EXPERIENCES IN CHEMISTRY

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i Using this Lab Manual

This manual is not a substitute for a chemistry textbook. It is designed to accompany a high school text by providing directions for a set of hands-on laboratory experiences which do not require a heavy investment in materials or in preparation time.

This manual is for the high school student and is not a teacher's manual. The manual can be used for younger advanced students who can understand a high school textbook. Very nearly **all of these experiments should be completed** so that the student meets all the requirements for a full high school level chemistry lab course. You can count 25 experiments completed with a textbook study as a full lab science requirement.

Sometimes, chemistry is divided into so many small pieces that the student never really has a chance to understand chemistry as a whole, to develop a framework through which he/she can understand all those bits and pieces. This manual can help provide that framework but does not include all the bits and pieces, so be sure to study a chemistry textbook.

The study of science requires several skills, including accuracy in observation and communication, clarity in recordkeeping and chart-making, and neatness. The student is expected to strive to be as accurate as possible in measuring, recording, and charting for each experiment contained in this manual.

Measurement

The practice of accurate measurement is good training for the future. **Most of the experiments in this manual do not require precise measurements.** However, the student should practice accurate measurement, laying the groundwork for future success in science. Measurements should be carried out to **three significant digits when possible**; techniques for this will be outlined in the student's chemistry textbook. In some cases accuracy is made easier by the use of a few pieces of laboratory equipment, such as a graduated cylinder and a scale with a set of weights.

Record-Keeping

There will not be enough space in this lab manual to record all the data for the experiments. This is done intentionally to encourage the students to keep their own data notebook to jot down notes, record times, scrawl thoughts and observations, and make drawings. There are some blanks and leading questions which should be used as a guideline for constructing your data notebook and completing a final report for each experiment.

Elements of a Good Report

- **Title (*such as "Newton's Laws"*)**
- **Procedure (*numbered short statements are ok*)**
- **Drawing of equipment set-up (*may use a photo, too*)**
- **Observation (*your description of what happened*)**
- **Calculations (*if needed*)**
- **Results (*a chart or graph showing data is good*)**
- **Conclusions (*and answers to the experiment questions*)**

There is an optional data notebook that has been created to align with the experiments in this book available online at www.castleheightspress.com

The records of a scientist contain the proofs that the experiment worked (or did not). They always have the procedure, the results and thoughts of the scientist on the "why" of the result. For a student, the laboratory write-ups record all of the above and, as well, they provide a reminder of past work, which is useful while studying. (To a scientist the write-ups also are reminders.)

There are many good styles for laboratory write-ups. Each plan usually emphasizes different skills. One example is a report which lists a procedure and then several insightful questions which cause the student to think about the exercise. Occasionally, the instructor likes to see a write-up in the form of the scientific method, step by step. However, in any style, the most important parts to a write-up are: name, date, topic title, a summary of what you intend to do, a summary of what occurred, and an explanation of what occurred.

Sometimes it is good to ask the student to make a guess about what the outcome will be, a hypothesis. With other experiments the result is obvious and the instructor wants to see if the student can use theory to explain the experience proven by answering questions, or by writing a good conclusion.

Steps in the Scientific Method

Statement of the Problem
Research of the Literature on the Topic
Hypothesis
Materials List
Procedure Used
Observations
Calculations
Results
Statistical Analysis
Sources of Error
Conclusions
Possibilities for Future Research

A Note About Terms and Definitions

Since this lab manual is designed to be a supplementary text, space is not taken to introduce every term before its use. The textbook the student is regularly using will have definitions for these terms; if it is not defined here, the student should look the term up in the textbook.

⚠ Safety Note

Occasionally you will encounter Safety Notes in the text. Pay attention! Serious injury may result if you do not heed these warnings.

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List of Equipment

You may either purchase a kit containing all required equipment and chemicals (www.homesciencetools.com) or put together your own using the following key to indicate where each item or chemical can be procured. It is recommended that you review the experiments first with their associated materials lists to ensure you are only buying the equipment and chemicals for the experiments you plan to complete.

C = Chemical supplier G = Grocery store H = Hardware store F = Feed store D = Discount store

Baking dish	G
Balance scales (Kitchen scales)	C
Balloons (round)	G
Beakers (250ml) (Canning jars)	G,C
Bottles	G
Buret Clamp	C
Candle	G
Cardboard for bottle covers	G
Clothespin	G
DC power source/ battery (optional)	G,H
Dropper	G,C
Evaporating dish (saucer)	C,G
Filter paper (Coffee filters)	G,C
Flask (500 ml/250 ml) (Canning jars)	C
Forceps (Pliers)	H
Funnel: triangle Kitchen funnel	C
Glass plate	C
Glass rod	C
Glass tubing	C,H
Goggles (or glasses)	H,C
Graduated cylinder (100ml)	C
Grease pencil (Crayon)	G
Heat source (candle)	H
Jars (spice) (glass with lids)	G
Litmus paper (red and blue)	C
Matches	G
Magnifying glass	D

Milk carton	G
Pie plate	G
Plastic bag (small)	G
Plastic container	G
Plastic tub (Plastic wash basin)	G
Plastic tubing or rubber tubing	H,C
Pot	G,H
Pneumatic trough (Baking pan)	G
Ring stand	C
Ring clamp	C
Ruler	G
Soap (liquid)	G
Stoppers (some with holes-they should fit your test tubes and flasks)	C,H
Straw	G
Tape	G
Test tubes	C
Test tube brush	C
Test tube holder	C
Test tube rack	C
Thermometer Celsius immersible (1 or 2) must go from 0 to 100	C
Triangle, pipestem	C
Tweezers /or tongs)	G
Thistle tube/ funnel	C
Wire plastic covered	H
Wire gauze with ceramic center	C
Wooden splints (small sticks)	G

V List of Chemicals

C = Chemical supplier G = Grocery store H = Hardware store O=Household item F = Feed store D = Discount store

Acetic Acid CH_3COOH (Vinegar)	G
Aluminum Foil (or aluminum can metal)	G,O
Ammonia NH_4	G
Ammonium Chloride NH_3Cl	C
Ammonium Hydroxide (household ammonia)	G
Baking Soda (Sodium hydrogen carbonate)	G
Battery (6-volt)	D
Calcium Carbonate (marble chips, chalk, shells, etc.)	C,F
Calcium Oxide (Pickling lime)	G,C
Carbon Rods	G,C
Charcoal, piece	G
Chocolate Chip Cookies (no substitutions)	G,O
Copper Penny	O
Copper Strip	H,C
Copper Sulfate $CuSO_4$ (Blue stone)	C
Copper (wire, copper wool scrubbing pad, copper foil)	G,H,C
C-Cell Batteries, (2),depleted/source for:	G
Carbon rods & Zinc foil (sand off the paint)	G,C
Cream of Tartar (Potassium hydrogen tartrate)	G,O
Distilled Water	G,O
Ferric Chloride	C
Hydrochloric Acid HCl (diluted)	C
Hydrogen Peroxide (3%)	G,O
Ice	O
Iron Filings Fe	H,C
Lead Pb (Plumbium, Fishing weights)	H,C
Limewater (made from CaO)	C,G
Liquid Detergent	G,O
Magnesium Strip Mg	C
Manganese Dioxide Mn O_2	C
Nitric Acid (dilute)	C
Paradichlorobenzene (moth ball crystals)	G
Phenolphthalein (or natural indicators like blueberry juice)	C
Potassium Chlorate	C
Potassium Hydrogen Tartrate (see Cream of Tartar)	G
Salt, Table NaCl	G,O
Seltzer Tablets	G,O
Sodium Bisulphate $NaHSO_4$	C
Sodium Carbonate $Na_2CO_3 \cdot 10\ H_2O$	C
Sodium Chloride (see Salt) NaCl	G,O
Sodium Hydrogen Carbonate (see Baking Soda)	G
Sodium Hydroxide NaOH	C
Sucrose $C_{12}H_{22}O_{11}$ (Sugar)	G
Steel Wool	H
Sugar (Sucrose $C_{12}H_{22}O_{11}$)	G
Sulfur S	C,H
Sulfuric Acid H_2SO_4 (diluted)	C
Water, Distilled H_2O	G
Yeast	G,O
Zinc (lining of C-cell batteries)	G,C

vi Fundamentals for the Chemistry Student

This is a list of topics in chemistry. If, at the end of the chemistry course, a high school student knows and understands *at least* these things, he/she has done well and is prepared for the freshman college chemistry course. This is *not* a comprehensive list of a high school course set of objectives, but a list of basics upon which a student may build. The use of "*etc*" means that the needed concepts are not all listed. They may be found in the student's textbook.

1. Memorize the common chemical symbols and atomic weights The easiest way to do this is through oral drill.

2. Know your way around the periodic table. Why is the table designed the way it is? What does it say about the elements, groups and periods, and the sequence of adding electrons? Know some of the characteristics of the groups, periods and what causes them.

3. Know the terms for the fundamental building blocks of matter. Parts of atoms, forces of matter and energy, ions, isotopes, etc. Be able to explain how they relate to each other.

4. Know the electron orbital concepts and be able to discuss the ideas of electron position, energy absorption, energy and light emission, bonding, valences, energy states, etc.

5. Know the characteristics for the three states of matter and how they relate to the kinetic theory. Know the energy requirements of changing states.

6. Memorize the types of reactions and be able to recognize them. Be able to predict products given the reactants.

7. Know the basics of acid-base reactions. pH, ions. titration, indicators, etc.

8. Know the physical and chemical characteristics of the most common elements and compounds. A few of these are carbon, oxygen, nitrogen, chlorine, metals, and hydrogen.

9. Know something about the history of chemistry and how humans started discovering the complexities of the world about us.

10. Know about the functions of metallurgy and how elements are purified and controlled so that the environment is not damaged.

11. Know how to produce and retain certain gases, including water-soluble gases.

12. Know the gas laws and be able to apply them to everyday life.

13. Understand the concepts of the Avogadro Constant and molarity.

14. Know the principles of heat transfer, measurement, calories, etc. Be able to work problems using these concepts.

15. Be able to balance chemical equations, including arrows showing direction of reaction and precipitant or gas formation, heat or light radiation or requirements.

16. Know techniques for filtration, distillation, evaporation, and condensation.

17. Be able to identify common laboratory equipment. Demonstrate the proper cleaning and care of equipment.

18. Practice observation, record-keeping and communication skills by writing a good laboratory notebook.

19. Be able to accurately follow the instructions in the writing of the laboratory report. The data must be written in ink for the report, or printed with the computer.

20. Know and use good safety practices.

2.4 Gases, Temperature, and Pressure

***Materials**:*
Flask
Glass or plastic tube
Grease pencil / crayon
Stopper with hole
Jar with water
Liquid soap
Ring stand and clamp

Introduction

Charles' Law states that as temperature increases, volume also increases, while pressure is constant. Or,

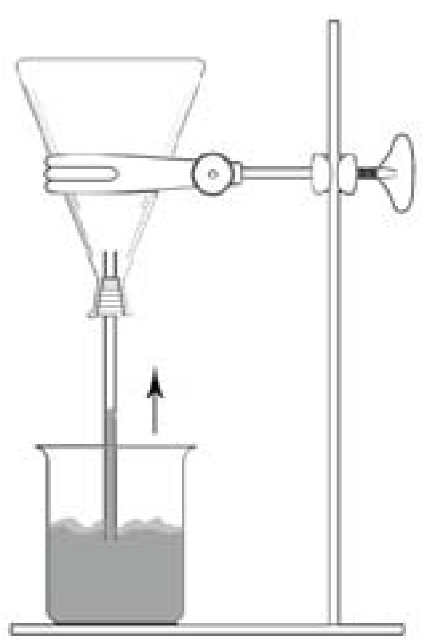
Where P=k
$\uparrow T \rightarrow \uparrow V$

Boyles' Law states that as pressure increases, volume decreases, while temperature is constant. Or,

Where T=k
$\uparrow P \rightarrow \downarrow V$

In this experiment, we see that as a gas is heated, the molecules get more energy and increase their rate of bouncing around. They impact the walls of the container more frequently and with more force. This can be observed as an increase in pressure against the walls of the container.

Procedure



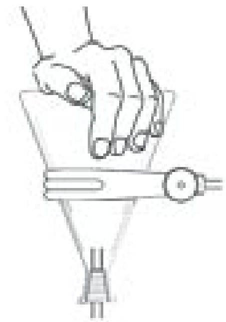
1. Reproduce the setup as in the figure without sealing the flask yet. The flask is set into the ring clamp to support it.

2. Adjust the water level in the glass tube then seal the flask.

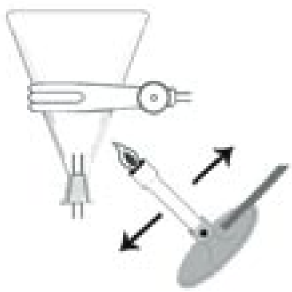
3. Observe the water level. Mark with a grease pencil.

4. Place ice on the inverted bottom of the flask. The air within the flask should cool and begin to draw the water up into the glass tube. The air molecules have lost energy and they are no longer pushing against the water as hard as before. The pressure of the atmosphere on the other side of the water has remained the same though and is now comparatively stronger and so the water goes up the tube.

5. Now, try to heat the flask with your hands. Observe the effect on the water level in the glass tube.



6. If you are using a flask which is heat resistant, you might try heating it directly with a cigarette lighter or burner. This produces a dramatic result showing the expansion of the volume of a gas when energy is added.



Safety Note

Do not heat the flask very much since the return of the cooler water when the heat is removed may break your flask. When heating the flask, do not heat it in one spot without moving the heat source, instead move the flame back and forth.

Thinking Critically

1. How would you relate the pressure of the air within the flask to the pressure of the air outside the flask during these events:

   A. During the application of ice?

   B. During the application of warm hands?

   C. When even more direct heat is added?

2. Draw a simple mechanism which will use solar heating on a sealed container of air pushing on water to provide water to a garden.

3. When the sun's rays hit an open, plowed field all day, the hot soil warms the air above it. This air expands. An asphalt runway or road will do the same. If you were flying above a sun-warmed stretch of asphalt, how would your aircraft react and why?

4. A water-cooled engine has a radiator filled with water which absorbs heat from the engine. If the water gets to 100^{O} C at one atmosphere of pressure, then it will boil off. An engine gets much hotter than this, so water does not work efficiently, unless it is pressurized. When the pressure of a liquid is increased so is its boiling temperature, meaning that it will need more energy to reach the boiling point. In