How to Use the GILBERT MICROSCOPE

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CHAPTER 9

Making Permanent Slides

The slides which we have looked at so far were of objects in water between the slide and the cover glass. These will not last because the water will dry out. When a drop of glycerine is used instead of water it will last much longer, but it is not a permanent preparation because the cover glass could be easily pushed off.

A drop of white Karo corn syrup makes a good mounting medium which partially dries and holds the cover glass fairly well.

For really permanent slides the material is cemented between the slide and the cover glass with balsam or dammar. Both are gums from the sap of certain trees. The pitch is dried and then dissolved in xylene for use by the microscopist. The one difficulty in using balsam is that the material to be mounted must be dry, because the balsam will not mix with water and the tiniest drops would appear like a fog when placed under the microscope.

For material which may be dried in air without injury like the hair samples you have just been examining, all that is necessary is to blot off the excess water on the slide and let the material stand until it is dry. It is a good plan to warm it gently just before mounting but one should be careful not to cook the material. Slight warming over a radiator, or an alcohol lamp, is all that is necessary. Then put on a drop of balsam and gradually lower a clean cover glass held with the forceps so one edge first touches the drop and then until the whole glass is on the drop. This way will aid in keeping out air bubbles.

A little practice will soon teach you how large a drop is necessary to just fill the space between the slide and the cover glass. If you get too much let the slide dry and then carefully scrape off the excess with a knife. Should you not have enough add a small drop to the edge of the cover glass and it will run in and fill the space. Straighten the cover glass with your forceps or a dissecting needle so that it is square with the slide and then put the slide on a flat surface where it will not be disturbed, or get dusty, until the balsam gets hard; which will take from a few to many days depending on how warm the room is and how much balsam you have used.

When the slide is dry use a knife to trim off any excess balsam from around the cover glass and wipe it with a little xylene on a soft bit of cloth. Paste a label on the left hand side of the cover glass and write, with ink, what the object is; what stain was used, if any; any special information you have; the date and your name or initials. If you have a record in your note book you can give the record and the slide the same number. Print your labels neatly and you will soon have a set of slides to be proud of, for your own use and to show your friends.

EXPERIMENT 42. Making a Permanent Slide with Karo Corn Syrup

Clean and dry some short lengths of hair and mount them in Karo corn syrup and set aside for a week to dry.

EXPERIMENT 43. Making a Permanent Slide with Balsam

Mount some of the hairs in balsam and set aside to dry in a place free from dust for a week.

At the end of a week examine both slides. Which seems to be the best method for making permanent slides? Clean and label each for future use. The slides in Karo syrup should be stored flat until they are well hardened or else the preparation will run.

It is more difficult to prepare wet specimens which will be injured by air drying and methods will be given later in Chapter 19.

You are now becoming familiar with your microscope and now know something of what it can do and its importance in the world. Next you should find out how we actually see with the microscope which will show how to use it correctly for the rest of your experiments.

To see anything, the light from it must enter the eye and be focused by the eye onto the sensitive retina in the back part of the eye, fig. 4. The light there changes certain chemicals in the cells of the retina and the changes affect the nerve fibers in the optic nerve which carry the nerve impulses to the brain. When they reach the brain they are interpreted and we recognize the result as seeing. To see through the microscope enough light must pass into the eye to bring about this process. What we see depends on the light entering the eye from the microscope, so our problem now is to see what happens to the light in passing through an object under the microscope.

A beam of white light coming to the eye from a plain white object shows no detail. By means of a prism it can be shown that white is a mixture of lights of various colors; of which the eye is able to see blue, blue-violet, blue green, through yellow, orange and red. You have seen these colors in a rainbow. A colored object is seen because it reflects to the eye a particular color or colors of the white light while absorbing the others. Many objects may be seen on the microscope because they transmit colors and other objects cannot be seen easily unless they are stained with a colored dye.

EXPERIMENT 44. Colored Image

Clean the handle of a spoon and then lightly scrape the inside of your mouth and then rub off the material in a drop of water on a clean microscope slide. Place a cover glass on this and you will find with the aid of your microscope some irregular, nearly clear cells, fig. 12A. Place a drop of thionine on one edge of the cover glass and then touch the opposite side with a bit of blotting or other absorbent paper. The thionine will be carried under the cover glass and will stain the cells so that they may be seen more easily and you will also see details within the cells. Staining is one of the commonest ways of making objects visible under the microscope.

When a beam of light passes from one medium into another its path is bent according to the amount of difference in the two materials. A pencil thrust into a half-full glass of water looks as if it was bent at the water surface; but it appears this way because the light reflected by the pencil to the eye is bent more by the water than by the air above it. The amount of bending is called the refractive index of the material.

EXPERIMENT 45. Refraction Images

Place a bit of broken cover glass in a drop of water on a clean slide. Bubble some air into the drop with your medicine dropper and place a cover glass on the preparation and examine with the microscope. The glass, the air and the water are not colored so you cannot see them as colored images; but they bend the light coming from the mirror differently and you see them by their refraction images.

EXPERIMENT 46. Determining the Direction of a Refraction image

Turn the mirror so that the air bubble is equally illuminated on all sides which insures that the light is centered (Exp. 18). Notice the edge of the air bubble as you focus up and down. Note that the brightest point is below the center of the drop which shows that the air has a lower refractive index than the water.

EXPERIMENT 47. The Becke Line

Now examine the bit of cover glass in a water mounting which is bounded by nearly vertical lines. The boundary is seen as a thin band of light, something like a halo. As you raise the body tube this bright band moves inward toward the glass which has the higher refractive index and when you lower the body tube of the microscope the bright line moves toward the medium of lower refractive index showing that the water has a lower refractive index. The band of light is called the *Becke line*.

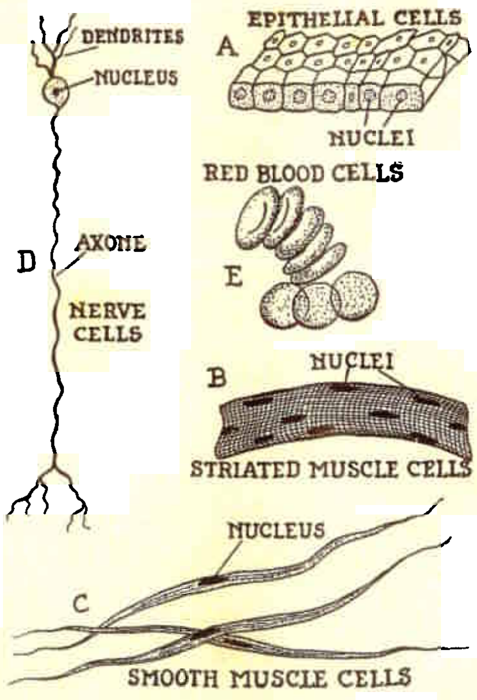


FIG. 12

EXPERIMENT 48. Determining Refractive Index

When a substance is in a mounting medium of the same refractive index it is nearly invisible. Dissolve a little salt in a drop of water on a clean slide and let the salt crystalize as the water evaporates. When the preparation is quite dry warm slightly and make a permanent slide of it in balsam as described in Chapter 9. After the balsam has hardened examine it and note that it is nearly invisible because the two refractive indices are nearly the same. You see the salt because it is not yellowish like the balsam.

Refractive index is determined by having a series of liquids of known refractive index and immersing the material into them until it is nearly invisible which shows that it has the same index as that liquid. Of course the liquids must be such that they will not affect the material examined.

EXPERIMENT 49. Refractive Index of a Heavy Oil

Repeat experiment 47 placing a bit of glass in heavy paraffine oil such as Nujol. Is the oil of greater or lesser refractive index than the glass? How would you say that the indices of the oil and water compared? The greater the differences of refractive index between the object and the surrounding medium the easier its boundaries are seen.

EXPERIMENT 50. Refractive Index of Clove Oil

Place a bit of cover glass in some clove oil under a cover glass. Is the refractive index of the oil and of the glass about the same?

EXPERIMENT 51. Refractive Index of Oil Bubbles

Test some oil bubbles in water in a manner similar to that of the last few experiments.

The following table gives the refractive indices of some common materials.

Substance	*Refractive Index*	*Substance*	*Refractive Index*
		Balsam	1.54
Water	1.33	Salt (Sodium chloride)	1.54+
Chloroform	1.44	Glass	1.5 to 1.6
Alcohol	1.36	Celluloid	about 1.53
Carbon tetrachloride	1.46	Bakelite	1.58 to 1.63
Glycerine	1.47	Clove oil	1.53
Olive oil	1.47	Cotton	1.53* 1.59*
Nujol	1.475	Starch	1.53
Cedar oil	1.515**	Wool	1.54* 1.55*

* Some materials have two or more refractive indices depending on how they are seen.

** Cedar oil has nearly the same refractive index as the cover glasses and is used with very high power microscope lenses between the cover glass and the lens so that no light is bent away by the air and all of the light goes into the lens.

Some objects are seen under the microscope because they reflect light. This occurs especially when dark objects are examined with light directed downward on them.

EXPERIMENT 52. Opaque Materials

Place a bit of fine dirt in a drop of water. You cannot make out much detail with the light from the mirror because the dirt is dark. Hold your microscope lamp so that the light falls directly on the material and then you can see it because it reflects the light. Use a lower power objective for this experiment so there will be plenty of room for the light to reach the dirt without the objective casting a shadow on the object.

Light travels in a straight line. If it did not there could be no shadows. However, the individual light waves of the different colors vibrate in a direction at right angles to the direction of the beam. Some substances cause the light to vibrate in only one direction rather than all the directions at right angles to the beam and when this happens the light is polarized. Reflected light is more or less polarized. Moon light is polarized because it is light from the sun reflected to us by the moon. When polarized light passes through a substance we can tell something of its structure and polarization images are another way that we can see under the microscope.

When a pattern is made up of very fine lines the lines separate the white light so that we see a color. The colors of the feathers of some birds and of the brighter colored insects are often of this nature.

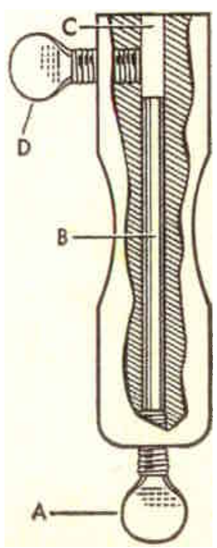
EXPERIMENT 53. Color from Diffraction Patterns

If you suspect the color of a bright feather or insect part is due to a diffraction pattern put a little oil on it and see if the color disappears when you look at it under the microscope. The oil does not bend the light rays the same as air and so the effect of the fine structure is lost. Not all colors are due to refraction images but are due rather to colored particles in the object.

The object on the microscope slide gives an image on the retina of the eye. The kinds of images are: color images, refraction images, reflection images, polarization images and diffraction patterns. Usually the image we see of the object is a combination of these rather than separate ones. As you look at things with your microscope decide which kinds of images you are using. The use of this knowledge makes possible special methods required in some of our later experiments.

The Hand Microtome

The use of the hand microtome is explained on pages 46 and 47.



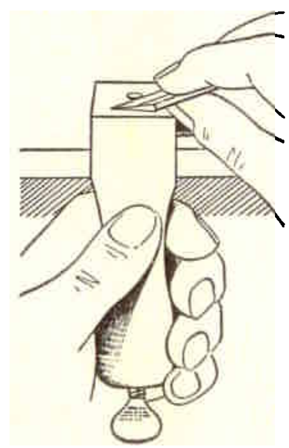


FIG. 14

CHAPTER 11

Preparation of Objects

Many of the objects that we wish to examine with the microscope are much too large and require special treatment before they may be seen to advantage. Certain specimens are prepared by methods adaptable to them and many or these will be given in various parts of the manual. However, there are some general methods which are used so frequently that we should learn them before continuing our experimenting.

Sifting material like grain, spices, foods, soils, etc., through a series of sieves of increasing fineness is one of the commonest methods used to get material for study with the microscope. Insects are separated from flour, when it has been infected, by an ordinary sieve like your mother uses. Very fine sieves are used for special purposes, and the finest of them are made of silk cloth called bolting cloth.

EXPERIMENT 54. Sifting

Sift a little whole wheat flour through a flour sieve or a fine screen and note how many kinds of particles you find.

Minerals, rocks and other hard materials must be crushed before they are looked at under the microscope and after crushing the particles are separated according to size with a screen. The crushing must not be too complete or the essential structure will be destroyed so that it will not be possible to recognize the material.

EXPERIMENT 55. Crushing and Sifting

Crush some of the particles that you found in the whole wheat flour and sift again. What seems to be the main difference between whole wheat and ordinary white flour?

EXPERIMENT 56. Kneading

Kneading is really a sifting process done under water. Place a little flour in the center of a square of muslin or calico cloth and fold the ends together so as to make a sack. Fill a small pan nearly full of water and then put the bag of flour under the water and gently knead it until the starchy part of the flour has been forced through the bag into the water. Examine the starchy water. The gluey part of the flour, the gluten, has been separated from the starch.

Are the starch grains all the same size? To separate the grains of different size we use a process called sedimentation.

EXPERIMENT 57. Sedimentation

Fill a tall glass with the starchy water from experiment 56 and let the starch settle out. The larger particles sink to the bottom first and the smallest last. After the glass has set until the liquid begins to clear at the top, take a drop with your medicine dropper from the surface of the water and place it on one end of a clean slide, place another drop from the center of the glass in the middle of the slide and place a drop from the bottom on the other side. After putting a cover glass on each look at them under your microscope and see to what extent they have been separated according to size.

Some substances are less dense than water and float on it. Other substances are heavier and sink. By choosing a liquid of the right density one can make any material float or sink and this way we can use sedimentation to separate materials so that we can examine them separately.

EXPERIMENT 58. Separation by Special Mixtures

Into a tall glass put two small glassfuls of glycerine and one small glass of water. Stir until they are well mixed. Then stir in some ground coffee. The coffee will rise to the surface after you stop stirring, but if any chicory is in with the coffee it will sink to the bottom. Coffee is sometimes adulterated with chicory and it would be tiresome to examine each grain under the microscope to see which it was. Separating them in this solution then makes it possible to quickly see and identify the chicory when it is present.

Sedimentation is often a slow process and in some laboratories a centrifuge is used rather than letting the material set in tubes. In this machine the tubes of material are put in a wheel and whirled rapidly. The faster the machine is run the quicker the material settles. A glass shaped like an ice cream cone with a base to hold it up is used for sedimentation as it is easier to pick up small particles from the narrow bottom.

Tall glasses may be too deep for you to reach the bottom with your medicine dropper. Use instead a collecting tube such as a piece of glass tubing or a straw.

EXPERIMENT 59. How to Use the Collecting Tube

Hold your index, or first finger, tightly on the end of a straw and push it to the bottom of the glass. Then take your finger off and the liquid and sediment will flow into the tube. By placing your finger on the end you can hold the material in the tube and carry it to your microscope slide. A little practice will make it possible to pick up a few drops this way and to put only one drop from a loaded tube onto a microscope slide.

The separation of particles may be made by elutriation which is a combination of sedimentation and decantation, or pouring off of part of the liquid. Rice is sometimes "faced" with talc to make it appear more polished.

EXPERIMENT 60. Obtaining Rice Facing

Shake a little rice in a test tube, fig. 3E, nearly full of water and then pour off the water into a second test tube and let the material settle. Pouring off the milky water from the rice is called decantation. After the sediment falls to the bottom examine a drop of it on the microscope to see if it is all starch. (Chapter 17).

EXPERIMENT 61. Starch or Talc?

If some of the granules do not seem to be starch add a drop of iodine and the talc if present will not be stained blue like the starch. If you wish to make certain, purchase a little talc from the drug store and compare the known talc with the sediment from your experiment.

EXPERIMENT 62. Sampling Soil

Shake up a little soil from your yard with water in a test tube and after only a moment of settling pour the muddy liquid into another test tube. Continue this two or three times. You have now elutriated the soil into samples of different kinds. For the finer particles this method is better than sifting, but in soil examinations the coarser particles are sifted out first and the finer ones separated by elutriation.

Oily substances are used as clearing agents to help us see different kinds of things in a mixture. If you have a little self raising flour in the house you know that it must have chemicals like baking powder in it to make the bread or pancakes raise. If you look at it as it comes from the package you cannot see these chemicals very easily in the dry powder. If they are washed out by kneading they go into solution and disappear. The best method to see them is to clear the rest of the preparation with oil.

EXPERIMENT 63. Clearing With Oil

Place a bit of self-raising flour on a clean slide in a thin layer. Put on it a drop of clove oil and then the cover glass. The starch of the flour becomes nearly transparent so that you can hardly see it but the crystals of the chemicals are now cleared so you can see them.

Various oils can be used like paraffine oil or even machine oil. In the study of foods cresol is used as a clearing material. The cresol is sometimes mixed with an equal amount of glycerine. Should you purchase any cresol from a drug store be careful not to get it on your skin as it will make it burn. Should you accidentally get some on you wash it off with water and then wash with rubbing alcohol. The alcohol destroys the cresol.

Oily materials are usually examined in an oil preparation.

EXPERIMENT 64. Mounting in Oil

Put a little ground mustard in a little clove oil on a slide and examine the particles with your microscope.

Materials that will dissolve in water can be obtained from a mixture by filtration.

EXPERIMENT 65. Filtration

Shake up a little self-raising flour in a test tube partly full of water. Fold up a piece of fine absorbent paper such as a thin blotter or a piece of paper towel, like a cone, fig. 13 and pour your material into it. The water will pass through and may be caught in a test tube or a glass and the starch and other insoluble matter will be kept in the paper cone. Put a drop of the liquid on a slide and let it stand until it dries. Any chemicals present will crystalize out and may be seen under the microscope

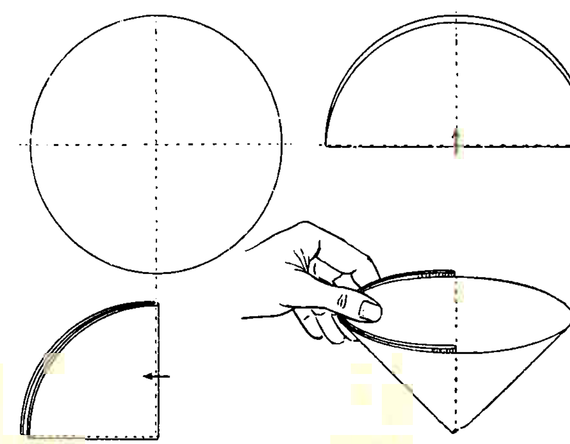


FIG. 13

Other solvents than water may be used to advantage in microscopic work and by the application of chemical methods, (chapter 14), many materials may be identified. The use of these methods is especially important in testing foods, drugs, and other substances for adulteration by less nutritious or cheaper materials.

When we want to look at parts of plants and animals that are too large to use under the microscope other methods are required. Sometimes simple dissection is adequate such as breaking off the leg of a dead bee so that the leg may be easily seen with the microscope. If you wish a part from a very small insect you may find it convenient to place it under the dissecting microscope while you are getting the part you wish.

Teasing is done by holding a bit of material in a drop of water on a slide with a dissecting needle, fig. 3B, in one hand and pulling it apart with the other dissecting needle in the other hand.

EXPERIMENT 66. Teasing Paper Specimens

Gently tease a bit of paper to separate the fibers so that they may be seen with the microscope.

EXPERIMENT 67. Teasing Meat Fibers

Tease apart the fibers of a bit of raw, lean meat until you can see them separately under the microscope, fig. 12B.

EXPERIMENT 68. Teasing Potato Cells

Tease a bit of potato and examine it with the microscope. Add a drop of iodine, that can be obtained in any drug store, which will stain the starch blue or blue-black depending on how much you use. It is better not to use too much stain in microscopic work because if the material is too stained not enough light passes through it for the eye to see. Is the teased potato all starch? or are there bits of other material?

You will now want to know how the starch was arranged in the potato and teasing it apart prevents your seeing. To see the starch in its normal position we must make a thin section instead of teasing.

EXPERIMENT 69. Sectioning

With a sharp razor blade cut as thin a section from a small piece of potato as possible. Repeat until you have a few that are very thin. Pick up one of the thinnest with your brush, or forceps, and place it under a cover glass in water on a slide. If it is thin enough you can see that the starch granules are grouped in cells. The edge of the section is apt to be thinner than the center. If the section is too thick to see clearly cut some more until you get one of the right thickness. Stain this with a little iodine and you can see that the potato is composed of cells filled with starch grains.

The Hand Microtome

In cutting thin sections of many kinds of material we need a machine which will control the thickness of the section. The hand microtome shown in Figure 14, on page 42, will solve this problem. The feed screw (A) in the end of handle moves the feed rod (B) up; this in turn moves the specimen, which has been placed in the well (C). This movement may be as small as one thousandth of an inch or less, which enables you to make very thin specimens. The lock screw (D) near the top is intended to steady the specimen; care should be taken not to crush the specimen with this screw.

EXPERIMENT 70. Use of the Hand Microtome

Turn the feed screw about half way out, then press the feed rod down using a matchstick or some such object. Place the specimen you wish to slice in the well, turn the lock screw until it gently contacts the specimen. Then holding the microtome against the edge of a table, as shown in Figure 14, on page 42, with a sliding stroke of a single edge razor blade, held flat on the microtome cutting surface, cut off the superfluous material. Now you are ready to cut as thin specimens as you wish. Cut a number of slices, feeding up by turning the feed screw a fraction of a turn each time. Select and use the best specimen. It may be picked up, using the brush or tweezers, placed on a slide with a drop or two of water before covering it with a cover glass. A good temporary slide is made in this way. To make permanent slides and for instructions in staining, see other pages in your manual.

EXPERIMENT 71. Sectioning Thin Materials

To cut a thin object like a leaf, whittle a piece of pith to fit the well in microtome. Cut a slot in one end of pith and in this slot place a piece of leaf. Place this in the microtome well, and cut through pith and leaf, saving for viewing only the thinnest most perfect sections of the leaf.

Very tough tissue like wood cannot be cut with the microtome without first undergoing a softening process. While very soft objects must be imbedded in wax or other materials before they can be sectioned in the microtome. You will find these methods described in books listed in the Appendix, but for our present exploring we will not need such special methods. As you cut sections, using a brush or needle, place them in a dish of water. When ready to view them with the microscope, select the thinnest best specimens. Some will be torn, some too thick, these may be discarded.

Be sure to clean and dry your microtome so that it will be ready for use when you need it another time.

EXPERIMENT 72. Sectioning with the Microtome

Cut thin sections from some of the following, so that with the microscope you may see how they are made. Interesting sections may be made from carrot, cork, celery, etc. Most parts of plants except the hard woody sections may be used.

CHAPTER 12
Fundamental Units of the Inorganic World

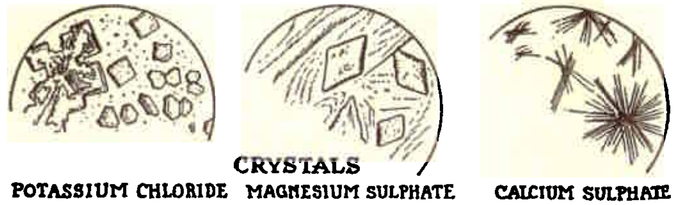


FIG. 15

The inorganic world is composed of rocks and all materials not part of living or dead organisms. The inorganic material is found in three states, gases, liquids and solids. These are composed of units, molecules, so small that they cannot be seen with the microscope. Solids are built up of crystal units in a definite pattern according to the kinds of units involved and these patterns can be seen with the microscope even though we cannot see the individual molecules themselves. A molecule is the smallest part of a pure substance. If it is divided any further it is broken up into the materials of which the molecules are made.

Most solid materials form crystals and even non-crystalline materials like rubber, glass, etc. have a definite structure which can be shown under proper conditions. The crystal can be thought of as the unit of the inorganic world and special instruments like the X-ray and the spectroscope show what the structure of the crystal is and how the crystal is built. Many materials used in living plants and animals have equally definite structure and the same methods are used for their study.

You have already examined how crystals form in chapters 6 and 10. There are many kinds of crystals. Besides the square type that you measured of salt, some form needles, others branches or dendrites, plates, etc., fig. 15.

EXPERIMENT 73. Dendrite Crystals of Aspirin

Dissolve one-half of an aspirin tablet in about three-quarters of a test tube of water. Let any solid matter settle and place a drop of the clear fluid on a slide. Watch the growth of branched, dendritic crystals as the solution dries.

EXPERIMENT 74. Starch Test With Iodine

If there is a sediment left in the test tube look at a little of it under the microscope and try staining it with a small drop of iodine. Does the material look like starch? Many pills and tablets have some starch in them as an inert material giving body to the tablet.

EXPERIMENT 75. Crystal Growth

Dissolve as much sugar as you can in a quarter test tube of hot water. Take a little of this and dilute it with as much cold water. Place a drop of the strong and of the diluted solution on a microscope slide and note how fast the crystals grow and from which drop you get the largest and more perfect crystals. Usually larger and more perfect crystals grow in dilute solutions.

Crystals will grow from metal as well as from a solution.

EXPERIMENT 76. Crystal Growth from a Metal

Dissolve a small amount of copper sulphate in a drop of water on a clean slide and then add a piece or two of zinc about a millimeter in size and watch the dark branching crystals of copper form on the zinc.

Only a certain amount of any material may be dissolved in a drop of water at a given temperature. When the temperature is raised many, but not all, substances will dissolve more at the higher temperature. When the drop is cooled it becomes supersaturated with more material than it would normally have so that the least disturbance causes a quick crystalization.

EXPERIMENT 77. Supersaturation

Dissolve as much borax (see experiment 92) as you can in a drop of warm water on a microscope slide. Warm the slide and then add more borax until you have saturated the drop at the higher temperature. If a tiny trace does not dissolve heat the drop very slightly more. Place it on the microscope to cool. As it cools it becomes viscous or syrupy, but does not crystalize out. However, if you stir it enough to scratch the slide under the drop or if you add the tiniest crystal of borax it will quickly crystalize.

EXPERIMENT 78. Speeding Crystal Growths

Repeat the above experiment but leave a bit of crystal in the solution and you will find it will crystalize as fast as it cools and does not become supersaturated, because the crystal forms a starting point for the crystaline growth.

When some crystals form they build water molecules into their crystals along with their own kind of molecules. If such crystals are heated the water is lost and the form of the crystal is destroyed.

EXPERIMENT 79. Water of Crystallization

Dissolve some copper sulphate on a slide and let the crystals form. After the slide has dried in the air heat it gently with an alcohol lamp or gas flame and you will notice crystals dry into a powder. If the slide stands in a damp atmosphere the copper sulphate will take water from the air and the crystals will form again.

Washing soda is sodium carbonate and if you have some in the house you should examine its crystals.

EXPERIMENT 80. Water in Washing Soda Crystals

Repeat the preceding experiment using washing soda instead of copper sulphate. It will also lose its water of crystalization when heated after the crystals are formed.

Crystal chemicals that are bought at a store are rarely perfect as the edges of the crystals are worn and the ends may be broken off. Often times they are partially ground so that they will dissolve easily. It is interesting to compare the forms and to watch how a crystal is repaired by more molecules adding onto the outside to replace those broken off or worn away.

EXPERIMENT 81. Broken Crystals

Prepare some crystals of table salt and sugar and then compare your carefully grown crystals with those that came out of the original package. Do you think that the package crystals have been broken from rubbing against each other, or have they been ground?

EXPERIMENT 82. Crystal Repair

Grow a large sugar crystal in a big drop of sugar solution. When it is dry cut off a corner of the crystal with a razor blade and then place the broken crystal into a drop of strong sugar solution and watch the crystal grow back into its original form under the microscope.

Many substances form beautiful crystals and you should try such chemicals as you have about the house. Some substances will not dissolve in water but will dissolve in other solvents such as carbon tetrachloride, chloroform, etc.

When you have a preparation that you would like to keep, dry it gently with very little heat from an alcohol lamp or gas flame and then put on a drop of balsam and a cover glass. You must be careful that you do not heat the crystals too much.

Some combinations form double salts which include two metallic elements and a nonmetallic group. Even more complex salts are known.

Certain substances form a precipitation membrane rather than just a simple crystalline precipitate. The membranes may be formed inside of a porous clay cup and can be used for studies of the pressure relations between different solutions.

EXPERIMENT 83. Precipitation Membrane Formation

Place a drop of copper sulphate solution close by a drop of sodium ferricyanide solution. Focus the low power of the microscope on the edges of both drops and then bring one to touch the other with your glass rod. You will note a membrane forms when they touch. This will show folds and may be bent by your rod.

Another method for the preparation of crystals is to melt a solid and then let it crystalize as it cools.

EXPERIMENT 84. Crystals from Fusion

Melt a little potassium nitrate on a slide under a cover glass with the aid of an alcohol lamp or gas flame and as it cools watch the formation of the crystals. Repeat the experiment without the cover glass.

When crystals form in a protein solution they are frequently of different appearance and the crystalization appears to be hindered.

EXPERIMENT 85. Effect of Gelatin on Crystal Growth

Dissolve some of the substances you have studied in previous experiments in this chapter in a weak gelatine solution. The gelatine solution may be made by dissolving about two parts of gelatin to ten parts of hot water. Take a drop of this on a microscope slide and dissolve the salt in it and then watch the crystallization with the low power of your microscope. Does the strength of the gelatine solution make any difference?

EXPERIMENT 86. Effect of Albumen on Crystal Growth

Repeat the last experiment using a little white of egg instead of gelatine.

A great many of the substances that you will find around the house will form interesting experiments. Try mouth washes, diluted tooth paste, medicines, etc. As some medicines are poisonous be careful not to spill them and to wash the dried materials from your slides unless you make permanent mounts in balsam of them.

CHAPTER 13
The Classification of Crystals

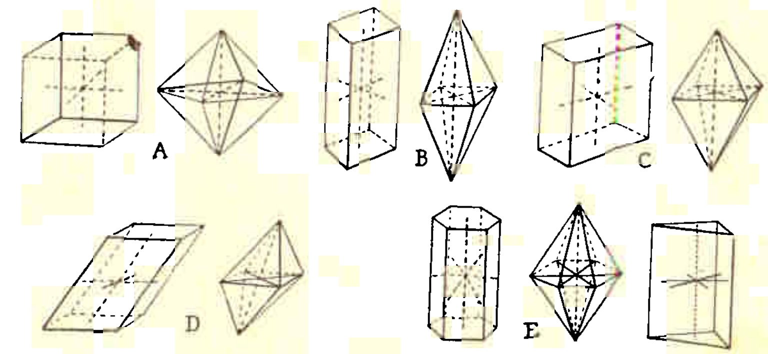


FIG. 16

The regularity of the crystal forms that you have seen will probably suggest to you that they may be arranged in groups, and that is indeed true. All crystals may be placed in one of 32 classes of 6 main groups. Examine the most perfect crystal in each of your experiments to make out its form.

The first group is composed of *cubic* crystals formed by three axes which cross each other at right angles as shown in fig. 16A. The crystal grows in the direction of its axes and it may grow faster along one axis than another, but in this group the growth is equally rapid along each axis. Some of the crystals in this group have eight instead of the six sides of a cube and are called octahedral crystals.

EXPERIMENT 87. Cubic Crystals of Salt

Examine again some crystals of table salt, sodium chloride, and note that they are cubic crystals.

EXPERIMENT 88. Octahedral Crystals of Alum

Make a slide of crystals of some alum (potassium aluminum sulphate) and you will see that these are octahedra. The alum is another example of a double salt of potassium and aluminum and the sulphate group. There are many alums but the common one found around the house is the one used in this experiment. The styptic pencils, or sticks, that used to be used to stop bleeding of a small cut, as from shaving, are usually made of alum.

The second class of crystals includes those of the *tetragonal* or *monometric* system. They also have three axes intersecting or crossing at right angles (90°) but one of the three axes is either longer or shorter than the other two which are of equal length. Such a crystal grows equally fast in two directions but at a different rate in the third direction, fig. 16B.

EXPERIMENT 89. Tetragonal Crystals

If you can find some of the following substances or get them from the drug store you will find their crystals belong to this system: urea, potassium dihydrogen phospate, potassium copper chloride.

The third class is called the *rhombic* or *trimetric* system and includes those crystals which have three axes intersecting each other at right angles but of which no two are of the same length, fig. 16C.

EXPERIMENT 90. Rhombic Crystals of Potassium Nitrate

Examine some potassium nitrate (exp. 84) crystals as an example of this class. Are equally good crystals formed from the evaporation of a water solution as from fusion? Other substances found in this class are silver nitrate and ammonium perchloride.

The *monoclinic* or *oblique* system is the fourth class of crystals. The three axes are equal, one is vertical to the other two and the other two are oblique to each other or are not at right angles, fig. 16D.

EXPERIMENT 91. Monoclinic Crystals of Borax

The crystals of borax (sodium biborate) illustrate this class. The household variety such as "Twenty Mule Team" should be examined. Other less common substances in this class are: ammonium tartrate, potassium chlorate, and cupric acetate.

The fifth class is called the *triclinic* system of crystals. In this class the three axes of the crystal are unequal and intersect each other at oblique angles rather than at right angles.

EXPERIMENT 92. Triclinic Crystals of Boric Acid

Prepare some crystals of boric acid, sometimes called boracic acid, to illustrate this kind of crystals. You will probably find this in your home medicine chest. Your potassium bichromate also crystallizes in this form.

The *hexagonal* system is the sixth and last class of crystals. These crystals have four axes or directions of growth. Three of them are in one plane, are of equal length and intersect or cross each other at angles of 60°. The fourth axis crosses them and may be longer or shorter than the other three, fig. 16E. Some substances having crystals of this class are: iodoform, sodium nitrate, calcium carbonate and thymol. Many complex salts of two or more substances form this kind of crystals.

Special microscopes are made for the observation and measurement of the crystal axes and have the necessary accessories for this work. They are called petrographic or chemical microscopes.

When you find a crystal add the system to which it belongs to your record. This brief description should be enough for you to classify the crystals into systems. The six systems are divided into 32 classes in detailed study. The first system has 5 classes, the second 7, the third 3, the fourth 3, the fifth 2 and the sixth system may be divided into two groups having 5 and 7 classes of crystals. For more information you may consult the books mentioned in the appendix.

CHAPTER 14

Chemical Microscopy

We have mentioned that a great deal of chemical study may be made to advantage with the help of the microscope. The chief advantage is that you may analyze a very small amount of material.

Microchemistry is fast becoming a very important means of doing chemical work when the amounts or conditions will not permit the usual methods. In industry it may be very important to learn what small impurities are. For instance, photographic film must be made free from imperfections. A spot in the film might spoil the picture of a person's face. The firms making film, inspect it very carefully and when a speck is found in a film this is cut out and sent to the microchemistry laboratory. They then find out what the speck is, because when they know what it is, they can find means of preventing this kind of material getting into the film in the future. Sometimes they must use chemical methods to identify it and sometimes they can tell that it is dirt, a fiber, or other material just by looking at it under the microscope.

The chemical methods consist of identifying crystals by their form as you did in the last chapter of the manual by its appearance, as hair, etc., by recognizing the substance from its behavior as it is heated or by the way it reacts when it is mixed with other chemicals. To learn microchemistry takes time and it may be studied in the colleges and the industrial schools. Some of the books on microchemistry are listed in the appendix of this manual. If you have a Chemistry Set you can devise and do a great many experiments in addition to the ones given here. To do microchemistry, the methods must be learned and we will now try some of them.

Use the glass rod, when transferring chemicals from their container to your slides. When the end is moistened, enough will stick to the rod. Wash the rod each time after you use it. Unless your chemicals are kept pure you cannot expect success in microchemistry.

The first test of an unknown is its solubility. Is it easily or difficulty soluble in water? When it will not dissolve in water, other solvents such as carbon tetrachloride are tried and if it then dissolves we know that it is probably one of the fatty substances. To test solubility a very small amount, about the size of the period at the end of this sentence, is added to a drop of water about 5 mm. in diameter. If this dissolves, that much more is then added, and so on until no more will dissolve. One then makes a note in the record book of about how much was dissolved. For really accurate work the amount of water would be carefully measured and the amount of material weighed.

EXPERIMENT 93. Solution in Other Liquids Than Water

Try dissolving a small amount of butter in water and in carbon tetrachloride. Let the solution in the carbon tetrachloride evaporate and examine the result with your microscope.

Sometimes a part of the material tested will dissolve, but the rest will not dissolve and we wish to separate the parts. This is called filtration and we have already used the method in chapter II. With very small amounts slightly different methods are used.

EXPERIMENT 94. Separation of Salt by Solution and Filtration

Rub up a little butter in a drop of water. Now put a small plug of blotting, or other absorbent paper, into the end of your medicine dropper. Place this on the drop and force out some of the air and gently suck in the water. If you were careful you will have clear water in the pipette. With your forceps take out the plug with any butter that may have become stuck on it.

EXPERIMENT 95. Test for Salts from Solution

Place the drop of clear water from the last experiment on a clean slide and let it evaporate. You may find a few small crystals which are square and suggest salt.

Another method of filtering is to place a narrow (1/8") strip of the paper about 3/4" long so that one end is in the drop with the butter and the other end touches another clean slide placed below the first. The water will run down through the paper onto the slide. The first slide should be held tipped partly edgewise.

EXPERIMENT 96. Strip Method of Filtering

Prepare another drop of butter in water and try this method for filtration.
The liquid may be separated from the drop by tilting the slide so it runs toward one side and then drawing a bit of the paper towel across it to separate it into two drops.

EXPERIMENT 97. Testing Tooth Paste

Dissolve a little tooth paste in a drop of water and separate the water and dissolved materials from the rest by this method. Let the clear drop evaporate and see if any crystals form. If they do form it shows that the tooth paste contained chemicals soluble in water.

EXPERIMENT 98. Salts in Soil

Try a little soil, or other material and use all three methods of separation and see what you can dissolve out with water.

EXPERIMENT 99. Another Test for Tooth Paste

Repeat the experiment using tooth paste and carbon tetrachloride and see if any fatty matter can be separated with this solvent.
Which method of separation do you think would be best for other kinds of materials?

Many of the methods of chapter II can be done with drops of material on a microscope slide.

EXPERIMENT 100. Micro-Decantation

Can you figure out how to use the method of decantation with a drop or two on a slide?

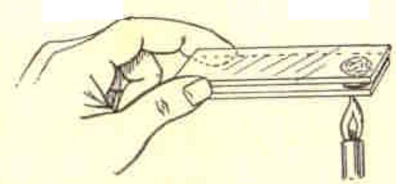


FIG. 17

Sublimation is a very useful method when one has only a small amount of material. The solid is placed on a slide near one end, or a drop of the material is placed similarly and let dry. Another slide is held so that it is about 1/4" from the residue of the material on the first, fig. 17. Then the slide with the material is gently heated and if the material evaporates easily it will condense on the second slide and may be examined on the microscope.

EXPERIMENT 101. Sublimation of Iodine

Sublime a little tincture of iodine or iodine solution by this method and examine the crystals of iodine which sublime onto the second slide. Do not heat it rapidly or the iodine vapors will be formed too fast to condense on the second slide held above the iodine and will get into the room and make you cough. The second, or receiving, slide should be cold.

EXPERIMENT 102. Sublimation of Tannin from Tea

If you are careful you can heat a little tea and the tannin will sublime on the second cold slide. Heat the tea until it is quite warm but not enough to burn.
If you have a very small metal or porcelain dish you may put the material, tea, into it and hold, or set, the slide over the dish. If the dish is too small to hold, put it and the slide on a piece of metal so that they can be held above an alcohol lamp. When using two slides they can usually be held by the far end so as not to burn your fingers.
The more generally used methods depend on the chemical behavior of the material and most of these either give a precipitate with a characteristic color or else produce a crystal that may be recognized. Some of the reactions are so specific that one may answer the question of identity, but usually one will tell the class of material involved and others are necessary for complete identification.

Copper and iron may be identified by their reaction with sodium ferrocyanide. Copper gives a reddish colored precipitate of fine crystals and iron a blue precipitate.

EXPERIMENT 103. Testing a Raisin for Copper

Grind a raisin in some water with your glass rod, which process is called maceration, and filter off a little of the water and place a drop of it on a slide. Dissolve a little sodium ferrocyanide in a drop of water close to the first drop and bring them together with the glass rod while you look at them with the microscope. A blue precipitate shows that iron is present.

EXPERIMENT 104. Testing Apple Seeds for Iron

Test some apple seeds for iron.

EXPERIMENT 105. Testing Lettuce for Iron

Test some lettuce for iron. Many other foods may be tested in a similar manner.

Another method of making the test is to burn a small bit of the material on a slide until only a white ash is left. You will need to heat the slide very slowly to prevent its breaking and to be careful not to set it on a cold object until it is cold. The slide may be held with a pair of pliers or placed on some metal to hold it above an alcohol lamp or gas flame.

EXPERIMENT 106. Testing Ash of Bean for Iron

Ash a little of a bean and test it for iron. You may test many other foods by the ashing method.

Many foods contain copper and the same test may be made, but in this case you will get a reddish or brownish precipitate.

EXPERIMENT 107. Testing Peas for Copper

Test some canned peas for copper using the same method that you used in experiment 103.

EXPERIMENT 108. Reagents on a Fiber

The reagents used for testing are sometimes used on fibers. Take some fine white cotton thread and soak it in a strong solution of the sodium ferrocyanide. Pull the thread out of the test tube of solution with the forceps and blot with paper towel or toilet paper and let dry. A piece of the treated thread may be cut off and placed in a drop of unknown. The thread should be not over half in the solution and then the preparation is examined with the microscope to see whether it has turned reddish or bluish.

Make some ferrocyanide thread and test some material like you did in experiments 103 and 106. The thread may be kept in a stoppered glass vial for future testing. Other test fibers can be made and are more convenient than the powder for testing.

Carbonates give off bubbles of carbon dioxide when they are placed in an acid. This makes a convenient test and when you have only a very small amount of material the test can be made to advantage under the microscope.

EXPERIMENT 109. Test for a Carbonate

Dissolve a little baking or washing soda in water on a microscope slide and add a cover glass. Place a drop of vinegar at one edge of the slide and draw it in by touching a bit of absorbent paper to the opposite edge of the cover glass. Do bubbles appear? Add a little soda to a little vinegar on the slide. The bubbles will form more rapidly.

EXPERIMENT 110. Testing Clam Shell for Carbonate

Place a bit of clam or other shell on a slide and add a drop of vinegar and see if a gas is liberated. When the bubbles are small you will have to look closely with your microscope to see them. The vinegar contains acetic acid which causes the carbon dioxide gas to form from the carbonate in the shell. Any other acid might be used, but vinegar is convenient. The vinegar tastes sour because it contains acetic acid. Strong vinegar contains about 3% acetic acid.

EXPERIMENT 111. Hydrogen Gas from Zinc

Place a little zinc in some vinegar under a cover slip and watch to see if bubbles of gas are formed.

It might be thought that this showed the zinc to be a carbonate, but we know that this is not true. Therefore, to be sure we must have a test to show whether the gas is really carbon dioxide. This can be done with lime water. You may find some lime water in your family medicine chest.

EXPERIMENT 112. Carbonate from Expired Air

Bubble a little air into some lime water with your medicine dropper and you will not see any change. Blow your breath through the lime water with the aid of a straw and a white precipitate will form showing that your breath contained carbon dioxide.

EXPERIMENT 113. Proving a Gas to Be Carbon Dioxide With Lime Water

Repeat experiments 110 and 111 in the following manner. Place a small drop of vinegar on a slide and at a little distance from it place a small drop of lime water. Near each place a piece of broken cover slip to hold up the cover glass. Add the shell or the zinc to the vinegar and carefully lower a cover glass over both drops. The drops must be small enough so that the cover glass will not force them together. Watch the drop of lime water with your microscope for any white precipitate. If a white cloudiness forms in the lime water you know that the gas is carbon dioxide. The test can be made a little more sensitive if the edges of the cover glass are sealed with vaseline or petroleum jelly.