the self-confidence to fight off the naysayers and the work ethic to get the job done.

I'd like to thank the people who taught me the proper practice of chemistry: Marcello DiMare, Chris Sarko, Monica Nelipovich, Nancy Levinger, and Ken DeBruin. Without their help, I wouldn't have enough knowledge to teach chemistry, much less write about it.

I'd also like to thank the people who taught me how to be a good teacher: Anita Scovanner Ramsey, Joy McManus, Jan Warner, JoAnne Harris, Eric Brent, and Sharon Lynch. The knowledge that these gifted educators have passed on to me has been invaluable.

I'd also like to thank Jannette Bloom, who took the cover photo, as well as Maddie Hall, Jane Luxner, and Leah Grady (the folks in the picture).

Finally, I'd like to thank everybody else who's ever given me inspiration and support with my writing (and life in general). Thanks to Matt, Cindy, and Owen, my Grandparents, Ilga and Stanley Paluch, Kevin Whelan, Kjirsten Wayman, Donna Delano, John the dog walker, Maalox and Nose, the guy who fixed my computer for next to nothing, Erik Luther, Rob Keil, Linda Williamson, Carl, Debbie, Sonja, and the other folks down at the Belle View Post Office, Rich and Susan, and everybody before me who has ever started their own label, 'zine, or publishing company for showing me that it's possible to make a difference without the support of a big corporate sponsor.

Handy tips for new teachers:

The following is a list of classroom supplies that all chemistry teachers should have. Many of these items can be purchased at the dollar store:

- Plenty of clear tape
- Crayons
- Stapler
- Three hole punch
- Lots of white paper
- A large stack of photocopied periodic tables
- A large stack of photocopied safety rules
- Extra goggles for visitors and forgetful students
- A tool kit containing a large claw hammer, large and small common (flathead) screwdrivers, large and small Phillips head screwdrivers, large and small crescent wrenches, complete set of hexagonal wrenches, utility knife, duct tape, electrical tape, multimeter, retractable tape measure, and triangular file. It's amazing how many simple repairs you'll need to do during the school year, and it's important that you have the tools to get the job done right.

Chapter 1: Unit Conversion Lab

Overview:

Although unit conversions can sometimes be boring, there's an easy way to spice them up. With this simple lab you'll give students a chance to do some unit conversions without a worksheet.

Estimated time to complete this lab: 45 – 60 minutes

Equipment:

- Station 1: Unsharpened pencil and ruler that measures centimeters.
- Station 2: Electronic or triple-beam balance and paper clip.
- Station 3: 10 mL graduated cylinder, very small beaker (20 mL, if available), and 1 liter of tap water.
- Station 4: Thermometer that measures temperature in degrees Celsius.
- Station 5: Stopwatch or wall clock that can measure seconds.
- Station 6: A rectangular paper towel and ruler that measures centimeters.

About the lab:

This lab consists of six stations. At each station the students will take measurements of everyday items. However, there's a twist. Instead of simply making the desired measurements, your students will convert these measured values to less familiar units. In some cases they will be required to convert between different metric units and in other cases they will be required to convert between metric and English units. When they finish this lab, your students should be able to do unit conversions for real-world measurements and not just when solving worksheets.

Students enjoy this lab simply because of the inherent silliness involved with measuring everyday items and events in unusual units. They will be motivated to work on this lab not because they love unit conversions but because they'll be curious to see how long they can hold their breath in years. Teenagers are, by nature, fairly silly. Tapping into this silliness motivates students far more than many other traditional classroom management strategies.

What can go wrong:

- Some of the things being measured get lost. Have several spare pencils, paper clips, and paper towels on hand in case they wander away.
- The students don't know how to use the measuring devices. I've never seen this to be a problem when working with a ruler, but it will occasionally cause trouble for students unfamiliar with using a triple beam balance. Time spent teaching your students how to use unfamiliar equipment is time well spent.

- The measuring devices break. This happens frequently with thermometers and anything electronic. Make sure you have working spares of all measuring devices used in this lab. If you use probeware, it's a good idea to make sure that you have at least twice as many working probes as you need.
- Your students will have problems with Station 6, where they find the area of a paper towel in square meters. This is because area is a derived unit rather than one that can be directly measured. It may make the lab easier if you suggest that your students convert centimeters to meters *before* they find the area of the towel, rather than after.

Answer key:

There isn't a set solution key for this lab because every item your students will be measuring has a unique mass, volume, length, and so on. However, here are some easy conversion factors that should make grading easier:

- Station 1: Multiply the length of the pencil in centimeters by 6.21×10^{-6} to find its length in miles.
- Station 2: Multiply the mass of the paper clip in grams by 1.10×10^{-6} to find its mass in tons.
- Station 3: Multiply the volume of the beaker in milliliters by 2.60×10^{-4} to find its volume in gallons.
- Station 4: Add 273 to the temperature of the armpit in degrees Celsius to find the temperature in Kelvins.
- Station 5: Multiply the time your student can hold his/her breath in seconds by 3.20×10^{-8} to find the time in years.
- Station 6: Students will need to convert centimeters to meters before multiplying the length of the towel by the width. To find the area of the towel in square meters, multiply the area of the towel in square centimeters by 1.0×10^{-4} .

Handy tip for new teachers:

Your stapler, hole punch, and other equipment will be less likely to wander away if you engrave your name or room number on it. Unlike labels, engraving your name on an item permanently marks it as yours. Engraving tools are very easy to use and available at most hardware stores.

Unit Conversion Lab

Use unit conversion calculations to answer each of the following questions. Show your work for each calculation.

Station 1: Length of a pencil

Find the length of the pencil in miles. There are 1.6 kilometers in a mile.

Station 2: Mass of a paper clip

Find the mass of the paper clip in tons. There are 2.2 pounds in a kilogram and 2000 pounds in a ton.

Station 3: Volume of a very small beaker

Find the volume of the beaker in gallons. There are 0.26 gallons in a liter.

Station 4: Temperature of your armpit

Find the temperature of your armpit in Kelvins. The temperature of a substance in Kelvins is equal to its temperature in Celsius plus 273.

Station 5: Length of time you can hold your breath

Find the maximum length of time you can hold your breath, in years. There are 365 days in one year.

Station 6: Area of a paper towel

Find the area of a paper towel in square meters.

Chapter 2: Graphing Lab

Overview:

A surprising number of students don't know how to draw a line graph. While they can make a pie chart out of practically anything and a fantastic bar graph with a spreadsheet program, many have less success when it comes to the line graphs used in chemistry class. The goal of this lab is to teach students how to make a high quality line graph.

Estimated time to complete this lab: 35 – 45 minutes

Equipment:

- Many broken pieces of spaghetti with random lengths
- Electronic or triple beam balance
- Graph paper or lab notebook

About the lab:

During the course of this lab, students will make a graph of the dependence of mass on the length of spaghetti noodles. Because of how spaghetti is made, there is a nearly linear correlation between length and mass. Though I realize that all of us require different things from student graphs, I have, for your reference, included the graphing rules I use in my classes below:

- **Always draw a line graph!** Students invariably believe that bar graphs work better than line graphs. Explain to them that bar graphs are useful when graphing a number of unrelated things on the same chart. For example, if you want to show the sales of Brussels sprouts, machine tools, and Gucci handbags on the same chart you'd use a bar graph. However, since we're graphing how one variable is changed by another one, a line graph is more appropriate.
- **The x-axis of the graph is the independent variable and the y-axis is the dependent variable.** In other words, y changes when x changes and not the other way around. A good example would be a graph of age versus weight. Will your age change when your weight changes or will your weight change when you age? Since the second is true, age goes on the x-axis and weight goes on the y-axis.
- **Abrupt changes in a graph tell you that something significant has happened.** We usually see straight lines or smooth curves on a graph. Obvious discontinuities suggest a significant change has taken place.
- **Graphs should always be shown as smooth lines or curves. Never connect the dots with straight lines to form a sawtooth pattern.** The reason we can't connect the dots with simple straight lines is that we recognize the data we take isn't perfect. Besides that, the actual values in the

regions between the dots almost never lie on a straight line. If we use our data points as a guide for drawing smooth lines or curves rather than as absolute truth, they are more useful for helping us identify the underlying trend that we are really interested in.

- **The title of a graph should always be “The dependence of [dependent variable] on [independent variable].”** Another way this is commonly written is “The effect of [independent variable] on [dependent variable].”
- **Units should always be drawn on both axes of the graph.** If you don’t know what units are being used, the graph isn’t very useful.
- **The data in the graph should fill the page.** If it doesn’t, rescale the axes so it does. The larger the area covered by the data, the better the graph will be as a predictive tool.
- **Use a ruler!** It looks sloppy if the x- and y-axes are drawn freehand, and linear trends drawn with freehand lines may harm the predictive ability of the graph. For these reasons, always use a ruler to draw the axes and make the best-fit lines.

What can go wrong:

Students sometimes forget to follow your rules for drawing a good graph, so keep an eye on what they’re doing and nudge them in the right direction if they get off track.

Answer key:

Each student should make a linear graph showing the dependence of spaghetti mass on length. Make sure you grade the graphs very thoroughly to ensure that the rules you set down are being followed.

Handy tip for new teachers:

A prearranged seating chart on the first day of school may not be popular among students, but helps greatly with classroom management. I recommend putting the students in alphabetical order and numbering the desks with a laundry marker so they can find their seats quickly on the first day.

Graphing Lab

In this lab you will be determining the relationship between the mass and length of spaghetti noodles. You will do this by making a data table where you record the lengths and masses of small pieces of spaghetti. In order to make the best possible graph, use widely varying lengths of spaghetti. Record your data in a table on a sheet of graph paper.

When you have measured the masses and lengths of 20 – 30 pieces of spaghetti, use your data table to make a line graph. You will be graded on how closely your graph conforms to the rules discussed in class.

Good luck!

Handy tips for new teachers:

Because of funding problems, many of us have to make do with whatever equipment we can scrounge or put together on our own. Here are some suggestions for making the most of your budget dollar:

- Have your students bring in empty contact lens solution bottles for use as dropping bottles. Make sure you clean them out with a dilute bleach solution before using them in class to ensure they are sterile.
- Empty film canisters are great for holding small quantities of solid reagents. Tell your local film-processing lab that you're a teacher and they'll usually be happy to save empty canisters for you.
- In a pinch, many common and important reagents can be purchased under different names at your local pharmacy. For example, Epsom salt is just another name for magnesium sulfate and ethanol and isopropanol can both be purchased in small bottles. If you need these or any other chemical at very short notice, ask your pharmacist to see if it's available.
- Instead of buying premade stirring rods, buy long glass rods and cut them to the desired length using a triangular file. After you've heated the ends over a Bunsen burner to smooth any sharp edges, these rough-cut stirring rods are just as good as the ones you buy from supply houses.
- Use your teacher discount! Many video stores don't charge teachers for videos that will be used in class and many national chain bookstores and office supply store offer discounts to teachers. Make sure you bring your school ID card!

Chapter 3: Chemical and Physical Changes Lab

Overview:

In a chemistry class, students believe that everything is caused by chemical changes. By the end of this lab, your students should have a good appreciation that not every process involves a chemical transformation.

Estimated time to complete this lab: 50 – 75 minutes

Equipment:

- Station 1: 100 grams of sodium chloride, 100 mL beaker, 1 L tap water, stirring rod, scoopula or large spatula.
- Station 2: 0.5 meters of magnesium ribbon (cut into 3 cm pieces), crucible tongs, Bunsen burner, flint striker.
- Station 3: 20 moderately sized pieces of mossy zinc, crucible tongs, Bunsen burner, flint striker, 100 mL beaker containing cold water.
- Station 4: 100 mL of 0.5 M AgNO_3 solution (made with distilled water and stored in a brown bottle), 100 mL of 0.5 M NaCl solution (made with tap water or distilled water), 10 mL test tube, disposable plastic pipet, 500 mL beaker for use as a waste container.
- Station 5: 0.5 L acetone, 100 mL beaker, at least 60 Styrofoam peanuts, 500 mL beaker for use as a waste container.
- Station 6: One bottle of naphthalene mothballs, fume hood, Bunsen burner, flint striker, forceps, crucible, ring stand fitted with ring and clay triangle, crucible tongs.
- Goggles for everyone!

About the lab:

This lab consists of six stations. At station one, students dissolve a scoopful of sodium chloride in water. At station two, students burn small pieces of magnesium ribbon by holding them over a Bunsen burner with crucible tongs. At station three, students melt mossy zinc held over a flame with crucible tongs. At station four, students precipitate silver chloride through the combination of silver nitrate and sodium chloride. At station five, students dissolve small pieces of Styrofoam in acetone. At station six, students burn a small amount of naphthalene in the fume hood. During all of these stations your students should determine whether they observed chemical or physical changes.

Before starting this lab, review with your students how one might determine whether a chemical or physical change has taken place. Generally, chemical changes involve the release or absorption of heat, a color change, the formation of a precipitate by the combination of two solutions, or a change in chemical and physical properties. Examples of chemical reactions include combustion, rusting

(oxidation), rotting (decomposition), and precipitation. During physical changes no heat is given off or absorbed, the color of the material rarely changes, no precipitates are formed, and the chemical properties of the resulting compound are the same as those of the reagents. Examples of physical changes include heating, boiling, melting, freezing, bending, and shattering.

Safety:

- Students should wear goggles at all stations.
- Station 2: Magnesium burns with an intense white flame. Though the flame is not an eye hazard if goggles are worn, the sudden brightness may startle students into dropping the burning magnesium. For normal laboratory benches, this should not present a problem. However, in the unlikely event that a magnesium fire breaks out, do not extinguish it with water! Wait until the magnesium has burned itself out (the intense white flames will disappear) and extinguish with a standard chemical fire extinguisher. If water is added to burning magnesium, explosive hydrogen gas is produced, causing an even larger problem than the magnesium fire itself.
- Station 3: Zinc remains hot for several minutes after it has been heated. I recommend that your students place the hot zinc into a beaker of cold water to avoid burning themselves.
- Station 4: It's not really hazardous, but silver nitrate turns black when exposed to light. Warn your students – you don't want them to panic if their hands turn black later in the day. Incidentally, this is the same reaction that causes the formation of images in black and white film.
- Station 5: Acetone is extremely flammable. Make sure that this station is situated away from the stations that involve fire.
- Station 6: Burning naphthalene produces toxic, thick black soot. If a fume hood is not available, skip this station.

Clean up:

The salt-water solution in station 1 may be put down the sink. The magnesium oxide ash (station 2), zinc fragments (station 3), and precipitated silver chloride (station 4) may be safely thrown away. The acetone from station 5 may be used again after the Styrofoam sludge has been removed. Because the naphthalene in station 6 is completely burned, no chemical waste is produced.

What can go wrong:

- Be ready to replenish any chemicals that run out during the course of this lab. Though students are told to use only very small amounts of each chemical, sometimes they get a little overzealous in their lab activities.
- The melted zinc in station 3 falls into and clogs the Bunsen burner. If this happens, wait until it solidifies and pry it out with a screwdriver.

- The Bunsen burner won't light in station 6 because the airflow in the hood keeps blowing it out. If this happens, open the hood sash until it lights properly.
- Students sometimes assume that a reaction has given off heat if something becomes hot. This is true when something spontaneously becomes hot, but not when heat has been applied from an external source. It may not be a bad idea to make this distinction when discussing the properties of chemical reactions in class.

Answer key:

Station 1: When sodium chloride dissolves in water, it is a physical change.

Station 2: Your students should observe a very bright white flame, followed by the formation of white magnesium oxide ash. This is a chemical change.

Station 3: It is a physical change when zinc melts.

Station 4: The precipitation of silver chloride from silver nitrate and sodium chloride is a chemical change.

Station 5: It is a physical change when Styrofoam dissolves in acetone.

Station 6: Your students will observe that naphthalene burns with a yellow flame and produces a large amount of black soot. This is a chemical change.

Handy tip for new teachers:

Don't feel discouraged if you don't know the answer to every question your students ask. Even though your students are not chemistry experts, their questions can be surprisingly sophisticated. Even the most experienced teachers get questions they can't answer. When faced with this problem, tell your students that you'll find the answer for them by next class. Kids understand that you can't know everything and they'll respect you for admitting you're not perfect. It's also good to praise students when they come up with questions like this. After all, the goal of education is to further the quest for knowledge, and if your students are asking difficult questions they're doing exactly what they're supposed to!

Chemical and Physical Changes Lab

In your lab book or on a separate sheet of paper, write your observations for each of the following processes. Based on these observations, indicate whether you have witnessed a chemical or physical change.

Station 1:

- Add a small scoopful of sodium chloride into a half-full 100 mL beaker of water. Stir the contents of the beaker for approximately one minute.
- When you are finished, you may pour this solution down the sink.

Station 2:

- Pick up a small piece of magnesium ribbon with the crucible tongs and heat it over the Bunsen burner until you observe a change.

Station 3:

- Pick up a small piece of zinc with crucible tongs and heat it over the Bunsen burner until you observe a change.
- When you have finished, place the residue into the beaker of water provided to you.

Station 4:

- Fill a test tube halfway with silver nitrate solution.
- Quickly squirt an entire pipet full of sodium chloride solution into the test tube.
- When you are finished with this station, pour the contents of the test tube into the waste beaker provided.

Station 5:

- Fill a 100 mL beaker about halfway with acetone.
- Slowly add four or five Styrofoam peanuts into the beaker.
- After you have observed a change, pour this solution into the waste beaker.

Station 6:

- In the fume hood, place a naphthalene mothball into a crucible with forceps.
- Place the crucible in a clay triangle on top of a ring stand.
- Adjust the ring stand so the crucible is approximately eight centimeters above the Bunsen burner.
- Light the Bunsen burner and wait until you observe a change.

Chapter 4: Density Lab

Overview:

Students usually don't have trouble with the idea of intrinsic and extrinsic properties. Intrinsic properties such as density, melting point, and boiling point do not depend on the amount of substance present. Extrinsic properties such as mass, volume, and length depend on the quantity of material present. However, there's a difference between defining intrinsic and extrinsic properties (which students can generally do) and using these definitions to solve a chemical problem. In this lab, students will use their wits to determine that density is an intrinsic property.

Estimated time to complete this lab: 45 – 60 minutes

Equipment:

- 500 grams of metal shot. Copper, iron, lead, zinc, and tin all work well.
- Electronic or triple-beam balance
- 6 – 50 or 100 mL graduated cylinders
- 6 watch glasses
- Students should also be notified that any other equipment in the lab is available for their use. It's a good idea to put out some unnecessary equipment to make your students really think about what they need.

About the lab:

Students will be asked to prove that density is an intrinsic property rather than an extrinsic property. The solution is simple – all the students need to do is compare the density of a small amount of metal with the density of a larger amount of the same metal. If the densities are the same, then density has been shown to be an intrinsic property. If the densities are different, then it is an extrinsic property. Not surprisingly, students should find that the densities match within the limits of experimental error.

Upon posing this question, students may have problems determining the density of a material. Density is equal to the mass of an object divided by its volume. Your students should easily be able to find mass using a balance. To find volume, fill a graduated cylinder about half full of water and place the object in it. The difference between the volume of water before and after you added the object is equal to its volume.

In case you were wondering, the reason you should tell your students that all lab equipment is available for their use is that it forces them to think about what's really necessary to do their experiment. Teaching them that they don't always need to use every tool available is a valuable lesson in experimental design.

Safety:

Most metals are relatively harmless, though it's a good idea to remind your students to wash their hands when they're finished with this lab, particularly if you have chosen lead as your metal.

What can go wrong:

Some students will prove that density is an extrinsic property rather than an intrinsic property. This problem occurs for three reasons:

- Students determine the volume of the metal incorrectly. Instead of using the water displacement method discussed earlier, students sometimes find the volume of the metal shot by directly measuring its volume in a graduated cylinder. Because there are many small spaces between adjacent pieces of metal shot, the volume is determined to be larger than the actual value.
- Students incorrectly find the mass of the metal because they forget to dry the metal before weighing it. As a result, the measured mass of the metal is larger than the actual mass.
- Students don't understand that very small density differences are the result of experimental errors. If they find the density of a metal to be 6.00 g/cm^3 for a small sample and 6.05 g/cm^3 for a larger sample, some students will incorrectly conclude that density is an extrinsic property.

Answer key:

Each lab should have the following features:

- Procedure: Your students should give a complete procedure that explains each step of their experiment. Though this is a fairly simple lab in terms of experimental procedure, it's good training for them to be as complete as possible whenever they write a procedure.
- Data collection: Mass and volume data should be collected for both quantities of the metal used. Make sure students write the correct number of significant figures as well as the proper unit.
- Calculations: The data collected should be used to determine the density of the metal used. The actual densities of several metals follow: copper, 8.92 g/cm^3 ; iron, 7.87 g/cm^3 ; lead, 11.34 g/cm^3 ; zinc, 7.14 g/cm^3 ; tin, 7.23 g/cm^3 . Again, be sure that students include the correct number of significant figures in their calculations as well as the unit g/cm^3 or g/mL .
- Conclusion: Students should explain whether their calculations showed density was intrinsic or extrinsic. If their data incorrectly shows that density is an extrinsic property, they should only receive credit if they make this their conclusion.
- Error analysis: Here's where your students have a chance to discuss where they may have made mistakes. If both densities are not identical, your

students should explain the errors that caused them to be different. If the densities are very dissimilar, they should additionally recognize that though their data indicates that density is extrinsic, they understand it really is an intrinsic property.

Handy tip for new teachers:

Even if you need that extra cup of coffee in the morning, don't drink it during class. Abstaining from food or beverage when you teach is a good way to show students you're serious about the "no food or drink in class" policy.

Density Lab

Prove that density is an intrinsic property rather than an extrinsic property. You may use any of the equipment available and as much of the sample as you like as long as you make sure that everything is in good condition when it is returned.

Your lab write up should include the following:

- Procedure: Give a detailed explanation of everything you did to prove that density is intrinsic.
- Data collection: Your data should be collected in an easy-to-read table and include units. Make sure to write your data with the correct number of significant figures!
- Calculations: Using the data you have collected, make the appropriate calculations to prove that density is an intrinsic property. Make sure you label your calculations so they are easy to follow. Again, you should include the proper units and make sure your answer is written to the correct number of significant figures.
- Conclusion: In just a few sentences, explain whether your calculations confirm that density is an intrinsic property. If your calculations clearly show that density is NOT an intrinsic property, you need to indicate this.
- Error analysis: Unless you've got perfect data, you should explain any possible sources of experimental error. This is particularly important if you've shown that density is an extrinsic property!

Good luck!

Chapter 5: Making a Solution

Overview:

Every chemistry teacher in the world gives endless worksheets about how to calculate the molarity of a solution. After a while, students feel ready to get in the lab and make some solutions of their own. This lab, which may be used in conjunction with the labs in Chapters 6 – 8 in this book, will give your students a chance to turn their theoretical calculations into laboratory reality.

Estimated time to complete this lab: 15 – 35 minutes.

Equipment:

- 100 grams of sodium hydroxide
- 6 – 100 mL graduated cylinders or volumetric flasks
- 6 scoopulas
- 6 – 125 mL Erlenmeyer flasks
- 6 rubber stoppers
- Electronic or triple-beam balance
- 3 pens for marking the flasks containing the finished solutions
- 2 liters of distilled water
- Goggles for everyone!

About the lab:

Your students will be given the task of making 100 mL of 0.1 M NaOH solution. You'd think this would be easy owing to the simplicity of the "M = moles/liters" equation, but students frequently have a hard time translating calculations into real world applications. In the beginning, you may need to give your students a little additional guidance to get them started.

Here are the instructions for making 100 mL of a 0.1 M NaOH solution:

- Find out how many grams of sodium hydroxide are required to make the solution using $M = \text{moles/liters}$. Since the desired volume is 0.1 liters and the desired molarity is 0.1 M, the number of moles required is 0.01.
- Convert 0.01 moles of sodium hydroxide to grams. Making this conversion, you will require 0.4 grams of sodium hydroxide.
- Place 0.4 grams of sodium hydroxide into a 100 mL graduated cylinder or volumetric flask.
- Add 80 mL of distilled water, and wait for the sodium hydroxide to dissolve. This is an exothermic process.
- When the sodium hydroxide is completely dissolved, add distilled water until the final volume of the solution is 100 mL.

One unusual thing about this lab is that there's no lab write-up associated with it. Because the whole point is to make a solution with a concentration of exactly 0.1 M, your students will be graded on how accurately they are able to make their

NaOH solution. The concentration of these solutions can be determined either through titration or with a pH probe (see the “Answer key” below).

A cautionary word: These solutions will never have a concentration of exactly 0.1 M. There are too many possible sources of experimental error present in any high school chemistry lab for this to be a reasonable goal. Before taking too many points off for deviations from 0.1 M, take a look at how close all lab groups get to this value. It suggests an inevitable systematic error if all lab groups get a molarity of 0.2 M rather than 0.1 M and grades should be assigned accordingly.

It is important to note that solid sodium hydroxide readily absorbs water from the atmosphere. To ensure that your NaOH stays dry, make sure your students close the reagent bottle when they are finished with it.

Safety:

Due to the danger of working with sodium hydroxide, goggles should always be worn. If students get any into their eyes, flush their eyes and face with water until medical help arrives. If NaOH comes into contact with the skin, wash with soap and water after determining there are no serious burns. When your students are cleaning up, give them an extra minute to wash their hands to ensure that they don't accidentally rub sodium hydroxide into their eyes later in the day.

Clean up:

The sodium hydroxide solutions may be neutralized with dilute acetic acid and poured down the sink when the pH is 7. As an environmentally correct alternative, save these solutions for use on occasions when a basic solution is required but the concentration is not important.

What can go wrong:

Students miscalculate and use 40, 400, or 4000 grams of sodium hydroxide rather than the necessary 0.4 grams. To avoid this trouble, tell students that under no circumstances should they use more than 10 grams of NaOH.

Answer key:

Your students should give you a labeled Erlenmeyer flask containing 100 mL of 0.1 M NaOH solution. The concentration of the solution can be determined by titrating with 0.1 M hydrochloric acid or with a pH meter (the pH should be exactly 13.00). It's likely that nobody will get a concentration of exactly 0.1 M. This is not surprising and can be due to many different common sources of experimental error. You may or may not choose to have your students outline these sources of error as a supplemental write-up activity.

As an alternative to titration, you may instead choose to evaporate all of the water from each beaker. By measuring the quantity of sodium hydroxide left behind, you can determine the molarity of the solution.

Making a Solution Lab

The goal of this lab is to make exactly 100 mL of a 0.1 M sodium hydroxide solution. You may use any available laboratory equipment.

There will be no write-up for this activity. You will be graded entirely on how close the concentration of your solution is to 0.1 M. All solutions should be placed in stoppered 125 mL Erlenmeyer flasks labeled with the names of the people in your lab group.

Remember to wear goggles at all times during this lab! Sodium hydroxide is extremely dangerous and causes severe eye damage. If any sodium hydroxide gets into your eyes, immediately flush them with water and summon help! If you get sodium hydroxide on your hands or clothing, wash them thoroughly with soap and water. When you finish the lab, take an extra minute to wash your hands to ensure that you don't accidentally rub sodium hydroxide into your eyes.

Good luck!

Handy tip for new teachers:

One of the most stressful things for new teachers is having their class observed by an administrator. Administrators usually sit in the back of the classroom and make detailed notes of everything that happens. If you feel like you've done something wrong, you may look up to find them recording it on a notepad.

Don't worry! When administrators visit your classroom, it's part of their job to write down everything you do in class so they have a complete summary of what took place. They don't just write down your mistakes – they write EVERYTHING.

When you meet with your administrator after class to discuss your performance, be honest and don't panic if everything didn't go perfectly. Your administrator is not there to punish you. Even the toughest administrator wants to see you succeed and will do anything they can to make your job easier.

Handy tip for new teachers:

Many school districts currently expect their teachers to open an email account. Unfortunately, these accounts are sometimes difficult to access from home (requiring the installation of software) and are routed through a school-owned server (which are sometimes unreliable). When you open your account, speak to your system administrator about the possibility of having your school email automatically redirected to a web-based email account (such as Yahoo! or Hotmail). Not only will you have reliable service, but you'll also be able to access your email from any internet-connected computer in the world!

Chapter 6: Dilutions

Overview:

It's one thing to do a dilutions problem using the familiar $M_1V_1 = M_2V_2$ equation but quite another to do it in the real world. By giving your students hands-on experience with diluting a solution, the monotony of doing dilution problems is broken and the kids will have a better understanding of why they are important.

Estimated time to complete this lab: 30 – 45 minutes

Equipment:

- 100 mL of 0.1 M NaOH solution
- 6 – 100 mL graduated cylinders
- 6 – 10 mL graduated cylinders or volumetric flasks
- 6 – 125 mL Erlenmeyer flasks fitted with rubber stoppers
- 1 liter of distilled water
- Pens for marking the flasks containing the finished solutions
- Goggles for everyone!

About the lab:

In this lab, students will be given the task of making a 0.005 M NaOH solution using a graduated cylinder, distilled water, and an excess of 0.1 M NaOH solution. To do this, they will use the equation $M_1V_1 = M_2V_2$.

Here are some instructions on how to conduct this dilution:

- Find out how many milliliters of 0.1 NaOH solution will be required. Using the equation above and plugging in 0.1 M for M_1 , 0.005 M for M_2 , and 100 mL for V_2 , they will determine that exactly 5 mL of 0.1 M NaOH solution is required.
- Measure out 5 mL of 0.1 M NaOH with a 10 mL graduated cylinder and pour it into a 100 mL graduated cylinder.
- Slowly add distilled water until the final volume of the solution is 100 mL.

As in Chapter 5, there is no write-up associated with this lab. Because the whole point of the lab is to make a 0.5 M NaOH solution, the lab will be graded entirely on how well your students are able to make this dilution, based on an Erlenmeyer flask containing their solution. The concentration of these solutions can be determined either through titration or with a pH probe (see the “Answer key” section on the next page).

Also as with Chapter 5, these solutions will never have a concentration of exactly 0.005 M due to experimental error. I would again recommend that before assigning final grades for this lab you determine what an “average” value for the

molarity of the solutions is and grade accordingly. After all, if everybody gets a molarity of 0.004 M, there may be systematic errors in your lab setup.

Safety:

Due to the danger of working with sodium hydroxide, goggles should always be worn. If students get any into their eyes, flush them with water until medical help arrives. If NaOH comes into contact with the skin, wash with soap and water to remove it after determining that there are no serious burns. When your students are cleaning up, give them an extra minute to wash their hands to ensure they don't accidentally rub sodium hydroxide into their eyes later in the day.

Clean up:

Sodium hydroxide solutions may be neutralized with dilute acetic acid and poured down the sink when the pH is exactly 7. As an environmentally correct alternative, save these solutions and use them when a basic solution is required but the concentration is not important.

What can go wrong:

Students miscalculate and find they need 500 mL of 0.1 M NaOH to make their solutions rather than 5 mL. It may be a good idea to tell students that under no circumstances should they use more than 25 mL of the 0.1 M NaOH solution.

Answer key:

The students should give you a labeled Erlenmeyer flask containing 100 mL of 0.005 M NaOH solution. The concentration of the solution can be determined using titration with a 0.01 M HCl solution or with a pH meter (the pH should be 11.70). As in Chapter 5, it's unlikely students will get a concentration of exactly 0.005 M. You may choose to have your students outline the sources of error that cause these deviations as a supplemental write-up activity.

As an alternative to titration, you may instead choose to evaporate all of the water from each beaker. By measuring the quantity of sodium hydroxide left behind, you can determine the molarity of the solution.

Handy tip for new teachers:

Whenever working with acids, keep a bottle of saturated baking soda solution handy and tell the kids where they can find it. Should there be an acid spill, the baking soda solution is an easy and quick way to neutralize the solution. It's also good for the immediate treatment of acid burns (though you should always seek medical attention for any acid burn that's serious enough to cause pain). Similarly, household vinegar may be used to neutralize base spills and minor base burns.

Dilutions Lab

Your mission is to make exactly 100 mL of 0.005 M sodium hydroxide solution using only the laboratory equipment at your disposal, distilled water, and 0.1 M NaOH solution.

There will be no write-up for this activity. You will be graded entirely on how close the final concentration of your solution is to 0.005 M. All solutions should be placed in stoppered 125 mL Erlenmeyer flasks and labeled with the names of the people in your lab group.

As with all labs, remember to wear your goggles! Sodium hydroxide is extremely dangerous and causes severe eye damage. If any sodium hydroxide gets into your eyes, immediately flush them with water and summon help! If you get sodium hydroxide solution on your hands or clothing, wash them well with soap and water. When you finish the lab, take an extra minute to wash your hands to ensure you don't accidentally rub sodium hydroxide into your eyes.

Good luck!

Handy tip for new teachers:

One of the most annoying things for teachers to deal with is a photocopy problem. Here are some things you can do to keep your copier healthy:

- Throw away the first and last pages of paper before putting a fresh ream of paper in the machine. Though you can't see it, these sheets sometimes have a small amount of glue on them from the packaging.
- If you're photocopying single page handouts, make sure you close the lid on the photocopier. This will get rid of the black border around your copies (making them more attractive) and will use less toner (which gums up the internal workings of the photocopier).
- It's a well-known phenomenon: After twenty people use the photocopier, the machine jams and won't work anymore. This happens because the machine is far more prone to jamming when the internal workings are hot. If you have a lot of photocopying to do, do it before the other teachers arrive in the morning or after everybody has left for the day.
- Report any problems with the photocopier immediately. After all, if the main office doesn't know it's broken, they can't get it fixed.
- Be nice to your photocopier repairman. Remember that the hand that fixes the photocopier controls the world.

Handy tip for new teachers:

Chemical waste is extremely expensive to dispose of. Here are two easy ways to decrease disposal costs:

- Do labs on very small scales. If you're doing a lab that requires a large amount of reagent, divide all numbers by two to halve the quantity of chemicals used.
- Shop around for the best disposal prices. Some companies charge far more than others for chemical waste disposal, so make sure you get at least three bids before choosing a company.

Chapter 7: Titration Lab

Overview:

Titration is probably the one thing that students remember most about studying acids and bases. The color changes are dramatic and fun to watch, making them quiet but sure-fire crowd pleasers.

In Chapters 5 and 6, your students made sodium hydroxide solutions with varying molarities. If you're studying acids and bases, you can have your students test the accuracy of these solutions using the procedure in this lab.

Estimated time to complete this lab: 40 – 60 minutes

Equipment:

- 500 mL of 0.1 M NaOH (Chapter 5). Label this "Solution A".
- 500 mL of 0.005 M NaOH (Chapter 6). Label this "Solution B".
- 500 mL of 0.25 M HCl
- 500 mL of 0.01 M HCl
- 6 dropper bottles of phenolphthalein or the cabbage extract indicator from Chapter 8.
- 6 watch glasses
- 25 disposable pipets
- Goggles for everyone!

About the lab:

In this lab, students titrate the 0.1 M and 0.005 M NaOH solutions with hydrochloric acid. If this lab is done with the solutions from Chapters 5 and 6, it will allow the students to determine for themselves how well they made and diluted their solutions.

This is a microscale lab, meaning that only very tiny amounts of reagents will be used. As a result, the unit of volume is "drops" rather than milliliters or liters. In the titration equation, $M_1V_1 = M_2V_2$, the unit of volume doesn't matter as long as it's the same on both sides of the equation. For this reason, it is extremely important that students use the same pipet for measuring out drops of acid and base! Otherwise, the drops of acid and base will have an unknown relationship to one another, throwing off the calculation.

Aside from the small scale, microscale titrations are done in exactly the same way as larger titrations. The benefits of doing this as a microscale lab are that very little waste is created and the quantities of reagent are safer to work with.

Safety:

As always, students should wear goggles to protect themselves from the acids and bases used in this lab. If either solution gets into your students' eyes, flush them with water until medical help arrives. If either solution gets on their skin, it can be washed off with soap and water after determining they have no serious burns. Acids and bases should be stored in separate locations to ensure they don't react with one another. Have students take an extra minute while cleaning up to wash their hands to ensure they don't rub any hydrochloric acid or sodium hydroxide into their eyes later in the day.

If phenolphthalein indicator is used for this lab, be aware that it's a very strong laxative when ingested. To avoid practical jokes, tell the kids that phenolphthalein is toxic without explaining exactly how it causes physical harm.

Clean up:

All waste should be poured together into a large beaker. When it has all been collected, add twenty grams of sodium bicarbonate to the beaker and stir. When this has dissolved, add 0.5 M acetic acid to the beaker until the bubbling stops. This corresponds to a slightly acidic solution which may be put down the sink.

What can go wrong:

The color of the solution never changes during the titration. This occurs either because no indicator has been added or because the base is being titrated with another base. Have the students show you exactly what they did in this experiment and they'll soon figure out what went wrong.

Answer key:

Part 1:

- The calculations should be complete and show the concentration of "Solution A" is about 0.1 M NaOH.

Part 2:

- The calculations should be complete and show the concentration of "Solution B" is about 0.005 M NaOH

Handy tip for new teachers:

If you're at the bookstore and see something you'd like to use in your classes, don't buy it! Instead, take down the name and publisher of the book and see if you can get your school to order it for you.

Titration Lab

In this lab, determine the concentration of two sodium hydroxide solutions by titration with hydrochloric acid. As with all titrations, you will use the equation $M_1V_1 = M_2V_2$.

Part 1: Titrating “Solution A”

Determine the concentration of a base (“Solution A”) by titrating with 0.25 M HCl following the procedure outlined below. To avoid contamination, make sure to rinse the pipet with distilled water before and after every use.

Procedure:

- Place 20 drops of “Solution A” into a watch glass with a pipet.
- Add two drops of indicator to the watch glass.
- After rinsing with distilled water, use the SAME pipet you used for the first step to slowly add 0.25 M hydrochloric acid until the color of the indicator changes. When it has changed, stop the titration.

Record the number of drops of 0.25 M HCl: _____

Calculation: From your data, determine the molarity of “Solution A”. Show all work below:

Part 2: Titrating “Solution B”

Using the same procedure that you used in Part 1, determine the concentration of NaOH in “Solution B”. The only difference is that in this section you will be using 0.01 M HCl rather than 0.25 M HCl for your titration.

Show all work and calculations below:

Handy tip for new teachers:

It takes a lot of people to make a school run smoothly. A good relationship with these people is vital because they can make your job easier:

- Secretaries and aides take phone messages from parents who are calling to discuss their child's grades with you. If they like you they can calm angry parents so subsequent calls and meetings go smoothly. They also usually handle the dispensing of school supplies, so if you need anything, you'll get it more quickly if you have a relationship of mutual support and respect.
- The folks in the finance office handle your purchase orders. It's not surprising to find that some departments get faster and friendlier service than others. A cheerful attitude and properly filled out purchase orders will keep this relationship a happy one.
- The custodians generally make your school a nice place to work. As repayment, they sometimes get ridicule from students (and occasionally from thoughtless staff). By treating the custodians with respect, you make their jobs more pleasant and set a good example for the students.

Handy tip for new teachers:

Don't let students come in and make up work during your lunch period. It's nice having a break during the day when you just kick up your feet and relax!

Chapter 8: Making an Indicator Lab

Overview:

When we think of acid-base indicators, we think of chemical compounds like litmus and phenolphthalein. However, many natural compounds are indicators. In this mini-lab, your students will make an indicator from red cabbage.

Estimated time to complete this lab: 45 minutes

Equipment:

- 6-250 mL beakers
- 6 hot plates
- 6 beaker tongs
- 2 L distilled water
- Large screw-top storage bottle
- 6 dropper bottles of 1 M HCl
- 6 dropper bottles of 1 M NaOH
- 2 red cabbages
- 12 watch glasses
- Goggles for all

About the lab:

In this lab your students will be making an acid-base indicator out of red cabbage. Frequently, this lab is followed by the question, “What do we do with this cabbage indicator when we’re done with it?” If you want to do titrations or determine if a compound is acidic or basic, this indicator works well. Just because it’s homemade doesn’t make it less effective than other indicators. At the end of the lab, students test its color in acid (purple) and base (green/yellow).

Here are some other ideas you might want to try:

- Study the properties of the cabbage indicator. Does cabbage work effectively as an indicator for all acids and bases? (It works best for strong acids and bases). When your students have finished this lab, you can have them write up a paper characterizing cabbage extract as an indicator.
- Study the indicator properties of other dyes. Boil other vegetables and determine whether the resulting juices can be used as acid-base indicators. I’ve never tried this experiment, but I have the sneaking suspicion that your students would find it interesting, particularly if you admit to them that you don’t know what the results will be. Kids love the act of discovery, and you might find yourself more engrossed in this lab than you thought possible.

Safety:

I’d recommend preparing your cabbage indicator in a well-ventilated room or fume hood due to its unpleasant smell. Take the normal precautions for working with NaOH and HCl (“safety”, p. 30), even though the quantities are very small.

Clean up:

Due to the small quantity of waste, everything can safely go down the sink.

Preparing an Indicator from Red Cabbage

Though acid-base indicators are usually man-made chemicals, the first indicators were naturally occurring compounds. It is said that this phenomenon was first discovered when a trail of ants was discovered walking over rose petals. Because some ants secrete formic acid from their feet, the red in the rose petals turned white where they walked because the red coloring is an indicator.

Procedure for making an indicator from red cabbage:

- 1) Pull a few leaves of red cabbage into very small chunks with your fingers.
- 2) Fill a 250 mL beaker halfway with the torn cabbage leaves and add water until the beaker is about two-thirds full. Place the beaker on a hot plate at medium heat.
- 3) You should notice that the water turns purple as the cabbage boils. When the water is very purple, remove the beaker from the heat with beaker tongs and let cool. The purple juice you made is an acid-base indicator!
- 4) To find the color of your indicator in acid, add one drop of indicator to one drop of 1 M hydrochloric acid in a watch glass.

Record the color of the indicator in acid _____

- 5) To find the color of your indicator in a base, add one drop of indicator to one drop of 1 M NaOH in a watch glass.

Record the color of the indicator in base _____

Chapter 9: It's Haiku Time!

Overview:

There are moments in a chemistry teacher's life that a good time-killing activity is needed such as the last day before Winter Break or an early dismissal for snow. No matter what the reason, it's always a good idea to have something in reserve for unexpected downtime.

Estimated time to complete this project: 25 – 45 minutes.

Equipment:

- Colored pencils or pens
- Colored construction paper
- Crayons
- Scissors
- Glue or double-sided tape
- Glitter, but only if you're exceptionally brave

About this activity:

In this activity, your students will make an art project for your class based on a chemistry-themed haiku. If you aren't familiar with traditional Japanese poetry, haikus are three line poems in which the first line has five syllables, the second has seven syllables, and the third has five syllables (an example is given in the student handout on the next page). The lines typically don't rhyme and are meant to evoke an image in the reader's mind. Needless to say, we take a few liberties with this ancient art form.

For this activity, tell your students to write a haiku about whatever subject you've been discussing in class. For example, if you're currently covering ionic compounds, have your students write a haiku about them. If the topic you're currently discussing doesn't lend itself to poetry, simply have your students write about chemistry in general.

When your students have finished, use these projects to decorate your classroom. It's amazing how some silly chemistry poems and fifteen pounds of glitter brighten up a room!

A warning: Art projects are messy. Glue, glitter, small scraps of paper, and supplies will enter every nook and cranny of your classroom. It helps if you give your students five minutes at the end of class to clean up. Have a dustpan and broom ready. Be strong.

Haiku Project

Haiku is a traditional Japanese form of poetry. Each haiku is meant to evoke a feeling or image in the mind of the reader. Though short, haikus are among the most beautiful and evocative forms of writing in the world.

Each haiku consists of three lines. The first line has five syllables, the second has seven syllables, and the third has five syllables. The lines don't need to rhyme.

For this project, you will do the following:

- 1) **Write a chemistry-themed haiku.** Remember that it's always a good idea to say nice things about chemistry when writing poetry in a chemistry class.
- 2) **Make your poem suitable for display in the classroom.** Use your artistic abilities and the art supplies provided to turn your poem into a beautiful work of art.

In case you need inspiration, here's a haiku to get you started:

**Dancing atoms play
Moving, reacting, forming
Chemistry rules all**

Chapter 10: Average Atomic Mass Lab

Overview:

Students usually have an easy time understanding the periodic table. There's only one thing that's not clear to students: If the weights of all atoms are multiples of one atomic mass unit, why are the atomic masses on the periodic table written as decimals? When your students are done with this activity, they'll understand.

Estimated time to complete this lab: 25 – 40 minutes

Equipment:

- As many high capacity balances as you can get your hands on.
- Several thousand plastic and glass beads of various types, available at your local hobby store. Each type of bead represents a different isotope, so each type should be of uniform size and easily distinguished from the other types. It's ideal if each type of bead is a different color than the others to make them more easily distinguishable from each other.
- Several plastic cups or beakers for use as weighing containers.
- A large bucket for holding the mixture of beads.

About the lab:

You have two goals during this lab. The first is to get the kids to understand why NO atoms of an element have the exact weight listed on the periodic table. The second is to get the kids to figure out which method of determining the average mass of a particle is best.

This lab involves the use of several different types of beads. Each type of bead represents a different isotope of an element. Essentially, this lab substitutes macroscopic beads for microscopic atoms, making it possible for your students to do average atomic mass calculations by manipulating the "atoms" themselves. This hands-on approach will be especially useful for students who have difficulty imagining what very tiny real-world atoms look like.

Before you get started with this lab you need to find the following:

- The number of each type of beads you have. Unfortunately, you'll need to count each individual bead. A packet that says, "Contains 500 beads" rarely contains exactly 500 beads.
- Add these numbers together to find the total number of beads.
- Find the percentage of beads you have of each type. For example, if you have 20 big green beads and a total of 60 beads, the percentage of big green beads is 33.3%.

- Find the total mass of all the beads present. This is where balances with large weighing capacities come in handy.
- Find the “average atomic mass” of the beads by dividing the total weight of beads by the total number of beads.

In this lab your students will be given the task of determining the average atomic mass of the beads in this sample. I have noticed in my experience that students try to determine the average mass in one of three different ways:

Method 1: Brute force. Students weigh all of the beads and divide this weight by the number of beads present. This is the most intuitively obvious and accurate way of solving the problem and is based on the mathematical method of finding an average. Because we don't determine average atomic masses using this method, discourage it by using a very large number of beads and limit the time available for weighing them.

Method 2: Fancy footwork. Students weigh one bead of each type and average these weights. This method is inaccurate because it doesn't take into account the fact that some beads are more abundant than others.

Method 3: Statistics. This is the statistical method that we use to teach students how to determine average atomic mass when doing problems in class. Encourage students to use this method by telling them how many of each type of bead is present. Students find data for and solve the following equation:

Average mass = (average mass of type 1) (abundance of type 1) + (average mass of type 2) (abundance of type 2) + and so on...

This method yields good results (as one would hope), though there will be some error in finding the average mass of each type of bead because the small sample your students use may not be representative of the whole mixture.

Whatever method your students decide on, you'll need to discuss their results at the end of the lab. Call each group back to their seats and have them tell you how they arrived at their final answer. When all groups have given you their results, tell them the correct answer.

Students who use the first method will wonder why it isn't the method we actually use when doing average atomic mass calculations. Even though this method should be most accurate, the method we use to find average atomic mass involves the equation in the third method. Why do we deliberately solve a problem with a less accurate method?

The answer is that the first method involves individually counting the precise number of atoms present in a sample. Though this works well when we have just a few hundred things (as with a small sample of beads), it works poorly when

there are $\sim 10^{24}$ very tiny atoms. The problem with this method is not that it is inaccurate; the problem is that it is impractical. This lab imperfectly simulates the difficulty of counting a huge number of atoms by using a very large number of beads.

Fortunately, it's easy to find the percentages of each isotope of an atom present in a sample. You may or may not want to discuss mass spectrometry, but should emphasize that any chemistry problem-solving method that involves counting atoms individually is a bad idea. For working with very large numbers, statistical methods are always used.

Clean up:

Beads wander all over the room during this activity, and you'd be surprised at how far they bounce. Make sure to leave students sufficient clean-up time to collect runaway beads.

What can go wrong:

If enough beads wander away during the lab, the average mass of the beads may change from the average you found before starting the lab. Though these errors are generally very small, they also tend to accumulate over time. It may not be a bad idea to find the average mass of the remaining beads each year before doing this lab to ensure that this is not a problem.

Answer key:

To do this lab, you'll need to find the average mass of a bead as discussed on the first page of this lab. No matter how meticulous your students are, experimental error will keep your students from getting the exact answer no matter what method they use.

Handy tip for new teachers:

Every new teacher wants every lesson to be perfect. As a result, many new teachers stay very late after school to prepare their lessons for the next day. There's nothing wrong with staying a few extra hours, but some first-year teachers take this to an extreme, staying at school until 9 p.m. every night and coming in on weekends. Give yourself some time off, and remember that your mental health is just as important as preparing good lessons.

Average Atomic Mass Lab

Using your ingenuity and any equipment available to you, determine the “average atomic mass” of the beads in the container at the front of the room. You may use any method you like to come up with your answer, but please make sure that all data and calculations are written in the space below.

Good luck!

Chapter 11: Energy Research Project

Overview:

Our society places great value on technology. Our current technology requires huge amounts of electricity, requiring us to use a wide variety of power sources including fossil fuels, nuclear power, solar power, geothermal power, wind power, and hydroelectric power. In this research project, your students will be broken into groups and present these energy generation methods to the class.

Estimated time to complete this project: 2 – 3 class periods

Equipment:

- The school library or internet-capable computer lab

About the project:

Break your class up into six groups. Each group will study one form of electrical power generation and present their findings to the class. Each presentation will include a discussion of how the technology works (including a visual aid), a description of the pros and cons of this technology, and an explanation of possible future technological advances.

The student handout outlines the basic requirements for this project. To use it, photocopy the handout six times and on each copy write one of the following topics: Fossil fuel power, nuclear power, solar power, geothermal power, wind power, hydroelectric power. Each group will research the topic on their handout.

You can make this project more productive with some simple preparations. Get a brief overview of each power generation method by researching them in an encyclopedia. This will give you enough background information about each technology to aid your students in their research. Next, discuss this project with your school librarian for good ideas about where to find useful information. Finally, make sure you sign up for time in your library or computer lab to ensure that your students will have access to the resources they need.

After they've finished with their research, give your students another class period to prepare their presentations. Make sure you keep an eye on each group to make sure that their presentations will meet the requirements on the student handout. Reproduce the grading rubric (p. 48) on the back of the student handout so students know precisely what is expected of them.

In addition to their presentations, each group will turn in a bibliography of their sources of information. It's never a bad idea to check one of the references from each group to make sure the sources are authentic.

What can go wrong:

Students frequently have trouble filtering truth from propaganda. If you use the internet, you may find that students are finding their “facts” about nuclear power plants at websites run by industry lobbying groups. Likewise, a book entitled The Nuclear Nightmare clearly has a political agenda.

Answer key:

I have included some very basic facts about each method of power generation to get you started:

- Fossil fuel power plants generate energy by using the combustion of fossil fuels to produce steam. This steam turns a turbine in a power generator. Coal strip-mining and oil drilling, as well as the smoke given off by power plants are all significant sources of environmental damage. Fossil fuels are non-renewable energy sources and have other significant drawbacks but currently provide most of our electricity.
- In nuclear power plants, nuclear fission is used to produce the heat for making steam that turns the turbine in a generator. Nuclear plants are generally nonpolluting – the most significant effluent is uncontaminated warm water from the coolant system. There is currently no long-term storage facility for spent nuclear fuel rods. Nuclear power plants have a long safety record, but the partial meltdown at Three Mile Island and the catastrophic reactor explosion at Chernobyl both loom large in the public’s mind, making nuclear power politically unfashionable.
- Solar power cells produce energy with sunlight. Solar cells tend to produce power at high cost and with modest efficiency, though both have improved significantly in recent years.
- Geothermal power produces energy by tapping into the earth’s internal heat. This technology is primarily used in regions with considerable volcanic activity. While promising, there are technical hurdles in scaling up the amount of power produced with this method.
- Wind power is used only in consistently breezy locations. Though wind turbines have been used with some success in some parts of the world, they each generate only a very small amount of electrical power.
- Hydroelectric power generates power when flowing water turns the turbine on an electric generator. While this is a renewable resource, hydroelectric plants are widely criticized for destroying river ecosystems.

Energy Research Project

As you know, our society requires large amounts of electricity. Unfortunately, there is no perfect method of generating large amounts of electrical power. As a result, we rely on a wide variety of power sources for our energy needs.

In this project, you will be presenting to the class one of the major technologies used to produce electrical power. The method you will be discussing is:

Your presentation should include each of the following:

- An explanation of how your assigned power generation technology works. Incorporate a poster-sized visual aid that includes a labeled sketch of the power plant. A good place to look for this information would be an encyclopedia or other general reference source.
- A description of at least three benefits to using your power source. Describe the reasons commonly cited for the continued use of your power source and explain specific advantages it has over other power generation methods.
- A description of at least three disadvantages to using your power source. Describe common criticisms used to discredit the use of your power generation method and explain its specific disadvantages.
- An explanation of how this energy production method may change in the future. If there are new improvements or likely advances in the efficiency of your technology, describe them. Explain whether you think this power source will be more or less utilized in the future, citing specific reasons.
- Your presentation should be between four and six minutes long. Every member of your group should take an active role in your presentation. You will be graded not only on how well you cover these topics but also on how well you present your ideas to the class. Make sure you practice ahead of time if you get nervous speaking in front of others!

In addition to your presentation, you will be required to turn in a bibliography showing your information sources. You should use at least three sources, only one of which may be an encyclopedia.

A copy of the grading criteria is on the opposite side of this sheet. Please refer to it when preparing your presentation to ensure that you meet the requirements.

Good luck!

Chapter 12: Colligative Properties Lab

Overview:

It's not difficult to teach students about colligative properties. The idea that concentrated solutions behave differently than dilute ones is intuitive and usually requires only a brief explanation. In this lab, your students will observe colligative properties in real solutions.

Estimated time to complete this lab: 45 minutes

Equipment:

- 2 – 1 liter glass bottles
- 1 – 1000 mL beaker
- 1 stirring rod
- 1 kg of sodium acetate
- 5 grams of calcium hydroxide
- 2 L of distilled water
- 6 Bunsen burners
- 6 ring stands with rings
- 6 pieces of wire gauze
- 2 flint strikers
- 6 beaker tongs
- 6 – 100 mL beakers
- 6 thermometers (should be able to measure up to 100 – 110⁰ C)
- Goggles for everyone!

About the lab:

In this lab your students will be given two solutions. The first solution is saturated sodium acetate and the second is saturated calcium hydroxide. Your students will figure out which of the two solutions is more concentrated using their knowledge of colligative properties.

Students sometimes think this is a trick question. After all, if both solutions are “saturated”, they must have the same concentration! Take a few minutes to explain that some compounds are more soluble in water than others, causing some “saturated” solutions to be more concentrated than others.

To make your sodium acetate solution, pour 500 mL of distilled water in the 1000 mL beaker and start adding sodium acetate. Because sodium acetate is extremely soluble in water (~130 grams per 100 mL) it will dissolve readily. When the solution is finally saturated and has residual sodium acetate at the bottom of the beaker, pour it into a 1 L bottle labeled “saturated sodium acetate”.

Making the calcium hydroxide solution is even easier. Since calcium hydroxide is relatively insoluble in water (~0.15 grams per 100 mL) a saturated solution can be made simply by placing 5 grams of it in a 1 L bottle and adding distilled water until the bottle is full. Label this bottle “saturated calcium hydroxide”.

Your students will probably employ several methods to determine which solution is most concentrated:

- They'll inspect the solution to see which one "looks more concentrated." Because calcium hydroxide is a fine white powder and sodium acetate is a clear crystal, calcium hydroxide solutions are milky and sodium acetate solutions are colorless. This may give students the erroneous idea that saturated calcium hydroxide is more concentrated.
- They'll find the densities of the solutions. The sodium acetate solution should be denser than the calcium hydroxide solution, suggesting a higher concentration of solute.
- They'll determine the boiling points of each solution. The calcium hydroxide solution will have a boiling point of almost exactly 100°C because only a very tiny amount of calcium hydroxide dissolves. The saturated sodium acetate solution has a much higher boiling point, but because most thermometers only have gradations to 110°C it can be difficult to measure accurately. The actual boiling point of the solution isn't terribly important as long as your students are able to determine that the sodium acetate solution has a higher boiling point.
- The amount of solute can be determined directly by placing 10 mL of each solution into an evaporating dish and boiling away the water. The weight of residual solute can be used to determine the molarity of the solution.
- Other tests: Students can be creative and invent tests for things that don't exist. Unless these tests are dangerous in some way (and it's hard to do anything truly dangerous in this lab), let them go ahead with their tests. Who knows, they just might work!

Depending on the results of their tests, some lab groups will finish earlier than others. If one group finishes the lab in ten minutes, suggest to them that it might be a good idea to do follow-up tests to confirm their conclusion.

For an interesting postlab demonstration, make a saturated zinc chloride solution using 20 mL of distilled water. The extreme solubility of zinc chloride (432 grams / 100 mL) makes it appear as if a nearly infinite amount of powder is dissolving in a very small amount of water. Zinc chloride also has a high heat of solvation, making this not only an interesting visual phenomenon but a tactile one as well.

Clean up:

When the students are done with their sodium acetate and calcium hydroxide solutions, have them place any residue in separate beakers. Reuse these reagents by putting them back in the 1 L bottles. With careful recycling, you can use the same solutions for the rest of your career!

An annoying problem during clean up is that spilled sodium acetate solutions form a giant sheet of crystals on your lab benches when the water evaporates. To get your table tops clean, rinse them two or three times with water.

Safety:

Sodium acetate and calcium hydroxide are both fairly nontoxic and pose no serious health threat. As a precaution, students should wear goggles during the course of the lab and wash their hands when they have finished.

What can go wrong:

Aside from the usual spills, this is a foolproof lab. Students almost always get the correct answer, though they are sometimes thrown off if they depend too heavily on the appearance of the solutions.

Answer key:

Your students should state that saturated sodium acetate is more concentrated than saturated calcium hydroxide, citing the results of their tests as evidence.

Handy tip for new teachers:

Looking for a cheap meal? Try the school cafeteria! Though there's not much ambience, you can usually get a healthy, balanced meal for less than four dollars. If your planning period is right before lunch, beat the rush by heading down five or ten minutes before the bell rings. By the time the kids are swarming over the lunch line, you'll be enjoying your midday meal.

If you share a lunch period with other teachers, make a point of eating with them in the faculty room or other communal areas of the school. Though the kids are wonderful to work with, it's good to get some adult conversation during the course of the day. It's also a good way to make friends if you're new to the area.

Colligative Properties Lab

Using available lab equipment and your knowledge of colligative properties, determine whether saturated sodium acetate or saturated calcium hydroxide has a higher concentration. You may do whatever tests you like as long as you don't use more than 50 mL of each solution at a time.

Clean up:

When you have finished, put all waste in the appropriately marked beakers. Please keep the sodium acetate and calcium hydroxide wastes separate so they can be recycled.

Write up:

On a separate sheet of paper, write down a brief description and the results of each of the tests you performed. Use the results from these tests to make a final determination about which solution is most concentrated.

Good luck!

Chapter 13: Mole Calculation Lab

Overview:

If you ask students at the end of the year what they remember most about gas laws, the first thing out of their mouths is “ $PV = nRT$ ”. With this lab, your students will use this equation to calculate the number of moles of air in your classroom.

Estimated time to complete this lab: 20 – 30 minutes

Equipment:

- One meter stick for every two students
- Thermometer
- Barometer for determining the current atmospheric pressure

About the lab:

In this lab your students will be using measured values of pressure, temperature, and volume to determine the number of moles of air in your classroom. Because the ideal gas equation doesn't distinguish between different gases, this calculation is possible even though air has many components. This lab is a simple activity that the kids enjoy.

If you'd like to take this lab one step farther and have the students find the mass of gas in the classroom, a fair estimate for the “molar mass” of air is 29 grams/mole. To find the mass of air in grams, multiply the number of moles of air by 29 grams/mole.

What can go wrong:

Students sometimes have problems with unit conversions, specifically the conversion of cubic meters to liters. The needed conversion factor is “1000 L in 1 cubic meter”. Students will also occasionally use the wrong value of the ideal gas constant. The correct value for this lab is $0.08206 \text{ L} \cdot \text{atm} / \text{mol} \cdot \text{K}$.

Answer key:

The proper answer for this lab depends on the volume, temperature, and pressure of your classroom. Depending on the size of your room, the answer is probably somewhere between 2,500 and 8,000 moles.

Handy tip for new teachers:

Quit smoking. The school day is too long to go without a cigarette. If you absolutely can't quit, use a nicotine patch to get you through the day.

Find the Number of Moles of Air in Your Classroom!

Determine the number of moles of air in your classroom using a meter stick, a thermometer, and the current atmospheric pressure. Assume that there are no solid objects within the room that take up space.

During this activity, make sure that you use all of the correct conversion factors and the correct value of the ideal gas constant. Show your measurements and calculations in the space below.

Good luck!

Chapter 14: The Hissing Gas Tank Lab

Overview:

Your students are probably learning to drive. While you're teaching them the importance of moles and the periodic table, they're counting the days until they get their license. A good way to teach your kids about the wonders of vapor pressure is to connect it with the siren call of their automobiles.

Estimated time to complete this lab: 20 – 60 minutes

Equipment:

- 150 mL of chilled acetone (it is important that you chill it before doing the lab)
- 6 – 125 mL Erlenmeyer flasks
- 6 rubber stoppers for the flasks.
- Goggles for everyone!

About the lab:

Your students will answer the following question: “On a hot day, why is there a hissing noise when you take off the gas cap from your car?” Contrary to what your students may believe, the hissing is not caused by the heat expansion of air in the gas tank as the car's temperature increases. The temperature increase simply isn't great enough for this to cause a significant increase in the internal pressure of the gas tank.

The additional pressure is produced by gas being given off by the liquid itself, or the vapor pressure. The idea of vapor pressure can be illustrated with a simple example. Imagine you were to take a very hot shower. When you get out of the shower, you have to wipe condensation from the mirror before you can see yourself. The condensed water comes from water vapor generated while you were taking the shower because the vapor pressure of water is high when its temperature is high. Now, imagine that you were to take a very cold shower. When you get out, the bathroom mirror won't have condensation on it because the temperature of cold water isn't high enough to cause vaporize it (the vapor pressure of water is low at low temperatures). The vapor pressure of a liquid increases exponentially with temperature.

Give your students this activity after you have talked about vapor pressure and the gas laws. Instead of starting class with a long pre-lab discussion, hand out the student sheet and see what your students are able to come up with. Some may figure out that the pressure inside the gas tank is caused primarily by the formation of gasoline vapor and others may need a little help. That's where the mini-lab comes in.

In groups of three or four have your students put goggles on and pour 25 mL of chilled acetone into the bottom of an Erlenmeyer flask and seal the flask closed with a rubber stopper. Next, they should gently swirl the acetone while gently warming the bottom of the flask with their hands. After five minutes, have them slowly pull the stopper from the flask. If they listen carefully, they should hear a pop caused by the increased vapor pressure of warming acetone. Give your students another few minutes to finish answering the question on the worksheet after completing this demonstration.

As a separate exercise, you may find it handy to have your students graph the dependence of vapor pressure on temperature using the data included in the chart below. By having your students analyze the vapor pressure data that goes with the mini-lab, they will be sure to understand this phenomenon.

The dependence of acetone's vapor pressure on temperature

Temperature (K)	Vapor Pressure (Torr)
242	10
264	40
281	100
313	400
330	760

Safety:

Acetone is highly flammable and should be kept away from heat sources such as ovens, hot plates, and Bunsen burners. Acetone is mildly toxic and students should not be exposed to its fumes for an extended period of time. Make sure your students wear goggles during the mini-lab section.

What can go wrong:

Sometimes the flasks don't make a popping noise when the stopper is removed. To solve this problem, lubricate the stopper with a very small amount of vacuum grease or petroleum jelly to ensure a good seal between the stopper and the flask.

Clean up:

The acetone may be collected and reused.

Handy tip for new teachers:

Whenever you talk to a parent, make a note in your gradebook with the date and time of your discussion, the topic discussed, and any conclusions reached. In the very unlikely event that a parent alleges discrimination or professional malpractice, this evidence can be used in your defense.

The Hissing Gas Tank Lab

Have you ever heard your gas cap hiss when you remove it to fill up your car on a hot day? Using your knowledge of chemistry, write an explanation in the space below for why you believe this phenomenon occurs.

Handy tip for new teachers:

New teachers frequently find that they spend a lot of their time with colds or the flu. Here are some suggestions for keeping away illness:

- Wash your hands frequently during the day, especially after grading papers.
- Buy a bottle of alcohol-based hand disinfectant and use it once an hour. If you find that it dries your skin, follow it up with a good moisturizer.
- Get a flu shot. They're inexpensive and most schools offer them to teachers for free or reduced prices. They're not foolproof, but any protection from the flu is well worth the money.
- Get plenty of sleep, at least eight hours a night. If you can't get this much sleep during the week, catch up on weekends.
- Take a Vitamin C supplement if you get sick. Even if you don't believe that Vitamin C fights illness, you've got to admit that it's healthy. At the very least, you won't have to worry about scurvy.
- When you get sick, buy zinc lozenges for your throat. They taste awful but seem to accelerate the healing process.

Handy tip for new teachers:

Houseplants always cheer up a classroom. If you decide to bring a houseplant into school, plants that require relatively low amounts of light do best, as do plants that have a high tolerance for dryness (after all, they don't get watered on school vacations).

Chapter 15: Molecular Motion Lab

Overview:

How fast do molecules move? Because they're so small, students usually assume they move very slowly. However, root mean square velocity calculations show the actual velocities are closer to half a kilometer per second. This is confusing to students – after all, when somebody opens a container of pickles across the room, it takes a few minutes for the smell to reach them. After this lab, your students will understand why the apparent velocity of molecules is so much less than the actual velocity.

Estimated time to complete this lab: 30 – 45 minutes

Equipment:

- Meter stick
- 250 mL of household ammonia
- A shallow dish (for holding the ammonia)
- Fume hood (recommended, but not required)
- 1 roll of masking tape
- A stopwatch or wall clock
- Goggles for everyone!

About the lab:

In this lab your students will measure the velocity of ammonia by tracking the rate that its smell travels across the room. This is accomplished by pouring it into a shallow dish in a fume hood. From the front of the fume hood, place a piece of masking tape at 0.50 meter intervals until you either run out of classroom or run out of students. Write the distance from the fume hood on each piece of tape.

At the beginning of the experiment, turn off the fume hood and open the sash as far as it goes. Record how long it takes each student to smell the ammonia as it travels across the room. For example, the first student may smell the ammonia after 45 seconds and the second student may smell it after 95 seconds. When all of your students have smelled the ammonia, stop the lab.

It's important to note that in an occupied room, the primary way that gases travel is not through diffusion (which is what this lab is trying to measure) but through air currents. To minimize the effect of these air currents, turn off your air conditioner a few minutes before starting the lab and limit your students' motion during the lab.

The students should make a table displaying the data they have collected. The table should include the measurements of time from all students and will be similar in appearance to the table on the next page:

Table showing the time required for ammonia to travel across the room

Distance from fume hood (meters)	Time (seconds)
0.00	0
0.50	45
1.00	95

Have your students use their data table to compute the average velocity of ammonia vapor as it traveled across the room. Averaging the observed velocities of ammonia as it traveled from one student to the other is the best way to do this. For example, considering only the data above, the average velocity of the ammonia would be the average of 0.011 m/sec (the velocity as it traveled the first 0.50 m) and 0.010 m/sec (the velocity as it traveled the second 0.50 m) for an average of 0.0105 m/sec. In correct significant figures this should be written as 0.011 m/sec.

The next question is this: If the velocity of ammonia at 20⁰ C is calculated to be 656 m/sec, why is the experimental value so much slower?

The answer is that molecules in a gas don't travel in straight lines, but bump into each other as they travel along. If there had been no air molecules in the room, the ammonia molecules would have traveled 656 m/sec. However, because ammonia molecules collided with air molecules and bounced back in the direction they came from, the ammonia appeared to have a much lower velocity. This ties in nicely to the idea of mean free path, the average distance a molecule travels before colliding with another molecule ($\sim 10^{-7}$ m at room temperature).

For honors students, you may want to expand the lab to include calculations of mean free path and root mean square velocity, while for general level students you may want to discuss them qualitatively. Either way, the kids like this lab because it turns them into sophisticated ammonia detecting devices.

Safety:

Ammonia fumes cause respiratory damage if inhaled for too long a period of time. Once students smell the ammonia, I recommend that you have them clear the area to ensure they don't get too strong a whiff of the fumes. When the lab is over, turn on the fume hood and continue the class in an unused room if the ammonia smell is too strong. Students with asthma should be the "timers" for this lab rather than the data collectors.

What can go wrong:

Sometimes the nearest student to the fume hood doesn't smell the ammonia first. This is because some students have a better sense of smell than others do. When this occurs, use the data of the student who smells it first. If this means

skipping a data point because one student has a poor sense of smell, the lab won't be negatively affected.

Clean up:

Pour the ammonia back into the bottle and use it as a cleaning solution. If you don't have a fume hood, make sure to open the windows and clear your room until the smell disperses.

Answer key:

In their lab notebooks, your students should have the following:

- A data table like the one on the last page measuring the amount of time it took for the ammonia to travel across the room.
- A series of calculations showing the velocity of ammonia molecules as they traveled from student to student. The number of calculations will depend on the number of students taking part in this lab.
- A final answer for the velocity of ammonia fumes. This is an average of each calculation in the section above. The value your students will find for ammonia velocity is impossible to predict because the fumes are probably traveling across your room in air currents and not by molecular motion at all. The velocity of these air currents will determine the measured velocity, though 0.01 m/sec is a common approximate answer.
- An explanation of why the observed velocity of ammonia is so much slower than the theoretical velocity of 656 m/sec. Your students should state that though the molecules are moving very quickly, their speeds seem much lower because they keep bumping into each other and into air molecules. Unusually perceptive students may also mention that air currents may further decrease the apparent velocity.

Handy tip for new teachers:

It's hard to learn the names of each student at the beginning of the year. On the first day of school, have each student make a name card for his or her desk and use that as a way to learn their names. If you're bad with names, tell your students on the first day so they won't be offended when you call them "Bernice", particularly if "Bernice" is the star football quarterback.

Molecular Motion Lab

In this lab you will be measuring the velocity of ammonia molecules as they travel across your classroom. To do this, you will place sensitive ammonia detectors at regular intervals from a source of ammonia. Fortunately, your noses are sensitive ammonia detectors.

Each of you should stand at one of the masking tape marks on the floor. After the experiment has started, let your teacher know when you smell the ammonia. You'll know it when you smell it! Once you finally smell it, slowly move to the other side of the room to avoid overexposure to the ammonia fumes.

Part 1: Making a data table

Make a data table that shows how long it took for the ammonia to travel across the room. The distances should be in intervals of 0.50 meters and the times will be based on your observations.

Part 2: Finding the velocity of ammonia molecules

Use the data chart to compute the velocity of ammonia molecules as they move from one mark to another. Velocity is calculated by dividing the distance an object travels by the amount of time it took for it to get there. For example, if it took 65 seconds for the ammonia to move from the 1.00 to 1.50 marks, you'd calculate the velocity of the ammonia molecules to be equal to the distance traveled divided by the time, or 0.50 meters divided by 65 seconds to get 0.0077 m/sec. Do this for each data interval. Don't worry if the velocities aren't the same for each data interval.

Part 3: Finding the average velocity of ammonia molecules

To find the average velocity of the ammonia molecules, average the velocities you found in part 2. Make sure to show this calculation.

The big question:

At a temperature of 20⁰ C, the velocity of ammonia molecules is calculated to be approximately 656 m/sec. Using your knowledge of chemistry and the experiment you just performed, explain why your calculated velocity is so much slower than the actual velocity.

Chapter 16: Chemistry Races

Chemistry class isn't all labs and fun activities. Sometimes students have to buckle down and do a worksheet. Typically, neither students nor teachers find worksheets to be the most exciting activity in the world.

If you can't get away from doing worksheets, you can at least put a new face on them. Instead of giving your students another page of problems, have them do a race! All of a sudden, a boring activity is an exciting contest! Maybe they'll even win!

To make a chemistry race, give a regular worksheet a title like "Molar Mass Race" so your students know it's something new and different. Though they are not actually doing anything more exciting than usual, it will feel exciting to them. A sample race is on page 64.

The rules for running these races are simple. Divide the students into groups of three. The first group of students to correctly answer all of the questions is the winner. It never hurts to give a token amount of extra credit to the students who win as an incentive. Though you might think only one student in each group will actively work, I've found that even students who aren't good with calculations pitch in, solving the easier problems while mathematically-inclined students solve the harder ones.

Some pieces of advice about chemistry races:

- Don't check to see if the answers are correct every time they solve a problem. It's best if you can check the answers every three problems or so for long problems (stoichiometry) or just once for very short problems (molar masses). If the students have answered a problem incorrectly, don't tell them which one. The uncertainty will cause them to reexamine how they think about solving problems.
- Even if it's not true, shout out encouraging comments that suggest a close race. It adds to the excitement and is a good motivator.
- Be enthusiastic! The races really are kind of fun, even if they are just reformatted worksheets.

Answer key for the sample formula writing race (page 64):

- | | | |
|---------------------------------------|---------------------------------|--------------------------------|
| 1) CuCl_2 | 7) Fe_3N_2 | 13) NH_3 |
| 2) $\text{NaC}_2\text{H}_3\text{O}_2$ | 8) GaAs | 14) $\text{Ca}(\text{OH})_2$ |
| 3) ZnCl_2 | 9) F_2 | 15) $\text{Co}(\text{NO}_2)_3$ |
| 4) N_2O_3 | 10) $\text{V}_3(\text{PO}_4)_5$ | 16) CH_4 |
| 5) MgO | 11) CCl_4 | |
| 6) $\text{Mn}(\text{SO}_4)_2$ | 12) AgNO_3 | |

Formula Writing Race

In this activity, your group will be competing against the rest of the class to determine who the champion formula writers are.

Here's how it works: Your group should come up with chemical formulas for the sixteen compounds below. After the first eight questions, bring your paper up for grading. If you have answered all eight correctly, you may move on to the next eight. If you have any incorrect answers, you will be told to go back and try again. You will be informed of how many problems you've missed, but not which ones. The winners of the race will earn extra credit.

- 1) copper (II) chloride _____
- 2) sodium acetate _____
- 3) zinc chloride _____
- 4) dinitrogen trioxide _____
- 5) magnesium oxide _____
- 6) manganese (IV) sulfate _____
- 7) iron (II) nitride _____
- 8) gallium arsenide _____

- 9) fluorine _____
- 10) vanadium (V) phosphate _____
- 11) carbon tetrachloride _____
- 12) silver nitrate _____
- 13) ammonia _____
- 14) calcium hydroxide _____
- 15) cobalt (III) nitrite _____
- 16) methane _____

Chapter 17: Creative Homework

It's pretty common to give students a reading assignment, a worksheet, or some problems out of the book for chemistry homework. Though many students respond well to learning this way, some find it boring and that may cause them to skip their homework altogether.

The trick in getting these kids to do their homework is to make it a creative experience. Even students who like chemistry often see it as being a very rigid subject that requires iron discipline. They need to be shown both in class and at home that chemistry requires imagination and creativity.

I have included some assignments on the next few pages to give you an idea of how you can spice up your homework.

Answer keys:

“Explain the Scientific Method to Your Parents” homework:

- The sheet should include the six steps of the scientific method (purpose, hypothesis, materials, procedure, results, conclusion) and an explanation of how they have been applied to an everyday problem. At the bottom, a parent or other adult should sign and date the paper. A suggestion: When giving this assignment, suggest to your students that their parents relate an everyday problem rather than a huge personal problem. Otherwise, you may find out more than you want about the family lives of your students. Tell your students that if they don't live with their parents or their parents are out of town they can explain the scientific method to another adult or older sibling instead.

“Separation of a Mixture Homework”:

- Your students should each bring in a heterogeneous mixture from home that has been separated into its components. A common heterogeneous mixture for this homework is breakfast cereal. Typically, a student separates it into each of the differently shaped and colored pieces. Praise any student who also brings in a successfully separated homogeneous mixture because this is difficult to do at home. Occasionally, a student will separate salt water by boiling it to dryness and collecting the condensed water from the pot lid. That's dedication!

“Is Color Intrinsic or Extrinsic?” Worksheet:

- Some students think of color as an intrinsic property and others think of it as an extrinsic property, depending on how they approach the problem. Some students will argue that since a drop of white paint has the same color as a bucket of white paint, color is an intrinsic property. Others will argue just as strongly that Kool Aid darkens when more is present. Both are right, because depending on the material, color can be either intrinsic or extrinsic.

Explain the Scientific Method to Your Parents

In class, we have been discussing the scientific method and how it formalizes the way we normally solve problems in our lives. This assignment will examine how your parents could have used the scientific method to solve an everyday problem.

Here are the rules:

- Explain the six steps of the scientific method to your parents. When you're done, they should have a good idea of what the six steps are and how they are used to solve problems.
- Ask your parents how they could have applied the scientific method to solve an everyday problem. Have them walk you through the six steps of the scientific method while you write the results below.
- Have your parents sign the bottom of this sheet, indicating that they worked with you on this activity.

By signing this, I certify that my child has explained the scientific method to me and that I now understand how to use it to solve everyday problems.

Your signature: _____ Date: _____

Separation of a Mixture Homework

In class, we've learned about elements, compounds, homogeneous mixtures, and heterogeneous mixtures. We've also learned that homogeneous mixtures are considerably more difficult to separate than heterogeneous mixtures because the components are so completely and evenly mixed.

Your mission:

Find an everyday example of a heterogeneous mixture in your house and separate the components. Bring the separated mixture to school for discussion and be prepared to explain how you performed the separation.

Extra credit mission:

Find an everyday example of a homogeneous mixture in your house and separate the components. Bring the separated mixture to school for discussion and be prepared to explain how you performed the separation.

Good luck!

Is Color Intrinsic or Extrinsic?

In class, we've learned about intrinsic and extrinsic properties. All properties can be said to be either intrinsic or extrinsic.

Consider the following observations you can make at home:

- One drop of paint has the same color as an entire bucket of paint. This suggests that color is an intrinsic property.
- A spilled puddle of cherry Kool Aid has a much fainter color than a pitcher of Kool Aid. This suggests that color is an extrinsic property.

These two observations contradict one another. Using your knowledge of intrinsic and extrinsic properties, explain in the space below whether color is primarily an intrinsic or extrinsic property. Make sure to explain your reasons!

Appendices

Appendix 1: Laboratory Safety	70
Appendix 2: Everyday Metric System	74
Appendix 3: Student Reference Sheet	77
Appendix 4: Suggested Teacher References	79
Appendix 5: Unusual Atomic Symbols	81
Appendix 6: Laboratory Maintenance	82
Appendix 7: Keeping Students Interested	84

Appendix 1: Laboratory Safety

Safety rules:

Safety is the most important thing for students to learn in a chemistry class. If your students never learn how to balance an equation or how to write the formula of an ionic compound, they will hurt their grade point averages. If your students never learn safety, they stand a good chance of harming themselves physically.

First and foremost, students need to wear goggles whenever they work with chemicals. This cannot be emphasized enough during the first few labs of the school year, as the habits they learn early in your course will remain with them for the rest of the year. In my class, failure to wear goggles results in a failing grade for the lab and removal from the laboratory area. I know it sounds harsh, but you simply can't go far enough when protecting the safety of your students.

Your students should also be familiar with the other safety rules before starting any lab work. I won't include these rules here, as most chemistry textbooks include a comprehensive safety section. However, it's vital that your students sign a copy of the safety rules and take a safety quiz before starting lab work to ensure they're familiar with safe lab practices.

A safety precaution students commonly overlook is to wash their hands after completing a lab. It's a simple thing to do that may prevent them from being poisoned as they eat lunch.

Hazardous materials:

Make sure your students understand the hazards and disposal of each chemical they use. The following section describes how to safely work with some of the most commonly encountered hazardous materials. Note: This is not a complete list of all hazardous materials you may encounter in the lab – before doing any lab, review the Material Safety Data Sheets (MSDS) for each chemical.

- **Acids:** All acids should be treated as dangerous materials. The most dangerous common acid is hydrofluoric acid (HF) – if you find any, have it removed by professionals immediately! Whenever working with acids, make sure your students wear goggles and gloves to minimize the danger of burns. As a precaution, place bottles of saturated sodium bicarbonate solution throughout the lab so burns can be quickly neutralized. Acids are properly disposed of by combining them with sodium bicarbonate and flushing them down the sink when the bubbling stops.
- **Bases:** Bases create severe burns on prolonged skin exposure. Early exposure to a strong base is frequently characterized by a slippery feeling on the skin - students should be trained to look for this when working with bases to minimize the severity of the burn. Gloves and goggles should be worn when working with bases and a bucket of vinegar should be placed in the

fume hood to neutralize burns. Bases are properly disposed of by combining them with vinegar and flushing them down the sink when neutralized.

- **Alcohols:** Alcohols usually don't pose a serious skin or eye hazard, but produce toxic and flammable vapors. The exception to the skin hazard rule is methanol – methanol is absorbed through the skin and may result in blindness after prolonged exposure. When working with alcohols, students should always wear goggles and gloves. Alcohols should be kept away from heat sources such as ovens, Bunsen burners, and hot plates. All organic compounds, including alcohols, are properly disposed of in glass bottles labeled “organic waste” for professional disposal. To minimize disposal charges, keep an inventory of the chemicals present in each waste bottle.
- **Other organic compounds:** Organic compounds are almost universally flammable, toxic, and carcinogenic. Particularly dangerous are acetone (C_3H_6O), methylene chloride (CH_2Cl_2 or “dichloromethane”), diethyl ether (CH_3OCH_3 , “ethyl ether” or “ether”), and benzene (C_6H_6). The use of organics should be avoided whenever possible because of the danger involved in working with them.
- **Nitrates:** Nitrates can explode when heated or subjected to shock. As a result, it's important that you keep them away from heat sources. Many nitrates may be disposed of by pouring their solutions down the sink, though nitrates containing toxic metals should be stored for professional disposal.
- **Mercury:** Due to the high toxicity of mercury vapor, its use is unwise in the classroom. If you currently use mercury thermometers, consider replacing them with alcohol thermometers. Mercury salts should never be present in any high school lab due to their extreme toxicity.
- **Halogens:** The use of halogens should be restricted in high school chemistry labs. Chlorine and fluorine should *never* be used, due to their extreme reactivity and the inherent difficulty in handling gases. Because bromine is a *very* volatile liquid, it should also be kept out of the lab. Iodine readily sublimates, but small quantities may be kept in the stockroom because it is used as an indicator in some experiments. When storing iodine, wrap the bottle with tape to keep the sublimed vapors from escaping.
- **Lead salts:** Lead salts are toxic. As a result, it's important that lead waste be disposed of carefully in a specially-labeled “lead waste” bottle. Add a couple of milliliters of aqueous potassium iodide to this bottle because the bright yellow lead iodide precipitate identifies the container as lead waste if the label falls off.
- **Phenolphthalein:** Phenolphthalein is a great acid-base indicator. Unfortunately, it's also a great laxative. After your students are done using phenolphthalein, make sure they wash their hands twice to ensure their continued digestive health.
- **Other compounds:** There are many other chemical compounds that are toxic, corrosive, or dangerous in some other way. Before working with any

chemical compound, make sure you know how to work and dispose of it properly. A good rule of thumb is to treat all chemicals as toxic unless they come out of a sealed food container and to treat them as flammable unless they are used for putting out fires.

Safety equipment:

If an accident occurs, it's important that you have the tools for containing the danger and dealing with injuries. Before starting any lab, determine what preparations are required to deal with the worst foreseeable accident and have the proper supplies handy.

The following equipment is absolutely necessary for running a safe chemistry lab program. Regularly check that all equipment is present and in good working order. Though the administration of your school is responsible for testing safety equipment, you are ultimately responsible for the safety of your students.

- **Fire extinguishers:** Every chemistry laboratory should have two multi-purpose fire extinguishers. Remember, your only priority is getting your students to safety, not to put out the fire. Leave fire fighting to the firefighters, and take care of the students. The only time you should ever use the fire extinguisher is to clear an escape route.
- **Fire blanket:** If a student catches fire, use a fire blanket to smother the flames. The fire blanket is safer than using a fire extinguisher, as fire extinguishers cause tissue damage that complicates the treatment of burns.
- **Eyewash:** The eyewash is the most important piece of equipment you'll never use (if your students wear goggles). If a student gets a chemical into his or her eyes, it's important that they get to the eyewash as soon as possible and flush their eyes until medical help arrives.
- **Safety shower:** If a student splashes an extremely large quantity of flaming or corrosive liquid on themselves, they should be placed under the safety shower until medical help arrives. Particular attention should be given to cleansing the eyes and face, as they are the most vulnerable parts of the body.
- **Gas and electricity cutoff switches:** Know where each of these switches is and how to operate them. In emergencies, it's important to turn off both the power and gas.
- **Saturated sodium bicarbonate solution:** Sodium bicarbonate is used to neutralize acid burns. One bottle of saturated sodium bicarbonate should be kept near each of the sinks to ensure students can find it in emergencies.
- **Plain white household vinegar:** Vinegar is used to neutralize base burns. One bottle is probably sufficient, as base burns tend to be less aggressive than acid burns. Facial burns should not be treated with vinegar.
- **First aid kit:** Any good first aid kit should do, though they should include rubber gloves for handling body fluids. Oddly enough, the first aid kit is

probably the least important piece of safety equipment in your room, as any injury serious enough to warrant more than a small bandage is serious enough that trained medical personnel should be called.

Steps you can take to enhance safety in your class:

- **Teach your students the proper use of all laboratory equipment:** A student who understands how to use a Bunsen burner is far less likely to burn him or herself than one who doesn't.
- **Teach your students how to deal with emergencies:** The first person to notice an accident is likely to be a student. If their response is instantaneous, serious injury is less likely to occur. Make sure students know the location and correct use of all safety equipment.
- **Take a first aid class:** In the very unlikely event that a student becomes injured, it's important that you are able to take the necessary steps to stabilize his or her condition until help arrives.
- **Find out about medical conditions:** There are many medical conditions that you need to know about to protect your students' safety. These include (but are not limited to) pregnancy, chemical and bee sting allergies, epilepsy, deafness, and sight problems.
- **Practice:** Make sure that your school conducts regular fire drills to ensure that your students know how to secure the lab during an emergency.

Handy tip for new teachers:

Don't leave expensive or easily-broken items on your desk. Expensive items sometimes walk off, and easily-broken items sometimes get knocked over. If you must have either, place them in a locked drawer.

Appendix 2: Everyday Metric System

Though most American chemistry teachers agree on the usefulness of the metric system, very few are able to use these units for everyday measurements. As a result, we tell our students to use meters, grams, and degrees Celsius while proclaiming that “It must be 95^o outside today”. The shortcuts in this section will allow you and your students to use the metric system like a pro!

Degrees Celsius:

One degree Fahrenheit is equal to $5/9^{\circ}$ Celsius. Unfortunately, for those of us who think in degrees Fahrenheit, $5/9$ isn't an easy number for making quick mental calculations. This is complicated by the fact that the Fahrenheit scale is offset 32^o from the Celsius scale. As a result, the conversion between Fahrenheit and Celsius requires you to subtract 32^o from the temperature in Fahrenheit, then multiply the result by $5/9$. Not an easy trick.

Here's an easier way to calculate degrees Celsius in your head: Subtract 30 from the temperature in Fahrenheit, then divide by two. For example, if you're trying to convert 70^o Fahrenheit into degrees Celsius, you subtract 30 from 70, giving you 40, and divide by two to find that the temperature is 20^o Celsius.

Though a quick way of finding the temperature in degrees Celsius, it's not particularly accurate outside of the interval from 20 – 100^o Fahrenheit. However, since most everyday temperatures fall within this range, this inaccuracy should be acceptable for day-to-day estimation. Table 2.1 shows how well this approximation matches the actual temperature:

^o F	Estimated ^o C	Actual ^o C
20	-5.0	-6.7
30	0.0	-1.1
40	5.0	4.4
50	10.0	10.0
60	15.0	15.6
70	20.0	21.1
80	25.0	26.7
90	30.0	32.2
100	35.0	37.8

Table 2.1 – Estimating degrees Celsius

Meters:

If you grew up in the United States you measure distances in “feet” rather than meters. Unfortunately, one foot equals 0.3048 meters, making this conversion difficult. To simplify this calculation, estimate that there are three feet in a meter – the conversion from feet to meters simply requires you divide by 3. This estimation is fairly inaccurate but should be acceptable for short distances.

When converting from yards to meters, the distances involved are usually large enough that the conversion factor above gives unacceptably poor answers. If you’ve got a calculator, the exact conversion factor is to multiply the distance in yards by 0.9144. However, if you’re estimating off the top of your head, an acceptable approximation is to subtract 10% from the distance in yards. For example, if you estimate that an object is 120 yards long, we’d guess that it’s $120 - 12 = 108$ meters long. Since 120 yards is actually equal to 109.7 meters, that turns out to be a pretty good estimation. Table 2.2 shows how well this approximation matches the actual distance.

Yards	Estimated meters	Actual Meters
20	18.0	18.3
40	36.0	36.6
60	54.0	54.9
80	72.0	73.2
100	90.0	91.4
150	135.0	137.2
250	225.0	228.6
500	450.0	457.2
750	675.0	685.8

Table 2.2 – Estimating meters

Kilometers:

The United States has made a half-hearted attempt to adopt the metric system, the main result of which is that some older highway signs measure distances in kilometers as well as miles. There are 1.609344 kilometers in a mile.

To convert miles to kilometers in your head, add 50% to the original distance in miles, then add another 10% of the original distance. For example, if you want to convert 80 miles to kilometers, add 50% (40, to give a distance of 120 km), plus another 10% (8, to give a final distance of 128 km). This conversion does a good job of estimating distance in kilometers for any distance. See Table 2.3 for a comparison of the estimated and actual distances in kilometers.

Miles	Estimated kilometers	Actual Kilometers
5	8.0	8.0
10	16.0	16.1
20	32.0	32.2
50	80.0	80.5
100	160.0	160.9
250	400.0	402.3
500	800.0	804.7
750	1200.0	1207.0

Table 2.3 – Estimating kilometers

Kilograms:

Kilograms are probably the least-often seen metric unit in the United States. Most international sports events are measured in meters, thermometers are usually calibrated in both degrees Fahrenheit and Celsius, and the speedometer on your car probably gives both miles and kilometers. Kilograms, on the other hand, are nowhere to be found. There are 0.45359237 pounds in a kilogram.

To convert between pounds and kilograms, divide the weight in pounds by two, then take ten percent off of the result. For example, if you weigh 160 pounds, divide by two (80) and subtract 10% of the result (8, to give a final answer of 72 kilograms). This answer is close to the actual value of 72.6 kilograms. See Table 2.4 for a comparison of the estimated and actual values.

Pounds	Estimated Kilograms	Actual Kilograms
10	4.5	4.5
20	9.0	9.1
50	22.5	22.7
100	45.0	45.4
150	67.5	68.0
200	90.0	90.7

Table 2.4 – Estimating kilograms

Appendix 3: Student Reference Sheet

Most chemistry teachers give their students an endless supply of photocopied periodic tables for solving problems. I've found that the opposite side of these tables is a great place for providing students with additional reference information.

I know that many teachers believe in having their students memorize the information on the following page. My philosophy is that it is unnecessary to memorize this information because students end up memorizing the periodic table, polyatomic ions, and oxidation states of the transition metals from having seen them repeatedly while solving problems.

Either way you look at it, the most important thing is that your students know how to use this information. Whether they've looked it up on a chart or memorized it, the periodic table and table of ions aren't useful unless the students understand how to use them to solve chemical problems.

The following page contains tables of polyatomic ions, metalloids, the common oxidation states of selected metals. You will notice that the names of some elements are listed after their atomic symbols – this reflects my practice of having the students memorize the names and symbols of only the first 36 elements. Again, it's a matter of style more than anything else, so if you prefer to have them memorize all of the elements, white out the element names.

Handy tip for new teachers:

Keep a toothbrush in your desk. If you get Oreos in your teeth or if your breath smells like the onions in your sandwich, your students will thank you!

Common polyatomic ions

Cations:

ammonium ion: NH_4^{+1}
dimercury (I) ion: Hg_2^{2+}
hydronium ion: H_3O^{+1}

Anions:

acetate ion: $\text{C}_2\text{H}_3\text{O}_2^{-1}$
bicarbonate ion: HCO_3^{-1}
carbonate ion: CO_3^{-2}
chlorate ion: ClO_3^{-1}
chlorite ion: ClO_2^{-1}
chromate ion: CrO_4^{-2}
cyanide ion: CN^{-1}
hydroxide ion: OH^{-1}
hypochlorite ion: ClO^{-1}
nitrate ion: NO_3^{-1}
nitrite ion: NO_2^{-1}
oxalate ion: $\text{C}_2\text{O}_4^{-2}$
permanganate ion: MnO_4^{-1}
phosphate ion: PO_4^{3-}
sulfate ion: SO_4^{-2}
sulfite ion: SO_3^{-2}

Table of metalloids

boron
silicon
germanium
arsenic
antimony (Sb)
tellurium (Te)
polonium (Po)
astatine (At)

Charges of selected metal ions

Element	Charges
Sc	+3
Ti	+2, +3, +4
V	+2, +3, +4, +5
Cr	+2, +3, +6
Mn	+2, +3, +4, +7
Fe	+2, +3
Co	+2, +3
Ni	+2, +3
Cu	+1, +2
Zn	+2
Y (yttrium)	+3
Zr (zirconium)	+4
Nb (niobium)	+3, +5
Mo (molybdenum)	+6
Tc (technetium)	+4, +6, +7
Ru (ruthenium)	+3
Rh (rhodium)	+3
Pd (palladium)	+2, +4
Ag (silver)	+1
Cd (cadmium)	+2
Sn (tin)	+2, +4
La (lanthanum)	+3
Sm (samarium)	+2, +3
Hf (hafnium)	+4
Ta (tantalum)	+5
W (tungsten)	+6
Re (rhenium)	+4, +6, +7
Os (osmium)	+3, +4
Ir (iridium)	+3, +4
Pt (platinum)	+2, +4
Au (gold)	+1, +3
Hg (mercury)	+1, +2
Tl (thallium)	+1, +3
Pb (lead)	+2, +4
Bi (bismuth)	+3, +5
U (uranium)	+3, +4, +5, +6
Np (neptunium)	+3, +4, +5, +6
Pu (plutonium)	+3, +4, +5, +6
Am (americium)	+3, +4, +5, +6

Appendix 4: Suggested Teacher References

Though education classes train new teachers how to find education-related journals, they frequently don't do a good job of guiding new teachers toward chemistry subject matter. As a result, many new teachers have a wide variety of teaching strategies but don't know where to go to for science source material.

The following is a list of chemistry reference resources I've found useful over the years. If you're buying them yourself, save some money by buying them used online (Amazon.com makes this easy).

***CRC Handbook of Chemistry and Physics*, The Chemical Rubber Publishing Company, updated yearly.**

This is, without a doubt, the most comprehensive collection of science-related information I've ever seen. Consisting of well over a thousand pages of reference tables, the *CRC* contains every table of information you'll ever need.

***The Merck Index: An Encyclopedia of Chemicals, Drugs, & Biologicals*, Merck & Company, updated periodically.**

The Merck Index is great for finding the properties, physical constants, and reactivities of about ten thousand commonly-used chemical compounds. Easy-to-read and very practical, the Merck Index is found on nearly every working chemist's desktop.

Your college general chemistry textbook

Though the textbook publishers would disagree, most college general chemistry textbooks are pretty much the same. All of them give a broad overview of inorganic and physical chemistry and include a little bit of biochemistry and organic chemistry. Your college chemistry textbook will give you all the information you need to teach the concepts, plus enough extra background to answer your students' more advanced questions.

J. DiStasio, *100 Reproducible Activities in Chemistry*, Instructional Fair Reproducibles

Sometimes you just need a good worksheet to help you pound an idea into your students' heads. Though the activities in this book aren't particularly creative (they're just worksheets), they cover most of the important parts of a general chemistry course and provide needed practice for students.

Additional references for more advanced teachers:

- P.W. Atkins, *Physical Chemistry*, W.H. Freeman and Company. This book is a valuable resource if you're likely to talk in depth about atomic structure, thermodynamics, or quantum mechanics with your students.

- P.W. Atkins, C.H. Langford, D.F. Shriver, *Inorganic Chemistry*, W.H. Freeman and Company. Your college general chemistry textbook gives brief explanations of how chemicals react with one another. *Inorganic Chemistry* fleshes this information out and ties it all together.
- J. March, *Advanced Organic Chemistry*, John Wiley and Sons. This book should be titled “Everything you ever wanted to know about organic chemistry, plus a lot of stuff you’ve never heard of.” *Advanced Organic Chemistry* is the finest, most complete organic chemistry reference text I’ve ever seen.

Organizations to consider joining:

The American Chemical Society is the professional society for chemists and chemical engineers. In addition to their focus on industrial chemistry they are extremely active in chemical education and provide outreach programs for K-12 educators. Find out more about the ACS at <http://www.chemistry.org> .

The National Science Teachers Association is the professional association for science teachers. In addition to putting out *The Science Teacher* (which frequently has good lab suggestions), they also run workshops and provide other resources for chemistry teachers. For more information, visit <http://www.nsta.org>.

One final suggestion:

T. Weller, *Science Made Stupid*, Houghton Mifflin Company. A classic book that makes fun of science education. From instructions about how to build your own nuclear powered hot tub to its description of the water cycle (elaboration, condensation, participation), this book is guaranteed to make you laugh. It’s out of print, so if you’re lucky enough to find a copy, make sure to buy it.

Handy tip for new teachers:

When you set up your classroom, always have your students turn in and pick up their work in the same location. This avoids the question of where papers should be turned in and gives you a safe place to keep them until you get around to your grading. Make sure there is a separate location for turning in and picking up work and that all classes have a separate box.

Appendix 5: Unusual Atomic Symbols

When discussing the periodic table, students frequently ask questions about why an element has a particular atomic symbol. This appendix is designed to answer these questions.

The following information was obtained from <http://www.webelements.com>, the most comprehensive online resource about the periodic table.

Antimony (Sb): Sb is from the Latin *stibium*, synonymous for stibnite, or Sb_2S_3 . Stibnite was used as eye makeup in Biblical times.

Gold (Au): Au is from *aurum*, Latin for gold.

Iron (Fe): Fe is from *ferrum*, Latin for iron.

Lead (Pb): Pb is from the Latin for lead, *plumbum*. The word “plumbing” comes from the early use of lead pipes in drains.

Mercury (Hg): Hg is from *hydrargyrum*, Latin for “liquid silver”.

Potassium (K): K is from the Latin *kalium*. The English name “potassium” is derived from potash, the material from which it was first obtained.

Silver (Ag): Ag is from the Latin *argentum*. The country Argentina was named after the element because of the silver deposits found there.

Sodium (Na): Na is from the Latin *natrium*.

Tin (Sn): Sn is from the Latin *stannum*.

Tungsten (W): W is derived from *wolframite*, a tungsten containing mineral.

Handy tip for new teachers:

Protect your car if your school is in a rough area! By replacing your lug nuts with wheel locks (the auto parts store will know what you mean) and your current gas cap with a locking gas cap, you can keep people from tampering with your car. I learned my lesson the hard way my first year of teaching when somebody stole the rear tire from my car. It's unlikely that something like this would happen to you, but the purchase of \$15 wheel locks may end up saving you your insurance deductible!

Appendix 6: Laboratory Maintenance

Probably the toughest thing about teaching chemistry is the labs. Not only do you have to plan the labs, but you have to make sure you have the proper equipment available. The following guidelines should help you keep your laboratory running smoothly:

- If you use electronic probeware, make sure you have twice as much equipment as you think you'll need. Probeware is notoriously prone to failure, so make sure everything works before the lab. It's also a good idea to have traditional lab equipment ready in case the probeware fails completely (for example, have alcohol thermometers ready when working with temperature probes).
- Check electrical equipment at the end of the school year for frayed cords. While the equipment you use in your lab is designed to hold up under heavy use, it's easy to tear the insulation on power cords. If you find a small cut in the insulation, patch it with electrical tape. If you find a larger cut or if the fraying occurs at the base of the cord, have the equipment replaced or professionally repaired.
- Make sure you're getting proper water flow in your classroom. It's not uncommon for the metal mesh on water faucets to become clogged over time with calcium deposits. If this occurs, unscrew the cap on the end of the faucet and clean out the mesh to ensure proper water flow. If you use aspirators, periodically check them to make sure they haven't become clogged. If an aspirator becomes clogged, it can usually be cleaned with CLR, a product designed to dissolve calcium, lime, and rust.
- Replace equipment as it breaks. It's very disconcerting to start a lab only to find that there are only five beakers for a class of 25 students.
- Replace chemicals as you use them. If you are missing equipment, you can probably fake your way through the lab. If you don't have chemicals, you're out of luck.
- Know where to find the electrical distribution box for your room. It's not unheard of for the supply circuit breaker or fuse to blow and kill the power in a classroom, rendering hot plates and balances inoperable. If you know where the fuse box is, you can get the problem solved quickly and without hassle. And, in the event of an electrical fire, de-energizing the supply will usually keep it from spreading.
- Know where the gas cutoff valve for your classroom is. Maintenance personnel sometimes turn off the gas during routine inspections and forget to turn it back on.
- Make sure the drains are flowing! We've all seen how students sometimes throw small pieces of trash into the sinks when we're not

looking. Over time, the small quantities of trash add up to drain-plugging blobs that make the sinks unusable. If you notice the sinks clogging, give the maintenance personnel at your school a call.

- Keep a few spare sets of goggles in case a student forgets his or her goggles or you have an unexpected visitor.
- Use plastic “glassware” whenever you can. Particularly useful are plastic graduated cylinders and plastic funnels, because their glass counterparts are extremely fragile. Plastic equipment is also considerably cheaper than glass, making this a good way to stretch your budget.
- Clean your water distillation apparatus yearly. Once a year, you should completely disassemble the still and replace all plastic tubing. Glass portions of the still should be soaked in CLR overnight to remove calcium deposits, and the heating element should be checked for electrical damage. Use copper wire to fasten the tubes in place to reduce the risk that they will pop off and cause a flood.
- Keep plenty of cleaning supplies handy. In addition to soap and test tube brushes, keep dishwashing sponges and steel wool handy for removing really stubborn dirt. Orange-based cleaners, particularly those with abrasives added, do a good job of cleaning lab benches. For big spills, keep a mop and pail handy for liquid spills and a dustpan and broom handy for solids.

Handy tip for new teachers:

Buy high quality, comfortable shoes. Though high quality shoes cost more than cheap ones, the amount of time you'll spend on your feet makes it a good investment. If you really want to stand in style, buy gel insoles. Your feet will thank you!

Appendix 7: Keeping Students Interested

One of the big problems new teachers sometimes have is keeping their students motivated to learn chemistry. Though there are exciting things to see and do in chemistry, some sections are usually considered boring by students. Topics that involve long periods of lecture are considered the worst of all.

The following are tricks I've used in my class to keep students interested during long lectures. These tricks may or may not work for you – as with any classroom management technique, the method you use must match well with your personality or it simply won't be effective.

- **Use silly examples:** If you're doing gas law equations in class, you won't keep your students interested very long with the following question: If I have a gas at a temperature of 35°C and a pressure of 1.00 atmospheres, what will the volume be when I heat the gas to 55° ? Rephrase the question to make it a little more interesting: If the air inside my head has a temperature of 35°C and a pressure of 1.00 atmospheres, what will the pressure be inside my head if I get angry and my body temperature rises to 55° ? (The answer, incidentally, is 1.06 atm).
- **Get noisy:** If the kids look like they're falling asleep on a warm day, get loud and obnoxious. Jump up on your desk and rant at them to wake up in a silly voice. You'll find your students stay awake if for no other reason than to see what you do next.
- **Blow something up:** Nearly every topic in chemistry has a cool demonstration that goes with it. Find that cool demonstration and you'll keep the kids hooked.
- **Make everybody stand up and stretch:** If your students have been sitting still for a long day of lecturing, a good stretch might just wake them up. Making them stretch also lets the students know you're aware they've been sitting for a long time and are concerned enough to do something about it.
- **Have students put their work on the board:** If numerical problems are short enough that they can be done in a couple of minutes, having your students put problems on the board will break up the lecture.
- **Make your students present the information to the class:** If the topic is something students can learn from the book, have them get into groups and teach a portion of the information to the class. It takes a little bit longer than lecturing but gives the students a chance to show off their creativity.

Handy tip for new teachers:

Bring a radio to school. Though it's not a good idea to play it in class, music can be relaxing while planning or grading.

About the Author

Ian Guch started his career as a chemist but moved into teaching when he realized it was a lot more fun. In addition to his teaching duties, he's written four books for chemistry teachers (this book, plus the three advertised on page 90) and runs a chemistry-related website (www.chemfiesta.com). In his spare time, Mr. Guch enjoys playing his bass guitar, driving his car faster than he should, and playing with his nephew, Owen.

About the Photographer for the Paperback Version of this Book

Janette Bloom is one of my honors chemistry students, and a heck of a photographer. She gave me a sheet which had some information she wanted in the book, but it was kind of weird, because she didn't want to say too much about herself in the book. Long story short, I lost the sheet of paper, so you're reading this instead. I do remember one thing on it, though – she likes beef jerky.

About the Helping Other Teachers Program

The Helping Other Teachers (HOT) program was created by Cavalcade Publishing as a method of providing chemistry teachers with quality educational materials. The focus of this program is to provide high quality resources to new teachers and teachers in low-income areas without charge or obligation.

The publication of this book is the culmination of the HOT program. The initial printing of this book consists of 500 bound copies and 1000 CD-ROMs, with additional copies made each year. With time, we hope to make enough copies of this book that any chemistry teacher who needs it can get a free copy. If we have additional funding, we'll make as many more as we can.

Here's how you can help:

- **Financially***: Sending money to the HOT program will allow us to increase production of this book and help more teachers each year. This money will be spent on printing costs, CD-ROM production costs, mailing supplies, and postage.
- **Materially**: If you have blank CD-ROMs, mailing supplies (particularly CD mailers and large padded mailing envelopes), postage stamps, or CD jewel cases to spare, send them to us and we'll use them in the direct production and mailing of these products.
- **With information**: Tell us if you know somebody who needs a copy of this book. If you know of a new chemistry teacher, a high-turnover science department, or a severely underfunded school district, tell us who we can get in touch with to supply them with copies of this book.

Mail us at:

Cavalcade Publishing – HOT program
P.O. Box 7163
Alexandria, VA 22307

Thanks for your help and consideration. We believe the people best able to help chemistry teachers are other chemistry teachers. Please join us in our efforts.

Notice of Tax-Deductible Status and Disclaimer:

Because we're not a nonprofit organization, money or supplies sent to us are not tax-deductible. For tax reasons, Cavalcade Publishing must treat all donations as income, though all donations go toward making more copies of this book. If you feel uncomfortable sending money for this reason, please help us in the other ways listed above.

Other Free Resources From Cavalcade Publishing

In addition to this book, Cavalcade Publishing has a variety of other free resources for chemistry teachers and students.

- **Mr. Guch's Cavalcade o' Chemistry:** A series of tutorials and practice worksheets for high school chemistry students, covering most of the topics in a first year chemistry course. Visit the Cavalcade o' Chemistry at <http://www.chemfiesta.com>.
- **Free labs, worksheets, and activities for teachers:** Cavalcade Publishing's website has over sixty worksheets, labs, and other free activities for chemistry teachers. Log on at <http://www.cavalcadepublishing.com>.
- **The Free Chemistry Worksheet of the Month Club:** Get a chemistry worksheet emailed to you at the beginning of each month by signing up for the Free Chemistry Worksheet of the Month Club. Find out how at <http://www.cavalcadepublishing.net>.

Extra Secret Bonus Demonstrations!

Nobody ever reads the back of the book. However, since you've gone to the trouble of looking back here, I thought I'd share some demonstrations your students might like. Make sure your students wear goggles!

The Boyle's Law Demo:

Your kids can see that $P_1V_1 = P_2V_2$ by inflating a small balloon and sitting on it. Sitting on a balloon causes the gas inside to be compressed, which raises the pressure inside the balloon and causes it to pop. Students love this demonstration because it's just scary enough to be fun.

The Empty Atom Demo:

Students sometimes wonder how atoms can seem so solid but still be mostly empty space. To help your students conceptualize this, dissolve a handful of Styrofoam packing peanuts in acetone. Because the Styrofoam is mostly blown gas, all that remains of the peanuts is a small white blob of goo.

The Scalded Hand Trick:

Liquids boil when their vapor pressure is equal to atmospheric pressure. As a result, you can vastly decrease the boiling point of a liquid by placing it in a partially evacuated container. To demonstrate this, place some warm water in a flask that's hooked up to a vacuum pump. When the pump is turned on, most of the air will be removed and the water will boil. To demonstrate that boiling water isn't necessarily hot, open the flask and quickly pour it on your hand. The lack of burns makes the point.

The Shattered Rubber Hose:

Most amorphous solids are soft and flexible. Glass is the main exception, as it behaves more like a network atomic solid. The reason for this is simple: Glass has a much higher melting point, so at room temperature it behaves in the same way other amorphous solids do at very low temperatures. To demonstrate this, obtain some liquid nitrogen and place a length of vacuum tube in it. After a minute or so has passed, pull the tubing out and shatter it with a hammer. Each of the fragments is very much like a piece of broken glass, so make sure all of your students are wearing goggles!

Extra secret bonus handy tip for new teachers:

If you need to get some work done but people keep interrupting you, try working in the school library. It's quiet, it has all the reference resources you'll ever need, and nobody will ever think of looking for you there.

Send A Copy Of This Book To A Friend!

If you've found this book to be helpful in your teaching, consider sending one to a new teacher free of charge. Simply fill out the form below and send it to us! (Note: This offer is good only for teachers who have been in the classroom for less than one year, or for student teachers. If you are requesting a copy for a teacher with more than one year of experience, please include \$3.95 to cover shipping and handling.)

Name of Friend: _____

Street Address: _____

City: _____ **State/Province:** _____

Zip Code: _____ **Country:** _____

Email address: _____

Name of Friend: _____

Street Address: _____

City: _____ **State/Province:** _____

Zip Code: _____ **Country:** _____

Email address: _____

Name of Friend: _____

Street Address: _____

City: _____ **State/Province:** _____

Zip Code: _____ **Country:** _____

Email address: _____

24 Lessons That Rocked the World

If you liked this book, you'll love 24 Lessons That Rocked the World! Each chapter contains a lab, an instructional student handout, a worksheet, and complete teacher resources including instructions for teaching the lab, instructional tips, and complete solution keys.

The 24 labs in this book include lessons about the scientific method, mixture separation, significant figures, the flame test, the periodic table, mole calculations, percent composition, ionic and covalent compound properties, the six types of chemical reaction, the law of conservation of mass, writing equations, simple stoichiometry, limiting reagents, heat capacities, calorimeters, energy diagrams, the combined gas law, gas stoichiometry, molarity, solubility, acid and base properties, titrations, kinetics, and radioactive decay.

Appendices at the back of the book include complete discussions of laboratory safety (including a student worksheet and safety contract) and suggestions on how to equip a high school chemistry laboratory on a tight budget.

To order 24 Lessons That Rocked the World by Ian Guch, please fill out this form and send it with your check or money order to:

Cavalcade Publishing
P.O. Box 7163
Alexandria, VA 22307

Please include \$5.95 shipping and handling for the first copy, and \$2.95 shipping and handling for each subsequent copy.

Please rush me _____ copies of 24 Lessons That Rocked the World at \$29.95 each!

Your name: _____

Mailing Address: _____

Email Address: _____

For more information about other titles from Cavalcade Publishing or for credit card orders, please visit our website at <http://www.cavalcadepublishing.com>. We currently offer books of worksheets and quizzes, as well as website design software.