GUIDEBOOK TO CONSTRUCTING

INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume II: Chemistry

Inexpensive Science Teaching Equipment Project

Science Teaching Center

University of Maryland, College Park

U.S.A.

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Inexpensive Science Teaching Equipment Project
Science Teaching Center
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CONTENTS

The Guidebook is presented in three volumes:

Volume I, Biology
Volume II, Chemistry
Volume III, Physics

The following table refers only to the contents of this volume, but the listing at the back of each volume provides an alphabetical index to all three volumes.

References within the text normally indicate the volume, chapter and number of the item referred to (e.g., BIOL/V/A3), but where a reference is to an item within the same volume the reference indicates only the chapter and number of the item (e.g., V/A3).

Table of Contents

FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-2 Study), the Project was to (1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; (2) improvise, wherever possible, equivalent inexpensive science teaching equipment; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours" that are available for apparatus production.

However, in designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest of ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8") capacity
Glass Cutter
Knife
Razor Blades
Scissors: 200 mm(8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (8")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90'
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i 1/32" 1/16" 3/32" 1/8" 5/32", 3/16", 7/32", 1/4") set
Wood Brace with'Ratchei: 250'mm (10")
Wood Augur, Bits: 6, 12, 18, 24 mm
(i.e., 1/4", 1/2", 3/4", 1")

Files, Double Cut

Flat: 100 mm, 200 mm (4", 8")
Round: 100 mm, 200 mm (4", 8")
Triangular: 100 mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper,. Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose- volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

- Set Square
- Square, Carpenter's: 300 mm (12") blade
- Spoke Shave: 18 mm (3/4")
- Wood Smoothing Plane

Pliers

- Combination: 150 mm (6")
- Needle Nose: 150 mm (6")
- Side Cutting: 150 mm (6")
- Vise Grips

Saws, Metal

- 300 mm (12") blades

Saws, Wood

- Back Saw: 200, 300 mm (8", 12")
- Coping Saw: 200 mm (8")
- Cross Cut: 600 mm (24")
- Hand Rip: 600 mm (24")
- Key Hole Saw: 200 mm (8")

Screw Drivers

- 100 mm (4") with 2 and 3 mm tips
- 150 mm (6") with 5 mm tip
- 200 mm (8") with 7 mm tip

Vises

- Metal Bench Vise: 75 mm (3")
- Wood Bench Vise: 150 mm (6")

Miscellaneous

- Asbestos Pads
- Goggles, Glass
- Oil Can: 1/2 liter (1 pint)
- Oil Stone, Double Faced
- Punch, Center
- Sandpaper and Carborundum Paper, Assorted grades
- Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

- All Purpose Cement (Elmers, Duco)
- Epoxy Resin & Hardener (Araldite)
- Rubber Cement (Rugy)
- Wood Glue (Weldwood)
- Cellophane Tape
- Plastic Tape
- Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2", 1", 2") lengths
Nails: 12, 24 mm (1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4", 1", 1 1/2") lengths
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5/16") diameter
Wingnuts (Steel): 5 mm(3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

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* U. S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be made in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (1/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass, Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm (1/16") diameter
*Copper: #20 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)
Grease
Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord, Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.

I. GLASSWARE TECHNIQUES AND ACCESSORIES

Equipment made of glass or using glass components has applications in all branches of science. This chapter includes some basic glass-working techniques that will be necessary for constructing much of the equipment in this book.

These are presented in sections which describe the type of equipment needed, the type of glass to use, and techniques for working with several forms of glass.

A. BURNERS, TOOLS, AND EQUIPMENT

This section discusses burners that can be used in working glass, as well as listing the tools and other items necessary for working with glass.

B. GLASS

This section describes the type of glass that works best with the burners listed in section A.

C. SAFETY

Notes for safe handling and working of glass are given here.

D. 'PROCEDURES FOR GLASS TUBING AND RODS

Directions for working with glass tubing and solid rods are given in this section.

E. GLASS SHEET OPERATIONS

This section tells how to cut and drill glass sheets.

F. BOTTLE AND JAR TECHNIQUES

Much useful laboratory glassware can be made by using discarded bottles and jars. This section includes directions for cutting and drilling these items.

G. STOPPERS

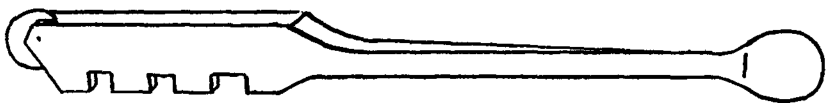
This section discusses types of stoppers and describes techniques for drilling holes in them.

A. BURNERS, TOOLS, AND EQUIPMENT

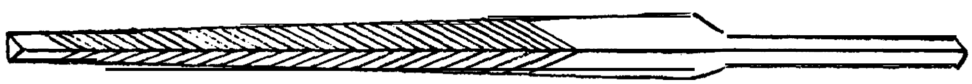
Glass-working techniques described here are designated for use with Modified Alcohol Burner (II/B2), and the Gas Burner (II/C2). Of these, the gas burner, if available, is most highly recommended.

The general items required for general glass-working techni'ques are as follows:

Glass Cutter

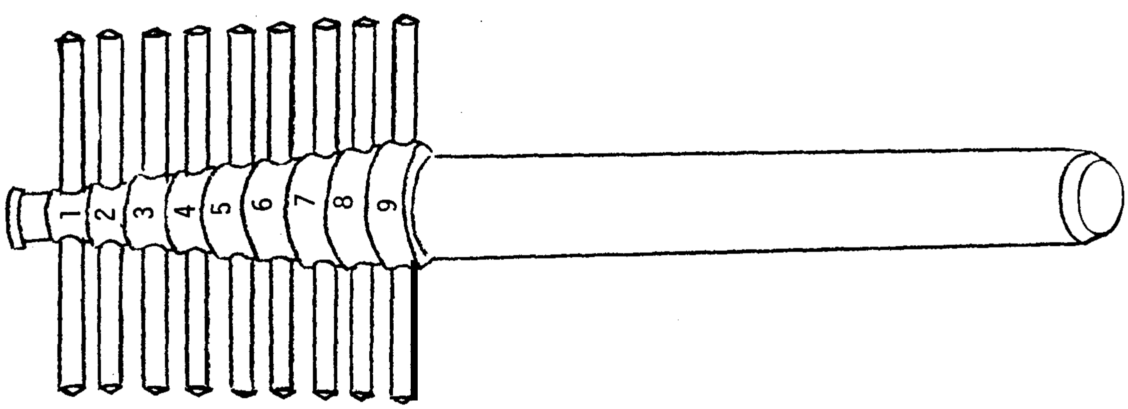


Triangular File



Round File

Set of Cork-borers



Pliers

Brick or Asbestos Pads

Rags or Pieces of Cloth

Clean rags, or pieces of cloth no smaller than about 10 cm x 10 cm.

String

Kerosene

Camphor

Ruler

Blotting Paper or Paper Towels

Emery Paper

Container of Sand

B. GLASS

There are many different types of glass, with different properties, depending upon the chemical composition of the glass. Two very common types of glass that are discussed here are "soft glass" and "hard glass."

Soft Glass

This term includes a number of the oldest known and most common types of glass in general use. Most bottles, jars, window glass, and much glass tubing and rods are made of some type of soft glass. Such glass is used for items of simple design and moderate thickness, that will not be subjected to very high temperatures.

One of the most important properties of soft glass, from the point of view of this book, is that it can be softened in the heat of an air-gas flame. This is the type of flame produced by the burners specified in section A. Also, soft glass has a wide range of working temperatures, which makes it easy to work even after it has been removed from flame.

Although it is easy to work, soft glass has some limitations and must be used with care. An empty container of soft glass cannot be greatly heated, or it will crack. If, however, such a container holds a liquid or powder, it can safely be heated, slowly. Also, a soft glass container, with or without anything inside, must not be suddenly cooled when hot or suddenly heated when it is cold. Otherwise, it will break.

Hard Glass

Hard glass has been developed during the twentieth century. Of a number of types produced, "Pyrex" is one of the most common brand names., Most manufactured laboratory glassware is now made of hard glass, which is harder stronger, more chemically inert, and safer to use over a wider temperature range than soft glass.

Laboratory glassware made of hard glass is safer than soft glass. It can be rapidly heated or cooled to greater temperature extremes without danger of breaking. It does not scratch easily, and it does not break as easily as soft glass if struck or dropped.

Although it is often manufactured into laboratory glassware, hard glass is not generally made into the bottles and jars that are used for much of the apparatus described in this book. Therefore, it is not as generally available as soft glass. As tubing, rods, and sheets, it is usually more expensive than the same items made of soft glass.

Hard glass's most important disadvantage here is that it must be worked in an oxygen-enriched flame. The burners described in section A cannot heat hard glass hot enough for working.

Therefore, only soft glass is suitable for use with the alcohol or gas burners described. The techniques here listed have been tested using soft glass and the air-gas flames produced by such burners.

Testing for Soft Glass

To determine whether a piece of glass is "hard glass" or "soft glass", heat it in the flame of an alcohol or gas burner. If the glass begins to glow and soften enough to be easily worked, it is soft glass. If it does not soften, it is hard glass and cannot be worked without specialized equipment.

C. SAFETY

Glass working, like most other laboratory procedures, carries a set of risks. By arranging a safe work area and taking a few precautions, however, most such risks can be avoided.

Sharp Edges and Points

There is always a danger of being cut by sharp points and edges of broken or cut glass. Be careful of such edges and points, and try to handle the glass away from the edges. Fire polish or smooth with emery paper any cut edges or points that are part of a finished project. Keep such edges away from the mouth and eyes at all times, and keep the work area clear of waste glass.

Burns

Hot glass looks just like cool glass! To avoid burns, allow heated glass to cool before handling it. Rest it on bricks or asbestos pads, or in a container of sand. Before picking up a piece of previously heated glass, touch it lightly with the fingertips to check that it is cool enough to handle. In cases where hot or warm glass must be handled, protect the hands with a holder of several layers of cloth, or use holders such as those described in the section on holders(IV). Protect the body from burns with clothing, an apron, overall, or laboratory coat.

Fire

Both the burner flame and hot glass can start a fire. Prevent this by keeping all flamable material, such as paper or cloth away from the flame and any hot glass. Set hot glass down on things that will not burn, such as bricks, asbestos pads, or sand. To keep hair or clothing from being singed or igniting, tie back long hair, roll up sleeves, and secure loose clothing close to the body. Inspect the burner, fittings, tubing, and fuel supply each time the equipment is used to prevent leaks of fuel that might lead to a fire. If any alcohol should spill, immediately put out the flame and mop up the spill.

The container of sand mentioned for holding hot glass is also useful for fire control. If paper, cloth, or spilled alcohol should ignite, smother the fire by dumping sand on it. If, on the other hand, the gas burner system (II/C) is used and a fire develops, get away fast!

Eye Damage

To prevent eye damage, keep all sharp edges and points, all hot glass, and all flames away from the eyes. Wear safety goggles or eye glasses to provide additional protection for the eyes.

Gas Danger

If natural gas or bottled gas is used as fuel for the burner, a leak in the system can release gas that is poisonous to breathe. To avoid this danger, inspect all pipes, tubing, and fittings often.

D. PROCEDURES FOR GLASS TUBING AND RODS

Dl. Cutting

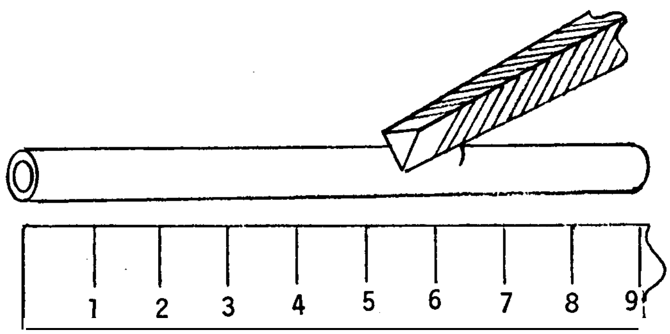
a. Materials Required

Length of soft glass tubing or solid rod

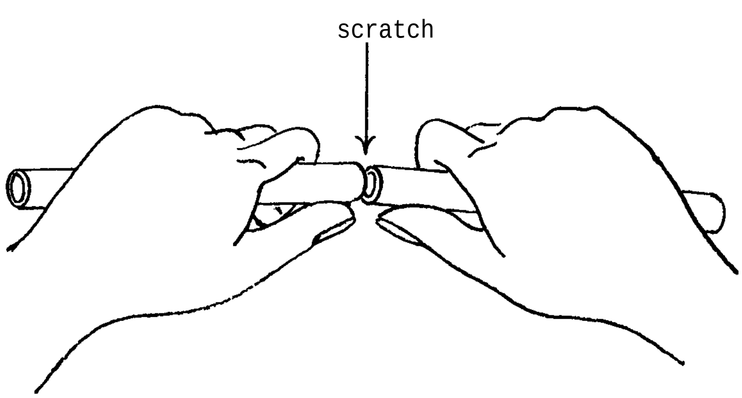
Triangular file

Ruler

b. Procedure



Lay the tubing or rod flat on the work surface and measure the desired length. Make a scratch on the glass at this point by drawing one edge of the file across the tube. Press hard enough with the file to make a deep scratch.



Moisten the scratch, then grasp the glass firmly in both hands with the thumbs on the side of the tube opposite the scratch. Apply pressure with the thumbs while pulling out and down with the hands until the tube or rod snaps cleanly.

D2. Bending

a. Materials Required

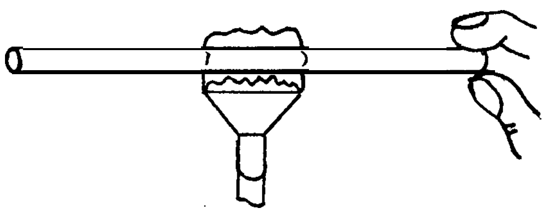
Burner: wide-flame alcohol burner
or
wing tip with gas burner

Length of soft glass tubing or solid rod

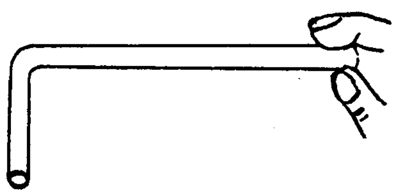
Cooling surface: brick
or
asbestos pad

b. Procedure

Gravity Bending

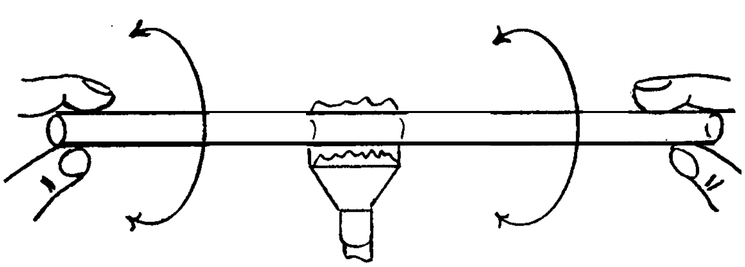


With one hand, hold the tubing or rod, just above the inner cone of the flame. Rotate the tubing to heat it evenly until the free end droops under its own weight.

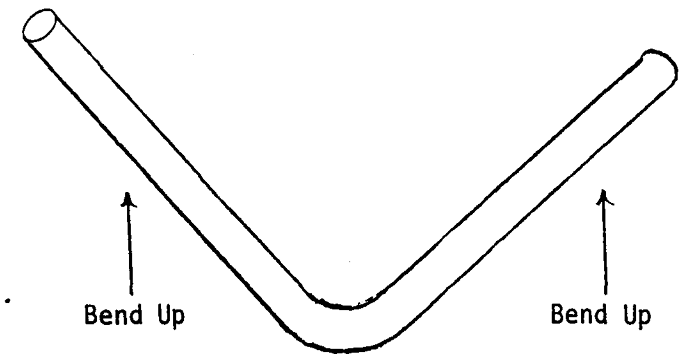


Remove the glass from the flame. It should bend to a right angle. Allow it to cool.

Manual Bending



Install the wing tip on the gas burner, and light the burner. Hold each end of the tubing or rod. Support the glass so that it is level, with its middle in the hottest part of the flame. Turn the tubing or rod back and forth by rotating the thumb and first finger. Continue to heat it evenly until it softens.

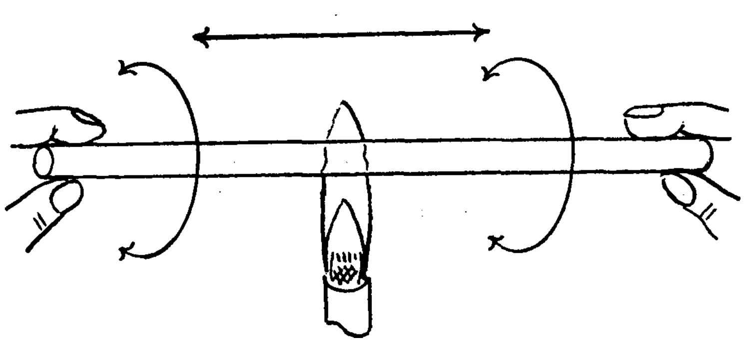


When the tubing or rod is soft, remove it from the flame. Immediately, bend the ends up until the tubing or rod is bent at a right angle (90').

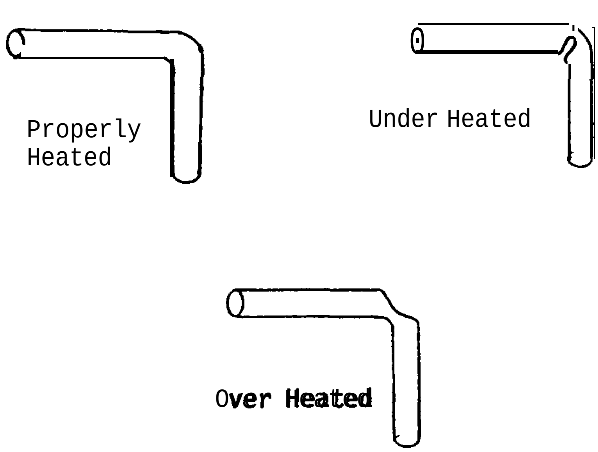
Rest the hot tubing or rod on a brick or other cooling surface.

c. Notes

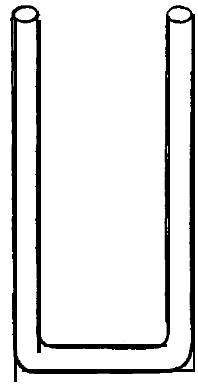
(i) If a wing tip is not available or if a standard alcohol burner is used, the tubing or rod must be heated differently. Hold each end of the glass and support it so that it is level with the middle just above the inner core of flame. Rotate the tubing back and forth. At the same time, move it to the left and right so that about 0.3 cm of its length of evenly heated. Continue to both rotate and move the tubing or rod until the heated section softens. Remove from the flame and bend it as described above.



(ii) With a little practice with glass tubing, you should be able to achieve a bend in which the opening stays the same throughout the bend. Overheating or underheating the tubing, however, will produce poor bends. Underheating causes the tube to fold in at the bend. Overheating causes the tube to collapse at the bend.



(iii) If a U-shaped bend is desired, first make one 90° bend as described above. After allowing the glass to cool, make another 90' bend near the first one.



D3. Stretching

a. Materials Required

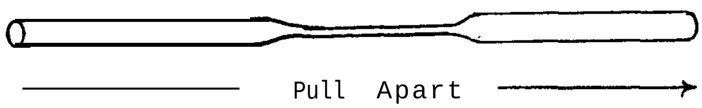
Burner: wide-flame alcohol burner

or

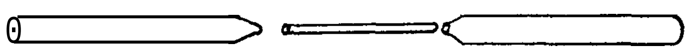
wing tip with gas burner

Length of soft glass tubing or rod

b. Procedure



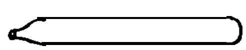
Hold the glass tubing or rod in the flame. Turn it as it heats, just as for making a bend. Heat the glass evenly until it softens. When the tubing or rod is soft, remove it from the flame. Pull the ends apart until the center has become narrow and stretched about 25 - 30 cm.



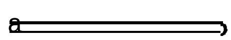
After the stretched part has cooled, it can be cut as required (I/Dl). Carefully fire polish the edges (I/D4).

c. Notes

(i) Stretched glass tubing has many applications in laboratory glassware. For example, the ends of the stretched tubing pictured above, with a narrow opening at one end, may be used as nozzles or jets.



The very narrow section of the tubing, the stretched part, may be used as a capillary tube.



(ii) If a wing tip or wide-flame burner is not available, follow the procedure given for heating a wide area of glass without the wing tip [I/D2, Note (i)].

D4. Fire Polishing Tubing

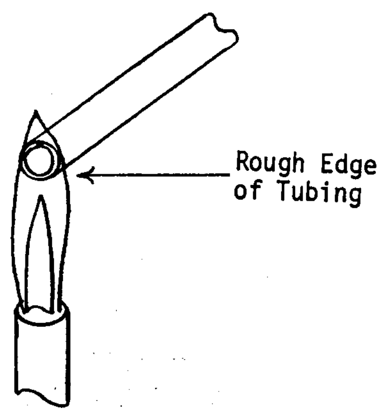
a. Materials Required

Glass tubing with cut edge

Burner

Cooling surface

b. Procedure



Hold the rough, cut end of the glass tubing in the hottest part of the flame, just above the inner cone. Turn the tubing constantly until the edge glows red.

Remove the tubing from the flame. Examine the heated end. If it is now rounded smoothly, rest the hot tubing on a brick, asbestos pad, or sand to cool. If the other end of the tubing is also rough, repeat the fire polishing procedure.

c. Notes

(i) Do not overheat the end of the tubing, or it will tend to close entirely.

(ii) Fire polish the ends of all glass tubing in use, as a safety measure.

(iii) Tubing with thick walls--for example, 0.5 cm (inside diameter) and larger--must be annealed to prevent cracking. To do this, hold the end in the flame for about one second, then remove from the flame for about one second. Repeat this procedure eight or ten times, then hold the end in the flame, turning it constantly until it is red hot. To cool thick-walled tubing slowly, remove it from the flame, but hold the tubing near the flame for a few seconds. Gradually move the hot end of the tubing further from the flame until it can be rested on the brick or other cooling surface.

D5. Closing Tubing

a. Materials Required

Burner

Glass tubing

Cooling surface

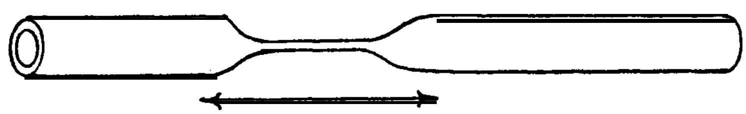
b. Procedure

Narrow Tubing

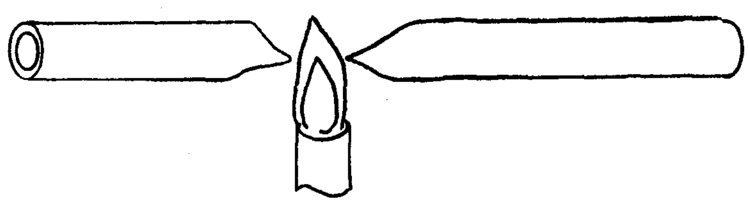
When using tubing with a diameter of less than 1.0 cm, hold the end of the tubing in the hottest part of the flame, just as for fire polishing. Turn the tubing constantly. Continue heating until the end closes.

Wide Tubing

When using tubing with a diameter greater than 1.0 cm, heat the tubing near one end, rotating the tubing as it heats. When the tubing is soft, pull it apart.



Continue to heat and pull the ends apart until the ends separate and the pointed end has closed.



D6. Glass Blowing

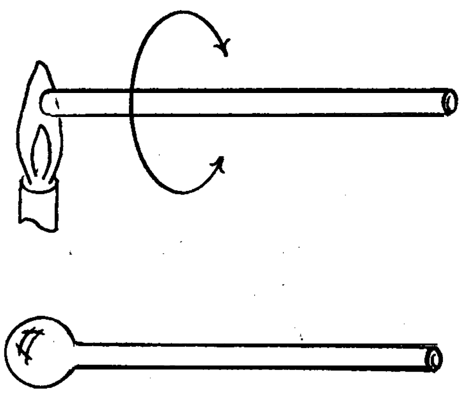
a. Materials Required

Gas burner

Length of soft glass tubing

Cooling surface

b. Procedure



Fire polish one end of the tubing. Allow it to cool. Close the_ other end by heating in the flame. Heat the closed end, rotating it constantly. While continuing to heat and rotate the tube, blow very gently, in short, light puffs, into the open end of the tube. Just as the closed end of the tube begins to swell and glow pale red, remove it from the flame. Blow strongly into the tube, while rotating it, to form a small round bulb.

c. Notes

(i) This procedure takes practice and patience to learn. It is helpful to begin with the narrowest tubing available; 0.3 cm tubing, for example. A common problem is blowing out the side of the bulb while the tubing is still in the flame.

(ii) A limiting factor in the size of tubing that can be used and the size of the bulb that can be blown is the burner used. The gas generating system (II/C1) and burner (II/C2) are adequate to allow 0.3 cm and 0.5 cm tubing to be blown into bulbs about 0.8 cm in diameter.

D7. Making Rim in Tubing

a. Materials Required

Burner

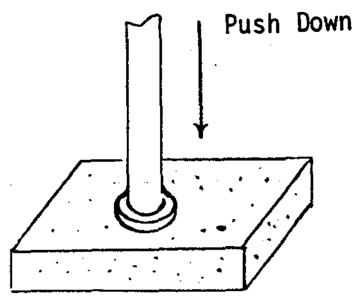
Glass tubing

Triangular file

Brick, or asbestos pad

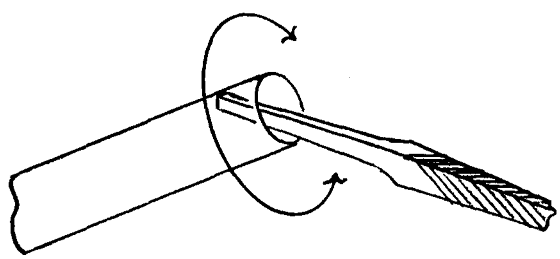
b. Procedure

Flattening



Hold one end of the tubing in the hottest part of the flame. Turn it constantly until the edge glows red. Remove the tubing from the flame. Quickly push the hot end evenly down against the brick or asbestos pad. A lip should form. Allow the glass to cool.

Flaring



Heat one end of the tubing until it is red hot. Remove the tubing from the flame. Hold the thin handle end of the file inside the end. Press gently outward on the file, while turning the tube to form a flared edge. Allow the glass to cool.

D8. Finishing Ends of Rods

a. Materials Required

Soft glass rods

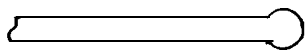
Burner

Brick, or asbestos pad

Pliers

b. Procedure

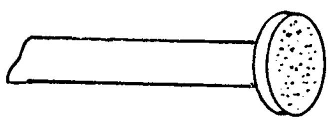
Fire Polishing



Follow the procedure for fire polishing glass tubing (I/D4). It will be necessary to heat the end of the rod for a longer period of time. The fire polished end will have a small, solid bulb. Holding the rod in the flame for a longer time will produce a larger bulb at the end.

Allow the rod to cool.

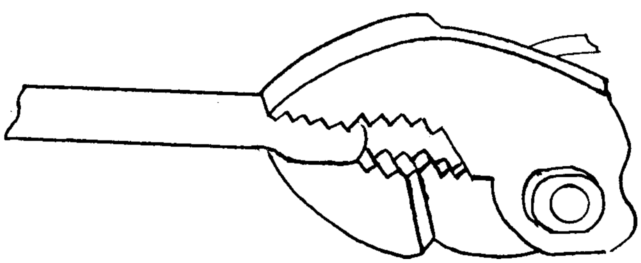
Flattening

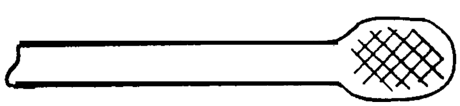


Follow the procedure for flattening glass tubing (I/D7) to form a flat disc at the end.

Allow the rod to cool.

Squeezing



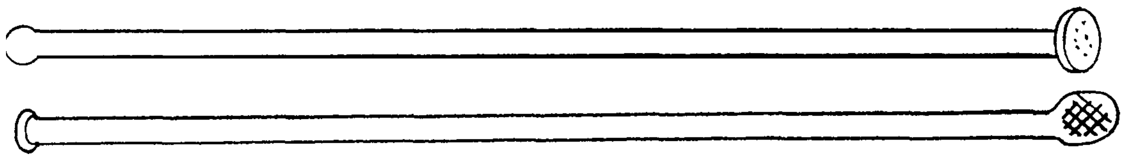


Heat one end of a rod as before. When it is hot, remove it from the flame. Compress about 1 cm of the end of the rod between the jaws of the pliers. A flattened paddle-shaped end will form.

Allow the rod to cool.

C. Notes

(i) A useful stirring rod can be made with a rod of about 0.3 - 0.5 cm diameter, 15 - 20 cm long. Flatten one end and squeeze or fire polish the other.



E. GLASS SHEET OPERATIONS

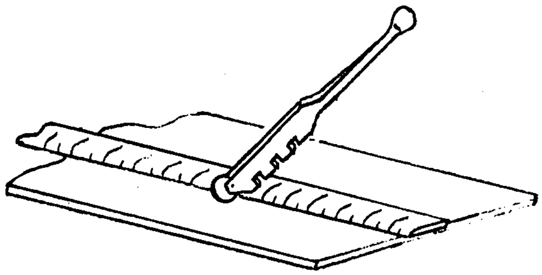
E1. Cutting

a. Materials Required

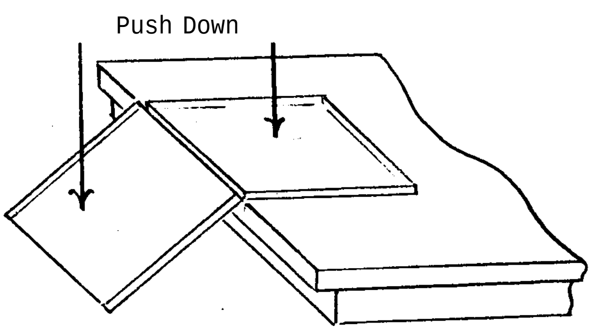
Glass cutter

Sheet of glass
(for example, a pane of window glass)

b. Procedure



Lay the glass flat on bench of table. Hold the ruler along the line to be cut, with one hand; and with the other hand, draw the wheel of the glass cutter on the glass along the ruler. Press hard enough to scratch the glass.



Place the underside of the scratch exactly over the edge of the table or bench. Press down on both sides to break the glass cleanly along the scratch.

E2. Drilling a Hole

a. Materials Required

Sheet of glass

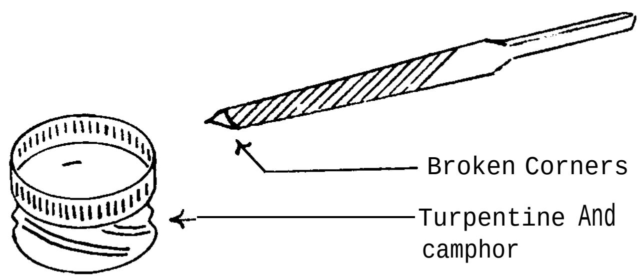
Triangular file

Hammer

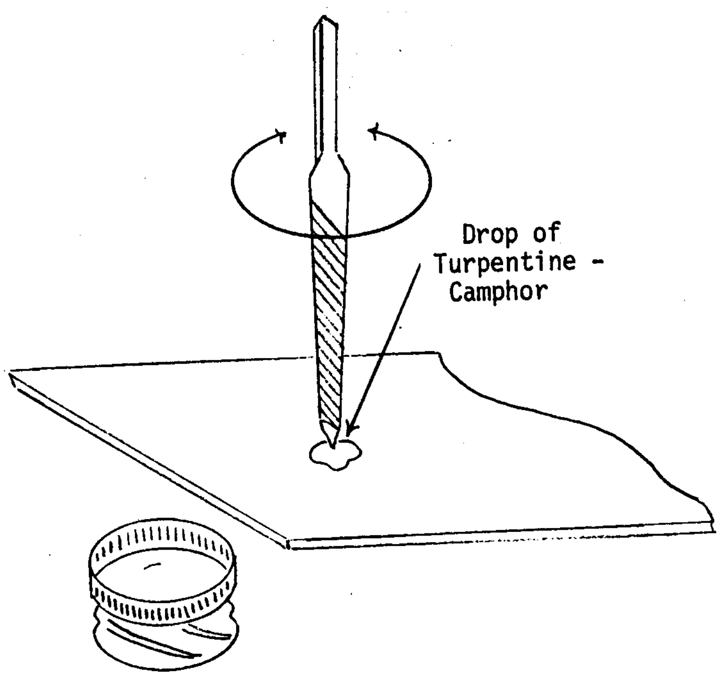
Turpentine

Camphor

b. Procedure



Take a little turpentine in a bottle cap. Put a small amount of camphor in it. Chip off the end of the triangular file with a hammer. This chipped end has sharp corners.



Place the glass flat on a table. Dip one of the sharp corners of the broken file into the turpentine-camphor mixture.

Press this corner of the file down on the spot to be drilled. Twist the file back and forth to drill into the glass. Use more turpentine-camphor as needed and continue drilling until the hole is complete.

c. Notes

(i) Drilling by hand is slow and may take ten or fifteen minutes.

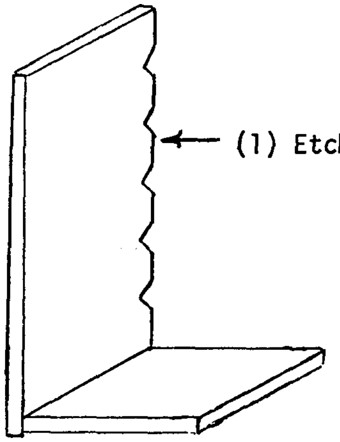
(ii) A completed hole can be enlarged with the edge of the triangular file or a round file, and the turpentine-camphor mixture.

(iii) After making the beginning hole on the surface of the glass, it is in fact easier to use a hand drill with the triangular file as the bit. However, extreme care must be taken. Do not push down on the drill at all, or the glass might break. Let only the weight of the drill be the force on the glass.

(iv) Follow this same procedure to drill a hole in a glass bottle or jar.

F. BOTTLE AND JAR TECHNIQUES

F1. Etching

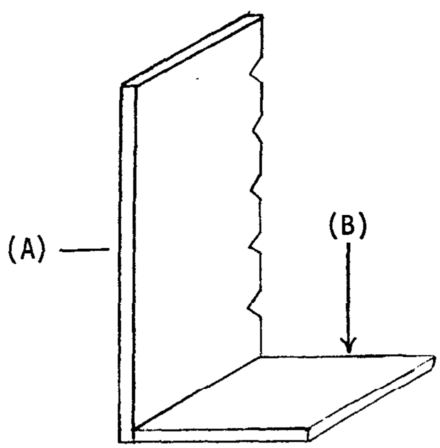


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Etching Guide	1	Wood (A)	Approximately 10 cm x 20 cm x 1 cm
	1	Wood (B)	Approximately 10 cm x 10 cm x 1 cm

b. Construction

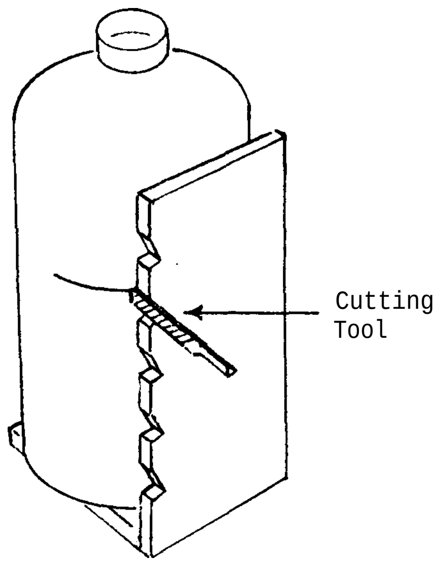
(1) Etching Guide



Cut V-shaped notches into one edge of a wooden board (A). Make the notches about 1 cm deep and about 2 cm (or other desired interval) apart. Then secure the base (B) at right angles to (A) with nails or glue and screws.

c. Notes

(i) The etching guide is used in combination with a triangular file or glass cutter to scratch a continuous line on a bottle or jar, prior to cutting. The



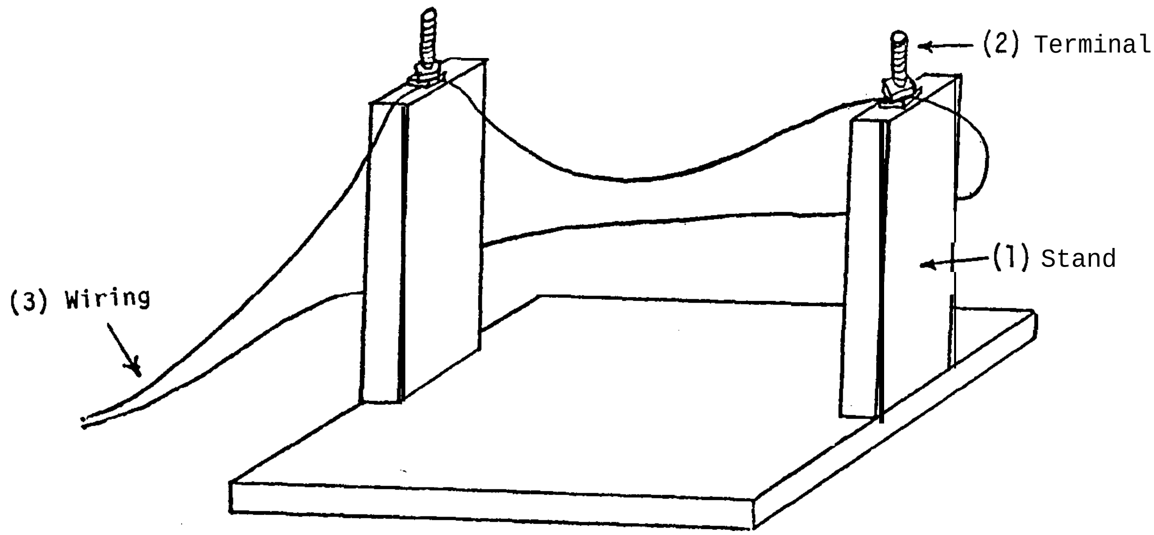
bottle or jar is placed on the stand and a glass cutter or triangular file is placed in a notch at the desired height. The bottle is rotated, and pressure is maintained against it with the tool so that a continuous scratch is scored around it.

(ii) A second method for etching a bottle, jar, light bulb, etc. to be cut is to wrap a strip of adhesive tape or paper around the glass as a guide. After the line has been scratched completely around the glass, the tape is removed.

(iii) After the glass has been etched in either of these two fashions, it may be cut using one of the techniques described in the following section.

F2. Cutting

Electrical Heating

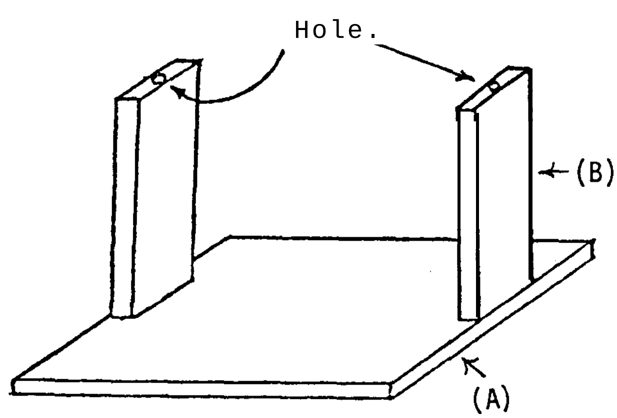


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stand	1	Wood (A)	30 cm x 10 cm x 2 cm
	2	Wood (B)	25 cm x 4 cm x 2 cm
(2) Terminal	2	Bolts (C)	3 cm long, 0.5 cm diameter
	4	Nuts (D)	0.5 cm
(3) Wiring	1	Nichrome Wire (E)	Size #24 (0.06 cm diameter), 34 cm long
	2	Insulated Copper Wire (F)	Size #20 (0.08 cm diameter), 125 cm long

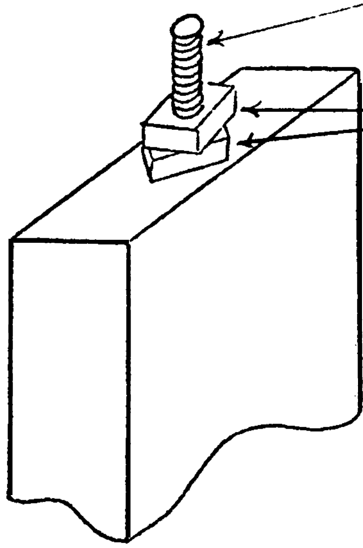
b. Construction

(1) Stand



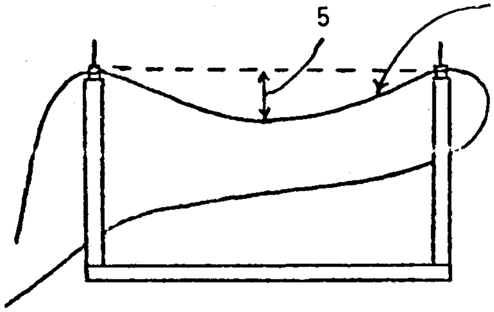
Drill a hole in one end of each of the two uprights (B). This hole should be slightly smaller in diameter than the bolts (C) used for the terminals. Next, nail or screw the uprights to the base (A).

(2) Terminal



Cut the heads off the two bolts (C), and put glue into the holes in the uprights (B). Screw the bolts down into the hole, leaving about 1.5 2 cm protruding. Next, secure the bolts by screwing on one nut (D) until it is tight. Screw on the second nut (D) loosely.

(3) Wiring



Wrap one end of the #24 nichrome wire (E) around one bolt (C) for one or two turns and do the same with the other end. Tighten the second nut (D) on the terminals until the nichrome wire is firmly held. There should be about a 5 cm sag in the middle. Fasten the copper wires (F) to each terminal in the same manner. Connect clips to these wires. For power use a transformer (PHYS/VII/A2) wired to a wall outlet [Note (iii)], or a heavy-duty battery.

C. Notes

(i) Prepare the jar, bottle, light bulb, etc., to be cut by etching a continuous line around the glass (I/Fl). Connect the cutter to a power supply until the wire is hot, then place the etched line on the hot wire, Hold the glass in this position until it cracks along the healed portion. Then rotate the glass to heat another portion of the etched line. Continue this procedure until the crack has circled the glass and the two sections separate.

(ii) The broken edges of the glass can be smoothed by rubbing them with wire gauze or wet sandpaper (emery paper).

(iii) If the wire cutter is used with a wall outlet (120 volt) then a transformer must be employed to bring the voltage down to 12 volts, 3 amps. The cutter can also be used with a standard 12 volt automobile battery. However, using a battery requires more time for heating the etched line, since the wire does not get as hot.

String Heating

a. Materials Required

Bottle, jar, or light bulb

String

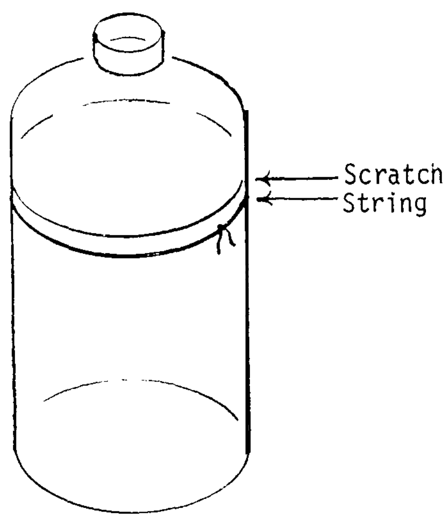
Container of cold water

Alcohol, kerosene, or turpentine

Tape or paper

Glass cutter or triangular file

b. Procedure



Prepare the bottle or jar as described in I/F1 above. After the paper or tape guide has been removed, tie a piece of string or cord which has been soaked in a flammable liquid around the bottle about 0.5 cm below the scratch. Light the string with a match, and as soon as the flame dies down, pour cold water on the bottle. The sudden change from hot to cold will break the bottle along the scratch. This process may have to be repeated to break thick glass. Smooth the cut edge of the glass as described in Note (ii) above.

Wet Paper Cooling

a. Materials Required

Bottle, jar or light bulb

Alcohol or gas burner, or candle

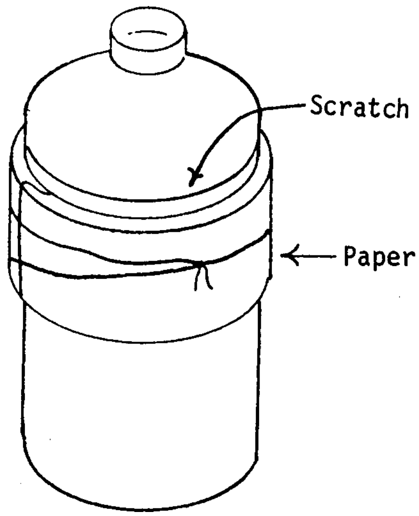
Triangular file or glass cutter

Blotting paper or wrapping paper

String

Container of cold water

b. Procedure



Wind a strip of blotting paper, paper towel, or wrapping paper about 5 cm wide around the bottle at one side of the line to be cut. Wrap the paper at least 0.5 cm thick and then tie the paper with string or rubber bands. With the file or glass cutter, scratch a line completely around the bottle at the top edge of the paper. Put the bottie into cold water until the paper is soaked (about five minutes). Remove the bottle from the water, and rotate it in a horizontal position, with the scratch on the glass just above a small, fine flame. Continue this for four or five minutes. If the bottle has not dropped apart, put the bottle vertically into the water. The bottle should break into two parts along the scratch. If it does not, repeat the heating and cooling until it does. It is crucial that the flame be very small so as to heat a minimum of glass on either side of the scratch.

c. Notes

(i) To drill a hole in a glass bottle or jar, follow the procedure outlined for drilling in a glass sheet(I/E2).

G. STOPPERS

Stoppers for use in scientific apparatus are commonly manufactured of either cork or hard rubber.

Rubber Stoppers

Rubber stoppers are more durable for general use than cork stoppers. They are available in standardized sizes, and are manufactured with no holes as well as with one, two or three holes. Although they tend to react with organic solvents like gasoline, they provide an excellent seal in most cases and can even be sterilized. (BIO/VII/A2). If a stopper with holes is specified in the directions for a piece of apparatus, use rubber stoppers with pre-drilled holes if at all possible. If it becomes necessary to drill a hole or holes in a rubber stopper, consult the notes following the discussions of boring and drilling holes in cork stoppers(I/G1 and G2).

Cork Stoppers

Cork stoppers, while generally less expensive than those made of rubber, are not as suitable for general use. They tend to lose their shape after long use, are not available with holes pre-drilled, tend to absorb reagents, and cannot be adequately sterilized. Should it be necessary to bore a hole or holes in a cork stopper for the insertion of glass tubing, one of the following methods may be employed.

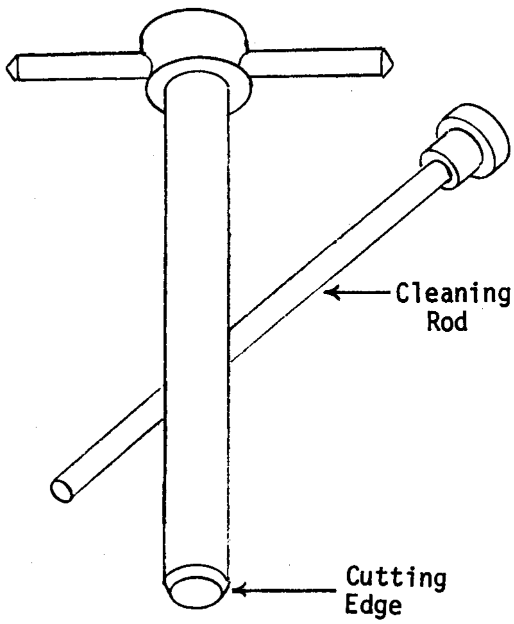
Gl. Cork Borinq

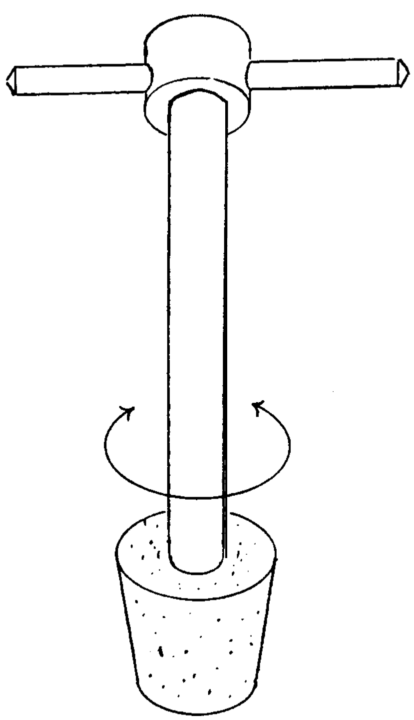
a. Materials Required

Cork stopper

Set of hand cork borers

b. Procedure





If a set of hand cork borers in graduated sizes is available from a scientific supply house, choose a cork borer of the same or slightly smaller diameter as the glass tubing that is to go through the cork.

The cork borer set generally is supplied with a rod to clean pieces of cork out of the borer. Soften the cork by wrapping it in a piece of paper and rolling it gently on the floor under your foot.

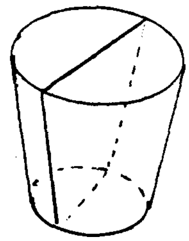
With one hand, hold the cork firmly on the table or bench, wide end up. With the other hand, place the cutting edge of the cork borer in the center of the cork. Then with a gentle twisting motion on the cork borer, bore into the cork until the tool is about halfway through the cork.

It is not necessary to push hard; but twist gently with light pressure. Remove the cork borer from the cork and push out small pieces of cork inside it with the cleaning rod.

Turn the cork over and repeat this process until there is a hole through the cork.

C. Notes

(i) If two holes are desired, the first must be bored near one edge of the cork



in the manner described above. The second hole is then bored in the same way. A guide line, drawn around the middle of the cork, is helpful in determining the positions of the two holes.

(Ii) This method is suitable for boring holes in rubber stoppers. However, the stopper as well as the end of the boring tool should be lubricated with glycerine.

G2. Cork Drilling

a. Materials Required

Cork stopper

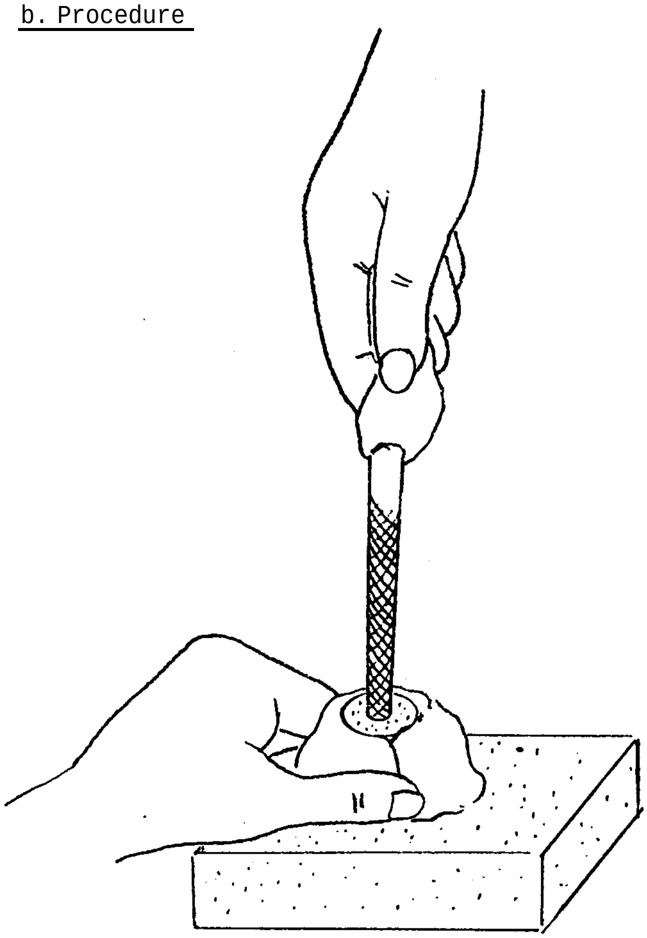
Round file

Cloth, or wooden handle

Burner

Brick or asbestos pad

b. Procedure



Soften the cork as described in I/G1 above. Hold the cork, wrapped in cloth or clamped in pliers, securely against the brick or asbestos pad with one hand. Hold the file, wrapped in cloth or in a wooden handle, by its four-sided end in the other hand. Heat the round end of the file in the burner flame. Remove the file from the flame when it glows red hot, and push it gently into the center of the cork. Push it only about half-way through the cork, then remove it.

Turn the cork over, reheat the file, and make another hole to meet the first one.

Allow the file to cool, then enlarge the hole to the desired size by gentle filing.

c. Notes

Care must be taken not to overheat the file, or it may set the cork on fire. Should this happen, blow the flame out quickly.

(ii) Two holes can also be made through the cork with this method.

(iii) Very small holes can be made in corks in the same manner by using heated wire.

(iv) If a hand drill or electric drill is available, holes can easily be bored by using either a regular drill bit or the round file as the drill bit, The cork must be rigidly held in a vise. For an accurate hole, just as with the other methods of drilling, a hole should be drilled halfway through the cork from each side, to meet in the center of the cork.

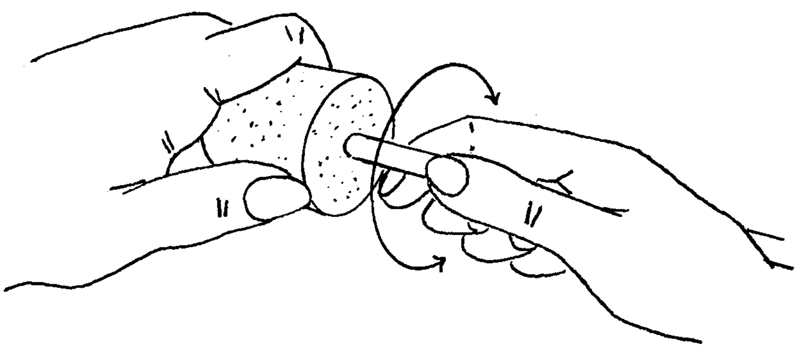
(v) It is possible to drill holes in rubber stoppers with a hand drill or electric drill, but the hot file method will not work in rubber stoppers.

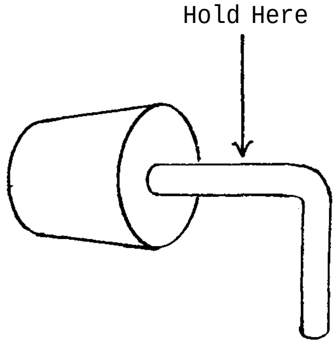
G3. Inserting Glass Tubing Through a Stopper

a. Materials Required

Glass tubing
Burner
One-hole cork or rubber stopper
Cloth
Glycerine

b. Procedure





Fire polish the end of the tube that is to go into the stopper. Allow it to cool. Hold the tubing about 2 - 3 cm from the fire-polished end in one hand. Lubricate this end of the tube with glycerine. Hold the stopper in the other hand. Gently and carefully push the tube into the stopper with a twisting motion. Do not use too much force or the tube will snap.

When pushing a piece of bent tubing into a stopper, always hold the tube between the bend and the stopper. Do not push on the bend; it is weak and will break easily.

c. Notes

(i) This is a technique that, if improperly done, can be quite dangerous. When done correctly, however, it is quite safe.

11. BURNERS

These have been grouped according to the type of fuel used.

A. SOLID FUEL BURNERS

These are the simplest burners to make, and include candles as well as charcoal burners.

B. LIQUID FUEL BURNERS

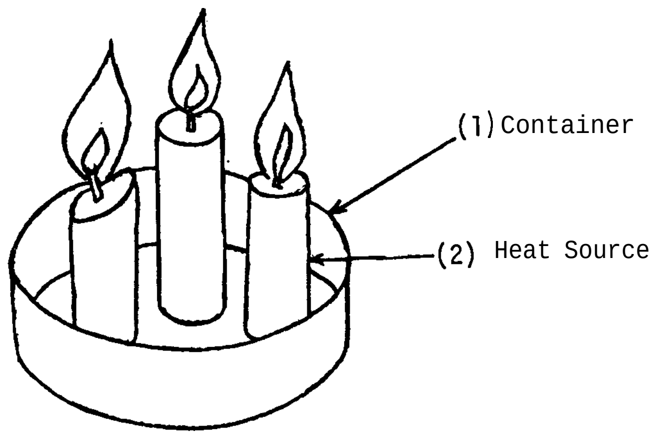
These include several types of alcohol burners.

C. GAS BURNERS AND SYSTEMS

These are functional items, providing the cleanest, most intense heat. However, they are somewhat more sophisticated for production purposes,

A. SOLID FUEL BURNERS

Al. Candle Burner



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Shallow Tin Can (A)	5 cm diameter or larger
(2) Heat Source	3	Household Candles (B)	Varies

b. Construction

(1) Container	Select a tin can (A) with low sides.
(2) Heat Source	Melt the wax at the base of the candles (B) and place them at equal intervals within the container.

c. Notes

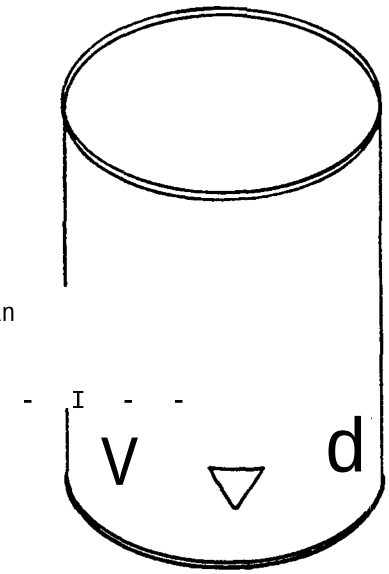
(i) The intensity of the heat produced may be increased by increasing the number of candles, but the total intensity is low.

(ii) The efficiency of a candle burner may be improved by collecting all the wax that melts into the container and using it again with new wicks made from soft string.

(iii) The candle flames tend to deposit soot on the surface of whatever is being heated.

A2. Charcoal Burner *

(1) Can

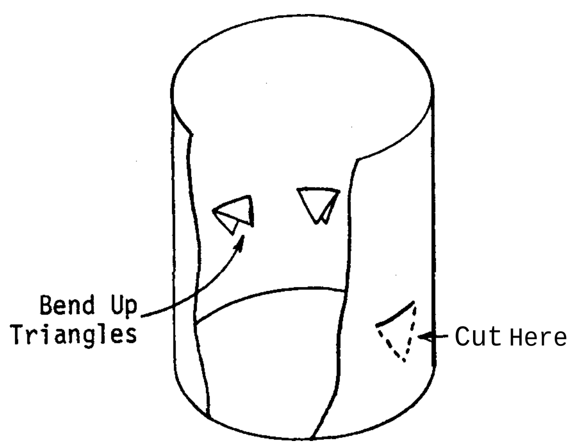


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Empty Metal Can (A)	10 cm diameter or larger

b. Construction

(1) Can



Remove top from can (A). Approximately 4 cm from the bottom of the can, mark off triangular windows all around.

With shears, cut along the sloping sides of each triangle to make the windows. Do not cut along the base line (horizontal edge) of the triangle.

Bend the triangles up to form a tray.

*Adapted from UNESCO, Source Book for Science Teaching, (Paris: UNESCO, 1967), pp 34-35.

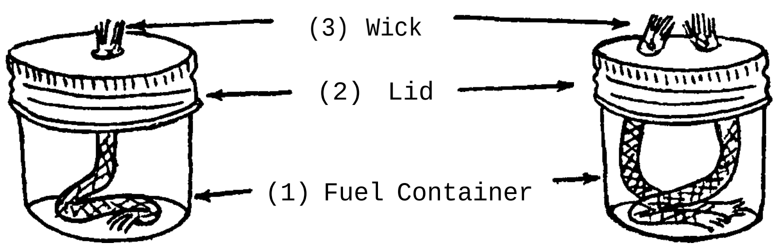
c. Notes

(i) The holes permit air to circulate freely to the burning charcoal.

(ii) Comments from users of the charcoal burners indicate that they are hard to start. Also, once started, they present a considerable fire and carbon monoxide risk.

B. LIQUID FUEL BURNERS

B1, Simple Alcohol Burner



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fuel Container	1	Glass or Metal Container (A)	150-200 ml, approximate capacity
(2) Lid	1	Screw Top (B)	To fit fuel container
(3) Wick	1	Soft Cotton Fiber Cord (C)	Long enough to extend to bottom of container and to cover it.

b. Construction

(1) Fuel Container — Make the fuel container from a glass or metal container (A) with a screw-on metal lid (B). Select a container with a wide base to insure stability.

(2) Lid — Punch a hole in the lid (B) with a nail, making it as round and smooth as possible, with a diameter smaller than that of the wick to be used.

(3) Wick — Select a piece of cord (C) with soft cotton fibers. The wick should protrude 0.5 cm above the surface of the lid.

c. Notes

(i) If a hotter, broader flame is required, punch two holes in the lid and use two wicks to produce a single, broad flame.

(ii) The wick should be soaked in alcohol before lighting the burner.

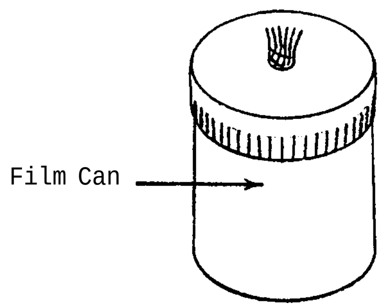
(iii) Methyl alcohol or denatured ethyl alcohol is the usual fuel used in the burner. Kerosene may also be used, but it tends to produce a smoky flame which blackens heated objects.

(iv) Important: Use a stable container. Otherwise, there is danger that the burner will tip over easily.

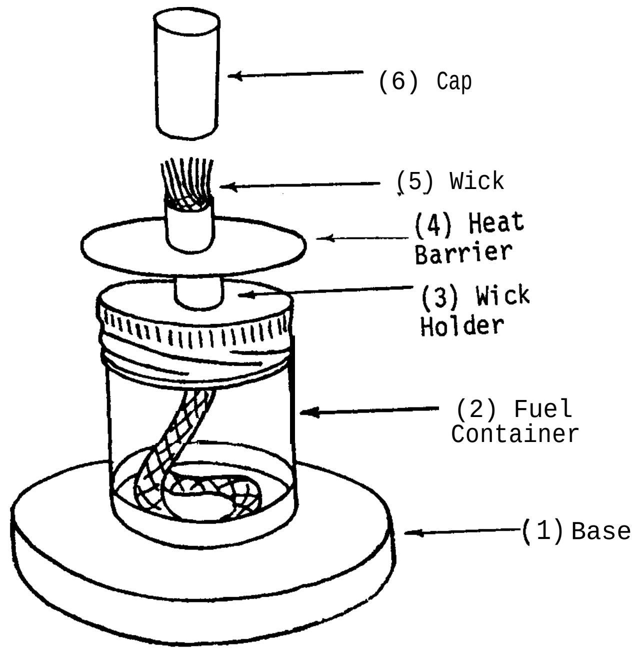
(v) If the burner is used for prolonged periods, overheating of the container, with build-up of internal pressure, is possible.

(vi) Make certain that the wick fits tightly into the hole in the lid. Otherwise, it is possible for the flame to climb down the wick into the container.

(vii) A user of alcohol burners notes that those made from 35 mm film cans have several advantages over larger ones made from glass containers. First, they are unbreakable. Second, if the inside is filled with cotton wadding (cotton wool) they are unspillable if knocked over. Also, these small film cans hold only enough for immediate use, so that evaporation losses are not serious.



B2. Modified Alcohol Burner

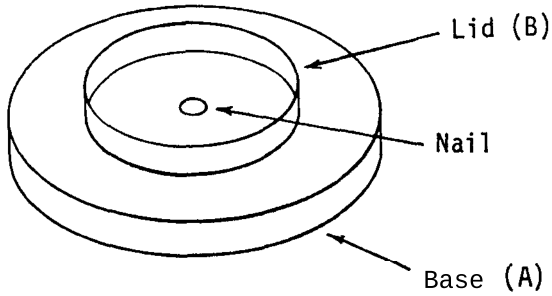


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wooden Platform (A)	Approximately 10 cm diameter (round), or approximately 10 cm x 10 cm (square)
	1	Metal Lid (B)	To fit fuel container bottom
(2) Fuel Container	1	Glass or Metal Container (C)	100-200 ml capacity
	1	Metal Lid (D)	To fit fuel container top (C)
(3) Wick Holder	1	Metal Tube (E)	Approximately 4 cm long, 0.7 cm or 0.8 cm diameter
(4) Heat Barrier	1	Metal Disc (F)	5 cm diameter or larger
(5) Wick	1	Cord (G)	Approximately 10 cm long, 0.5 cm or more in diameter
(6) Cap	1	Ball Point Pen Top or Metal Tube (H)	To fit wick holder

b. Construction

(1) Base

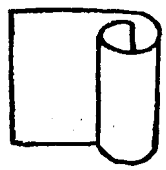


Nail the metal lid (B) (with a diameter equal to that of the fuel container) to the round or square wooden base (B).

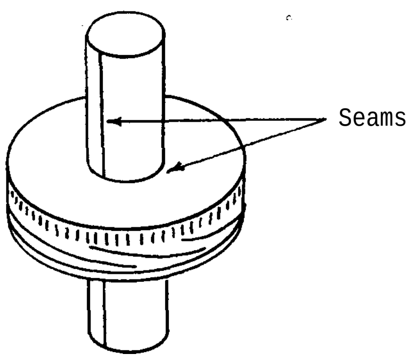
(2) Fuel Container

Select a glass or metal container (C) with a screw-on lid (D).

(3) Wick Holder

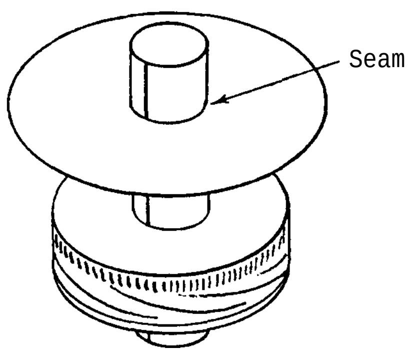


Make the wick holder from a metal tube (E) about 4 cm long x 0.7 or 0.8 cm internal diameter, or roll a piece of sheet metal (4 cm x 2.5 cm) into a tube.



Drill a hole in the fuel container lid (D) large enough to allow insertion of the wick holder. Insert the wick holder so that it penetrates about 1 cm into the container. Solder the seam along the tube and between the tube and the lid.

(4) Heat Barrier



Cut the metal disc (F) from metal sheeting, or use a tin can top. The disc should be slightly larger than the fuel container lid (D).

Drill a hole in the center of the disc large enough to allow insertion of the wick holder (E). Insert the wick holder so that about 1.0 - 1.5 cm protrudes above the disc. Solder the seam between the heat barrier and wick holder.

(5) Wick

Make the wick from a piece of cord (G) or rope with soft cotton fibers. Insert the wick into the wick holder. Trim the wick with scissors so that about 0.4 - 0.5 cm protrudes above the top of the wick holder.

(6) Cap

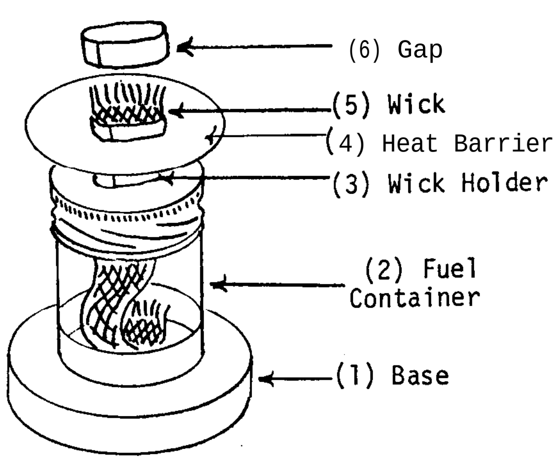
Use a ball point pen top (H) as a cap or make a metal cap large enough to fit snugly over the wick holder when the burner is not in use. The cap prevents evaporation of the alcohol.

C. Notes

(i) The design of this burner overcomes the major hazards of the simple alcohol burner (I I/Bl).

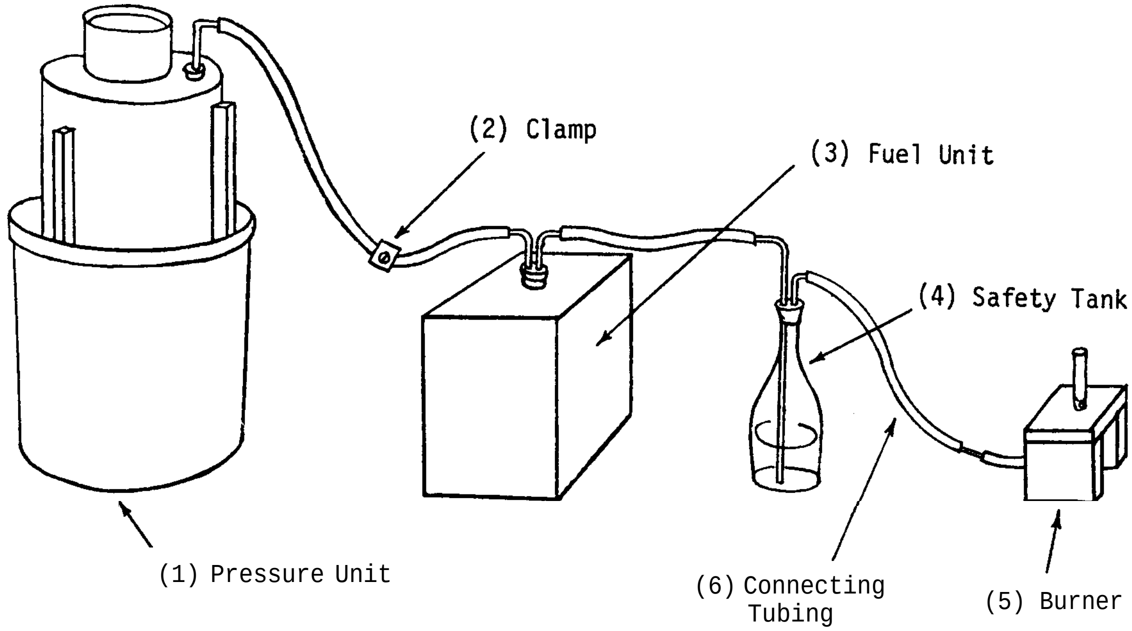
(ii) This 'design can be modified to produce a wide flame that is particularly useful for working with glass. All parts of the design are the same, except for the shape of the wick, wick holder, and cap.

For the wick holder, cut a piece of metal sheeting about 5 cm x 4 cm. Bend it into a flat tube about 2 cm wide and 0.5 cm deep. Solder the seam. Install this wick holder in the fuel container lid and heat barrier just as in the previous design. For the wick. use flat cotton webbing about 2 cm wide and 10 cm long, or braid (plait) a flat wick from six to ten strands of cotton cord or string. Make a cap from metal sheeting to fit snugly over the wick holder when the burner is not in use,



C. GAS BURNERS AND SYSTEMS

Cl. Fuel System for Gas Burner *



a. Materials Required

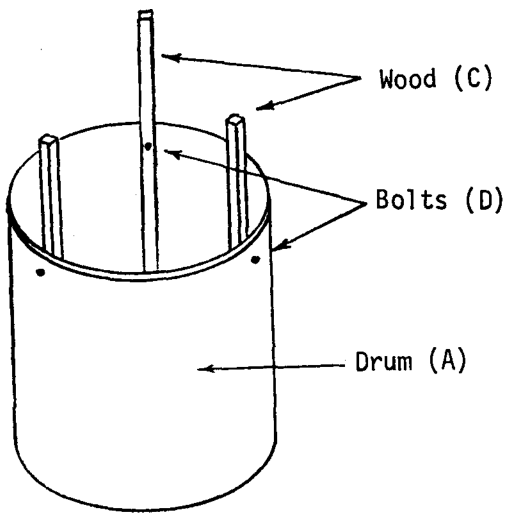
Components	Qu	Items Required	Dimensions
(1) Pressure Unit	1	Metal Drum (A)	Approximately 26 liter capacity
	1	Metal Drum (B)	Approximately 16 liter capacity
	3	Wood (C)	3 cm x 2 cm x 65 cm
	3	Bolts (D)	0.5 cm diameter, 4 cm long
	1	l-Hole Stopper (E)	Approximately 2.5 cm diameter (large end)
	1	Glass Tubing (F)	0.5-0.7 cm diameter, 10 cm long
	1	Container and Sand (G)	Approximately 6 kg
(2) Clamp	1	Screw Clamp (H)	IV/A5
(3) Fuel Unit	1	Metal Can (I)	4 liter capacity, approximately
	1	2-Hole Rubber Stopper (J)	To fit opening in can

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 140-141.

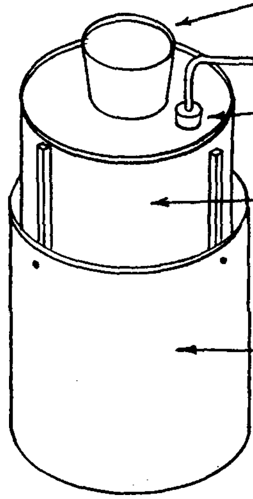
	1	Glass Tubing (K)	0.5 cm diameter, 10 cm longer than height of can
	1	Glass Tubing (L)	0.5 cm diameter, 10 cm long
(4) Safety Tank	1	Narrow-neck Bottle (M)	500 ml capacity, approximately
	1	2-Hole Rubber Stopper (N)	To fit bottle
	1	Glass Tubing (0)	0.5 cm diameter, 10 cm longer than height of bottle
	1	Glass Tubing (P)	0.5 cm diameter, 10 cm long
(5) Burner	1	Gas Burner (Q)	II/C2
(6) Connecting Tube	3	Plastic or Rubber Tubing (R)	Approximately 1 cm diameter, and approximately 1 meter long

b. Construction

(1)Pressure Unit



Select two metal drums (A,B) of approximately the same depths, but different diameters, so that one drum (B) will fit inside the other (A). Each drum should have one end open. Bolt the three pieces of wood (C) to the larger drum (A) with the bolts (D) so that the space between them is just sufficient to allow the smaller drum (B) to slide down easily between them.



Use an alcohol lamp to make a 90' bend in the middle of the glass tubing (F), or cut a shorter piece of straight tubing. Fit the glass tube into the stopper (E). Bore a hole near one side in the bottom of the smaller drum (B). Insert the stopper into this hole.

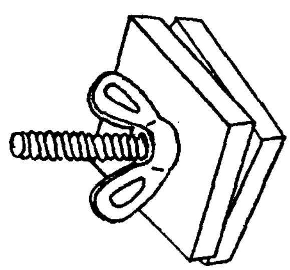
Fill the larger drum (A) with water equal to the volume of the smaller drum.

Fit the smaller drum, open side down, between the wooden uprights of the larger drum.

Push down on the upper (air) drum (B). It should slide down into the lower drum (A). Air should be felt escaping from the glass tubing (F).

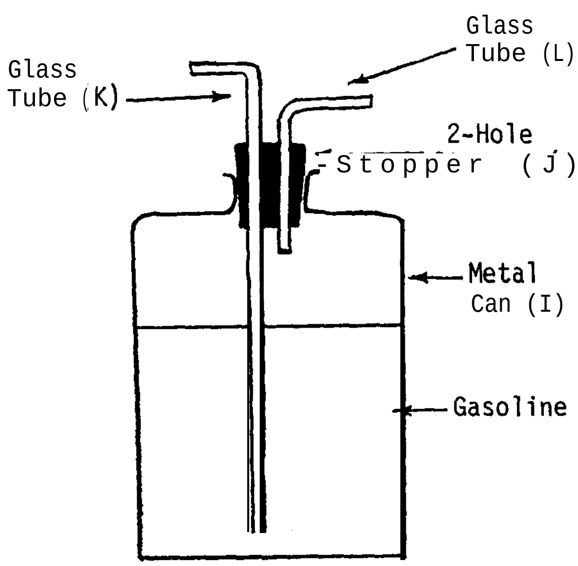
Place a can or bucket filled with sand (G) on the air drum, as a weight.

(2) Clamp



Use the screw-type clamp (H) or any standard screw-type clamp to control the air pressure from the fuel tank.

(3) Fuel Unit



Fuel Unit
(Cross-section)

Make the fuel container from a metal drum (I) or can with a single outlet, rather than a lid. Fit the drum with a two-hole rubber stopper (J).

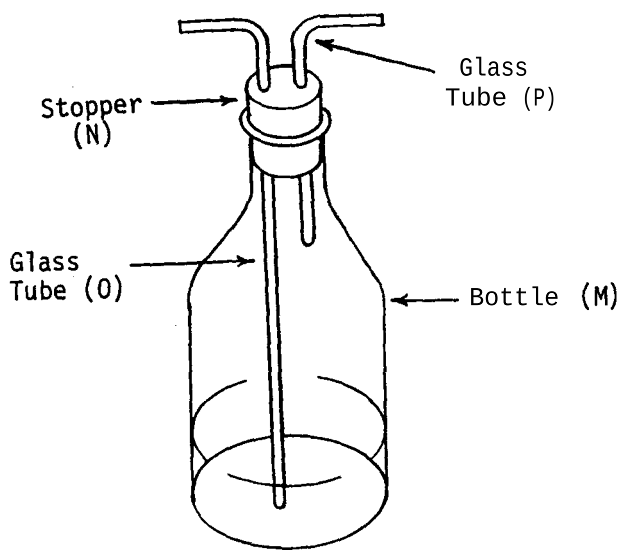
Make a 90' bend about 5 cm from one end of the longer piece of glass tubing (K), or use a slightly shorter piece of straight tubing.

Make a 90" bend in the middle of the short piece of glass tubing (L).

Insert both pieces of tubing into the stopper as illustrated.

Fill the can about 3/4 full of gasoline (petrol).

(4) Safety Tank



Select a glass or metal container (M) with a narrow neck. Fit the container with the two-hole rubber stopper (N).

Bend both, pieces of glass tubing (0,P) as described above, and insert each into the stopper as illustrated.

Fill this container about 1/3 full of water.

(5) Burner

Construct a Bunsen burner (Q) as described in the next section (II/C2).

(6) Connecting Tubing

Use flexible tubing (R) (rubber or plastic) to connect the apparatus as illustrated.

Connect the tubing from the Pressure Unit (1) with the long glass tube of the Fuel Unit (3).

Connect the tubing from the short glass tube of the Fuel Unit (3) with the long glass tube of the Safety Tank (4).

Attach the connecting tubing from the short glass tube of the Safety Tank (4) to the Bunsen burner (5). Take care to see that the tubing is not kinked anywhere.

When all components are assembled and correctly connected, remove the weight and stopper from the upper (air) drum. Lift the drum until its lower edge is just below the water level in the lower drum. Replace the stopper and check to see that it is tight, and replace the weight on top of the drum.

c. Notes

(i) As the air drum sinks into the water of the lower drum under its own weight and the pressure of the weight on top, the air thus displaced is driven into the fuel drum and bubbles up through the petrol. The petrol evaporates as the air passes through it, and the air-gas mixture is driven through the water in the safety tank to the burner.

(ii) This system is potentially dangerous because the petrol-air mixture present from the fuel tank is an explosive mixture, but several safety precautions have been incorporated into the design.

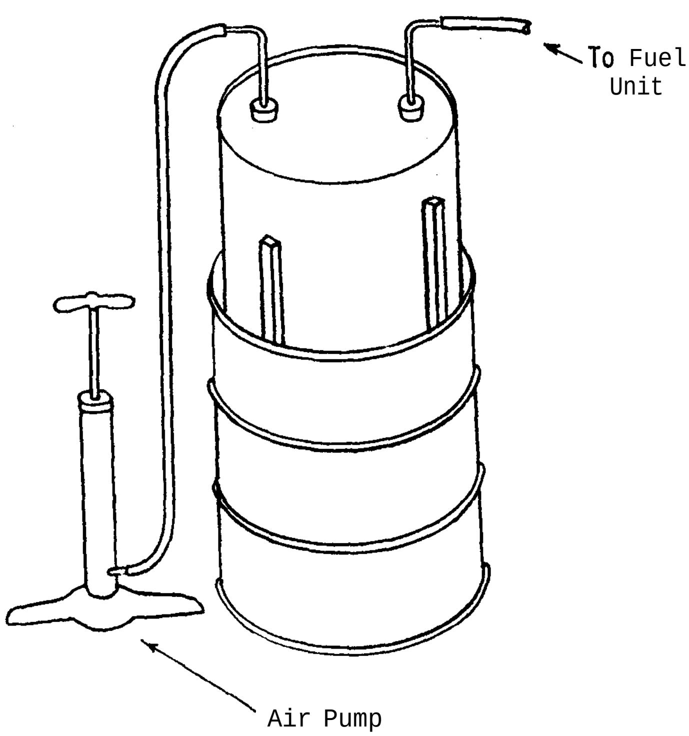
The greatest safety factor is the needle valve in the burner; even when the burner occasionally "backfires" (the flame jumps down from the end of the burner tube to the needle opening) the flame is very unlikely to move back through the needle's narrow opening. In the unlikely event that a flame should move back down the tubing, the safety tank prevents it from reaching the fuel drum. As a further safety measure in the safety tank, the stopper should be snug, but not jammed tightly into the neck of the container. Thus, should the flame move back into the safety tank, it will be more likely to blow the stopper out of the tank than to blow the tank apart.

Despite the built-in safety precautions, however, feedback comments suggest extreme care in the use of this system.

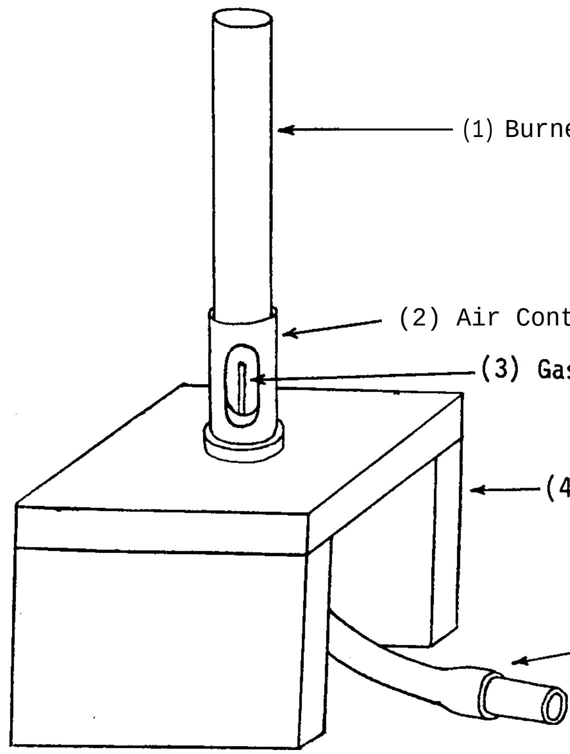
(iii) In the system described here, a glass bottle, encased in a cage of wire mesh for additional safety, was used as a water tank. This made it possible to observe the rate of bubbles in the water, an indicator of the pressure in the system. A fairly rapid rate of bubbles, about 100 or more per minute, was necessary to produce a burner flame 3 - 4 cm high. It is recommended, however, that once the bubbling rate is established, a metal safety tank of similar size be substituted for the glass bottle.

(iv) A weight of approximately 5.5 kg on an air drum with an area of 490 cm^2 (diameter 25 cm) provided 11 g/cm^2 pressure to run the Bunsen burner described in the following section (II/C2) for about a half-hour.

(v) The system and dimensions described here constitute a small, laboratory version suitable for running one Bunsen burner. For a larger system, the same components and principles apply, but experimentation on the details of construction will be necessary. For example, a larger pressure system, with a large, heavy oil drum for the upper drum would provide pressure for a longer period of time and might not require a weight on top. An air pump could be added to fill the drum with air without lifting it.



C2. Gas Burner *



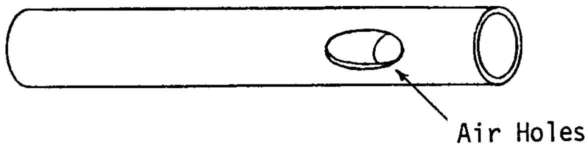
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Burner Tube	1	Copper Tubing (A)	10.5 cm long, 1 cm diameter
(2) Air Control Sleeve	1	Metal Sheet (B)	3 cm x 3.5 cm
(3) Gas Valve	1	Hypodermic Needle (C)	18 gauge (0.125 cm outside diameter)
	1	Adhesive Tape or Electrical Tape (D)	Approximately 1 cm wide, 15-30 cm long
(4) Base	1	Wooden Block (E)	10 cm x 10 cm x 2 cm
	2	Wooden Block (F)	10 cm x 5 cm x 2 cm
(5) Gas Tubing	1	Rubber or Plastic Tubing (G)	Approximately 15-20 cm long, approximately 0.6 cm internal diameter
	1	Metal Tube (H)	3 cm long, 1 cm diameter

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 138, 141.

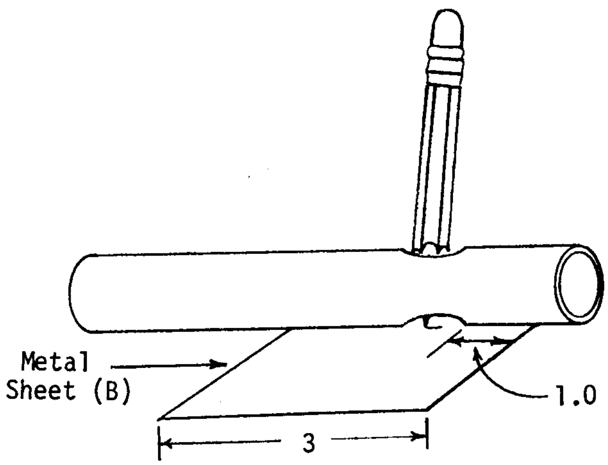
b. Construction

(1) Burner Tube



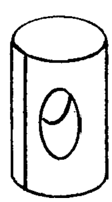
Drill two holes on opposite sides of the copper tube (A) about 2 - 2.5 cm from one end. Enlarge the holes to an oval shape, about 1 cm long x 0.6 cm wide.

(2) Air Control Sleeve



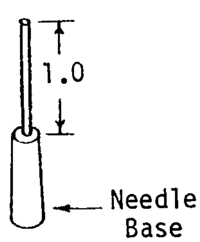
Lay the metal sheet (B) flat on a table. Lay the burner tube on it with the end of the tube with the holes in it about 1.0 cm from the 3.5 cm edge. Actually, the holes themselves should be 1.0 cm from the 3.5 cm edge.

Use a pencil to trace the outline of one of the holes in the tube onto the metal sheet. Cut this hole out. lineWrap the metal sheet around the burner tube until it forms a cylinder. Align the hole in the metal sheet with one of those in the tube. lineTrace the outline of the other hole in the tube onto the metal sheet. Remove the metal sheet, and cut out the second hole.

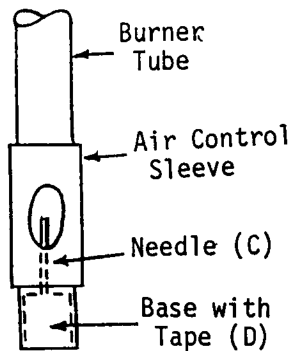


Reroll the air control sleeve and place it in position on the burner tube.

(3) Gas Valve



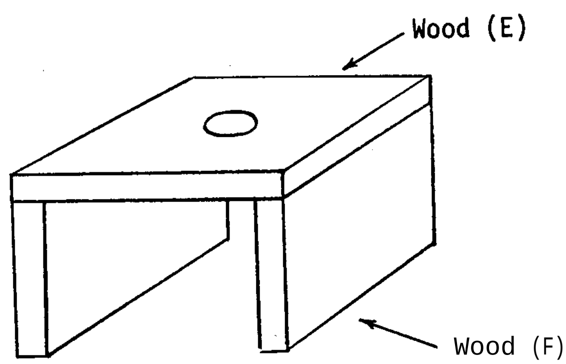
Cut the top off the hypodermic needle (C) so that about 1 cm of the needle remains. File the linecut end of the needle open.



Side View

Wrap the adhesive tape (D) or electrical tape around the needle holder until the base of the needle will fit tightly into the bottom of the burner tube. The open end of the needle should be near the middle of the air holes.

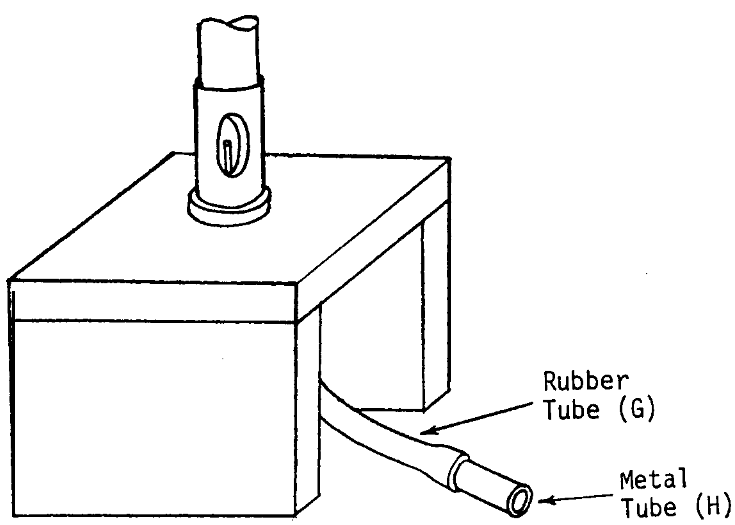
(4) Base



Drill a hole approximately 1.2 cm in diameter in the center of the square piece of wood (E). Enlarge the hole with a file to tightly hold the burner tube and gas tubing in place.

Nail the two rectangular pieces of wood (F) to the square to form the sides of the base.

(5) Gas Tubing



Connect one end of the plastic or rubber tubing (G) to the bottom of the burner tube. Then push the burner tube through the hole in the top of the base. It should fit snugly in place and should not wobble.

Pass the other end of the gas tubing through one open side of the base. Insert the small metal tube (H) into the open end of the gas tubing.

Connect tubing from the gas supply to this metal tube.

c. Notes

(i) This burner has been tested with both commercially supplied natural gas and with the gas generating system described in the previous section II/Cl.

(ii) When the burner is lit, the air control sleeve can be used to control the nature and intensity of the flame. The sleeve is closed when its holes and the holes in the burner tube.are not lined up with each other. No air enters the burner tube. The flame is smoky, yellow, and glowing. It gives little heat. The absence of air prevents the gas from being completely burned.

When the sleeve is turned so that its holes and those of the burner tube are partly lined up, some air enters the burner tube. The flame is almost colorless, and does not glow. It is quite hot. The gas is more completely burned in this flame because of the presence of some air.

When the holes of the air control sleeve completely match those in the burner tube, the maximum amount of air enters the burner tube.

This produces a very hot, roaring flame with a bright blue center cone. The gas is completely.burned, producing the hottest flame, because there is plenty of air entering the burner tube.

Purplish Cone - hot part of the flame, called the **oxidizing flame.** Combustion of the gas is most complete.

Hottest part of the flame just above the inner blue cone of flame.

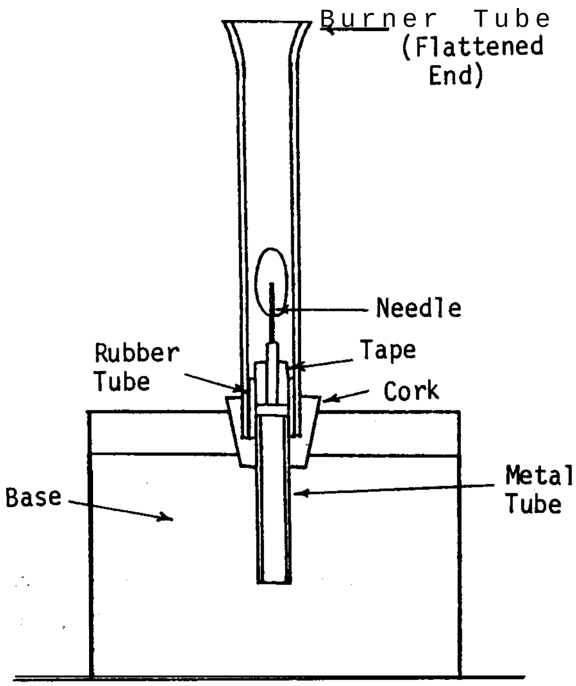
Blue cone not as hot as the outer cone because there is insufficient oxygen mixed with the gas to completely burn it. Called the reducing flame because it can take oxygen away from some oxides.

Dark cone - not a flame at all. It is filled with a mixture of unburned gas and air coming from the barrel.

Use a blue flame, about 4 cm high, for glass-working operations and most other heating operations. Adjust the gas supply and air control sleeve of the burner to produce a quiet blue flame with distinct cones.

(iii) In use this burner produced an excellent flame suitable for working soft glass and for blowing small bulbs in 0.3 cm and 0.5 cm soft glass tubing. However, the burner tube tended to heat up after a few minutes use. The larger diameter burner, of slightly more complex design, avoids this difficulty to some extent.

(iv) If a larger diameter tube (e.g., 1.5 cm diameter) is used for the burner tube, several alterations must be made to the design of the burner. First, a larger diameter syringe needle is needed (16 gauge, 0.15 cm outside diameter), and it must be cut off shorter, i.e., 0.5 cm rather than 1.0. Secondly, the end of the burner tube must be flattened slightly to restrict the flow of air/gas mixture through it. Thirdly, the connection between burner tube, gas valve, and gas tube must be altered. One way in which this can be done is to drill a hole 1.0 cm in diameter through a cork. Enlarge the hole at one end to 1.5 cm diameter, and 1.5 cm deep. Insert a 1.0 cm diameter piece of metal tubing through the hole and place a short (1.0 cm) piece of rubber tubing on the end of it. Insert the needle into the rubber tube (the base may have to be built up with tape). Insert the burner tube into the enlarged hole in the cork. Make certain the fit is tight. Finally, insert the cork into the hole in the base, put the air control sleeve in place, and attach the gas tubing.

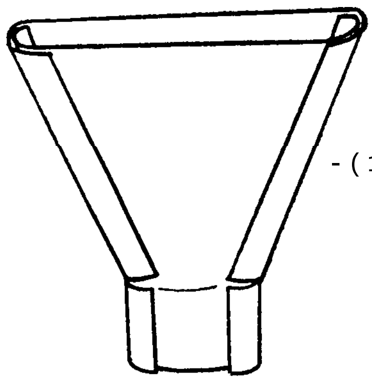


Cross Section

If, when this burner is in use, the flame should tend to blow itself out because the tube opening is too wide, decrease it further by pinching with pliers.

(v) It must be noted that various components of the burner design are dependent on the diameter of the burner tube. These include burner tube length, size of the air holes, gauge and length of the needle, width at the top of the tube, and various connecting devices such as metal and rubber or plastic tubing. For example, if the diameter of the burner tube is increased, the diameter of the needle used and the length of the tube must also be increased, but the size of the opening at the top of the tube must be decreased. Therefore, if tubing of a size different from those described here is used, experimentation with the other components will be necessary in order to construct a working Bunsen burner.

13. Wing Tip

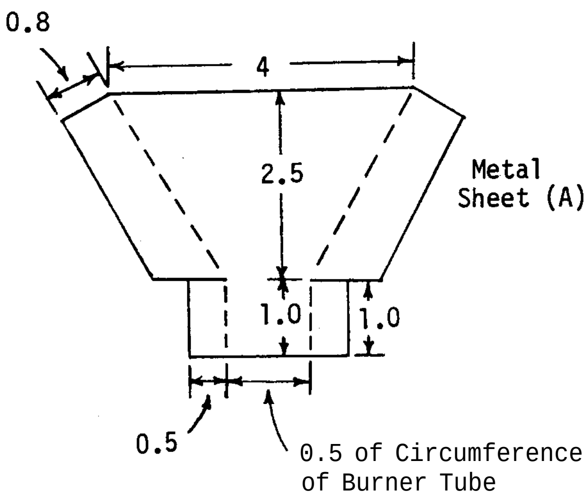


a. Materials Required

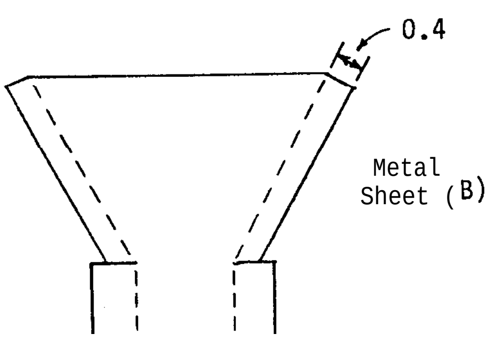
Components	Qu	Items Required	Dimensions
(1) Wing Tip	1	Metal Sheet (A)	6 cm x 4 cm
	1	Metal Sheet (B)	6 cm x 4 cm

b. Procedure

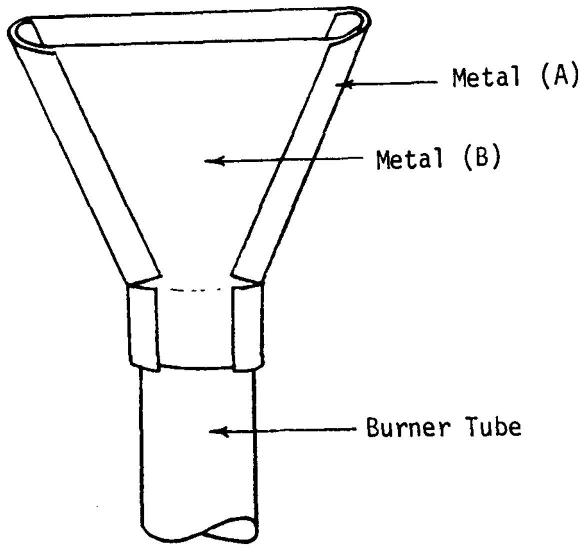
(1) Wing Tip



Measure the circumference of the burner tube. Draw and cut out a paper pattern as illustrated. Cut one piece of this pattern from the metal sheeting (A). Cut on the solid lines. Bend on the dotted lines.



Cut another piece from the metal sheeting (B), but trim the flaps on the wing to 0.4 cm. Cut on the solid lines. Bend on the dotted lines.



Bend the wing flaps on piece (B) at 90°. Bend the wing flaps of piece (A) around the outside of the flaps on (B). Pinch the flaps on (A) to hold (B) in place.

Place the wing tip on the burner tube, such that the wing extends above the burner tube.

Bend the support strip flaps of (B) and (A) to fit snugly around the burner tube. Small holes left at the corners of the flaps will not affect the wing tip's performance.

c. Notes

(i) The wing tip is an accessory used with the gas burner when a wide flame is desired. It is especially useful for working with glass.

III MEASURING APPARATUS

A. DEMONSTRATION DEVICES

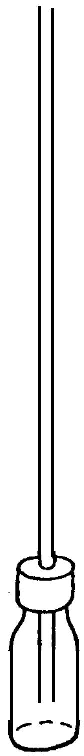
These devices demonstrate thermal expansion of liquids and solids,

B. VOLUMETRIC MEASURES

These are all measures of liquid volume and range from single volume measures like volumetric flasks to multiple measures such as measuring cylinder. Also included under this heading is the specific gravity bottle.

A. DEMONSTRATION DEVICES

Al. Demonstration Thermometer



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Thermometer	1	Pill Bottle (A)	7 cm high, 3 cm diameter
	1	Pill Bottle Cap (B)	To fit pill bottle (A)
	1	Glass Tubing (C)	25 cm long, 0.5 cm outside diameter, 0.3 cm inside diameter

b. Construction

(1) Thermometer

Make a hole in the pill bottle cap (B) (or a suitably sized cork) through which the glass tubing (C) is inserted.

Be certain the seal is airtight (it may be necessary to use glue to insure an airtight seal).

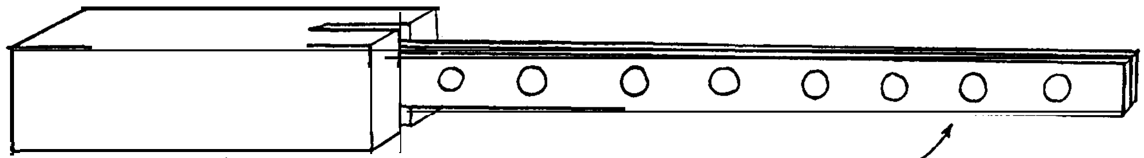
Fill the bottle (A) completely with water or other liquid. Force the cap or cork down onto the mouth of the bottle so that some liquid is forced up into the tube and the rest of the excess liquid spills over the side of the bottle where it is wiped away. Some liquid must rise up far enough into the tube so that it can be seen.

C. Notes

(i) This thermometer is used simply to demonstrate the expansion of a liquid as it is used in standard thermometers. Putting the demonstration thermometer into a 60°C water bath will cause the level of the water in the tube to rise about 2 cm.

(ii) Be certain to eliminate all air bubbles from the bottle unless it is desirable to show the effect of having air trapped in the bottle.

A2. Bi-Metal Strip

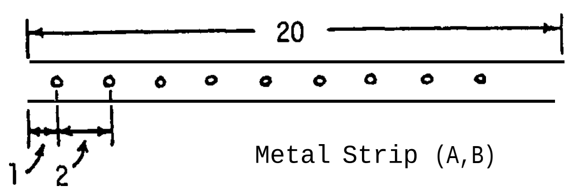


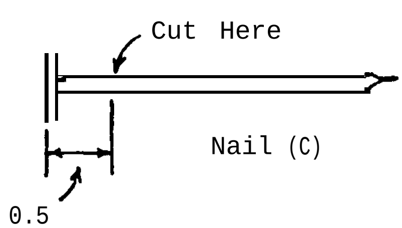
a. Materials Required

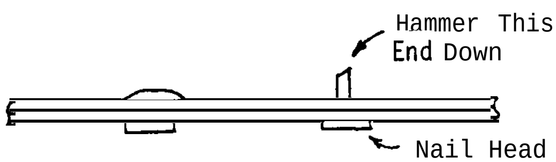
Components	Qu	Items Required	Dimensions
(1) Bi-metal Strip	1	Steel Strapping (A)	20 cm x 1.2 cm x 0.8 cm
	1	Aluminum Sheet (B)	20 cm x 1.2 cm x 0.6 cm
	9	Nails (C)	#4 d (0.2 cm diameter with large heads)
(2) Handle	1	Wood (D)	1.5 cm x 2.0 cm x 10 cm

b. Construction

(1) Bi-metal Strip





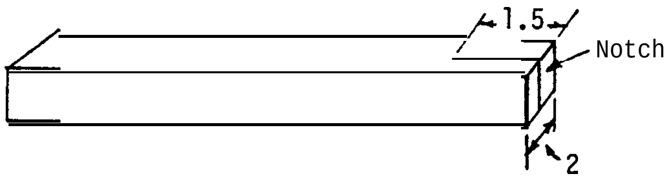


Side View

Hold the two pieces of metal (A,B) tightly together, and drill nine holes through both at 2 cm intervals beginning 1.0 cm from one end. These holes must be very slightly larger in diameter than the nails (C) used.

Cut the head off each nail (C) with a hacksaw, chisel, or tin snips so that the portion with the head is about 0.5 cm long. Push the nails through the holes in the two strips (A,B) and hammer down the cut ends to rivet the two strips together. It is best to begin by riveting the strip at its center and moving out toward each end at the same time. The strips should be firmly held together all

(2) Handle



along their length.

Make a narrow notch in one end of the wood (D) the width of a saw blade. This notch ought to be about 1.5 cm deep. Insert the end of the bi-metal strip into this notch to complete the device.

C. Notes

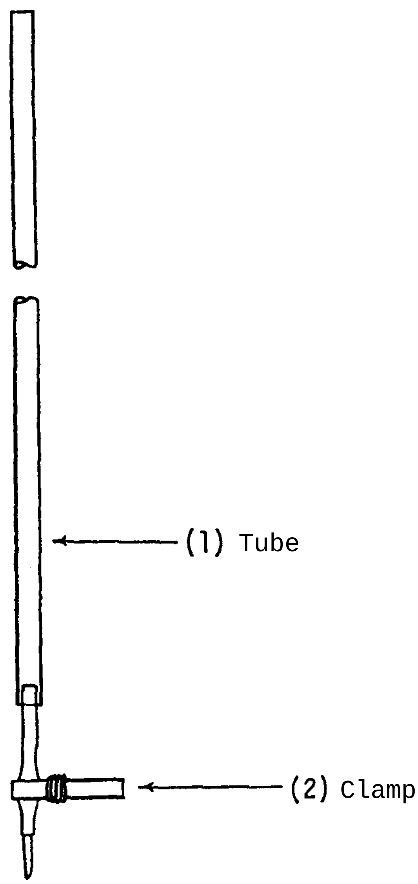
(i) This device is used to demonstrate the fact that metals expand when they are heated. When the bi-metal strip is held in a flame, it will bend in the direction of the steel since the aluminum expands more than does the steel.

(ii) Different combinations of metals (e.g., copper and steel, brass and aluminum, etc.) can be used with the same results.

(iii) The metal strips may be soldered together as opposed to riveted. Melt a thin layer of solder onto the surface of one of the two strips. Lay the other strip on top of it and hold the soldering iron down on both strips until the solder melts between the two strips. Keep the two strips pressed together with a screwdriver or other object to prevent them from coming apart before the solder cools. Repeat this process until the two strips are soldered all along their lengths. (Note: This procedure will not work if aluminum is used as one of the metals unless special solder is used.)

B. VOLUMETRIC MEASURES

B1. Burette

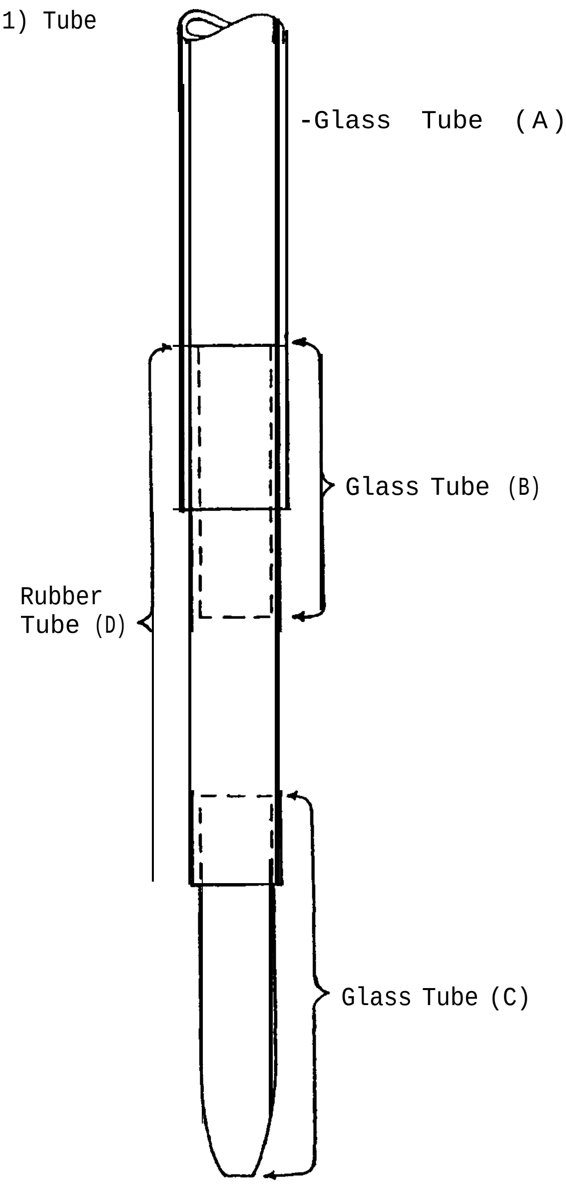


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tube	1	Glass Tube (A)	45 cm long, 1.3 cm outside diameter, 1.1 cm inside diameter
	1	Glass Tube (B)	4 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
	1	Glass Tube (C)	9 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (D)	10 cm long, 1.0 cm outside diameter
(2) Clamp	1	Pinch Clamp (E)	IV/A4

b. Construction

(1) Tube



Detail

Insert the glass tubing (B) into the end of the rubber tubing (D) so that the ends of both pieces of tubing are even. Insert this end into one end of the large glass tubing (A) for a distance of about 1 - 1.5 cm. If the seal between the rubber and large glass tubing is not watertight, use thin rubber sheeting (e.g., balloon material) to fill in the gas. Seal this joint with glue to insure a watertight fit. Draw out one end of the remaining piece of glass tubing (C) in a flame to form a narrow neck. Break off the neck, and fire polish the end of the tube. Insert the wide end of this tube into the end of the rubber tubing (D) for a distance of about 2 cm. Check the tube now for watertightness.

(2) Clamp

Use the clamp (E) to regulate flow in the burette. Be sure the clamp is large and strong enough to completely shut off flow from the burette.

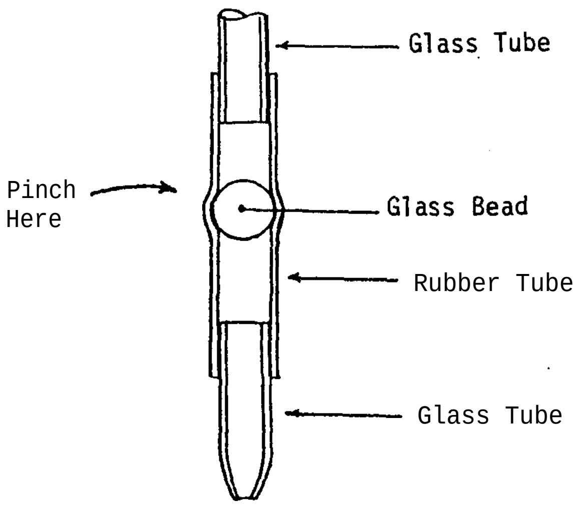
c. Notes

(i) The most common use of the burette in chemistry is in doing titrations.

Quite often they are used in pairs, and must always be supported by a stand.

(ii) Each burette needs to be fitted with a scale. Attach a long, thin strip of paper to the burette tube with transparent tape. Fill the burette from a known source (e.g., a plastic syringe) one milliliter at a time and mark the level of the meniscus on the paper. Place the "0" mark in such a way that several milliliters of liquid will still remain in the burette when "0" is reached as this will insure greater accuracy.

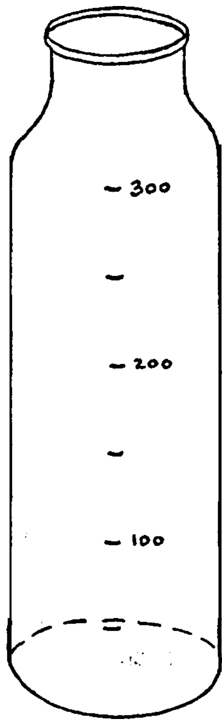
(iii) A glass bead just slightly larger than the internal diameter of the rubber tubing may be used in place of the pinch clamp. Push the bead into the rubber tubing before inserting the glass nozzle. The bead will seal the rubber tube. To dispense liquid from the burette, squeeze the tube between thumb and forefinger at the location of the head.



Cross Section

(iv) Because of the use of rubber tubing in this burette, it is not suitable for use with strong corrosives that attack rubber.

BZ. Measuring Glass



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Glass Bottle (A)	Variable

b. Construction

(1) Bottle

Use a glass bottle (A) with straight sides and a flat bottom. Make graduations by calibrating the bottle using a known source. The graduations may be tape, paint, or scratches on the glass itself.

c. Notes

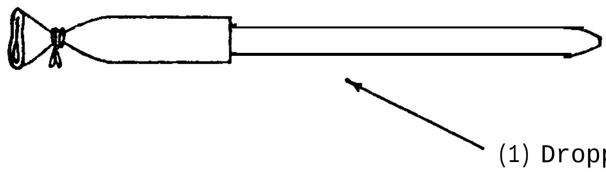
(i) Inaccuracies may occur due to transfer of liquid from the known source, failure to wait for liquid to "settle" before making calibration marks, and human error in marking exact height of liquid. However, for most purposes these measuring glasses are adequate.

(ii) Graduations may be made every 10, 25, 50, or 100 ml, depending on the size of the bottle and the uses to which it is to be put.

C.Notes

(iii) If the bottle is narrow enough in diameter, the graduations may be made closer together (i.e., every milliliter), but the accuracy will not approach that of a commercially made graduated cylinder.

B3. Dropper



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Dropper	1	Dropper	BIOL/II/A6

b. Construction

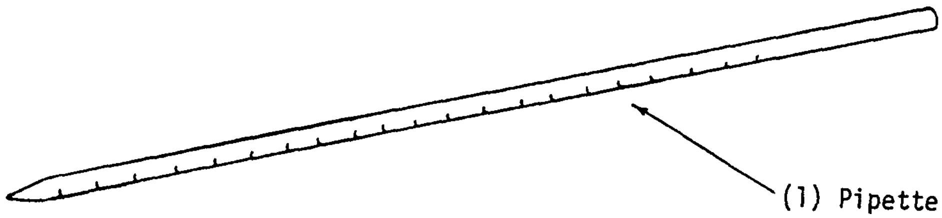
(1) Dropper

Construct the dropper as described in BIOL/II/A6.

c. Notes

(i) Since commercial droppers are usually readily available and inexpensive, this item is as easily purchased as it is improvised.

B4. Pipette



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pipette	1	Transfer Pipette	BIOL/VII/A5

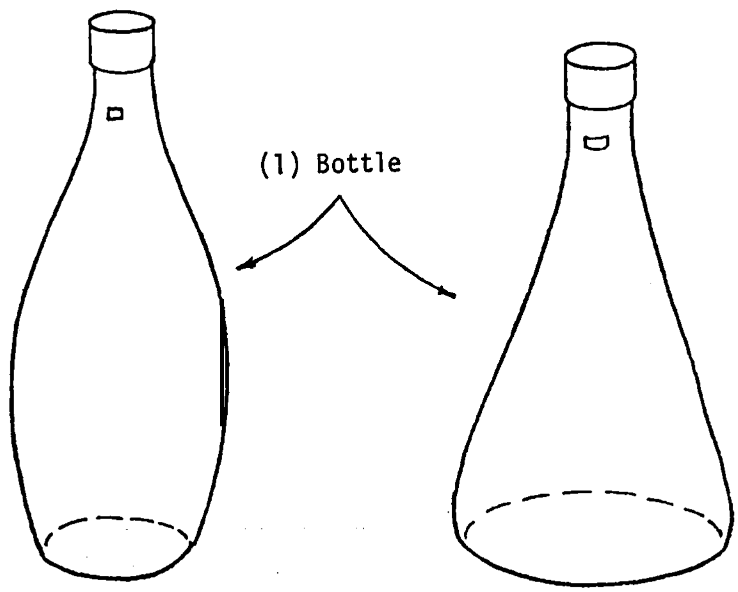
b. Construction

(1) Pipette — Construct the pipette as described in BIOL/VII/A5.

c. Notes

(i) The pipette is used to transfer and precisely measure quantities of liquids.

B5. Volumetric Flasks



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Transparent Glass Bottle (A)	Variable
	1	Bottle Cap (B)	To fit bottle (A)

b. Construction

(1) Bottle

Select any common glass bottle (A) with a narrow neck.

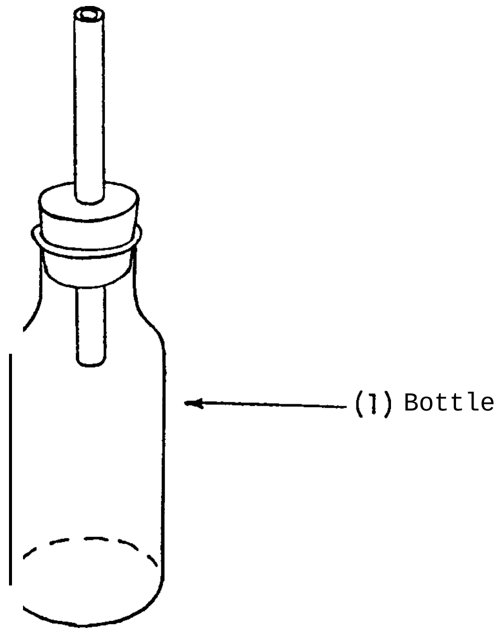
(2) Cap

Use a cap seal (B) which will be airtight to prevent leakage and evaporation.

c. Notes

(i) The flasks must be calibrated from a known source. Put a single calibration mark on the neck of the bottle to indicate its capacity. This may be done with paint, tape, a scratch mark, etc.

B6. Specific Gravity Bottle



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Pill Bottle (A)	5 cm high, 3 cm diameter
	1	Rubber or Cork Stopper (B)	To fit bottle (A)
	1	Glass Tube (C)	8 cm long, 0.5 cm outside diameter, 0.3 cm inside diameter

b. Construction

(1) Bottle

Simply insure that there are airtight seals between the stopper (B) and bottle (A), and between the glass tube (C) and cork (B).

c. Notes

(i) To use the specific gravity bottle, first remove the stopper and tubing and fill the bottle to the brim with the liquid to be measured. Reinsert the stopper, making sure liquid flows completely out of the end of the tubing and that there is no air trapped in the bottle. Wipe away the excess liquid on the outside of the bottle. Accurately weigh this amount of liquid and subtract the mass of the empty specific gravity bottle. Compare the mass of the liquid to that of an equal volume of water (found in the same way) to find the specific gravity of the liquid.

(ii) A screw-top bottle may be used instead of the stopper arrangement. Punch a hole in the top and seal the joint between the tubing and top with waterproof cement.

IV. SUPPORTS, STANDS, AND HOLDERS

A. HOLDERS

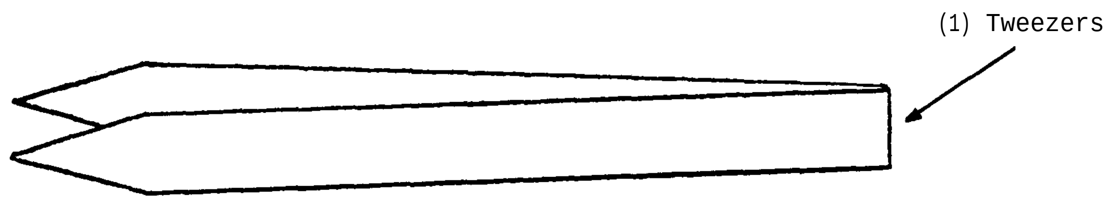
Holders are classified as small, portable, hand-held devices used to support other pieces of apparatus.

B. SUPPORTS AND STANDS

These devices are used to hold items stationery for relatively long periods of time.

A. HOLDERS

Al. Tweezers (Forceps)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tweezers	1	Forceps	BIOL/II/A4

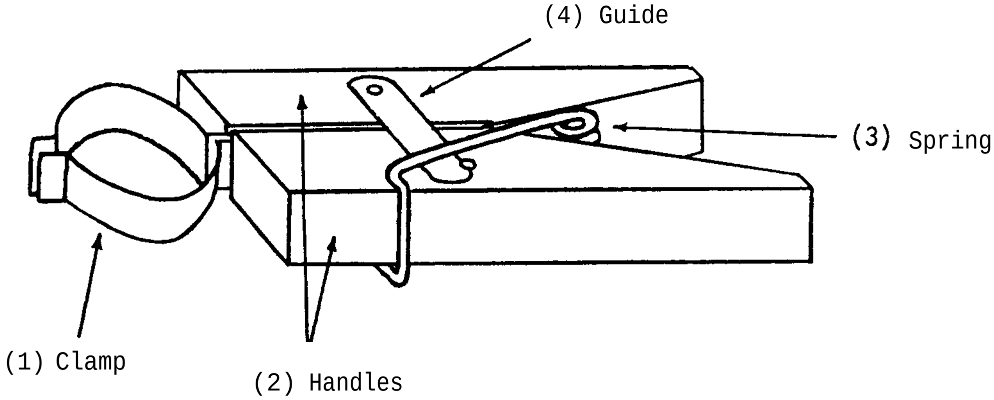
b. Construction

(1) Tweezers — See BIOL/II/A4 for construction details.

c. Notes

(i) Uses of forceps in chemistry operations include the handling of small items or radioactive materials.

A2. Multi-Purpose Design Holder

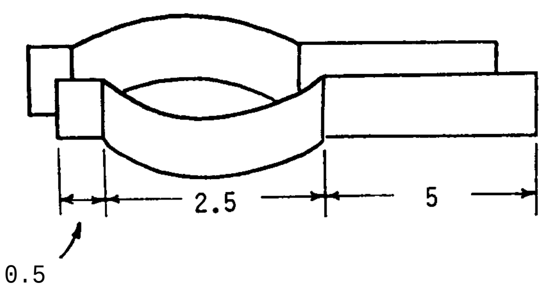


a. Materials Required

Components	Qu	Items Required	Dimensions.
(1) Clamp	2	Metal Strapping (A)	B cm x 1.5 cm
(2) Handles	1	Wood Block (B)	2cmx 4 cm x 15 cm
	4	Nails (C)	0.5 cm thick x 1 cm long
(3) Spring	1	Heavy Iron Wire (coat hanger) (D)	Approximately 30 cm long
(4) Guide	2	Metal Strapping (E)	1.5 cm x 3.5 cm
	4	Nails (F)	0.5 cm thick x 1 cm long

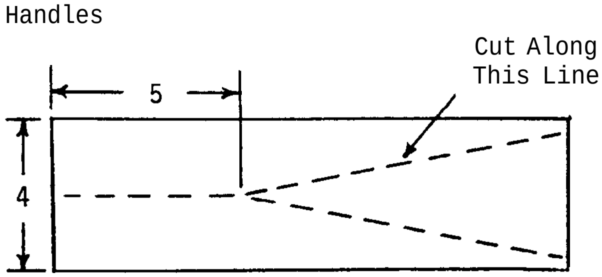
b. Construction

(1) Clamp

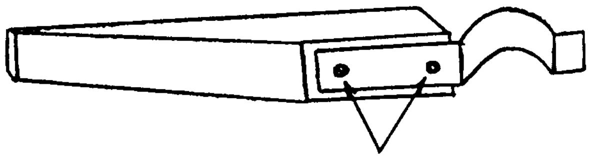


Bend the two pieces of metal strapping (A) as indicated.

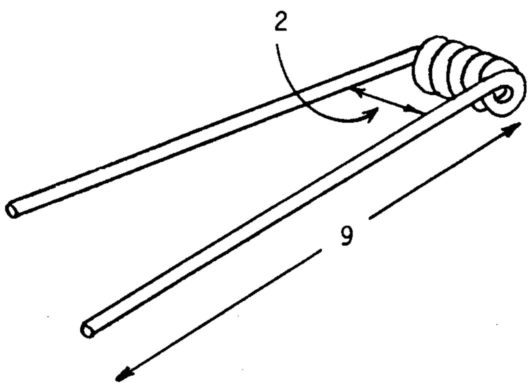
(2) Handles



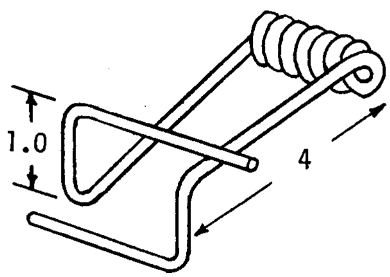
With a pencil and ruler, section the wood block (B) as shown. Cut two wedges and discard the triangular portions as waste.



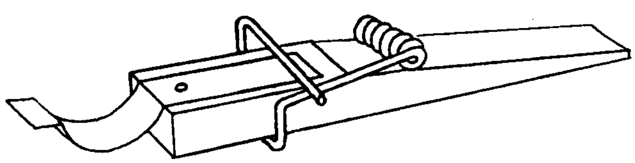
Fasten one strapping clamp to the short end of each of the handles with the nails (C).



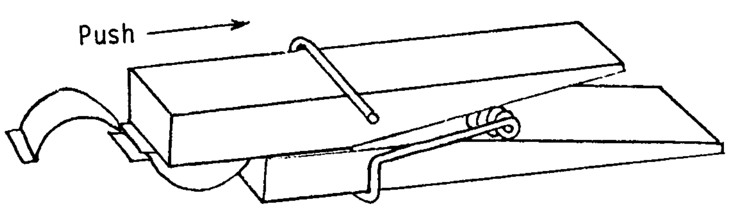
Clamp a pencil or stick of about 0.8 cm diameter in a vise, Starting at the center of the wire (D), coil the wire around the pencil. Make at least six turns, or a coil that extends beyond the width of the wood block (2 cm) by one wire-thickness on each side, Leave at least 9 cm of straight wire at each end of the spring.



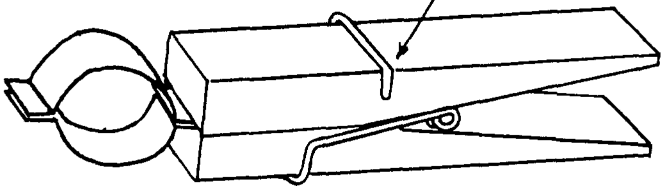
Approximately 4 cm from the spring, make a 90' bend in each straight section of wire, as shown. One cm from each of the first bends, make a second 90' bend.



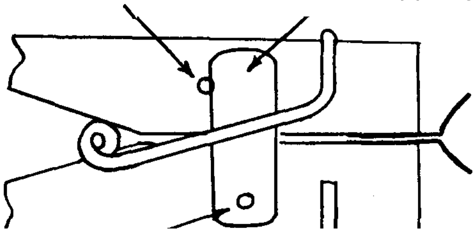
Slide the spring on to one of the handles as shown.



Slide the second handle into place.



Trim excess wire to within 1.5 cm of the edge of the handle. Bend this remaining wire around handles to hold the spring in place.



Top View

Lay the holder on its side. Slide one small piece of strapping under the spring as shown. Secure the strapping in place on one handle with one nail. Nail a second guiding nail into the other handle just at the edge of the strapping. Turn the holder over and repeat with another small piece of strapping. These guides keep the handles from twisting out of alignment.

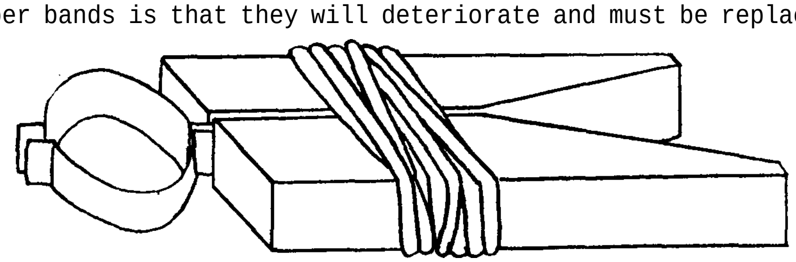
C. Notes

(i) This design is based on the spring-type clothespin. If one is available, it will be a helpful construction guide.

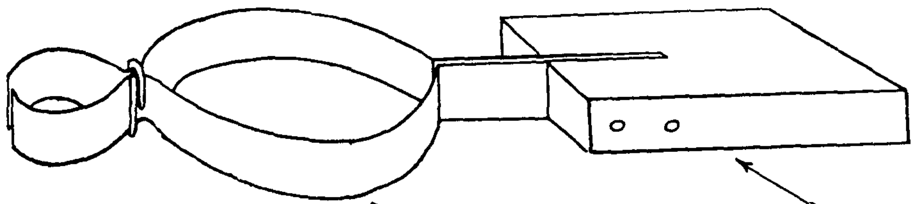
(ii) Squeezing the handles together will cause the clamp to open and close.

(iii) The sizes of the components used in this item will vary with the use to be made of the holder. The clamp and handle can be reduced in size for use with test tubes, or enlarged for use with large flasks.

(iv) For a simpler version of this design, three or four strong rubber bands provide the spring action. Cut the handles and attach the clamps as described. Then place the two handles together as indicated in the diagram. Wrap the rubber bands around the top part of the handles to draw them together. The chief problem with using rubber bands is that they will deteriorate and must be replaced from time to time.



A3. Test Tube Holder



a. Material Required

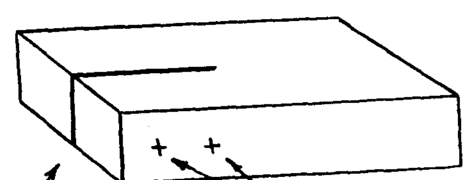
Components	Qu	Items Required	Dimensions
(1) Clamp	2	Metal Strapping (A)	20 cm long
	1	Thin Wire (B)	Approximately 0.1 cm thick, 4-5 cm long
(2) Handle	1	Wood Block (C)	Approximately 10 cm x 3 cm x 2 cm

b. Construction

(1) Clamp

Bend two loops in each piece of strapping (A) as shown. Fit the smaller loops to the test tubes to be used. Wrap a small piece of wire (B) around the two pieces of strapping at the point where they curve inward, just behind the front loops, to hold the pieces together.

(2) Handle



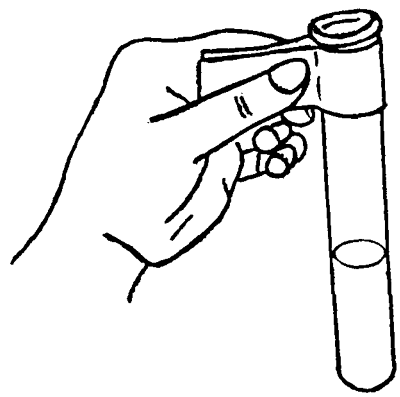
Cut a slit about halfway down the center of the block (C). Insert the flat portions of the strapping clamps into the slit. Secure the clamp to the handle with two nails.

c, Notes

(i) To open this clamp, squeeze together the large loop between the handle and the wire. Release the loop to close the clamp.

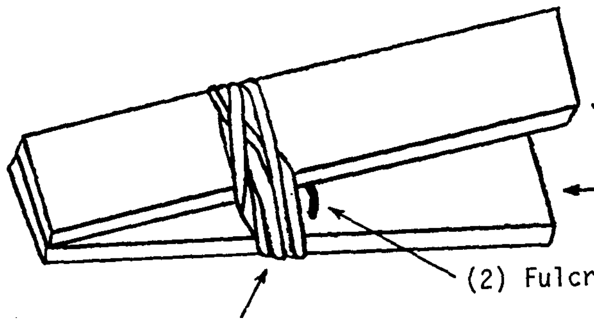
(ii) This design is best suited for small, light-weight test tubes.

(iii) A quick and convenient holder for handling hot test tubes can be made with a piece of paper measuring approximately 15 cm x 8 cm. The paper is folded into



thirds, lengthwise, to form a strip. This strip can be wrapped around a test tube near the top. then grasped tightly, next to the test tube.

A4. Wooden Pinch Clamp



a. Materials Required

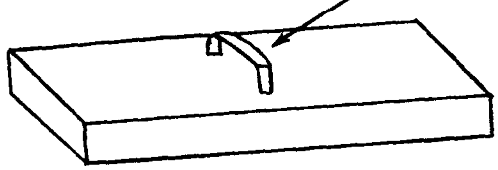
Components	Qu	Items Required	Dimensions
(1) Handles	2	Wooden Strips (A)	2 cm x 8 cm x 0.5 cm
(2) Fulcrum	1	Metal Staple or Tack (B)	1 cm wide
(3) Band	2	Rubber Bands (C)	0.5 cm x 9 cm

b. Construction

(1) Handles

Sand any splinters or rough edges from the wood strips (A).

(2) Fulcrum



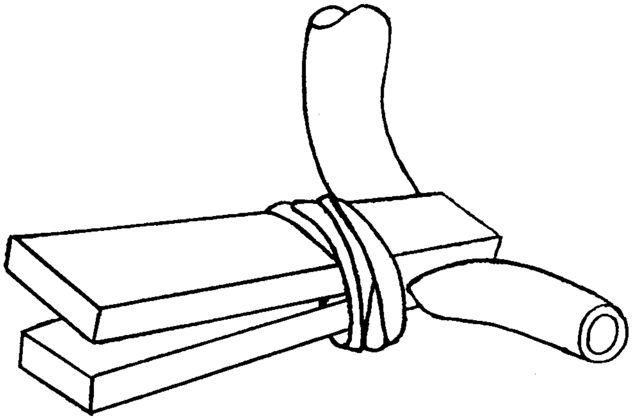
Drive the staple (B) or tack into the middle of one of the handles. Allow about 0.5 cm of the staple or tack to protrude from the wood.

(3) Band

Place the handles together with the fulcrum between them. Wrap the two rubber bands (C) tightly around the handles at a point just in front of the fulcrum.

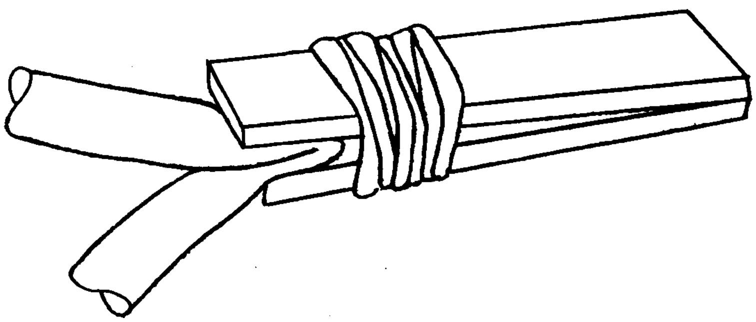
c. Notes

(i) If the rubber bands are sufficiently tight, it should be possible to



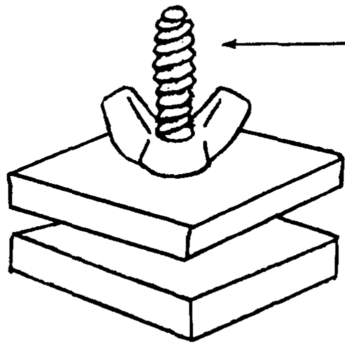
completely close off the flow of a liquid such as water through 1 cm wide rubber tubing,

(ii) To completely close off plastic tubing and heavier rubber tubing, it will be necessary to bend the tubing back upon itself and secure the clamp at the bend.



(iii) If pinch-typeclothespinsare available, they may be substituted for this clamp. However, it will be necessary to bend rubber tubing as well as plastic tubing back upon itself, as in the above illustration, in order to completely close the tubing with a clothespin clamp.

A5. Wooden Screw Clamp



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jaws	2	Wood (A)	3.5 cm x 3.5 cm x 0.7 cm
(2) Bolt Assembly	1	Bolt (B)	0.5 cm diameter, approximately 4-5 cm long
	1	Wing Nut (C)	To fit bolt (B)

b. Construction

(1) Jaws

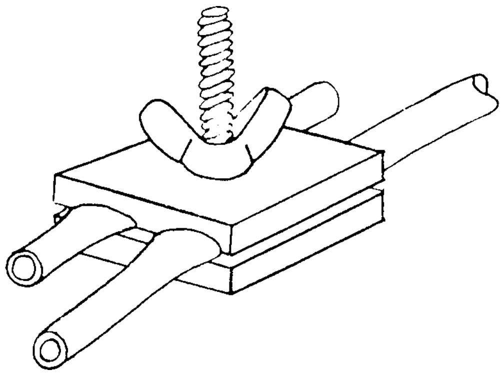
Sand the wood squares (A) to remove rough edges and splinters. Drill a hole 0.6 cm in diameter in the center of each square.

(2) Bolt Assembly

Insert the bolt (B) through the hole in each square and check to see that the holes are just large enough to permit the bolt to slide through easily. Screw the wing nut (C) in place on the bolt.

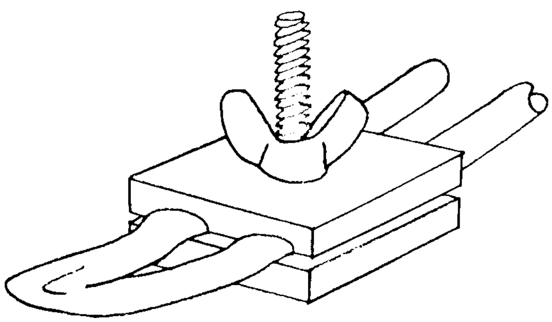
c. Notes

(i) To use this clamp with rubber tubing, a short (approximately 4 cm long) section of tubing of the same type as that in use is cut. The tubing in use is



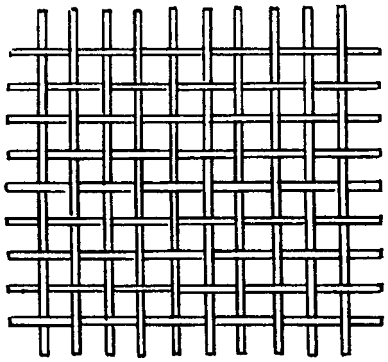
passed through the jaws on one side, as close to the bolt as possible. The short section of tubing is passed through the jaws on the opposite side to balance the force of the clamp. By turning the wing nut to tighten the clamp, the flow of a liquid or gas through rubber tubing can be controlled or shut off completely.

(ii) The flow rate of a liquid or gas through plastic tubing can be controlled in the same way, but the stiffness of plastic tubing makes it difficult to close the tubing completely. To close plastic tubing, it is necessary to bend the tubing back on itself, passing each section of the tubing through the clamp and tightening the wing nut as much as possible.



B. SUPPORTS AND STANDS

Bl. Wire Gauze



a. Materials Required

Components	Qu	Items Required	Dimensions
(1)Wire Gauze	1	Wire Mesh (A)	Approximately 10 cm x 10 cm of heavy guage wire

b, Construction

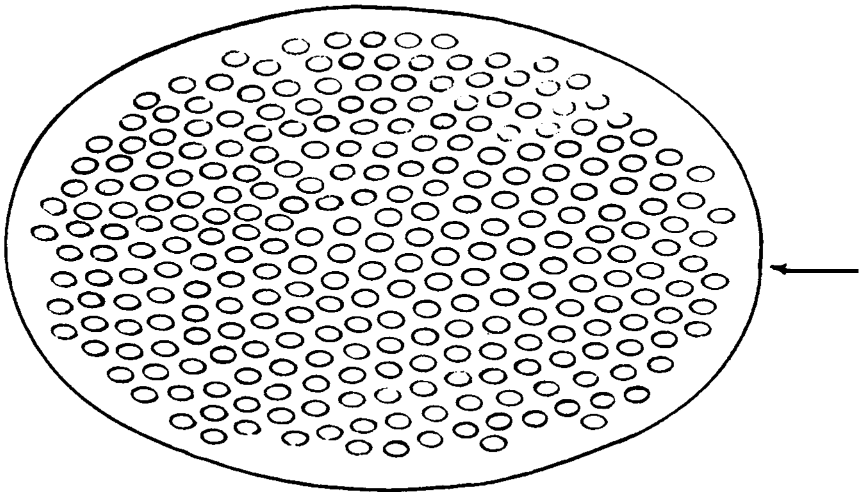
(1) Wire Gauze

Cut the wire mesh (A) to a size approximately 10 cm x 10 cm. Trim off sharp ends.

c. Notes

(i) This item is generally used in conjunction with the tripods and ring stand described in the sections that follow. The wire screen is placed on the tripod, heating stand, or ring to support a flask or beaker. A burner may be placed beneath the stand to heat the contents of the container.

B2. Heating Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Shelf	1	Tin Can Top or Bottom (A)	10 cm diameter or larger

b. Construction

(1) Shelf

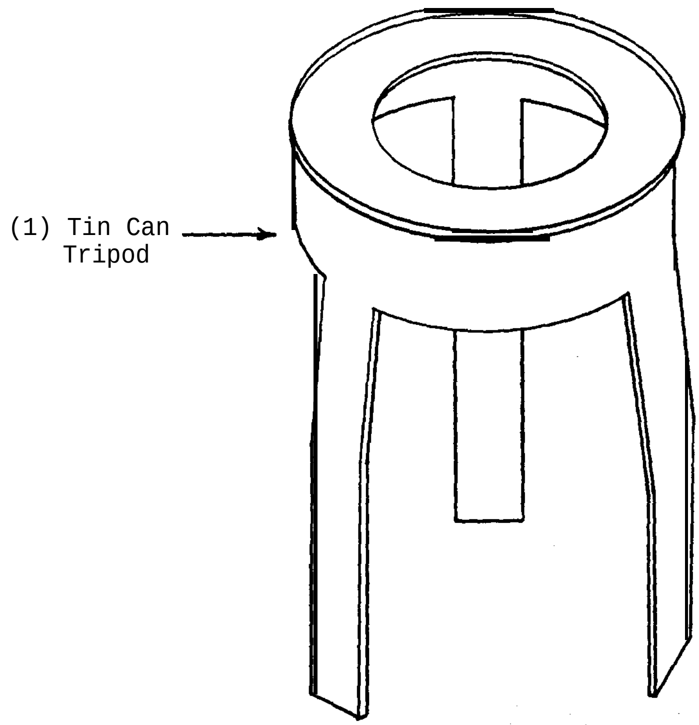
Remove the top (A) or bottom from a tin can. Punch many holes in it with a large nail.

c.Notes

(i) This item is used in the same way as the wire gauze (IV/Bl); that is, to support a flask, beaker, or other container upon a tripod or similar support.

(ii) This is also a useful item to keep hot glass from contacting the tabletop.

B3. (1) Tripod (Tin Can)

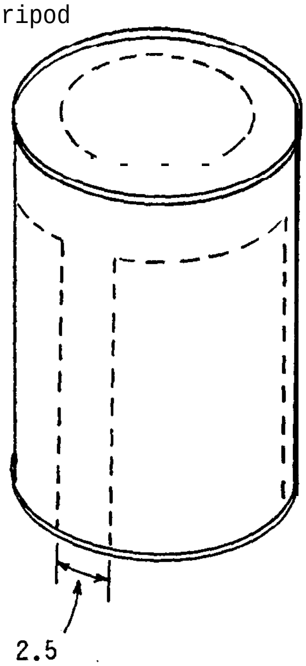


a. Material Required

Components	Qu	Items Required	Dimensions
(1) Tin Can Tripod	1	Tin Can (A)	Approximately 8 cm diameter, 12 cm high

b. Construction

(1) Tin Can Tripod

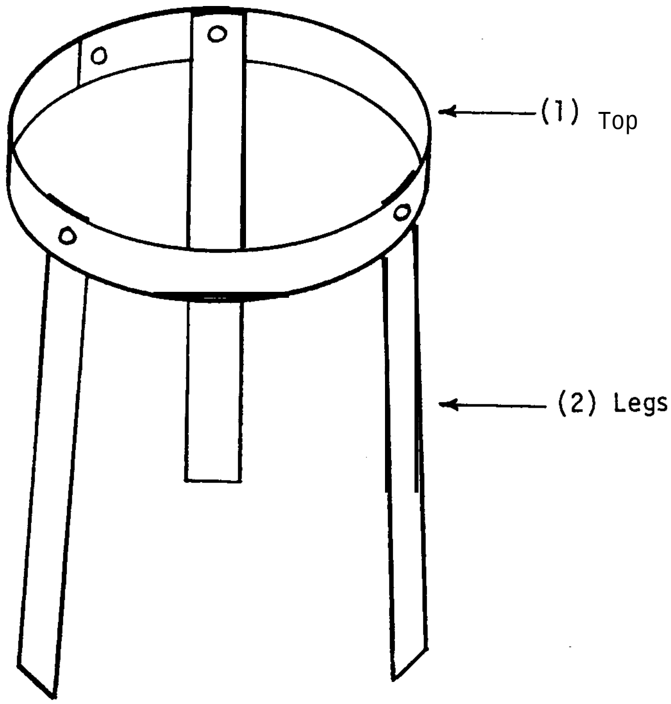


Cut a circle about 5 cm diameter from the bottom of the can (A). Mark the position for three legs, evenly spaced around the can. Allow a ring of about 1.5 cm at the top of the tripod before marking the legs. Allow approximately 2.5 cm for the width of each leg. Then cut along the marked lines to produce the three legs. With pliers, bend in the outside edge of each leg slightly to provide extra support.

C.Notes

(i) This tripod is simple to make, but it must be used with caution because of sharp edges and instability. It is suitable for supporting lightweight items, such as a funnel.

B3 (2). Tripod (Strappings)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Top	1	Metal Strapping (A)	1.5 cm x 42 cm
(2) Legs	3	Metal Strapping (B)	1.5 cm x 34 cm

b. Construction

(1) Top

Bend the section of strapping (A) into a circle and secure the ends with a metal rivet.

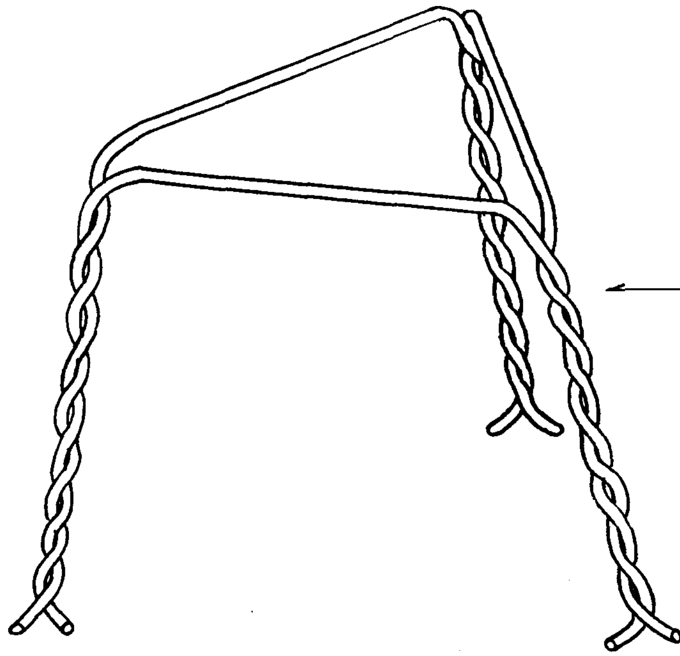
(2) Legs

Fold each of the three sections of strapping (B) in half and pinch the fold closed. Secure the open ends of each leg to the top with metal rivets.

c. Notes

(i) The dimensions given produce a tripod that is useful for most applications, but this tripod can also be made larger or smaller by varying the length of the strapping used.

B3 (3). Tripod (Wire)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wire Tripod	3	Heavy Wire	0.2 cm diameter, 40 cm long

b. Construction

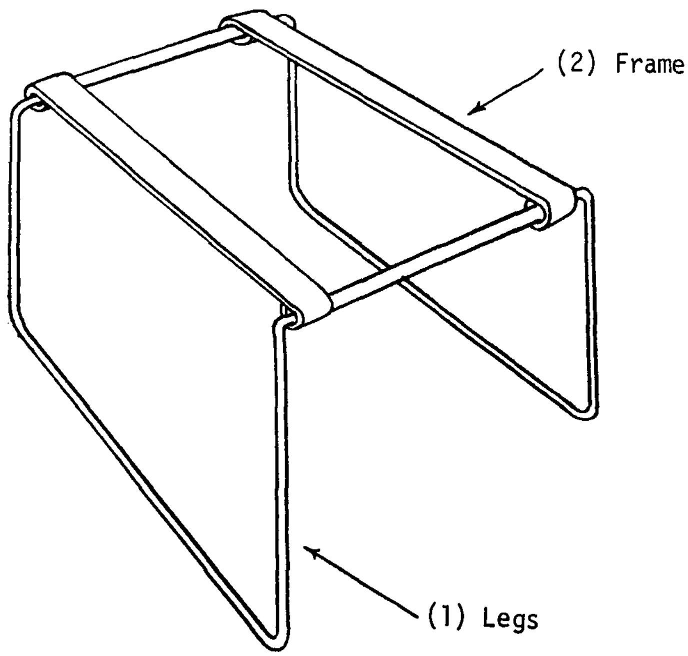
(1) Wire Tripod

Twist together the ends of two pieces of wire (A) for approximately 15 cm to form one leg. Twist the free ends of these two pieces together with each end of the third piece of wire. Make each twisted leg 15 cm long. Bend the legs down to form a tripod with a level top, as illustrated.

c. Notes

(1) This size tripod is useful for most applications, but it may also be made larger or smaller by varying the length of the wire used.

B4. Collapsible Heating Stand



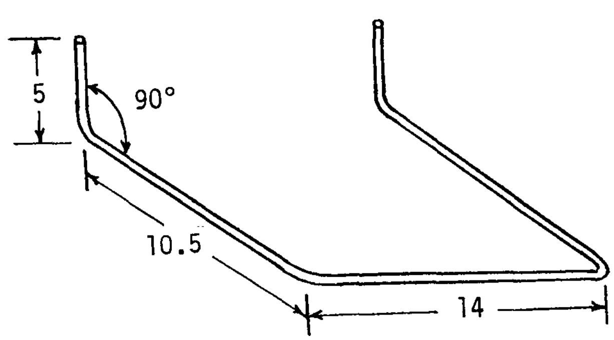
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Legs	2	Thick Wire (A)	0.4 cm diameter, 45 cm long
(2) Frame	2	Metal Sheeting (B)	10 cm x 3 cm
	2	Metal Strapping (C)	1.5 cm x 16 cm

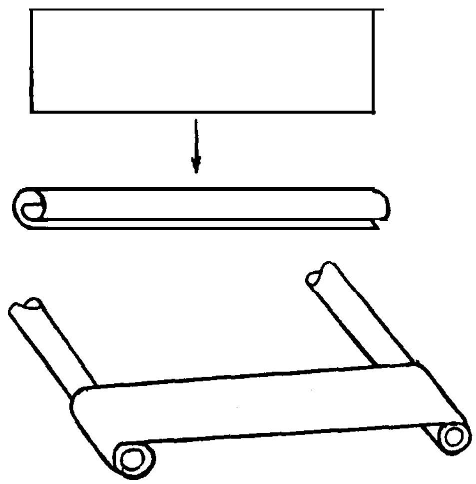
b. Construction

(1) Legs

Bend the two pieces of heavy wire (A) to the shape indicated.



(2) Frame



Strapping

Roll each of the rectangular pieces of metal sheeting (B) into long tubes that just fit around the legs.

Roll 3 cm at each end of the metal strapping pieces (C) around each end of the tubes.

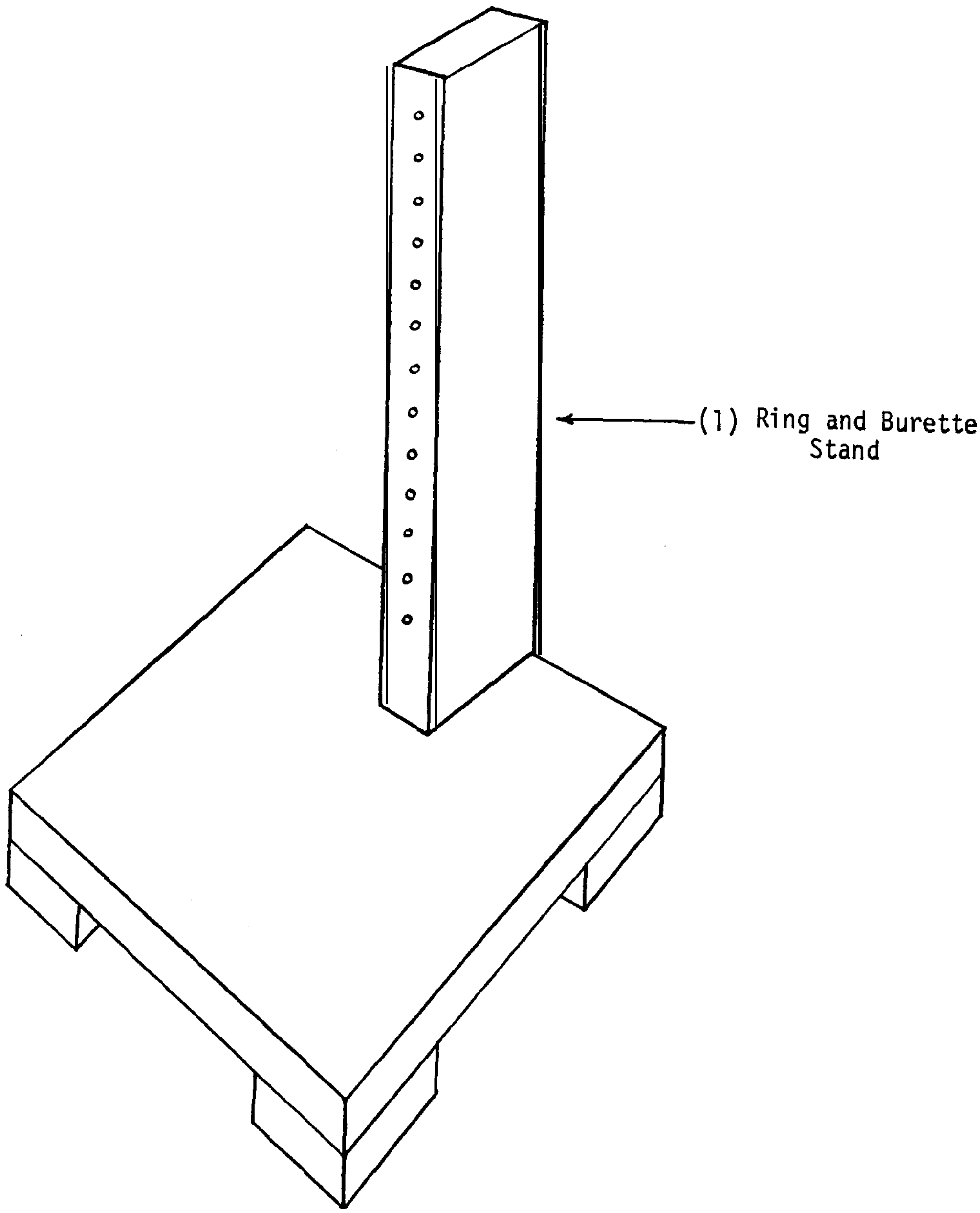
Insert the free ends of the legs (A) into the ends of the tubing (B) to complete this stand.

C. Notes

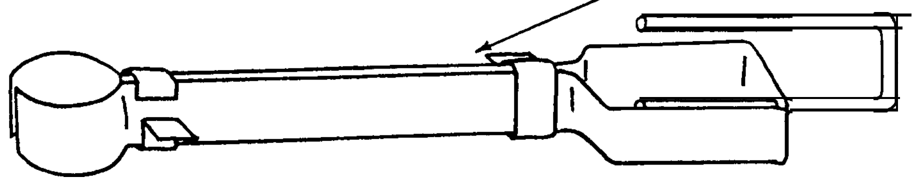
(i) Like the tripods, this stand is generally used with wire gauze (IV/Bl) or heating shelf (IV/B2).

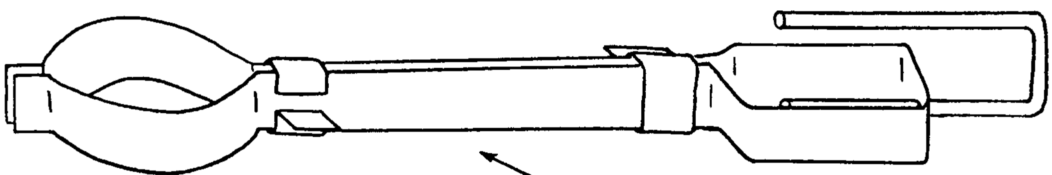
(ii) When this stand is not in use, the legs may be removed for ease in storing.

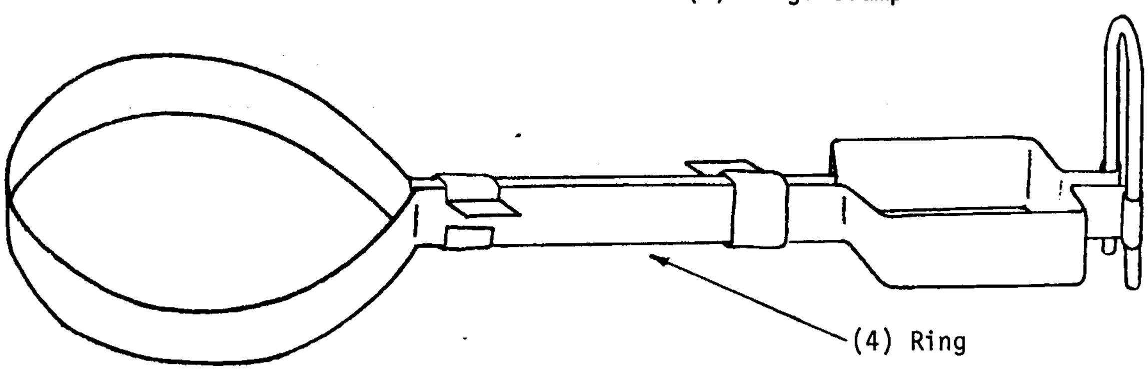
B5. Ring and Burette Stand with Attachments*

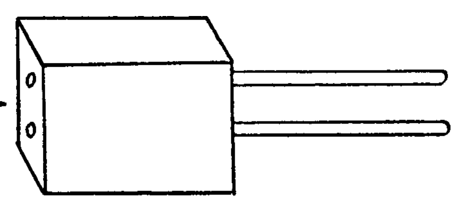


*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 144-146.









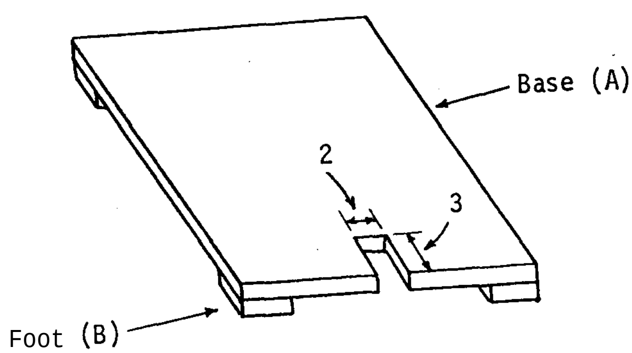
a. Materials Required

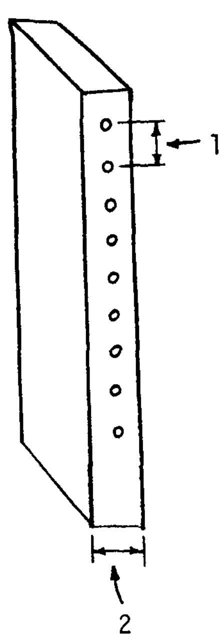
Components	Qu	Items Required	Dimensions
(1) Ring and Burette Stand	1	Wood Block (A)	14 cm x 18 cm x 2 cm
	4	Wood Block (B)	2 cm x 4 cm x 1.5 cm
	1	Wood Block (C)	3 cm x 2 cm x 40 cm

(2) Burette Clamp	1	Metal Strapping (D)	1.5 cm x 27 cm
	2	Metal Strapping (E)	1.5 cm x 5 cm
	1	Heavy Wire (F)	0.2 cm diameter, 10-12 cm long
(3) Large Clamp	1	Metal Strapping (G)	1.5 cm x 35 cm
	2	Metal Strapping (H)	1.5 cm x 5 cm
	1	Heavy Wire (I)	0.2 cm diameter, 10-12 cm long
(4) Ring	1	Metal Strapping (J)	1.5 cm x 50-60 cm
	2	Metal Strapping (K)	1.5 cm x 5 cm
	1	Heavy Wire (L)	0.2 cm diameter, 10 cm long
(5) Support Block	1	Wood Block (M)	5 c m x 2 c m x 4 c m
	2	Nails (N)	0.35 cm diameter, 8 cm long

b. Construction

(1) Ring and Burette Stand

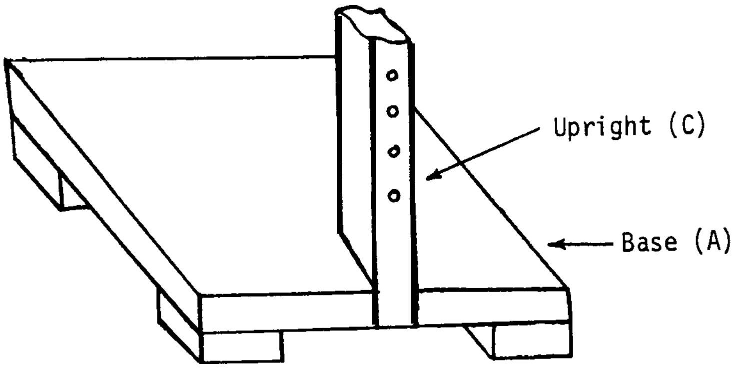




Sand all the wood blocks to remove splinters and rough edges. Nail a small wood block (B) to each corner of the flat block (A) to make feet.

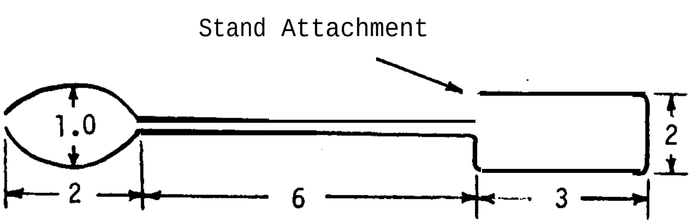
In the center of one of the short sides of the base (A) cut a rectangular notch 3 cm long x 2 cm wide.

Drill 0.6 - 0.7 cm holes at 1 cm intervals all the way through the long block (C) as shown.

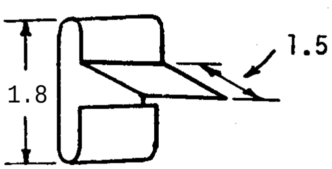


Fit this block into the rectangular notch in the base (A) and nail it in place to form the upright.

(2) Burette Clamp

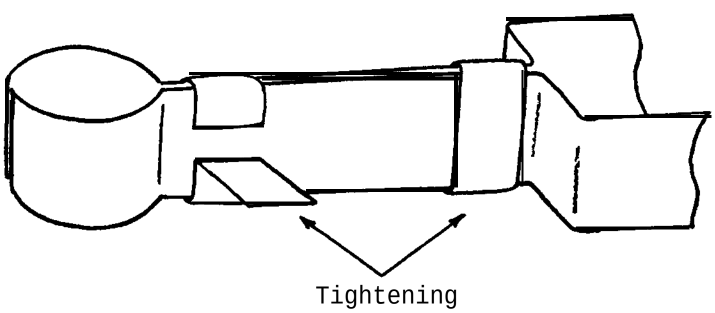


Bend the piece of metal strapping (D) as shown. Adjust the stand attachment section so that it will fit securely around the upright of the stand, yet be able to slide up or down along the upright.

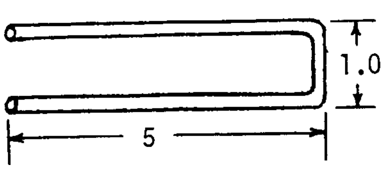


Tightening
Clip (E)

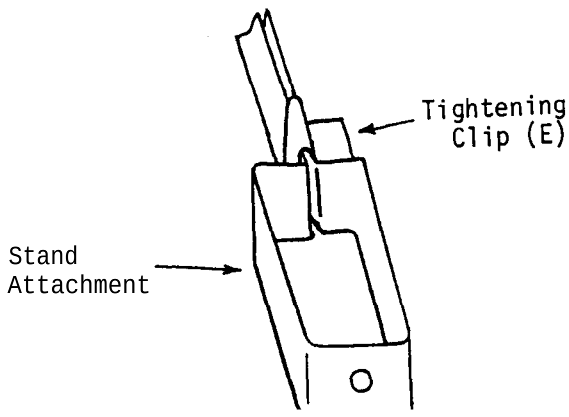
Bend two small pieces of strapping (E) as indicated to form tightening clips. Fit them around the straight section of the burette clamp to hold the clamp tightly closed.



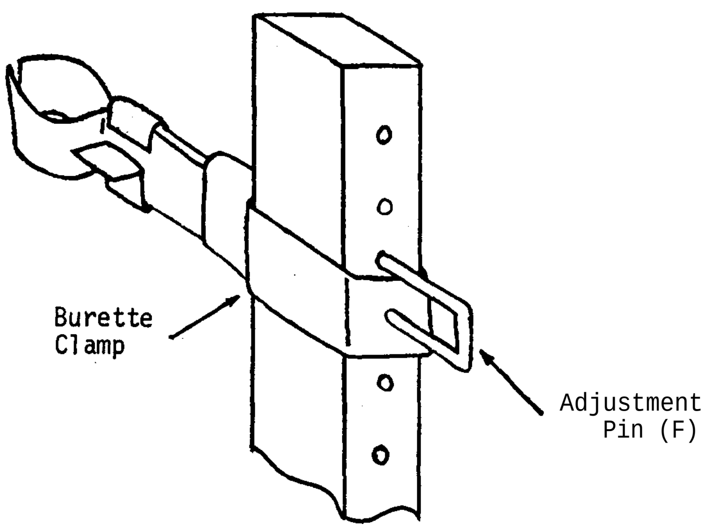
Adjustment Pin (F)



Bend a 10 - 12 cm piece of heavy wire (F) as indicated to make an adjustment pin. Adjust the width between the legs to match the holes drilled in the upright.

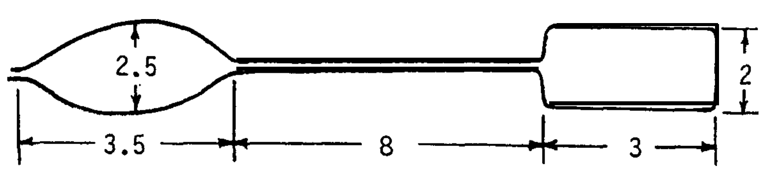


Drill a hole approximately 0.4 cm diameter in the burette clamp as shown.

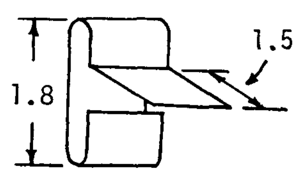


To position the burette clamp on the stand, slide the rectangular section of the clamp along the upright to the desired height, with the clamp facing the base of the stand. Align the hole in the burette clamp with a hole in the upright. Insert one of the legs of the adjustment pin through the burette clamp and into the upright. Insert the other leg of the pin into the next higher hole of the upright.

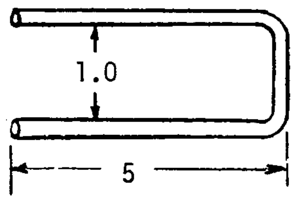
(3) Large Clamp



Bend the piece of strapping (G) in the same general shape as the burette clamp, but slightly larger.



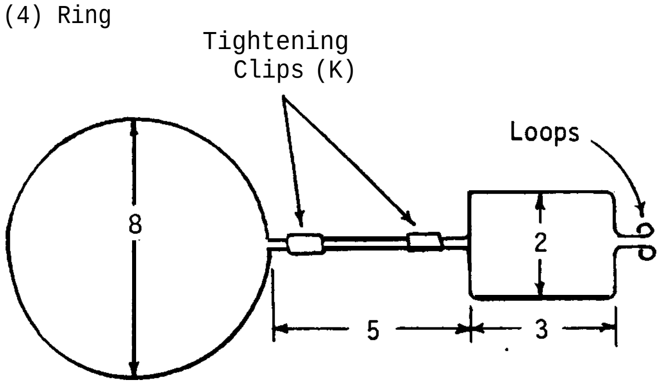
Construct two tightening clips (H) just as with the burette clamp. Position the clips on the clamp to hold it closed.



Construct an adjustment pin from a piece of heavy wire (I). Follow the procedure given for the burette clamp,

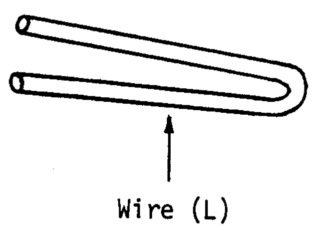
Drill a hole in the large clamp for the adjustment pin, as described for the burette clamp.

(4) Ring

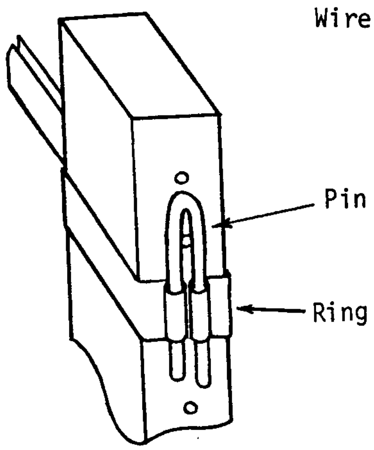


Bend the piece of metal strapping (J) into the shape shown. Bend the ends of the strapping into loops approximately 0.4 cm diameter.

Make two tightening clips according to the directions given with the burette clamp from the strapping (K). Secure them in the positions shown.

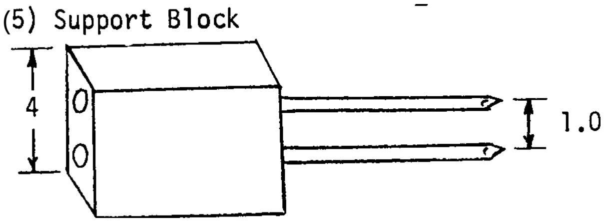


Construct a pin to hold the end loops together by bending the length of heavy wire (L) in half.

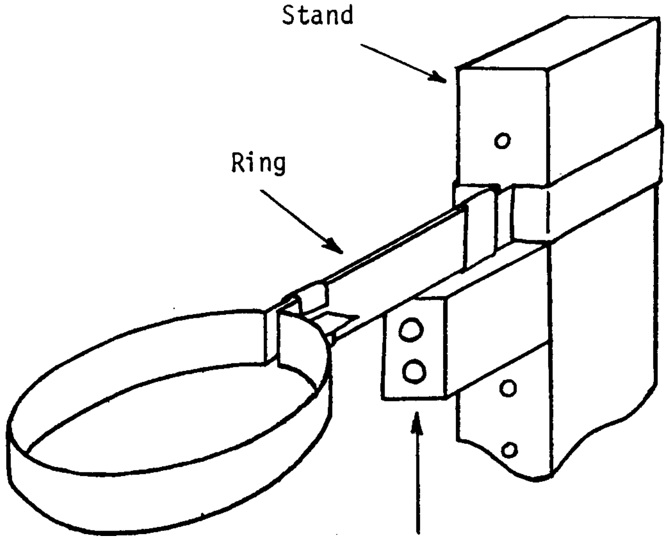


To position the ring on the stand, slide the rectangular section of the ring along with the upright to the desired height, with the clamp facing the base of the stand. Push the pin through the end loops.

(5) Support Block



Drive two nails (N) all the way into a small block of wood (M) 1 cm apart.



Position the support block to prevent the front of the ring from leaning forward under the weight of materials placed on it. Insert the two prongs of the support block into the two holes in the upright just below the ring.

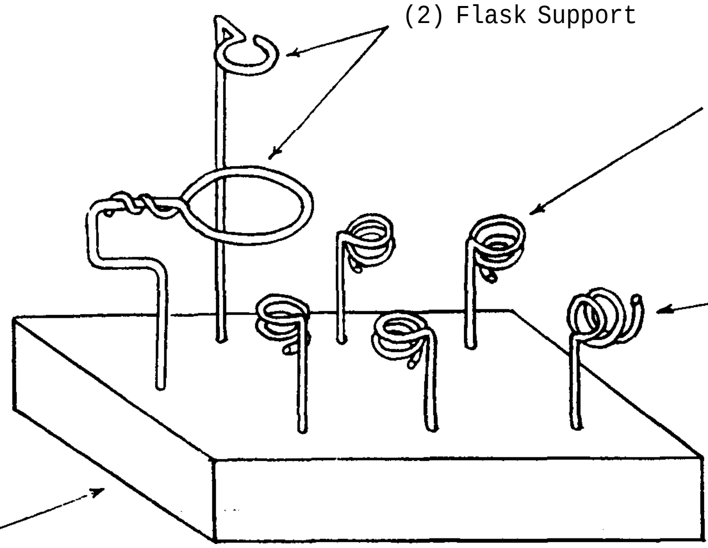
C.Notes

(i) To loosen the burette clamp or large clamp, slide the tightening clips toward each other. To tighten, slide the clips away from each other.

(ii) Although the burette clamp and large clamp have adjustment pins to hold them in place, they are much more stable when the support block is pushed into theupright iammediately beneath the clamp. This prevents the burette clamp or large clamp from leaning forward.

(iii) The ring will safely support masses up to about 1 kilogram. It can support round-bottomed containers or flat-bottomed containers with a diameter slightly larger than that of the ring. To support smaller containers, a wire gauze (IV/Bl) or heating shelf (IV/B2) may be placed on the ring. For large conatiners, a more stable support, such as one of the tripods (IV/B3) or the collapsible heating stand (IV/B4) is recommended.

B6. Multipurpose Stand



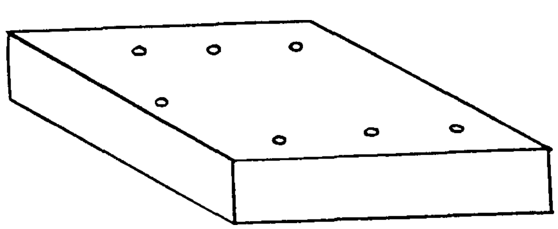
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	9 cm x 4 cm x 18 cm
(2) Flask Support	1	Heavy Wire (coat hanger) (B)	0.2 cm diameter, 35 cm long
	1	Heavy Wire (coat hanger) (C)	0.2 cm diameter, 40 cm long
(3) Test Tube Support	4	Heavy Wire (coat hanger) (D)	0.2 cm diameter, 15-20 cm long
(4) Heating Clamp	1	Heavy Wire (coat hanger) (E)	0.2 cm diameter, 20 cm long

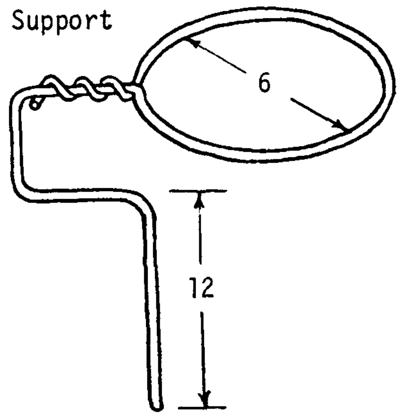
b. Construction

(1) Base

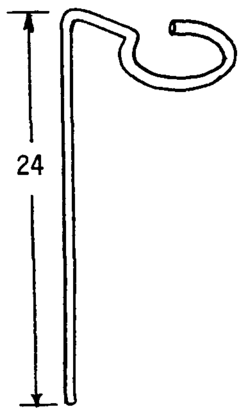
Drill seven holes approximately 0.2 cm in diameter into the wood block (A) as shown. If a larger block is used, or if more attachments are desired, drill more holes,



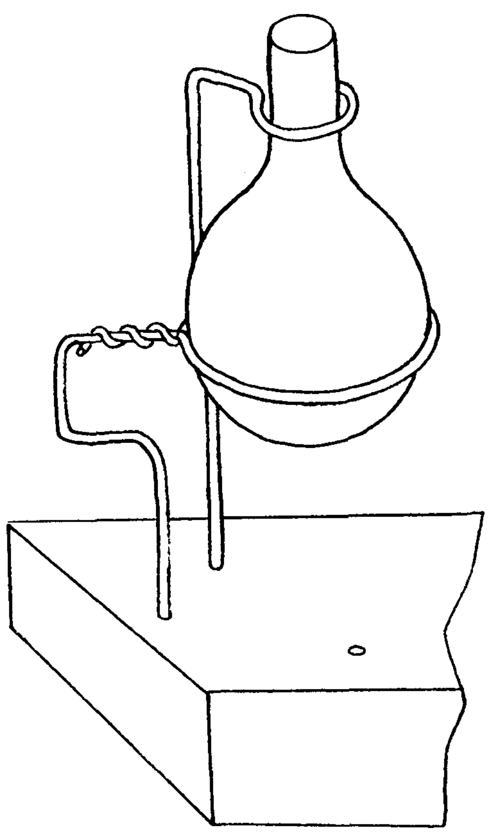
(2) Flask Support



Bend the piece of heavy wire (C) as shown to form the base of the flask support. Make the circular loop about 6 cm in diameter.

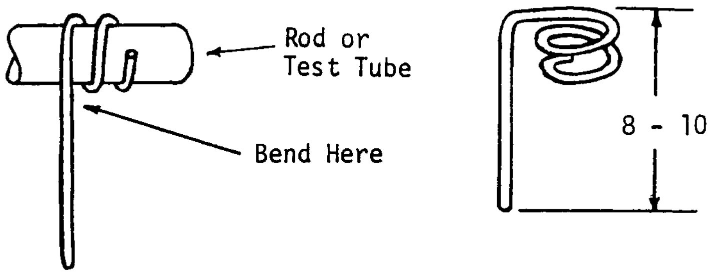


Bend the shorter piece of heavy wire (B) into a loop to form a support for the neck of a flask or light-bulb flask (IV/Al), Make the open loop about 4 cm in diameter.



Insert the two sections of the support into adjacent holes in the base. Adjust them so that they will support a flask or light-bulb flask as illustrated.

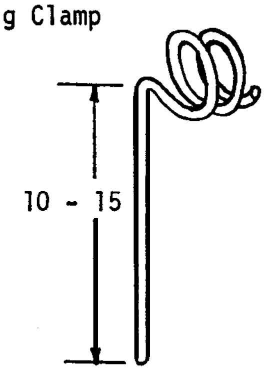
(3) Test Tube Support



Use pliers to bend each of the pieces of heavy wire (D) around a wooden rod or test tube of the desired diameter (2 cm for example). Follow the steps illustrated.

Insert the supports into holes in the base.

(4) Heating Clamp

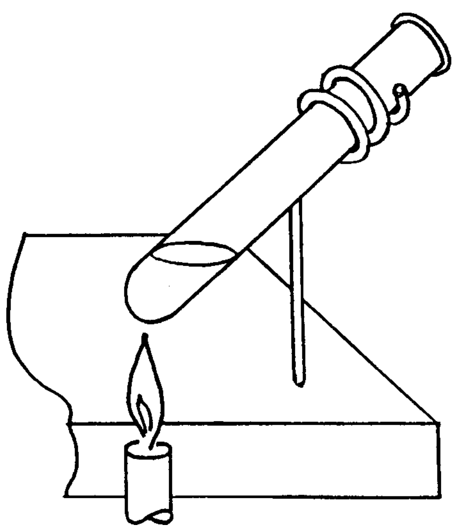


Bend the piece of heavy wire (E) into loop just as for the test tube support shown above. However, tilt the loop at an angle, rather than vertically as was done for the test tube supports. Insert the heating clamp into one of the holes in the base.

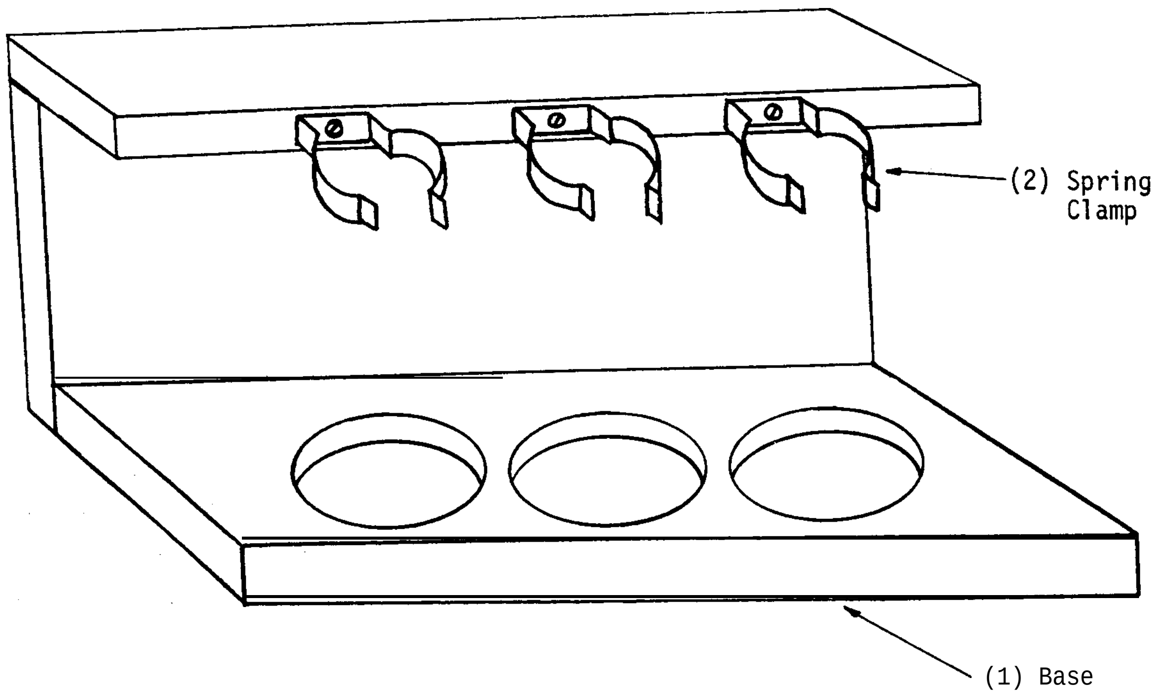
C.Notes

(i) Sizes and number of the supports constructed, as well as the size of the base, may be varied to suit individual needs.

(ii) The heating clamp is used to hold a test tube at an angle while its contents are heated. Supporting the test tube at an angle presents a greater area to be heated. As a safety measure, it allows the mouth of the test tube to be pointed away from everyone in the vicinity.



B7. Rack for Light-Bulb Glassware

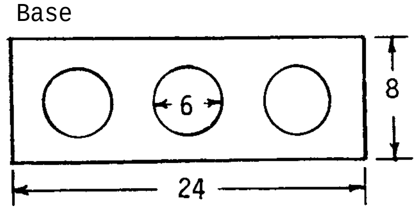


a. Materials Required

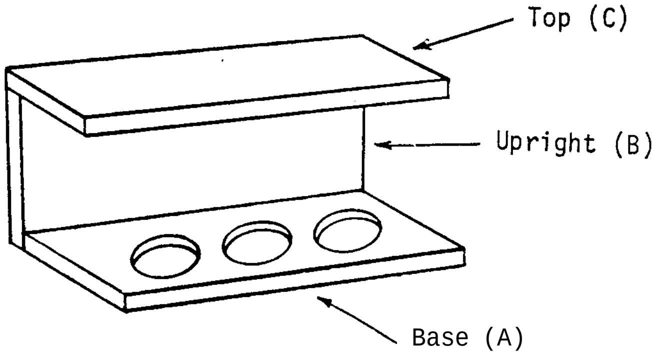
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	8 cm x 24 cm x 2 cm
	1	Wood (B)	9 cm x 24 cm x 2 cm
	1	Wood (C)	4 cm x 24 cm x 2 cm
(2) Spring Clamp	3	Metal Strapping (D)	1 cm x 14 cm

b. Construction

(1) Base

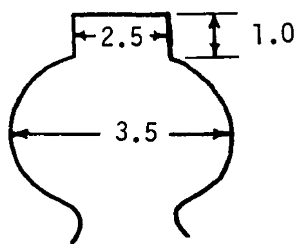


Drill or cut three circular holes, 6 cm in diameter in the large piece of wood (A). Allow about 1.5cm between holes.



Attach top (C) and upright (B) with glue and screws as shown,

(2) Spring Clamp

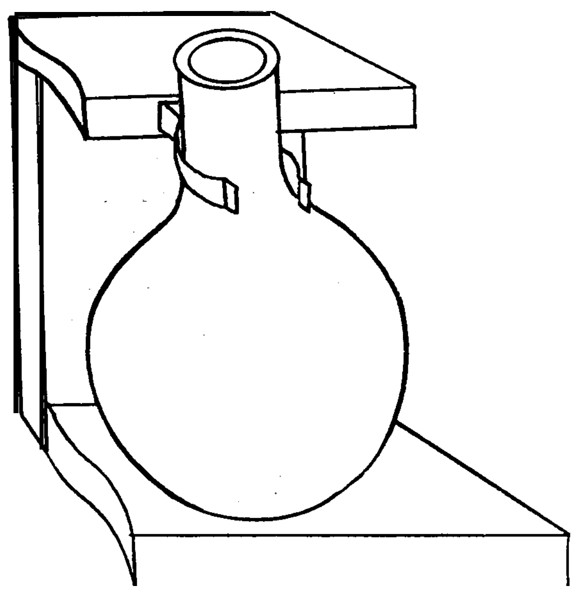


Drill a hole approximately 0.5 cm diameter in the center of each of the pieces of metal strapping (D). Bend each piece of metal strapping into the shape shown.

Center each clamp over each hole in the base. Secure each clamp to the top (horizontally) piece of the base with a screw.

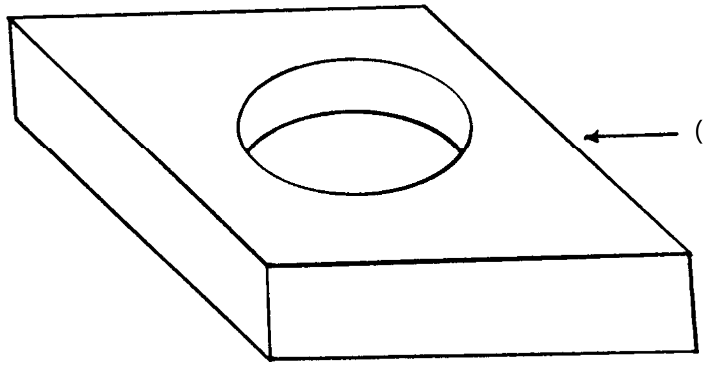
c. Notes

(i) The spring clamp holds the neck of a light-bulb flask securely, while the hole in the base supports the round bottom of the flask.



(ii) This design may be modified to accommodate more flasks, or flasks of different sizes.

B8. Stand for Light-Bulb Glassware



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask Stand	1	Wood Block (A)	9 cm x 9 cm x 4 cm

b. Construction

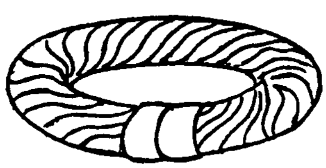
(1) Flask Stand

Drill or cut a circular hole through the center of the block (A). Adjust the diameter of the hole to the size of the light-bulb flask used:

6 cm diameter hole for bulbs from 60 to 200 watts. 7 cm diameter hole for larger bulbs.

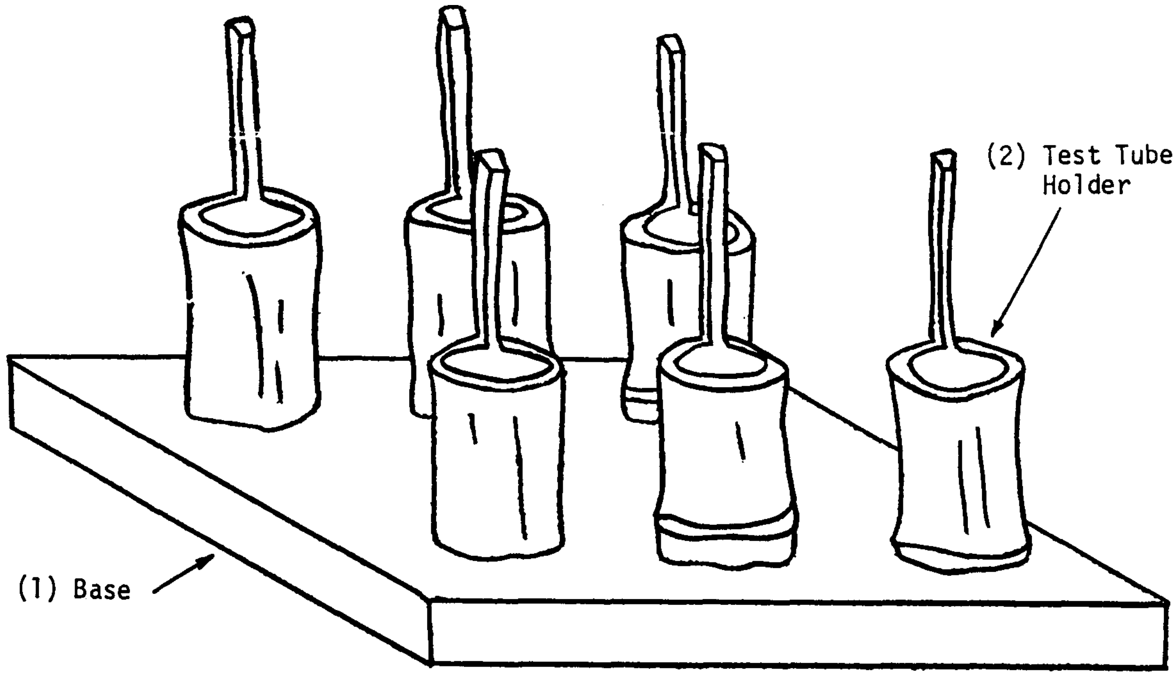
c. Notes

(i) Another stand for a single piece of light-bulb, or any round-bottomed glassware, can be made with a piece of heavy rope approximately 3 cm in diameter.



The rope is cut to a length slightly shorter than the maximum circumference of the flask, and the ends of the rope are taped or spliced together to form a ring.

B9. Bamboo Test Tube Rack



a. Materials Required

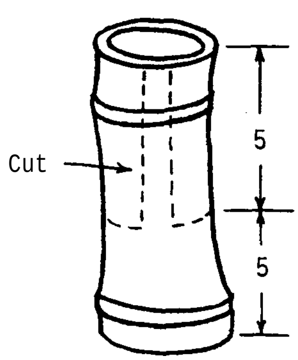
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood Block (A)	1 cmx 7 cmxl8 cm
(2) Test Tube Holder	6	Bamboo Sections (B)	Approximately 2.5 cm outside diameter, 10 cm long

b. Construction

(1) Base

Sand the wood block (A) to remove splinters and rough edges.

(2) Test Tube Holder



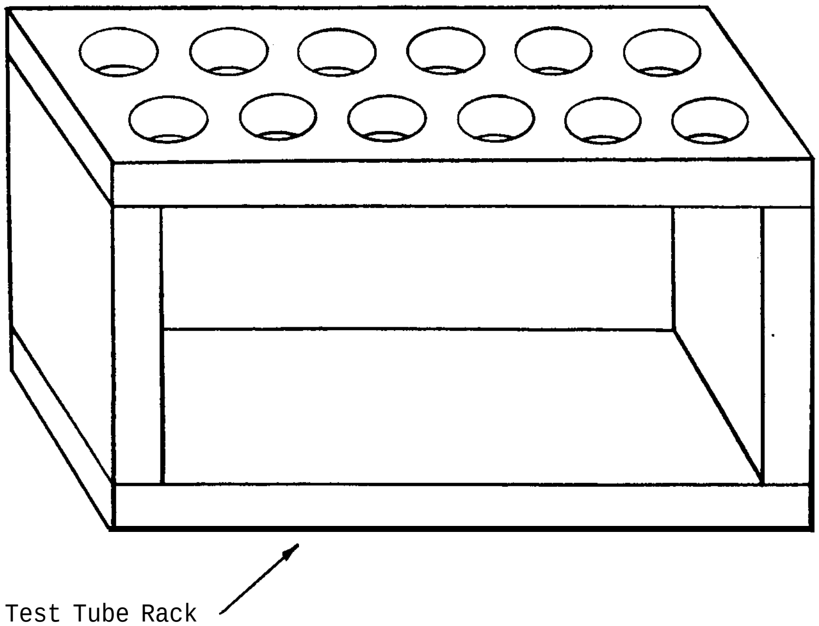
Select bamboo sections (B) with thick walls (at least 0.2 cm). Cut away approximately half the length of each bamboo section, but leave one upright piece as shown. Cement these cylinders to the base.

C. Notes

(i) The upright section remaining on each bamboo cylinder is used to support test tubes upside down for drying.

(ii) The size of the base may be varied to accommodate a convenient number of bamboo cylinders. The diameter of the bamboo cylinders may be varied to suit the size of the test tubes used.

B10. Wooden Test Tube Rack



(1) Test Tube Rack

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Test Tube Rack	2	Wood (A)	8 cm x 20 cm x 1 cm
	2	Wood (B)	8 cm x 12 cm x 2 cm

b. Construction

(1) Test Tube Rack

Drill 12 holes, 2.2 cm in diameter at evenly spaced intervals in one of the larger pieces of wood (A) to form the top of the rack.

Secure the sides (B) to the top (A) as shown, with nails or cement. Secure the bottom (A) in place with nails or cement.

c. Notes

(i) For larger or smaller test tubes, the dimensions may be varied.

V. GLASSWARE AND CROCKERY

A. GLASSWARE

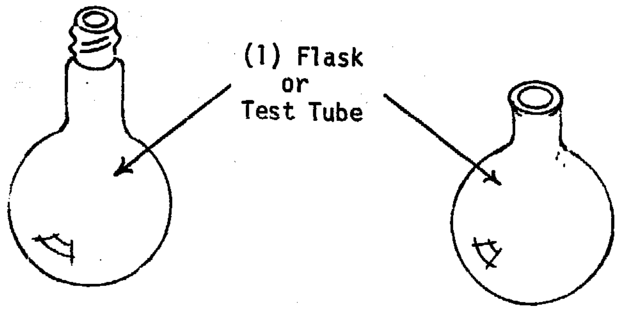
This section describes the construction of various items of laboratory glassware. The chief activity in making these is glass cutting, which is described in detail in a separate section. Refer to GLASSWARE TECHNIQUES AND ACCESSORIES (I) for specific direction for cutting and working glass.

B. CROCKERY

Included in this section is one item composed of concrete.

A. GLASSWARE

A1. Light Bulb Glassware *



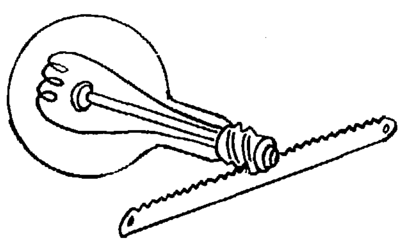
a. Materials Required

Components	Qu	Item Required	Dimensions
(1) Flask or Test Tube	1	Clear Incandescent Light Bulb (A)	Varies

b. Construction

(1) Flask or Test Tube

Sawing



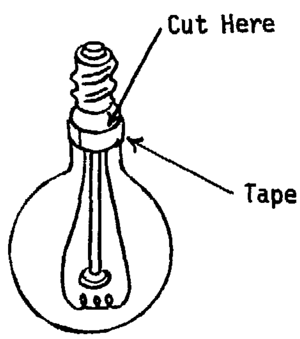
Secure a hacksaw blade in a vise. Hold the bulb (A) horizontally, and wrapped in cloth for safety. Cut around the edge of the base near the terminals. Remove the end thus cut.

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: The American Peace Corps, 1968), pp 146-147.

With a triangular file, puncture the inner seal and remove all the parts from inside the bulb. Smooth cut edge with emery paper or the file.

Heat cutting

Wrap a piece of tape around the neck of a clear bulb (A), about 0.3 cm from the base, as a cutting guide. With a triangular file or glass cutter, make a continuous scratch all the way around the neck of the bulb.



Remove the tape, and use the electric bottle cutter (I/F2) to heat the scratch until the bulb cracks all the way around. Discard the base and internal components.

Wrap the lower portion of the bulb in cloth to protect the hands. Hold the cut edge in a gas or alcohol burner flame until the edge softens and curls back upon itself to form a smooth lip.

c. Notes

(i) The average 150 watt bulb forms a flask of about 150 ml capacity, the average 200 watt bulb a flask of about 200 ml capacity

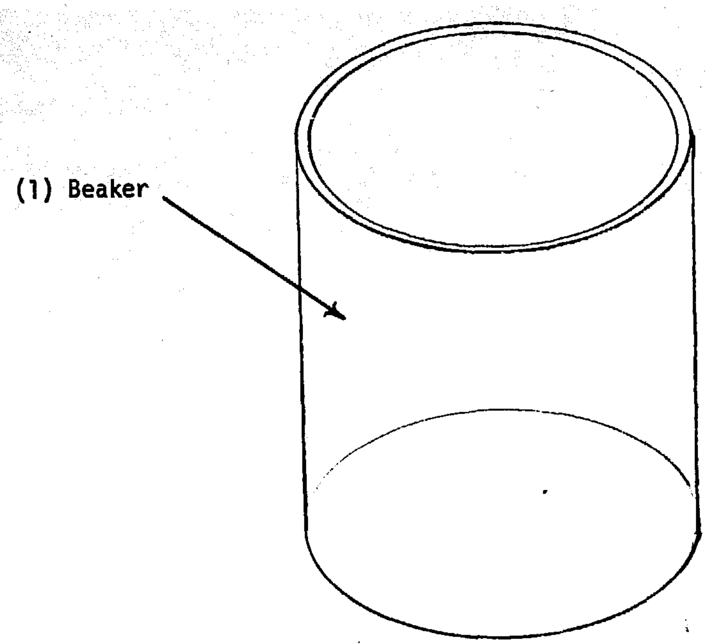
(ii) Bulbs of 100 watts or less may be used for test tubes.

(iii) Small test tubes may also be made from glass medicine vials or discarded antibiotic ampules.

(iv) The bulb is made of thin enough glass to be heated safely while containing a liquid.

(v) The glassware made from light bulbs requires special supports to hold it upright. Consult the section on Supports, Stands, and Holders (IV) for suggestions.

A2. Beaker



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Beaker	1	Wide-bottom Jars or Bottles (A)	Varies

b. Construction

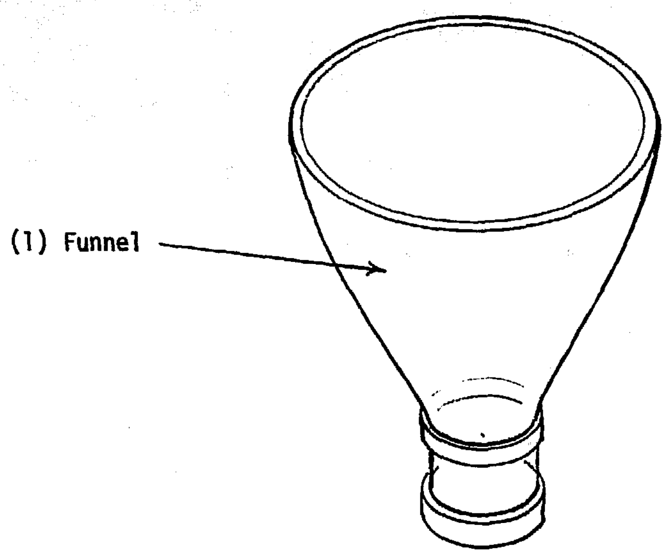
(1) Beaker

Cut off the bottom portion of jars or bottles (A) to make beakers of various sizes (I/F2). Smooth the rough edge by filing with emery paper or a file.

c. Notes

(i) Since bottles and jars are generally made of soft glass, rather than hard, heat resistant glass; beakers made from bottles or jars cannot be used for hot substances or for substances that are to be heated. When heated, they will break.

A3. Funnel



a. Materials Required

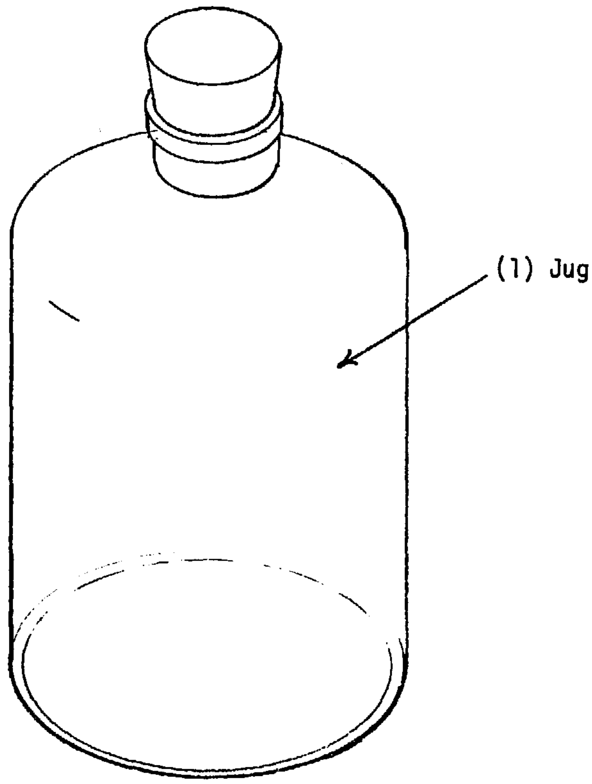
Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	Varies

b. Construction

(1) Funnel

Cut off the top portion of narrow-mouthed glass bottles (A) to make funnels of various sizes (I/F2).

A4. Bell Jar



a. Materials Required

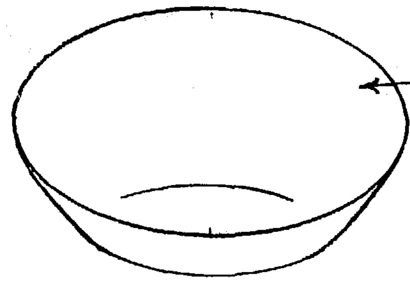
Components	Qu	Items Required	Dimensions
(1) Jug	1	Glass Jug or Carboy (A)	4-8 liters
	1	Rubber or Cork Stopper (B)	To fit Jug (A)

b. Construction

(1) Jug

Cut off the bottom of the glass jug or carboy (A). Sand the cut edge smooth with emery paper. Seal the neck of the jug with the stopper (B).

A5. Watch Glass



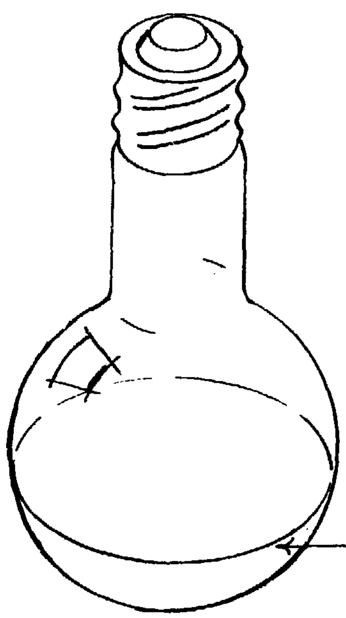
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Watch Glass	1	Light Bulb (A)	Varies

b. Construction

(1) Watch Glass

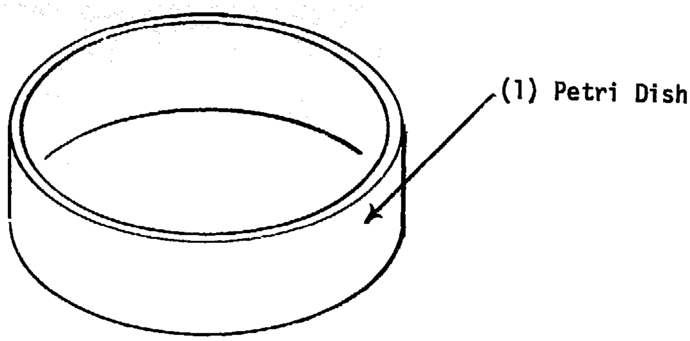
Carefully cut the tops off old light bulbs (A) to make watch glasses of various sizes. Smooth the cut edges by fire polishing.



c. Notes

(i) The watch glass is commonly used to hold small quantities of a solution from which crystals are to be collected.

A6. Petri Dish



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Petri Dish	1	Wide-bottom Bottles or Jars (A)	Varies

b. Construction

(1) Petri Dish

Cut off the bottom of a wide-bottom glass bottle or jar (A). Make as many as needed. Smooth the rough edge with emery paper.

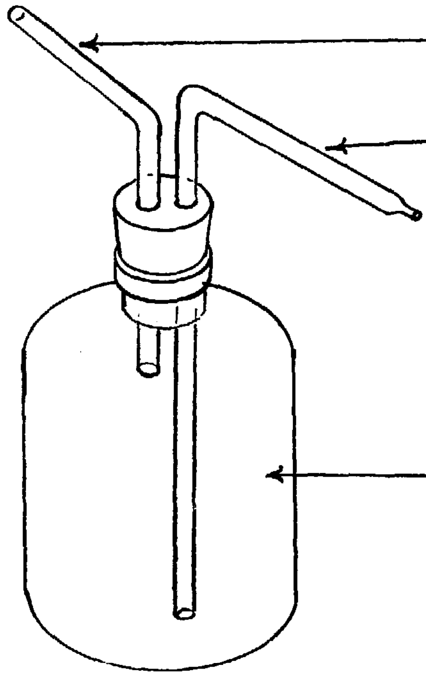
c. Notes

(i) Jar lids or aluminum foil make satisfactory tops for these dishes. Waxed paper or cardboard dipped in wax also make suitable covers.

(ii) Petri dishes are often used to hold small quantities of a liquid from which crystals are to be collected.

(iii) They may also be used to contain food or culture media for growing bacteria, fungi, or molds. When petri dishes are used for culturing purposes, they must be used with lids and must be sterilized (BIOL/VII/A2).

A7. Wash Bottle



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass or Plastic Bottle (A)	Approximately 250 ml capacity
	1	2-Hole Stopper (B)	To fit container (A)
(2) Delivery Tube	1	Glass Tubing	Approximately 0.5 cm diameter, and at least 20 cm longer than height of container.
(3) Mouthpiece	1	Glass Tubing (D)	About 0.5 cm diameter, and shorter than delivery tube.

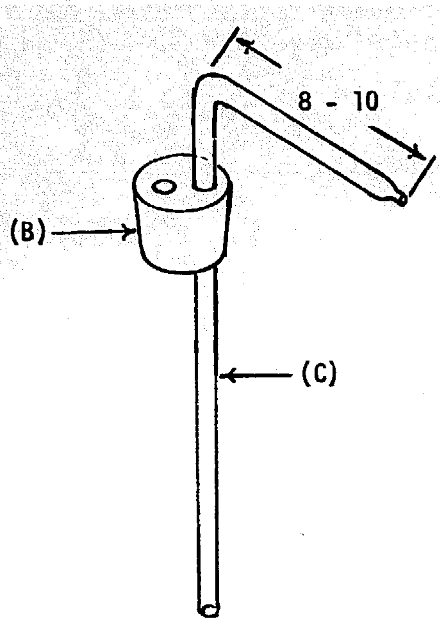
b. Construction

(1) Container

Select a glass or plastic bottle with a narrow neck and a capacity of about 250 ml or larger (A).

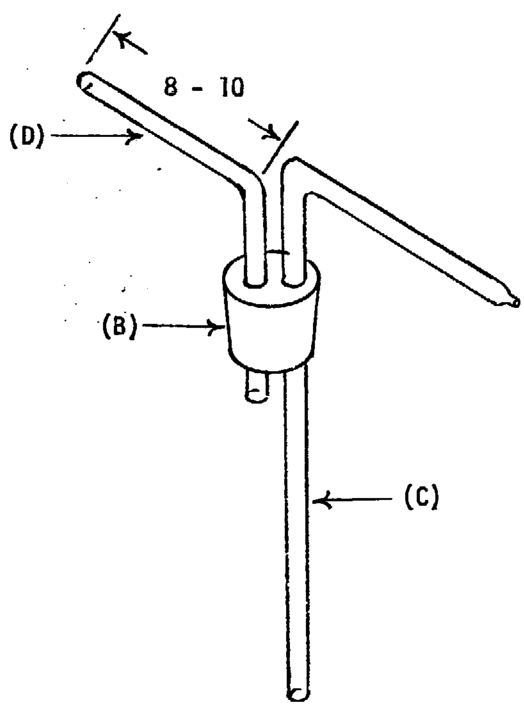
Fit the container (A) with a two-hole stopper (B).

(2) Delivery Tube



Make a nozzle (I/D3) at one end of the long glass tube (C). Fire polish both the nozzle and the other end and let the tube cool. Next, bend the tube, about 8 - 10 cm from the nozzle end at a sharp angle as shown. When it is cool, carefully push the tube into the stopper (B) so that it extends to within 0.5 cm of the bottom of the container. Trim to the correct length, if necessary, and fire polish the end.

(3) Mouthpiece

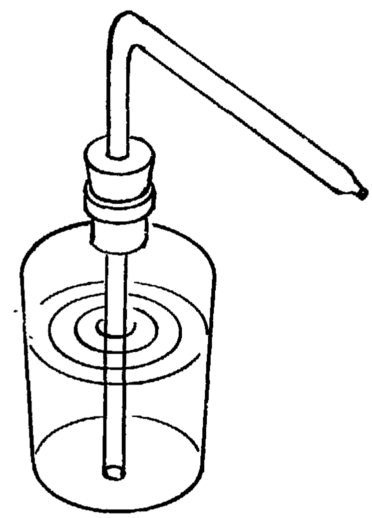


Fire polish both ends of the glass tube (D). About 8 - 10 cm from one end, make a wide-angled bend. When the tube has cooled, push it carefully into the stopper (B). Insert the stopper into the container (A).

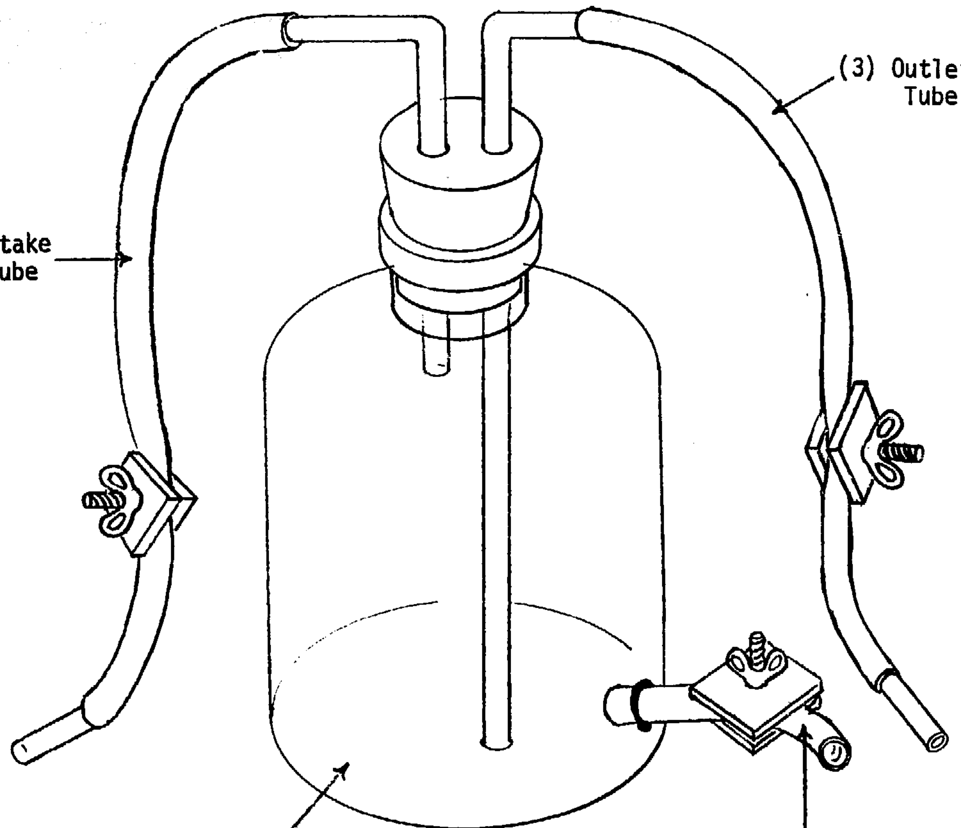
c. Notes

(i) To use the wash bottle, fill it with (distilled) water. Direct the delivery tube in the desired direction and blow through the mouthpiece to force water through the nozzle in a fine stream.

(ii) If a soft plastic squeeze bottle is used, only the delivery tube and a one-hole stopper are necessary. Squeeze the bottle to force water out the nozzle.



A8. Aspirator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Bottle (A)	4-8 liter capacity
	1	2-Hole Rubber Stopper (B)	To fit Bottle (A)
(2) Intake Tube	1	Glass Tubing (C)	0.5 cm diameter, approximately 15 cm long
	1	Glass Tubing (D)	0.5 cm x 10 cm
	1	Plastic or Rubber Tube (E)	Approximately 1.0 cm diameter, 35 cm long
	1	Screw Clamp or Pinch Clamp (F)	(IV/A4 and A5)
(3) Outlet Tube	1	Glass Tube (G)	0.5 cm diameter, 10 cm longer than height of bottle
	1	Glass Tube (H)	0.5 cm x 10 cm
	1	Plastic or Rubber Tube (I)	Approximately 1.0 cm diameter, 35 cm long

	1	Screw Clamp or Pinch Clamp (J)	(IV/A4 or A5)
(4) Drain Tube	1	Plastic or Rubber Tube (K)	Approximately 1.0 cm diameter, 20 cm long
	1	Screw Clamp or Pinch Clamp (1)	(IV/A4 or A5)

b. Construction

(1) Container

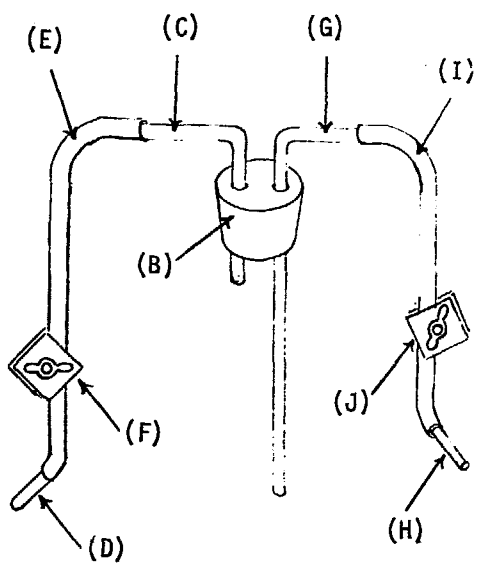
Fit the bottle (A) with a two-hole rubber stopper (B). Carefully bore a hole approximately 1.0 cm in diameter, 2 cm from the bottom of the bottle.

(2) Intake Tube

Make a 90° bend about 5 cm from one end of the longer glass tube (C). Insert this tube into one of the holes in the stopper of the bottle. Fit the other end of the tube into the plastic or rubber tubing (E). Insert the short glass tube (D) into the open end of the plastic or rubber tubing (E).

Construct a screw clamp or pinch clamp (F) (IV/A4 or A5) to close the tubing (E).

(3) Outlet Tube



Make a 90° bend about 5 cm from one end of the longer glass tube (G). Insert this tube into one of the holes of the rubber stopper (B) such that the straight section of the tube reaches within 2 cm of the bottom of the bottle as illustrated.

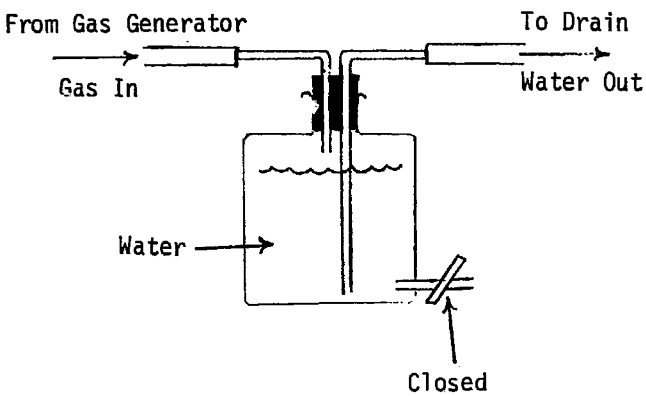
Attach the plastic or rubber tubing (I) to the other end of the glass tube (G). Fit the shorter glass tube (H) into the free end of the tubing (I) and close it with a clamp (J).

(4) Drain Tube

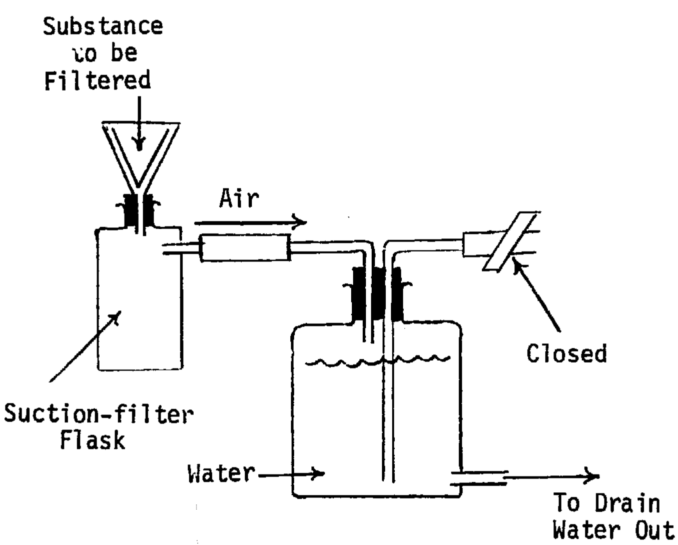
Insert the plastic or rubber tubing (K) into the hole in the side of the container extending it 1 - 2 cm inside the bottle. Seal the tubing (K) in the hole with epoxy resin. Close the tube with a clamp (L).

c. Notes

(i) This item may be used to collect gas by water displacement. First, the bottle is filled with water and all three tubes are closed with clamps. The intake tube is then attached to the gas generator and the outlet tube is directed into a drain or waste receptacle. When both the intake and outlet tubes are opened (drain tube remains closed) gas will enter the bottle, and displaced water will be forced out through the outlet tube.

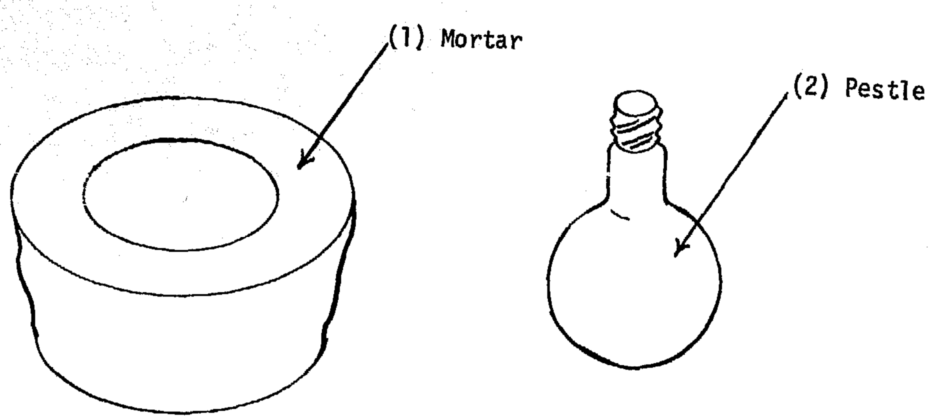


(ii) The aspirator may also be used to provide suction to aid in filtration. Again, the bottle is filled with water, and all three tubes are closed with clamps. The intake tube is connected to the suction tube of a suction-filter flask (VI/A4). The drain tube is directed into a drain or waste receptacle. The liquid to be filtered is poured into the filter funnel (fitted with filter paper), and the intake and drain tubes are opened. The outlet tube remains closed. The flow of water from the aspirator bottle creates a negative pressure that tends to increase the rate of filtration in the suction filtration apparatus.



B. CROCKERY

B1. Mortar and Pestle

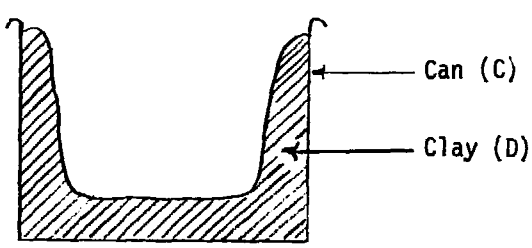


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Mortar	0.5 kg	Sand (A)	Fine grain
	1.5 kg	Cement (B)	--
	1	Tin Can (C)	Capacity approximately 0.5 kg
	0.5 kg	Modeling Clay (Plasticine) (D)	--
	1	Wire Mesh (E)	10 cm x 10 cm
	1	Epoxy Glue (F)	--
	1	Light Bulb (G)	100 watts
(2) Pestle	1	Light Bulb (H)	60 watts
	1	Epoxy Glue (I)	--
	1	Nail (J)	Approximately 10 cm long

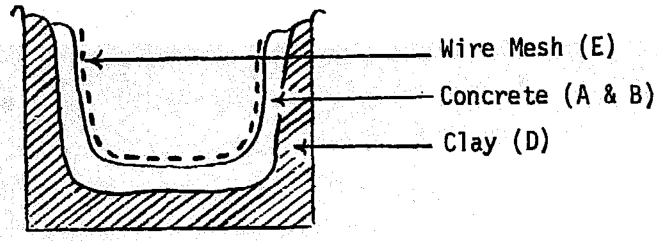
b. Construction

(1) Mortar



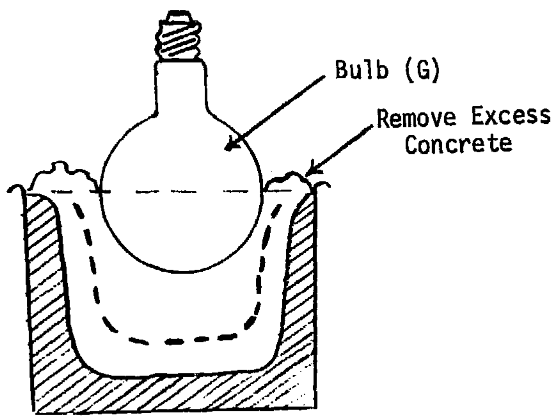
Cross Section

Cut the tin can (C) in half. Pack the modeling clay (plasticine) (D) into the bottom half of the can. Then mold the clay into the external shape of the mortar. Make the bottom of the clay mold smooth and flat, as this will be the bottom of the mortar.

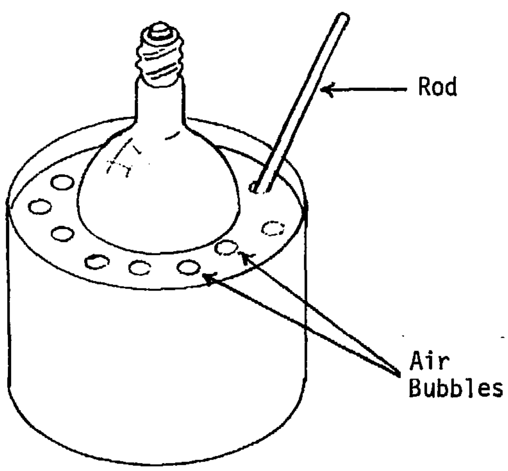


Cross Section

Make a mixture of 3:1 cement (B)/ sand (A). Add water to make a thick concrete paste. Next, cover the mold with a 2 - 3 cm layer of concrete (A and B). Cut the wire mesh (E) into 2 cm wide strips and press the strips on the coating of concrete. Cover the entire surface of concrete with the screening strips (E).



Fill the remaining space with concrete. Cover the 100 watt light bulb (G) with oil and press it halfway into the mold. Scrape away and discard any concrete that overflows the mold. Level off the top of the concrete.

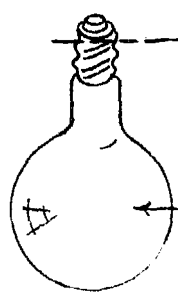


Take a thin wooden or metal rod and push it in and out of the concrete around the bulb (G), touching the bulb. Break up, in this way, any air bubbles between the bulb and the concrete.

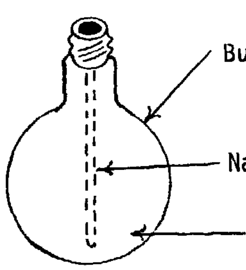
Allow at least 24 hours or more for the concrete to dry. Then cut away the can with a can opener and tin snips and peel away the clay mold. Break and remove the bulb, taking care to remove all pieces of broken glass. Place the mortar in a large can or crock and cover it with water. Allow it to soak for three weeks in order to cure. Add water to the container as it is absorbed by the mortar.

When the mortar has cured, remove it from the water and allow it to dry. Then cover the entire surface with epoxy glue (F) to seal the concrete, fill air bubbles, and provide a smooth grinding surface.

(2) Pestle



Cut the metal tip off the 60 watt light bulb (H) with a hacksaw. Remove the insides. File the cut edges smooth with a round file.



Support the bulb upright in a container of sand or appropriate stand and fill the entire bulb with the concrete paste (A and B). Insert a nail almost all the way to the bottom of the bulb, to provide support for the concrete.

Allow the concrete to dry (at least 24 hours). Break the glass glass, leaving the metal end intact. Cure the pestle immersed in water for three weeks. Remove, dry, and coat with epoxy glue (I), making sure all air bubbles are filled.

c. Notes

(i) The mortar and pestle are used to grind crystals or lumps of substances into powder. The substance to be ground is placed in the mortar, and ground with the pestle to the desired consistency.

(ii) If the epoxy-coated grinding surfaces of the mortar and pestle become worn away with use, clean them and reapply a layer of epoxy glue to provide a smooth surface.

VI. SEPARATORS AND PURIFIERS

This section on separators and purifiers has been divided into four subsections:

A. MECHANICAL SEPARATORS

These are devices for separating solid/solid, liquid/solid, or solid/liquid mixtures. Included are magnets, sieves, filtration apparatus, and separatory funnels.

B. DISTILLATION APPARATUS

These devices are used for separating liquid solutions and include several types of distillation apparatus.

C. ELECTRICAL SEPARATOR

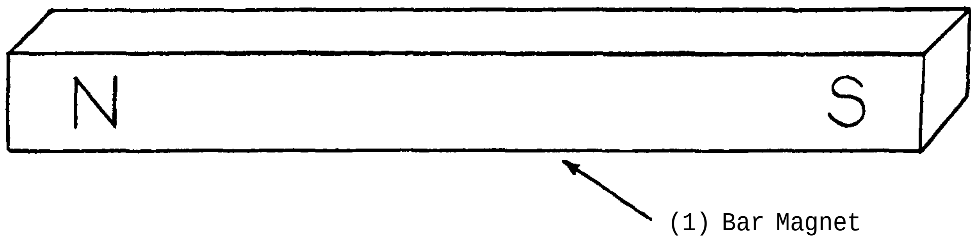
This device is used in the electrolytic separation of substances and to demonstrate Faraday's quantitative laws of electrolysis.

D. CENTRIFUGAL SEPARATORS

Centrifugal separators are used to cause the rapid precipitation of materials in suspension.

A. MECHANICAL SEPARATORS

Al. Magnets



(1) Bar Magnet

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bar Magnet	1	Bar Magnet	PHYS/IX/Al, Notes

b. Construction

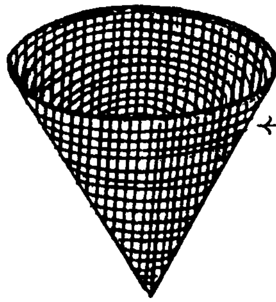
(1) Bar Magnet — Purchase a magnet, or magnetize a steel bar according to the instructions described in PHYS/IX/Al, Notes.

c. Notes

(i) Magnets are used to separate ferromagnetic materials from other materials, such as dirt or sand.

(ii) Magnets in a variety of shapes, materials, and field strength may be purchased from commercial sources and may be used in place of the bar magnet above.

A2. Cone Sieve

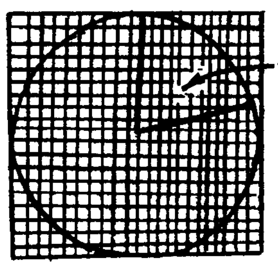


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cone Sieve	1	Wire Mesh (A)	Approximately 7 cm x 7cm
	1	Thin Wire (B)	Approximately 10 cm

b. Construction

(1) Cone Sieve



Cut a circle from the wire mesh (A). Then cut out and remove a segment of the circle as shown.

Roll the wire mesh into the shape of a cone, overlapping the edges slightly. Thread the thin wire (B) in and out of the wire mesh, at the overlapped edges, to hold them together.

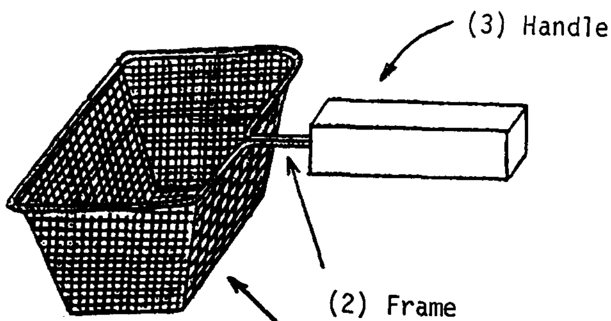
c. Notes

(i) This cone may be made larger or smaller by varying the dimensions of the wire mesh used.

(ii) Material suitable for replacing the wire mesh may be made by dipping a cloth having a very coarse weave into melted wax, varnish, or starch.

(iii) Sieves are suitable for grading small particles or washing small amounts of materials under a stream of water.

A3. Basket Sieve

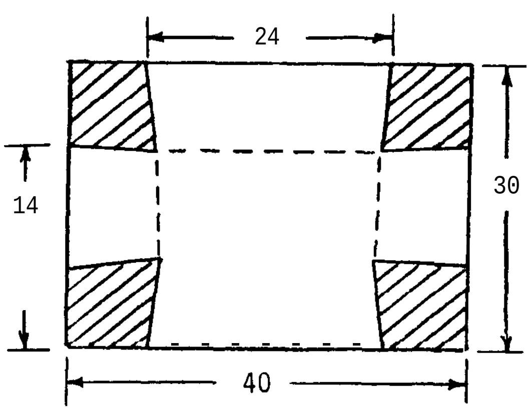


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basket	1	Wire Mesh (A)	Approximately 30 cm x 40 cm
	4	Thin Wire (B)	Approximately 20 cm
(2) Frame	1	Stiff, Heavy Wire (C)	Approximately 4 cm diameter, 80 cm long
	1	Thin Wire (D)	Approximately 80 cm long
(3) Handle	1	Wood (E)	2 cm x 2 cm x 15 cm

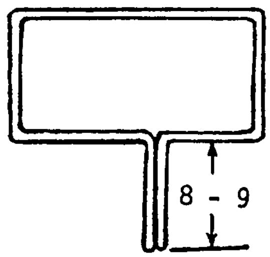
b. Construction

(1) Basket



Cut the wire mesh (A) according to the pattern shown, and discard the shaded portions. Then fold all the flaps up along the dashed lines. Overlap the cut edges slightly, and thread the thin wires (B) in and out of the wire mesh at the overlapped edges to hold them together.

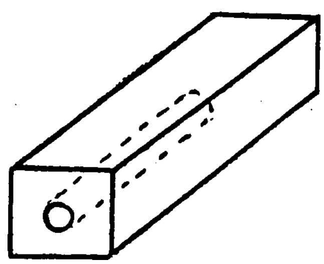
(2) Frame



Bend the heavy wire (C) as shown, to fit the dimensions of the top of the basket. Allow an extension of 8 - 9 cm to fit into the handle (E).

Fold the top 1 cm of the basket around the frame to the inside, and lace the thin wire (D) in and out of the basket mesh to secure the frame in place.

(3) Handle



Drill a hole approximately 0.8 cm in diameter and approximately halfway through the length of the wooden handle (E).

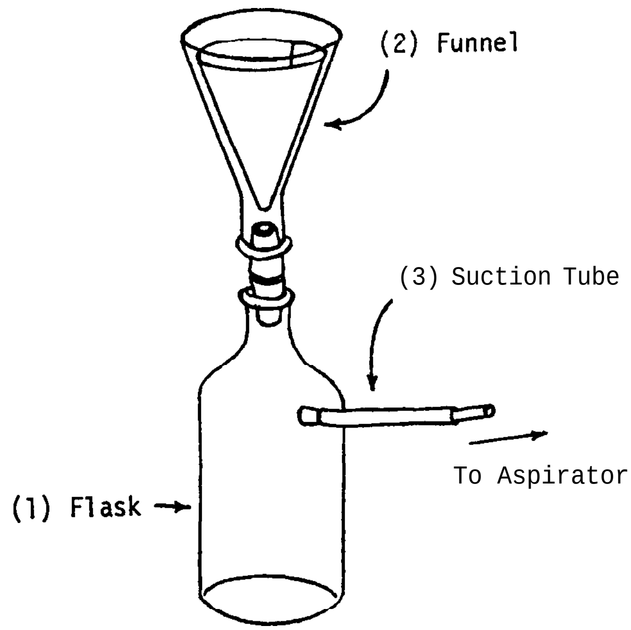
Insert the straight section of the frame into this hole in the handle, and cement it in place.

C. Notes

(i) This basket sieve may be made larger or smaller by varying the dimensions of the wire mesh, frame, and handle used.

(ii) This sieve is used just as the funnel sieve in the preceding section, but for larger amounts of material.

A4. Suction-Filter Flask

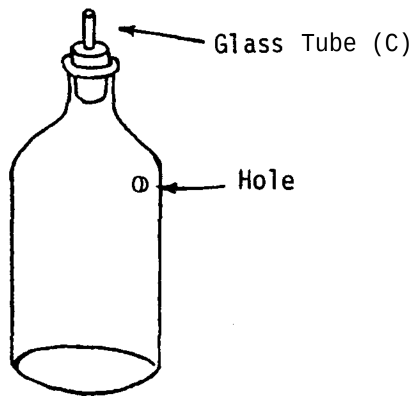


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask	1	Glass Bottle (A)	Capacity 250-500 ml
	1	l-Hole Rubber Stopper (B)	To fit bottle (A)
	1	Glass Tube (C)	0.5 cm diameter, 6 cm long
(2) Funnel	1	Funnel (D)	V/A3
	1	l-Hole Rubber Stopper (E)	To fit neck of funnel (D)
	1	Filter Paper (F)	Approximately 15 cm diameter
(3) Suction Tube	1	Rubber Tube (G)	1.0 cm diameter, 15 cm long
	1	Glass Tube (H)	0.7 cm diameter, 10 cm long

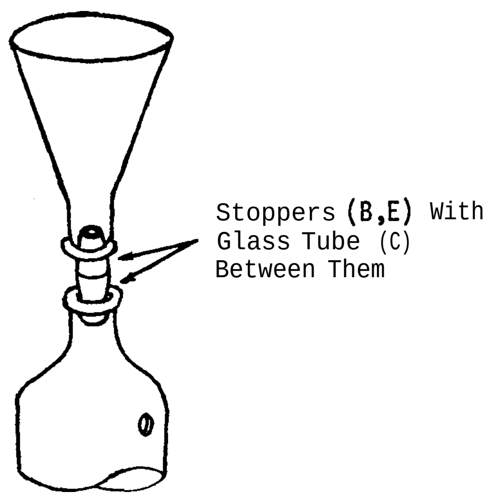
b. Construction

(1) Flask



Bore a hole (I/E2) just slightly smaller than 1.0 cm in diameter in the side of the bottle (A) near the top. Insert the glass tube (C) into the rubber stopper (B) so that approximately half the tube protrudes from the top of the stopper. Fit the stopper into the mouth of the bottle.

(2) Funnel



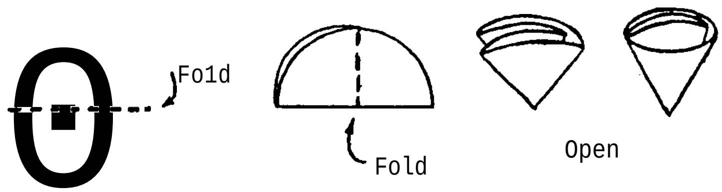
Insert the protruding end of the glass tube into the stopper (E) for the funnel (D). Push the two stoppers together, and fit the funnel stopper into the neck of the funnel (D).

(3) Suction Tube

Insert the rubber tubing (G) into the hole in the side of the bottle so that about 1 cm of tubing is inside the bottle. Seal the tubing in place with eqoxy resin. Insert a short piece of glass tubing (H) into the open end of the rubber tubing.

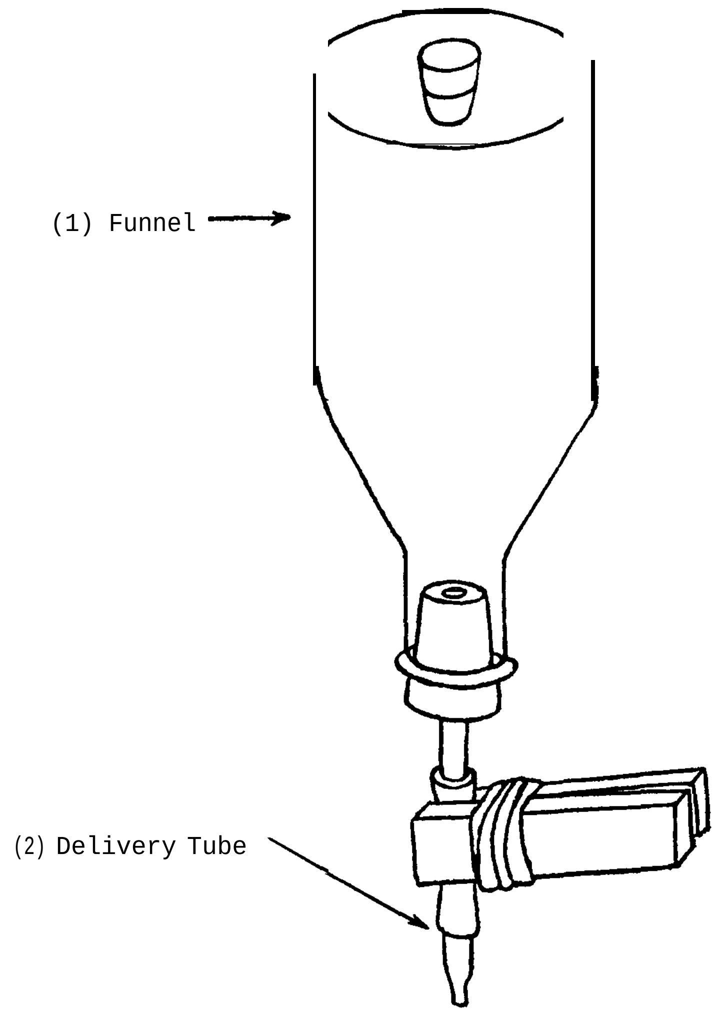
c. Notes

(i) A circle of filter paper is folded as illustrated and placed in the funnel. The suction tube is then connected to the water-filled aspirator (V/A8). The material to be filtered is placed in the filter paper in the funnel. Water is then allowed to drain from the aspirator. The partial vacuum thus formed will draw air from the flask, and air on the outside will be drawn through the funnel, causing more rapid filtration to occur.



(ii) Filter paper is available from commercial suppliers, but substitutes include paper towels, blotting paper, or cotton.

A5. Separatory Funnel

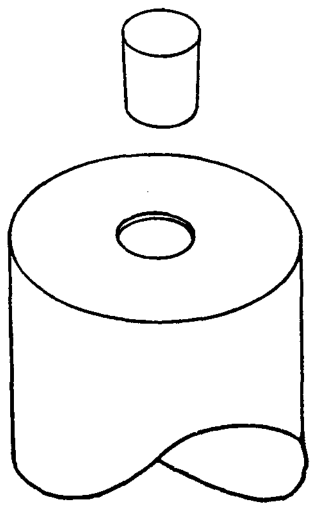


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	Capacity 250-500 ml
	1	Rubber Stopper (B)	Approximately 2 cm diameter (large end)
(2) Delivery Tube	1	l-Hole Rubber Stopper (C)	To fit bottle (A)
	1	Glass Tubing (D)	0.7 cm diameter, 15 cm long
	1	Rubber Tubing (E)	1 cm diameter, 8 cm long
	1	Wooden Pinch Clamp (F)	IV/A4

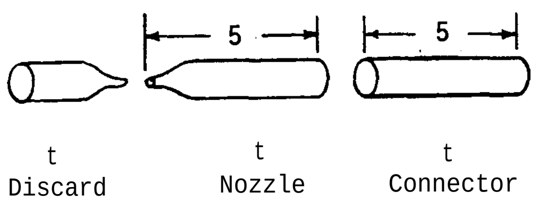
b. Construction

(1) Funnel

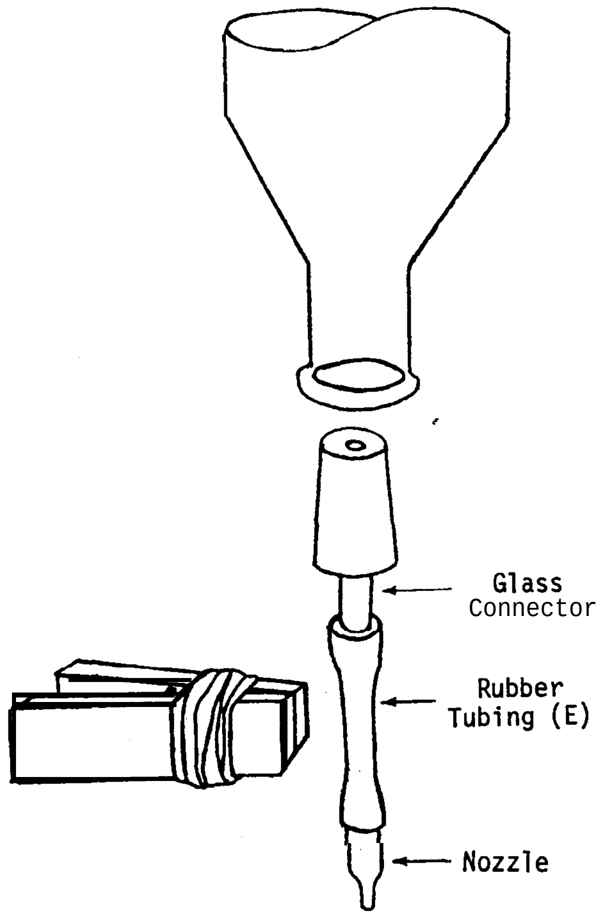


Select a clear glass bottle (A) with a tapered, narrow neck. Drill a hole in the bottom of the bottle and enlarge it sufficiently to receive the rubber stopper (B). Smooth the rough edge with emery paper before sealing.

(2) Delivery Tube



Heat the glass tubing (D) with a burner and draw it out near one end and cut as shown to leave a 5 cm long nozzle and a 5 cm long connector. Carefully fire polish all cut edges.'

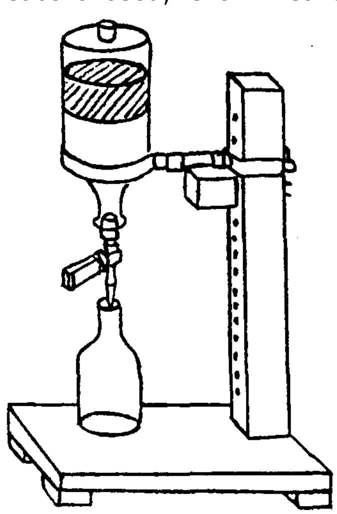


Fit the glass connector into, but not through, the one-hole rubber stopper (C). Insert the other end into the rubber tubing (E), and connect the rubber tubing to the nozzle. Fit the stopper into the neck of the bottle.

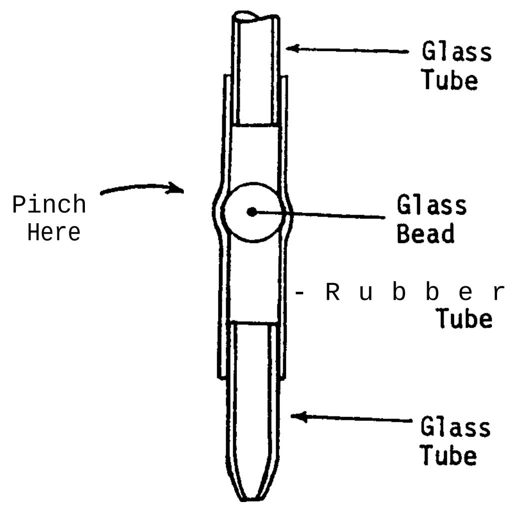
Construct a wooden pinch clamp (IV/A4) and use it to close the rubber tubing.

C. Notes

(i) The separatory funnel is used to separate two liquids that do not mix. With the delivery tube closed, the mixture of liquids is poured into the funnel through the hole at the top, (bottom of bottle). The funnel is then sealed and shaken vigorously for several seconds. Then the funnel is secured in a ring stand (IV/B4) or other appropriate support and allowed to rest undisturbed until the liquids separate into layers. The lower liquid is then drained through the delivery tube by opening the pinch clamp. In order to allow the funnel to drain properly, the stopper must be removed from the top.



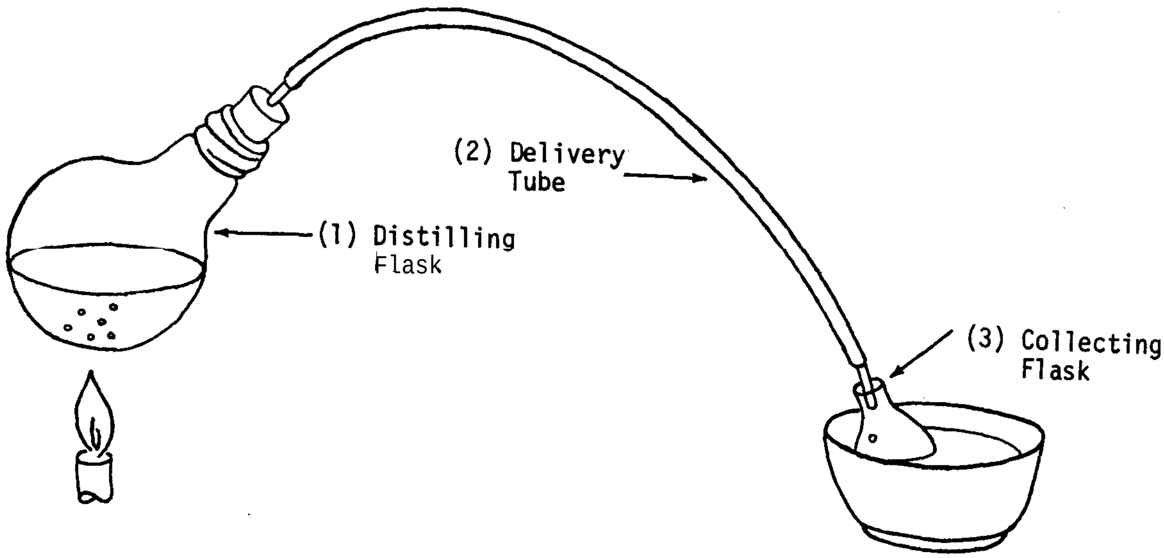
(ii) A glass bead just slightly larger than the internal diameter of the rubber tubing may be used in place of the pinch clamp. Push the bead into the rubber tubing before inserting the glass nozzle. The bead will seal the rubber tube. To dispense liquid from the funnel, squeeze the tube between thumb and forefinger at the location of the bead.



Cross Section

B. DISTILLATION APPARATUS

Bl. Simple Distillation Apparatus



a. Materials Required

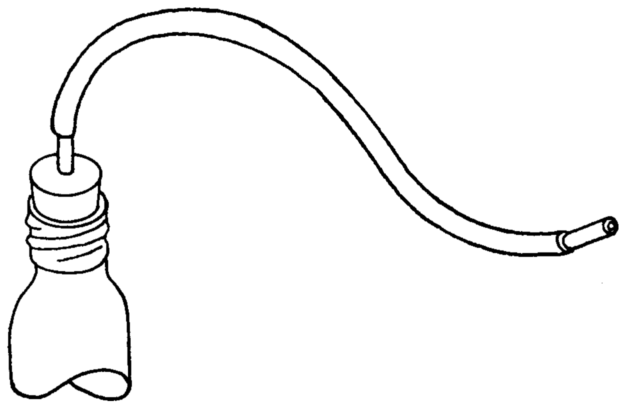
Components	Qu	Items Required	Dimensions
(1) Distilling Flask	1	Flask (A)	Capacity approximately 200 ml
	1	l-Hole Rubber Stopper (B)	To fit flask (A)
(2) Delivery Tube	2	Glass Tubing (C)	0.7 cm diameter, 5 cm long
	1	Rubber or Plastic Tubing (D)	1 cm diameter, approximately 60 cm long
(3) Collecting Flask	1	Flask or Bottle (E)	Capacity approximately 200 ml

b. Construction

(1) Distilling Flask

Fit the light bulb flask (A) or other flask with the one-hole rubber stopper (B).

(2) Delivery Tube



Support the flask in a stand, (IV/B4, B5, or B6).

Insert a short piece of glass tubing (C) into the stopper in the flask. Attach the other end of the glass tube to a long piece of rubber or plastic tubing (D). Insert another short piece of glass tubing (C) into the other end of the rubber or plastic tubing.

(3) Collecting Flask

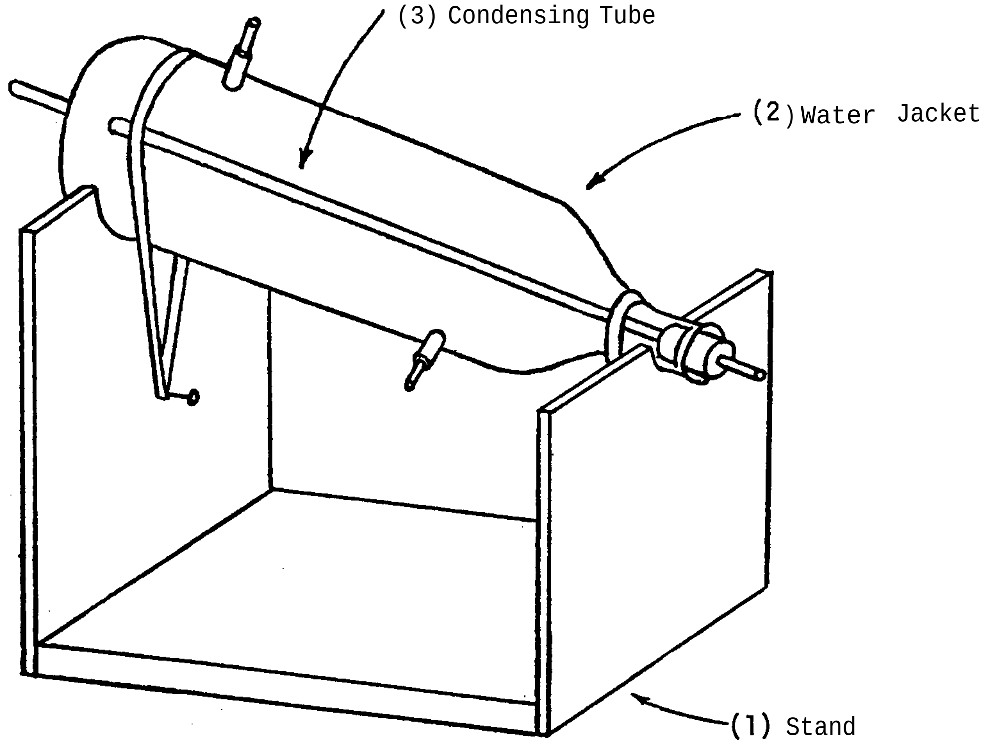
Place a flask (E) or jar in a bowl or pan of cool water and lead the free end of the delivery tube into the flask.

c. Notes

(i) A sample of a liquid--impure water, for example--to be distilled is placed in the distilling flask, and the stopper is inserted into the flask. The liquid is heated until it boils. As the liquid boils, its vapor travels through the delivery tube and is cooled enough by air surrounding the tube to condense and drip into the collecting flask. The water in the bowl helps cool the condensed liquid still more, as it is quite hot when first collected.

(ii) This simple apparatus is ideal for student participation in simple distillation operations involving small volumes of liquids.

B2. Condenser

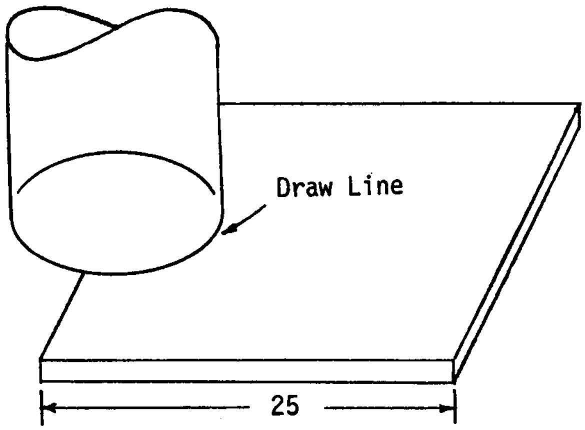


a. Materials Required

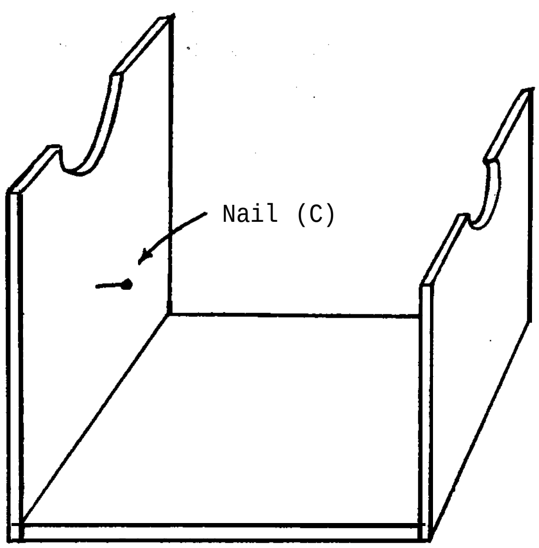
Components	Qu	Items Required	Dimensions
(1) Stand	2	Wood (A)	18 cm x 15 cm x 1 cm
	1	Wood (B)	25 cm x 15 cm x 1 cm
	2	Nails (C)	3 cm long
	2	Rubber Bands (D)	5 cm x 9 cm
(2) Water Jacket	1	Plastic or Glass Bottle (E)	Capacity approximately 1-2 liters
	1	1-Hole Rubber Stopper (F)	To fit bottle (E)
	2	Rubber Tubing (G)	1 cm diameter, 3 cm long
	2	Glass Tubing (H)	0.7 cm diameter 10 cm long
(3) Condensing Tube	1	Glass Tubing (I)	0.7 cm diameter, 10 cm longer than bottle

c. Construction

(1) Stand



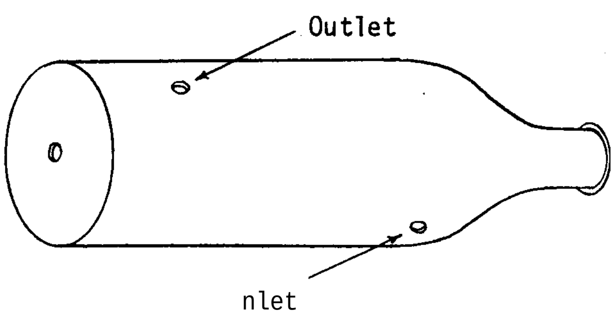
Trace around the base of the bottle (E) on the larger piece of wood (B) as shown. Cut along the traced line.



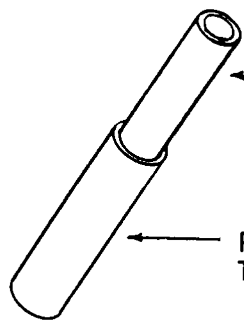
In a similar fashion, make a small semicircular cutout to accommodate the neck of the bottle (E) in one of the smaller pieces of wood (A).

Nail the two sections with cutouts to the third (A) to form the stand. Drive a nail (C) into each upright to anchor the rubber bands (D) that hold the water jacket in place.

(2) Water Jacket



Take a plastic bottle (E) if possible, a glass bottle if necessary. Drill three holes approximately 1 cm in diameter in the bottle as illustrated.



(3) Condensing Tube

Fit each short piece of glass tubing (H) into a piece of rubber tubing (G). Insert each piece of rubber tubing into one of the holes in the side of the bottle. Seal with epoxy resin if necessary to make sure that the seal is watertight.

Fit the mouth of the bottle with a one-hole rubber stopper (F).

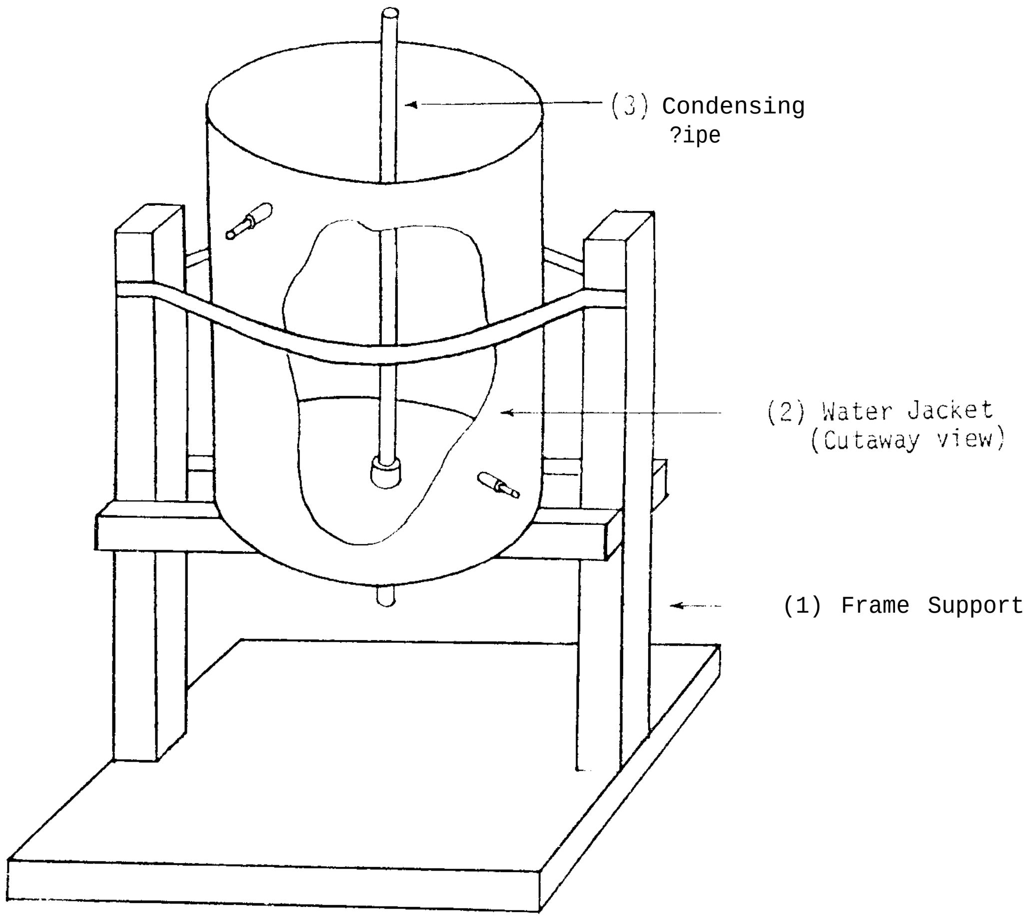
Insert a long glass tube (I) through the hole in the base of the bottle, all the way through the bottle, and through the rubber stopper to the outside again.

Rest the bottle in the stand with the base higher than the neck and the inlet tube below the outlet tube. Loop the rubber bands (D) around the base and neck of the bottle to secure it in position.

C. Notes

(i) To use this condenser, fasten a rubber or plastic tube from the flask in which a liquid is being boiled to the upper end of the condensing tube (that end protruding from the bottom of the bottle). Another tube, from a cold water source, is connected to the inlet (lower) tube, and a third rubber or plastic tube is attached to the outlet and led to a drain. As hot gas flows through the condensing tube, it is cooled by the water jacket and condenses, to drip as a liquid from the lower end of the condensing tube where it can be collected in a beaker.

B3. Water Still



a. Materials Required

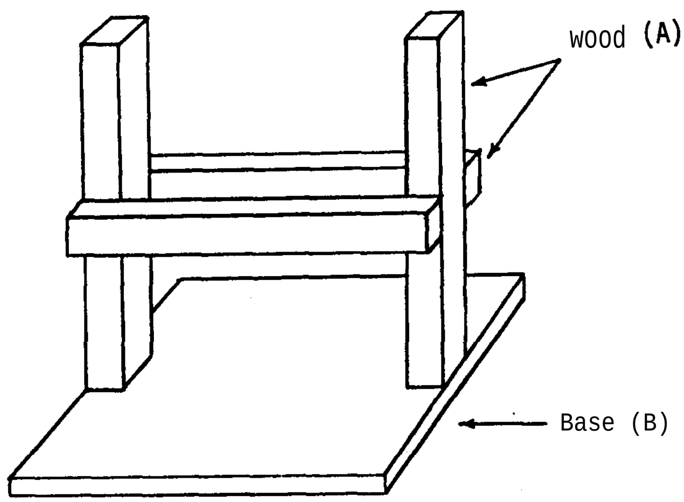
Components	Qu	Items Required	Dimensions
(1) Frame Support	4	Wood (A)	4 cm x 5 cm x 25 cm
	1	Wood (B)	2 cm x 16 cm x 25 cm
(2) Water Jacket	2	Metal Strapping (C)	1.5 cm x 23 cm
	1	Large Tin Can (D)	Capacity approximately l-l.5 kg
	2	Rubber Tubing (Ej	? cm diameter, 5 cm long
	2	Glass Tubing (F)	0.7 cm diameter 5 cm long
(3) Condensing	1	Copper pipe (G)	1 cm outside diameter, 5 cm longer than can height
	1	1-Hole Rubber Stopper (H)	Approximately 2.5 cm diameter (large end)

1	Glass Tubing (I)	0.7 cm diameter, 5 cm long

b. Construction

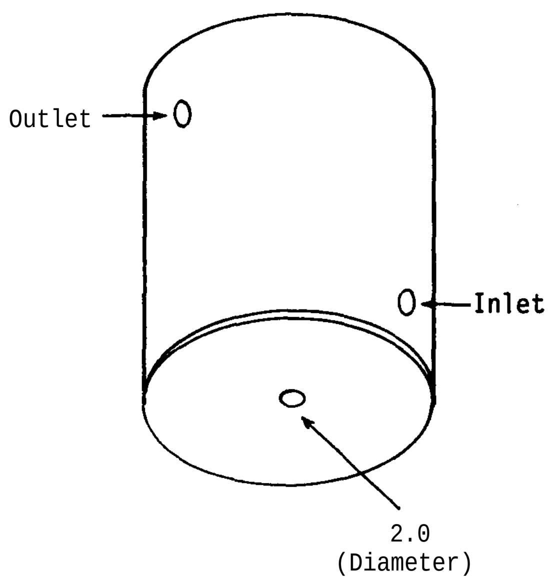
(1) Frame Support

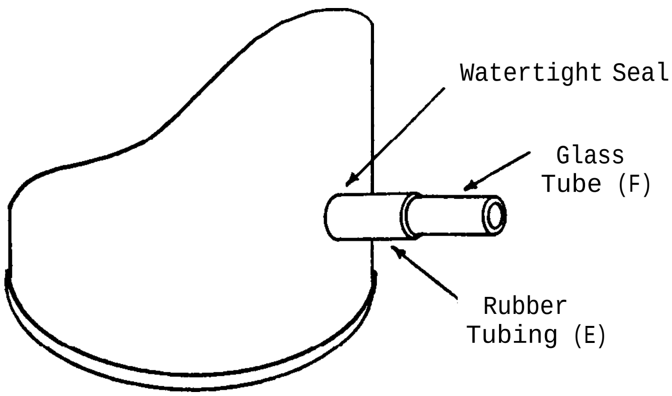
Nail two pieces of wood (A) to a flat piece (B) to form a base and uprights. Then nail two more pieces of wood (A) to the outsides of the uprights, as shown, to form supports for the can.



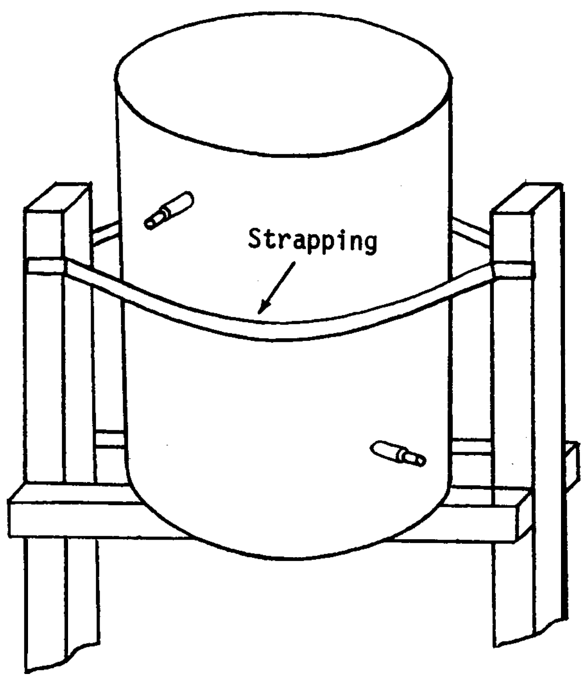
(2) Water Jacket

Cut a hole approximately 2 cm in diameter in the center of the bottom of the can (D). Crimp the cut edges inward. Cut a smaller hole, not quite 1 cm in diameter, in the side of the can near the bottom, to accommodate the inlet tube. Cut another small hole, not quite 1 cm in diameter, in the side of the can near the top, for the outlet tube.





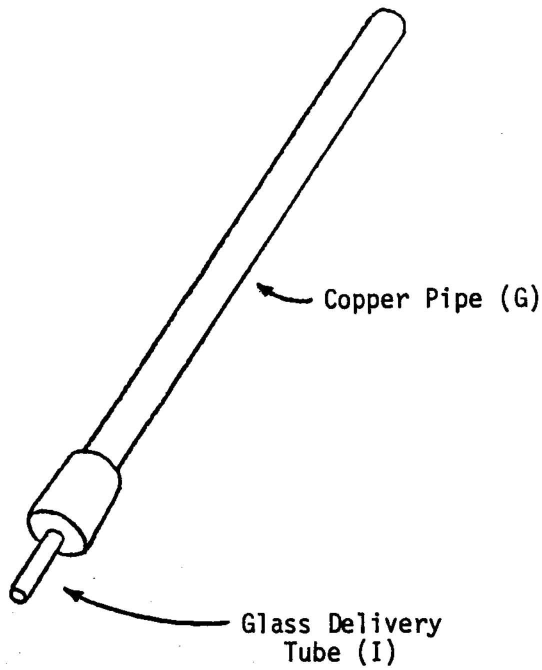
Insert each short piece of glass tubing (F) into a short piece of rubber tubing (E). Insert each rubber tube into one of the two small holes in the can. If the rubber tubes do not fit snugly by themselves, make a watertight seal with candle wax or epoxy resin.



Set the can in place in the frame support. To secure it in position, nail two pieces of strapping (C) to the frame support, one on each side of the can.

(3) Condensing Pipe

Choose a one-hole rubber stopper (H) that tightly seals the hole in the bottom of the water jacket can. Insert a short piece of glass tubing (I) part way through the stopper, from the large end. Insert the copper pipe (G) into the stopper from the other end.



Insert the condensing pipe into the water jacket can through the hole in the bottom of the can. Push the stopper tightly into the hole from the outside. Seal with candle wax or epoxy resin, if necessary, to produce a watertight seam.

c. Notes

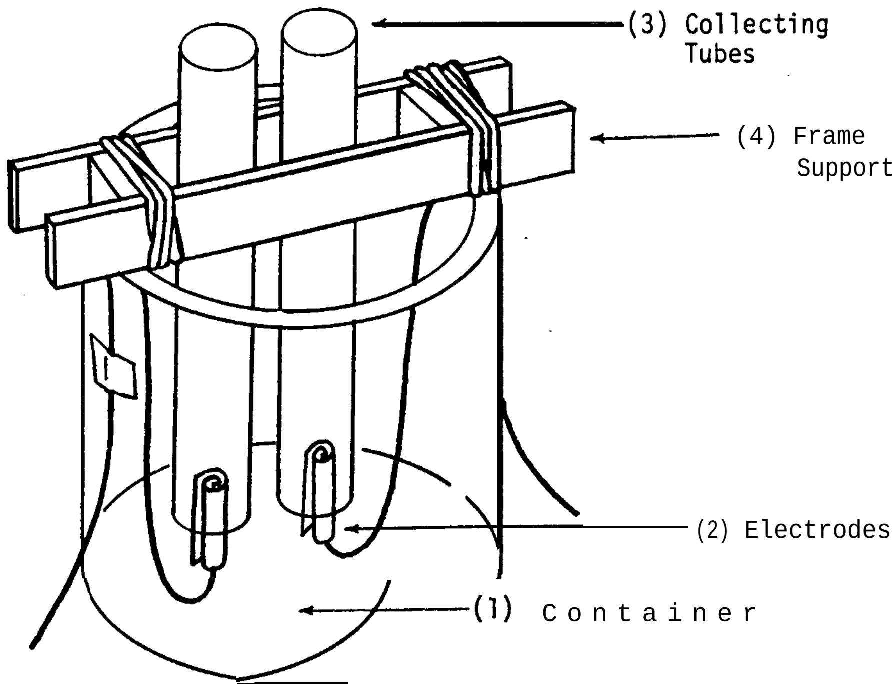
(i) A plastic or rubber tube from a water source is attached to the inlet tube, and another tube is attached to the outlet tube and led to a drain. A plastic or rubber tube from the container in which water is boiled is connected to the free end of the copper condensing pipe. Water vapor flowing through this tube will condense and drip from the glass delivery tube at the bottom of the still, where it can be collected.

(ii) This still is suitable for continuous operation, in order to produce distilled water for class use. In such a case, a large kettle should be used for boiling the water, and a plastic or rubber tube can be attached to the delivery tube and led to a storage container.

(iii) The size of the frame support for this still is determined by the size of the can used for the water jacket. Its dimensions will vary, according to the size of the can used.

C. ELECTRIC SEPARATOR

Cl. Electrolysis Apparatus



a. Materials Required

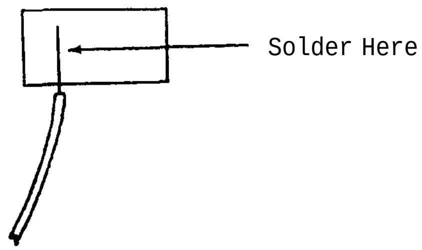
Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Jar (A)	Approximately 100-200 ml capacity
(2) Electrodes	2	Stiff Wire, Insulated (B)	Approximately 0.1 cm diameter, 25 cm long
	2	Thin Copper Sheet (C)	1.5 cm x 3.0 cm
	2	Masking or Adhesive Tape (D)	2 cm x 4 cm
(3) Collecting Tube	2	Test Tubes or Vials (E)	Approximately 1.5 cm diameter, 10 cm long
(4) Frame Support	2	Wood Strips (F)	0.2 cm x 2 cm x 15 cm
	2	Wood Blocks (G)	Approximately 2 cm x 2 cm x 1.3 cm
	2	Rubber Bands (H)	Approximately 0.2 cm x 4 cm

b. Construction

(1) Container

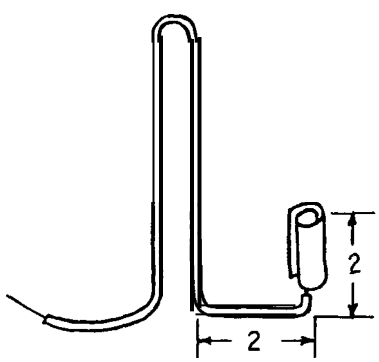
Choose a small glass jar (A) with a capacity of 100 - 200 ml, or cut off the top of a jar to make a container of appropriate size.

(2) Electrodes

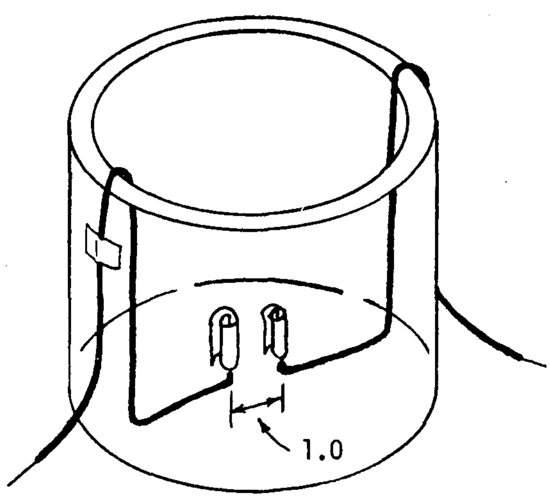


Strip about 1.5 cm of the insulation off each end of the stiff, insulated wire (B). Solder one end of each wire to a piece of the copper sheet (C), as shown.

When the solder has cooled, roll the copper sheet (C) into a spiral plate.



Bend each of the stiff wires (B) as illustrated. Make the large loop long enough to fit over the lip of the container (A) when the flat 2 cm portion of the wire is resting on the bottom of the container.



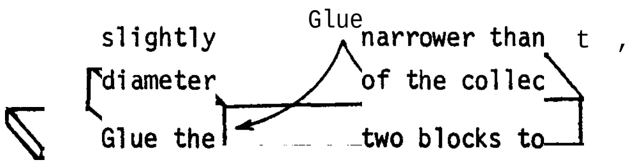
Place the electrodes at opposite sides of the container. Adjust the bends, if necessary, so that the plates of the electrodes are about 1 cm apart. Secure the wires to the outside of the container with tape.

(3) Collecting Tubes

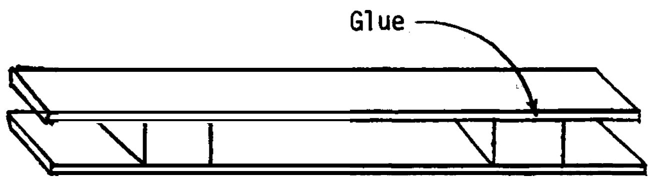
For the collecting tubes (E), use small glass or plastic test tubes or vials that are slightly taller than the height of the container (A).

(4) Frame Support

For the frame support, use two thin, flexible wooden strips (F) about twice as long as the diameter of the container. Cut two small wooden blocks (G) just h e diameter of the collecting tubes.



to one of the strips, about 5 cm apart.



Glue the other strip to only one of the blocks, as shown.

Hold the rubber bands (H) aside until the apparatus has been set up [see Note (i)].

C. Notes

(i) This apparatus is used to separate water into oxygen and hydrogen, which are collected in the tubes. The container is filled with water sufficient to cover the terminals by less than 1 cm. A little vinegar or washing soda ($Na_2CO_3 \cdot 10H_2O$) is added to the water to increase its conductivity. The collecting tubes are filled with the same acidic (vinegar) or basic (Na_2CO_3) solution. Then, with the open end sealed with a thumb or forefinger, each tube is inverted and placed into the container. The open end of the tube must be placed below the surface of the solution before it is uncovered. Then, without being lifted out of the solution, each tube is placed over one of the electrodes.

The frame support may be placed around the two collecting tubes. It is secured tightly around the tubes with rubber bands at each end. With the tubes thus supported, the frame is rested on the top of the container and the tubes are carefully adjusted so that the open ends do not rest on the bottom of the container, but are about 1 cm above the bottom and below the surface of the solution in the container.

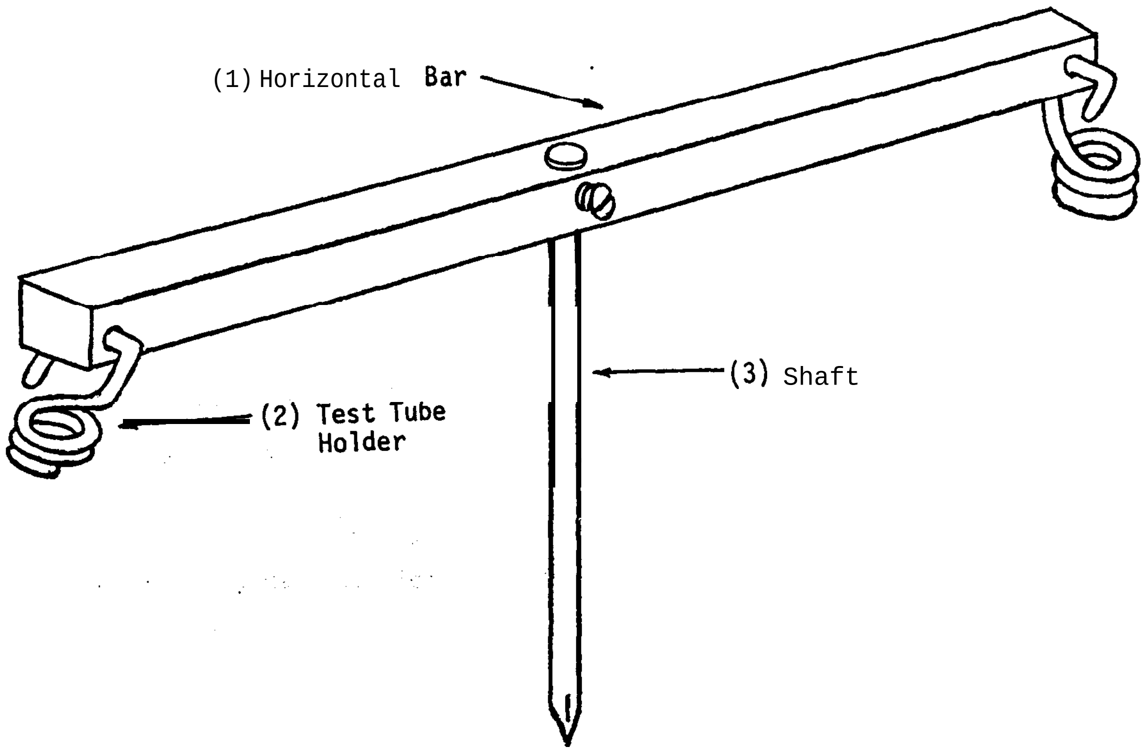
When the free ends of the electrodes are connected to three or more 1.5 volt cells connected in series, sufficient current passes through the solution to break down the water. Hydrogen is the gas generated at the negative plate (cathode) and collected in the tube placed over that plate. Oxygen is generated at the positive plate (anode) and is collected approximately one half as rapidly as hydrogen.

(ii) This apparatus is quite suitable for student use in the laboratory, as it is simple to set up and requires little current. With three or more 1.5 volt cells, the gases are evolved rapidly and the tubes can be filled in about 20 - 30 minutes.

(iii) Several factors enhance the efficient operation of this apparatus. The small volume of solution used and the proximity of the plates reduce the amount of resistance in the system and allow it to function on low current. If the plates are cleaned after each use, the apparatus will also function more efficiently.

D. CENTRIFUGAL SEPARATORS

Dl. Hand Drill Centrifuge

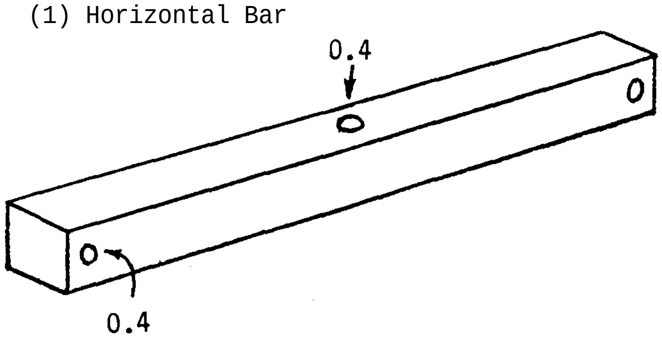


a. Materials Required

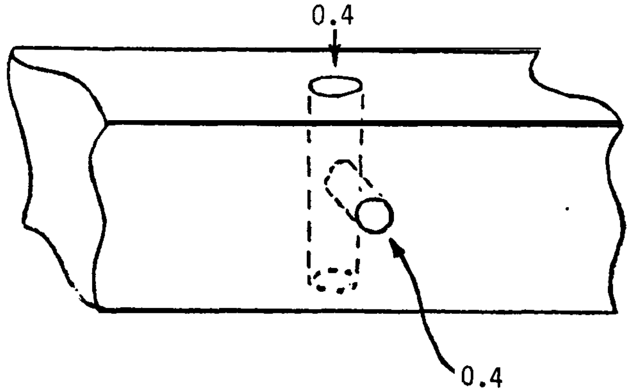
Components	Qu	Items Required	Dimensions
(1) Horizontal Bar	1	Wood (A)	2 cm x 2 cm x 32 cm
(2) Test Tube Holder	2	Stiff Wire (B)	Approximately 0.2 cm diameter, 30 cm long
(3) Shaft	1	Nail (C)	0.5 cm diameter, 18 cm long
	1	Bolt (D)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Horizontal Bar

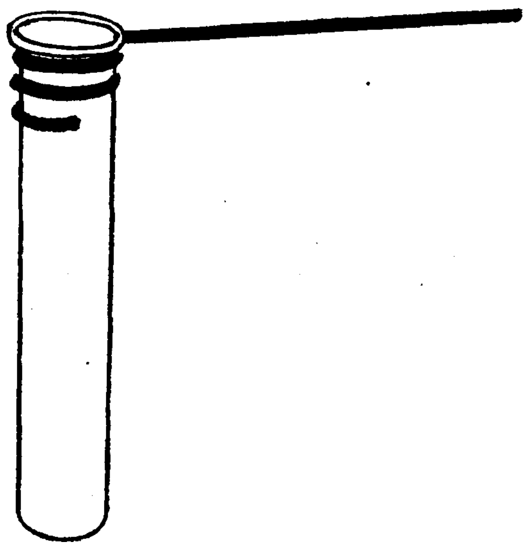


Drill holes, approximately 0.4 cm in diameter, at each end of the wooden bar (A). Drill a hole through the center of the bar, as shown. Make the diameter of this hole slightly smaller than the diameter of the nail (C) used for the shaft.

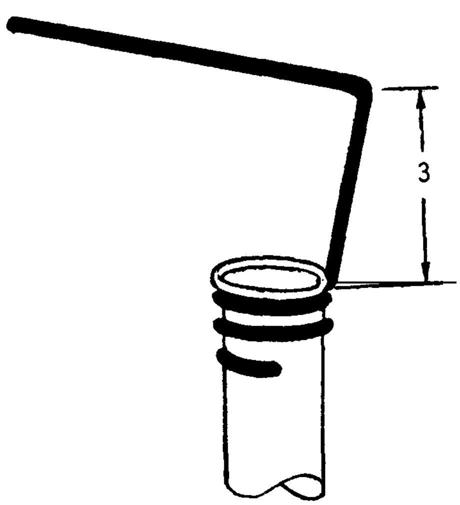


Then, drill a hole perpendicular to and intersecting the hole in the center of the bar. Make the diameter of this hole slightly smaller than the diameter of the bolt (D) used to hold the shaft in place.

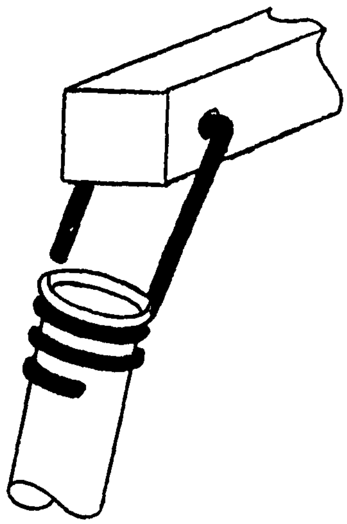
(2) Test Tube Holder



Take a test tube of the size that will be used in the centrifuge. Wind one piece of heavy, stiff wire (B) (coat hanger wire, for example) around the test tube two or three times. Make the coil very snug around the test tube so that the test tube lip will not slip through it. Leave a straight portion of about 8 - 9 cm at the top of the coil.



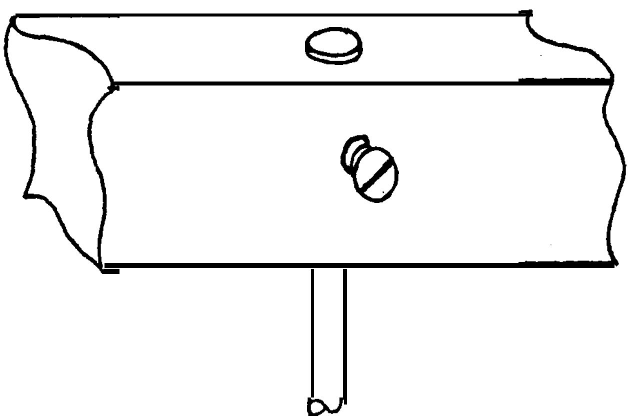
Bend the straight portion of the wire at an angle to the rest of the coil as shown. About 3 cm from the coil, bend the wire again, at right angles to the upright portion.



Fit the free end of the wire into one of the end holes in the horizontal bar. Check to see that the fit is loose enough for the holder to swing easily. Then bend the excess wire down, as shown, to secure the holder in the horizontal bar.

Repeat this procedure for the construction of the second test tube holder.

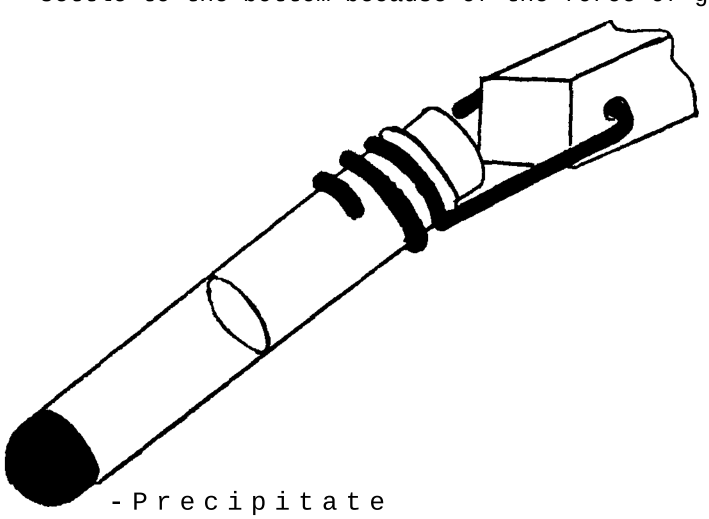
(3) Shaft



Carefully thread the short bolt (D) into the center, horizontal hole in the horizontal bar. Then unscrew it halfway. Fill the nail hole (vertical hole) with epoxy glue and tap the nail (C) into the hole. Tighten the bolt against the nail and coat the threads of the bolt with epoxy glue.

C. Notes

(i) A precipitate formed by a chemical reaction in a test tube will eventually settle to the bottom because of the force of gravity acting upon it. The time required for a given precipitate to settle is dependent on several factors; among these are the volume, density, and particle size of the precipitate. Spinning such material in a test tube in a centrifuge reduces this duration by creating a strong centrifugal force, which causes the heavier precipitate to settle to the



outside of the centrifuge. When the test tube holders are free to pivot outward, as in this centrifuge, the test tubes will assume a nearly horizontal position when the centrifuge is in rapid motion. Thus, the bottom of the test tube becomes the "outside" of the centrifuge, and precipitate is pulled to the bottom of the tube.

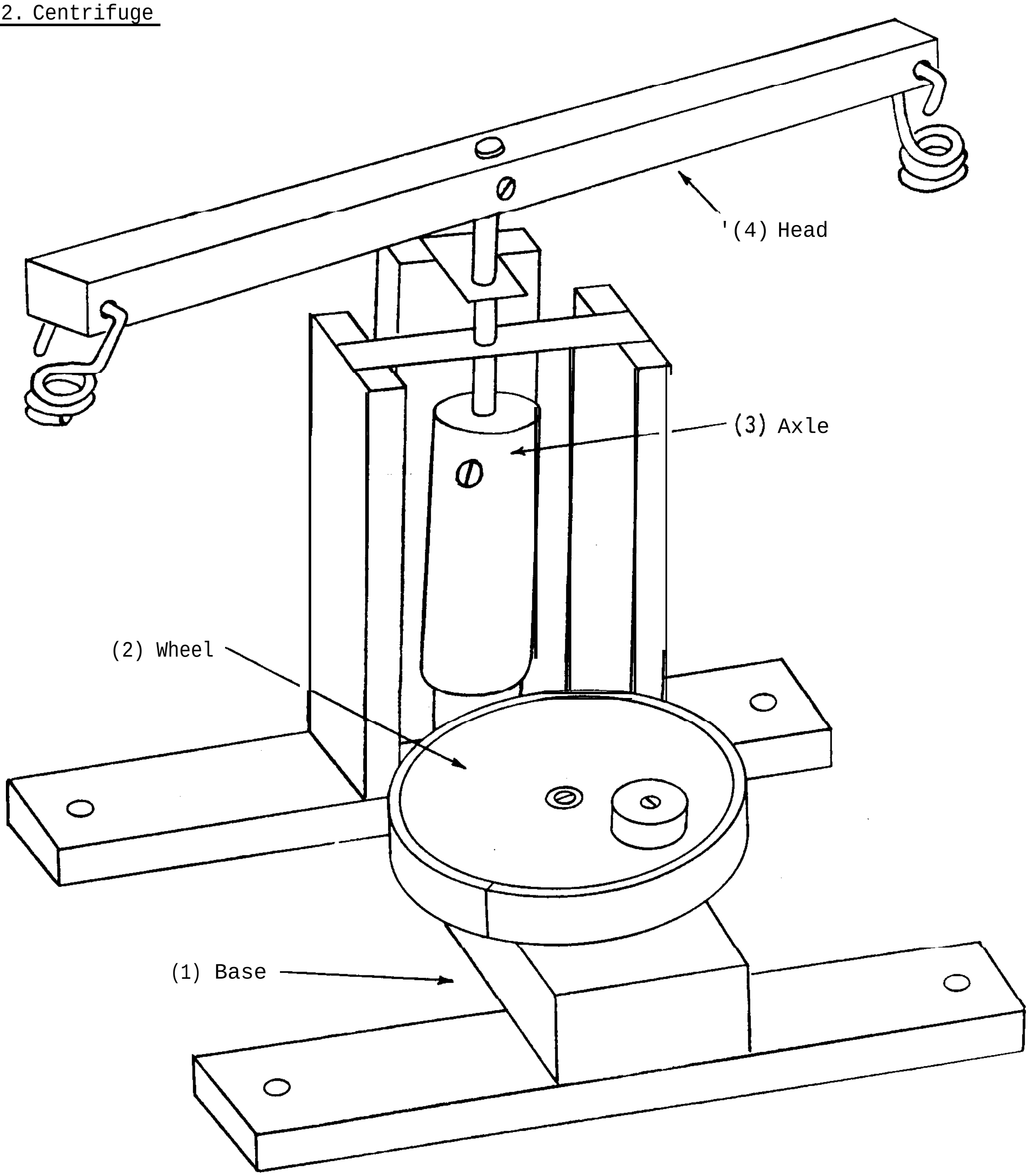
(ii) To use this centrifuge, place an appropriately sized test tube containing material to be centrifuged through one of the wire holders. To balance the centrifuge, place a test tube with an equal volume of water in the other holder. Take care to insure that the test tubes are securely held in place by the holders. Seal both test tubes with corks or stoppers to prevent spillage. Fix the end of the shaft firmly in a hand drill. Clamp the drill handle tightly in a heavy vise, stand at arm's length from the drill, and turn the handle of the drill. The centrifuge will spin, causing the precipitate to collect at the bottom of the test tube. To stop the centrifuge, let go of the drill handle and allow the centrifuge to continue to spin until it comes to a gentle stop. Another way to stop the centrifuge is to turn the drill handle more and more slowly until it is brought to a gentle stop. Sudden stops, which will shake up the precipitate, are to be avoided.

(iii) If a vise is not available, the drill may be held at arm's length from the body while the centrifuge is spun.

(iv) This centrifuge is capable of being spun at 300 - 500 revolutions per minute. It was tested with several precipitates, such as $CaCO_3$ and $AgNO_3$, and was found to reduce settling time from several hours (gravity) to less than one minute.

(v) This centrifuge, whether clamped in a drill or held at arm's length, must be used with extreme care since the test tubes swing close to the user. A safer, more permanent centrifuge, which incorporates this centrifuge as its rotating assembly, is described in the following section.

D2. Centrifuge



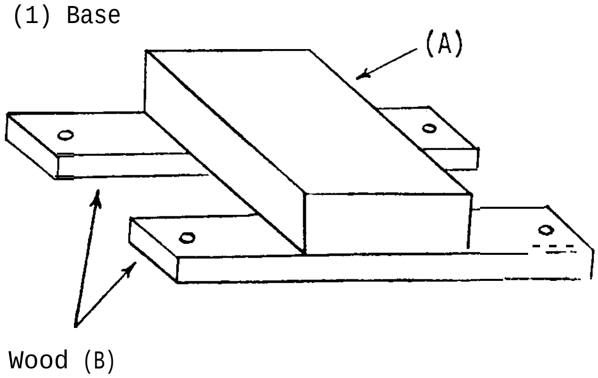
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	4 cm x 9 cm x 30 cm
	3	Wood (B)	2 cm x 5 cm x 30 cm
	2	Wood (C)	2 cm x 5 cm x 25 cm

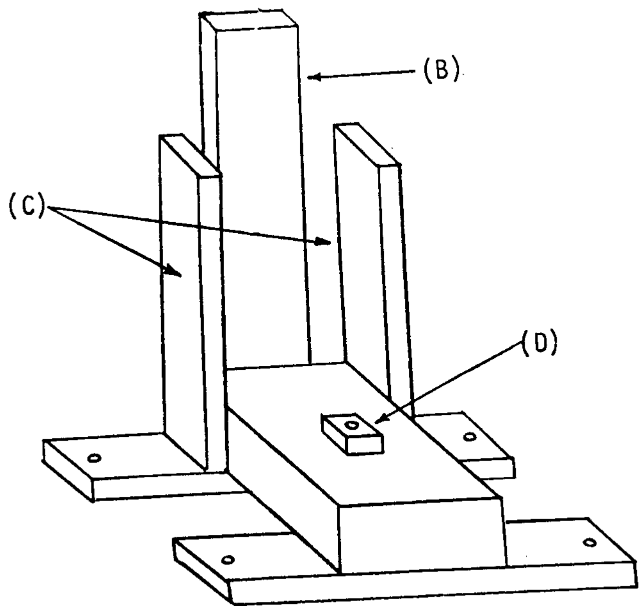
	1	Wood (D)	Approximately 3 cm x 3 cm x 1 cm
(2) Wheel	1	Wood (E)	1 cm x 15 cm x 15 cm
	1	Wooden Spool (F)	Approximately 3 cm x 3 cm x 3 cm
	2	Washers (G)	Approximately D.8 cm inside diameter, 2.0 cm outside diameter
	1	Screw (H)	Approximately 0.6 cm diameter, 6.0 cm long
	1	Screw (I)	Approximately 3 cm long
	1	Rubber Strip (J)	1 cm x 50 cm
(3) Axle	1	Wood (K)	4 cm x 4 cm x 16 cm
	1	Wooden Spool or Dowel (L)	3 cm diameter, 3.5 cm long
	3	Finishing Nails (M)	Approximately 5 cm long
	1	Screw (N)	Approximately 0.6 cm diameter, 6.0 cm long
	2	Washers (0)	Approximately 0.8 cm inside diameter, 1.5 cm outside diameter
	1	Nail (P)	0.5 cm diameter, 18 cm long
	1	Bolt (Q)	Approximately 0.5 cm diameter, 2 cm long
	1	Rubber Strip (R)	3.5 cm x 10 cm
	2	Metal Strapping (S)	11 cm x 1 cm
(4) Head	1	Wood (T)	2 cm x 2 cm x 32 cm
	2	Stiff Wire (U)	Approximately 0.2 cm diameter, 30 cm long
	1	Bolt (V)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Base

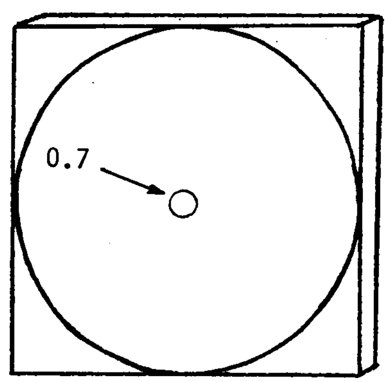


With nails or glue and screws, secure the thick piece of wood (A) to two pieces of wood (B) as shown to form the feet and bottom of the base. Drill a hole approximately 0.5 cm in diameter at each end of the feet (B).



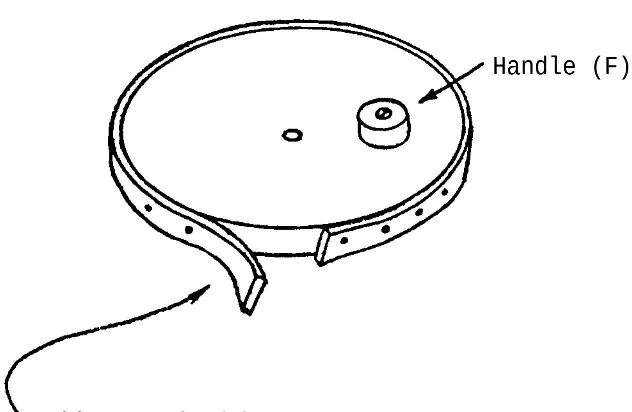
Next, nail or glue and screw the third piece (B) to the bottom of the base, in an upright position as shown. Secure the two shorter uprights (C) in position as shown. Glue the small piece of wood (D) to the center of the horizontal board. When the glue has dried, drill a hole about 0.5 cm in diameter through the small piece of wood (D) and a centimeter or so into the base (A).

(2)Wheel



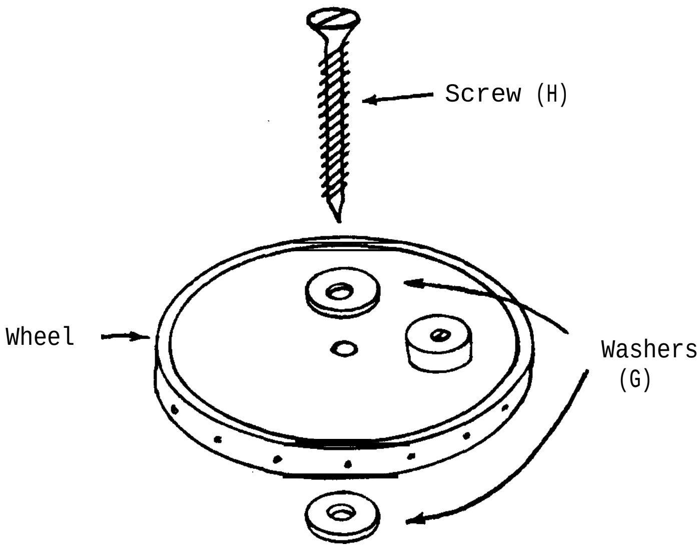
Wood (E)

Inscribe a circle in the thin wooden square (E). Carefully cut out the circle. Drill a hole, 0.7 cm diameter, through the center of the circle.



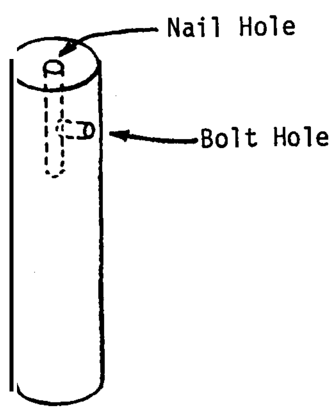
Fasten the strip of rubber sheeting (J) (e.g., from a tire inner tube) to the circumference of the wheel with glue and small nails with heads.

With the shorter screw (I), fasten the wooden spool (F) loosely to the wheel about halfway between the center and edge of the wheel. The handle must be free to rotate around the screw.

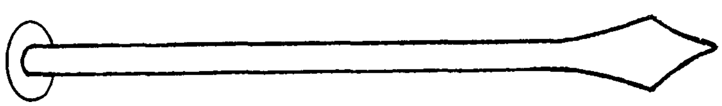


Mount the wheel to the base by inserting the long screw (H) through a washer (G), through the wheel, then through the second washer (G). The holes in the wheel and washers should be slightly larger in diameter than the screw (H). Finally, turn the screw firmly into the small piece of wood (D) on the horizontal board of the base. Make certain that the wheel will rotate freely around the screw without wobbling.

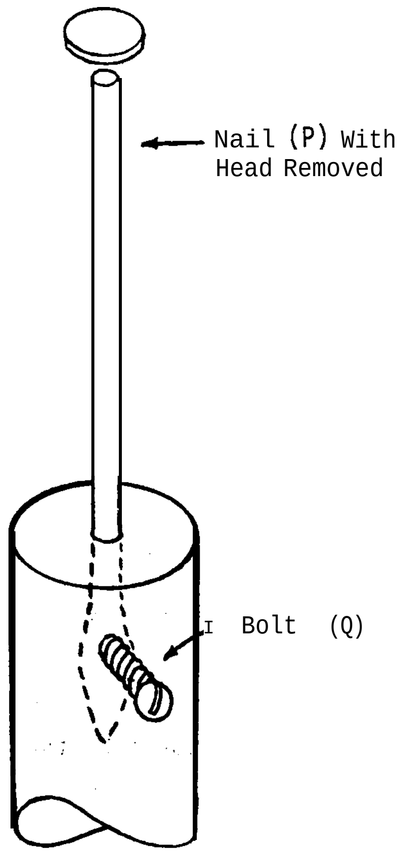
(3) Axle



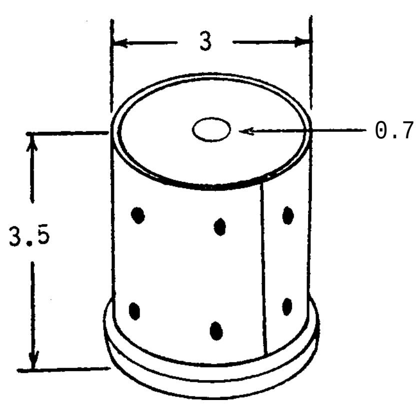
For the upper section of the axle, use the wooden block (K) or dowel. Drill a hole approximately 0.4 cm in diameter and approximately 5 cm deep into the center of one end of the block. Then drill a second hole, about 2.5 cm from the end, at a right angle to and intersecting the first hole. Make the hole about 0.4 cm in diameter, or just a little smaller than the bolt (Q) which is to be threaded into it.



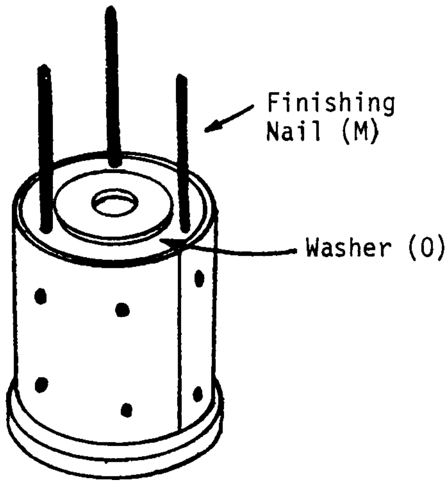
Flatten the end of a large nail (P) by hammering it on a metal block or anvil.



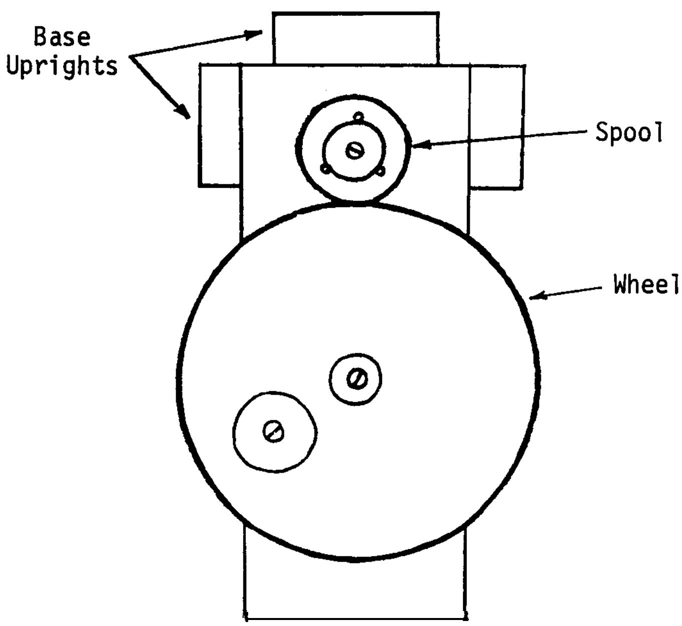
Carefully thread the bolt (Q) as far as possible into the bolt hole in the axle, then unscrew it halfway. Fill the nail hole with epoxy glue, and tap the nail (P) into the hole. Tighten the bolt against the nail, then coat its threads with epoxy glue. Finally, cut the head off the nail.



For the lower section of the axle, use a wooden spool (L) from which the thread has been removed, or a 3 cm diameter dowel. Cut the spool or dowel to a height of about 3.5 cm. Fasten a strip of rubber sheet (R) around the outside, just as for the wheel. Enlarge the hole in the spool to about 0.7 cm diameter.

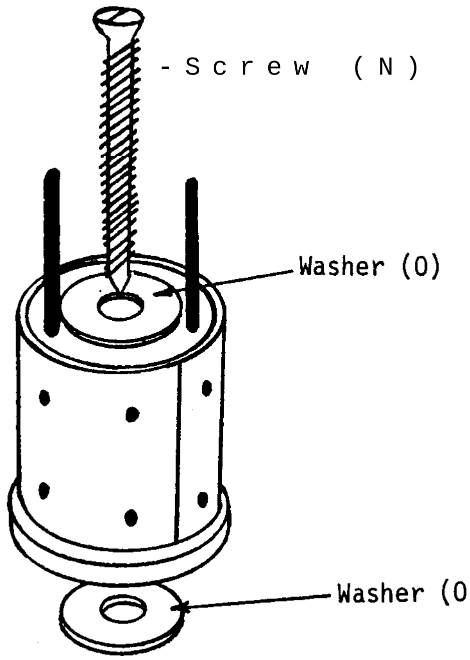


Fit one washer (O) on the top of the spool, aligning the holes of spool and washer. Drive three small finishing nails (M) into the top of the spool, outside the washer. Let approximately 3 cm of nails protrude from the top of the spool, and cut off their heads.

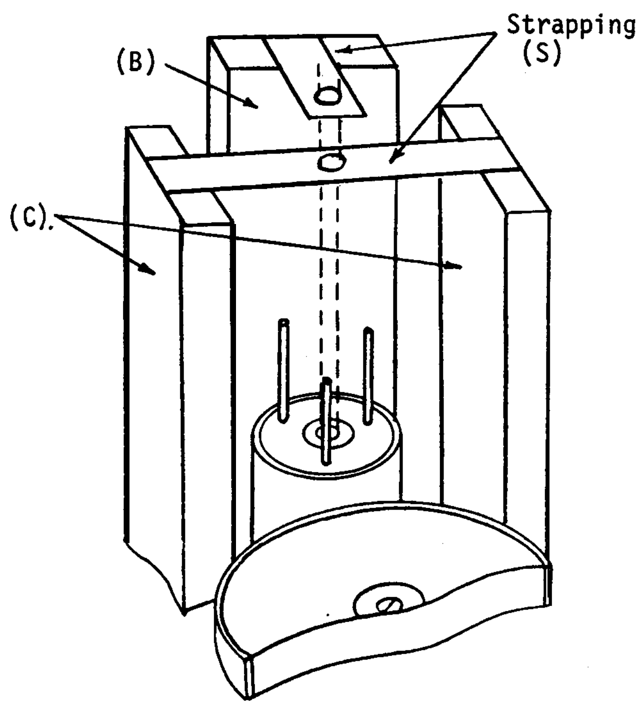


Overhead View of Base, Wheel
and Axle Location

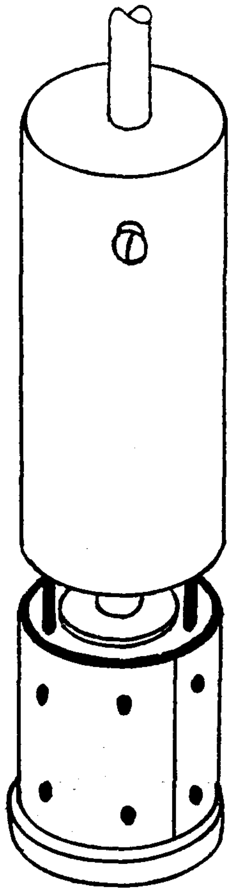
Locate the position of the axle by setting the spool on the horizontal board (A) of the base such that the rubber strip on the spool presses firmly against the rubber strip on the wheel. Mark the position of the center of the spool, and drill a small hole at that position.



Mount the spool (L) on the horizontal board (A) of the frame by passing a long screw (N) through the washer (0) and spool (L); then through a second washer (O), and into the hole in the base. Turn the screw firmly into the horizontal board, so that the spool is free to rotate. In addition, the edge of the wheel must rub the edge of the spool firmly enough so that when the wheel turns, the spool also rotates.



Construct strapping braces for the axle as follows: Drill a hole 0.8 cm in diameter in the center of one of the pieces of metal strapping (S). Nail this piece to the two shorter uprights (C) of the base such that the hole in the strapping is directly over the center of the spool on the base below. Drill a similar hole near one end of the other piece of strapping (S), and nail it, as shown, to the taller upright of the base (B) such that its hole is directly over the hole in the strapping below it. Trim off any excess.



Slip the nail end of the upper section of the axle through the holes in the strapping braces. Rest the other end of the upper section evenly on the tops of the three nails in the spool, and then drive the upper section into the nails with a hammer so that the spool and upper section will form a continuous solid piece. However, do not drive the upper section so far down that its end will hit the top of the screw and prevent the entire axle from turning. If this operation has been done correctly, the axle will turn when the wheel is rotated.

(4) Head

Prepare the horizontal bar and test tube holders according to directions given for the Hand Drill Centrifuge, VI/Dl, using the wood (T) and stiff wire (U). Secure the nail of the axle to the centrifuge head according to directions given in VI/D1 with the bolt (V).

c. Notes

(i) The centrifuge should be bolted or clamped to the table top before using.

(ii) To use this piece of apparatus% the substance to be centrifuged is placed in an appropriately sized test tube. A second test tube is filled with an equal amount of material to be centrifuged or an equal volume of water. Each test tube is placed in one of the holders and checked to see that they will not slip out through the holder. Both test tubes are sealed with stoppers. Stand at arm's length from the centrifuge and turn the wheel, first slowly, then more and more rapidly. The tubes will be spun about in a nearly horizontal position. Do not try to stop the centrifuge suddenly by holding the wheel stationary; either let go of the wheel and allow the centrifuge to come to a gentle stop, or turn the wheel more and more slowly until the centrifuge is brought to a gentle stop.

(iii) Matched pairs of test tube holders of various sizes may be constructed and used interchangeably in the same centrifuge head, if desired.

(iv) When the wheel of this centrifuge is turned rapidly, about 150 turns per minute, for example, the centrifuge head spins at nearly 500 revolutions per minute.

VII. GAS GENERATORS

The apparatus used in the production of gases has been placed in two sections, one of which contains the complete apparatus for gas generation while the second section contains two devices useful in collecting gases.

A. GAS GENERATORS

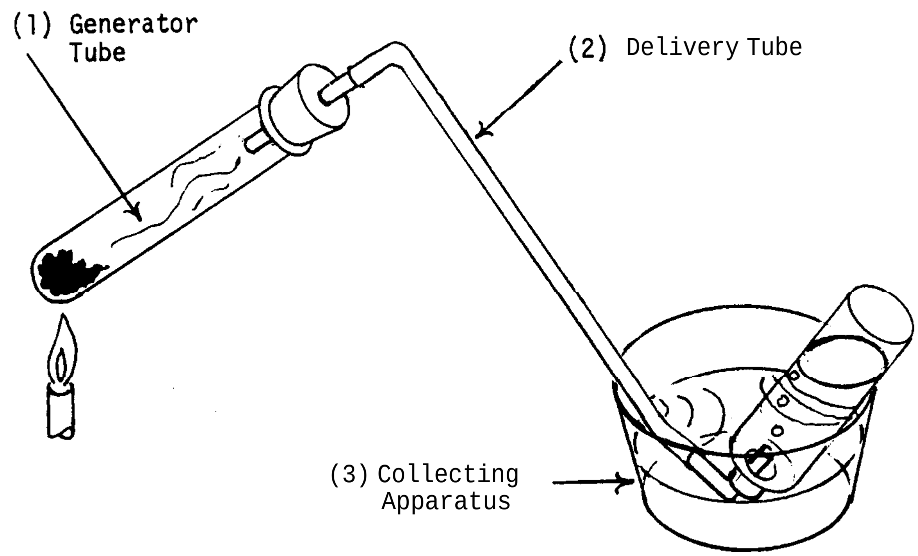
Three types of generators will be given: simple devices for which no special equipment is required; and an inexpensive version of Kipp's gas generator.

B. ACCESSORIES

Included here are the beehive shelf and metal sheet shelf.

A. GAS GENERATORS

Al. Simple Gas Generator and Collecting Apparatus



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Generator Tube	1	Test Tube or Flask (A)	Capacity at least 50 ml
	1	l-Hole Rubber Stopper (B)	To fit generator tube (A)
(2) Delivery Tube	1	Glass Tubing (C)	0.5 cm diameter, 5-10 cm long
	1	Rubber or Plastic Tubing (D)	To fit glass tubing (C and E), 30 cm long
	1	Glass Tubing (E)	0.5 cm diameter, 15-25 cm long
(3) Collecting Apparatus	1	Test Tube, Flask, or Bottle (F)	Capacity at least 50 ml
	1	Bowl or Pan (G)	250 ml or greater capacity

b. Construction

(1) Generator Tube

For the generator tube, use a hard-glass test tube or flask suitable for heating (A). Secure test tube in a slanted position with an appropriate clamp or support (IV/B5 or B6).

Fit the generator tube with a one-hole rubber stopper (B).

(2) Delivery Tube

Insert the shorter glass tube (C) through the one-hole rubber stopper. Connect the rubber or plastic tubing (D) to the free end of the glass tube (C). Bend the longer glass tube (E) at a 90' angle or less, and connect it to the flexible tubing (D).

(3) Collecting Apparatus

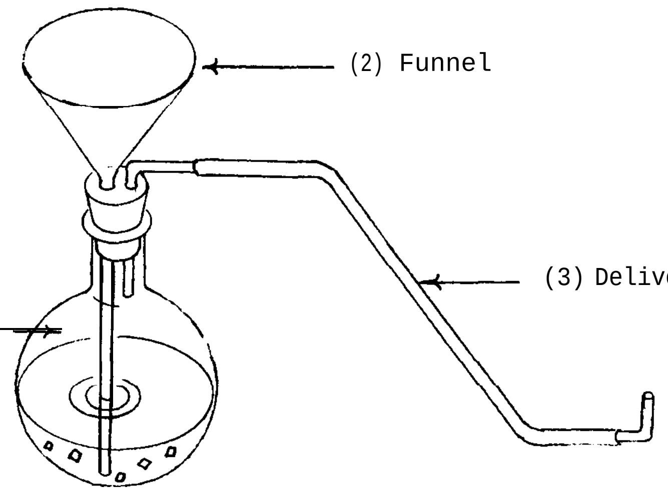
Select a large test tube, flask, or bottle (F). Fill with water, cover the opening, and invert in a bowl or pan of water (G) so that the water is held in the bottle (F). Uncover the opening and place the free end of glass tubing (E) into the mouth of the collecting tube.

c. Notes

(i) This apparatus is suitable for student use in generating small amounts of gases which are insoluble or only slightly soluble in water.

(ii) Small amounts of reactants are placed in the generator tube and carefully heated (if heating is required). The gas generated passes through the delivery tube, and is collected by displacing the water in the collecting tube.

A2. Flask Generator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Generator Flask	1	Flask or Bottle (A)	250 ml capacity or larger
	1	2-Hole Rubber Stopper (B)	To fit flask (A)
(2) Funnel	1	Long-necked Funnel (C)	Approximately 10 cm diameter (large end)
(3) Delivery Tube	2	Glass Tubing (D)	0.5 cm diameter, 15-25 cm long
	1	Plastic or Rubber Tubing (E)	To fit glass tubing, approximately 30 cm long

b. Construction

(1) Generator Flask

Support the flask or bottle (A), if necessary, in a suitable support. Fit the flask with a two-hole rubber stopper (B).

(2) Funnel

Select a funnel (C) with a sufficiently long neck to reach nearly to the bottom of the flask (A). Carefully push the funnel neck through one of the holes in the stopper (B).

(3) Delivery Tube

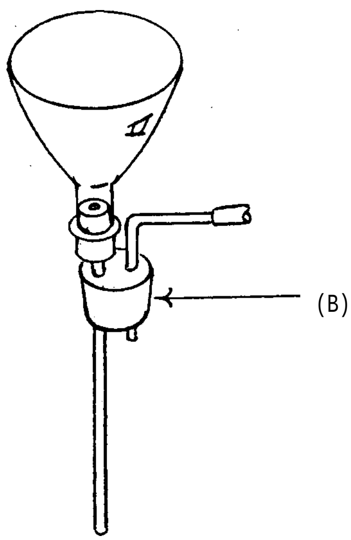
Make a 90' bend in each piece of glass tubing (D). Connect these with flexible tubing (E). Insert one of the glass tubes into the second hole of the rubber stopper (B).

c. Notes

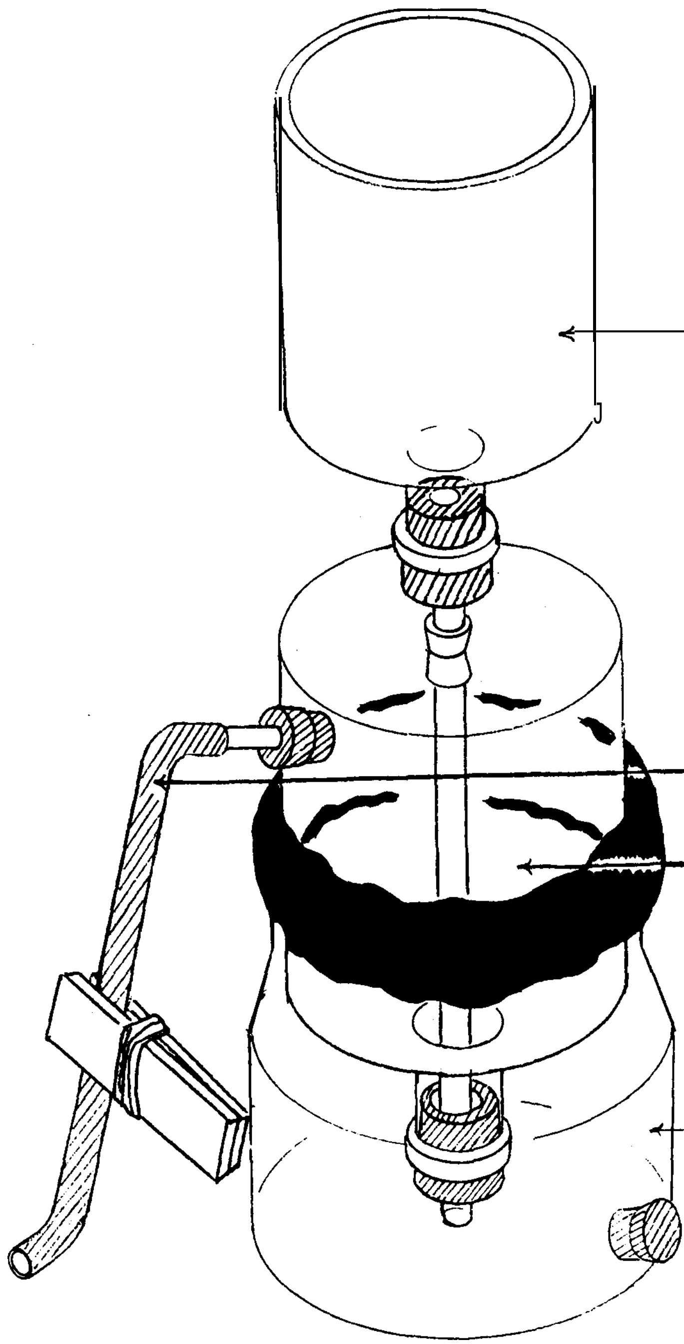
(i) This apparatus is used in conjunction with the collecting apparatus just as described in the previous section (VII/Al).

(ii) This device is generally chosen when the gas generating reaction involves a solid (such as zinc) and a liquid (such as dilute sulfuric or hydrochloric acid). The solid is placed in the bottom of the generator flask, then the rest of the apparatus is placed in position. When the collecting bottle is in place, the liquid reagent is added through the funnel. Thus, the reaction does not begin until the apparatus is sealed. Additional liquid can be added to the flask without dismantling the apparatus.

(iii) If a funnel made from a cut-down bottle is used (V/A3), it will be necessary to adapt the construction of this item slightly. Connect such a funnel to the flask (A) with a long piece of glass tubing running through the stopper (B) and a one-hole stopper fitted into the funnel.



A3. Kipp's Generator *



*Adapted from C S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 174-175.

a. Materials Required

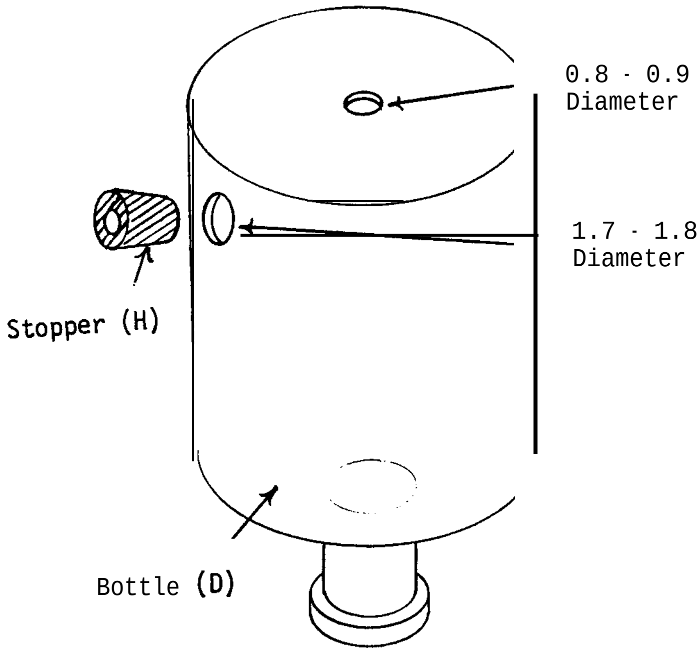
Components	Qu	Items Required	Dimensions
(1) Acid Container	1	Glass Jar (A)	Capacity approximately 500 ml
	1	Rubber Stopper (B)	Approximately 2.0 cm diameter (large end)
	--	Plasticine (Modeling Clay) or Pitch (C)	4 cm x 4 cm x 4 cm
(2) Reaction Flask	1	Glass Bottle (D)	Capacity approximately 500 ml
	1	1 or 2-Hole Rubber Stopper (E)	To fit bottle (D)
	1	Glass Tubing (F)	Approximately 0.7 cm diameter, 30 cm long
	1	Rubber Tubing (G)	1.0 cm diameter, 3 cm long
	1	l-Hole Rubber Stopper (H)	Approximately 2.0 cm diameter (large end)
(3) Gas Delivery Tube	1	Glass Tubing (I)	0.7 cm diameter, 5 cm long
	1	Rubber Tubing (J)	1.0 cm diameter, 30 cm long
	1	Pinch Clamp (K)	(IV/A4)
(4) Funnel	1	Glass Bottle (L)	Capacity approximately 1 liter
	1	l-Hole Rubber Stopper (M)	To fit bottle (L)

b. Construction

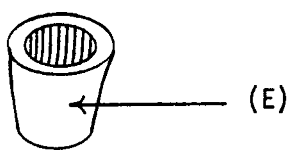
(1) Acid Container

Select a low, wide-mouth jar with a capacity of about 500 ml (A). Drill a hole in the side of the jar, just above the bottom, (I/E2). Enlarge the hole, by filing with a round file, to a diameter of 1.7 - 1.8 cm. Seal this hole with a solid rubber stopper (B).

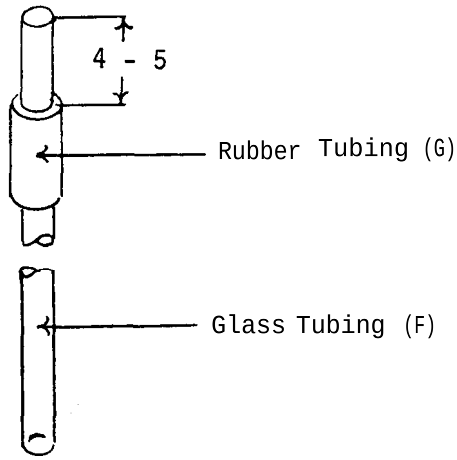
(2) Reaction Flask



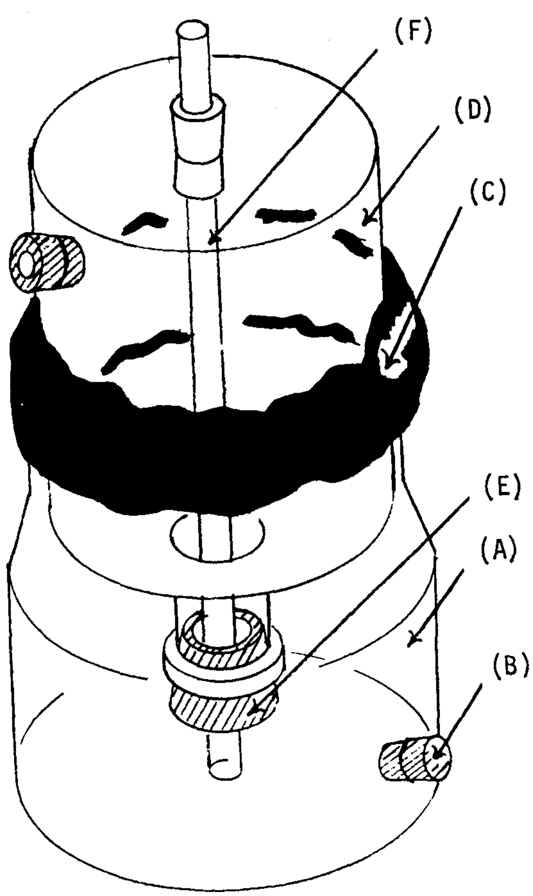
For the reaction flask, choose a narrow-necked bottle (D) that will just fit into the neck of the acid container (A). Drill a hole in the center of the bottom of the bottle (D), and enlarge the hole to a diameter of 0.8 - 0.9 cm. Drill a second hole in the side near the bottom. Enlarge this hole to a diameter of 1.7 - 1.8 cm. Fit a one-hole rubber stopper (H) into the side hole.



Select a stopper (E) that fits the neck of the bottle (D). If it is a one-hole stopper with a round file, enlarge the hole in the stopper to about two to three times its normal diameter. Fit this stopper into the neck of the bottle. If a two-hole stopper is available, make no alterations, and fit the stopper into the neck of the bottle (D).



Fire polish (I/D4) both ends of the glass tubing (F). Insert one end into the short length of rubber tubing (G). Allow 4 - 5 cm of glass tubing (F) to protrude beyond the rubber tubing (G).



Insert the long end of the glass tubing (F) into the bottle (D), from the bottom. Fit the end through the enlarged hole of the stopper (E), and carefully push and twist until the rubber tubing (G) around the glass tightly seals the hole in the bottom of the bottle (D).

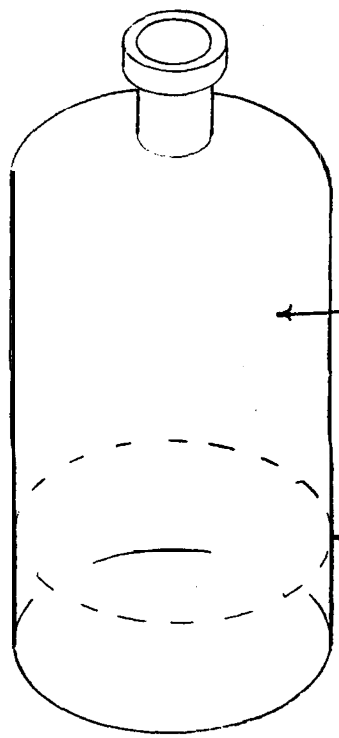
Set the reaction flask (D), neck down, into the neck of the acid container (A). Adjust and cut the glass tubing (F), if necessary, so its lower end is about 0.5 cm from the bottom of the acid container (A).

Roll the modeling clay (plasticine) (C) into a long cylinder and wrap it around the seam between reaction flask (D) and acid container (A). Press the clay firmly in place to make an airtight seal.

(3) Gas Delivery Tube

Insert a short piece of glass tubing (I) into the stopper in the side of the reaction flask. Attach rubber tubing (J) to the other end of the glass tube. Use a wooden pinch clamp (K) (IV/A4) or other suitable clamp to close the rubber tubing.

(4) Funnel



Construct a large funnel with a capacity equal to that of the acid container by cutting off the bottom third of a narrow-necked bottle (L) (I/F2). Smooth the rough cut edge of the funnel with emery cloth. Select a one-hole rubber stopper (M) to fit the funnel neck. Insert the glass tube (F) from the reaction flask (D) into the stopper (M).

Invert the funnel (L) and fit its neck tightly over the stopper (M).

Support the funnel in a ring stand (IV/B5) or other suitable holder.

C. Notes

(i) To complete the gas generating apparatus, the gas delivery tube of the Kipp's Generator must be connected to a suitable collection device such as that described in VII/A1 or the aspirator described in V/A8.

(ii) The solid reactant, such as zinc chips is added to the reaction flask (D) through the hole in the side. The solid will sit, for the most part, on the stopper (E) in the neck of the flask. The stopper (H) and gas delivery tube are then securely replaced in the reaction flask, and all connections and seals are checked to insure that they are gastight. Then the liquid reagent, such as 6M hydrochloric acid, is poured into the funnel (L).

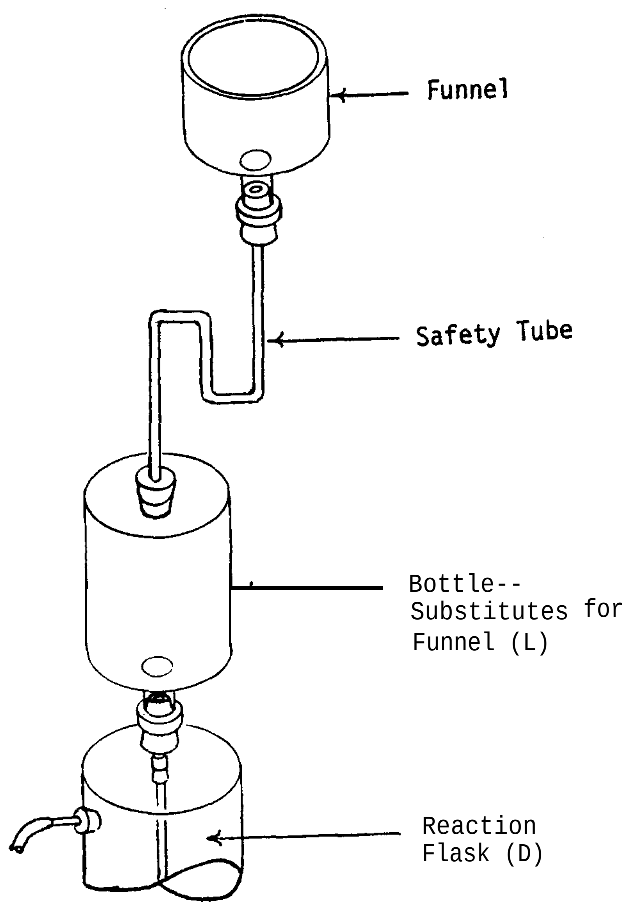
When the pinch clamp (K) is removed from the gas delivery tube, the acid will flow into the acid container (A). As the acid level rises above the neck of the reaction flask (K), it will flow into the reaction flask through the enlarged or second hole of the stopper (E) and will react with the solid to produce a gas (hydrogen, in this example). The gas will pass through the delivery tube to the collecting vessel.

(iii) The reaction can be stopped without removing any of the reactants or dismantling the equipment. When the gas delivery tube is closed with the pinch clamp, the pressure of the gas accumulating in the reaction flask will force the acid out of the reaction flask and back into the acid container until it is no longer in contact with the solid. Some of the acid will also be forced back up the glass tube and into the funnel. The funnel must therefore be large enough to safely contain a large volume of acid that might be backed up.

To restart the reaction, the delivery tube is opened, and acid again flows into the acid container and.reaction flask to evolve more gas.

(iv) This device is suitable for evolving large quantities of a gas for class use, or as a demonstration. It should be possible to build a larger model, but experimentation with the size relationships between the funnel, reaction flask, and acid container will be necessary.

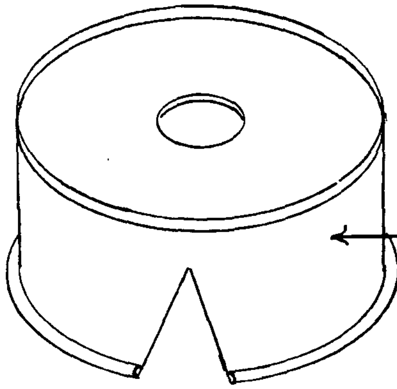
(v) If the Kipp's Generator is to be employed for continuous classroom use, a safety tube and funnel may be substituted for the large funnel to prevent the escape of unpleasant or undesirable acid fumes. A piece of glass tubing, approximately 0.7 cm diameter and 35 - 40 cm long, is bent as shown. This is connected, by means of a rubber stopper at the upper end, to a funnel. A bottle with a hole drilled in the bottom is substituted for the large funnel (L), and the lower end of the safety tube is connected to this bottle with a one-hole rubber stopper or short piece of rubber tubing.



The whole apparatus must be supported in a stand or frame of some kind.

B. ACCESSORIES

Bl. Beehive Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	9 cm diameter x 5 cm high

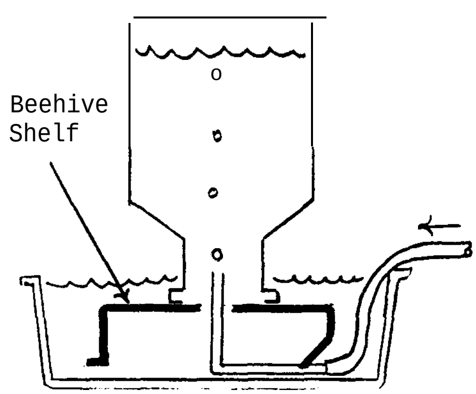
b. Construction

(1) Tin Can Shelf

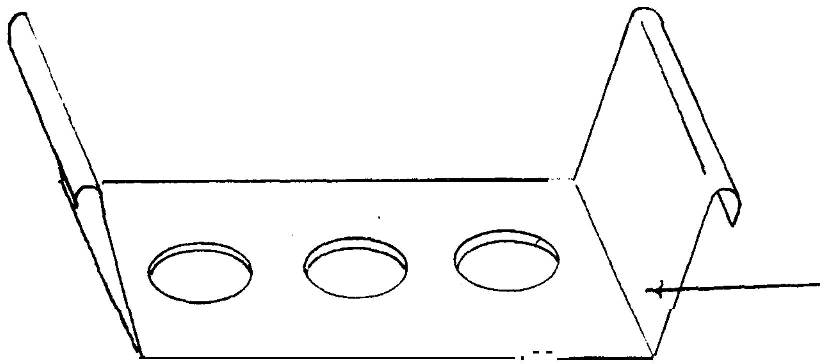
Select a short tin can with one end removed (A). Cut a V-shaped notch about 1 cm high in the side of the can. Drill a hole 1.5 cm in diameter in the center of the end of the can. Varnish the can.

c. Notes

(i) The beehive shelf is placed in the bottom of a pan of water. A gas collecting tube or jar, filled with water as described in VII/Al, is inverted on the shelf, with the mouth of the jar over the hole in the shelf, The gas delivery tube is then inserted through the notch of the shelf, up through the hole, and into the neck of the collecting jar.



B2. Metal Sheet Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Shelf	1	Metal Sheet (A)	Approximately 0.05 cm thick, 8 cm x 30 cm

b, Construction

(1) Metal Sheet Shelf

Cut the metal sheet from heavy aluminum sheeting or a tin can. Cut three holes, 1.5 cm in diameter, in the sheet (A) as shown. Bend the edges up as shown. Finally, make curved bends approximately 1 cm from each end.

C. Notes

(i) This shelf may be hung from the sides of a rectangular pan measuring from 12 to 20 cm wide. The shelf must be covered with water. Collecting bottles, filled with water, are inverted over the holes and set on the shelf.

VIII. METALWARE AND CLEANER

A. METALWARE

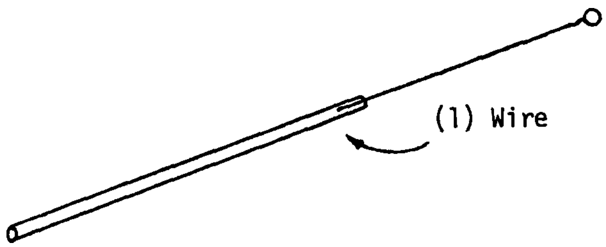
The items in this section are small pieces of metalware which can be constructed from scrap strapping, wire and the like. Items which can be improvised from normal household items, such as knives, have not been included.

B. CLEANER

This item can be used to clean the test tubes utilized in chemistry.

A. METALWARE

Al. Flame Test Wire



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wire	1	Transfer Loop	BIOL/VII/A3

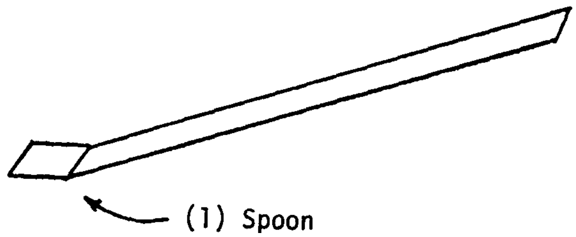
b. Construction

(1) Wire — See BIOL/VII/A3 for construction details.

c. Notes

(i) Use this wire to flame test compounds. Simply get a small amount of the chemical caught in the wire loop and hold it in a hot flame to observe the color of the flame.

A2. Deflagrating "Spoon"

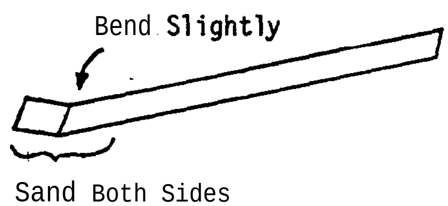


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Spoon	1	Metal Strapping (A)	About 10 cm x 3 cm

b. Construction

(1) Spoon



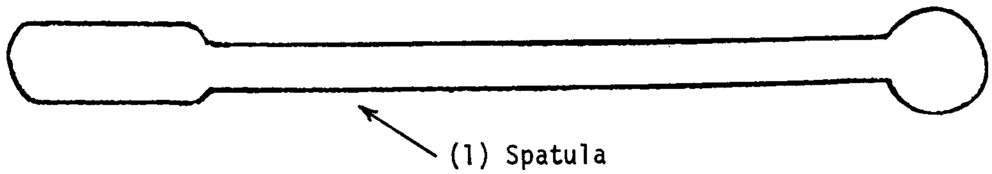
Carefully sand off all the paint from one end of the metal strapping (A) so that there is only bare metal. Make a slight bend in this end about 1.0 cm from the end.

c. Notes

(i) To use the deflagrating spoon, place a small amount of the chemical to be heated on the bent portion of the strapping. Hold the spoon in a holder (e.g., IV/A4). and hold the chemical in the flame of a burner until it burns or melts. The deflagrating spoon is used mainly in doing flame tests on unknown compounds.

(ii) When the end of the spoon becomes contaminated, either clean it with sand-paper or simply cut it off, sand the new end, and bend it as before.

A3. Spatula

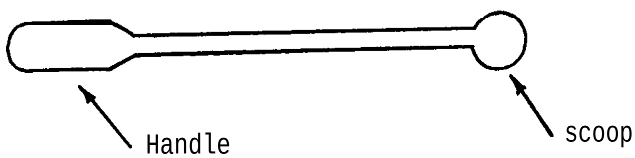


a.Materials Required

Components	Qu	Items Required	Dimensions
(1) Spatula	1	Tin Can or Strapping Wire (A)	20.0 cm long, 3.0 cm wide

b. Construction

(1) Spatula



Cut a piece of tin can metal (A) or a piece of wire strapping to the desired length and width. Cut the metal to the shape illustrated.

Make a depression in the scoop by hammering a steel ball in the circle.

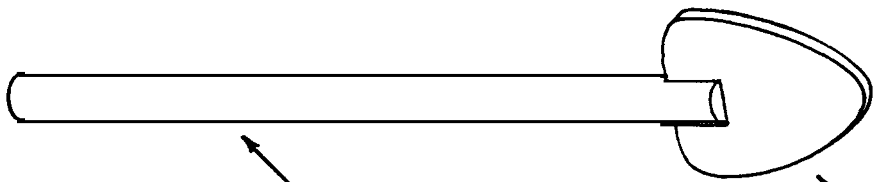
Depress the center of the handle slightly for easier handling.

c. Notes

(i) This spatula may be converted to a deflagrating spoon by bending the handle backward at a 90' angle with the shaft and bending the scoop forward at a 90' angle with the shaft.

B. CLEANER

Bl. Test Tube Cleaner or Spatula

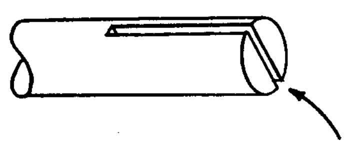


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Dowel (A)	25 cm long
(2) Cleaner	1	Piece of Rubber Inner Tube (B)	5 c m x 5 c m

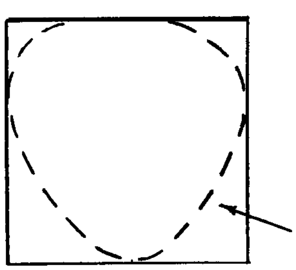
b. Construction

(1) Handle



Use a piece of wooden dowel (A) about 25 cm in length. Make a slit about 2.0 cm long in the center of one end of the handle.

(2) Cleaner



Cut a triangular piece of rubber (B) about 5.0 cm long from a discarded inner tube. Insert this in the slit made in the handle. Drive a small nail through the handle and cleaner to hold them in place, if necessary.

IX. HEATERS AND DRYERS

The apparatus in this section has been divided into two categories, as follows:

A. DRYERS

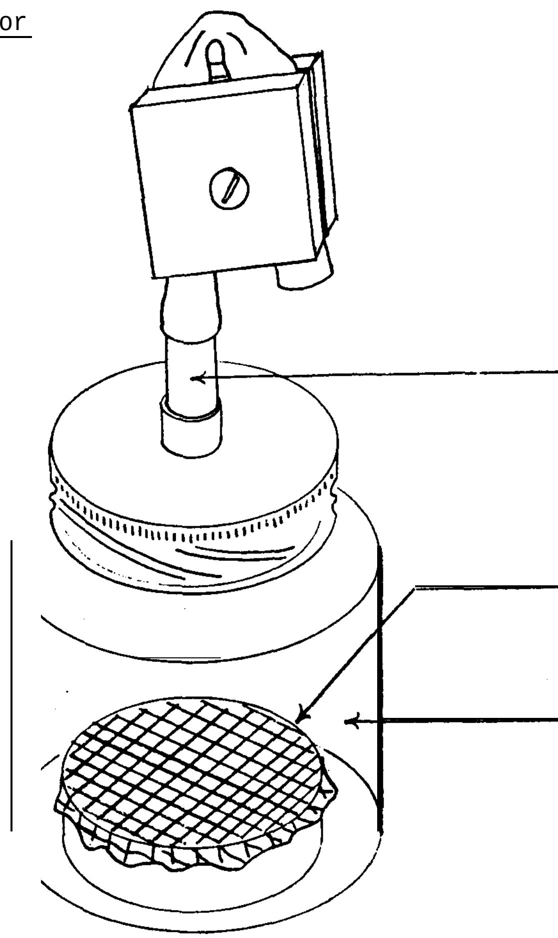
Dryers are devices used to remove the moisture content from chemical compounds.

B. HEATER

This is a device that is intended to produce a heat intense enough to incinerate precipitates.

A. DRYERS

Al. Dessicator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Jar (A)	Capacity 200 ml or more
	1	Lid (B)	To fit jar (A)
(2) Dryer	1	Small Tin Can (C)	To fit inside jar (A)
	1	Wire Mesh (D)	To cover tin can (C)
		Calcium Chloride or Silica Gel (E)	--
(3) Tubing	1	Rubber Tubing (F)	1 cm diameter, 15 cm long
	1	Glass Tube (G)	0.7 cm diameter, 5 cm long
	1	Screw Clamp or Pinch Clamp (H)	(IV/A4 or A5).

b. Construction

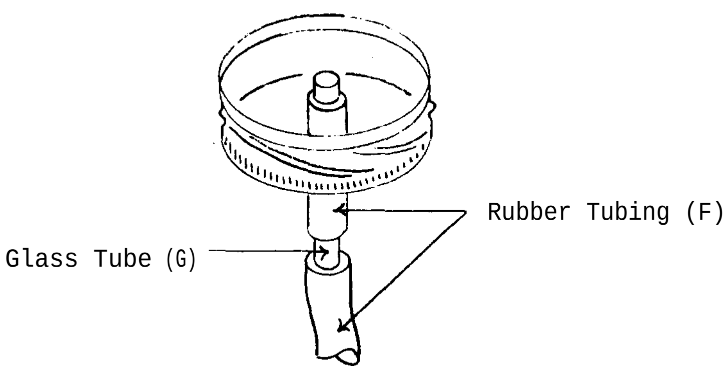
(1) Container

Select a jar (A) with a screw top (B) and a very wide mouth. Cut a hole slightly less than 1.0 cm in diameter in the center of the jar lid (B).

(2) Dryer

Take a short tin can (C) which fits easily into the jar, or cut a taller can to a height of 2 - 3 cm.

Place a drying agent, such as calcium chloride ($CaCl_2$) pellets or silica gel (C) in the can. Cover the can with wire mesh (D) and set it in the bottom of the jar (A).

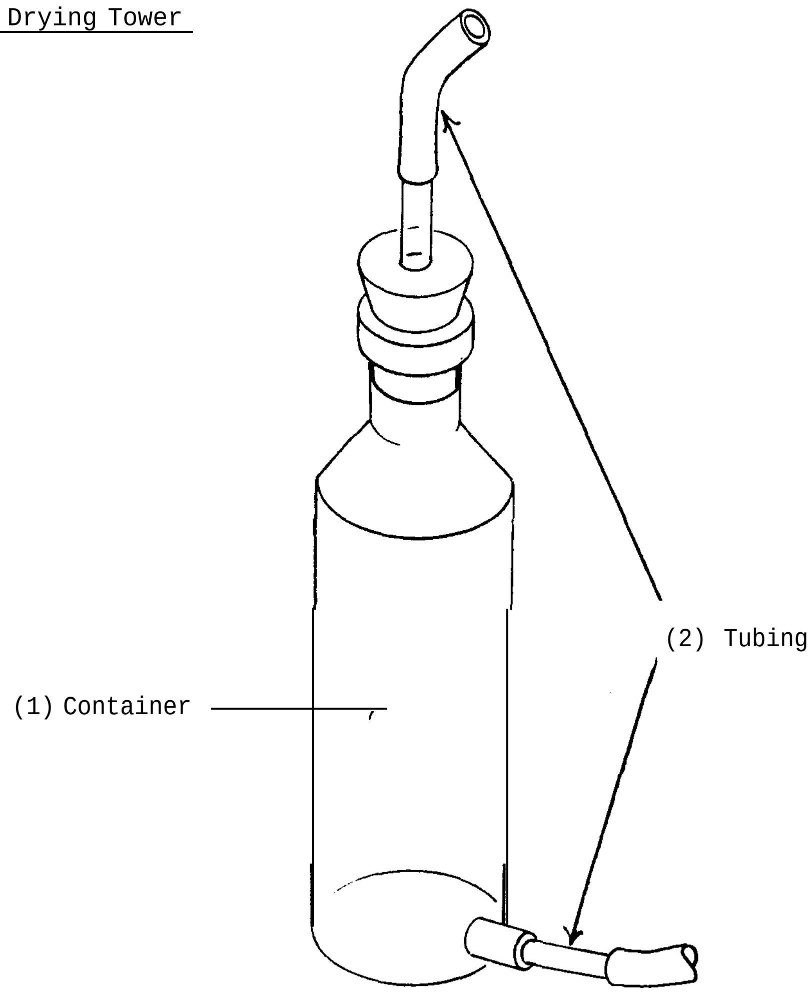


Cut a section of about 3 cm from the piece of rubber tubing (F). Insert one end of the glass tube (G) all the way into this short piece of rubber tubing. Insert the other end of the glass tube (G) into the longer section of rubber tubing. Push the shorter piece of rubber tubing, with the glass tube inside, into the hole in the top of the jar lid (B). Seal the tubing into the hole in the jar with cement, if necessary, to make an airtight seam. Seal the long rubber tube with a pinch clamp (IV/A4) or screw clamp (IV/A5).

c. Notes

(i) Powders or substances to be kept free of moisture are placed in containers inside the dessicator, and the top is sealed. The rubber and glass tube arrangement permits a partial vacuum to be formed in the dessicator if it is used in conjunction with a vacuum pump.

A2, Drying Tower



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Bottle (A)	Capacity approximately 300-400 ml
	1	l-Hole Stopper (B)	To fit bottle (A)
(2) Tubing	3	Rubber Tubing (C)	1 cm diameter, 5 cm long
	2	Glass Tubing (D)	0.7 cm diameter, 5 cm long

b. Construction

(1) Container

Drill a hole just slightly smaller than 1.0 cm in the side of the bottle (A) near the bottom (I/E2). Fit the bottle (A) with a one-hole cork or rubber stopper (B).

(2) Tubing

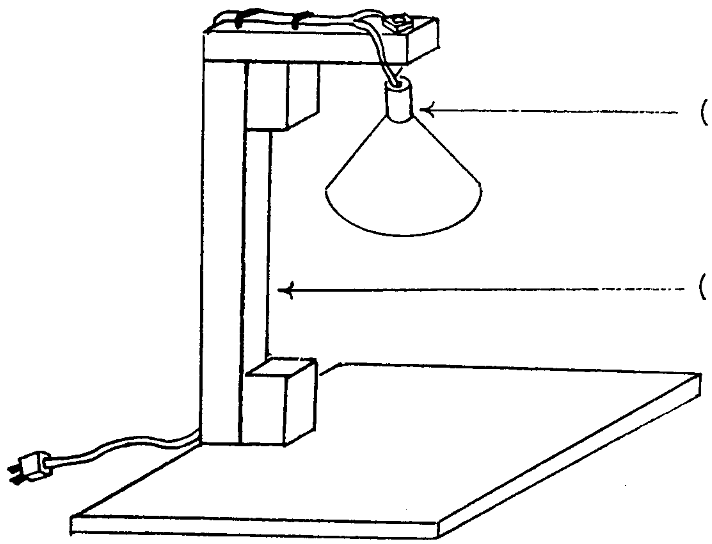
Insert one of the pieces of glass tubing (D) into the one-hole stopper, and push a piece of rubber tubing (C) on to the other end of the glass tube.

Insert one piece of rubber tubing (C) into the hole in the bottle (A), and cement it in place to make an airtight seal. Push the second piece of glass tubing (D) into the rubber tubing (C), and connect the last piece of rubber tubing (C) to the glass tube (D).

c. Notes

(1) This apparatus is used in removing moisture from gases. For example, moisture can be eliminated from H_2, O_2, N_2, Cl_2, and SO_2 by filling the drying tower with calcium chloride or other drying agent and connecting it by means of the tubing connections at top and bottom, between the gas generator and collecting device. As the gas passes through the drying tower, moisture is absorbed by the drying agent.

A3. Electric Lamp Dryer



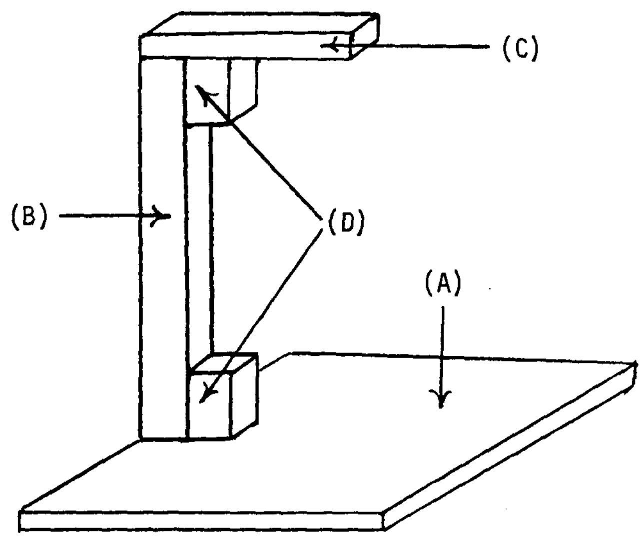
a. Materials Required

Components'	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	30 cm x 30 cm x 1 cm
	1	Wood (B)	1 cm x 2 cm x 32 cm
	1	Wood (C)	1 cm x 2 cm x 18 cm
	2	Wood (D)	4 cm x 4 cm x 2 cm
(2) Lamp	1	Lamp Socket (E)	--
	1	Insulated Electrical Cord and Plug (F)	--
	1	Incandescent Bulb (G)	100 watts
	4	Large Staples or Thin Nails (H)	--
	1	Bolt (I)	Approximately 0.8 cm x 3 cm
	1	Nut (J)	To fit bolt (I)
	1	Wire Mesh (K)	20 cm x 20 cm
	1	Thin Wire (L)	15 cm
	1	Aluminum Foil (M)	20 cm x 20 cm

b. Construction

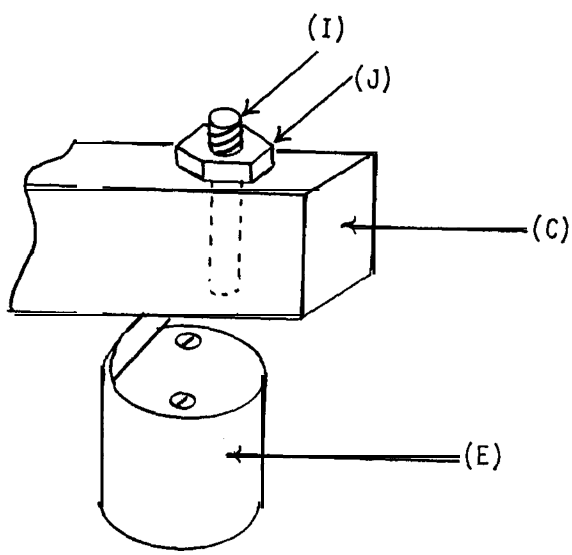
(1) Support

Construct the support as illustrated. Use glue and screws to secure the parts (A), (B), (C) and (D) to one another.

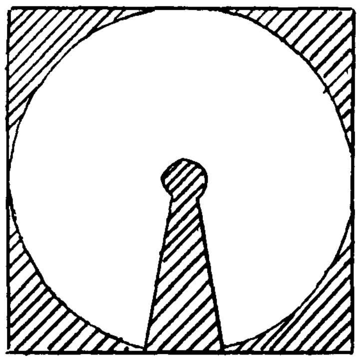


(2) Lamp

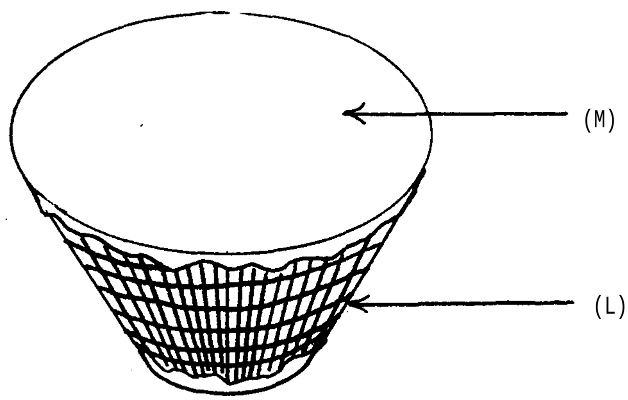
Secure the lamp socket (E) to the top horizontal bar (C) with the nut (J) and bolt (I).



Attach the electrical cord, with plug attached (F), to the socket (E). Run the wire along the top bar (C) and down the back of the vertical support (B). Secure the cord in position with large staples (H), bent nails, or tape.



From the wire mesh (K), cut a circle. Cut out and remove the shaded portion as shown. cut a similar but slightly larger shape from the aluminum foil (M). Curve the wire mesh (K) into a cone with an open end that will fit over the base of the incandescent bulb (G), and secure the cut edges together by threading the thin wire (L) in and out of the wire mesh.



Cover the inside of the wire mesh cone (K) with the foil (M), shiny side to the inside of the cone. Secure the foil reflector (M) to the wire mesh (L) by bending the foil edges around the wire mesh cone.

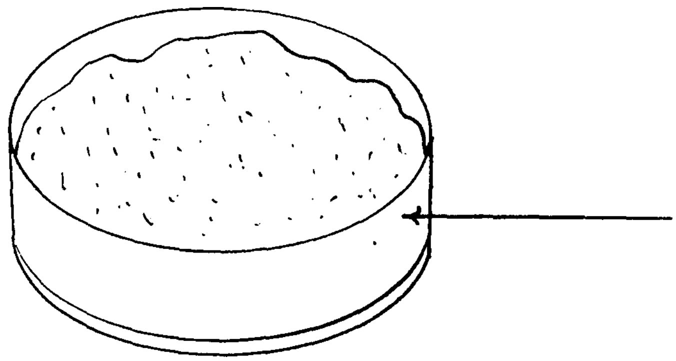
Slip the small end of the reflector over the neck of the bulb (E) and screw the bulb into the socket (E).

c. Notes

(i) The light provides a heat source for drying precipitates which are placed in shallow containers, watch glasses (V/A5) or petri dishes (V/A6).

(ii) Experimentation in the use of the dryer might include varying the size of the reflector, distance of the bulb from the material, wattage of bulb and number of bulbs used.

A4. Sand Bath



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Large Tin Can (A)	15-20 cm diameter
	--	Sand (B)	--

b. Construction

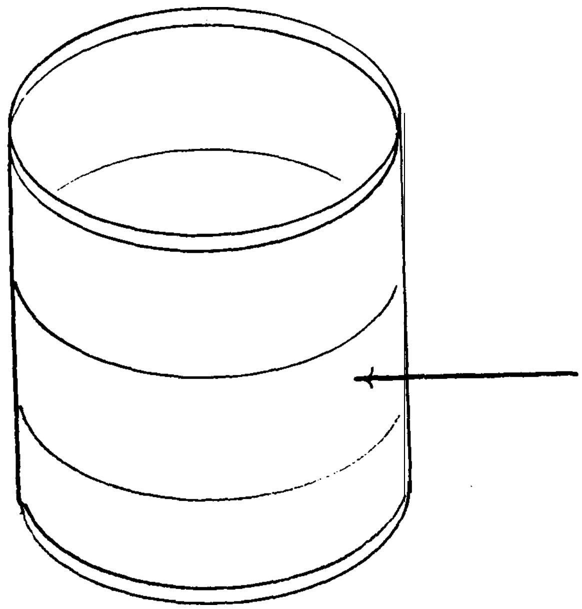
(1)Can

Use a large, shallow tin can (A) as a container, or cut a larger can to a height of about 5 cm. Fill the container with sand (B).

c. Notes

(1) Solutions or precipitates that must be evaporated or dried slowly may be placed in shallow containers, watch glasses, or petri dishes which are rested on the sand, The sand bath is then rested on a tripod (IV/B3), heating stand (IV/B4) or other suitable support and slowly heated with an alcohol or gas burner.

A5. Water or Steam Bath



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Tin Can (A)	Capacity approximately 150-300 ml

b. Construction

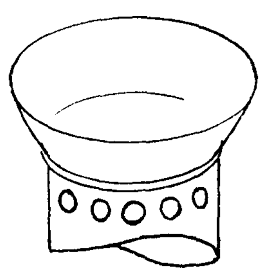
(1) Container

Use an empty, clean tin can (A) for the container. Fill it about 2/3 full of water.

c. Notes

(i) Use of the water bath is a safe way to heat materials that must not, for technical or safety reasons, be heated above about 100'C. Test tubes containing material to be heated are placed in the water bath. The water bath is rested on asuitable support and heated with an alcohol or gas burner. Materials heated in the test tubes will be heated to a temperature not higher than the boiling point of the water.

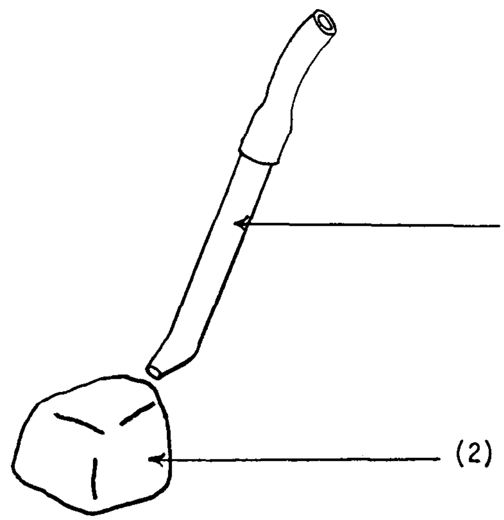
(ii) The water bath may be converted to a steam bath by the addition of a row of holes punched or drilled around the can near the top. The can is filled about 1/3 full of water, and a petri dish (V/A6) or watch glass (V/A5) containing material to be heated is rested on top.



The steam bath is rested on a suitable support and heated; as the water boils, the steam will heat the material in the petri dish or watch glass and will be able to escape through the holes in the top of the can.

B. HEATER

Bl. Blowpipe for Charcoal Block



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Blowpipe	1	Rubber Tubing (A)	Approximately 1.0 cm diameter, 10 cm long
	1	Glass Tubing (B)	Approximately 0.7 cm diameter, 20 cm long
(2) Charcoal Block	1	Charcoal Block (C)	--

b. Construction

(1) Blowpipe	Heat the glass tubing (B) near one end and bend it slightly as shown. Then heat it again, just past the bend, in order to draw it out to form a nozzle. Fit the rubber tubing (A) over the other end of the glass tube (B).
(2) Charcoal Block	Use a lump of charcoal (C) as a heat source.

c. Notes

(i) This item is used to create a concentrated heat source by blowing through the blowpipe onto the charcoal ember.

X. MOLECULAR MODELS

Four types of models to assist in the instruction and understanding of molecular structure are described.

A. SPACE-FILLING MODELS

These roughly represent relative sizes and positions of atoms within a molecule.

B. SKELETAL MODELS

These models more accurately represent atomic radii and bond angles than do those in the previous section.

C. CRYSTAL MODELS

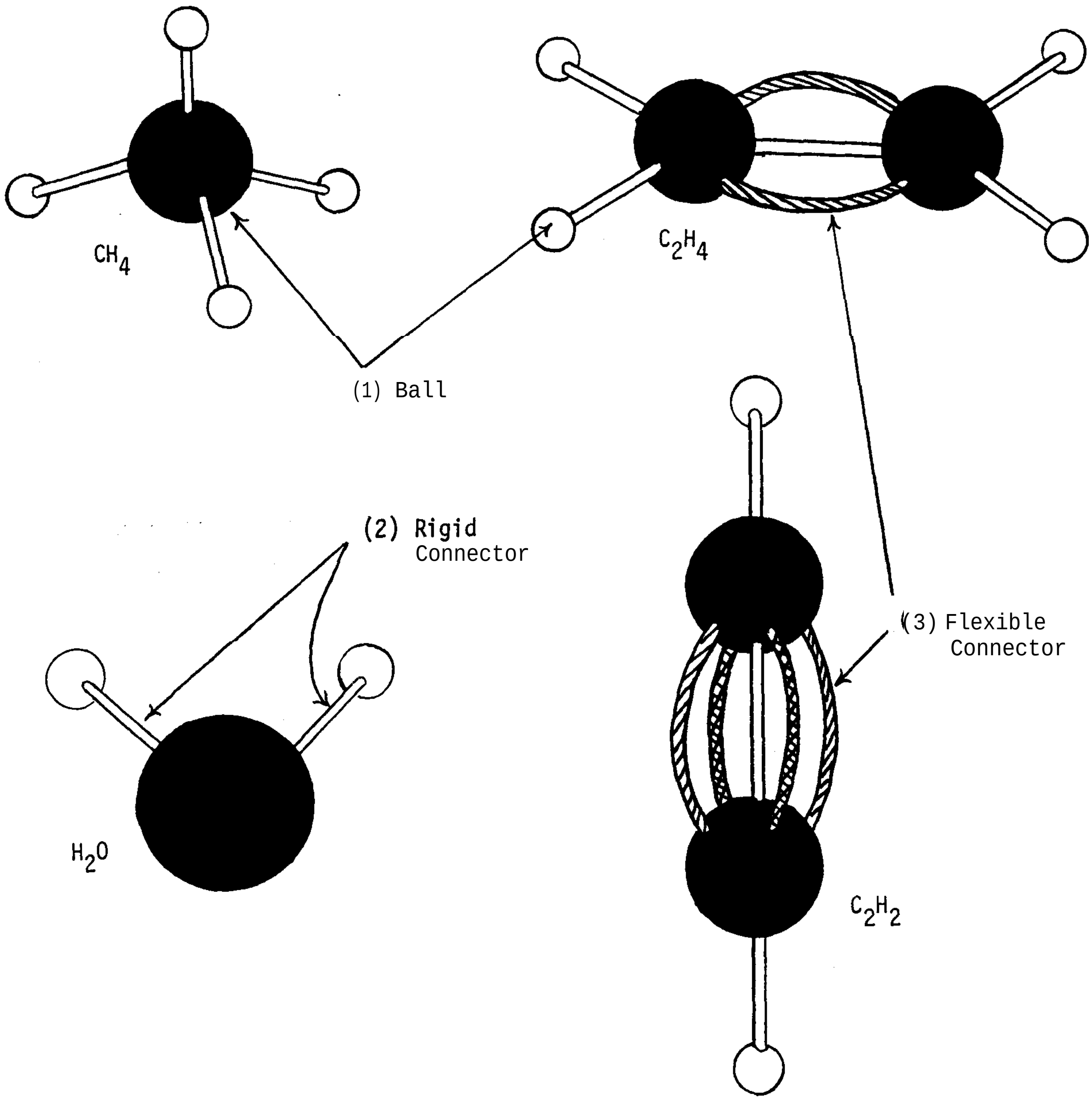
These are three-dimensional models that represent shape and atomic packing within crystals.

D. KINETIC-MOLECULAR MDDEL

This two-dimensional model demonstrates the kinetic theory of matter.

A. SPACE-FILLING MODELS

Al. Ball-and-Stick Models



a. Materials Required

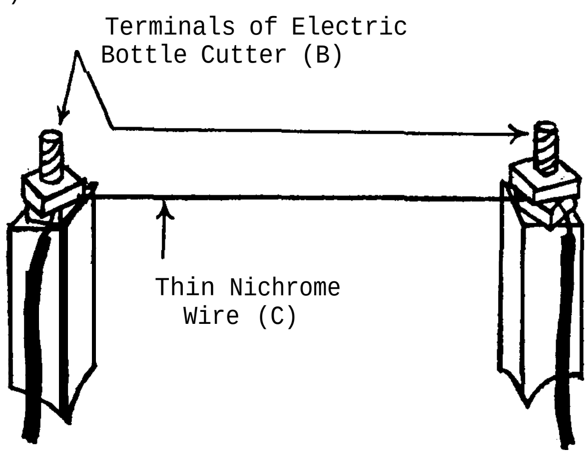
Components	Qu	Items Required	Dimensions
(1) Ball	1	Block of Styrofoam Plastic or Foam Polystyrene (A)	Approximately 4 cm x 10 cm x 10 cm
	1	Electric Bottle Cutter (B)	(I/F2)
	1	Thin Nichrome Wire (C)	0.02 cm diameter, 35 cm long

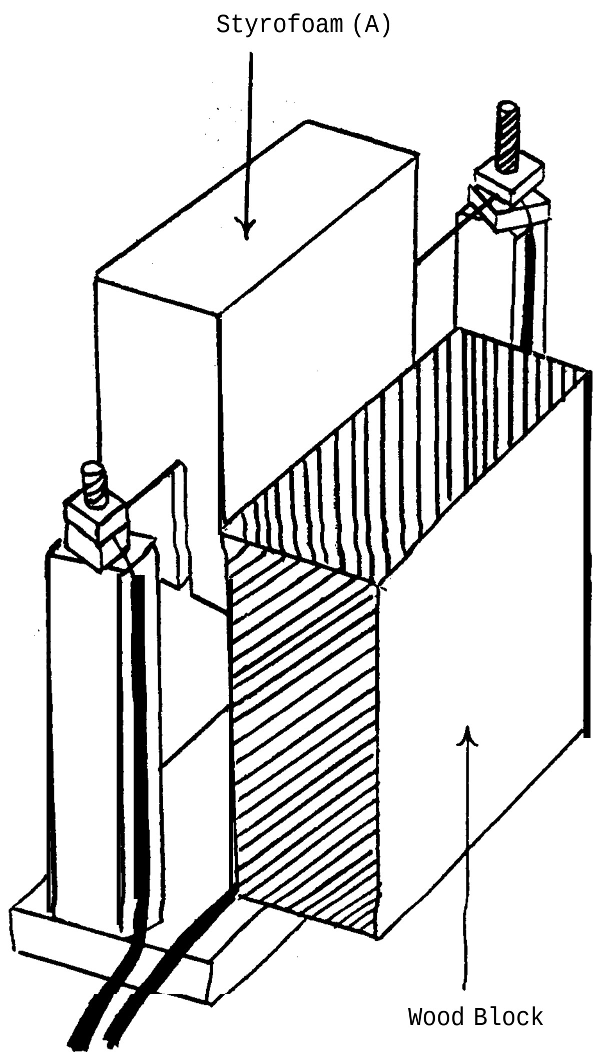
(2) Rigid Connector 1 Box of Toothpicks (D) Approximately 250

(3) Flexible Connector 1 Package of Pipe Cleaners (E) Approximately 25

b. Construction

(1) Ball



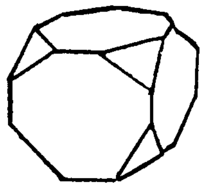


Construct the electric bottle cutter (B) according to directions given in (I/F2). Substitute the thin nichrome wire (0.02 cm diameter) for that described and stretch it tightly between the terminals, Connect the terminals to a six volt battery or a transformer that steps line current down to about six volts.

Form the Styrofoam (A) into small balls, First, cut the block into cubes, determining the sizes according to the element each represents:

H - 1.5 cm on a side
C - 3 cm " " "
O - 3 cm " " "
Si - 4 cm " " "

To cut a precise straight line, brace a large wooden block against the base of the bottle cutter, with one edge as far from the taut wire as the width of the desired cut. Push the Styrofoam block (A) down on the hot, taut wire to slice it, holding it against the wooden block which acts as a guide.



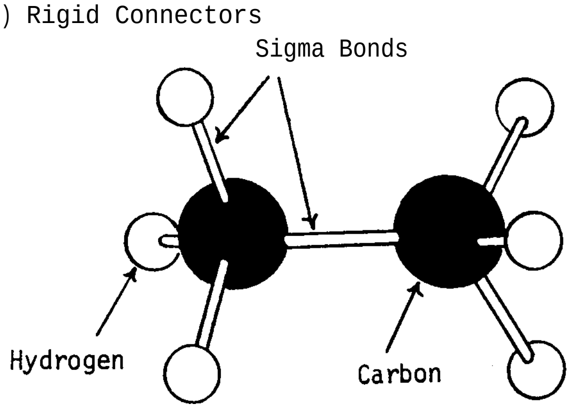
Carefully cut the corners off each cube to approach the shape of a sphere.

Last, shape the trimmed cubes with the fingers more exactly into spheres.

For clarity in the finished models, paint the balls with tempera (poster paint) to which a small amount of dissolved soap has been added. Use the following colors to represent:

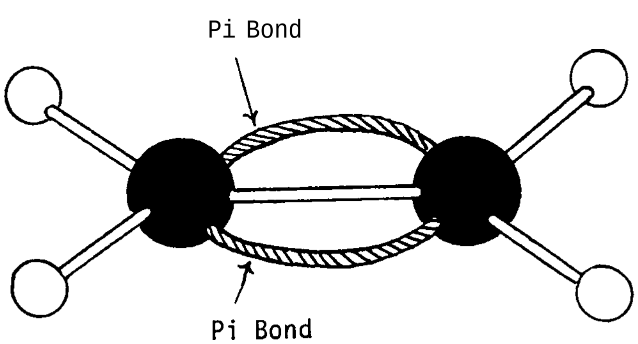
H - white
C - black
0 - red

(2) Rigid Connectors

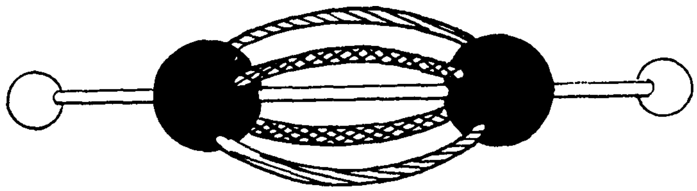


Stick toothpicks (D) into the Styrofoam balls to represent sigma bonds between atoms, as in the ethane molecule (C_2H_6) represented here.

(3) Flexible Connectors



Use pairs of pipe cleaners (E) cut to approximately 5 cm lengths to represent pi bonds between atoms, as in the ethene (ethylene; C_2H_4) molecule represented here.



When triple bonds (one sigma and two pi bonds) are to be represented, dye the two pairs of pipe cleaners different colors for clarity. This diagram represents a molecule of ethyne (acetylene; C_2H_2).

c. Notes

(i) If commercially manufactured Styrofoam or foam polystyrene balls are easily available, they may be substituted for the hand-made balls described here.

(ii) The scale of approximate sizes of the balls used in these models is based on the atomic radii for stable compounds listed in the Periodic Table of the elements, for example:

Element	Atomic Radius in Angstroms	Approximate Ratio
C	0.77	2
N	0.75	2
0	0.73	2
H	0.32	1

(iii) If Styrofoam or foam polystyrene is not available, modeling clay (plasticine) may be used for the balls and painted appropriate colors. However, once the clay balls are painted, repeated puncturing of them with toothpicks will disfigure them. Thus, it is recommended that they be used only to make permanent demonstration models.

(iv) Pipe cleaners or match sticks may be substituted for the toothpicks if desired.

(v) A kit for teacher use should contain:

2 dozen balls representing Carbon
2 dozen " " Hydrogen
2 dozen " ' Oxygen
1 dozen " " Halogens
1 dozen " " Nitrogen
1 dozen " ' Sulfur
several dozen each straight and flexible connectors,

This would provide sufficient materials for constructing demonstration models in the classroom. The same quantities listed above would be adequate for laboratory use for from one to four students.

(vi) The use of molecular models in the study of chemistry can enhance thestudents' understanding of and ability to predict the various properties and interactions of elements and compounds. These ball and stick models illustrate, roughly, the relative bond angles, sizes and positions of atoms within a molecule in a clear and simple form. They are not, however, scale representations of bond lengths or atomic molecular sizes and shapes. In order to demonstrate the mathematical relations of electrons in a given molecule, it will be necessary to employ a different style model, that which is described in the next section.

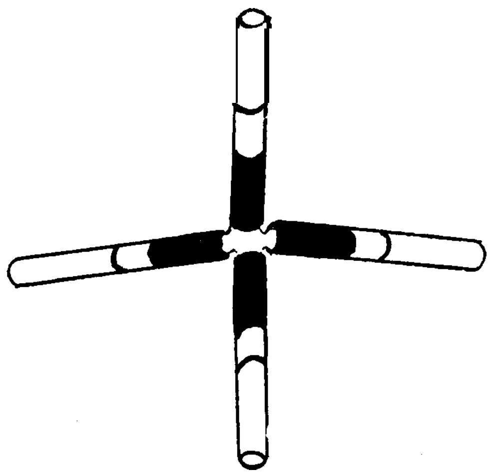
(vii) The color code * used in these models is as follows:

Hydrogen - white
Carbon - black
Oxygen - red
Nitrogen - blue
Sulfur - dark yellow
Flourine - light green
Chlorine - dark green
Bromine - orange
Iodine - brown
Phosphorous - violet
Silicon - light yellow

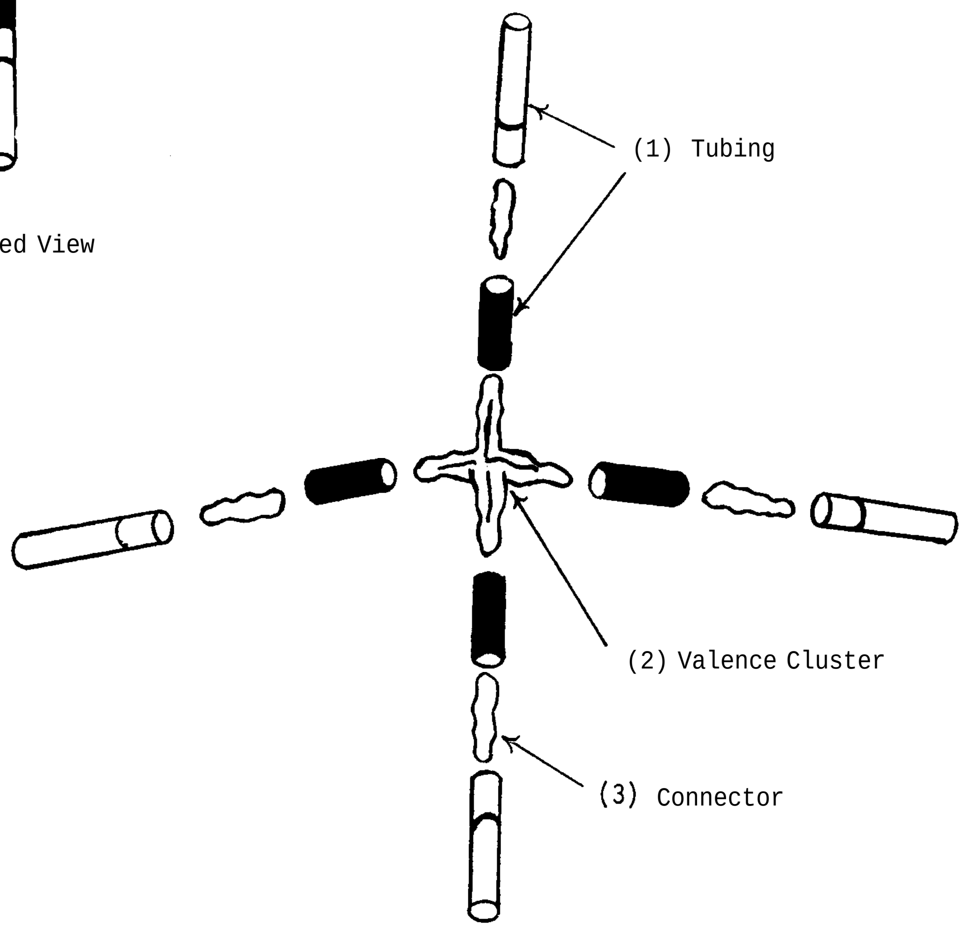
*From the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, Portland, Oregon: Portland Project Committee, (1971, p l/.

B. SKELETAL MODELS

Bl. Molecular Model Units*



Assembled View



Exploded View

*Adapted from George C. Brumlik, Edward J. Barrett, and Reuben L. Baumgarten, "Framework Molecular Models," Journal of Chemical Education, XLI (1964), pp 221-223.

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tubing	--	Milk Straws (Paper or Plastic) (A)	0.4 cm diameter, approximately 20 cm long
	--	Tempera (Poster) Paints (B)	Black, white, red, yellow, green, blue, orange
(2)	--	Pipe Cleaners (C)	--
(3) Connector	--	Pipe Cleaners (D)	--
	--	Finishing Nails (E)	Approximately 0.1 cm diameter, 1.5 cm long
	--	Soft Iron Wire (F)	Approximately 0.05 cm diameter

b. Construction

(1) Tubing

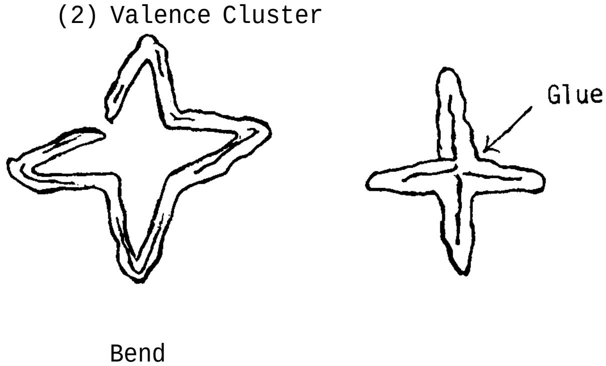
Mix a small amount of liquid or dissolved soap with the tempera paints (B) to reduce their surface tension. Using this mixture, paint several milk straws (A) according to the atom they are to represent:

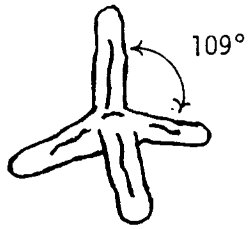
Carbon - black
Hydrogen - white
Oxygen - red
Nitrogen - blue
Sulfur - dark yellow
Bromine - orange
[Consult Note (ii) for addltional colors.]

Cut the straws into various lengths depending upon the scale used and bond represented.

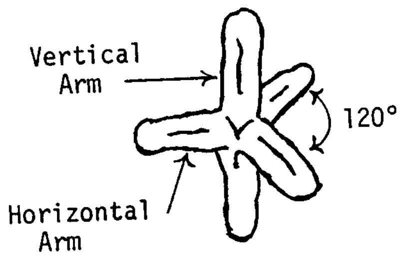
(2) Valence Cluster

Bend a pipe cleaner (C) into the shape desired, and glue the joint in the middle. When the glue has dried, adjust the angles of the arms of the connector to suitable angles.

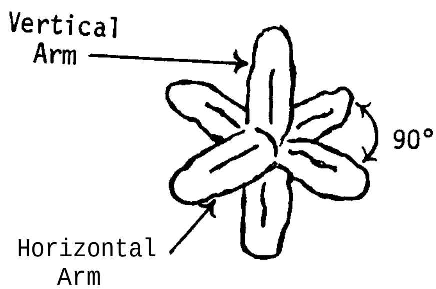




Make tetrahedral (4 arms) shapes with the angles of the arms at about 109'.

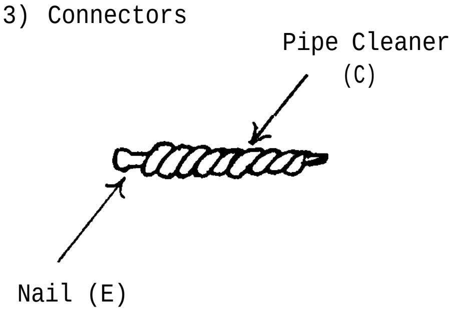


Make trigonal bipyramid (5 arms) shapes. Arrange the angles between the three horizontal arms to 120'. Adjust the two vertical arms at right angles to the horizontal arms.

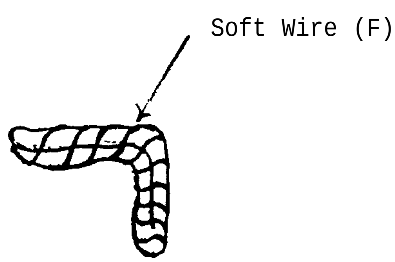


Construct octahedrons (8-pointed), Adjust the angles between the four horizontal arms to 90'. Arrange the two vertical arms at right angles to the horizontal arms,

(3) Connectors



Construct straight connectors to represent bonds between atoms by wrapping a pipe cleaner (C) around a nail (E). Vary the length of pipe cleaner used according to the tightness desired.



To make angular connectors to be used to complete various structures, bend a pipe cleaner (C) in half. Then wrap soft wire (F) around the pipe cleaner and bend the assembly to a 90' angle.

c. Notes

(i) These units can be used to build models of almost any molecule, The valence clusters represent atomic nucleii, the intersection of the arms representing the center of the atom. The tetrahedral (4-armed) valence cluster depicts bond angles of approximately 109°, for sp^3 hybridized orbitals or atoms with eight electrons in their valence shell. The five-armed valence cluster can depict sp^2 hybridization, with 120' bond angles, for atoms engaged in (pi) bonds, as well as d sp^3 hybridization, with 90° and 120° bond angles for atoms with ten atoms in their valence shell. The six-armed valence cluster can represent sp hybridization with bond angles near 180°, or d^2sp^3 hybridization for atoms with twelve electrons in their valence shell. The straight connector depicts Ó (sigma) bonds between like or unlike atoms.

Electrons, whether bonded or unshared, are represented by the straws, color coded and cut to scale.

The straws in a completed molecular model represent covalent radii of bonding atoms, and van der Waals radii in the non-bond direction.

(ii) Below are charts* to guide the coloring and cutting of straws to represent covalent radii or van der Waals radii. Any convenient scale may be used to simulate the Ångstrom unit (Å) measurements of these forces. For example, a scale of 10 cm/Å produces large models ideal for lecture demonstrations, while a scale of 2 cm/Å yields smaller models suitable for student use.

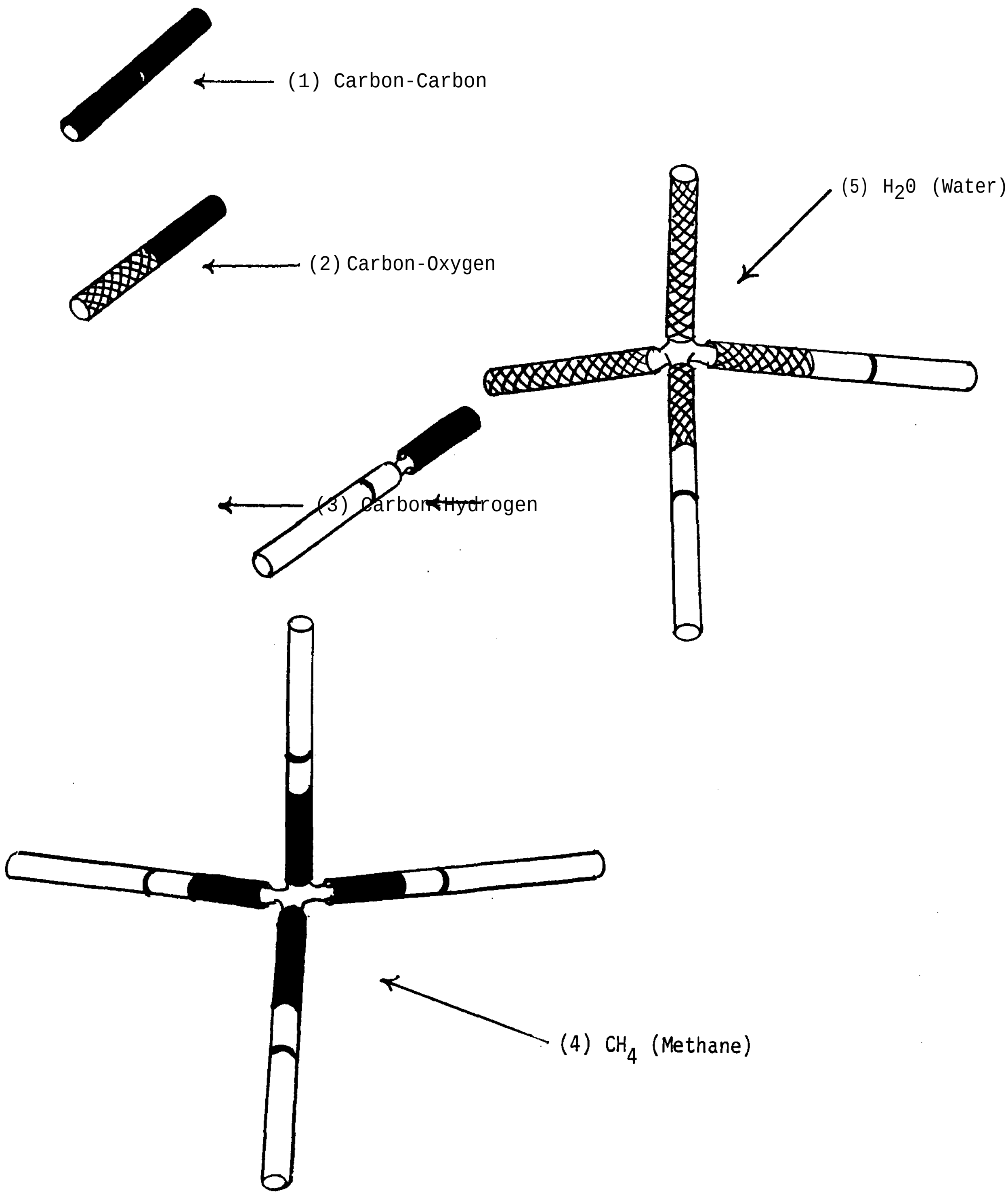
Bond	Atomic Covalent Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm (Scale: 2 cm/Å)	Color of Straw
C - single	0.77	7.7	1.5	
C - double	0.67	6.7	1.3	black
C - triple	0.60	6.0	1.2	
O - single	0.74	7.4	1.5	
O - double	0.62	6.2	1.2	red
O - triple	0.55	5.5	1.1	
N - single	0.74	7.4	1.5	
N - double	0.62	6.2	1.2	blue
N - triple	D.55	5.5	1.1	

*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971), pp 8-18.

Bond (single)	Atomic Covalent Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm 2 cm/Å)	Color of Straw
H	0.30	3.0	0.6	white
F	0.64	6.4	1.3	light green
Si	1.17	11.7	2.3	light yellow
P	1.10	11.0	2.2	violet
S	1.04	10.4	2.1	dark yellow
Cl	1.00	10.0	2.0	dark green
Br	1.14	11.4	2.3	orange
I	1.33	13.3	2.7	brown

Atom	Van der Waals Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm (Scale: 2 cm/Å)	Color of Straw
H	1.2	12.0	2.4	white
O	1.40	14.0	2.8	red
F	1.35	13.5	2.7	light green
S	1.85	18.5	3.7	dark yellow
Cl	1.80	18.0	3.6	dark green
Br	1.95	19.5	3.9	orange
I	2.15	21.5	4.3	brown
N	1.5	15.0	3.0	blue
P	1.9	19.0	3.8	violet

B2. Single Bond Structures*



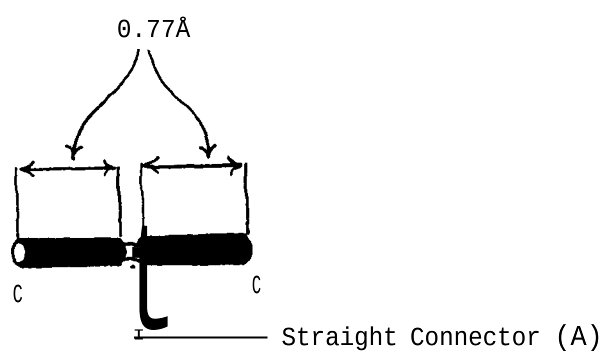
*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971), pp 19-28.

a. Materials Required

Components	Qu	Iterns Required	Dimensions
(1) Carbon-Carbon	1	Straight Connector (A)	X/B1
	2	Black Straws (B)	1.5 cm
(2) Carbon-Oxygen	1	Straight Connector (C)	X/B1
	1	Black Straw (D)	1.5 cm
	1	Red Straw (E)	1.5 cm
(3) Carbon-Hydrogen	1	Straight Connector (F)	X/B1
	1	Black Straw (G)	1.5 cm
	1	White Straw (H)	3.0 cm
(4) CH_4 (Methane)	1	4-armed Valence Cluster (I)	X/B1
	4	Carbon-Hydrogen Bonds (F,G,H) [see (3) above]	4.5 cm
(5) H_2O (Water)	1	4-armed Valence Cluster (J)	X/B1
	2	Red Straws (K)	i5 cm
	2	Red Straws (L)	2.8 cm
	2	White Straws (M)	3.0 cm
	2	Straight Connectors (N)	X/B1

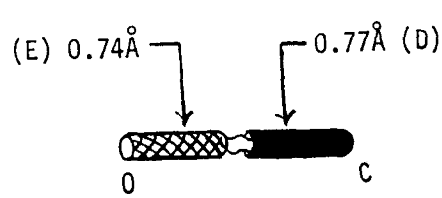
b. Construction

(1) Carbon-Carbon



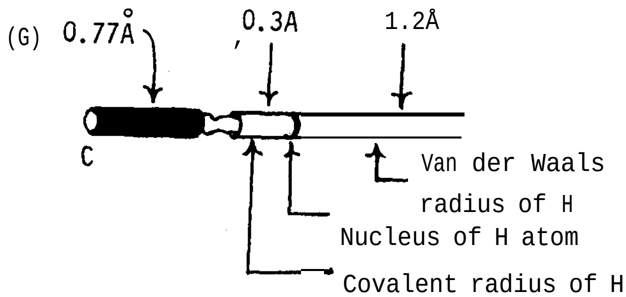
To represent this single covalent bond between like atoms, cut two black straws (B) to a scale representation of the single bond covalent radius of carbon (X/BI), Note (ii). For example, cut the straws to 1.5 cm for a scale of 2 cm/Å. Join these two straws with a straight connector (A).

(2) Carbon-Oxygen



To construct this model of a single covalent bond between unlike atoms, cut one black straw (D) to represent the single bond covalent radius for carbon (1.5 cm, for example) and a red straw to represent the single bond covalent radius for oxygen (E) (1.5 cm). Connect these two straws with a straight connector (C).

(3) Carbon-Hydrogen

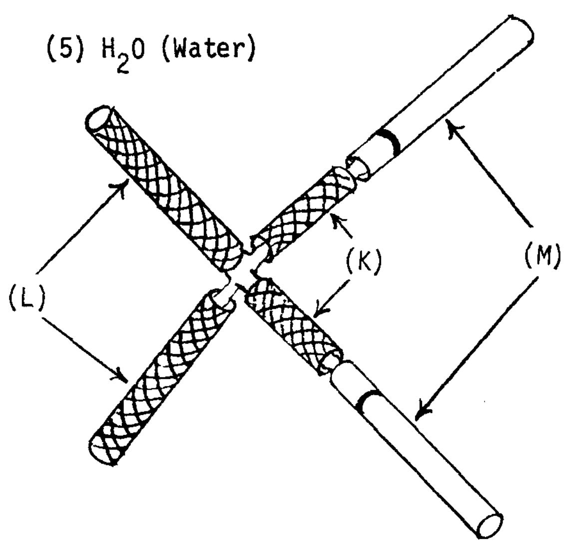


Construct the carbon-hydrogen bond to include a representation of the van der Waals radius for hydrogen. Cut one black straw (G) to indicate the single bond covalent radius for carbon. Cut one white straw (H) to show the covalent radius of H (0.6 cm) plus the van der Waals radius of H (2.4 cm). Draw a line around the white straw at the intersection of these two values to indicate the position of the hydrogen nuculeus, then join the black and white straws with a straight connector (F).

(4) CH_4 (Methane)

Construct four carbon-hydrogen bonds (F,G,H) as described above. Join them all together at the carbon end by sliding each onto an arm of the four-armed valence cluster (I) and pushing all the straws together so that the connectors do not show.

(5) H_2O (Water)



Cut two red straws (L) to represent the van der Waals radius of O (2.8 cm). These will represent two unshared electron pairs, Cut two red straws (K) to indicate the single bond covalent radius of O (1.5 cm). Use a straight connector (N) to join each of these with a white straw (M) representing the covalent and van der Waals radii of H (3.0 cm). Connect the two red straws and two O - H bonds with a four-armed connector (J) as illustrated.

C. Notes

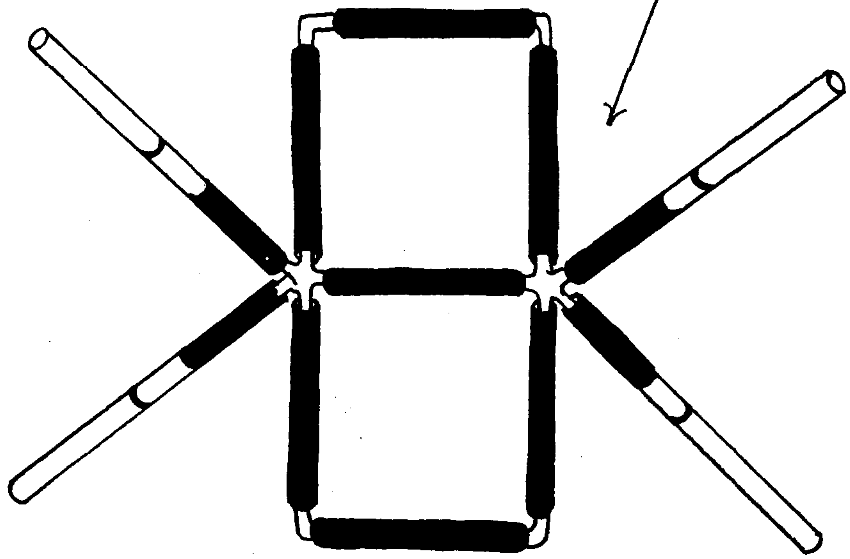
(i) Single covalent bonds between like atoms, such as the carbon-carbon bond, may also be represented by one straw, appropriately colored, cut to twice the covalent radius. Thus, the carbon-carbon bond would be represented by one black straw, 3 cm long.

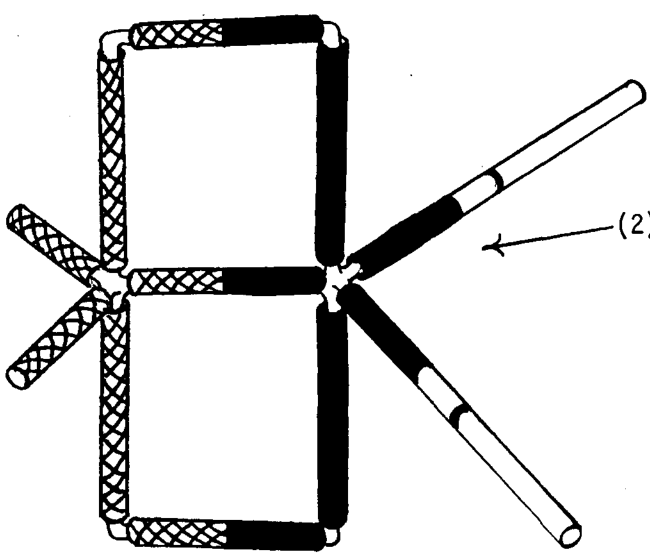
(ii) Unlike the space-filling models of X/Al, these models do not show molecular shape. The shape of the constituent atoms within a molecule must be imagined; the scale and orientation of the parts of the model show bond lengths, bond angles, and bond thicknesses in reasonably accurate scale.

(iii) These skeletal molecular models are based on atomic orbital geometry, which deals with the behavior of electrons in paths, or orbitals, in the space around the nucleus of an atom. For a complete discussion of electrons, nucleii, and orbitals, consult recent chemistry texts, such as Chemical Bond Approach Project, Chemical Systems, (Webster Division McGraw-Hill Book Company, 1964), Chapter 10.

B3. Double Bond Structures*

(1) $H_2C = CH_2$
(Ethene)





(2) $H_2C = O$
(Formaldehyde)

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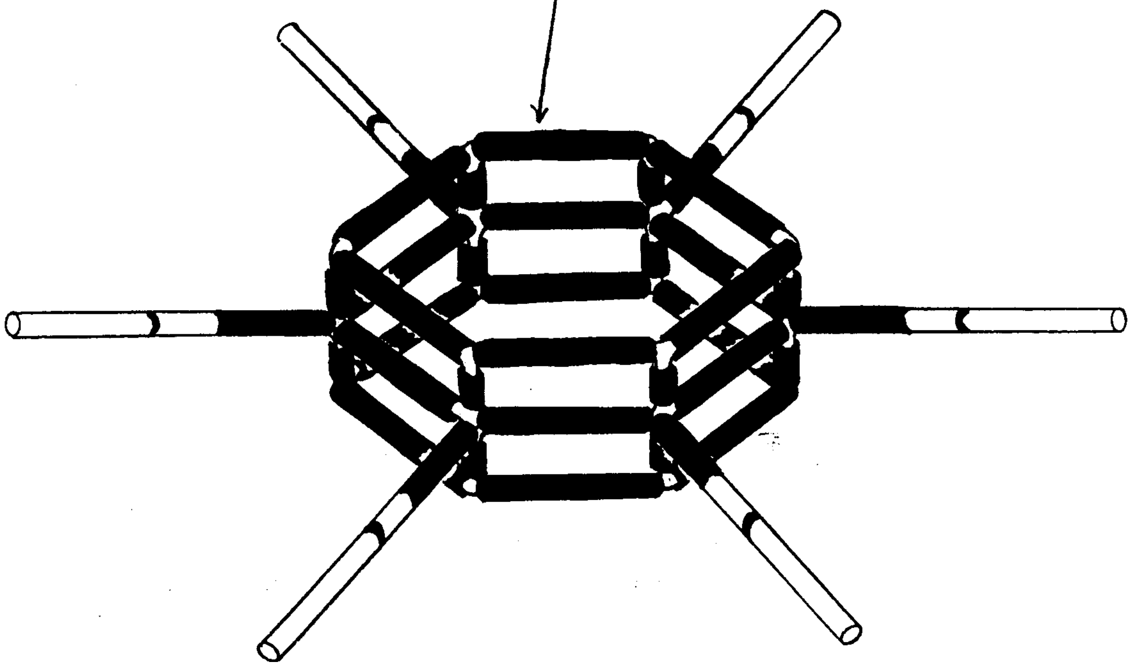
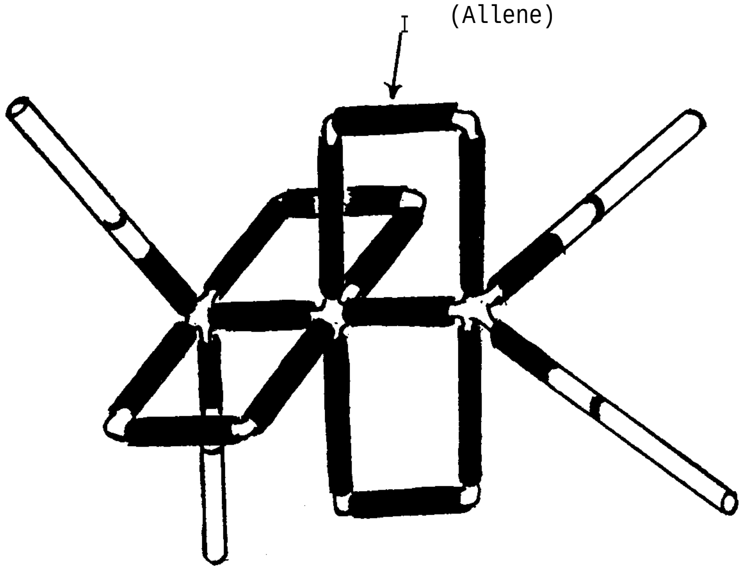
*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, i9/l) pp 28-36.

(3) C_6H_6
(Benzene)



(4) $H_2C = C = CH_2$

(Allene)



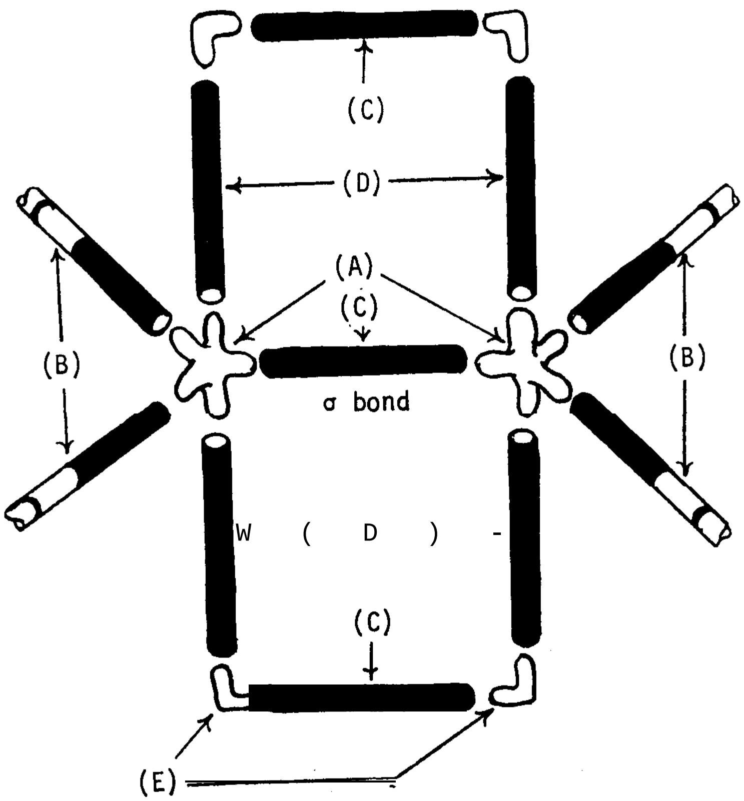
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) $H_2C=CH_2$ (Ethene)	2	5-armed Valence Clusters (A)	X/B1
	4	C-H Bonds (B)	4.5 cm
	3	Black Straws (C)	2.6 cm
	4	Black Straws (D)	3.0 cm
	4	Angular Connectors (E)	X/B1
(2) $H_2C=O$ (Formaldehyde)	2	5-armed Valence Clusters (F)	X/B1
	4	Angular Connectors (G)	X/B1
	2	C-H Bonds (H)	4.5 cm
	3	Red Straws (I)	1.2 cm
	3	Black Straws (J)	1.3 cm
	2	Red Straws (K)	3.0 cm
	2	Black Straws (L)	3.0 cm
	2	Red Straws (M)	1.5 cm
	3	Straight Connectors (N)	X/B1
(3) C_6H_6 (Benzene)	18	5-armed Valence Clusters (0)	X/B1
	6	C-H Bonds (P)	4.5 cm
	18	Black Straws (Q)	2.6 cm
	12	Black Straws (R)	3.0 cm
(4) $H_2C=C=CH_2$ (Allene)	2	5-armed Valence Clusters (S)	X/B1
	1	6-armed Valence Clusters (T)	X/B1
	4	C-H Bonds (U)	4.5 cm
	6	Black Straws (V)	2.6 cm
	8	Black Straws (W)	3.0 cm
	8	Angular Connectors (X)	X/B1

b. Construction

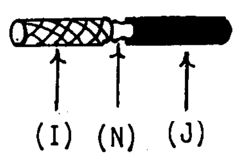
(1) $H_2C=CH_2$ (Ethene)

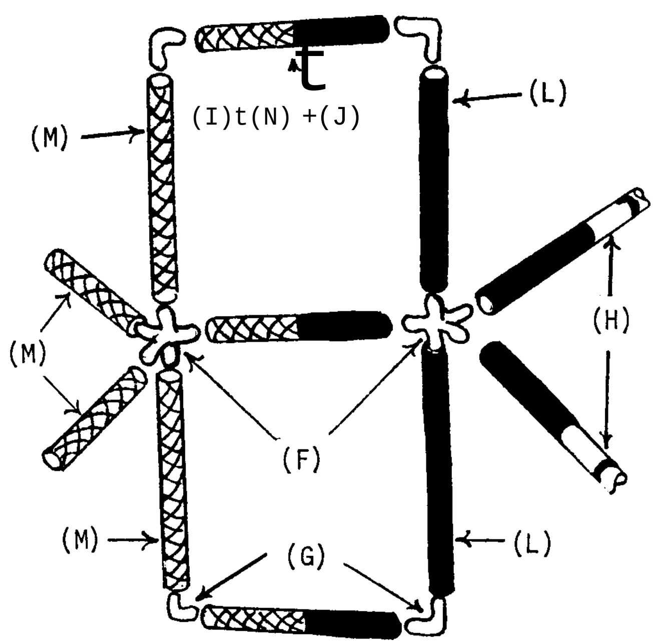
First construct four C-H bonds (B) (X/B2). Then complete the $H_2C=CH_2$ molecule as shown. Use three 2.6 cm black straws (C) to represent double bond formation between like atoms. The central black straw (C)



represents the a bond. The two outside sections of black straws (C) represent the two arms of the bond, the thickness of which is shown by the four 3.0 cm black straws (D). Their length represents the single bond covalent radius of carbon.

(2) H_2C=0 (Formaldehyde)

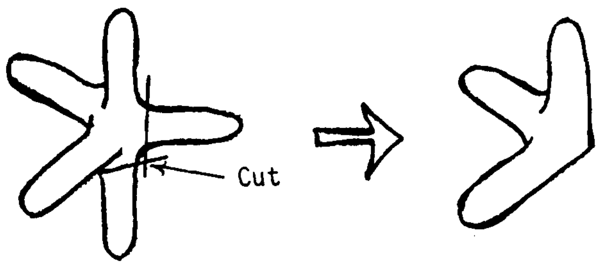




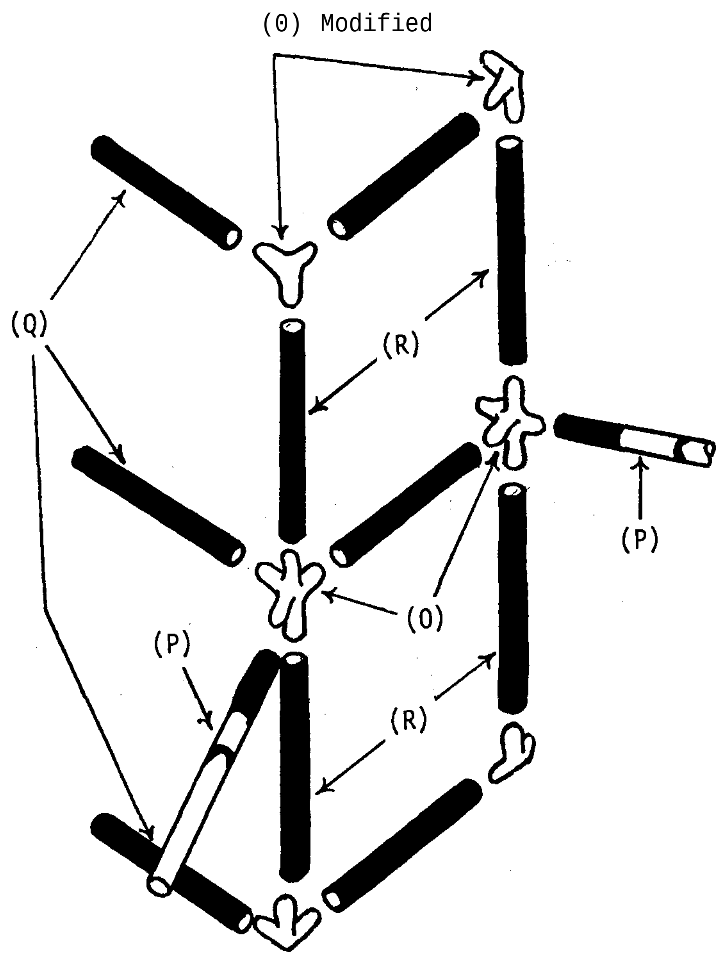
Construct this model showing **double bond formation between like atoms. First, construct three C=0 bonds representing** the double bond radii C (J) and 0 (I), as shown. Make two C-H bonds (H) (X/B2).

Use the 5-armed valence clusters (F) and angular connectors (G) to join the straws. Indicate the thickness of the IT bond by red straws on the oxygen side, black straws on the carbon side.

(3) C_6H_6 (Benzene)

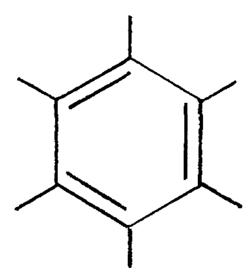


Cut off and discard one horizontal and one vertical arm from each of twelve 5-armed valence clusters (O) to form 3-cornered clusters.



One corner, exploded view

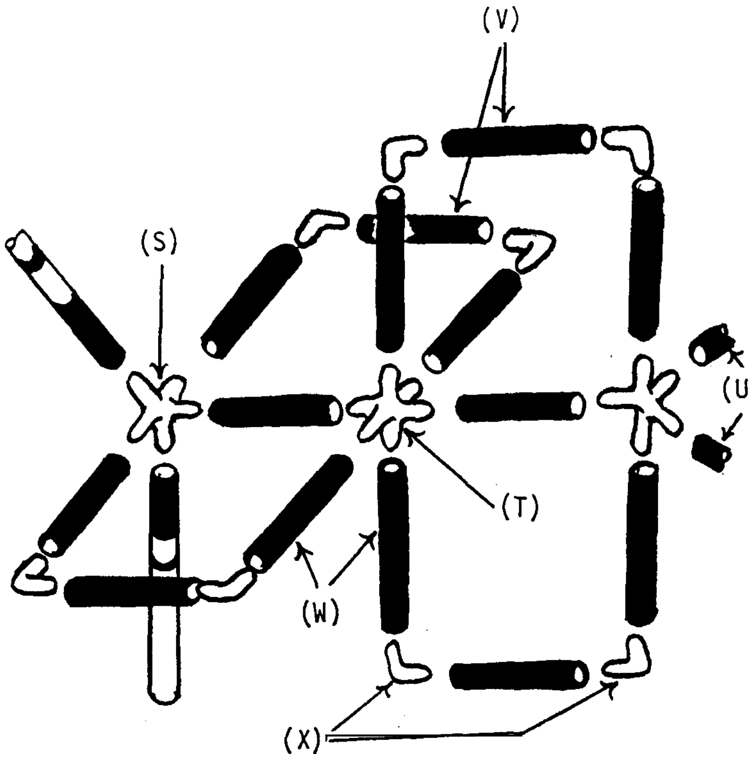
Make six C-H bonds (X/B2) (P). Construct the three layered model as shown. Use the twelve 3.0 cm black straws (R) to represent the thickness of the bonds (twice the single covalent radius of carbon). Use the eighteen 2.6 cm black straws (Q) to represent the bond lengths (twice the double covalent bond radius of carbon). The shared-bond aspect of the ring structure often pictured:



is represented in the model by the three-layered structure.

(4) $H_2C{=}CH_2$ (Allene)

Construct four C-H bonds (U). Use one 6-armed valence cluster (T), as well as two 5-armed clusters (S), to connect the the components of the H_2C-C-CH_a (allene) molecule.



Place the 6-armed cluster (T) as shown to indicate that the middle carbon atom is bonded to each of the side carbons.

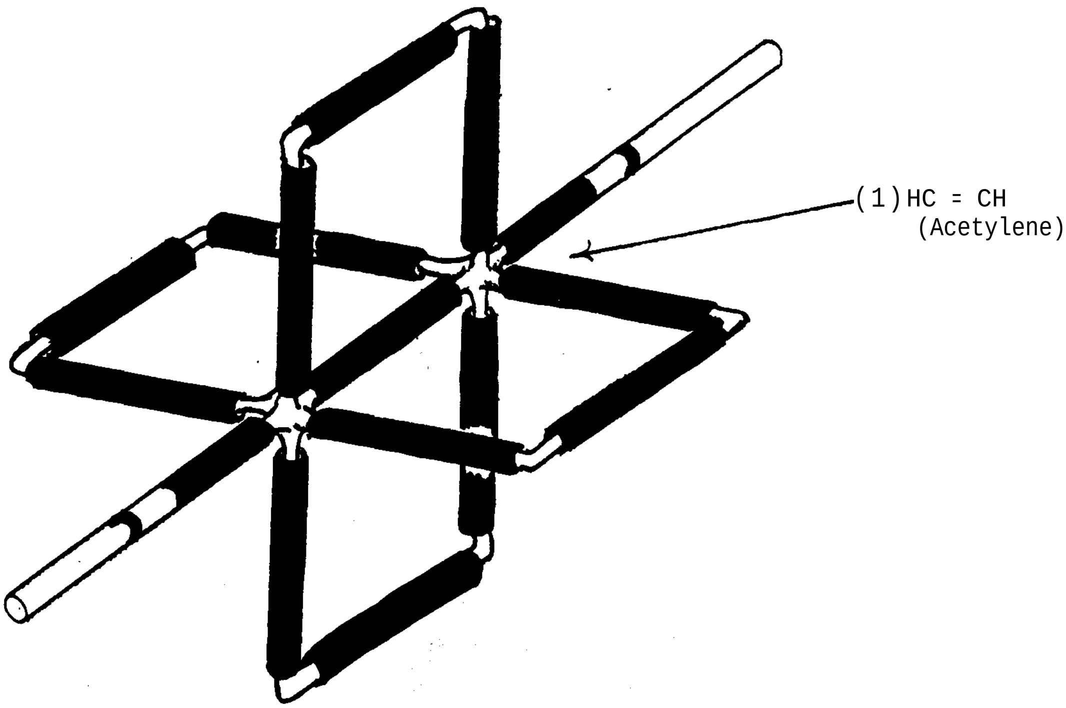
C. Notes

(i) These four examples of double bond models illustrate some of the complex double bond forms that can be built. By applying the principles thus illustrated, it should be possible to construct almost any simple or complex double bonded molecule.

(ii) because the forces holding two nucleii together in a double bond are greater than those in a single bond, the nucleii are closer together, Thus, the straws representing the C=C or C=R covalent distance are shorter than those representing the C-C or C-R distance.

(iii) In the $H_2O=O$ (formaldehyde) molecule, the slightly longer tubing representing the bond thickness at the carbon atom than at the oxygen atom indicates a certain strain on the double bond. The covalent radius of oxygen is used to model the unbonded electrons, rather than the van der Waals radius as in the model of water, because the C=O bond "pulls" or distorts the oxygen electron cloud. C=N bonds may be constructed just as C=C and C=O bonds; blue tubing represents N.

B4. Triple Bond Structure*



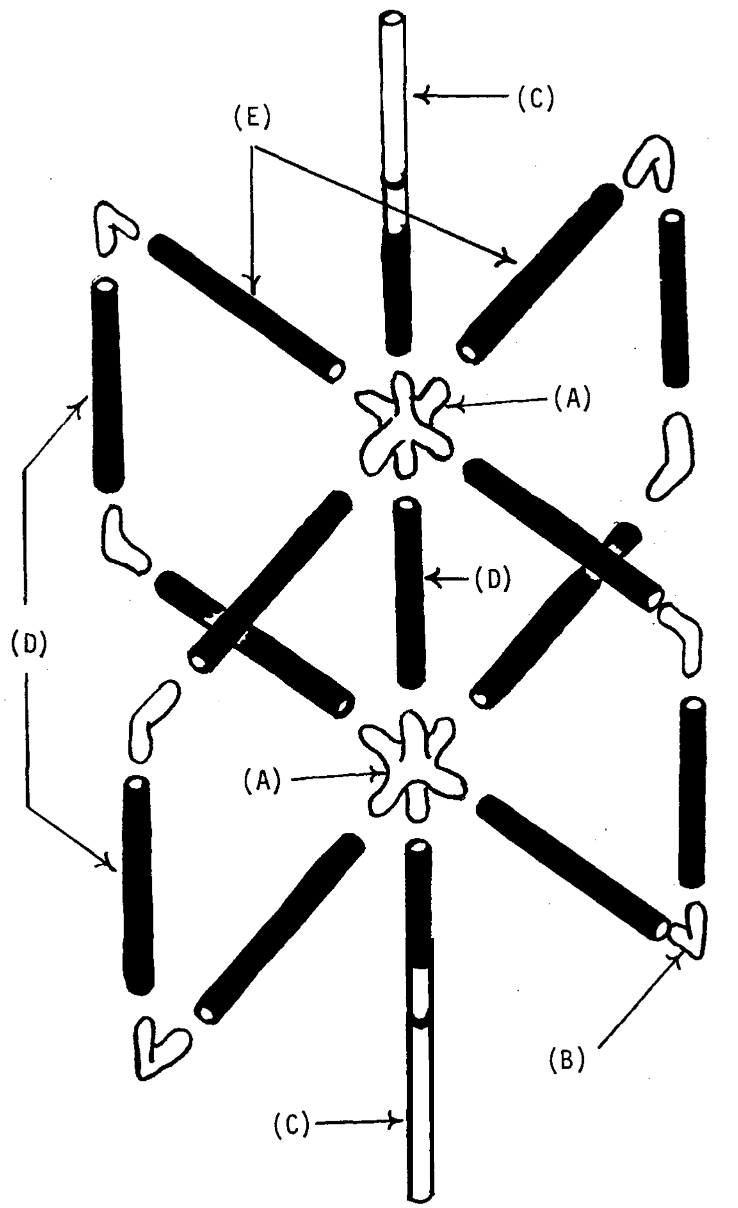
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) HC=CH (Acetylene)	2	6-armed Valence Clusters (A)	X/B1
	8	Angular Connectors (B)	X/B1
	2	C-H Bonds (C)	4.5 cm
	5	Black Straws (D)	2.4 cm
	8	Black Straws (E)	3.0 cm

*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971), pp 36-3/.

b. Construction

(1) HC=CH (Acetylene)



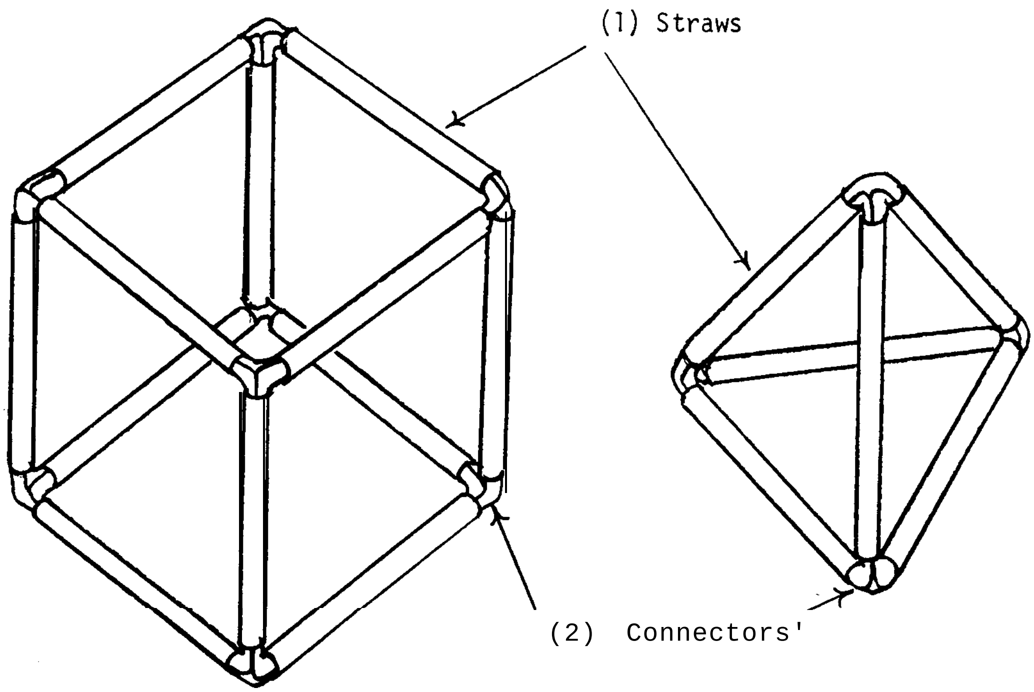
First make two C-H bonds (C) (X/B2) Then use two 6-armed valence clusters (A) and eight angular connectors (B) to connect the parts of the HC=CH (acetylene) molecule as shown. The 2.4 cm black straws (D) indicate the length of the triple bond, and are cut to represent twice the triple covalent bond radius for carbon. Bond thickness is indicated by the 3.0 cm straws (E) or twice the single bond radius for carbon.

c.Notes

(i) Because the forces holding two nucleii together in a triple bond are stronger even than those of a double bond, the nucleii are closer together. Thus, the straws representing the C=R covalent distance are shorter than those representing the C=R distances. Nucleii involved in sp hybridization with triple bond formation are represented in the model by the 6-armed sp valence cluster.

(ii) In the HC=B (acetylene) model, the central carbon-carbon bond represents the Ó bond. The four outside sections of black straws represent two double-armed bonds.

B5. Geometric Structures*



a. Materials Required

Components	Qu	Iterns Required	Dimensions
(1) Straws	--	Paper or Plastic Milk Straws (A)	Approximately 0.4 cm diameter
	--	Pipe Cleaners (B)	Approximately 3 cm long

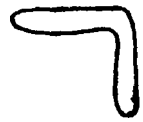
b. Construction

(1) Straws

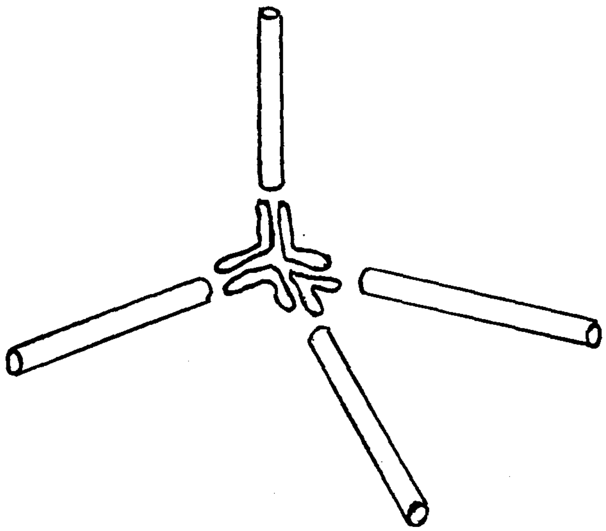
Cut the straws (A) to any convenient length, 5 cm, for example. Paint the straws, if desired, with poster (tempera) paints to which a small amount of dissolved soap has been added.

*Adapted from D.C. Hobson and C. V. Platts, "Milk-Straw Molecular Models," School Science Review, CLXIII (1966) pp 694-701.

(2) Connectors



Bend the cut pipe cleaners (B) to form right angles.



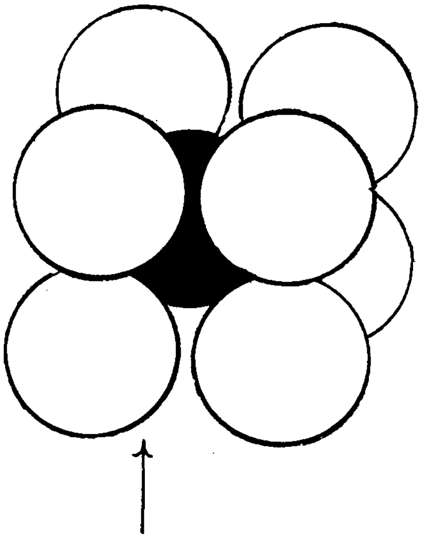
Insert the pipe cleaners (B) into the straws (A), as shown, to form secure connections.

C.Notes

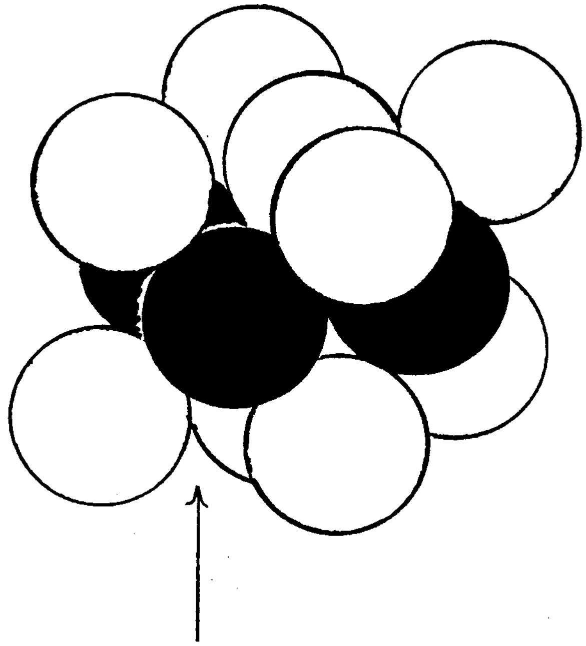
(i) By selecting appropriate numbers of straws and connectors, a variety of geometric forms may be built.

C. CRYSTAL STRUCTURE MODELS

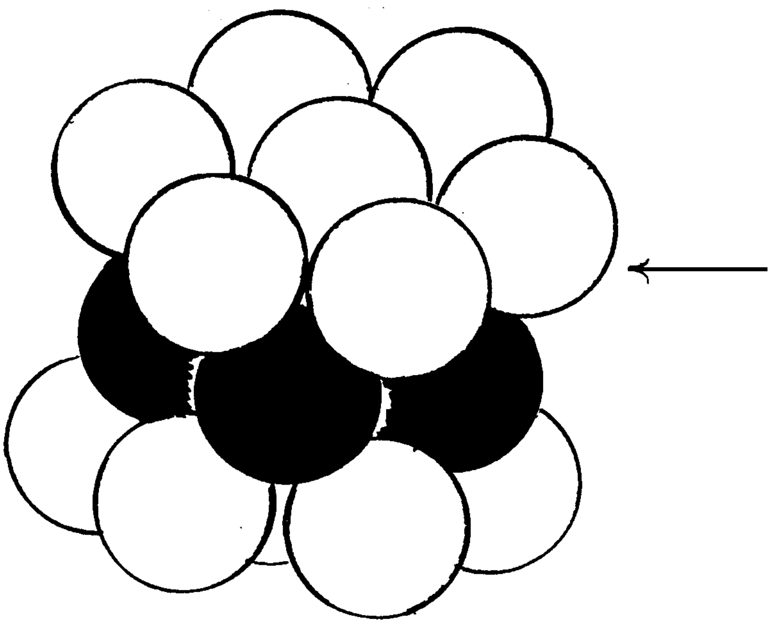
Cl. Crystalline Packing Models*



(1) Body-Centered
-Cubic Unit Cell



(2) Face-Centered
Cubic Unit Cell



(3) Closely-Packed
Hexagonal Unit Cell

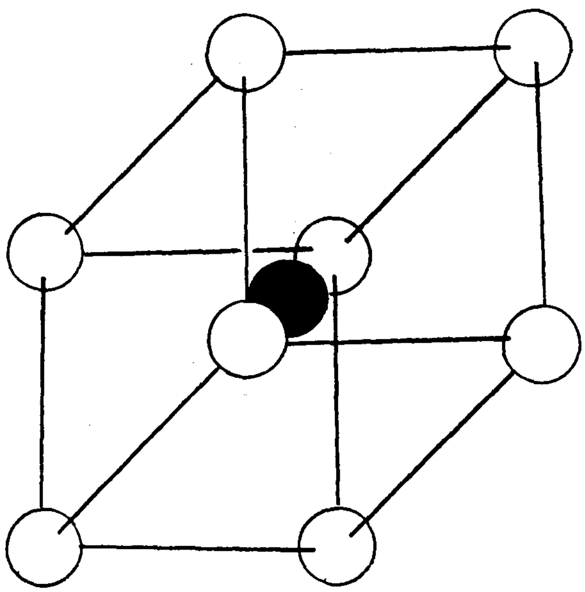
*Adapted from J. W. Coakham, W. Evans, and H. Nugent, "Introducing Crystal Structures," School Science Review, CLXXIV (1969), pp 61-71.

a. Materials Required

Components	Qu	Items Required		Dimensions
(1) Body-Centered Cubic Unit Cell	9	Styrofoam or Foam Polystyrene Spheres	(A)	Approximately 4 cm diameter
(2) Face-Centered Cubic Unit Cell	14	Styrofoam or Foam Polystyrene Spheres	(B)	Approximately 4 cm diameter
(3) Closely-Packed Hexagonal Unit Cell	17	Styrofoam or Foam Polystyrene Spheres	(C)	Approximately 4 cm diameter

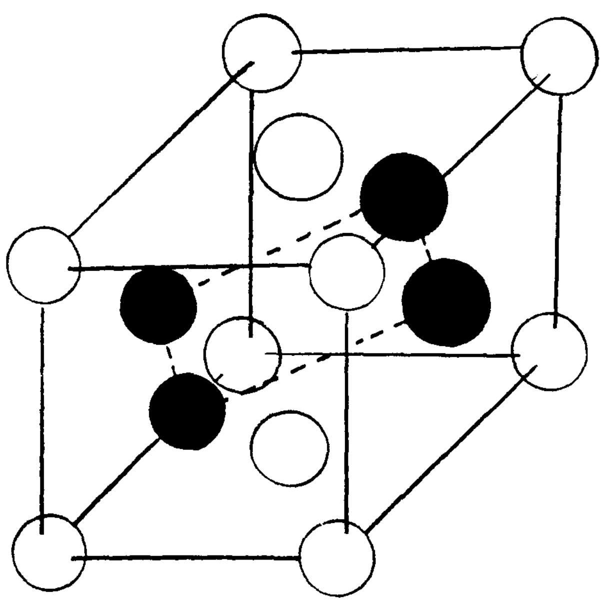
b. Construction

(1) Body-Centered Cubic Unit Cell



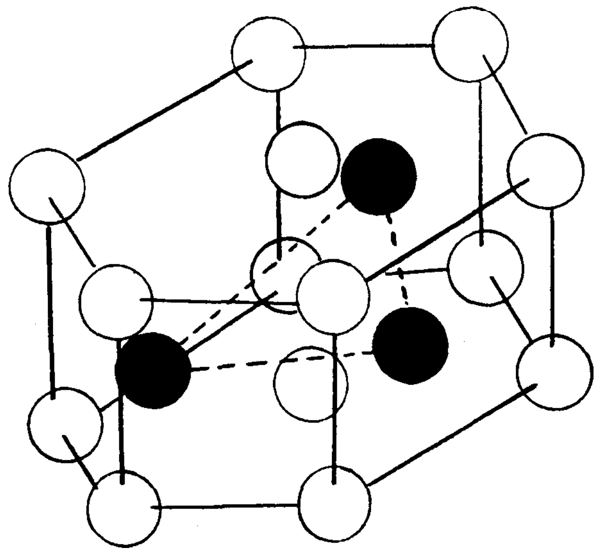
Make the spheres (A) from Styrofoam or foam polystyrene (X/Bl) or purchase spheres from a commercial source. Use the nine spheres to represent the atoms of the crystal according to the "exploded" diagram. Place four spheres in the top and bottom layers, and one in the middle. Use toothpicks, pipe cleaners, match sticks, or cement to hold the spheres together,

(2) Face-Centered Cubic Unit Cell



Use this exploded diagram as a guide for building the face-centered cubic unit cell from 14 spheres (B). Place five spheres in both top and bottom layers, and four spheres in the middle layer.

(3) Closely-Packed Hexagonal Unit Cell

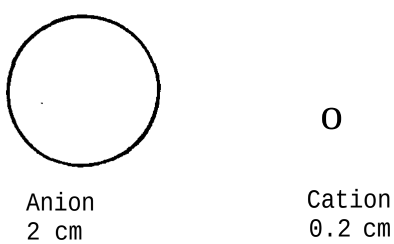


Use seventeen spheres (C) as illustrated to build the closely-packed hexagonal unit cell. Place seven spheres in the top and bottom layers, with three in the middle layer.

C. Notes

(i) The models described demonstrate three-dimensional patterns found in crystals of metals, where the atoms are all of one size and the bonding forces are equal in all directions. As with previous models, the use of molecular models aids the student in both understanding the structure and predicting the characteristics of the substances studied.

(ii) If it is necessary to construct crystal models showing different ion sizes, smaller or larger Styrofoam spheres may be used. For example, ionic crystal models may be constructed using spheres 2 cm in diameter for anions, and 0.2 cm diameter for cations,

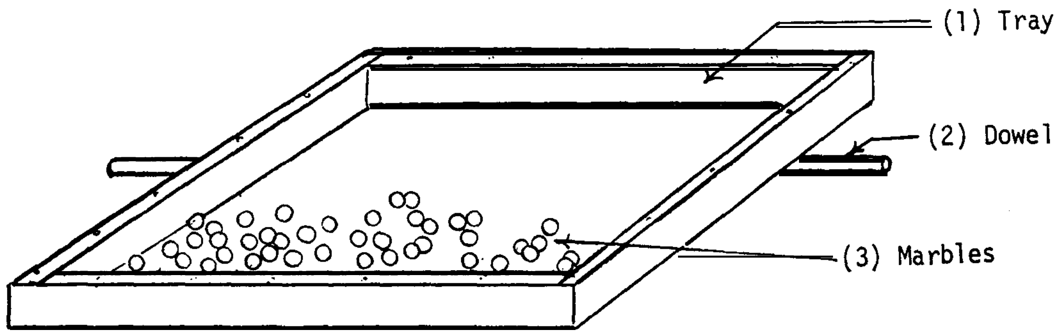


(iii) These models may be also used to demonstrate such aspects of crystal structures as coordination number, most closely-packed planes and Miller Indeces,

(iv) For further discussions on the application of these models to the study of the molecular structure of crystals, consult J, W. Coakham, W. Evans, and H. Nugent, "Some Aspects of Crystal Structure, Part I," School Science Review, CLXXIX, pp 339-350.

D. KINETIC-MOLECULAR MODEL

Dl. Kinetic Theory Model*



a, Materials Required

Components	Qu	Items Required	Dimensions
(1) Tray	1	Wood (A)	1 cm x 30 cm x 30 cm
	2	Wood (B)	2 cm x 2 cm x 26 cm
	2	Wood (C)	2 cm x 2 cm x 30 cm
(2) Dowel	1	Wooden Dowel (D)	Approximately 1.5 x 40 cm
(3) Marbles	250	Marbles or Glass Beads (E)	Approximately 1.0-1.5 cm diameter
	5	Marbles or Glass Beads (F)	Larger than the others

b. Construction

(1) Tray

Nail or glue the four wood strips (B and C) to the flat wood square (A) to form a tray. Varnish the tray inside and out to provide a slick inside and outside surface.

(2) Dowel

Select a dowel (D) to support one end of the tray.

(3) Marbles

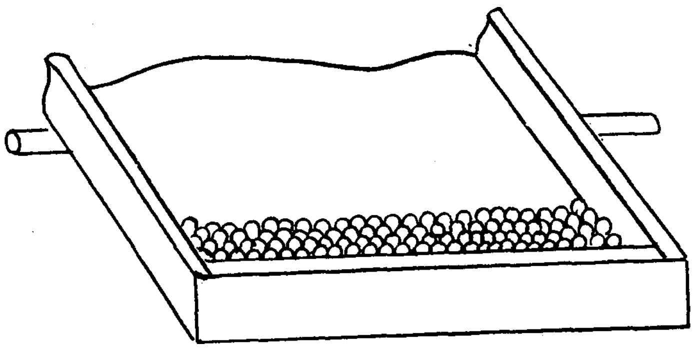
Place the marbles or plastic or glass beads (E) in the tray. Use all of them to represent the molecules in a solid or liquid. Use only 40 - 50,

*Adapted from I. D. Taylor, "Kinetic Theory Nodels," School Science Review, CLXIII(1963), pp 780-783.

plus the few larger marbles (F), to represent the molecules in a gas.

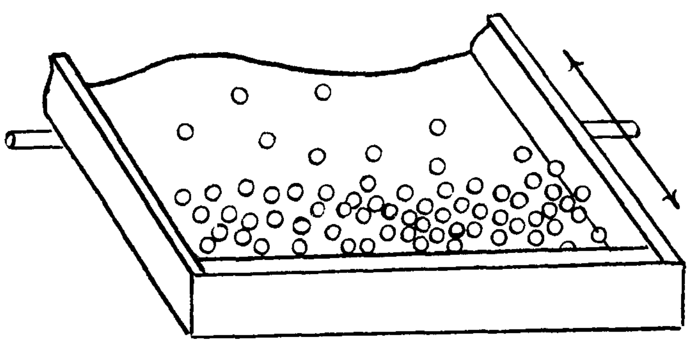
c. Notes

(i) To demonstrate, two-dimensionally, the kinetic activity of molecules in matter, place all the marbles in the tray. Rest one end of the tray on the dowel so that the marbles all roll to the opposite end, packing into a regular structure with each marble, or "molecule" touching six neighbors.



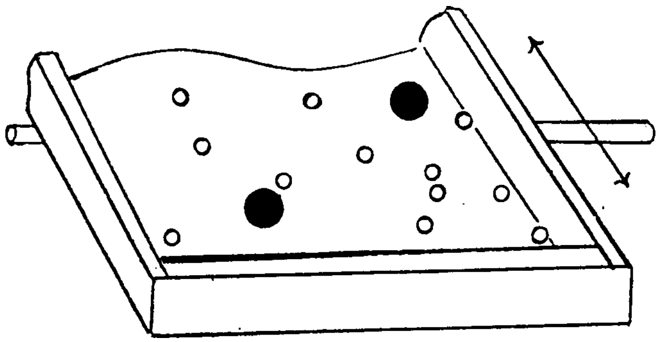
(ii) When the tray is at rest, none of the "molecules" move, representing the theoretical condition of matter at absolute zero. When the tray is gently agitated back and forth, the "molecules" begin to vibrate and to show "thermal expansion". They occupy a larger volume, but generally retain the same relative position. Occasionally a few molecules jump clear of the surface, representing the slight vapor pressure of a solid.

(iii) As the tray is agitated still harder, with greater amplitude, the "solid" "melts" with the "increase in temperature" (increase in kinetic energy). The molecules slip out of place, the volume increases, and more molecules jump away from the surface.



By slowing down the rate and amplitude of vibration, the "liquid" can be converted back to a "solid". Slowing the vibration gently represents gradual cooling and results in a regular structure. If, however, the vibration suddenly ceases, rapid cooling is demonstrated. The resulting "solid" shows an irregular structure with many imperfections.

(iv) For a demonstration of a "gas", most of the molecules are removed, and the tray is agitated more rapidly than for the "solid" or "liquid". All the



molecules move rapidly and randomly about, traveling large distances before colliding with one another. A few larger marbles, added to the "gas", move with small, irregular, jerky motions, representing the Brownian motion of dust or smoke particles in air.

(v) If a clean glass tray and overhead projector is available, the model may be projected on a screen for a large class to see. The "molecules" show on the screen as shadows.

XI. CHROMATOGRAPHIC APPARATUS

Chromatography, a powerful analytical technique of recent development, may be performed with relatively simple apparatus. It is based upon the differential migra tion of solutes in a liquid or solid medium and maybe used for both qualitative and quantitative analysis of solutions.

A. QUALITATIVE CHROMATOGRAPHIC APPARATUS

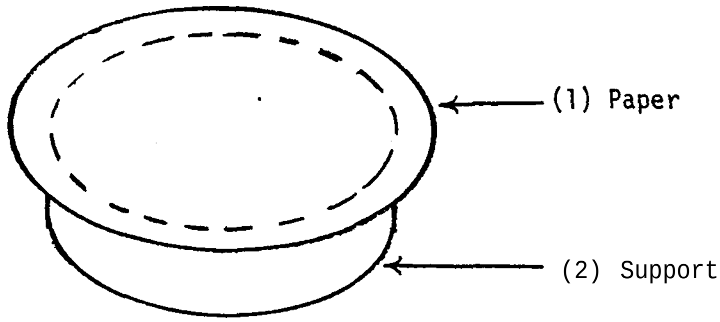
This section includes chranatographic devices employing paper as the stationary medium and briefly describes a few techniques for using these devices to identify the components of a mixture.

B. QUANTITATIVE CHROMATOGRAPHIC EQUIPMENT

This section describes a device that allows for the separation of the components of a mixture as well as the recovery of individual components for further experimenta- tion or purification.

A. QUALITATIVE CHROMATOGRAPHIC APPARATUS

Al. Horizontal Paper Chromatography Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper'	1	Filter Paper (A)	Approximately 10 cm diameter or larger
(2) Support	1	Petri Dish (B)	Slightly smaller than filter paper

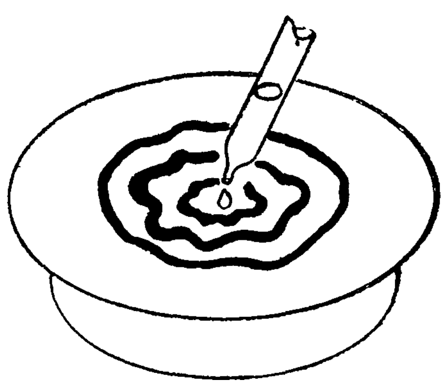
b. Construction

(1) Paper — Use a circle or square of filter paper (A) as the medium for the chromatogram.

(2) Support — Select a petri dish or other shallow container (B) just slightly smaller than the paper (A) on the support (B).

c. Notes

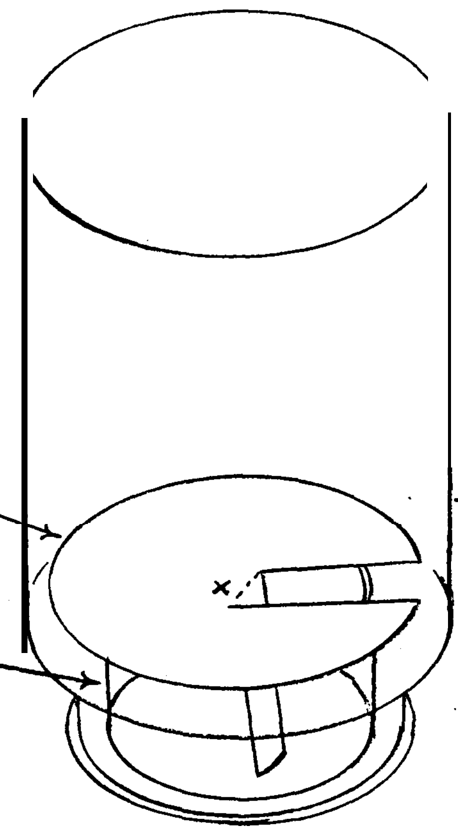
(i) This apparatus can be set up almost instantaneously for rapid, qualitative work. A drop of a colored solution to be analyzed is placed in the center of the paper. Then, successive, small drops of the eluting solvent are dropped on top of the original drop. The solution spreads radially, and as separation of components occurs, concentric rings of color will appear on the paper.



(ii) As an example of a test solution, a drop of black or blue-black, washable ink may be used. The eluting solvent in this case could be water, methanol (methylated spirits) or 70% ethanol.

(iii) Chromatography paper, white paper towels, blotting paper, newsprint paper, or other white or light-colored, coarse-grained paper may be substituted for the filter paper (A).

A2. Horizontal Paper Chromatography Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper	1	Filter Paper (A)	Approximately 10 cm diameter or larger
(2) Support	1	Cup or Jar (B)	Slightly smaller than filter paper
(3) Cover	1	Glass Jar or Bowl (C)	To cover paper and support

b. Construction

(1) Paper

Take a circle or square of filter paper (A) or suitable substitute and cut a tongue across the paper to within about 1 cm of the center of the

*Adapted from A. V. Jones, "Chromatography for Junior Schools," School Science Review, CLXXIX: (1970), 298-300.

paper. Bend the tongue down at a right angle to the paper (A).

(2) Support

Select a small cup or jar (B) just slightly smaller than the paper (A). Rest the paper (A) on the jar (B) with the paper tongue extended into the jar.

(3) Cover

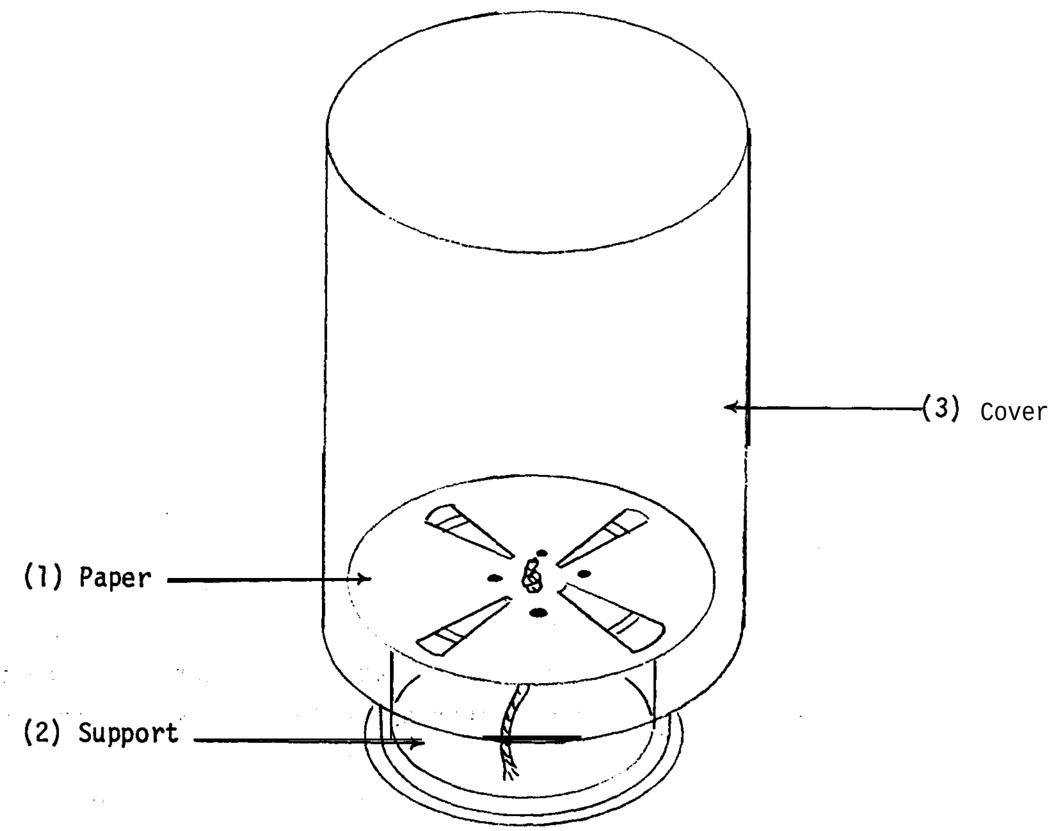
Select a large glass jar or bowl (C) to cover the support and paper. Invert the cover to enclose the other two components.

c. Notes

(i) This apparatus, while only slightly more complex than that in the previous section, has the added advantage that, once set up, it may be left to stand for some time. A spot of test solution (e.g., ink or a concentrated extract made from plant flowers, leaves , stems, or roots) is placed at the center of the paper (A). Then the small jar (B) is filled to within about 2 cm of the top with solvent (e.g., water or alcohol). When the paper tongue is placed in the solvent, the liquid will soak up the tongue to the test spot, and beyond. The components of the test solution separate out, in rings, as the solvent progressively soaks the paper. Covering the apparatus with a bowl or jar (C) helps prevent evaporation of the solvent before it has had time to soak the paper.

(ii) The experiment continues until the solvent front reaches to within about 1 cm of the edge of the paper, or until it is apparent that it has stopped moving. The paper is then removed from the apparatus and rapidly dried, using the drying lamp (IX/A3), a fan, or other source of dry heat or moving air.

A3. Horizontal Paper Chrcmatography Device *

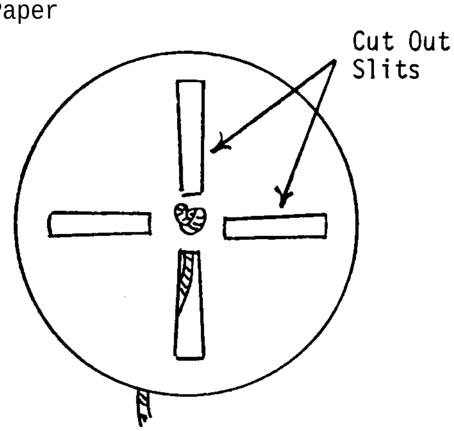


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper	1	Filter Paper (A)	Approximately 10 cm diameter or larger
	1	String (B)	Approximately 0.2 cm diameter, 5-10 cm long
(2) Support	1	Cup or Jar (C)	Slightly smaller than filter paper (A)
(3) Cover	1	Glass Bowl or Jar (D)	To cover paper (A) and support (C)

b. Construction

(1) Paper



Take a circle or square of filter paper (A) or suitable substitute and cut several slits radiating from the center as shown. Punch a small hole in the center and secure a piece of string (B) with a knot, to act as a wick.

(2) Support

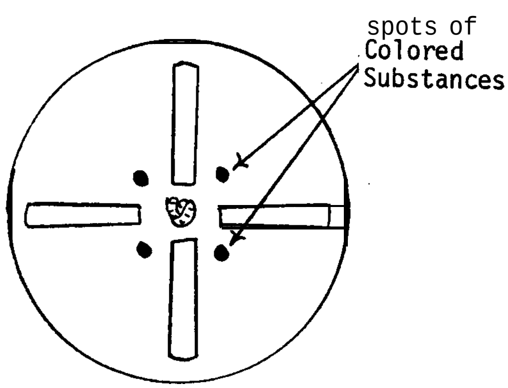
Select a small cup or jar (C) just slightly smaller than the paper (A). Rest the paper (A) on the rim of the jar (B) so that the string wick (C) extends into the jar.

(3) Cover

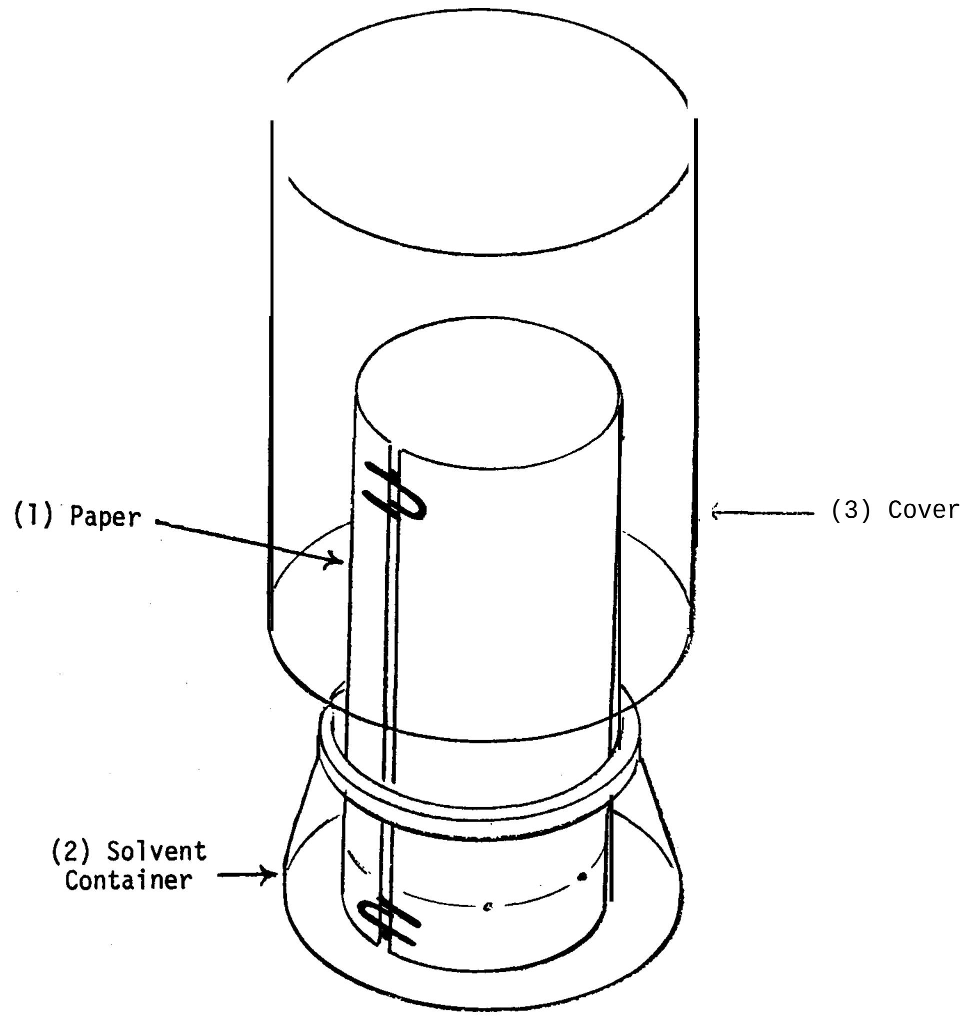
Select a large glass jar or bowl (D) to cover the support and paper. Invert the cover to enclose the other components.

c. Notes

(i) This apparatus is used in the same fashion as the preceding device. However, the slits in the paper allow for more than one colored substance or test solution to be used simultaneously. The spots are placed inside the "V" of the slits, which prevent the colors from merging.



A4. Vertical Paper Chromatography Equipment

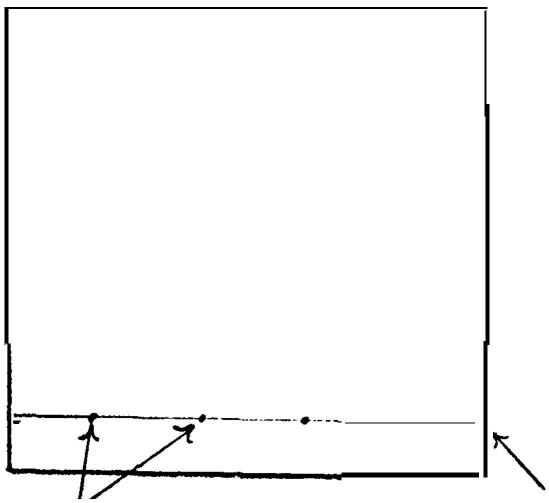


a. Materials Required

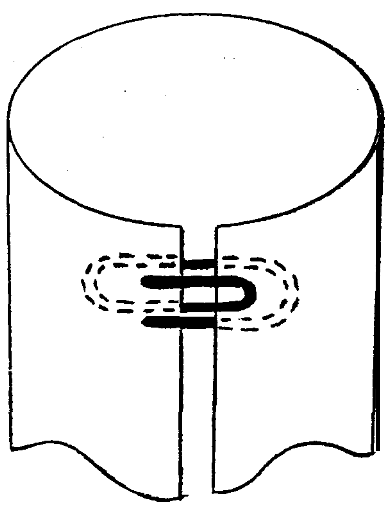
Components	Qu	Items Required	Dimensions
(1) Paper	1	Chromatography Paper (A)	Approximately 15 cm x 15 cm
(2) Solvent	1	Beaker, Bowl or Jar (C	To contain paper (A) when rolled into tube
(3) Cover	1	Glass Jar or Bowl (D)	To fit on or over Solvent Container (C)

b. Construction

(1) Paper



With a pencil, draw a faint line approximately 2 - 3 cm from one edge of the paper (A). Use this line as a guide for locating the spots of solution or solutions to be tested. Make the spots as small as possible and about 2 cm apart.



Roll the paper (A) loosely into a tube. Secure the edges together with the paper clips (B) such that the edges do not touch or overlap.

(2) Solvent Container

Set the rolled paper (A) into the beaker, bowl, or jar (C) and pour solvent into the container (C) to a height of about 1 cm.

(3) Cover

Rest a large glass jar or bowl (D) on or over the solvent container (C) to prevent evaporation of the solvent.

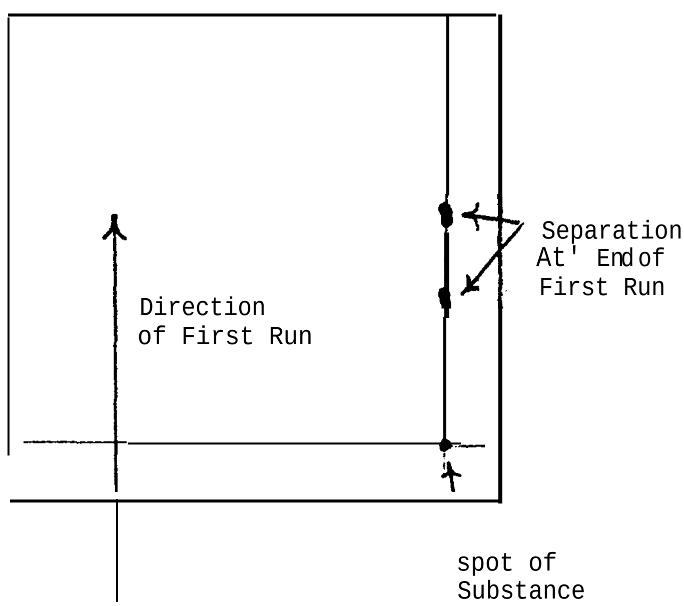
c. Notes

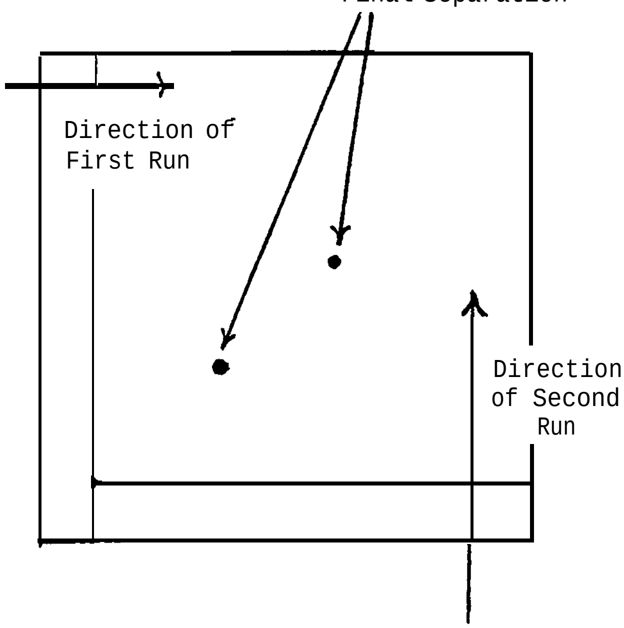
(i) If chromatography paper is not available, white paper toweling or blotting paper may be substituted.

(ii) When this apparatus is in use, the solvent front migrates up the paper, (by capillary action) resulting in the separation of the components of the test spot. This is allowed to continue until it has reached to within several cm of the top of the paper or until it is apparent that the solvent front will move no further (when the rate of capillary action is in equilibrium with the rate of evaporation). The paper is then removed from the apparatus and dried, and the final locations of the color spots may be circled with pencil for easy identification.

(iii) This apparatus is also suitable for performing separation of colorless substances, as long as the completed chromatogram can be treated in some way to make visible the final location of the component of the substances. For example, proteins, while generally colorless, may separate in this fashion. The dried chromatogram is then sprayed with a ninhydrin solution, which reacts with the amino acids in their final locations, making them visible as bluish spots or smudges.

(iv) It is possible, with this apparatus, to submit a substance to chromoto-graphic separation by two different solvents on the same sheet of paper. To run such a two-dimensional chromato-gram, a spot of the substance is placed at the intersection of two lines drawn on the paper and treated as described above. with one solvent. At the end of the first run, the chromatogram is removed from the apparatus and dried.

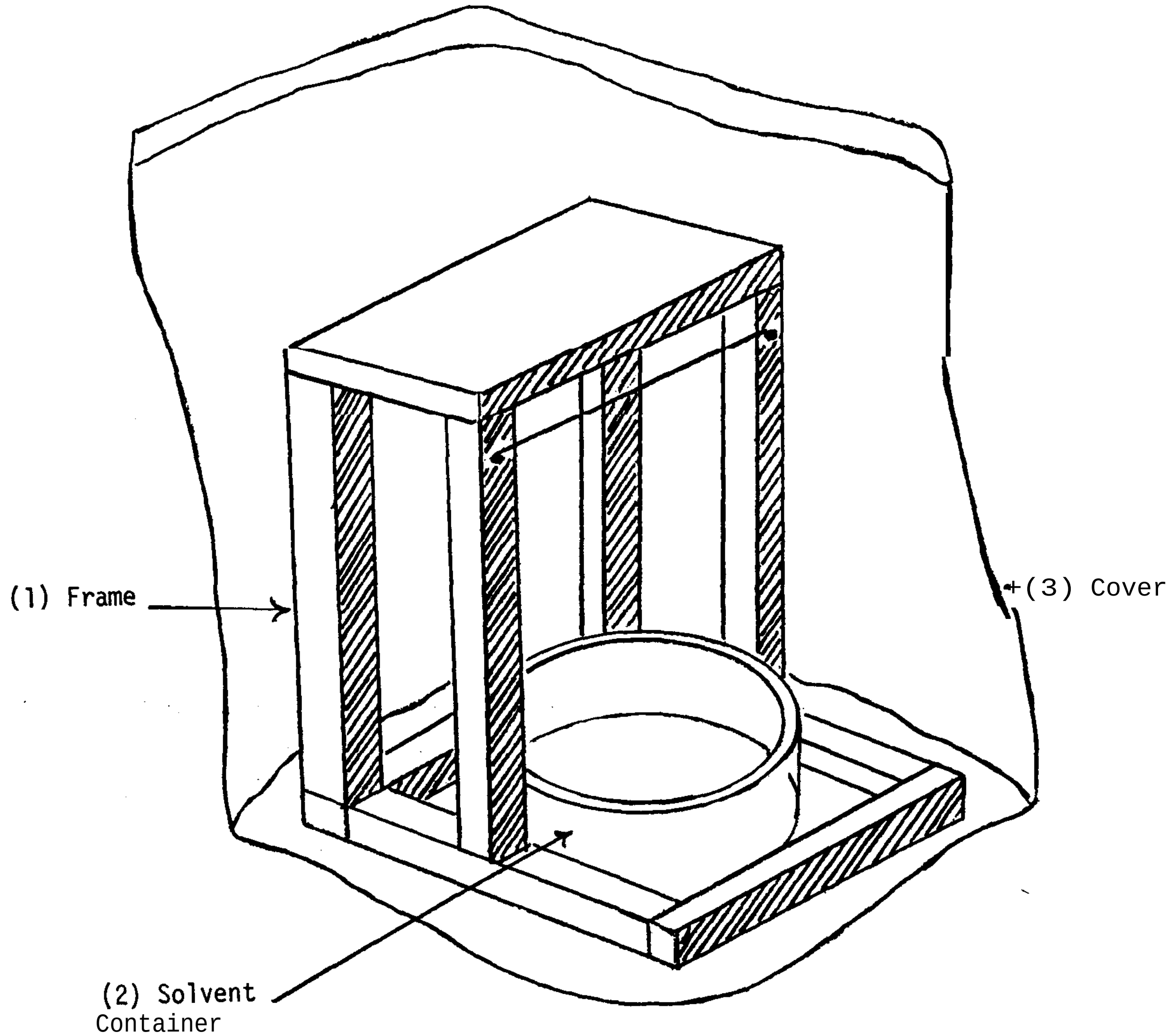




Then the paper is rotated 90° and again rolled into a tube, with the first separation at the bottom edge of the tube. This tube is run a second time with a second solvent. Thus, it is possible to effect a more complete separation than is possible with one solvent alone.

(v) A complete discussion of techniques and substances appropriate to chromatographic separation is beyond the scope of this guidebook. For further information, texts and resources on biochemistry, chemistry, and chromatography should be consulted.

A5. Vertical Strip Paper Chromatography Equipment

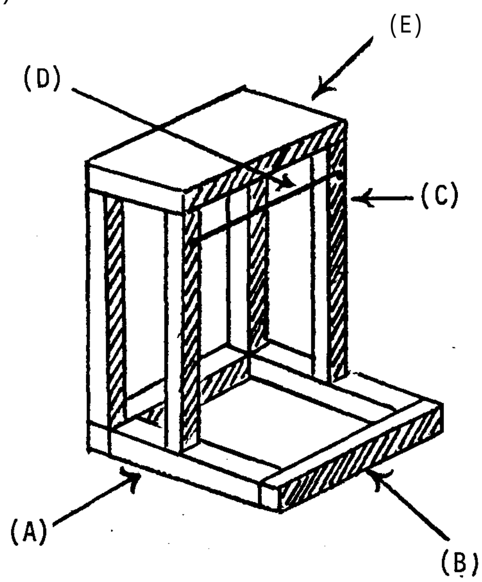


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	2	Wood (A)	1 cm x 1 cm x 8 cm
	2	Wood (B)	1 cm x 1 cm x 10 cm
	4	Wood (C)	1 cm x 1 cm x 20 cm
	1	Wood or Masonite (D)	6 cm x 10 cm x 0.2 cm
	1	Thin, Stiff Wire (E)	Approximately 11 cm long
(2) Solvent	1	Cup or Jar (F)	Approximately 4 cm high, to fit inside frame
(3) Cover	1	Plastic Bag (G)	To fit loosely over frame

b. Construction

(1) Frame



With nails and glue, secure the frame parts (A), (B), (C), and (D) as shown. Secure the wire (E) to the frame, about 2 cm from the top, with two small nails.

(2) Solvent Container

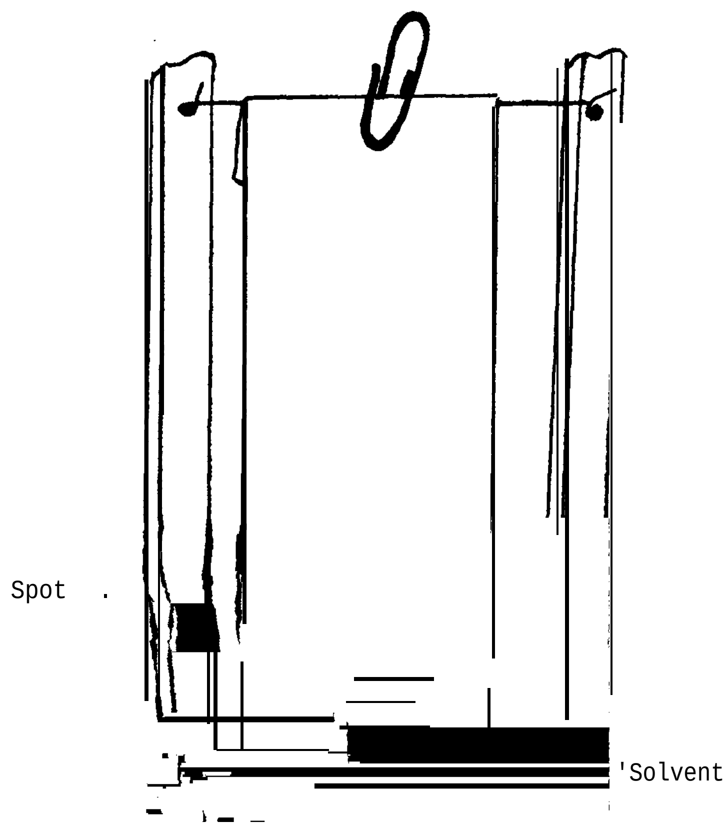
Select a shallow cup or jar (F) that will fit inside the frame. If necessary, cut a tall jar down to a height of 3 - 4 cm (I/F2).

(3) Cover

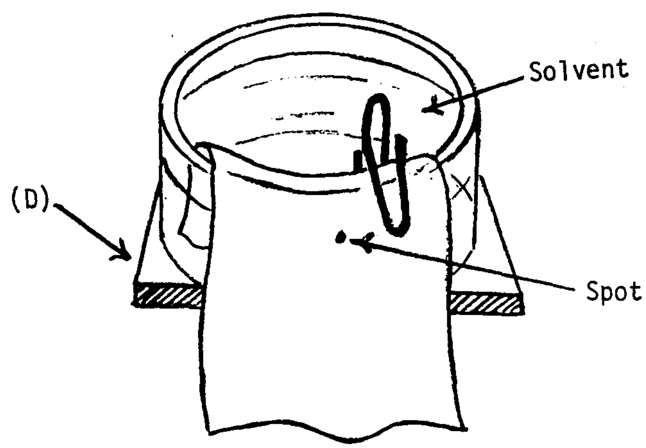
Select a plastic bag (G) that will fit loosely over the frame. It may be held in place by clipping it with a clothespin to a clamp or ring that is supported about 10 cm above the frame on the ring and burette stand (IV/B5) or other suitable support. Alternatively, a frame to support the bag may be constructed out of stiff (e.g., coat hanger) wire.

C.Notes

(i) This frame may be used to support a strip of chromatography paper or suitable substitute for either ascending or descending chromatographic operations. For ascending operations, the solvent container (F) remains at the bottom of the frame. The Paper strip, with one end just touching the solvent, is hung from the wire with a paperclip The spot or spots of substance to be separated is located at the lower end of the strip, just above the solvent. The apparatus should be kept covered by the plastic bag (G) during the course of the experiment to keep solvent evaporation to a minimum.



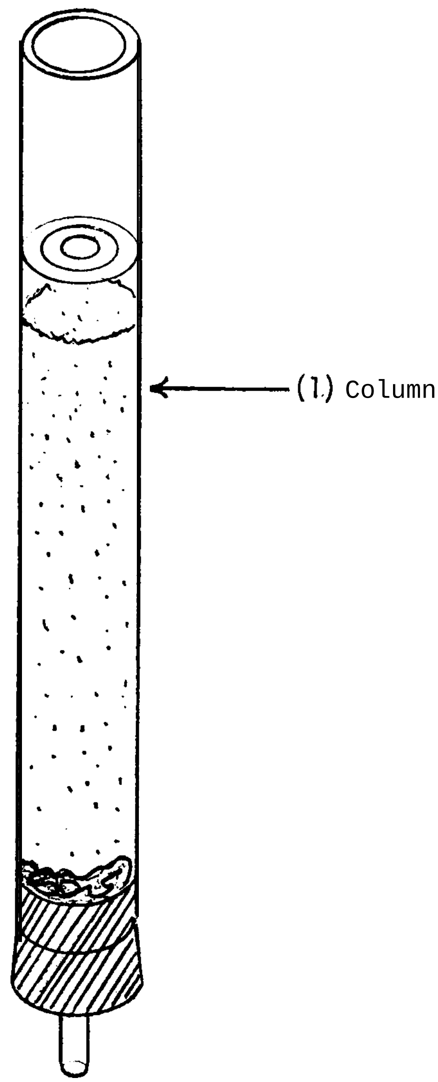
(ii) In order to use the frame for descending operations, the solvent container (F) is placed on the top shelf (D). The paper strip is then hung from the solvent container, held in place with a paper clip or clothespin, and with a short piece folded over to dip into the solvent. The spot is located near the top of the strip, outside the solvent container. The solvent front then moves down the paper in the course of the experiment.



(iii) If a sufficiently large jar is available, it may be used as a cover in place of the plastic bag (G).

B. QUANTITATIVE CHROMATOGRAPHIC EQUIPMENT

Bl. Liquid-Column Apparatus

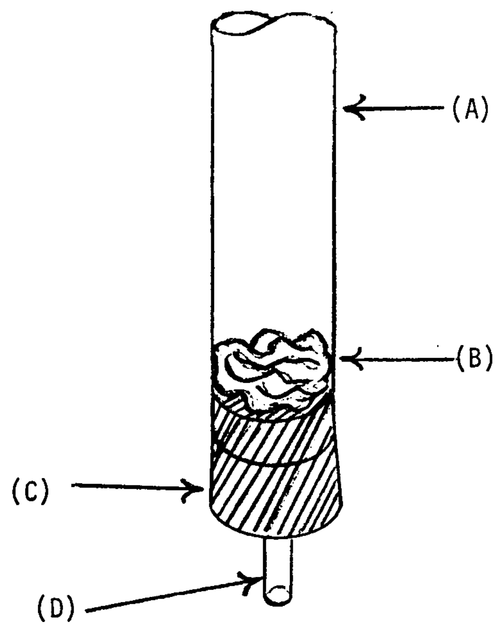


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Column	1	Glass Tube (A)	Approximately 1.5 cm outside diameter, 25 cm long
	1	Cotton or Glass Wool (B)	--
	1	l-Hole Stopper (C)	To fit tube
	1	Glass Tubing (D)	Approximately 0.5 cm diameter, 5-10 cm long
		Silica Gel (E)	28-200 mesh

b. Construction

(1) Column



Fire polish both ends of the glass tube (A) to eliminate sharp edges. Push a small wad of cotton or glass wood (B) about 1 cm into one end as a plug.

Insert the small glass tube (D) into the stopper (C) and push the stopper into the large glass tube (A), and support the column in a vertical position in a burette clamp (IV/B5) or other suitable support.

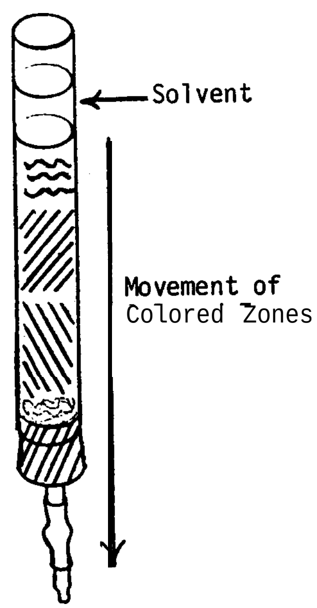
To pack the column with the stationary medium, make a slurry with several grams of the silica gel (E) and water. Pour this slurry into the top of the column, and allow the water to drain through the small glass tube (D), while the moist silica gel is retained by the plug (B). If necessary, pour additional slurry into the column until about 15 cm of the column is packed with silica gel and about 1 cm of water remains on top of the silica gel. If desired, the packing operation may be hastened by applying slight suction, by means of the suction-filter flask (VI/A4) coupled with a suction pump, aspirator (V/A8) or other source of suction.

c. Notes

(i) The flow of liquid through the column may be controlled, if desired, by the addition of a stopcock, or flexible rubber tubing coupled with a pinch clamp (IV/A4) or glass bead (III/Bl). A glass nozzle may also be added to the free end of the flexible tubing.

(ii) To use this apparatus, the water remaining on the column is allowed to drain until less than 1 cm remains to cover the silica gel. Then a small quantity of a solution of colored material to be tested, in a concentrated form, is gently pipetted on to the medium. The desired solvent is then added to the column, and the column is allowed to drain slowly, using either gravity or very slight suction.

As the solvent moves down the column, carrying the substance with it, separation will occur, as indicated by colored zones appearing on the medium. As additional solvent is added to the column, the zones themselves will migrate down the column; if sufficient solvent is added, each zone, consisting of a specific component of the substance tested, may be washed off the column and recovered separately.



(iii) In addition to separating components of a substance and washing them down the column with one solvent, it is possible to use additional solvents to wash down a component or components that do not migrate at all with the first solvent. To do this, allow the column to drain until less than 1 cm of the first solvent remains on top of the medium, then add the second solvent to the column and proceed with the washing as described above.

(iv) Other interesting results may be obtained by reversing the order of solvents used, in successive runs, with the same test substance. For example, alcohol and water are two solvents that may be used, in either order, to separate a mixture of vegetable dyes or ink.

(v) One of the chief advantages of the liquid-column method of chromatographic separation over paper chromatography is that the components of the substance tested are recovered individually for use in further experiments or in quantitative determinations. For example, a measured quantity of the test substance, in a known concentration, is added to the column, and the solvent used and the solutions recovered are measured. Then the components eluted are submitted to volumetric or gravimetric quantitative analysis to determine the proportion of each component present in the original sample.

(vi) Substances other than 28 - 200 mesh silica gel, and solvents other than alcohol or water, may be used in liquid-column chromatography. Further experimentation, as well as research into the technical literature on chromatography, is suggested for the development of this technique. A useful reference for this purpose is Erich Heftmann, Chromatography, Second Edition, (New York: Reinhold Publishing Corporation, 1967).

XII. MULTIPURPOSE SYRINGES

Many chemical techniques and experiments are readily performed using disposable plastic syringes. Some of these uses will be described in this section, and the devices have been grouped according to the concepts they illustrate. In addition to those uses given here, syringes can also be used in column chromatography, ion exchange devices, and other areas in chemistry.

A. TECHNICAL DEVICES

Two items of use in the chemistry laboratory are included here.

B. GAS STUDIES APPARATUS

Included here are several ways in which syringes may be used in studying the production, collection, and properties of gases.

C. DIFFUSION APPARATUS

Diffusion of both gases and liquids can easily be studied with the aid of plastic syringes.

D. OXIDATION APPARATUS

This section describes a number of devices used in the study of oxidation reactions.

E. ANALYTICAL APPARATUS

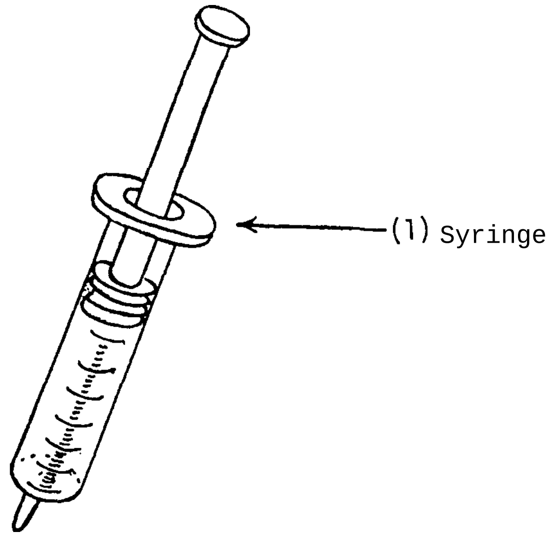
These devices are used in experiments to determine chemical formulae, structures, and molecular weight.

F. CONDUCTANCE APPARATUS

The variation in conductivity of different solutions can be studied with the aid of several devices which are fairly easily constructed with disposable syringes.

A. TECHNICAL DEVICES

Al. Dropper/Pipette



a. Materials Required

Components	Qu	Items Required	Dimensions
(1)Syringes	1	Plastic Disposable Syringe (A)	Capacity 10-50 ml

b. Construction

(1) Syringe

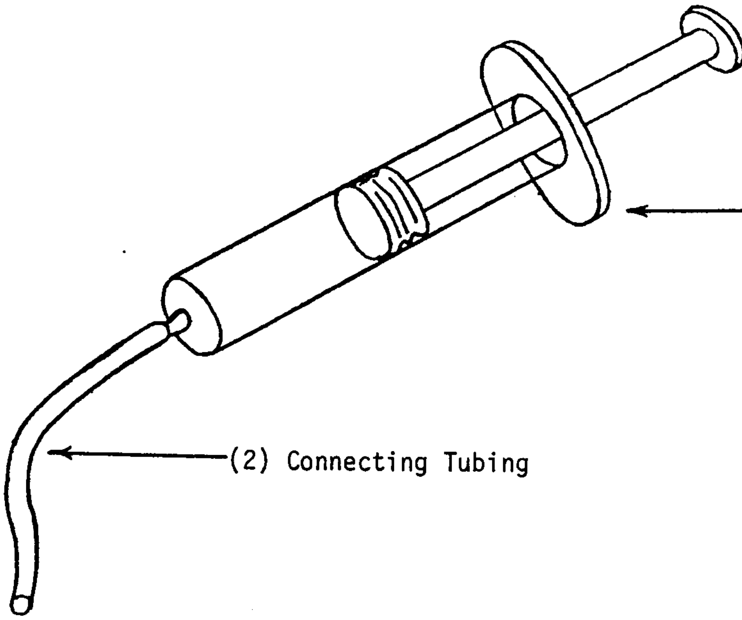
Select a calibrated, plastic disposable syringe (A) with a volume appropriate for the desired use.

c. Notes

(i) In the smaller sizes, disposable syringes make excellent droppers with an advantage being that the amount dispensed is measurable. Similarly, they can be used for the same purposes for which pipettes are used. In the larger sizes, syringes can substitute for burettes in titration experiments. Finally, syringes may be utilized in calibrating improvised flasks, beakers, etc., of unknown capacity.

(ii) Placing a medium-sized diameter needle (inside diameter approximately 0.03 cm) on the syringe nozzle will allow solutions to be carefully and accurately delivered, drop by drop.

A2. Pump



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 20 ml
(2) Connecting Tube	1	Plastic or Rubber Tubing (B)	Approximately 10 cm long, diameter to fit syringe nozzle (A)

b. Construction

(1) Syringe

Take a plastic, disposable syringe (A) with a volume appropriate for the desired use.

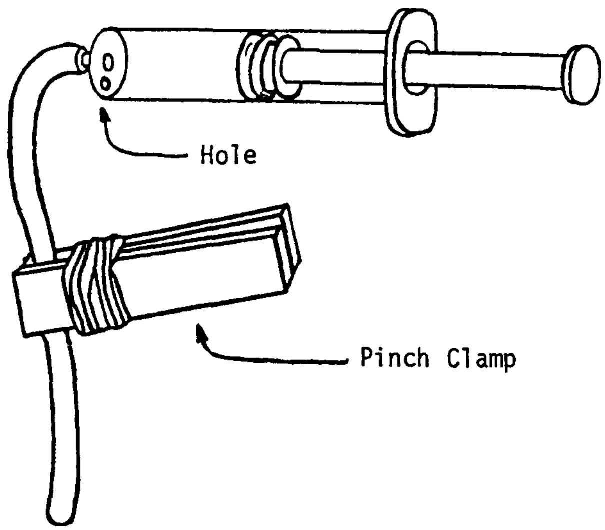
(2) Connecting Tubing

Attach a length of plastic or rubber tubing (B) to the syringe nozzle when the pump is to be used in hard-to-reach places.

c. Notes

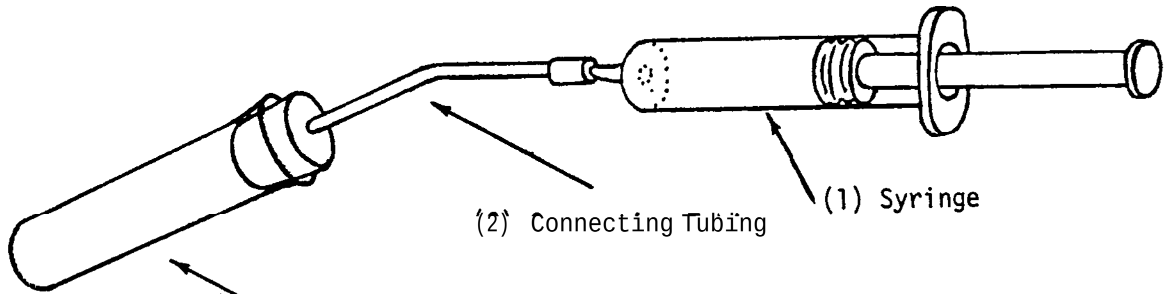
(i) To use the pump, connect the tubing to the object from which gas or liquid is to be removed. Withdraw the plunger to draw gas or liquid into the syringe. Then remove the tubing from the object or container, direct the tubing into an appropriate container or waste receptacle , and depress the plunger to expel1 the gas or liquid through the tubing.

(ii) With two modifications, the syringe may be used to provide continuous pumping action without removing the tubing from the object from which substances are pumped. Make a small hole in the base of the syringe barrel with a drill or hot wire, and add a pinch clamp (IV/A4) to the tubing to close it off. In use, the tubing is connected to the object from which gas or liquid is to be removed. Then the pinch clamp is removed from the tubing and the hole in the syringe barrel is covered with a finger. The plunger is withdrawn to draw material into the syringe. To expel1 the contents of the syringe through the hole, the tubing is closed with the pinch clamp, the hole is uncovered, and the plunger is depressed.



B. GAS STUDIES APPARATUS

B1 Gas Production and Collection Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 10-50 ml
(2) Connecting Tube	1	Rubber or Plastic Tubing (B)	2 cm long, diameter to fit syringe nozzle (A)
	1	Glass Tubing (C)	Approximately 0.5 cm diameter, 10 cm long
(3) Reaction Chamber	1	Hard Glass Test Tube or Flask (D)	Capacity 20-100 ml
	1	l-Hole Stopper (E)	To fit test tube or flask (D)

b. Construction

(1) Syringe

Select a plastic, disposable syringe (A) of appropriate capacity.

(3) Connecting Tubing

Connect the short piece of flexible rubber or plastic tubing (B) to the syringe nozzle.

Heat the glass tubing (C) sufficiently to bend it to a slight angle (about 30°). Connect

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 19.

one end of the glass tubing to the rubber or plastic tubing (B).

(3) Reaction Chamber

Seal a hard glass test tube or flask (D) (capacity from 20 to 100 ml, depending on the desired use) with a one-hole stopper (E). Use a rubber stopper if caustic materials are to be used in the apparatus. Insert the free end of the glass tubing into the hole in the stopper.

C. Notes

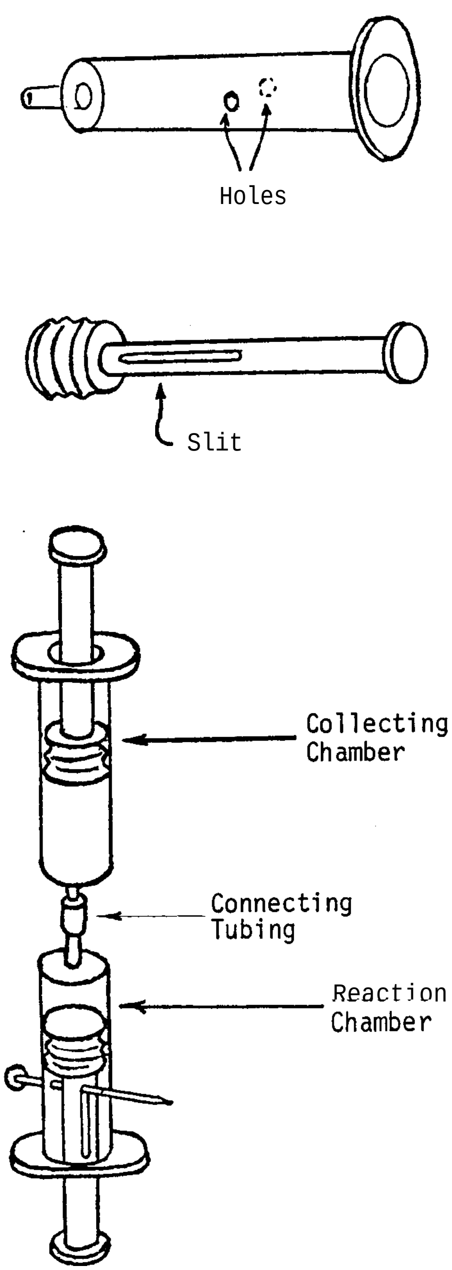
(i) This simple reaction apparatus, suitable for either lecture demonstration or student laboratory use, may be employed in a number of ways. In the simplest qualitative experiments, the use of the syringe allows liquids to be introduced into the reaction chamber where they react with solids or other liquids. A number of gases can be produced using this or similar devices. For example, injecting a 3% solution of hydrogen peroxide from the syringe into a suspension of dried yeast and water in the test tube will yield oxygen gas. Also, injecting a concentrated solution of baking soda from the syringe into vinegar will yield carbon dioxide. Finally, injecting vinegar into water and a piece of magnesium ribbon will cause hydrogen gas to be liberated. The gas liberated will collect in the syringe, pushing the plunger out as more and more gas is given off. Turning the plunger slightly will assure that the gas is at atmospheric pressure.

(ii) This apparatus may also be used for quantitative studies in the above reactions. The solid reactants must be carefully weighed or measured, and the use of the syringe allows very precise amounts of liquids to be introduced into the reaction chamber. The volume of the gas evolved may be read from the syringe. The change in volume of gas in the syringe may be plotted against time to give a measure of the rate of reaction. In addition, the volume of gas liberated may also be plotted as a function of temperature and/or the concentration of one or more of the reactants used.

(iii) In a third type of experiment using this apparatus, solids which give off gases when heated are placed in the test tube, and the gas is collected in the syringe. Begin with the syringe plunger fully depressed, and as the gas is evolved, it will push the plunger back, giving a quantitative measure of the amount of gas produced. In using this device, clamps to hold both the test tube and syringe are needed. As an example, red lead can be heated in the test tube, and the gas evolved collected in the syringe. It should be noted, however, that this will spoil the test tube. Instead, potassium permanganate can be used, and no spoilage of the test tube will occur. However, some asbestos wool must be put in the upper end of the test tube to prevent pieces of the potassium permanganate from entering the syringe.

(iv) The experiments based on the use of this apparatus are adapted from Nuffield O-Level Chemistry, Collected Experiments, (London: Longmans/Penguin Books, 1967), pp 9, 229-231, 297-299.

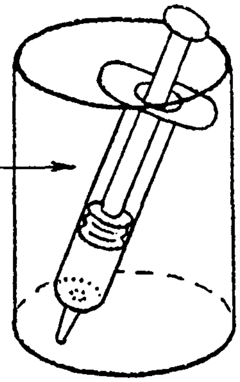
(v) If a glass reaction chamber is not available or is not desired, a second syringe, the same size as the first but slightly modified, may be substituted. First, with a hand drill or hot nail or wire, bore two holes, approximately 0.3 cm in diameter, opposite each other about half-way along the length of the barrel. With a drill and saw or hot nail, make a slit in the syringe plunger as shown. Push the plunger into the syringe, and lock it in place by inserting a nail approximately 0.3 cm wide and 5 cm long through the holes in the barrel and slit in the plunger. Place in the lower syringe a small piece of material which will react with the liquid to be placed in the upper syringe. Replace the plunger in the lower syringe, insert the nail stop, and depress the plunger until the nail prevents further movement. Draw a quantity of liquid into the upper syringe, and fasten the two together with the short piece of tubing. Next, inject all of the liquid into the lower syringe and



leave the upper syringe plunger in the depressed position. As gas is given off in the lower syringe, it will expand and push out the plunger of the upper syringe until the upper syringe is filled with gas or the reaction stops. Solids and liquids which can be used as outlined to produce gases include animal charcoal and hydrogen peroxide (to form oxygen), metals and dilute acids, carbonates and acids.

(vi) The above modification is based on a design by Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 30-31.

B2. Micro-Generator *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Disposable Plastic Syringe (A)	Capacity 10-50 ml
(2) Beaker	1	Glass Jar or Beaker (B)	To accommodate syringe as shown

b. Construction

(1) Syringe

Select a plastic, disposable syringe (A) of a size appropriate to the amount of gas desired.

(2) Beaker

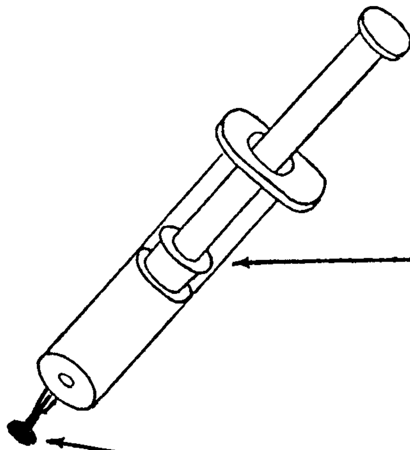
Select a glass jar or beaker (B) such that the syringe can be rested in it more or less vertically.

C. Notes

(i) As an example of its use, the micro-generator can be employed to generate hydrogen sulphide gas (H_2S). Simply place a small piece of ferrous sulphide in the syringe, and put a small amount of dilute hydrochloric acid in the beaker. Draw a portion of the acid up into the syringe until it touches the ferrous sulphide, and leave the syringe resting in the beaker. The gas will collect in the syringe, above the acid. If desired, the needle may be reattached to the syringe when it comes time to bubble the gas through a test solution.

*Adapted from L. A. George, "Two Further Uses for Disposable Syringes," School Science Review, CLXX (1968), 113.

B3. Gas Solubility Device/Reaction Rate Chamber



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 25 ml
(2) Plug	1	Nail (B)	To fit syringe nozzle (A)

b. Construction

(1) Syringe — Take a plastic, disposable syringe (A) of 25 ml or other desired capacity.

(2) Plug — Use the nail (B) to completely seal the syringe after a substance has been drawn into it.

c. Notes

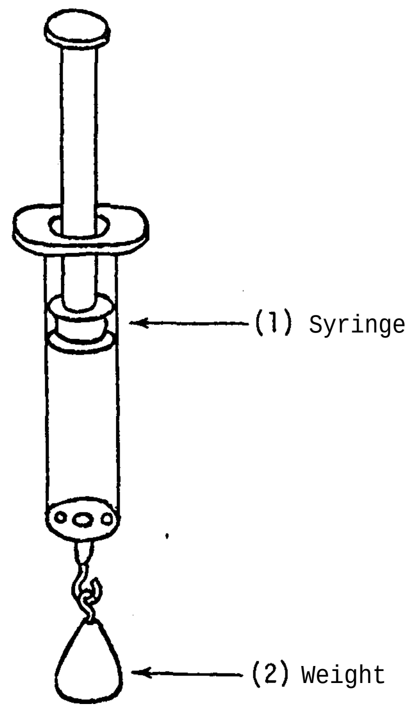
(i) A number of simple solubility experiments may be done with syringes that can be sealed airtight. For example, the syringe may be half filled with cold water, with the plunger just above the water level. Seal the nozzle, and when the plunger is withdrawn further, air will be seen to bubble out of the water. This same demonstration may be repeated with distilled water, or cold water through which CO_2, O_2, N_2, etc., have been bubbled. A slightly more sophisticated demonstration involves water through which has been bubbled for about five minutes. When a small amount of bromothymol blue is added, the solution will be yellow. Add this to a sealed syringe, and as the plunger is withdrawn, CO_2 will bubble out and the color of the solution will change to pale green. If the syringe is shaken, the CO_2 will be redissolved, and the solution will once again be yellow. The experiment may be tried repeatedly.

(ii) A single syringe can also be used to illustrate the effect of pressure on solubility. Attach a short length of rubber tubing to the nozzle, and also attach a clamp or piece of wire to the rubber tube which can be used to close the tube. Fill the syringe half full of water, and fill the remainder of the barrel with CO_2. Shake the syringe vigorously, then hold the tube under water, release the clamp (or loosen the wire), and note the rise in water level in the syringe. Repeat the experiment, but depress the syringe plunger while shaking it. There will be a noticeable difference in the rise of the water level.

(iii) The above experiments have been adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 35-37.

(iv) Another experiment that can be performed with the sealed syringe involves the relationship between reaction rate and pressure. Fill the syringe partially with vinegar and add sodium bicarbonate. Carbon dioxide will be given off, and this reaction can be speeded up or slowed down and stopped by decreasing or increasing the internal pressure with the plunger, respectively. This experiment is based on Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 6.

B4. Charles' Law: Volume/Temperature Device *

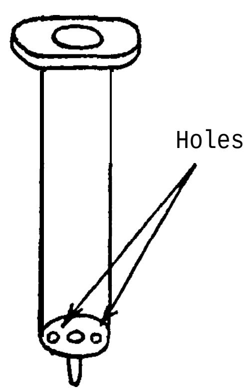


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 35 ml
	1	Small Eyed Screw (B)	To seal syringe nozzle (B)
(2) Weight	1	Lead Sinker or Weight (C)	Approximately 30 g

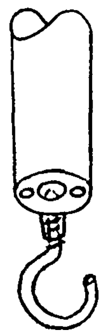
b. Construction

(1) Syringe



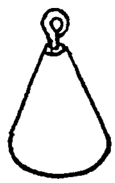
Make two small holes in the bottom of the syringe barrel (A) with a hand drill or hot wire.

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 32.



Screw a small, eyed screw (B) into the syringe nozzle to seal the nozzle and to provide an attachment for the weight (C).

(2) Weight



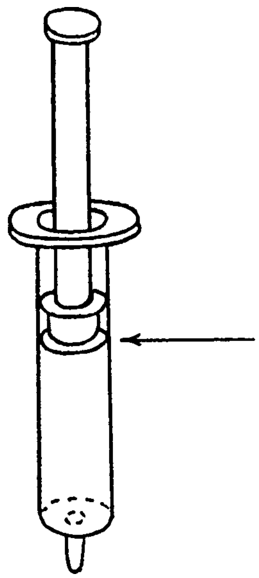
Hang a lead sinker (C) or other suitably sized weight (approximately 30 g) from the eyed screw.

C. Notes

(i) With the plunger set so that a 35 cc volume of air is trapped in the syringe barrel, the device is put into a container of hot water. Water will be seen to enter the syringe barrel as the expanding air leaves it through the small holes (the effect will be more visible if a drop of vegetable dye is placed in the nozzle depression before beginning). Varying amounts of water will enter the syringe depending upon the water temperature. Good quantitative data can be gotten by comparing the water temperature with the amount of water entering the syringe (or the air volume of the syringe after the water enters). The device should be removed from the water to return the air volume to its original reading for each temperature/pressure reading.

C. DIFFUSION APPARATUS

Cl. Liquid Diffusion Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 50 ml

b. Construction

(1) Syringe

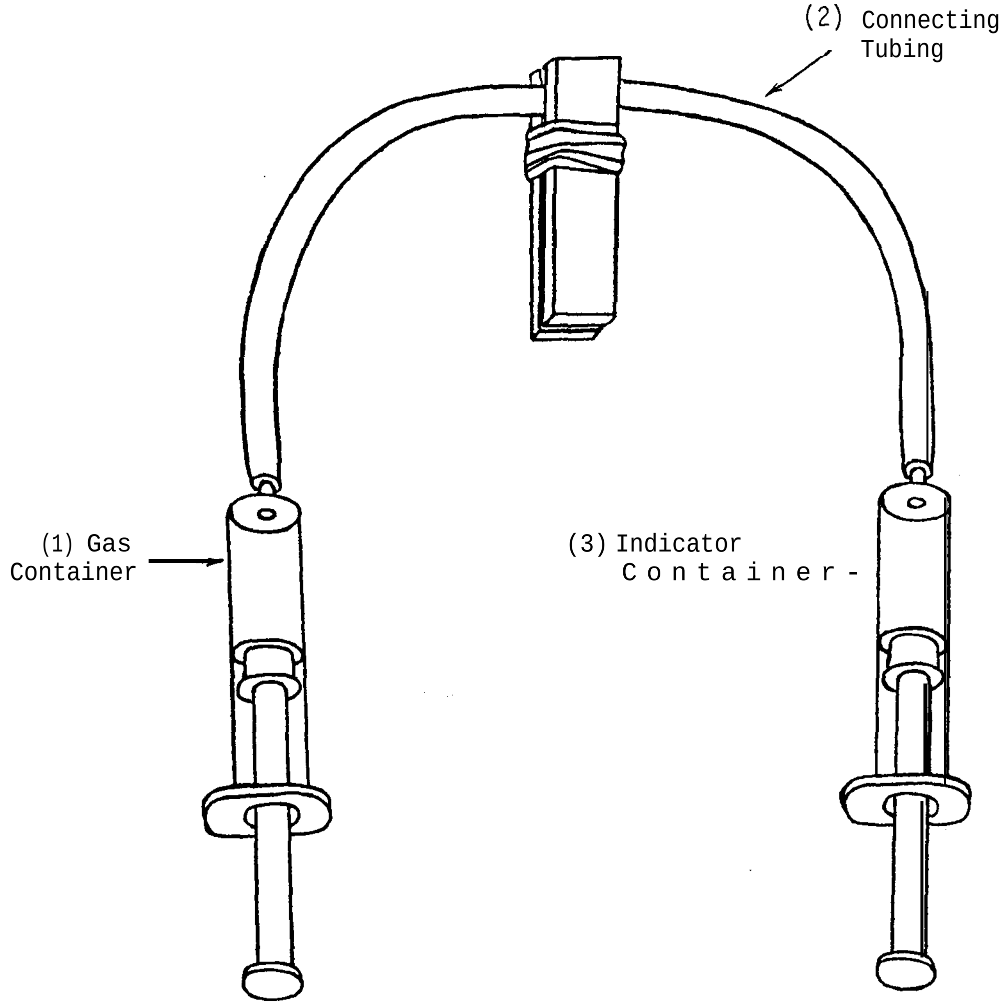
Select a plastic, disposable syringe (A) of a large capacity (35 - 50 ml, for example).

c. Notes

(i) To use this device to study diffusion of liquids, fill the syringe almost completely with cold water. Then, draw a small amount of colored solution into it and let the'syringe stand. Diffusion should be complete after two or three days. Colored solutions which work well include potassium permanganate and copper sulphate.

(ii) This experiment has been adopted from Andrew Farmer, "The Disposable Syringe: Additional Experiment," School Science Review, CLXXVIII (1970), 60.

C2. Gas Diffusion Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Gas Container	1	Plastic Disposable Syringe (A)	Capacity approximately 25 ml
(2) Connecting Tubing	1	Rubber or Plastic Tubing (B)	Approximately 15 cm long, diameter to fit syringe nozzles
	1	Pinch Clamp (C)	IV/A4
(3) Indicator Container	1	Plastic Disposable Syringe (D)	Capacity approximately 25 ml
	--	Indicator Solution (E) (Limewater or Litmus Solution)	Approximately 5 ml

*Adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 35.

b. Construction

(1) Gas Container

Select a plastic, disposable syringe (A) of about 25 ml capacity.

(2) Connecting Tubing

Use a length of flexible tubing (B) to connect the two syringes together. Make a pinch clamp (C) or use another suitable clamp to close the tubing.

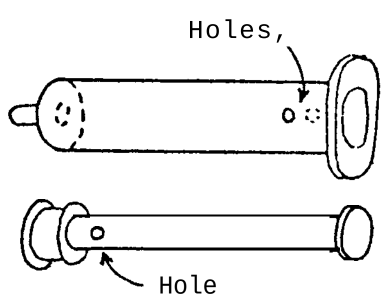
(3) Indicator Container

Select a plastic, disposable syringe (D) with the same capacity as that used for the gas container. Fill it with the indicator solution (E).

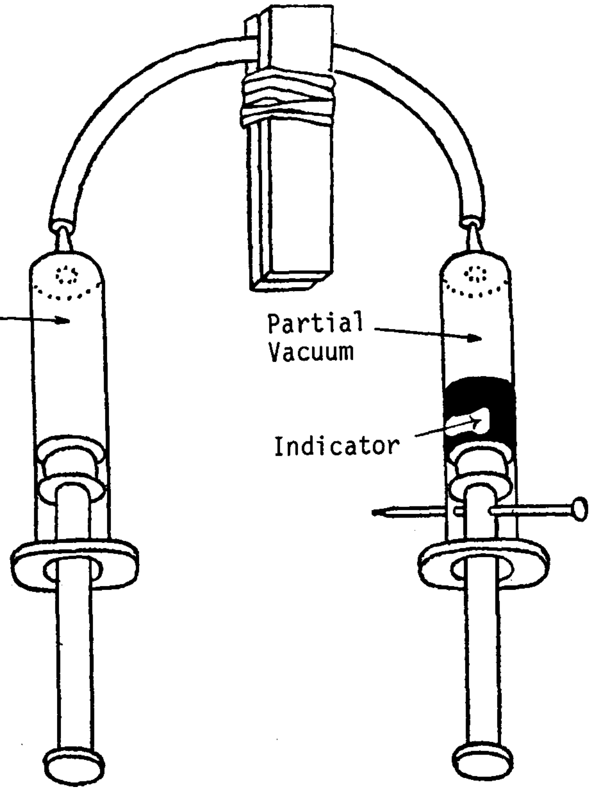
c. Notes

(i) Place an indicator solution (e.g., limewater) in the indicator container. A gas (e.g., CO_2) is collected in the gas container syringe and the two syringes are connected by the tubing. When the clamp is released, the gas will diffuse until it reaches the indicator solution and causes a reaction (white precipitate when CO_2 meets limewater). The time taken for the gas to diffuse may be measured.

(ii) A slight modification of the indicator container will allow a comparison of gas diffusion rates in air and in a partial vacuum. This is done by making two holes opposite each other near the mouth of the syringe barrel with a hand drill or heated nail. Then one hole is made in the plunger, as shown. The holes should be made so that a nail can be pushed through the barrel and plunger.



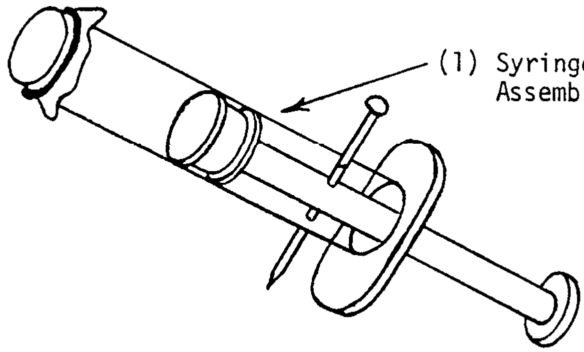
To repeat the above experiment with a partial vacuum, the nail is removed



from the indicator syringe and several ml of indicator solution are drawn into the syringe. Then the tubing, closed by the clamp, is attached to the syringe. With the clamp in place the plunger is pulled back, to create a partial vacuum, and the nail is pushed through the syringe barrel and plunger to hold the plunger in position. Gas is collected in the other syringe and allowed to diffuse to the indicator solution, and the time taken is compared to the results of the first experiment.

D. OXIDATION APPARATUS

Dl. Oxidation Indicator: Membrane Type *

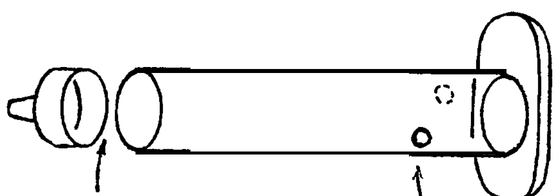


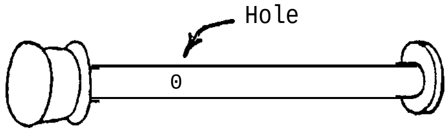
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe Assembly	1	Plastic Disposable Syringe (A)	Capacity 25-50 ml
	1	Nail (B)	Approximately 0.2 cm diameter, 4 cm long
(2) Membrane	1	Thin Sheet Rubber (C)	Approximately 5 c m x 5 c m
	1	Rubber Band or Thin Wire (D)	--

b. Construction

(1) Syringe Assembly





Take a medium to large capacity (25 - 50 ml) plastic, disposable syringe (A). Cut off the end of the barrel near the nozzle. Then, with a hand drill or hot nail, make two holes approximately 0.3 cm in diameter opposite each other near the mouth of the barrel.

In the same fashion, make one hole in the stem of the plunger, near the plug, as shown.

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 6.

Insert the plunger into the syringe barrel, and push the nail (B) through the holes in the barrel and plunger to fix the plunger in position.

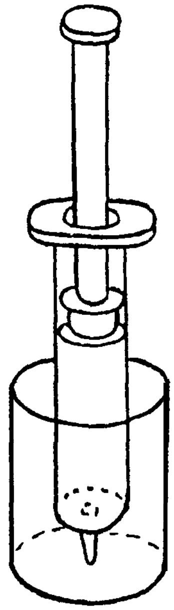
(2) Membrane

Cut a 5 cm x 5 cm square of thin sheet rubber (C) (from a toy balloon, for example). Stretch it over the open end of the syringe barrel and secure it in place with a rubber band (D) or length of thin wire.

C. Notes

(i) This simple device will give a visual indication that oxidation is taking place. For example, if wet steel wool or a piece of cotton soaked in alkaline pyrogallol [Note (i) XII/D41 is inserted into the barrel of the syringe and the plunger fixed in place with the nail , as the material reacts with the oxygen in the air the pressure inside the syringe will gradually be lowered. This can be seen since the rubber sheet will be pulled further and further into the syringe.

D2. Oxidation Indicator: Displacement Type *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 35 ml
(2) Beaker	1	Jar or Beaker (B)	To support syringe

b. Construction

(1) Syringe — Select a plastic, disposable syringe (A) of medium to large capacity (35 - 50 ml). No modifications are necessary.

(2) Beaker — Choose a small glass jar (B), beaker, or other container that will support the syringe, as shown.

c. Notes

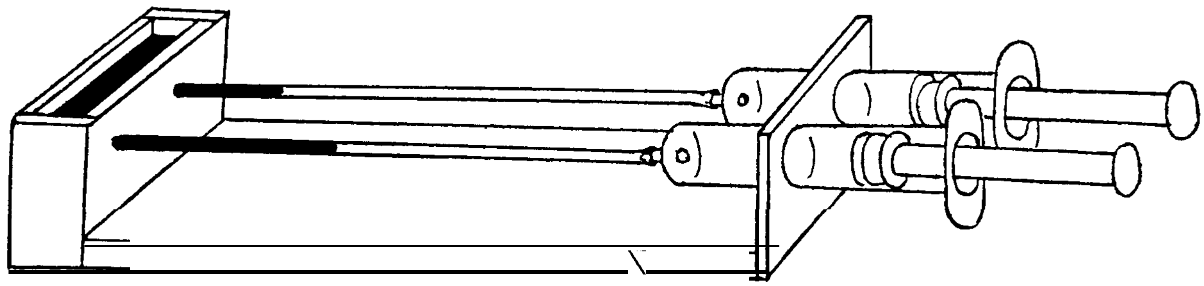
(i) Place a portion of wet steel wool (it may have to be washed in vinegar to remove the anti-rust coating) in the syringe barrel and position the plunger

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 2.

so that some predetermined air volume is trapped in the syringe. Place the syringe into a small amount of water in the beaker so that the nozzle is under water. As the steel wool reacts with the oxygen in the air, pressure inside the syringe will drop and water will be drawn up into the syringe barrel. Dyeing the water with non-fast vegetable dye will make the visual display more evident.

Cotton wool or other absorbent material soaked with alkaline pyrogallol [Note (i) XII/D4] may be substituted for the wet steel wool.

D3. Oxidation Rate Indicator *



(1) Indicator

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Indicator	1	Respirometer	BIOL/VIII/Dl(l)

b. Construction

(1) Indicator

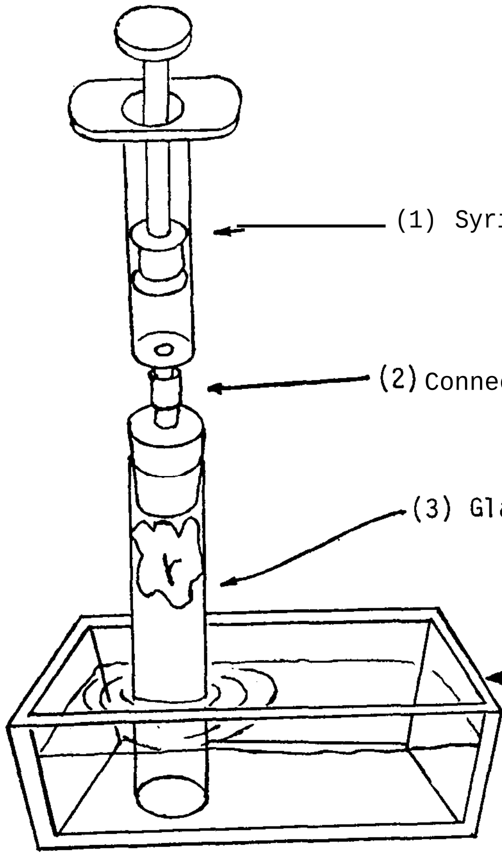
Construct this item according to directions given for the Respirometer, BIOL/VIII/Dl(l).

c. Notes

(i) Begin operation of this device by fastening the plastic tubing to the reservoir and to the nozzles of the syringes. Fill the reservoir with water which has been colored with non-fast vegetable dye. Items which react with oxygen in the air, including wet steel wool, white phosphorus, or alkaline pyrogallol (soaked cotton wool), are placed in the barrel of one syringe, where they react, removing oxygen from the trapped air. This results in a lowering of pressure which causes the colored water to be drawn from the reservoir into the clear tubing. The second syringe serves as a control, containing only air. The rate of the reaction can be judged from the speed with which the water column moves toward the syringe.

*Adapted from Paul D. Merrick Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 11.

D4. Stoichiometry Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 10 ml or more
(2) Connecting Tube	1	Rubber or Plastic Tubing (B)	To fit syringe
	1	Glass Tubing (C)	0.5 cm diameter, 2 cm long
(3) Glass Tube	1	Glass Tubing (D)	2-3 cm diameter, 10 cm long
	1	l-Hole Stopper (E)	To fit large tubing
	--	Cotton (Cotton Wool) (F)	--
(4) Water Container	1	Pan or Tray (G)	Capacity approximately 1 liter

*From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 19.

b. Construction

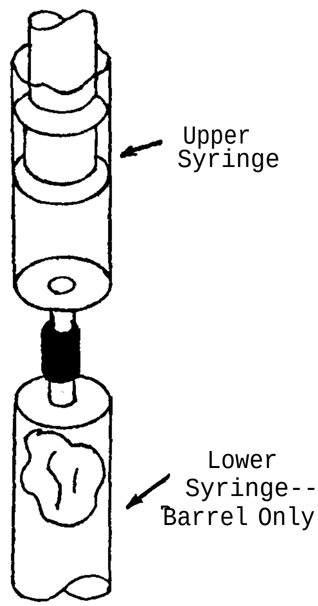
(1) Syringe	Select as many plastic, disposable syringes (A) of the same capacity (approximately 10 ml) as desired.
(2) Connecting Tubing	Connect the short rubber or plastic tubing (B) to the syringe nozzle. Connect the free end of the rubber or plastic tube to the short piece of glass tubing (C).
(3) Glass Tubing	Seal one end of a large diameter glass tube (D) with a one-hole stopper (E) and insert the glass tube (C) into the hole in the stopper.
	Push a small wad of cotton (F) (cotton wool) into position near the top of the glass tube, below the stopper.
(4) Water Container	For the water container, use a pan, tray, jar, or beaker (G) into which the desired number of syringe assemblies can be filled.

c. Notes

(i) An alkaline pyrogallol solution must be prepared for use with this apparatus. Put 10 g powdered pyrogallol [1, 2, 3 -- trihydroxybenzene, $C_6H_3(OH)_3$] and 2 g sodium hydroxide (NaOH) pellets into a small flask or test tube. Add about 30 ml H_2O. Tightly cap the container and shake it until all the solid dissolves. Avoid stirring the container to introduce air, as the alkaline solution will rapidly absorb oxygen and become useless for the experiment.

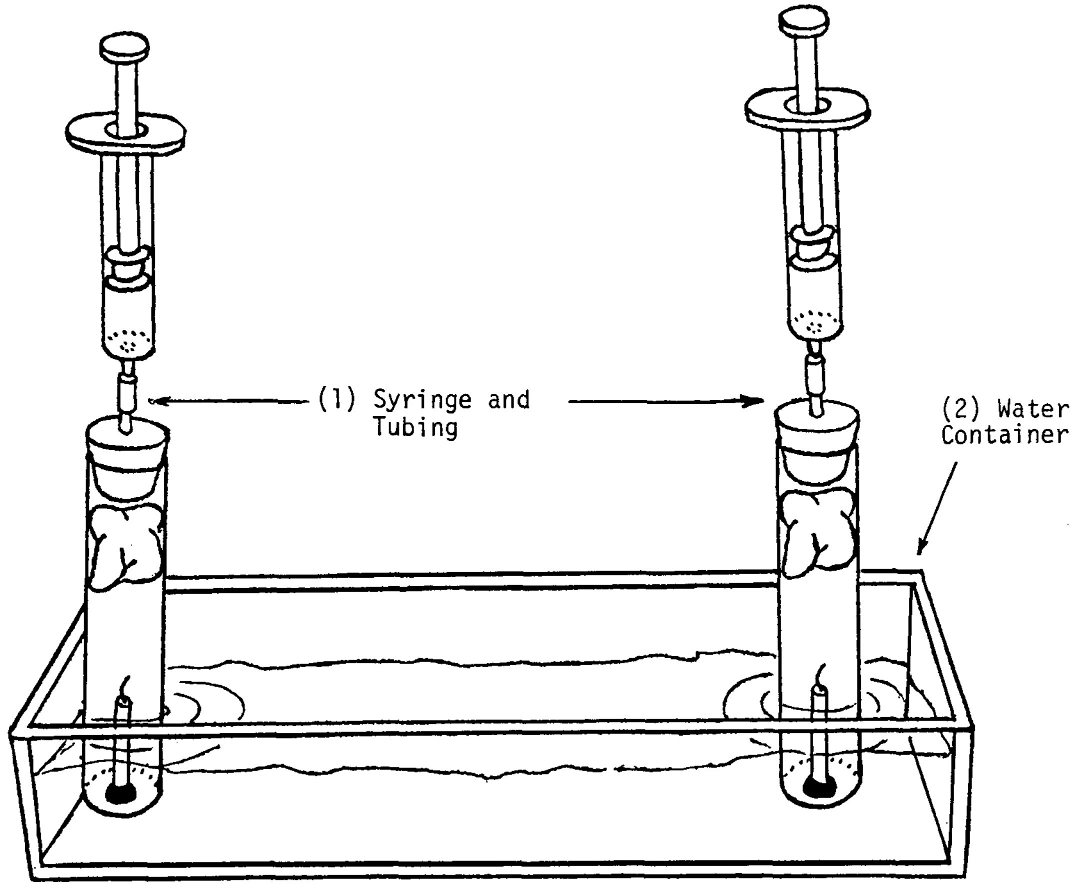
(ii) For experimentation in stoichiometry, several of these syringe assemblies need to be set up. Each should have an identical amount of the pyrogallol solution (or other reducing agent) in the syringe. Place all the devices open end down in the water container. Inject varying amounts of the pyrogallol (for example, 0.5, 1, 1.5 . . . 10 ml) into the glass tube where it will be absorbed in the cotton. The pyrogallol will then react with the oxygen in the air in the tube, and continue to react until either the pyrogallol or oxygen is consumed. As oxygen is removed from the air, pressure in the tube will fall, and water will be drawn up into it from the trough. The height of the water in the tube then becomes a measure of the amount of oxygen consumed, and will be seen to be proportional to the amount of pyrogallol used, until the upper limit is reached.

(iii) If glass tubes are not available, syringe barrels may be substituted. A short piece of plastic or rubber tubing is used to connect the upper syringe and lower syringe barrel, which is used in an inverted position.



E. ANALYTICAL APPARATUS

El. Air Composition Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe and Tubing	2	Stoichiometry Device (A)	XII/D4, Components (l), (2), and (3)
(2) Water Container	1	Pan or Tray (B)	Approximately 1 liter
	--	Limewater (C)	--
	2	Modeling Clay (D) (Plasticine)	Small wads
	2	Candles (E)	Approximately 0.5 cm diameter, 5 cm long

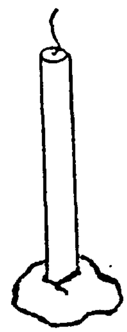
*From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 20.

b. Construction

(1) Syringe and Tubing

Prepare two syringe and tubing (A) assemblies, as described for the Stoichiometry Device (XII/D4).

(2) Water Container



Support each candle (E) in a small wad of modeling clay (D), about 5 - 10 cm apart on the bottom of the pan or tray (B). The clay wad must be smaller than the diameter of the glass tube used.

Pour sufficient limewater (C) into the pan or tray to cover the wad of clay and 1 cm or so of the candles.

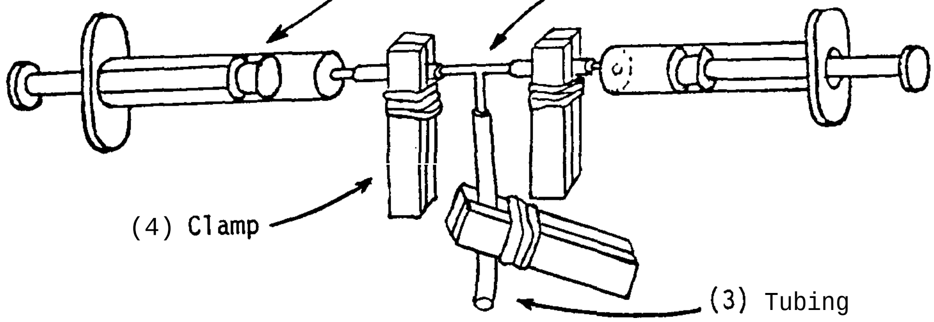
c. Notes

(i) To investigate the proportion of oxygen in the air, an alkaline pyrogallol solution, prepared according to instructions in XII/D4, is required. Each syringe should contain an equal amount of the pyrogallol solution (5 ml, for example).

(ii) When the syringe assemblies, with alkaline pyrogallol solution in each syringe, and the candles in the limewater have been prepared, light one candle. After a few seconds, place one of the syringe assemblies over each candle. Allow them to stand for about five minutes after the burning candle goes out to allow the limewater to remove CO_2 from the air in its tube. At this time, limewater will have risen into the tube to compensate for the lost CO_2. Mark this level of limewater with a wax pencil or felt-tipped marker.

Using a syringe pump (see XII/A2), remove air from the other tube until the limewater rises to the same level in the second tube as it had in the first. Mark this level, also. Now, inject alkaline pyrogallol from the syringes onto the cotton wads. This will react with the oxygen in the air, and remove all of it if enough pyrogallol is used. The water level in each tube will have risen. The amount of rise in the first tube (the one containing the candle) will be compared to the amount of rise in the second tube. Also, the change in trapped air volume in both tubes should be noticed. By doing this, it will be found from the first tube that the burning candle removes only about 25% of the oxygen in the air, while the change in volume in the second tube will show that air is about 21% oxygen.

E2. Gas Reaction Chamber *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	2	Plastic Disposable Syringe (A)	Capacity 50 ml
(2) "T" Tube	1	Glass "T" Tube (B)	Approximately 0.5 dm diameter
(3) Tubing	3	Rubber Tubing (C)	To fit syringe nozzle, approximately 8 cm long
(4) Clamp	3	Pinch Clamp (D)	IV/A4

b. Construction

(1) Syringe

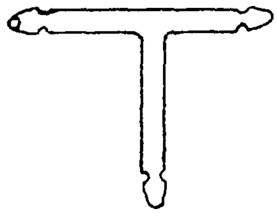
Select two 50 ml plastic, disposable syringes (A). Secure the syringes in a horizontal position by appropriate supports.

(2) "T" Tube

Use a glass or metal "T" tube (B) with three outlets. If available, a three-way valve (stopcock) may be substituted for the clamps and "T" tube.

*Adapted from Nuffield O-Level Chemistry, Collected Experiments, (London:Longmans/ Penguin Books, 1967), p 237.

(3) Tubing



Connect the two syringes to the "T" tube with two short pieces of rubber tubing (C). Use a third piece of tubing (C) to connect the apparatus to a source of gas.

(4) Clamp

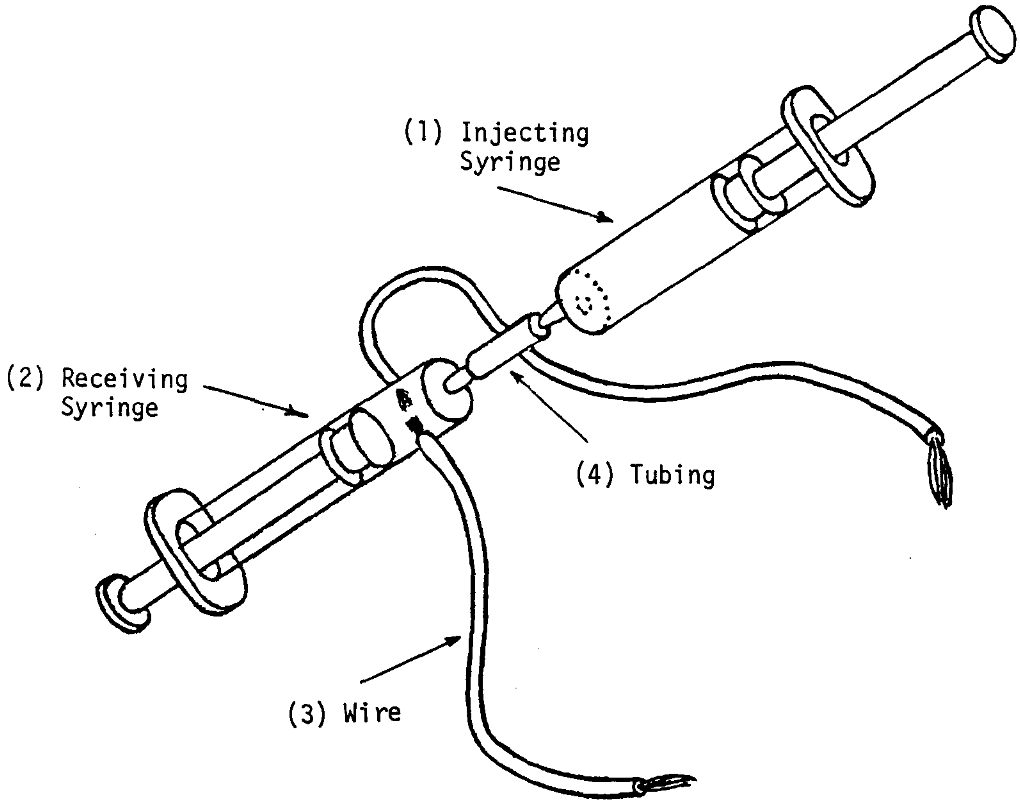
Use three pinch clamps (0)or other suitable clamps to close each section of tubing.

C.Notes

(i) To determine the number of gram-molecules of hydrogen chloride that react with one gram-molecule of ammonia, set up the apparatus as shown in the main illustration. Using the correct combination of open and closed clamps, fill one syringe with dry amnonia gas, empty it, and repeat one or two more times to "flush" the syringe. Follow the same procedure with the other syringe using dry hydrogen chloride. Then, fill the first syringe with 40 cc of the dry ammonia and fill the second with 50 cc of the dry hydrogen chloride. With the two syringes open to each other but closed to the atmosphere, inject the hydrogen chloride into the syringe of ammonia. The two gases will react, forming ammonium chloride. That about 10 cc of hydrogen chloride remains unreacted is shown by passing the gas over damp indicator paper. Thus, 40 cc of amnonia reacts with 40 cc of hydrogen chloride.

F. CONDUCTANCE APPARATUS

Fl. Conductance Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Injecting Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 35 ml
(2) Receiving Syringe	1	Plastic Disposable Syringe (B)	Capacity approximately 35 ml
(3) Wire	2	Insulated Wire (C)	Approximately 0.3 cm diameter, 50 cm long
(4) Tubing	1	Plastic or Rubber Tubing (D)	To fit syringe nozzles, 2 cm long

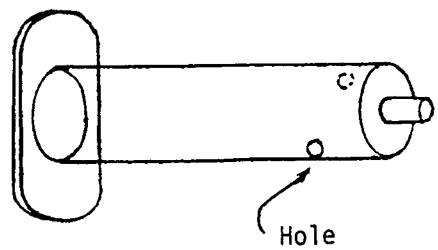
b. Construction

(1) Injecting Syringe

Use a 35 ml plastic, disposable syringe (A), with no modifications, for this component.

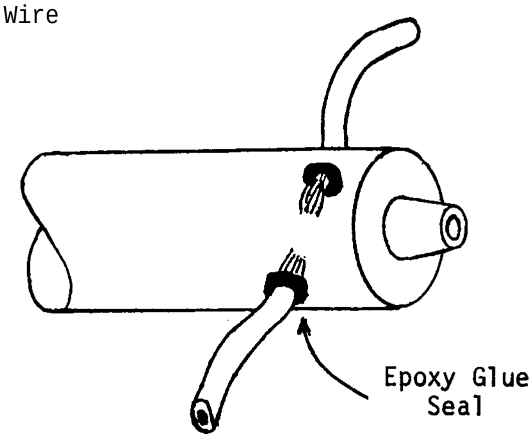
*Adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 32-34,

(2) Receiving Syringe



Take a 35 ml plastic, disposable syringe (B) and with a hand drill or hot wire make two holes, approximately 0.2 cm in diameter, opposite each other near the base of the barrel.

(3) Wire



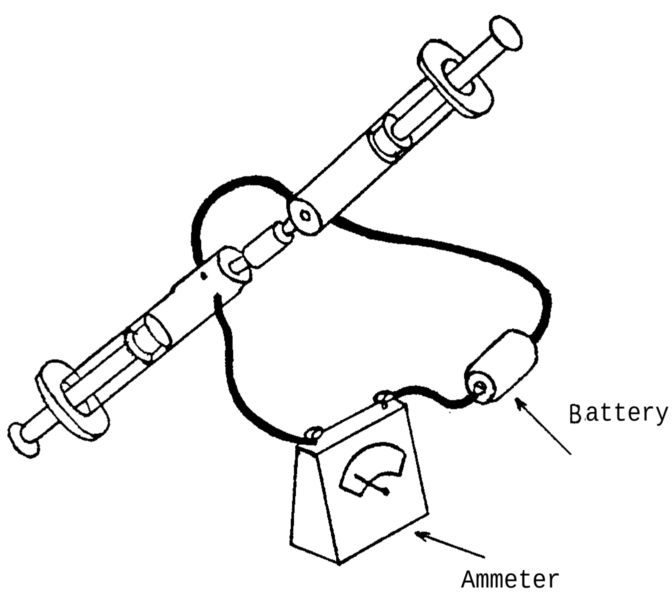
Remove about 1.0 cm of insulation from each end of both wires (C). Insert one bare end of each wire through the holes in the syringe barrel (B). Seal the holes with epoxy glue, taking care to see that no epoxy covers the bare wire inside the syringe barrel.

(4) Tubing

Connect the two syringes together with a short piece of plastic or rubber tubing (D).

c. Notes

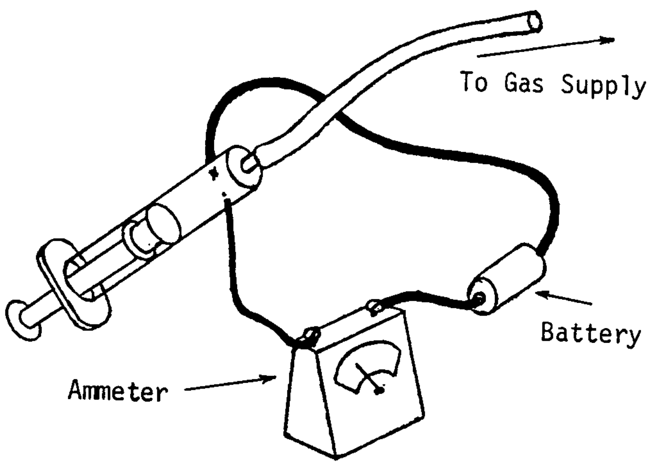
(i) This apparatus may be used to investigate the variation of conductance as two solutions are mixed. The wires are connected in series to a 1.5 volt cell and an ammeter as shown. One liquid is placed in the receiving syringe, another in the injecting syringe, and the current is measured on the ammeter. Then the solution in the injecting syringe is gradually fed into the receiving syringe, and any changes in the current are noted. Conductance, the reciprocal of resistance, may be calculated from the



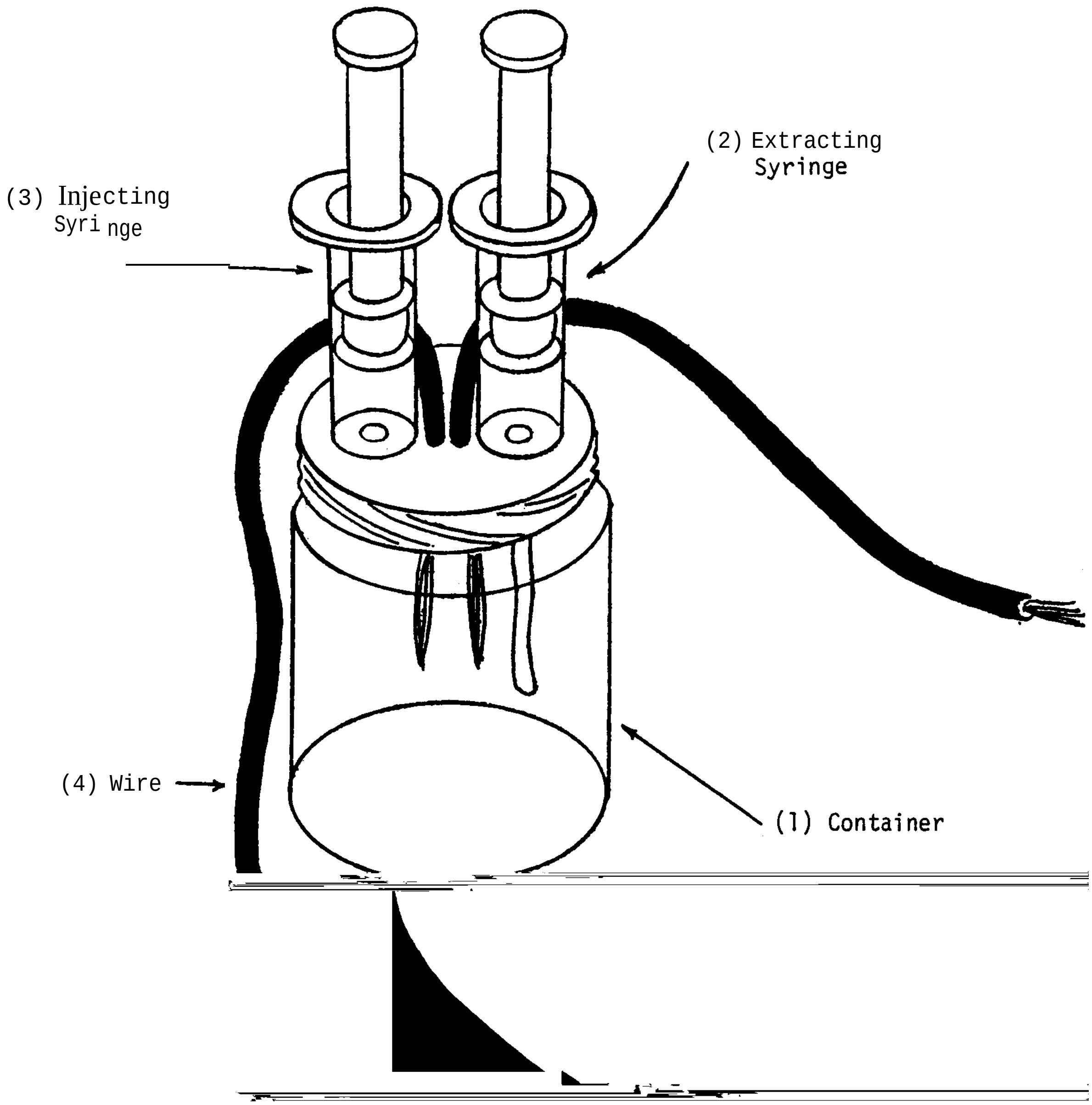
current and voltage: $R = \frac{E}{I}$ mhos $= \frac{1}{R}$

(ii) Solutions which may be tested in this apparatus include water in the receiving syringe and salt solution or HCl solution in the injecting syringe; dilute H_2SO_4 in the receiving syringe and $Ba(OH)_2$ solution in the injecting syringe; and dilute HCl in the receiving syringe with NaOH in the injecting syringe.

(iii) This device, with one modification, may also be used to investigate the variation of conductance as a gas is bubbled into a solution. The injecting syringe is removed and replaced with a section of plastic or rubber tubing that connects the remaining syringe to a gas source. For example, the syringe is filled with a limewater solution, and the current is noted on the ammeter. Then CO_2 is passed through the limewater, and the change in current as well as the change in color of the solution can be seen. Phenolphthalein can also be added to the limewater initially, and the color change from red to clear will indicate the neutralization has occurred.



F2. Constant Volume Conductance Device



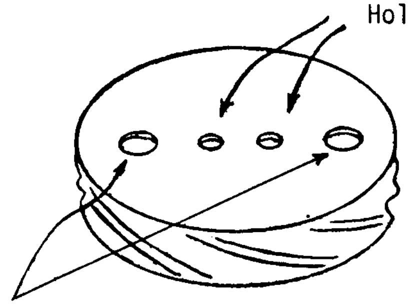
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Jar with Lid (A)	Capacity approximately 200-250 ml
(2) Extracting Syringe	1	Plastic Disposable Syringe (B)	Capacity approximately 20 ml
	1	Rubber or Plastic Tubing (C)	Diameter to fit syringe nozzle; length, about 1 cm shorter than jar height

(3) Injecting Syringe	1	Plastic Disposable Syringe (D)	Capacity approximately 20 ml
(4) Wire	2	Insulated Wire (E)	Diameter 0.3 cm, 50 cm long

b. Construction

(1) Container



Puncture four holes in the jar lid (A). Make the two outside holes about 0.5 cm in diameter to accommodate the syringe (B,D) nozzles. Make the two inner holes about 1 - 2 cm apart and 0.4 cm in diameter, to accommodate the insulated wire (E).

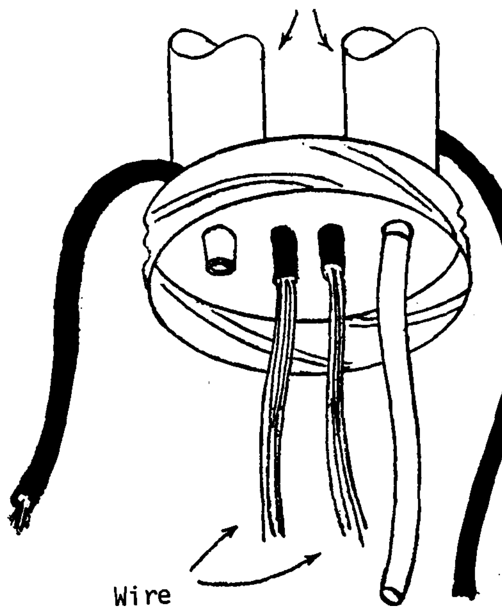
(2) Extracting Syringe

Push the nozzle of a plastic, disposable syringe (B) through one of the outer holes in the jar lid. Attach the rubber or plastic tubing (C) to the syringe nozzle from the inside of the lid.

(3) Injecting Syringe

Push the nozzle of a second plastic, disposable syringe (D) through the other outer hole in the jar lid.

(4) Wire



Strip 5 - 7 cm of insulation from one end of each wire (E). Push each stripped end of wire through the inner holes in the jar lid, from the outside of the lid. Allow about 8 - 9 cm of each wire to extend from the inside of the lid.

C. Notes

(i) In order to use this apparatus to investigate variations in the conductance of a solution as its composition (but not its volume) is changed, the wires from the container must be connected, in series, to a 1.5 volt battery and an ammeter. [See diagram, Note (i), XII/Fl.] A solution, such as water, is placed in the container. A second solution (concentrated salt solution, for example) is placed in the injecting syringe and the lid placed on the jar. Current is measured; then a measured amount of solution from the injecting syringe is added to the container, the solution mixed well, and volume of solution equal to that added to the container is withdrawn with the extracting syringe so that the electrode depth is unchanged. Current is again measured, and conductance calculated as described in Note (i), XII/Fl.

(ii) This equipment is adopted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 34-35.

BIBLIOGRAPHY

A number of texts have proved to be extremely valuable references to the Inexpensive Science Teaching Equipment Project, and these are listed below.

American Peace Corps, Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968).

This handbook contains many ideas for improvising science teaching equipment.

Association for Science Education, The School Science Review, (London: John Murray).

A quarterly journal containing articles on science experiments and equipment in all the sciences at all school levels.

Association for Science Education, The Science Master's Book, Part 2 (Chemistry) Series 1-4, (London: John Murray).

These materials, selected from The School Science Review, describe apparatus and experiments for a wide range of chemistry activities.

Coulson, E. H., A. E. J. Trinder, and Aaron E. Klein, Test Tubes and Beakers: Chemistry for Young Experimenters, (Garden City, New York: Doubleday and Company, Inc., 1971).

This book describes simple apparatus and experiments for youngsters in a home laboratory.

Bowker, M. K., and A. R. D. Hunt, Making Elementary Science Apparatus, a Handbook for Teachers in Tropical Areas, (London: Thomas Nelson and Sons, Ltd., 1968).

This book outlines instructions for construction and use of inexpensive, elementary science apparatus.

The Portland Project Committee, Teacher Guide, Chemistry of Living Matter, Energy Capture, and Growth, (Portland, Oregon, U.S.A.: The Portland Project Commiittee, 1971).

This guide is one of a three-year sequence integrating biology, chemistry, and physics into one secondary science program. Student guides are also available.

Richardson, John S., and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, (New York, Toronto, and London: McGraw-Hill Book Company, Inc., 1951).

This guide describes investigations and laboratory techniques for secondary level physics and chemistry.

United Nations Educational, Scientific, and Cultural Organization, UNESCO Source Book for Science Teaching, (Paris: UNESCO, 1962).

This book, recently revised, contains many simple ideas for teaching-science at a relatively elementary level.

In addition to the above texts, the materials from a large number of projects in the files of the International Clearinghouse on Science and Mathematics Curricular Developments at the University of Maryland have also been particularly valuable. Further details of these projects may be found in:

The Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments, 1970. (College Park, Maryland, U.S.A.: University of Maryland, 1970).

This is a source of information on curriculum projects throughout the world, and indicates materials available, project directors, publishers, etc. The Eighth Report will be available in late 1972.

ALPHABETICAL INDEX