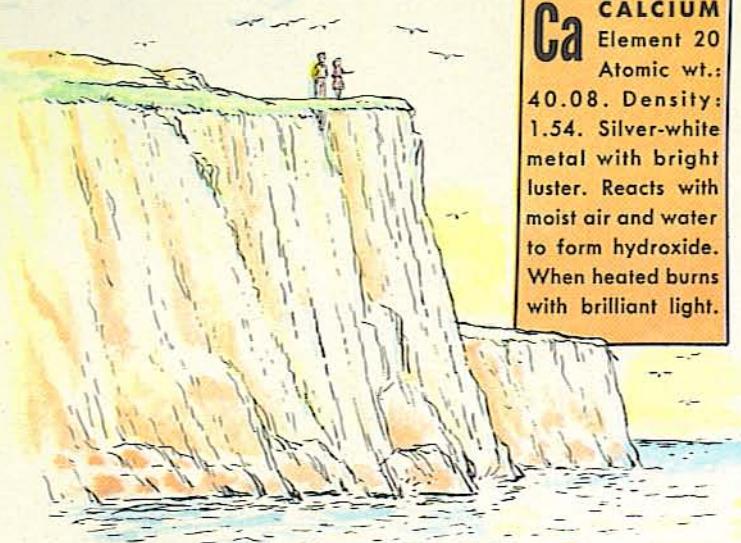


Ca**CALCIUM**

Element 20

Atomic wt.: 40.08.

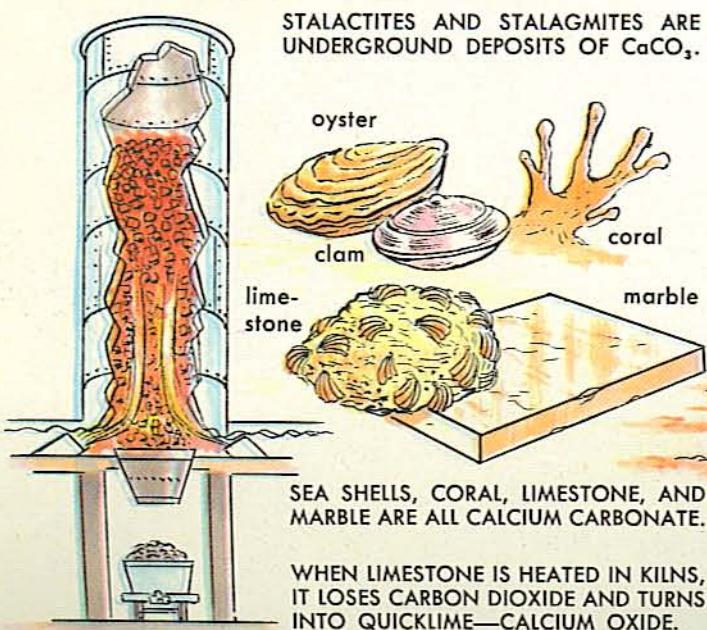
Density: 1.54. Silver-white metal with bright luster. Reacts with moist air and water to form hydroxide. When heated burns with brilliant light.



"THE WHITE CLIFFS OF DOVER" CONSIST OF ALMOST PURE CALCIUM CARBONATE IN THE FORM OF CHALK.



STALACTITES AND STALAGMITES ARE UNDERGROUND DEPOSITS OF CaCO_3 .



SEA SHELLS, CORAL, LIMESTONE, AND MARBLE ARE ALL CALCIUM CARBONATE.

WHEN LIMESTONE IS HEATED IN KILNS, IT LOSES CARBON DIOXIDE AND TURNS INTO QUICKLIME—CALCIUM OXIDE.

Calcium—for Building

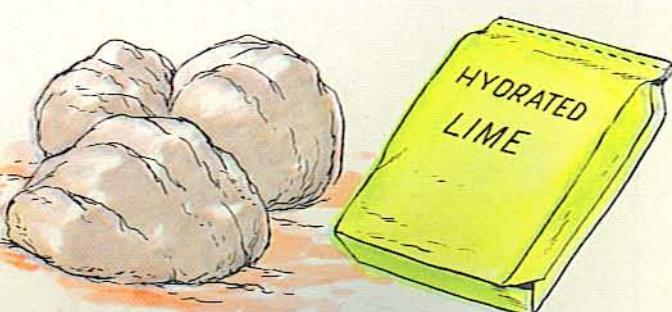
STAND UP STRAIGHT. You can do it because your bones contain calcium. Tell a mason to put up a brick house. He can do it with mortar containing calcium. Tell a master builder to build a monument. He will make it from marble—calcium again. Tell a hen to "go lay an egg." She can do it if she gets enough calcium in her feed to make the shell.

Calcium carbonate (CaCO_3) is the starting point for most calcium compounds—and for other chemicals as well. It is found in nature in cliffs and mountain ranges in the form of chalk and limestone and marble. And it makes up the shells of clams and muscles and billions of tiny sea creatures.

Calcium carbonate is almost insoluble in water. But if the water contains carbon dioxide, some goes in solution as calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$). This explains the formations in our famous limestone caves. Rainwater containing carbon dioxide seeped through the ground and dissolved a small amount of limestone. In falling from the cave ceiling and drying, the drops gave up H_2O and CO_2 and left CaCO_3 behind. The minute deposits of falling drops during thousands of years created the stalactites hanging from the roof of the caves and the stalagmites rising from the floor.

A widespread mineral called gypsum is the sulfate of calcium. In this, each molecule of sulfate has two molecules of water attached to it ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). When gypsum is heated, it loses three quarters of its water and becomes plaster of Paris ($2\text{CaSO}_4 \cdot \text{H}_2\text{O}$). When you mix plaster of Paris and water, it again takes on the full amount of H_2O and hardens into a hydrate similar to the original gypsum.

The name of calcium was given to the metal hidden in limestone by its discoverer, Humphry Davy. It comes from *calx*, the old Latin name for lime.



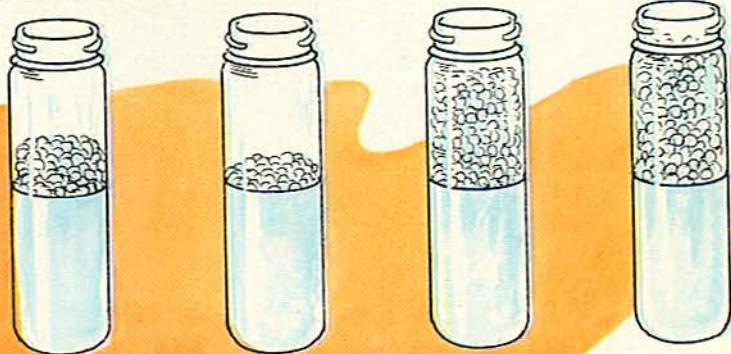
WHEN WATER IS ADDED TO LUMPS OF QUICKLIME (CaO), THEY CRUMBLE INTO A WHITISH POWDER OF SLAKED OR HYDRATED LIME ($\text{Ca}(\text{OH})_2$). (SEE ALSO PAGE 45.)

TESTING HARDNESS OF WATER



1 MAKE TEST SOLUTION BY DISSOLVING 1 g SOAP FLAKES IN 20 ml DENATURED ALCOHOL. FILTER.

2 FILL A SLENDER JAR HALF FULL OF WATER TO BE TESTED. ADD 10 DROPS OF SOAP SOLUTION. CLOSE MOUTH OF JAR. SHAKE VIGOROUSLY. CHECK AMOUNT OF FOAM.

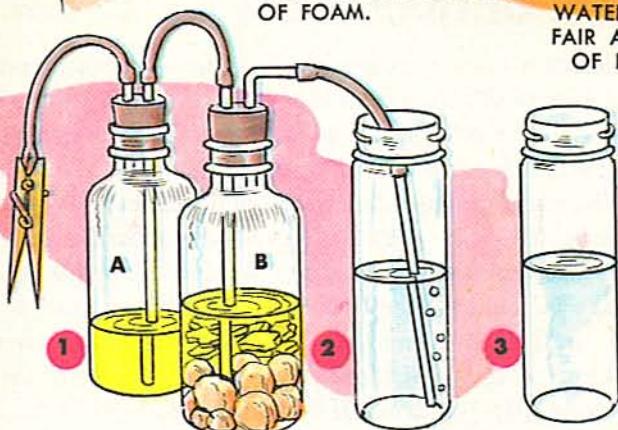


SOFT TAP
WATER GIVES
FAIR AMOUNT
OF FOAM.

HARD TAP
WATER MAKES
VERY LITTLE
FOAM.

HARD WATER
SOFTENED WITH
WASHING
SODA MAKES
FOAM.

DISTILLED
WATER MAKES
LARGE
AMOUNT
OF FOAM.

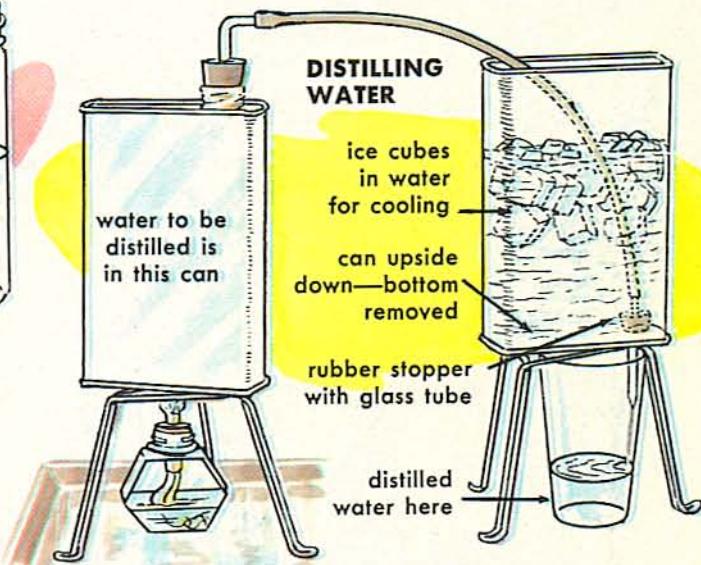


MAKING "HARD" WATER

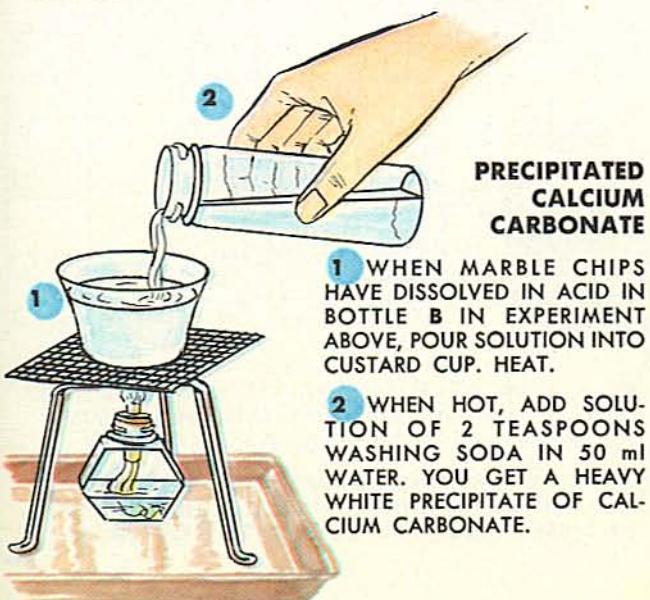
1 SET UP GAS GENERATOR AS SHOWN ON PAGE 31. BOTTLE A CONTAINS HYDROCHLORIC ACID. IN BOTTLE B, PLACE MARBLE CHIPS ON TOP OF PEBBLES. POUR ACID ON MARBLE CHIPS TO MAKE CO_2 .

2 LEAD THE CARBON DIOXIDE INTO LIME WATER. IT TURNS MILKY THROUGH FORMATION OF CaCO_3 .

3 CONTINUE LEADING CO_2 INTO MILKY SOLUTION. MILKINESS DISAPPEARS. INSOLUBLE CaCO_3 HAS BEEN TURNED INTO SOLUBLE $\text{Ca}(\text{HCO}_3)_2$. THIS IS THE SUBSTANCE THAT MAKES MOST HARD WATER "HARD."



IN THE SCIENTIFIC LABORATORY, ALL IMPURITIES (CALCIUM CARBONATE AND SULFATE, AND OTHERS) MUST BE REMOVED FROM WATER TO BE USED AS SOLVENT. THIS IS DONE BY EVAPORATING THE WATER AND CONDENSING THE STEAM. YOU CAN MAKE A DISTILLATION APPARATUS FROM TWO PINT-SIZE CANS.



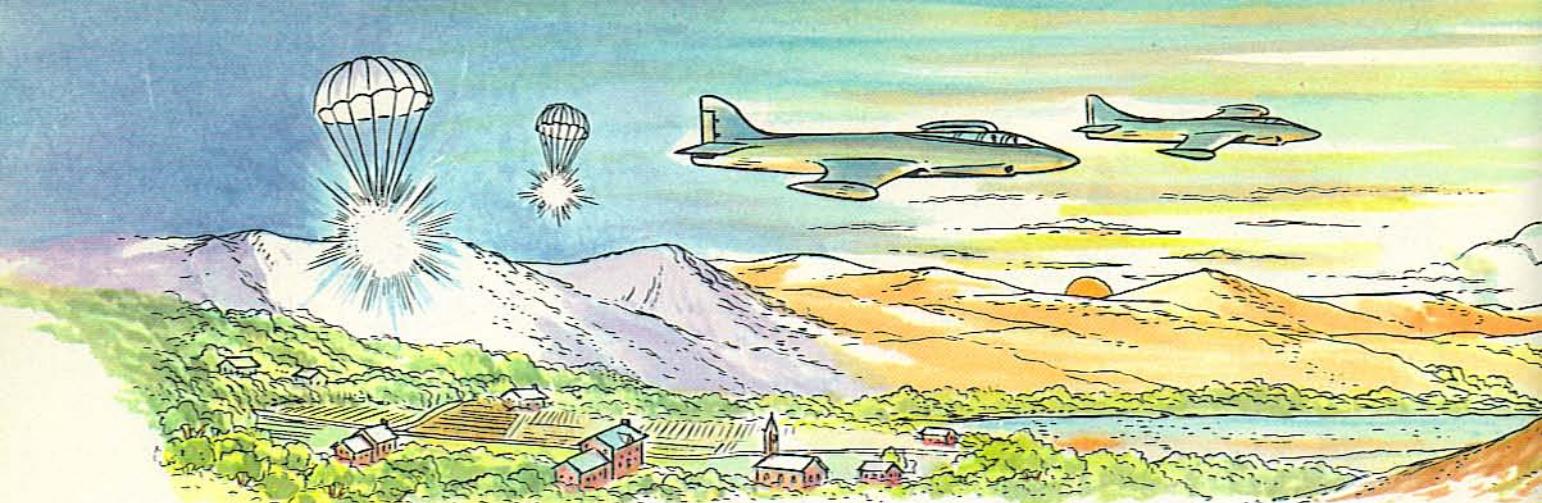
PRECIPITATED CALCIUM CARBONATE

1 WHEN MARBLE CHIPS HAVE DISSOLVED IN ACID IN BOTTLE B IN EXPERIMENT ABOVE, POUR SOLUTION INTO CUSTARD CUP. HEAT.

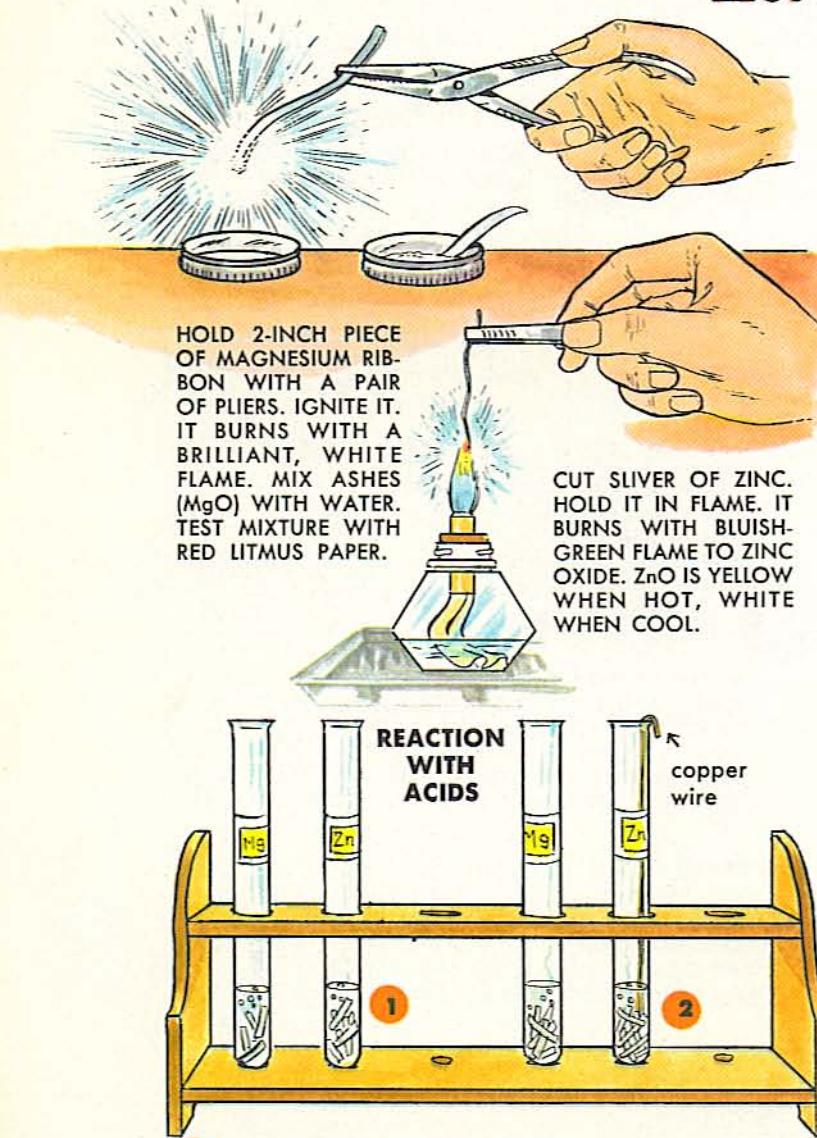
2 WHEN HOT, ADD SOLUTION OF 2 TEASPOONS WASHING SODA IN 50 ml WATER. YOU GET A HEAVY WHITE PRECIPITATE OF CALCIUM CARBONATE.

CASTING WITH PLASTER OF PARIS
PLASTER OF PARIS ($2\text{CaSO}_4 \cdot \text{H}_2\text{O}$) IS USED IN POLICE WORK FOR MAKING CASTS OF TRACKS. MIX PLASTER WITH WATER UNTIL IT HAS CONSISTENCY OF MEDIUM CREAM. POUR IN TRACK. LEAVE TO SET ONE HOUR.





Let's Compare Two Metals



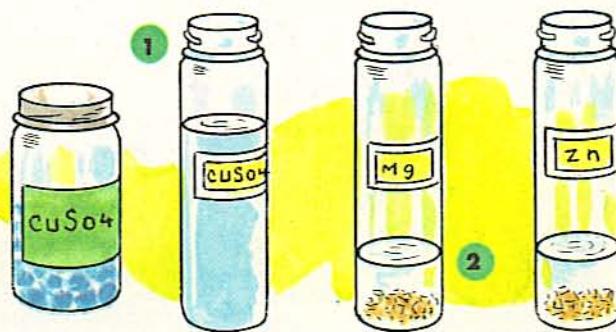
- 1 BOTH METALS REACT WITH WEAK ACIDS, EVEN WITH VINEGAR—Mg WITH COLD VINEGAR, Zn WITH HOT.
- 2 POUR SOLUTION OF 1 g SODIUM BISULFATE IN 10 ml WATER ON Mg AND Zn. Mg REACTS FAST, Zn SLOWLY. NOW TOUCH ZINC WITH A COPPER WIRE. REACTION SPEEDS UP, CAUSED BY ELECTRIC PROCESS.

TAKE A LOOK at the periodic table of elements on pages 38-39. In column IIA you find the metal magnesium, in column IIB the metal zinc. The fact that the two families in which they are found both have the Roman numeral II would indicate that they are related. But the fact that they are in separate "sub-groups" would suggest that they differ in certain respects. That is exactly the case.

In their compounds they are very much alike. One atom combines with one atom of oxygen to form the oxide (MgO and ZnO), and one atom replaces two atoms of hydrogen in forming a salt ($MgCl_2$ and $ZnCl_2$, for instance). But in some of their reactions they do not behave alike — as you will learn.

Before World War II, magnesium had little use — mainly in flash photography because it burns with a blinding, white light. But the metal became important when lightweight planes were needed — melted together with other metals it forms an "alloy"

REPLACEMENT OF COPPER



- 1 DISSOLVE 4 g COPPER SULFATE IN 40 ml WATER. POUR HALF OF THE SOLUTION OVER STRIPS OF MAGNESIUM, THE OTHER HALF OVER SLIVERS OF ZINC.
- 2 COPPER IS FORCED OUT AND Mg AND Zn GO INTO SOLUTION. IF ENOUGH METAL IS USED, THE BLUE COLOR DISAPPEARS. $MgSO_4$ AND $ZnSO_4$ ARE COLORLESS.

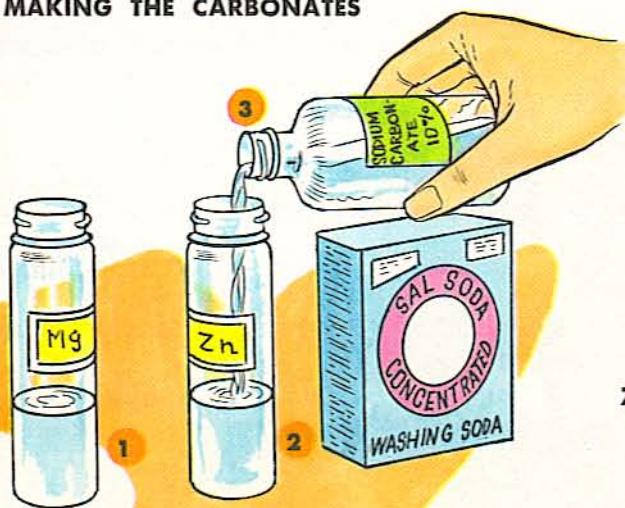


Mg MAGNESIUM	Zn ZINC
Element 12.	Element 30.
Atomic wt.: 24.32.	Atomic wt.: 65.38.
Density: 1.75. Silver-white metal.	Density: 7.1. Bluish-white metal.
Ductile, malleable.	Ductile and malleable. Distils when heated to boiling.
Reacts with boiling water. Burns in air with very brilliant white light.	Reacts with boiling water. Burns in air with very brilliant white light.

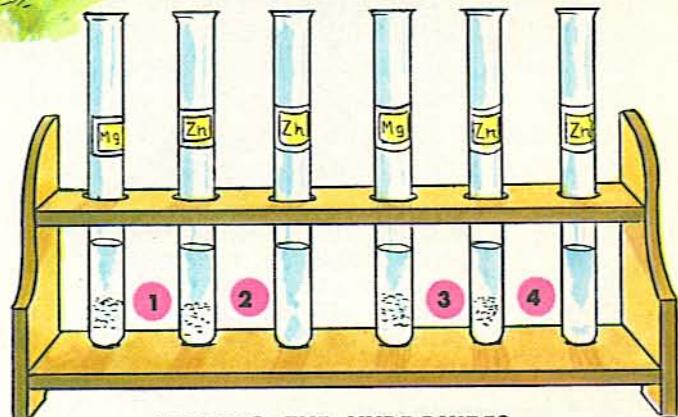
that is light yet very strong. Some magnesium compounds are used in medicine: milk of magnesia ($Mg(OH)_2$) and Epsom salt ($MgSO_4 \cdot 7H_2O$).

Zinc has been used for ages to coat iron pails and pipes to prevent them from rusting — "galvanized iron." Zinc is also a part of many alloys (German silver and brass) and is important in the making of dry-cell batteries.

MAKING THE CARBONATES

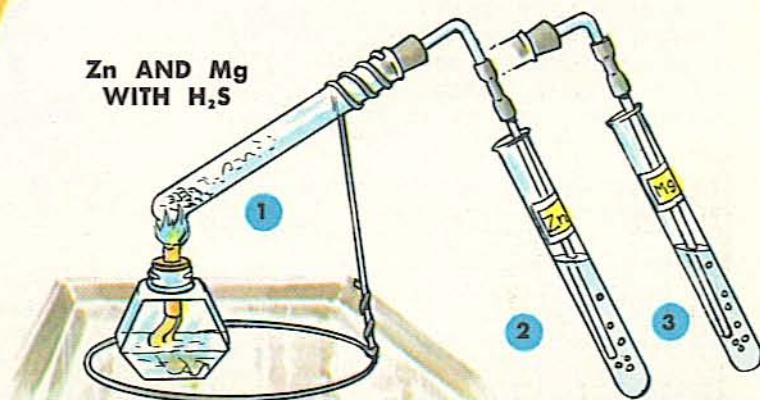


- 1 DISSOLVE 2 g EPSOM SALT (MAGNESIUM SULFATE, $MgSO_4 \cdot 7H_2O$) IN 20 ml WATER.
- 2 GET FROM HARDWARE STORE SMALL BOTTLE OF "TINNERS' FLUID." THIS IS A STRONG SOLUTION OF ZINC CHLORIDE. DILUTE 5ml OF FLUID WITH 15 ml WATER.
- 3 MAKE SOLUTION OF 5 g WASHING SODA (SODIUM CARBONATE) IN 50 ml WATER. ADD SOME OF THIS SOLUTION TO THE OTHER TWO. IN BOTH JARS YOU WILL GET A HEAVY WHITE PRECIPITATE. IN THE Mg JAR, THIS IS NORMAL MAGNESIUM CARBONATE ($MgCO_3$). IN Zn JAR, CO_2 IS SET FREE AND BASIC ZINC CARBONATE ($Zn(OH)_2 \cdot ZnCO_3$) RESULTS.



MAKING THE HYDROXIDES

- 1 ADD SODIUM HYDROXIDE SOLUTION TO SOLUTION OF MAGNESIUM SULFATE. WHITE $Mg(OH)_2$ FORMS.
- 2 ADD SMALL AMOUNT OF NaOH SOLUTION TO DILUTED TINNERS' FLUID ($ZnCl_2$). $Zn(OH)_2$ IS FORMED. ADD MORE NaOH. PRECIPITATE DISSOLVES WITH FORMATION OF SODIUM ZINCATE (Na_2ZnO_2).
- 3 ADD AMMONIA (AMMONIUM HYDROXIDE) TO MAGNESIUM SULFATE SOLUTION. AGAIN $Mg(OH)_2$ FORMS.
- 4 ADD SMALL AMOUNT OF AMMONIA TO DILUTED TINNERS' FLUID. $Zn(OH)_2$ FORMS. ADD MORE. THE $Zn(OH)_2$ DISSOLVES, FORMING COMPOUND WITH NH_3 .



- 1 SET UP HYDROGEN SULFIDE APPARATUS SHOWN ON PAGE 53.
- 2 LEAD HYDROGEN SULFIDE (H_2S) INTO DILUTED TINNERS' FLUID ($ZnCl_2$). YOU GET A WHITE PRECIPITATE OF ZnS .
- 3 LEAD H_2S INTO SOLUTION OF EPSOM SALT ($MgSO_4$). HERE ALSO YOU GET WHITE PRECIPITATE. BUT NOT OF MAGNESIUM SULFIDE. THIS REACTS WITH THE WATER TO MAKE $Mg(OH)_2$.



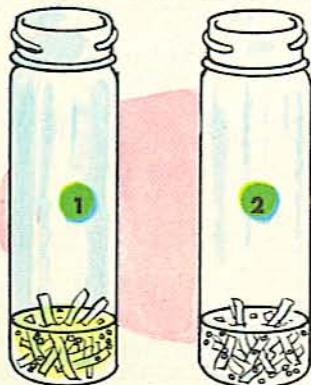
Al ALUMINUM

Element 13.
Atomic wt.:
26.98. Density:
2.70. Silver-white
metal; ductile, malleable,
able to take a high polish.
Amphoteric. Will burn
in oxygen with white flame.

MAKE A SMALL AMOUNT OF ALUMINUM POWDER BY FILEING IT OFF AN OLD ALUMINUM POT. SPRINKLE IN FLAME TO MAKE SPARKS OF BURNING ALUMINUM.



DISSOLVING ALUMINUM



1 CUT ALUMINUM FOIL IN SMALL STRIPS. DROP THEM IN A LITTLE DILUTED HYDROCHLORIC ACID. HYDROGEN IS RELEASED; ALUMINUM CHLORIDE IS FORMED.

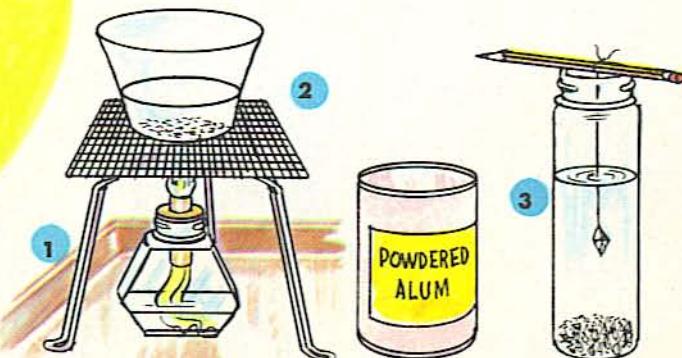
2 DROP STRIPS OF ALUMINUM FOIL IN 10% NaOH SOLUTION. HYDROGEN IS FREED AND SODIUM ALUMINATE (NaAlO_2) IS FORMED.

Aluminum—in Abundance

IT IS ALMOST impossible to imagine our world without aluminum. Almost everywhere you look you see items made of this silver-white metal — from the pots in the kitchen to the airplanes flying overhead.

Although aluminum is the most abundant metal on earth, no one had ever seen it until 1825 when a Danish scientist, Hans Christian Ørsted, isolated it from aluminum chloride (AlCl_3). For a number of years aluminum was so expensive that it was considered in class with gold and silver. The solid aluminum cap placed on top of the Washington Monument in 1884 was first put on public display so that everyone could have a look at such a great rarity. Two

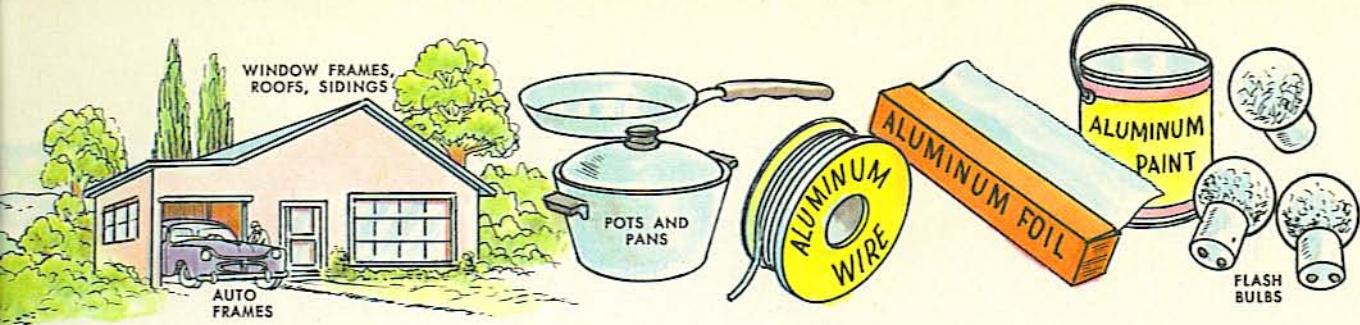
GROWING ALUM CRYSTALS



1 HEAT WATER UNTIL IT IS SLIGHTLY MORE THAN LUKE-WARM. STIR INTO IT POTASSIUM ALUM OR AMMONIUM ALUM UNTIL NO MORE DISSOLVES. POUR LIQUID OFF UNDISSOLVED ALUM. SET ASIDE TO COOL.

2 WHEN CRYSTALS HAVE FORMED, PICK OUT LARGEST ONES. ADD TO SOLUTION AS MUCH MORE ALUM AS IS REPRESENTED BY THE CRYSTALS YOU REMOVED. HEAT GENTLY AGAIN UNTIL ALL IS DISSOLVED. COOL.

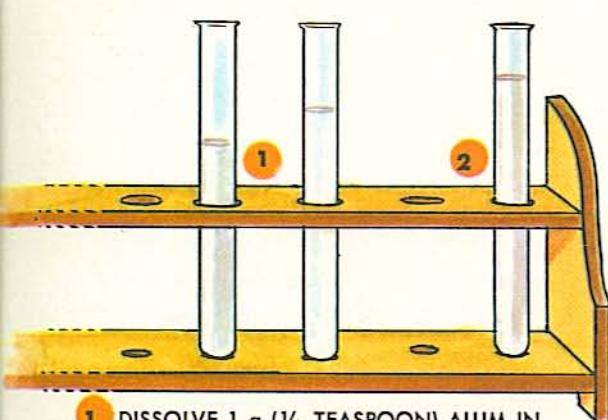
3 POUR COOLED SOLUTION INTO NARROW GLASS. TIE THREAD TO LARGEST CRYSTAL YOU PICKED. HANG THIS IN SOLUTION FROM A PENCIL. PLACE IN QUIET SPOT. LET THE CRYSTAL GROW FOR A WEEK OR MORE.



years later, a 22-year-old American chemist, Charles Martin Hall, invented a way of producing aluminum cheaply from aluminum oxide (Al_2O_3). Since then aluminum has become one of the most popular of all metals—mostly because of its lightness.

The mineral bauxite (AlHO_2 , $\text{Al}(\text{OH})_3$) is our main source of aluminum. But aluminum is also found in nature as oxide and in many complex silicates. Clay, for instance, is an aluminum silicate.

MAKING ALUMINUM HYDROXIDE



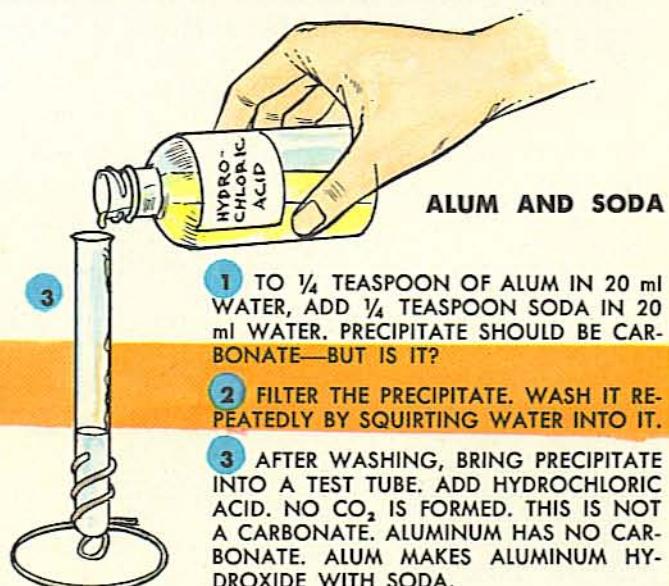
1 DISSOLVE 1 g (1/4 TEASPOON) ALUM IN 10 ml WATER. ADD A LITTLE 10% NaOH SOLUTION. YOU GET JELLY-LIKE ALUMINUM HYDROXIDE. THIS WILL DISSOLVE IN MORE NaOH TO FORM SODIUM ALUMINATE.

2 AMMONIA ADDED TO ALUM SOLUTION GIVES ALUMINUM HYDROXIDE. BUT THIS DOES NOT DISSOLVE IN MORE AMMONIA.



1 POUR WATER INTO A PINT JAR AND STIR INTO IT 1 TABLESPOON EARTH FROM THE GARDEN OR FROM A FLOWER POT.

2 IN ANOTHER JAR, MAKE A SIMILAR MIXTURE. IN THIS, DISSOLVE 1/4 TEASPOON ALUM. ADD 1 TEASPOON AMMONIA. DIRT SETTLES FASTER IN THIS JAR THAN IN THE FIRST JAR.

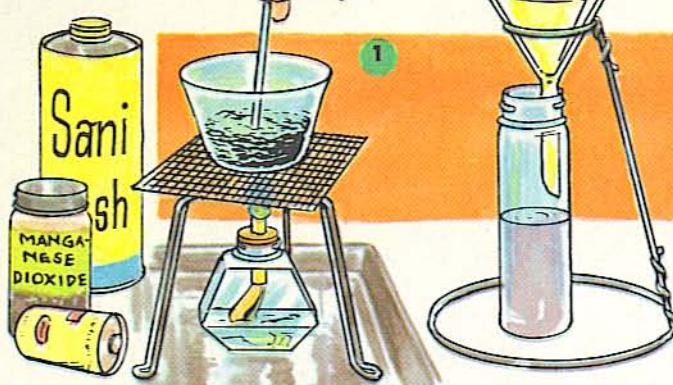


1 TO 1/4 TEASPOON OF ALUM IN 20 ml WATER, ADD 1/4 TEASPOON SODA IN 20 ml WATER. PRECIPITATE SHOULD BE CARBONATE—BUT IS IT?

2 FILTER THE PRECIPITATE. WASH IT REPEATEDLY BY SQUIRTING WATER INTO IT.

3 AFTER WASHING, BRING PRECIPITATE INTO A TEST TUBE. ADD HYDROCHLORIC ACID. NO CO_2 IS FORMED. THIS IS NOT A CARBONATE. ALUMINUM HAS NO CARBONATE. ALUM MAKES ALUMINUM HYDROXIDE WITH SODA.

MANGANESE
DIOXIDE TO
MANGANESE
SULFATE



1 IN A PYREX CUSTARD CUP, MIX 2 g MANGANESE DIOXIDE, 6 g SODIUM BISULFITE, AND 10 ml WATER. HEAT MIXTURE GENTLY. IT WILL BUBBLE VIGOROUSLY BECAUSE OXYGEN IS SET FREE.

2 AFTER A FEW MINUTES, ADD 30 ml WATER. FILTER. FILTRATE CONTAINS MANGANESE SULFATE ($MnSO_4$) AND SODIUM SULFATE.

MANGANESE
SULFATE TO
MANGANESE
HYDROXIDE



3 INTO HALF OF THE MANGANESE SULFATE SOLUTION YOU HAVE MADE, POUR 10% SOLUTION OF $NaOH$ UNTIL NO MORE PRECIPITATE FORMS. WHITISH $Mn(OH)_2$ OXIDIZES INTO BROWN $MnO(OH)$.

Manganese—Metal of Many Colors

METALLIC MANGANESE has no use by itself. But add up to 15 per cent of it to steel and the result is an alloy — "manganese steel" — so hard that it is suitable for machine parts that are exposed to a lot of rough wear.

The most common ore from which manganese is extracted goes under the name of "pyrolusite." This is nothing but your old friend manganese dioxide (MnO_2) which you found in your flashlight battery

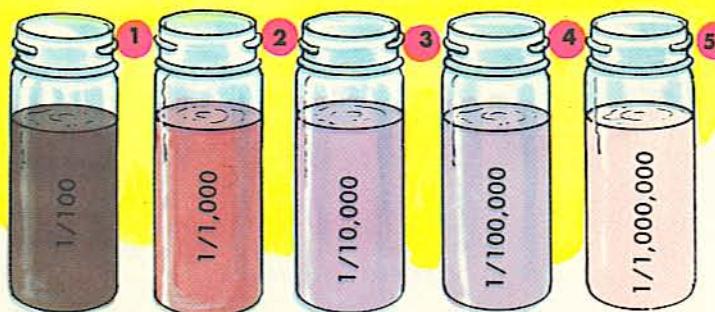
and have already used in a great number of your chemical experiments.

The compounds of manganese come in almost any color you can think of: black and brown, white and pink and red, violet and green. In working with these compounds, your fingers and glassware may get brown. You can get rid of this stain easily with diluted hydrochloric acid. Rinse thoroughly with water afterwards.

EXPERIMENTS WITH POTASSIUM PERMANGANATE

$KMnO_4$ WILL GIVE YOU AN IDEA OF SMALLNESS OF MOLECULE.

- 1 DISSOLVE $\frac{1}{2}$ g POTASSIUM PERMANGANATE IN 50 ml WATER. THIS GIVES A SOLUTION OF 1 TO 100, OR 1/100.
- 2 DILUTE 5 ml OF THIS SOLUTION WITH 45 ml WATER. YOU NOW HAVE A SOLUTION OF 1 TO 1,000, OR 1/1,000.
- 3 AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/10,000.
- 4 AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/100,000.
- 5 AGAIN, 5 ml TO 45 ml WATER FOR SOLUTION 1/1,000,000. COLOR YOU STILL SEE IS CAUSED BY THE PRESENCE OF MORE THAN 600,000,000,000,000,000 MOLECULES OF $KMnO_4$.



REDUCING $KMnO_4$

PLACE A FEW CRYSTALS OF POTASSIUM PERMANGANATE ON BOTTOM OF A TEST TUBE. DROP A FEW DROPS OF HYDRO-CHLORIC ACID ON THEM. THE $KMnO_4$ IS REDUCED (THAT IS, IT GIVES UP OXYGEN). IT OXIDIZES HCl AND SETS CHLORINE FREE.

THE EXPERIMENTS ALONG THE TOP OF THESE PAGES SHOW HOW IT IS POSSIBLE TO MOVE FROM ONE COMPOUND TO ANOTHER.

MANGANESE SULFATE TO MANGANESE CARBONATE



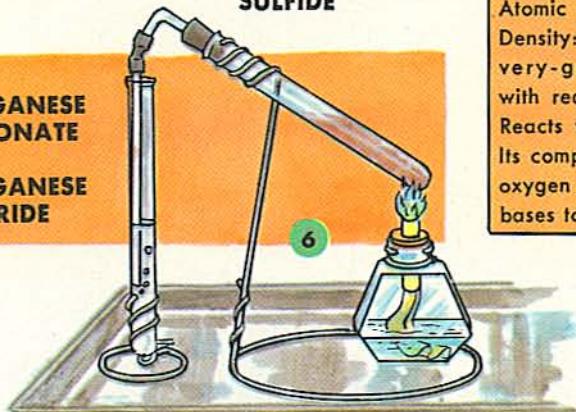
4 INTO SECOND HALF OF SOLUTION, POUR SOLUTION OF 4 g SODIUM CARBONATE IN 10 ml WATER. WHITE PRECIPITATE IS MnCO_3 .



MANGANESE CARBONATE TO MANGANESE CHLORIDE

5

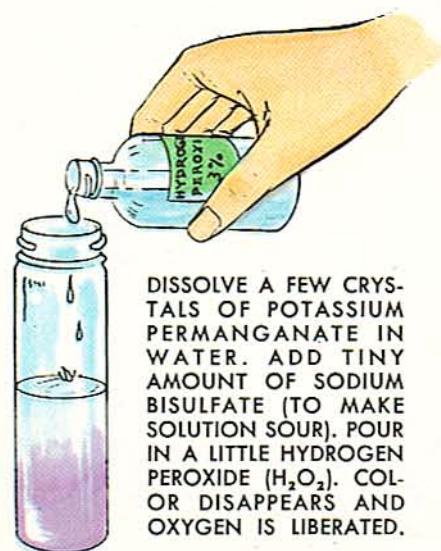
5 LET MANGANESE CARBONATE SETTLE. POUR LIQUID OFF PRECIPITATE. ADD HYDROCHLORIC ACID BY THE DROP UNTIL DISSOLVED. RESULT IS MANGANESE CHLORIDE (MnCl_2).



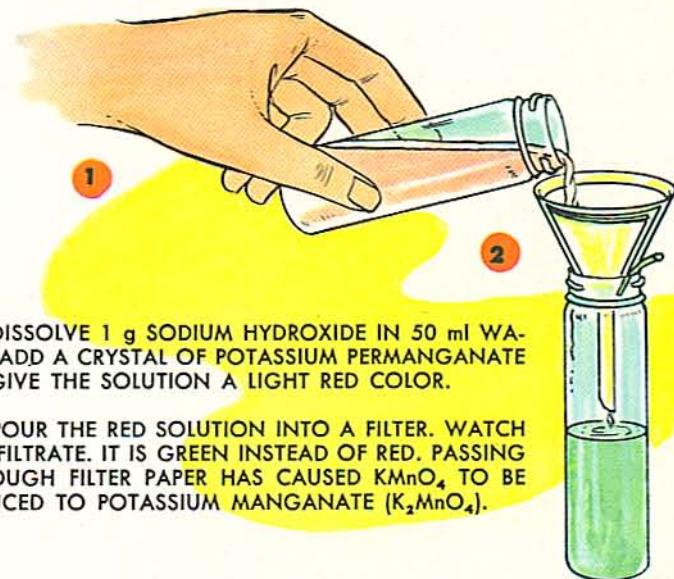
MANGANESE CHLORIDE TO MANGANESE SULFIDE

Mn MANGANESE
Element 25.
Atomic wt.: 54.94.
Density: 7.44. Silvery-gray metal with reddish tinge. Reacts with water. Its compounds with oxygen range from bases to acids.

6 SET UP APPARATUS FOR MAKING HYDROGEN SULFIDE (SEE PAGE 53). POUR SOLUTION OF MnCl_2 INTO TEST TUBE. DILUTE IT IF NECESSARY. LEAD H_2S INTO IT. YOU GET MANGANESE SULFIDE.

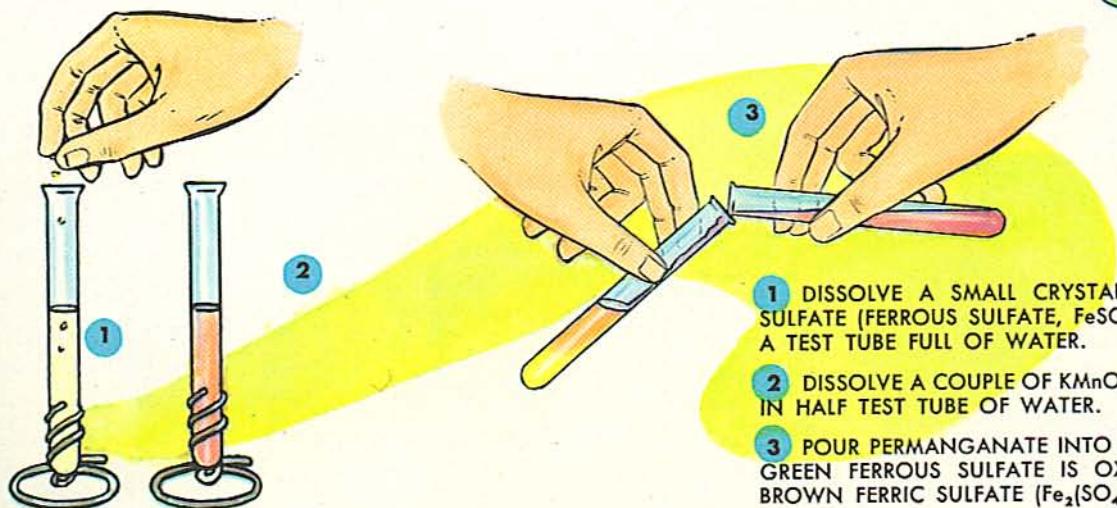


DISSOLVE A FEW CRYSTALS OF POTASSIUM PERMANGANATE IN WATER. ADD TINY AMOUNT OF SODIUM BISULFATE (TO MAKE SOLUTION SOUR). POUR IN A LITTLE HYDROGEN PEROXIDE (H_2O_2). COLOR DISAPPEARS AND OXYGEN IS LIBERATED.



1 DISSOLVE 1 g SODIUM HYDROXIDE IN 50 ml WATER. ADD A CRYSTAL OF POTASSIUM PERMANGANATE TO GIVE THE SOLUTION A LIGHT RED COLOR.

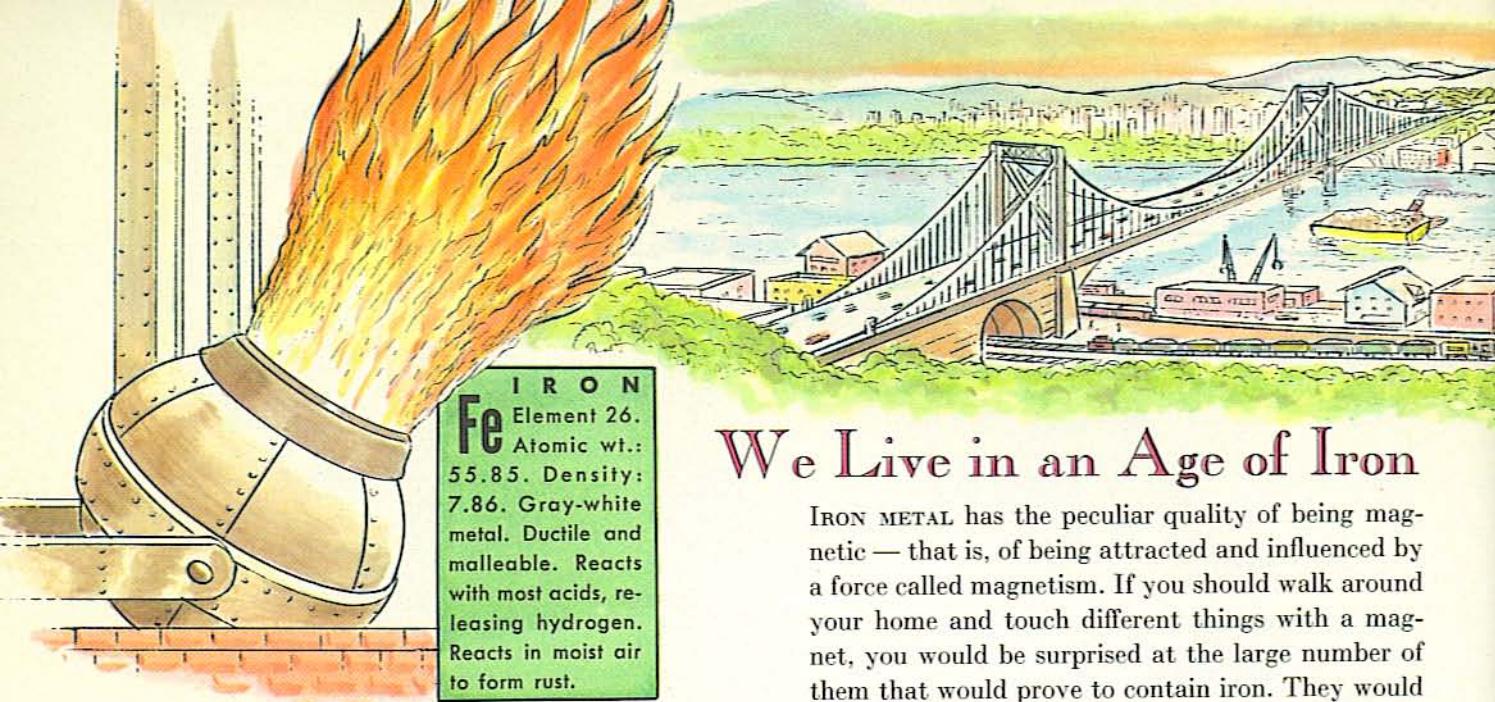
2 POUR THE RED SOLUTION INTO A FILTER. WATCH THE FILTRATE. IT IS GREEN INSTEAD OF RED. PASSING THROUGH FILTER PAPER HAS CAUSED KMnO_4 TO BE REDUCED TO POTASSIUM MANGANATE (K_2MnO_4).



1 DISSOLVE A SMALL CRYSTAL OF IRON SULFATE (FERROUS SULFATE, FeSO_4) IN HALF A TEST TUBE FULL OF WATER.

2 DISSOLVE A COUPLE OF KMnO_4 CRYSTALS IN HALF TEST TUBE OF WATER.

3 POUR PERMANGANATE INTO IRON SALT. GREEN FERROUS SULFATE IS OXIDIZED TO BROWN FERRIC SULFATE ($\text{Fe}_2(\text{SO}_4)_3$).



We Live in an Age of Iron

IRON METAL has the peculiar quality of being magnetic — that is, of being attracted and influenced by a force called magnetism. If you should walk around your home and touch different things with a magnet, you would be surprised at the large number of them that would prove to contain iron. They would range in size from the car in the garage and the refrigerator and stove in the kitchen to the nails in the walls and the needles and pins in your mother's sewing box.

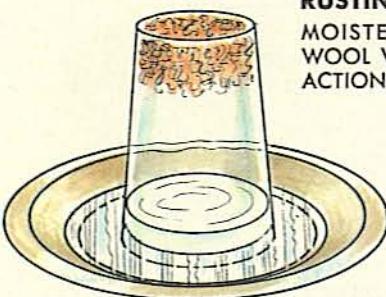
The moment you step outdoors and look around, you will be even more amazed. Skyscrapers and

TWO KINDS OF IRON COMPOUNDS

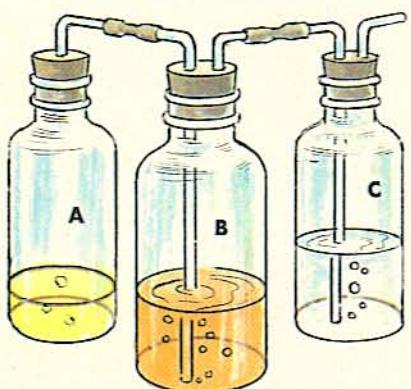
IRON FORMS TWO KINDS OF COMPOUNDS. IN FERROUS SALTS, EACH IRON ATOM HAS REPLACED TWO HYDROGEN ATOMS. IN FERRIC SALTS, EACH IRON ATOM HAS REPLACED THREE HYDROGEN ATOMS. GREEN FERROUS SALTS EASILY OXIDIZE INTO RED-BROWN FERRIC SALTS.

RUSTING OF IRON

MOISTEN A WAD OF FINE STEEL WOOL WITH VINEGAR (TO SPEED UP ACTION). WEDGE IT IN BOTTOM OF A GLASS. INVERT GLASS IN PIE PLATE OF WATER. IN A FEW DAYS, WATER HAS RISEN IN GLASS. IRON HAS REACTED WITH OXYGEN AND MOISTURE TO FORM RUST— $(Fe_2O_3)_2 \cdot 3H_2O$.



MAKING A FERRIC SALT



SET UP APPARATUS FOR MAKING CHLORINE (SEE PAGE 35). INTO BOTTLE B POUR FERROUS CHLORIDE SOLUTION YOU HAVE JUST MADE. THE CHLORINE TURNS THE GREEN FERROUS CHLORIDE ($FeCl_2$) INTO A BROWN FERRIC CHLORIDE ($FeCl_3$).

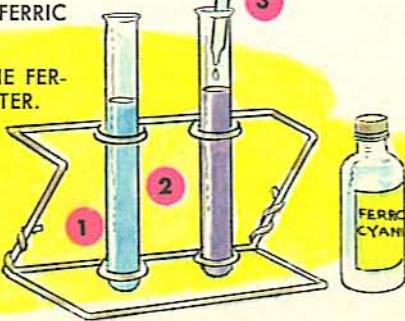
MAKING A FERROUS SALT

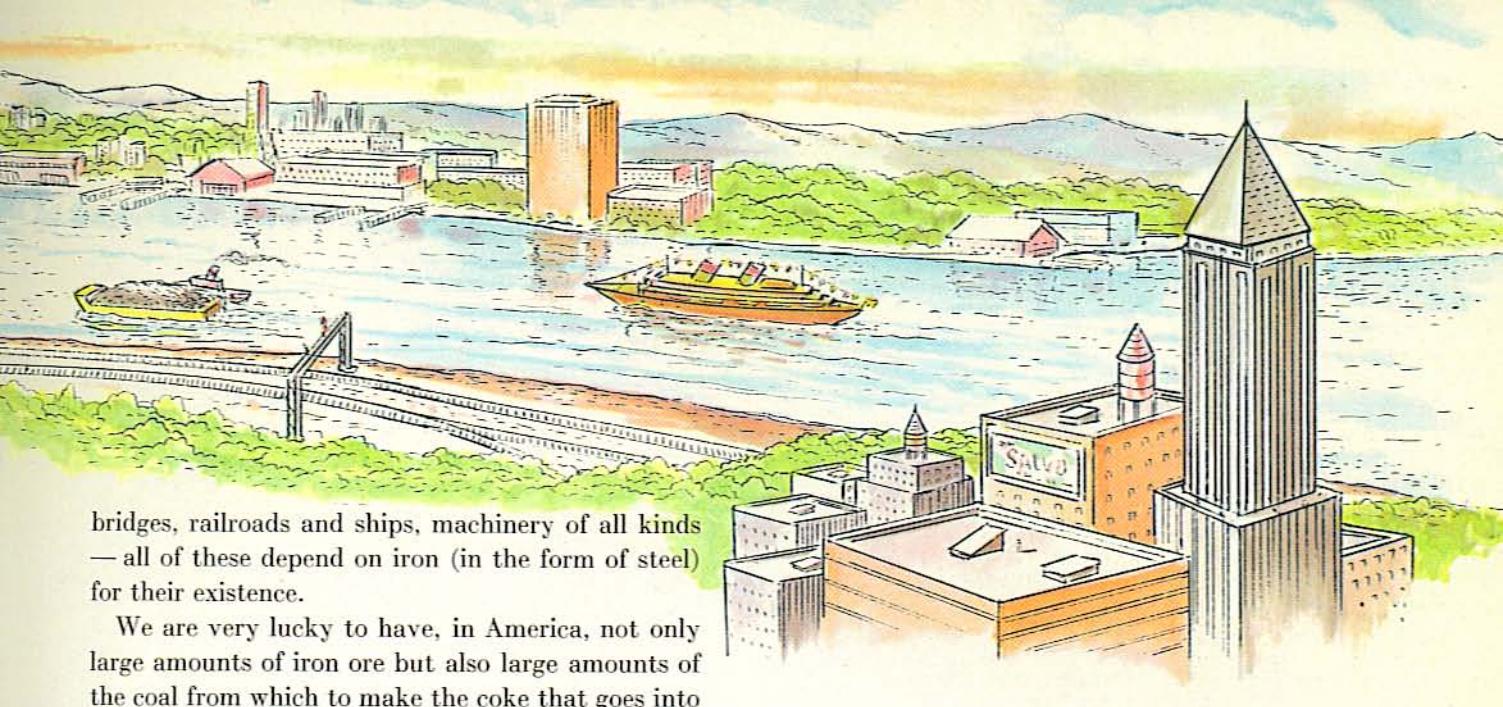
- 1 POUR HYDROCHLORIC ACID OVER STEEL WOOL. HYDROGEN IS SET FREE AS STEEL WOOL DISSOLVES. FILTER THE SOLUTION.
- 2 LIGHT-GREEN FILTRATE CONTAINS FERROUS CHLORIDE ($FeCl_2$).



TEST FOR IRON SALTS

- 1 IN ONE TEST TUBE, DILUTE SOME FERRIC CHLORIDE SOLUTION WITH WATER.
- 2 IN ANOTHER, DILUTE SOME OF THE FERROUS CHLORIDE SOLUTION WITH WATER.
- 3 TO EACH, ADD A FEW DROPS OF SOLUTION OF $\frac{1}{4}$ TEASPOON POTASSIUM FERROCYANIDE IN 50 mL WATER. FERRIC SALT MAKES A DEEP BLUE PRECIPITATE OF PRUSSIAN BLUE. FERROUS SALT MAKES LIGHT BLUE PRECIPITATE.

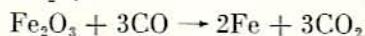
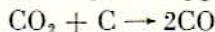
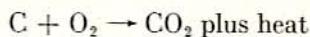




bridges, railroads and ships, machinery of all kinds — all of these depend on iron (in the form of steel) for their existence.

We are very lucky to have, in America, not only large amounts of iron ore but also large amounts of the coal from which to make the coke that goes into iron production.

The iron is driven out of its ore (mostly Fe_2O_3) in huge furnaces. Each furnace can make as much as 1,000 tons of iron at one time from 2,000 tons of ore, 1,000 tons of coke, and 500 tons of limestone. A blast of hot air is forced through the mixture. The coke burns with great heat to carbon dioxide. This, with more coke, forms carbon monoxide, and this, in turn, reduces the iron oxide to metallic iron. In chemical language, this is what happens:

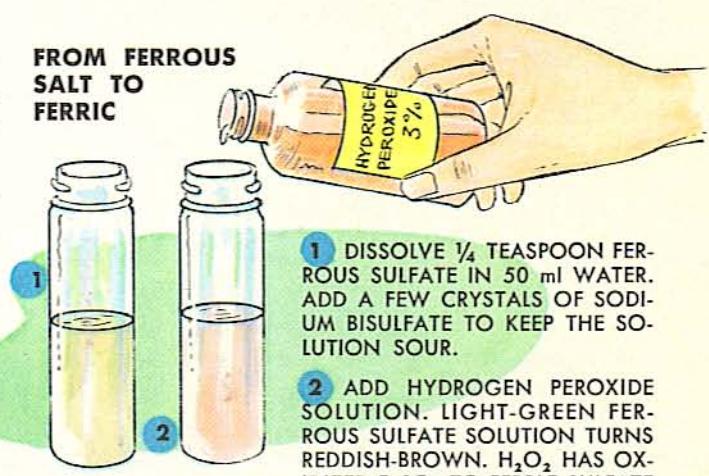


At the same time, the limestone combines with various impurities to form a glass-like compound called "slag." This is removed when the white-hot iron is poured out into moulds and cooled into bars of "pig iron."

The pig iron is brittle because it contains close to 5 per cent carbon. To turn it into steel, the carbon must be burned out until only from .5 to 1.5 per cent remains. This is done either by the Bessemer process (named for an Englishman, Henry Bessemer) or by the open-hearth process. The finished steel is molded into "ingots" and shipped to manufacturing plants all over the country.

In chemical experiments, the most commonly used iron compound is the iron sulfate (ferrous sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) — also called "green vitriol" and "copperas." Don't let the last name mislead you — it has nothing to do with copper but comes from an old French word, *couverose*.

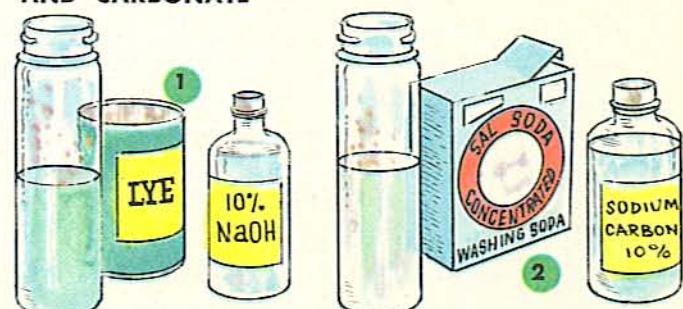
FROM FERROUS SALT TO FERRIC



1 DISSOLVE $\frac{1}{4}$ TEASPOON FERROUS SULFATE IN 50 ml WATER. ADD A FEW CRYSTALS OF SODIUM BISULFATE TO KEEP THE SOLUTION SOUR.

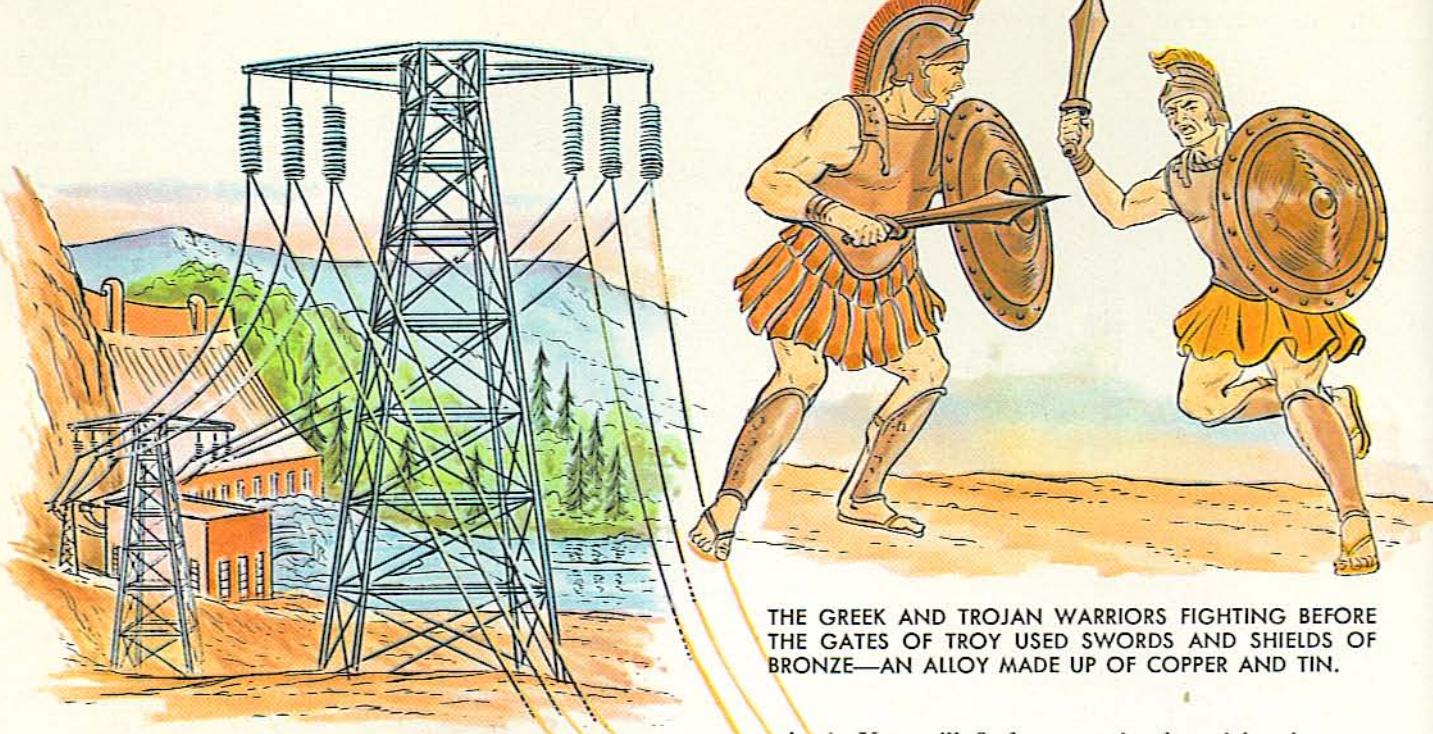
2 ADD HYDROGEN PEROXIDE SOLUTION. LIGHT-GREEN FERROUS SULFATE SOLUTION TURNS REDDISH-BROWN. H_2O_2 HAS OXIDIZED FeSO_4 TO FERRIC SULFATE ($\text{Fe}_2(\text{SO}_4)_3$).

IRON HYDROXIDES AND CARBONATE



1 TO SOLUTION OF $\frac{1}{4}$ TEASPOON FERROUS SULFATE IN 50 ml WATER, ADD SOLUTION OF SODIUM HYDROXIDE. PURE FERROUS HYDROXIDE IS WHITE, BECAUSE OF IMPURITIES, YOU GET DIRTY-GREEN PRECIPITATE OF $\text{Fe}(\text{OH})_2$, SOON OXIDIZING TO BROWN FERRIC HYDROXIDE.

2 TO ANOTHER PORTION OF FERROUS SULFATE SOLUTION ADD SODIUM CARBONATE SOLUTION. PURE CARBONATE MADE WITH NO OXYGEN PRESENT IS WHITE — BUT YOU GET MUDDY, WHITISH-GREEN PRECIPITATE OF FERROUS CARBONATE, EVENTUALLY TURNING INTO FERRIC HYDROXIDE.



THE GREEK AND TROJAN WARRIORS FIGHTING BEFORE THE GATES OF TROY USED SWORDS AND SHIELDS OF BRONZE—AN ALLOY MADE UP OF COPPER AND TIN.

Copper—Yesterday, Today

COPPER IS ONE of the few metals found free in nature. That is why it was used long before historic times for weapons and utensils. The main trouble with it was its softness. This was remedied when some early coppersmith discovered that copper and tin (also found free in nature) melted together formed an alloy that was much harder than either of the two metals. This alloy gave its name to more than two thousand years of human history — the period called the "Bronze Age."

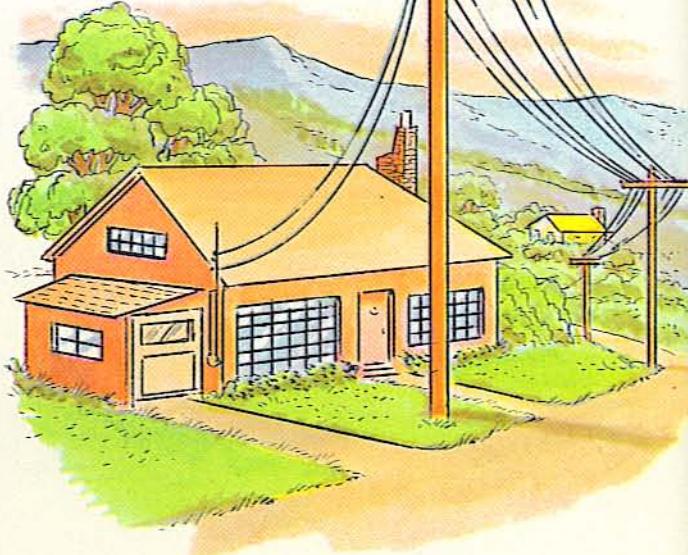
A great number of weapons from the Bronze Age have been found in Greece. When they were dug out of the ground, they were covered with a green "rust." This deposit was called verdigris — literally "green of Greece" (from old French, *vert de Grèce*). It consists of basic cupric carbonate — the same compound you will see on a bronze statue or a copper-clad church spire exposed to wind and weather.

Copper became especially valuable less than a hundred years ago when a satisfactory method for producing a steady flow of electricity was invented. After silver, copper is the best conductor of electricity. Today, the most important use for copper is for electrical purposes. It serves to bring the current from the place where it is produced to the place where it is to be used (although, within recent years, some aluminum has taken its place for high-tension

wires). You will find copper in the wiring in your own home and in every electrical gadget you use.

Copper makes two kinds of salts. In cuprous salts, one copper atom has taken the place of one hydrogen atom; in cupric salts, one copper atom has taken the place of two hydrogen atoms. Cuprous salts (such as cuprous chloride, CuCl) are colorless, while cupric salts (such as cupric sulfate, CuSO₄•5H₂O) are bright blue in color.

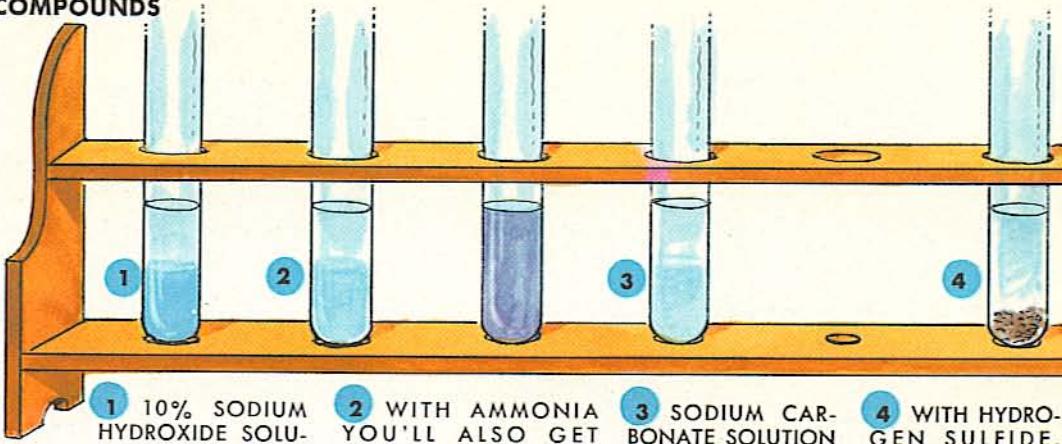
MOST IMPORTANT USE OF COPPER TODAY IS FOR ELECTRIC WIRING.



MAKING COPPER COMPOUNDS



DISSOLVE 10 g COPPER SULFATE IN 100 ml WATER. POUR 10 ml INTO EACH OF FOUR TEST TUBES.



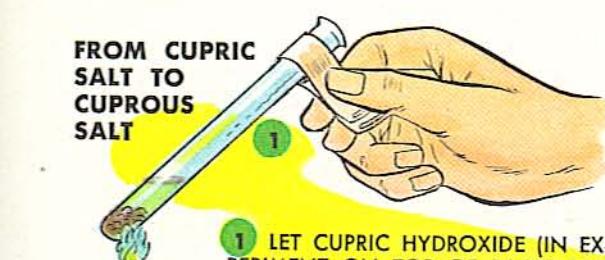
1 10% SODIUM HYDROXIDE SOLUTION PRECIPITATES DIRTY-BLUE CUPRIC HYDROXIDE (Cu(OH)_2).

2 WITH AMMONIA YOU'LL ALSO GET Cu(OH)_2 , BUT THIS DISSOLVES IN MORE AMMONIA WITH DEEP BLUE COLOR.

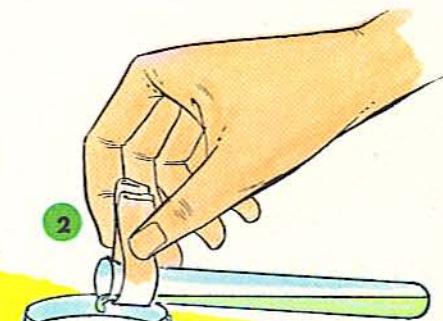
3 SODIUM CARBONATE SOLUTION GIVES BLUE-GREEN CUPRIC CARBONATE PRECIPITATE.

4 WITH HYDROGEN SULFIDE, BROWNISH-BLACK PRECIPITATE OF CUPRIC SULFIDE.

FROM CUPRIC SALT TO CUPROUS SALT



1 LET CUPRIC HYDROXIDE (IN EXPERIMENT ON TOP OF PAGE) SETTLE. THEN POUR OFF LIQUID. ADD HYDROCHLORIC ACID UNTIL ALL IS DISSOLVED. ADD SMALL PIECES OF COPPER WIRE. HEAT TO BOILING.



2 POUR A FEW DROPS OF THE HOT SOLUTION INTO A LARGE AMOUNT OF WATER. YOU GET A WHITE PRECIPITATE. WHEN YOU DISSOLVED CUPRIC HYDROXIDE IN HCl, YOU MADE CUPRIC CHLORIDE WHICH IS SOLUBLE IN WATER. BY TREATING THIS WITH METALLIC COPPER, YOU GOT CUPROUS CHLORIDE, INSOLUBLE IN WATER.

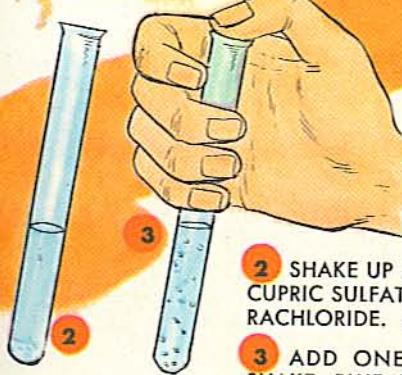
CU COPPER
Element 29.
Atomic wt.: 63.54. Density: 8.97. Soft metal of reddish color. Easily rolled and drawn into wire. Next to silver, is the best conductor of electricity.

COPPER SULFATE IN CHEMICAL ANALYSIS

WATERFREE (ANHYDROUS) CUPRIC SULFATE SHOWS IF WATER IS PRESENT IN A LIQUID BEING TESTED.



1 CRUSH A FEW CUPRIC SULFATE CRYSTALS. HEAT WHILE STIRRING UNTIL THEY HAVE TURNED INTO A WHITE POWDER.



2 SHAKE UP A LITTLE ANHYDROUS CUPRIC SULFATE WITH CARBON TETRACHLORIDE. NOTHING HAPPENS.

3 ADD ONE DROP OF WATER. SHAKE. BLUE CRYSTALS FORM.

REPLACING COPPER WITH IRON



1 DROP SEVERAL CLEAN NAILS INTO A SOLUTION OF COPPER SULFATE. LEAVE FOR HALF AN HOUR.

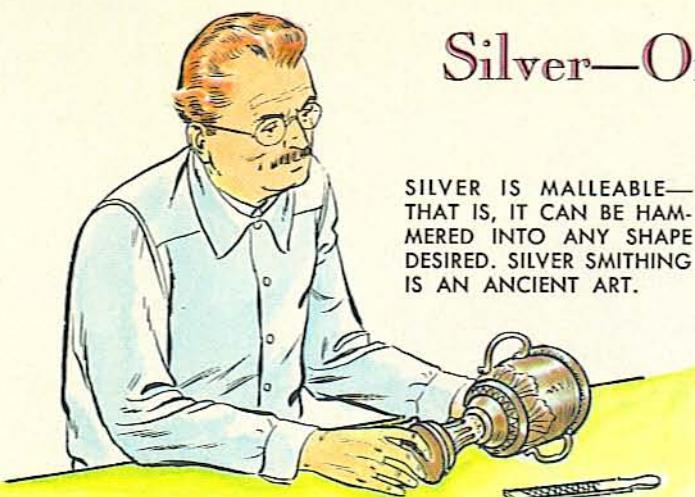
2 NAILS ARE NOW COATED WITH METALLIC COPPER AND THE SOLUTION CONTAINS FERROUS SULFATE.

METALS CAN BE ARRANGED IN A REPLACEMENT SERIES. ANY METAL IN THE SERIES WILL DRIVE OUT ANOTHER METAL BELOW IT AND TAKE ITS PLACE IN THE SALT.

REPLACEMENT SERIES

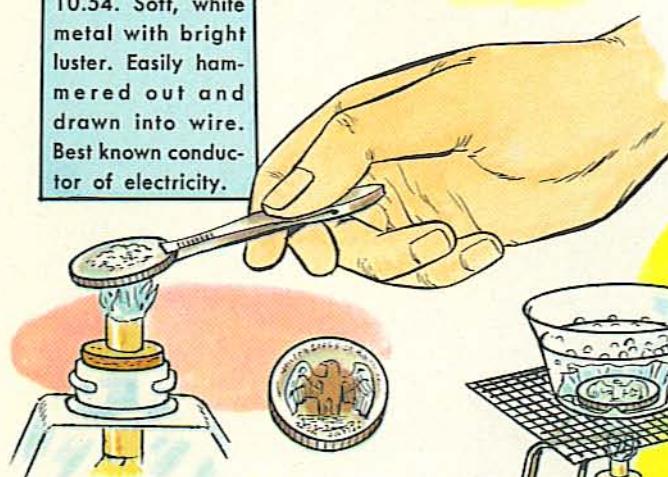
POTASSIUM
SODIUM
CALCIUM
MAGNESIUM
ALUMINUM
ZINC
CHROMIUM
IRON
NICKEL
TIN
LEAD
COPPER
MERCURY
SILVER
PLATINUM
GOLD

Silver—One of the “Noble” Metals



SILVER IS MALLEABLE—THAT IS, IT CAN BE HAMMERED INTO ANY SHAPE DESIRED. SILVER SMITHING IS AN ANCIENT ART.

Ag	SILVER
Element 47.	
Atomic wt.:	
107.880. Density:	
10.54. Soft, white metal with bright luster. Easily hammered out and drawn into wire. Best known conductor of electricity.	



TARNISHED SILVER

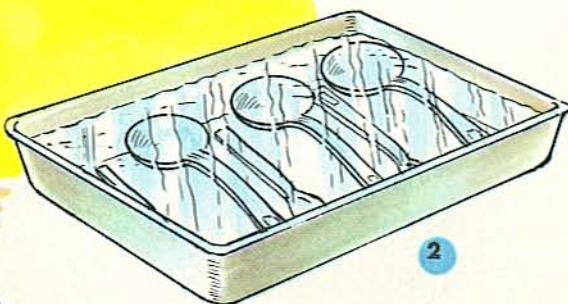
SILVER TARNISHES WHEN IT IS EXPOSED TO SULFUR. PLACE A FEW CRYSTALS OF SODIUM THIOSULFATE ("HYPO") ON A SILVER COIN. HEAT UNTIL HYPO MELTS. WASH. HYPO HAS LEFT STAIN OF BROWN-BLACK SILVER SULFIDE.



REMOVING TARNISH FROM SILVER

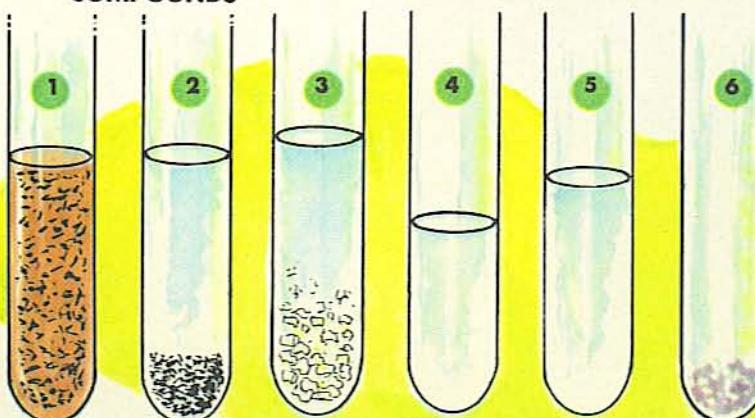
1 LINE BOTTOM OF CUSTARD CUP WITH ALUMINUM FOIL. PLACE TARNISHED COIN ON FOIL. POUR CUP HALF FULL OF WATER. ADD $\frac{1}{4}$ TEASPOON SODIUM CARBONATE. BOIL GENTLY. TARNISH VANISHES.

2 YOU CAN USE THIS METHOD FOR CLEANING SILVERWARE. PLACE SILVER TO BE CLEANED IN ALUMINUM TRAY. ADD WATER AND SODA. BRING TO A BOIL. THE SILVER BECOMES SHINY AGAIN.



SILVER COMPOUNDS

GET 5 g SILVER NITRATE IN YOUR LOCAL DRUG STORE. DISSOLVE IN 50 ml WATER.



1 TO 5 ml SILVER NITRATE (AgNO_3) SOLUTION, ADD SODIUM HYDROXIDE SOLUTION. YOU GET DARK-BROWN PRECIPITATE—NOT OF HYDROXIDE, BUT OF SILVER OXIDE.

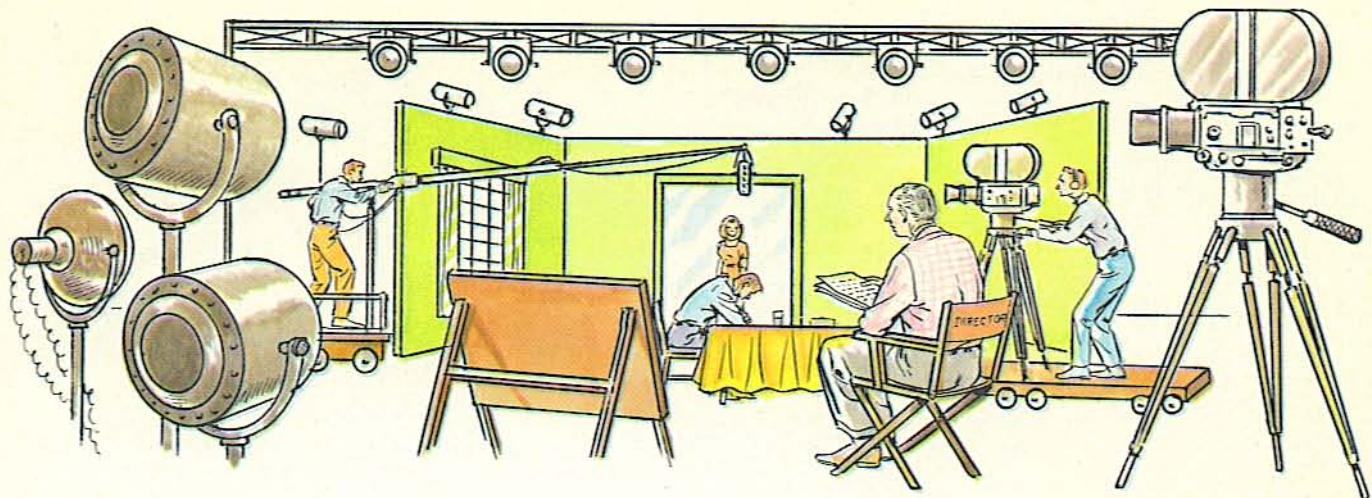
2 TO 5 ml AgNO_3 SOLUTION, ADD AMMONIA. PRECIPITATE OF SILVER OXIDE DISSOLVES WHEN YOU ADD MORE AMMONIA.

3 TO 5 ml AgNO_3 SOLUTION, ADD TABLE SALT (NaCl) SOLUTION. CHEESELIKE PRECIPITATE IS SILVER CHLORIDE (AgCl).

4 TO PART OF AgCl PRECIPITATE, ADD AMMONIA. SILVER CHLORIDE DISSOLVES.

5 TO ANOTHER PART OF AgCl , ADD SODIUM THIOSULFATE SOLUTION. AgCl DISSOLVES.

6 PLACE REMAINING AgCl IN THE SUN. IT TURNS VIOLET FROM METALLIC SILVER.



In making a photographic film, the manufacturer spreads an emulsion of gelatin that contains silver bromide (AgBr) over a transparent sheet of cellulose acetate. When the silver bromide is exposed to light, a certain amount of it gives up metallic silver ($\text{AgBr} \rightarrow \text{Ag} + \text{Br}$). More of this silver is brought out in the developing bath. When fully developed, the film is placed in a fixing bath which removes all unexposed silver bromide. After washing and drying, you have a photographic negative in which the white parts you photographed appear black and the black parts appear white.

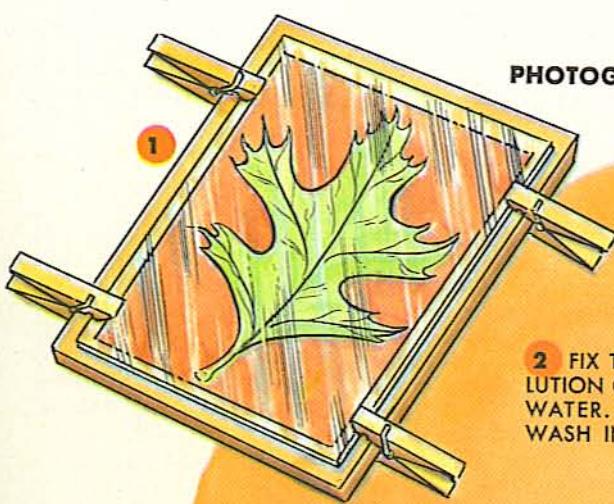
To make a natural-looking picture, you place the negative on a piece of photographic paper and go through a similar procedure, as above, of exposing, developing, fixing, washing, and drying.

MORE THAN 150 TONS OF SILVER ARE USED EACH YEAR IN MAKING FILM FOR THE MOVIES.

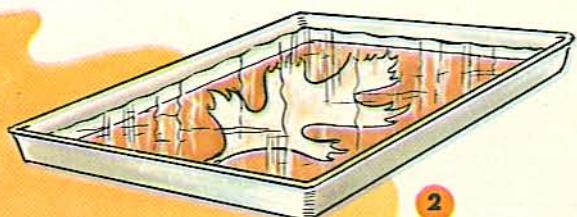


PHOTOGRAPHY INVOLVES A WHOLE SERIES OF CHEMICAL PROCESSES.

PHOTOGRAPHING WITHOUT A CAMERA



1. FROM A COMMERCIAL PHOTOGRAPHER, GET A FEW SHEETS OF "PRINTING-OUT PAPER," A SLOW PHOTOGRAPHIC PAPER. IN THE SHADE, PLACE SHEET ON PIECE OF PLYWOOD, SENSITIZED SIDE UP. ON TOP OF IT, LAY A LEAF AND A SHEET OF GLASS. HOLD IN POSITION WITH SPRING CLOTHES PINS. EXPOSE TO SUN UNTIL PAPER IS BLACKISH-VIOLET.

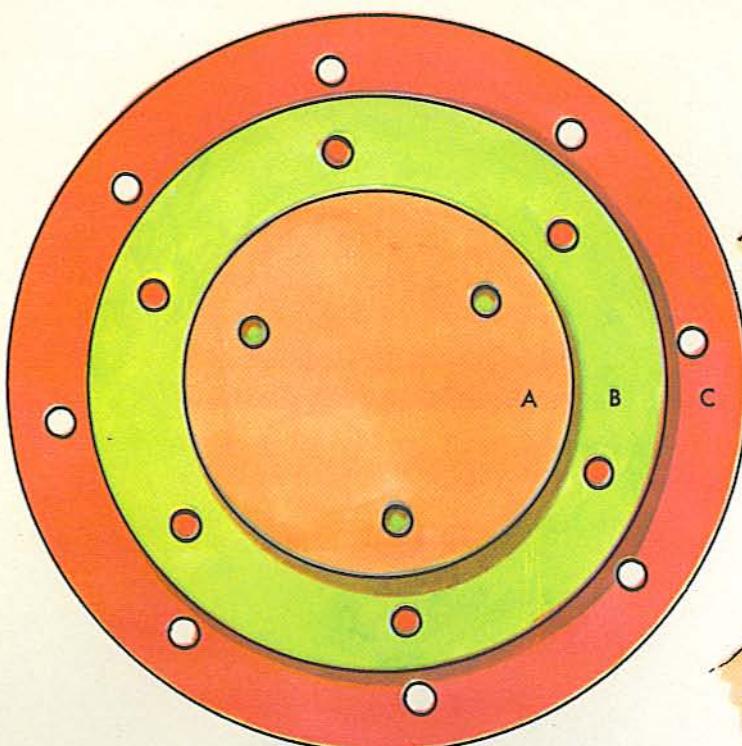


2. FIX THE LEAF PRINT IN A SOLUTION OF 10 g HYPO IN 100 ml WATER. AFTER FIVE MINUTES,

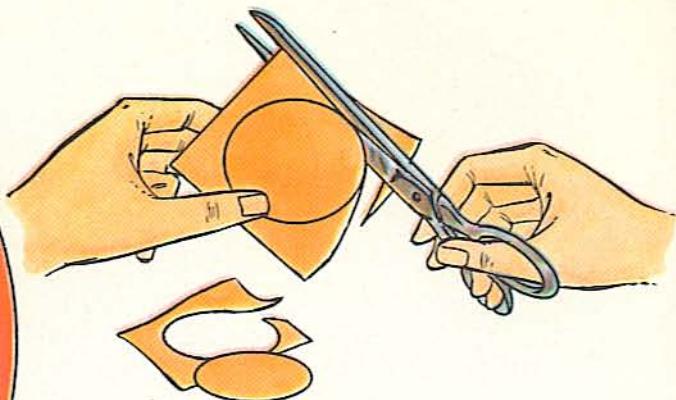
WASH IN RUNNING WATER.

3. DRY THE PRINT IN THE AIR ON TOP OF NEWSPAPER. WHEN DRY, FLATTEN PRINT IN A BOOK.

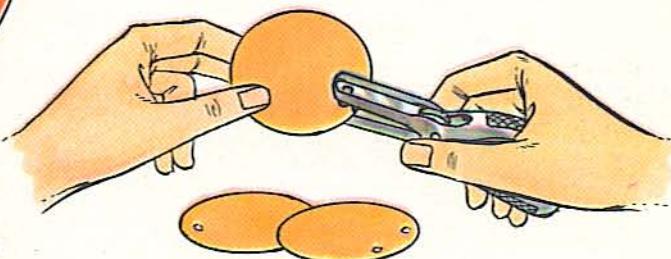




TRACE EACH OF THE CIRCLES SHOWN ABOVE ONTO CARDBOARD. PUNCH HOLES AS INDICATED. USE AS PATTERNS FOR CUTTING CIRCLES OF CONSTRUCTION BOARD.



USING PATTERNS AT LEFT, CUT OUT SEVERAL CIRCLES OF CONSTRUCTION BOARD IN VARIOUS COLORS.



PUNCH THE HOLES NECESSARY TO INDICATE VALENCES.

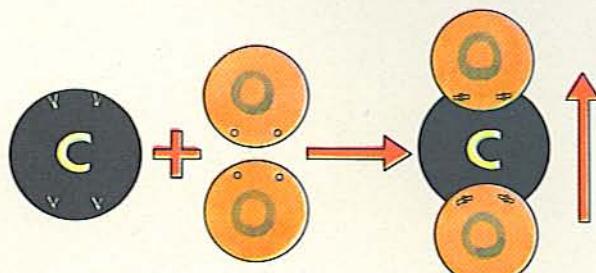
Valences and Formulas

AS YOU HAVE studied the chemical formulas in the text, you will have noticed that one atom of hydrogen combines with one atom of chlorine (HCl), two hydrogen atoms with one atom of oxygen (H_2O), and three hydrogen atoms with one atom of nitrogen (NH_3).

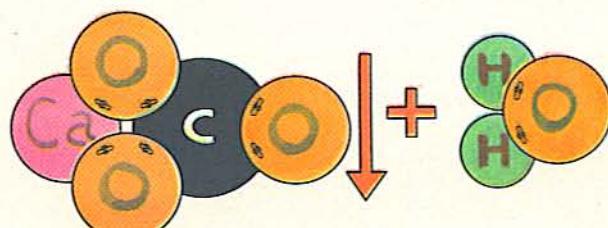
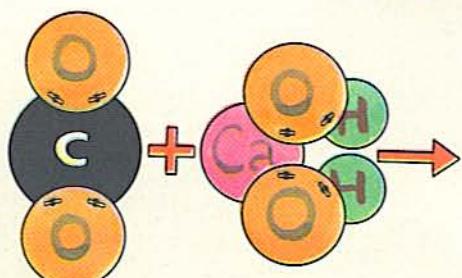
The capacity of one atom to hold on to other atoms is called its valence (from Latin *valentia*, strength).

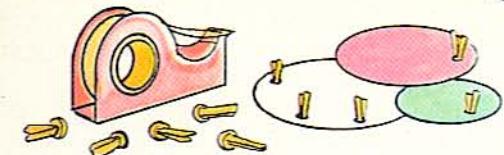
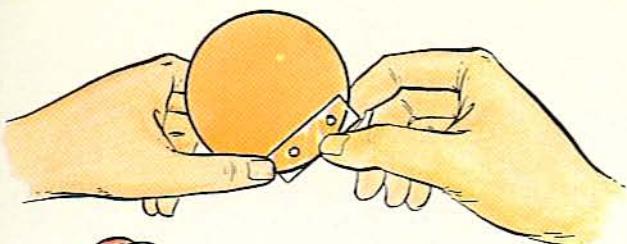
No atom has a lower valence than the hydrogen atom, so we use hydrogen as our starting point and give it a valence of 1. Two hydrogen atoms combine with one oxygen atom — that gives oxygen a valence of 2. Nitrogen has a valence of 3. Two oxygen atoms combine with one carbon atom to make CO_2 . Carbon has a valence of 4.

The chart on page 75 shows some of the common

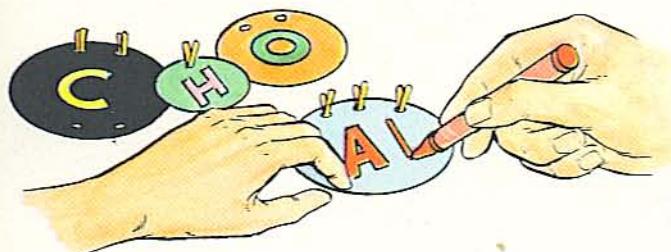


THESE DIAGRAMS SHOW WHAT HAPPENS WHEN YOU BURN CARBON AND TEST FOR CO_2 . ONE CARBON ATOM (WITH FOUR POSITIVE VALENCES) COMBINES WITH TWO ATOMS OF OXYGEN (EACH WITH TWO NEGATIVE VALENCES) TO FORM ONE MOLECULE OF CO_2 (ARROW POINTING UP INDICATES THAT THIS IS A GAS). ONE MOLECULE CARBON DIOXIDE COMBINES WITH ONE MOLECULE CALCIUM HYDROXIDE TO FORM ONE MOLECULE OF CALCIUM CARBONATE (ARROW POINTING DOWN INDICATES THAT IT IS A PRECIPITATE) AND ONE MOLECULE OF WATER.





PUT $\frac{1}{4}$ " BRASS CLIPS IN HOLES SHOWING POSITIVE VALENCES. HOLD THEM IN PLACE WITH SCOTCH TAPE.



WRITE THE NAMES OF THE ELEMENTS WITH CRAYONS.

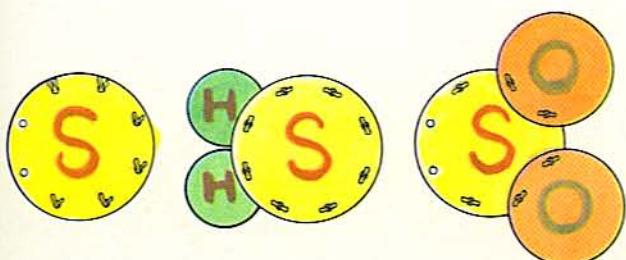
valences for making up formulas. Most of the items are elements, but some of them are "radicals"—that is, groups of atoms that hang together in chemical reactions, such as the ammonium radical (NH_4^+) that behaves as a metal, and the sulfate radical (SO_4^{2-}) that goes into the making of salts.

Notice that some valences have plus (+) signs, others have minus (—) signs. When you make up the formula for a compound, there must be the same number of pluses and minuses. Hydrogen with one

SOME COMMON VALENCES					
Positive Valences			Negative Valences		
Item	Valence	Circle	Item	Valence	Circle
Ag	+ 1	A	Cl	- 1	A
Al	+ 3	C	I	- 1	A
B	+ 3	C	N	- 3	B
C	+ 4	C	O	- 2	B
Ca	+ 2	B	S	- 2	C
Cu	+ 1 + 2	B			
Fe	+ 2 + 3	B			
H	+ 1	A			
K	+ 1	A			
Mg	+ 2	B			
Mn	+ 2	B	CO_3	- 2	B
Na	+ 1	A	NO_3	- 1	A
S	+ 4 + 6	C	OH	- 1	A
Si	+ 4	C	SO_3	- 2	B
NH_4	+ 1	A	SO_4	- 2	B

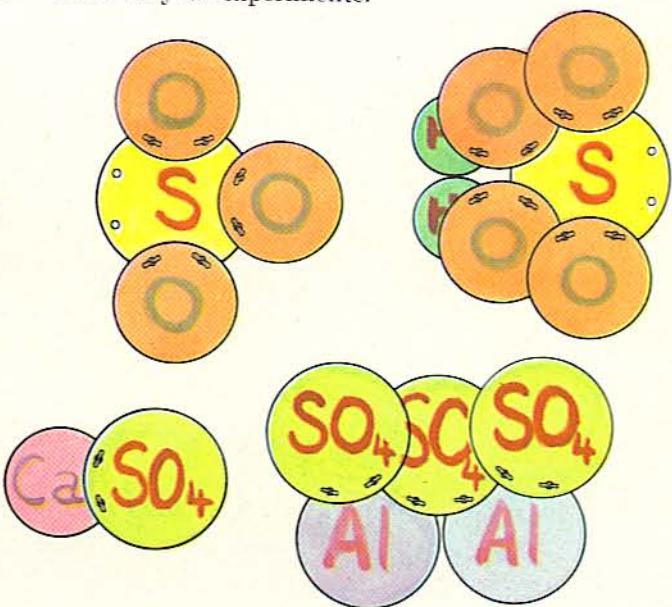
plus (H^+) and oxygen with two minuses (O^{--}) would not fit together—you need H_2 to combine with O. Similarly, C with + 4 (C^{++++}) takes two O, each with -2 (O^{--}), in order to balance.

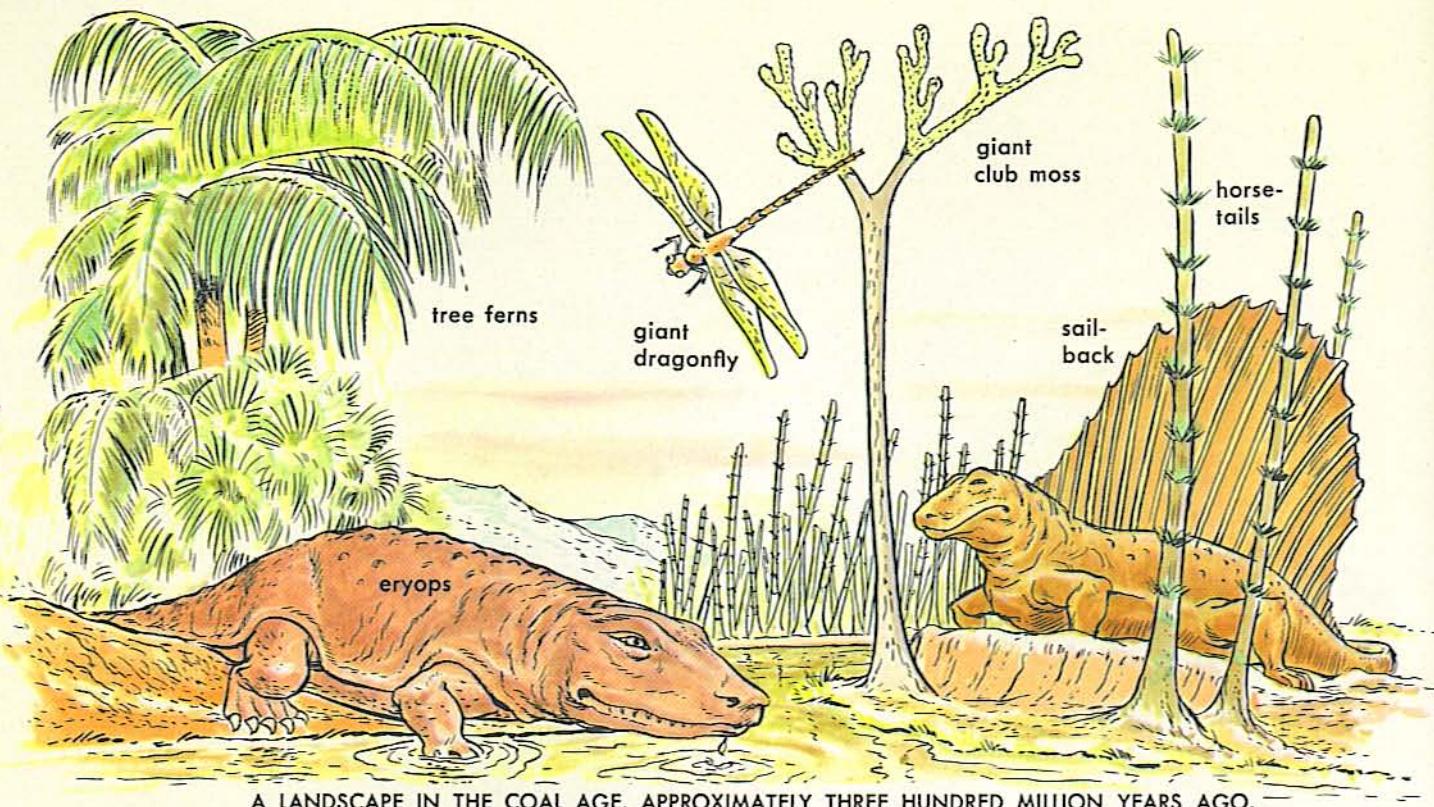
To get a clear understanding of chemical formulas, make yourself a set of atom models as shown on these pages. With these models you will be able to figure out how compounds are made up and what happens in the various chemical reactions you will cause in your experiments.



SULFUR HAS SEVERAL VALENCES. IT HAS A VALENCE OF -2 IN H_2S , OF $+4$ IN SO_2 , AND OF $+6$ IN SO_3 . IN MAKING THE CIRCLE FOR SULFUR, YOU CAN SHOW THESE VALENCES WITH TWO EMPTY HOLES AND SIX BRASS CLIPS.

INSTEAD OF USING ONE SULFUR CIRCLE AND FOUR OXYGEN CIRCLES TO INDICATE A SULFATE, YOU CAN MAKE UP A SINGLE CIRCLE TO STAND FOR THE SULFATE RADICAL (SO_4^{2-}) WITH TWO NEGATIVE VALENCES.





A LANDSCAPE IN THE COAL AGE, APPROXIMATELY THREE HUNDRED MILLION YEARS AGO.

Carbon—Element of a Million Compounds

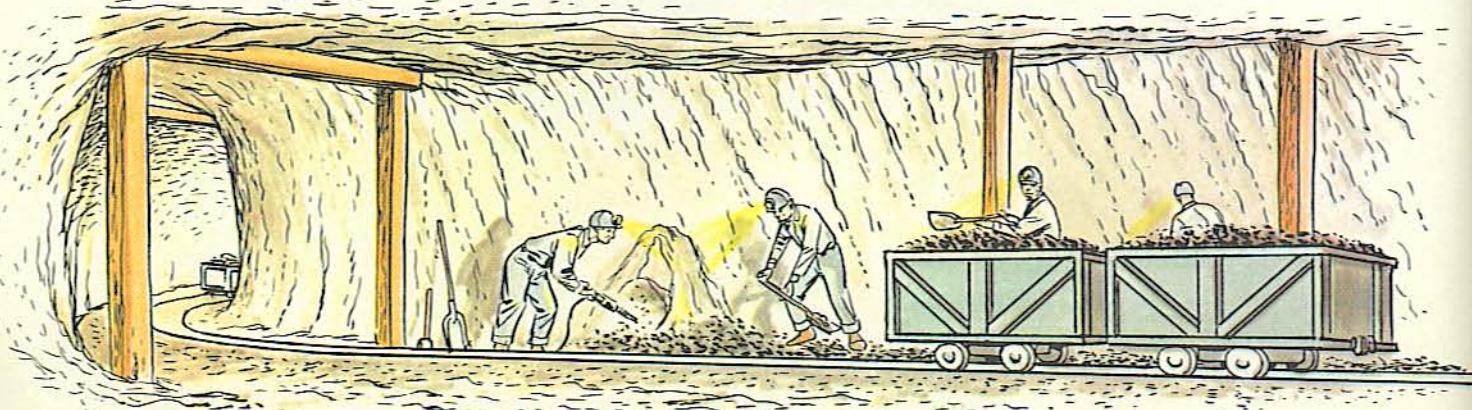
TO THE OLD ROMANS, *carbo* meant coal — a black rock that would burn. To the modern chemist, carbon is an element found in all living things — plants and animals — and in many dead things. It is hidden in the whitest sugar and the reddest rose and the greenest apple, in hundreds of thousands of compounds produced by nature and in many thousands more created in the laboratory.

The soot from a smoking candle is almost pure carbon. So is also the graphite that forms the "lead" of your pencil and the diamond in the jeweler's window. The coal that we use for fuel contains from 80

to 90 per cent carbon — the other 10 to 20 per cent is made up of various substances from which a great number of important and valuable chemical compounds are made.

All the coal we mine deep underground today is made up of the remains of plants that grew around three hundred million years ago — huge tree ferns, giant club mosses and horsetails. They thrived in the hot, humid climate, died and tumbled to the ground. During the ages they were covered by other dead trees and by layers upon layers of mud. Eventually, pressure and heat turned them into coal.

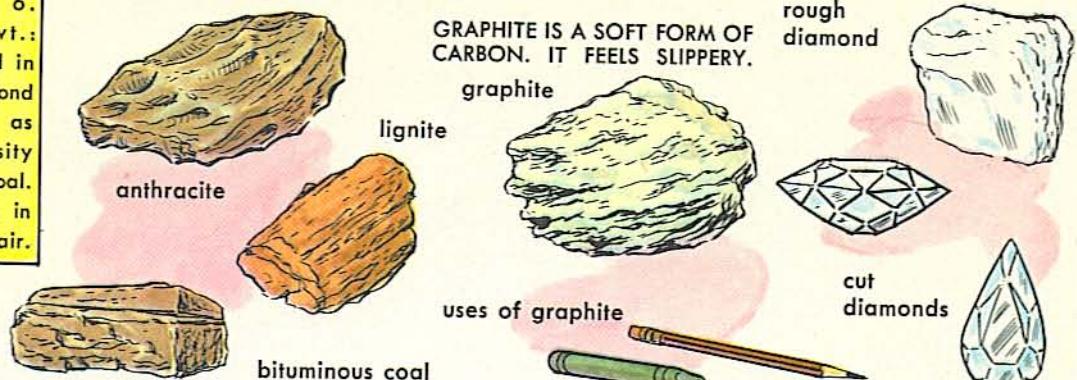
PRESSURE AND HEAT TURNED TREES AND OTHER PLANTS INTO THE COAL WE USE TODAY.



CARBON

Element 6.
Atomic wt.:
12.011. Found in
nature as diamond
(density 3.52), as
graphite (density
2.25), and as coal.
Diamond burns in
oxygen, coal in air.

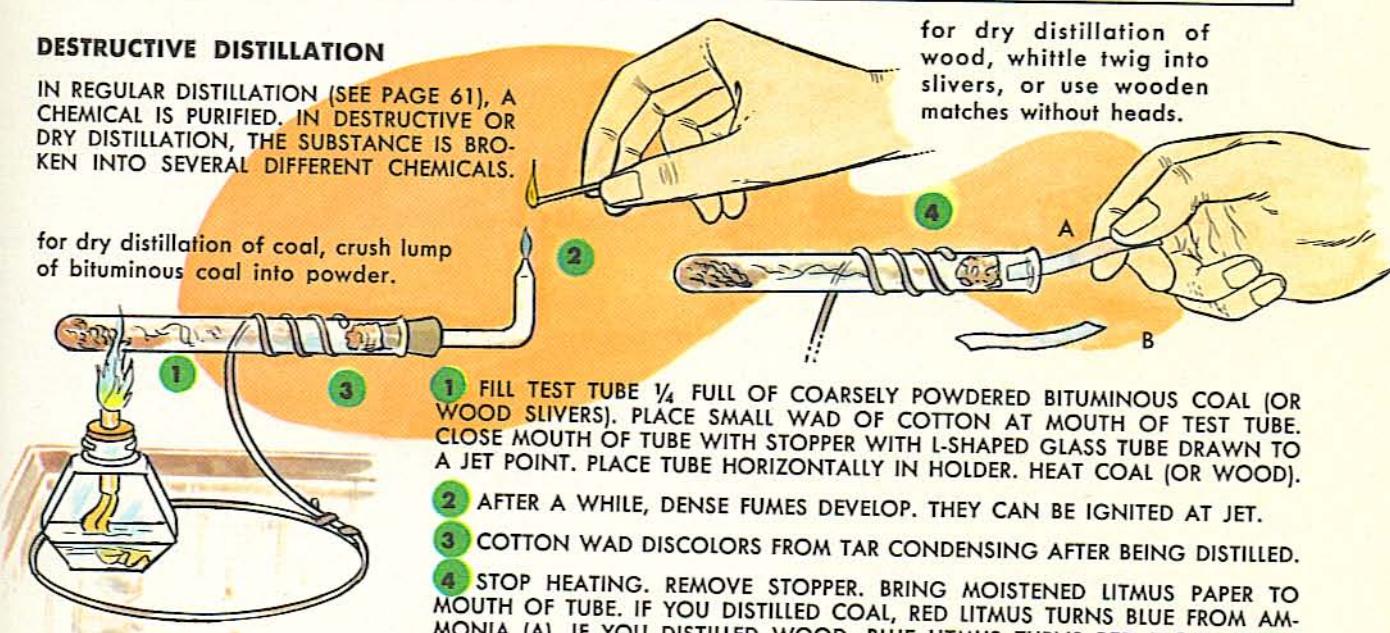
THREE FORMS OF CARBON



ANTHRACTITE IS ALSO CALLED HARD COAL. BITUMINOUS COAL IS SOFT COAL. LIGNITE IS BROWN COAL. GRAPHITE IS A SOFT FORM OF CARBON. IT FEELS SLIPPERY. DIAMOND IS THE HARDEST SUBSTANCE KNOWN.

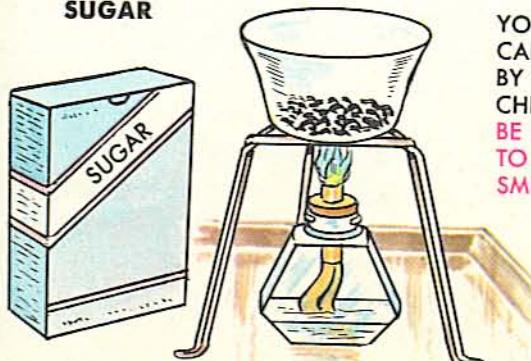
DESTRUCTIVE DISTILLATION

IN REGULAR DISTILLATION (SEE PAGE 61), A CHEMICAL IS PURIFIED. IN DESTRUCTIVE OR DRY DISTILLATION, THE SUBSTANCE IS BROKEN INTO SEVERAL DIFFERENT CHEMICALS.



- 1 FILL TEST TUBE $\frac{1}{4}$ FULL OF COARSELY POWDERED BITUMINOUS COAL (OR WOOD SLIVERS). PLACE SMALL WAD OF COTTON AT MOUTH OF TEST TUBE. CLOSE MOUTH OF TUBE WITH STOPPER WITH L-SHAPED GLASS TUBE DRAWN TO A JET POINT. PLACE TUBE HORIZONTALLY IN HOLDER. HEAT COAL (OR WOOD).
- 2 AFTER A WHILE, DENSE FUMES DEVELOP. THEY CAN BE IGNITED AT JET.
- 3 COTTON WAD DISCOLORS FROM TAR CONDENSING AFTER BEING DISTILLED.
- 4 STOP HEATING. REMOVE STOPPER. BRING MOISTENED LITMUS PAPER TO MOUTH OF TUBE. IF YOU DISTILLED COAL, RED LITMUS TURNS BLUE FROM AMMONIA (A). IF YOU DISTILLED WOOD, BLUE LITMUS TURNS RED FROM ACETIC ACID (B). COAL HAS TURNED TO COKE, WOOD HAS BECOME CHARCOAL.

CARBON IN SUGAR

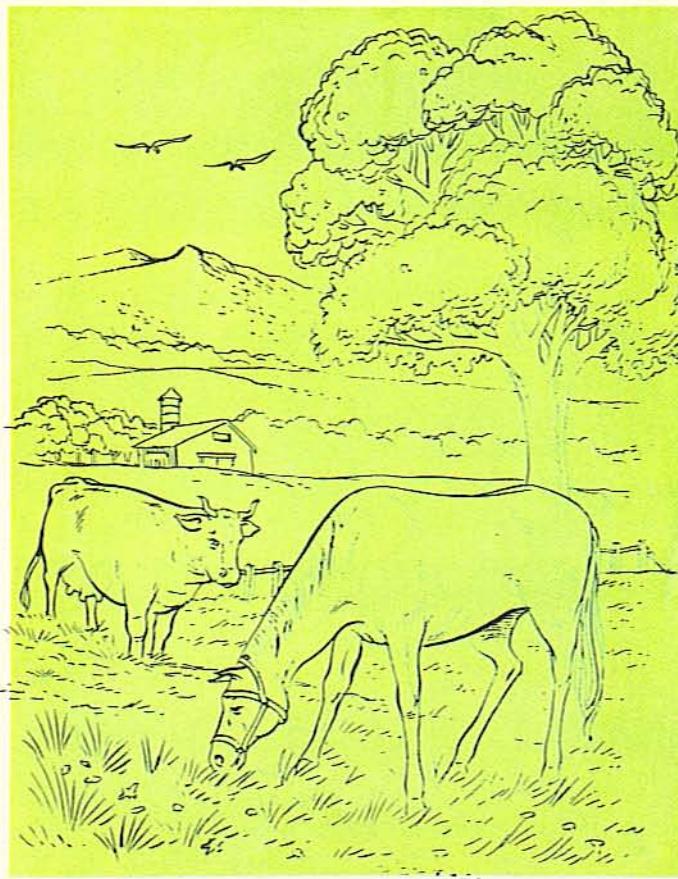


HEAT 1 TEASPOON CANE SUGAR IN A CUSTARD CUP. FIRST, SUGAR MELTS. THEN IT TURNS BROWN —IT "CARAMELIZES." NEXT IT GIVES OFF THICK VAPORS THAT CAN BE IGNITED. FINALLY, A PURE FORM OF COAL REMAINS.

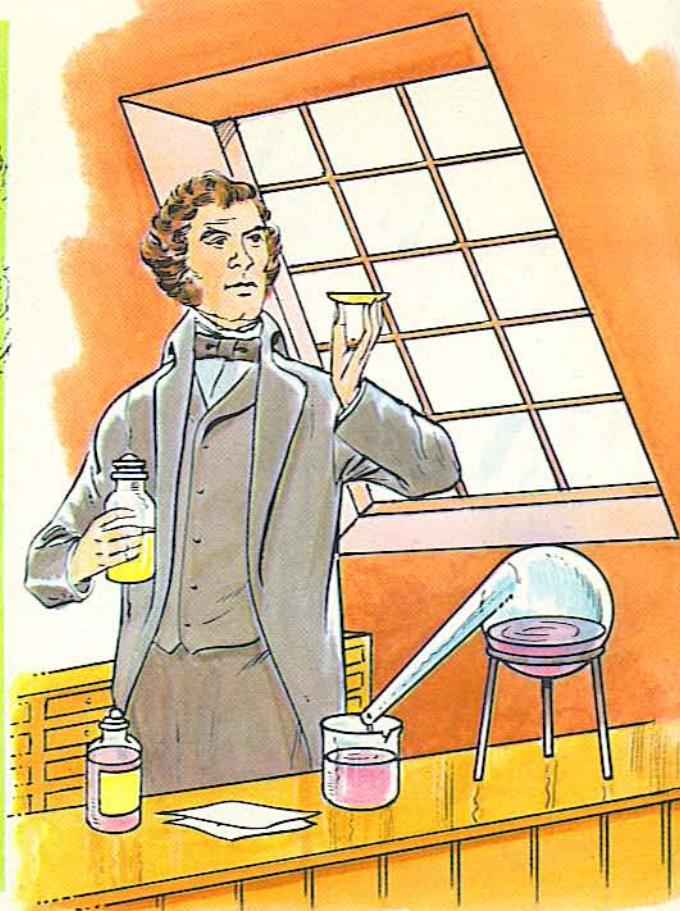
YOU CAN PROVE PRESENCE OF CARBON IN THE FOOD YOU EAT BY HEATING SMALL SAMPLES OF CHEESE, BREAD, MEAT, SUGAR. BE SURE TO DO THIS OUTDOORS TO PREVENT EXPERIMENTS FROM SMELLING UP THE WHOLE HOUSE.



RUB A LUMP OF SUGAR WITH CIGARETTE ASHES (TO ACT AS CATALYST). IGNITE. DIP TEST TUBE IN LIME WATER. HOLD OVER BURNING SUGAR. FILM OF CALCIUM CARBONATE SHOWS CO₂ IN FLAME—PROVING THAT THERE IS CARBON IN SUGAR.



IT WAS ONCE BELIEVED THAT ORGANIC COMPOUNDS COULD BE PRODUCED ONLY BY LIVING ORGANISMS.



IN 1828, FRIEDRICH WÖHLER SUCCEEDED IN MAKING AN ORGANIC COMPOUND ARTIFICIALLY IN HIS LABORATORY.

The Chemistry of Carbon Compounds

THE CHEMISTS of about two hundred years ago divided all compounds very neatly into two groups — organic and inorganic. The organic compounds were those produced by living organisms — that is, plants and animals. The inorganic compounds were made up of dead things — rocks and minerals, water and various gases. No organic compound, these chemists insisted, could ever be produced artificially — they required the force we call "life" for their creation. And then, in 1828, a German chemist, Friedrich Wohler, completely upset this idea.

In his laboratory, Wöhler had mixed ammonium sulfate ($(\text{NH}_4)_2\text{SO}_4$) and potassium cyanate (KCNO), expecting to get ammonium cyanate. After evaporating, he analyzed the compound he had made. To his amazement he discovered that it was not ammonium cyanate at all, but urea — a compound produced in the kidneys of living animals, including man. The atoms of the ammonium cyanate molecule had rearranged themselves into a urea molecule.

$\text{NH}_4 \text{CNO}$ had turned into $(\text{NH}_2)_2\text{CO}$.

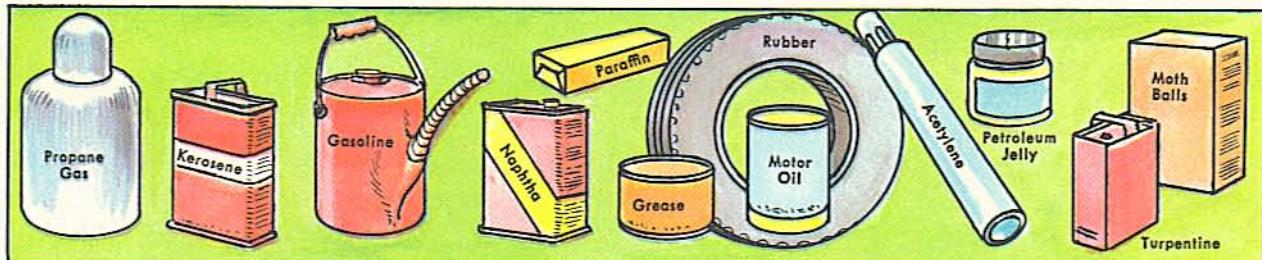
A few years later, another organic compound — acetic acid — was made artificially. And then the lid really blew off. More and more products of plant and animal life were put together — synthesized — in the laboratory. And as if this were not enough, chemists began producing organic compounds that were not even found in nature.

It became clear that the old meaning of organic chemistry no longer was right. And so, the definition was changed. Today, organic chemistry is defined as "the chemistry of the carbon compounds." This definition is almost, but not 100 per cent, correct. The metallic carbonates, for instance, are still considered to be inorganic compounds, and carbon dioxide and carbonic acid are regarded as being both organic and inorganic.

You may think it odd that a whole branch of chemistry should deal with the compounds of a single element. But you will not be surprised at all when you start experimenting with a few of the close to 1,000,000 carbon compounds.

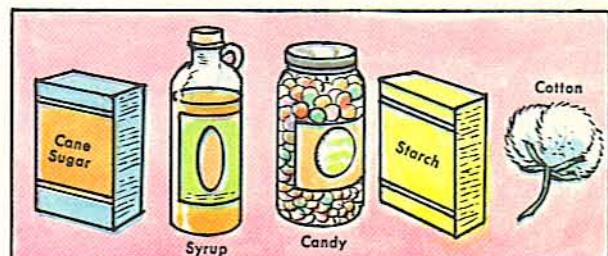
HYDROCARBONS CONTAIN TWO ELEMENTS ONLY: CARBON AND HYDROGEN. HYDROCARBONS WITH

FEW ATOMS TO THEIR MOLECULES ARE GASES. OTHERS WITH MANY ATOMS ARE LIQUIDS AND SOLIDS.



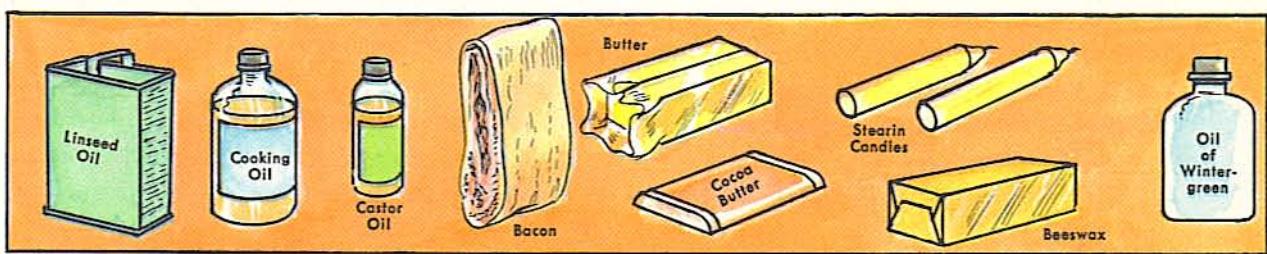
ALCOHOLS MAY BE CONSIDERED HYDROCARBONS IN WHICH A HYDROGEN ATOM IS REPLACED BY OH.

CARBOHYDRATES ARE IN MANY OF OUR MOST VALUABLE FOODSTUFFS AS STARCH AND SUGARS.



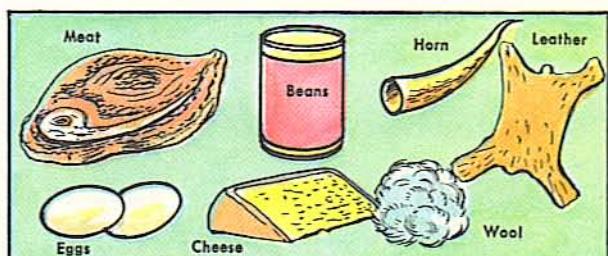
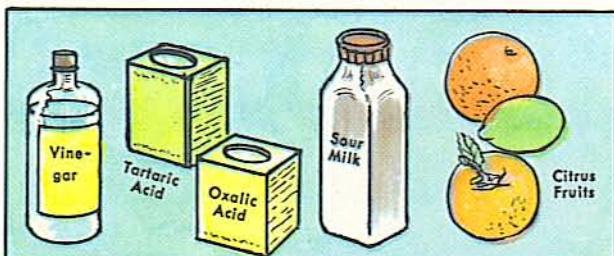
ESTERS IN ORGANIC CHEMISTRY CAN BE COMPARED TO SALTS IN INORGANIC CHEMISTRY. FATS AND OILS

ARE THE MOST IMPORTANT ESTERS. THESE ARE THE "SALTS" OF GLYCERINE AND FATTY ACIDS.



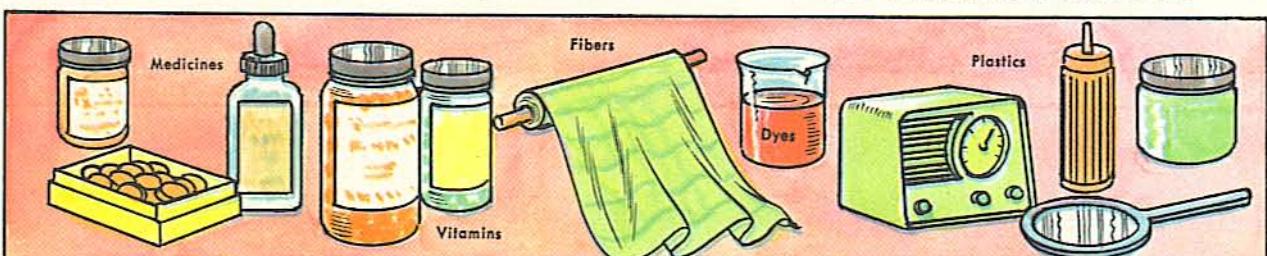
CARBOXYLIC ACIDS ARE NAMED FOR THE CARBOXYL GROUP—COOH—FOUND IN THEIR FORMULAS.

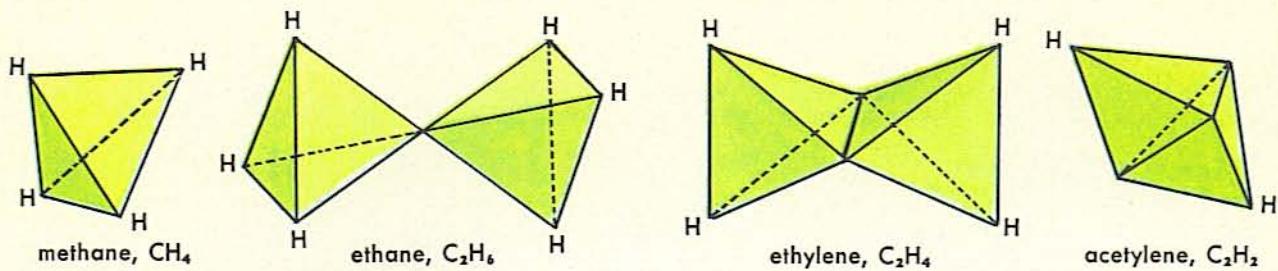
PROTEINS ARE COMPLEX COMPOUNDS THAT CONTAIN CARBON, HYDROGEN, OXYGEN, NITROGEN.



OTHER CARBON COMPOUNDS—IN ADDITION TO THE MAIN GROUPS ILLUSTRATED ABOVE, THERE ARE

NUMEROUS OTHER KINDS OF CARBON COMPOUNDS. MANY HAVE VERY COMPLICATED FORMULAS.





The Formulas of Carbon Compounds

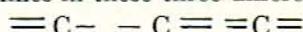
HOW IS IT POSSIBLE for carbon to make so many different compounds of such tremendous variety? That was one of the great questions facing chemists during the last century.

It was easy enough to explain carbon dioxide. Carbon has a valence of 4, oxygen of 2 — the formula had to be CO_2 . It was also easy to explain the molecule of the simple hydrocarbon methane (CH_4). But how explain compounds consisting of two atoms of carbon and six of hydrogen (C_2H_6 , ethane), or two atoms of carbon and four of hydrogen (C_2H_4 , ethylene), or two of carbon and only two of hydrogen (C_2H_2 , acetylene)?

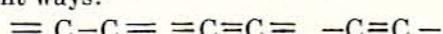
A German chemist and professor, Friedrich August Kekulé, came up with the solution. The answer was quite simple:

While the atoms of most elements "hook on" to the atoms of other elements according to their valences, the atoms of carbon "hook on" to each other as well. To understand this, write out carbon atoms

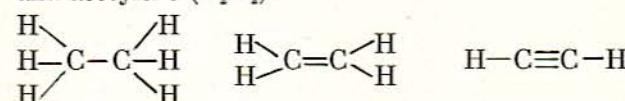
with four lines to indicate the valence bonds, but arrange the lines in these three different ways:



Then hook them together, two by two, in these three different ways:

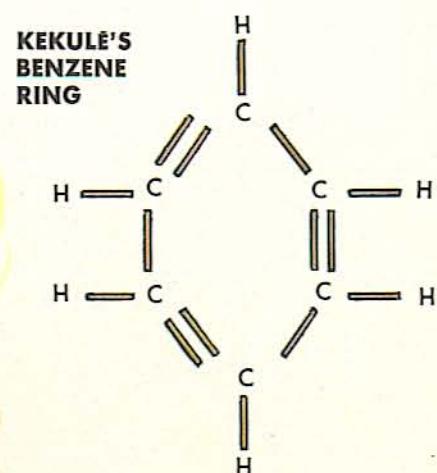


Now add a hydrogen atom to each of the free bonds — and there you have the formulas for the three hydrocarbons — ethane (C_2H_6), ethylene (C_2H_4), and acetylene (C_2H_2):

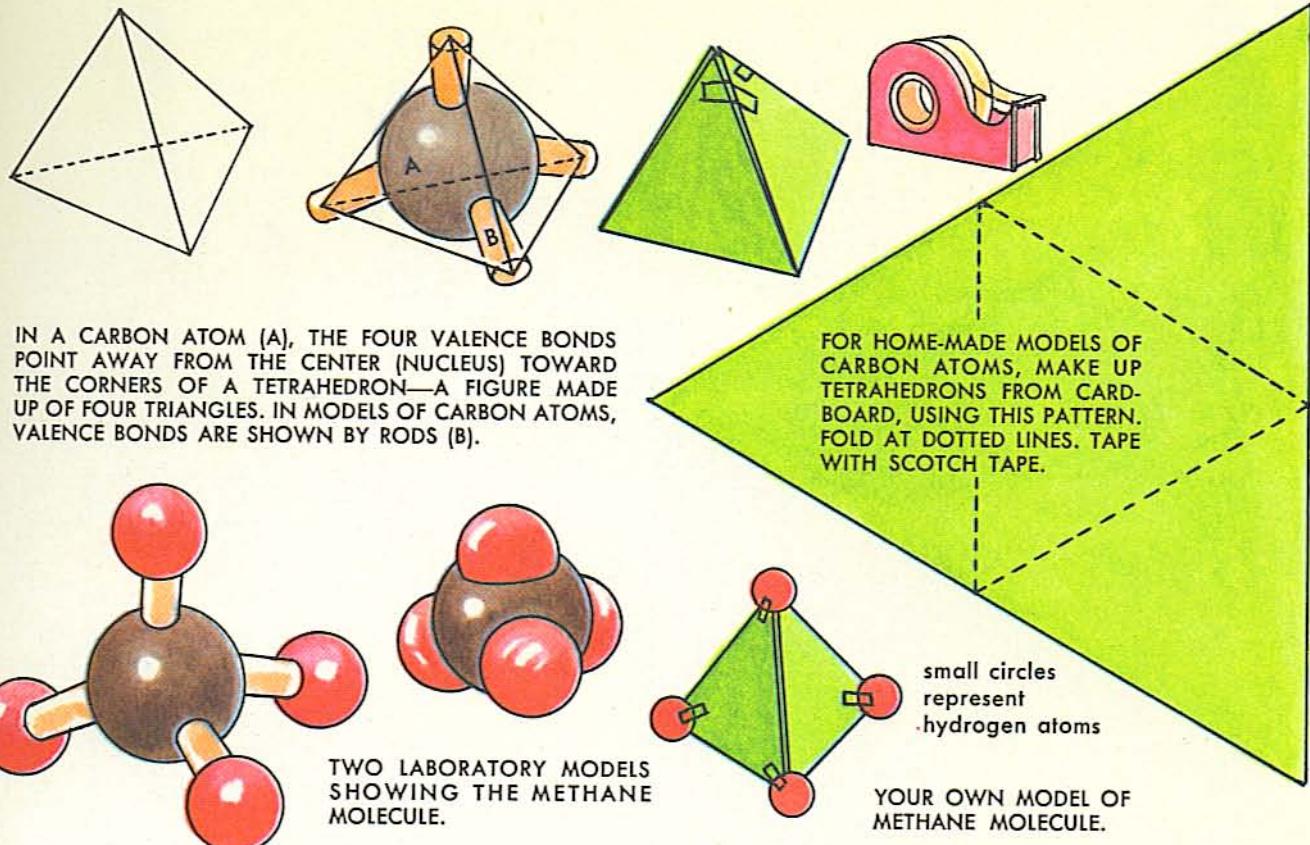


So far so good. But there were still many carbon compound formulas that would not line up in this kind of arrangement. C_6H_6 , for instance — benzene, an important hydrocarbon obtained by distillation of coal.

Again, it was Kekulé who offered the explanation. This time it came to him in a dream. He had been



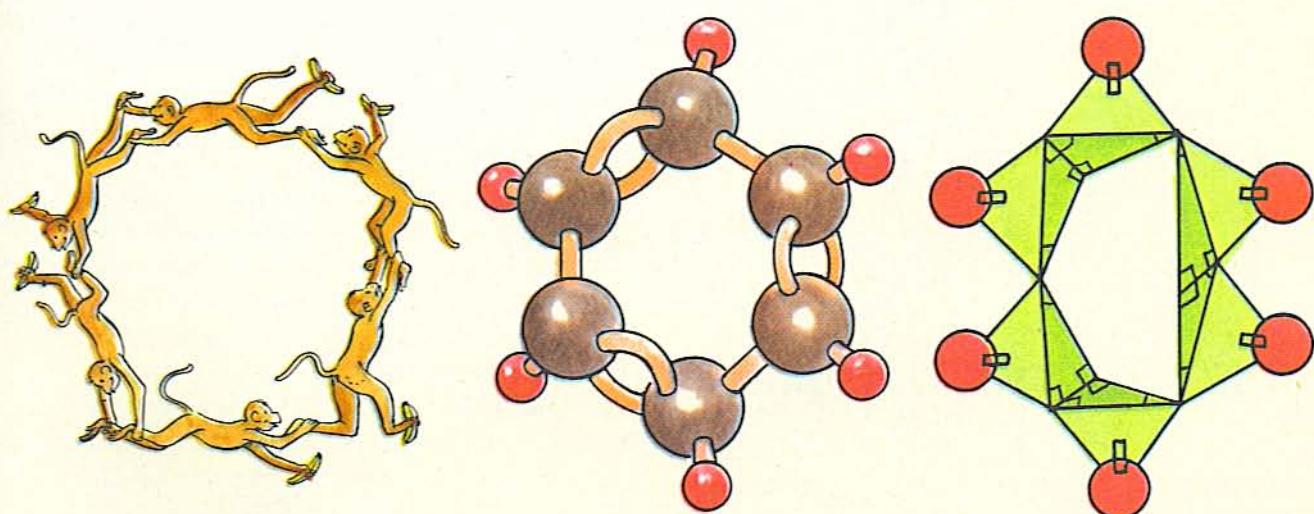
AUGUST KEKULE HIT UPON THE STRUCTURE OF THE BENZENE MOLECULE IN A DREAM. A SNAKE SEEMED TO WHIRL IN A RING BEFORE HIS EYES. BY ARRANGING THE SIX CARBON ATOMS IN A RING, THE PROBLEM WAS SOLVED.

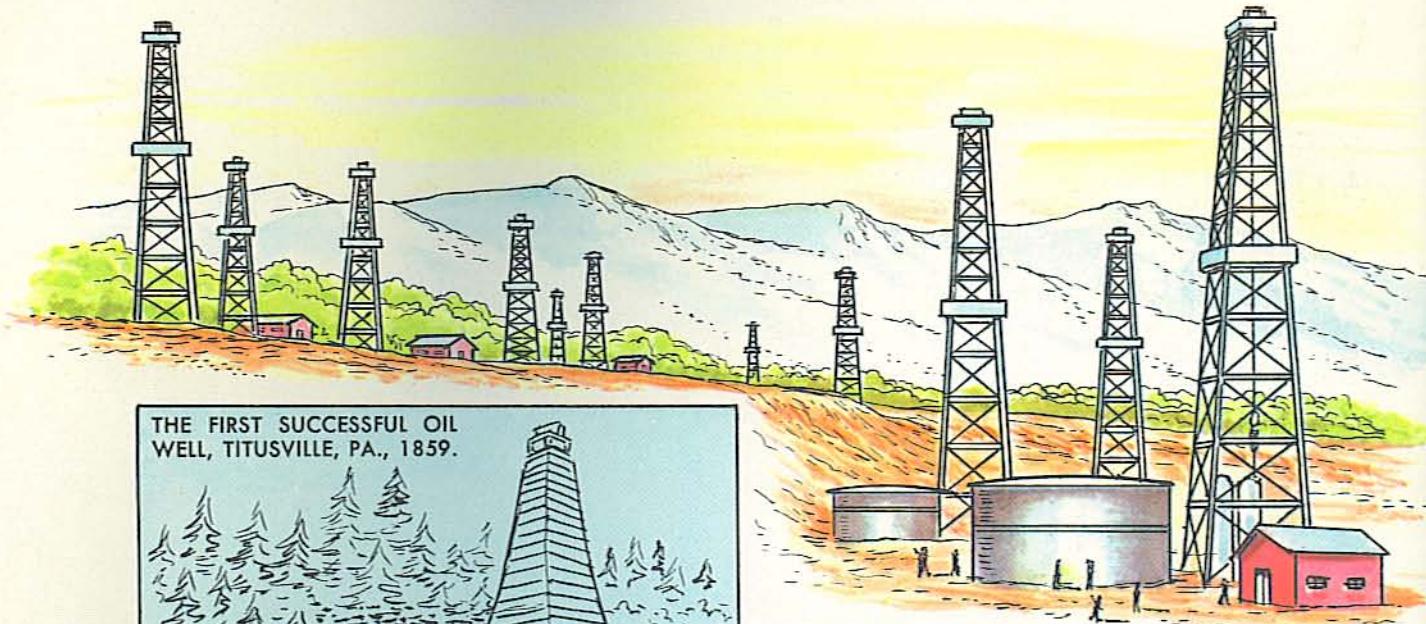


working all day with long lines of organic formulas. In the evening he dozed before the fire. In his dream, the lines of formulas turned into snakes, twisting and twining — until suddenly one of the snakes grasped its own tail and whirled around in a ring. This dream gave Kekulé the clue: the carbon atoms in benzene

hang together in a ring, each atom using three of its bonds to hang on to the atoms next to it, with one bond free to hook onto a hydrogen atom.

Starting from these very simple formulas, modern scientists can figure out the most complicated chemical formulas.





A HUNDRED YEARS AFTER THE FIRST OIL WELL IN PENNSYLVANIA, OIL FIELDS ARE FOUND IN SEVERAL STATES.

A Lot of Hydrocarbons

THE FAMILY CAR stops at the service station.

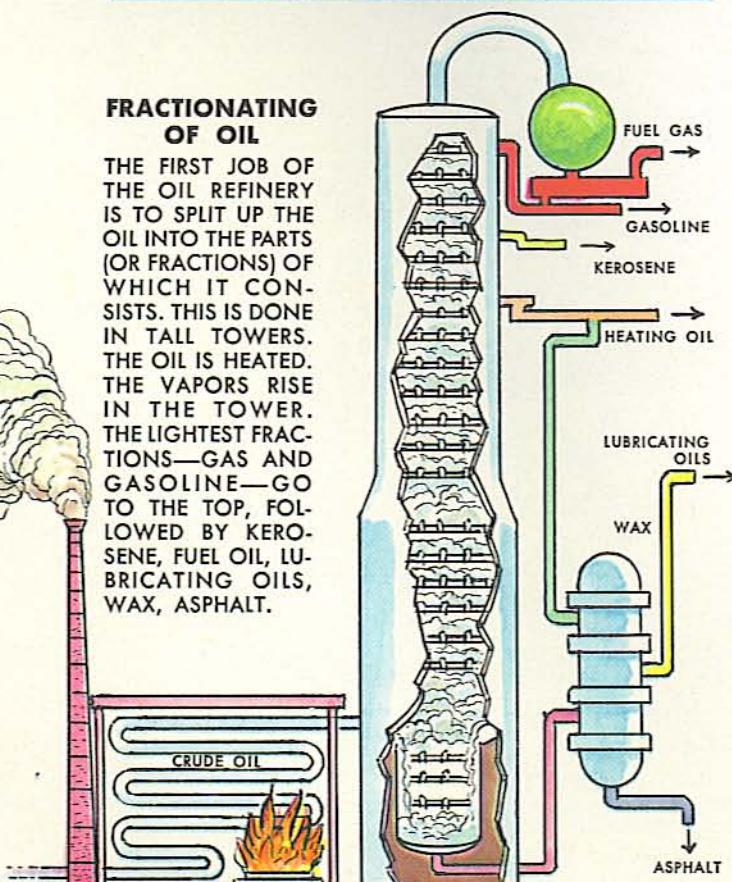
"Fill 'er up!" The attendant pours what may be a hexane-septane-octane-nonane mixture into the gas tank. "Check your oil, mister?" Into the engine goes another hydrocarbon mixture — possibly along the line of $C_{20}H_{42}$ - $C_{21}H_{44}$ - $C_{22}H_{46}$. And so you take off — on hydrocarbon tires. Yes, gasoline, motor oil, and rubber are all hydrocarbons — compounds that contain only hydrogen and carbon.

A great number of hydrocarbons come from petroleum (crude oil). Coal and natural gas provide several others. Many more are produced by nature — natural rubber, turpentine, camphor, to mention a few. Even the red coloring of tomatoes and the yellow of carrots are hydrocarbons.

One of the remarkable things about hydrocarbons is that it is possible to combine some of those with small molecules into others with larger ones (as in making synthetic rubber), as well as to "crack" those with large molecules into others with smaller ones (as when a heavy oil is "cracked" into gasoline). But that is only the beginning. By replacing one or more hydrogen atoms with hydroxyl groups (OH) or carboxyl groups (COOH) or chlorine atoms (Cl), for instance, it is possible to build up more complicated compounds — which can then be built up further and further. And that is exactly what chemists are doing today — giving us medicines and dyes, plastics and explosives, and countless other things.

FRACTIONATING OF OIL

THE FIRST JOB OF THE OIL REFINERY IS TO SPLIT UP THE OIL INTO THE PARTS (OR FRACTIONS) OF WHICH IT CONSISTS. THIS IS DONE IN TALL TOWERS. THE OIL IS HEATED. THE VAPORS RISE IN THE TOWER. THE LIGHTEST FRACTIONS — GAS AND GASOLINE — GO TO THE TOP, FOLLOWED BY KEROSENE, FUEL OIL, LUBRICATING OILS, WAX, ASPHALT.



1 HAMMER LUMPS OF BITUMINOUS COAL INTO A COARSE POWDER. FILL FUNNEL WITH IT. BRING FUNNEL INTO LARGE JAR.

2 TURN JAR UPSIDE DOWN. FILL JAR WITH WATER. PLACE A WATER-FILLED TEST TUBE OVER FUNNEL. IN A FEW DAYS, TUBE IS FILLED WITH METHANE.



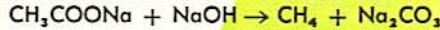
METHANE—CH₄



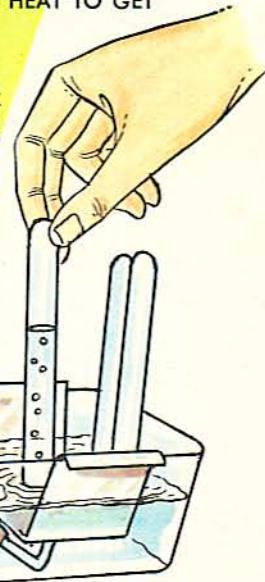
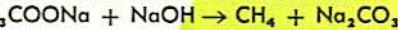
IN THE LABORATORY, METHANE IS MADE BY HEATING WATER-FREE SODIUM ACETATE WITH "SODA LIME."

1 TO MAKE SODIUM ACETATE, ADD WASHING SODA TO $\frac{1}{2}$ CUSTARD CUP VINEGAR UNTIL NO MORE CO₂ IS GIVEN OFF. EVAPORATE MIXTURE AT LOW HEAT TO GET WHITE POWDER OF SODIUM ACETATE.

2 MIX 5 g SODIUM ACETATE (CH₃COONa), 5 g SODIUM HYDROXIDE, AND 5 g CALCIUM OXIDE. DROP INTO TEST TUBE. SET UP APPARATUS FOR COLLECTING GAS AS SHOWN BELOW. HEAT TO MAKE METHANE:



2



NAPHTHALENE—C₁₀H₈

NAPHTHALENE IS USED IN MAKING MOTH BALLS.

NAPHTHALENE CAN BE PURIFIED BY SUBLIMATION. TO DEMONSTRATE THIS, CRUSH A COUPLE OF MOTH BALLS. HEAT THEM IN A CUSTARD CUP. FIRST THEY MELT, THEN GIVE OFF VAPOR. PUT JAR FILLED WITH ICE WATER OVER CUP. NAPHTHALENE SETTLES ON BOTTOM IN LEAFY CRYSTALS.



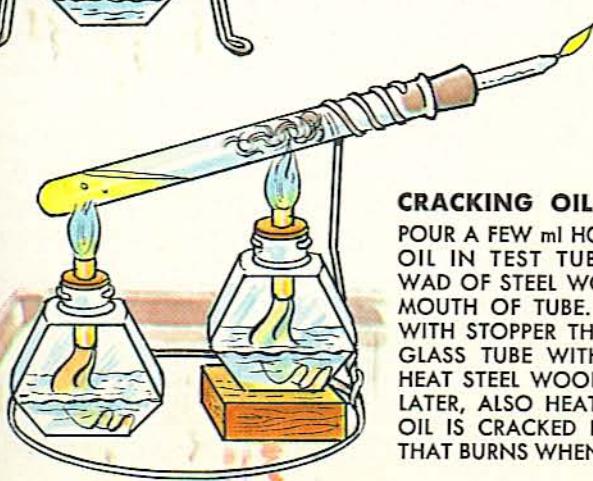
TURPENTINE—C₁₀H₁₆



1



2

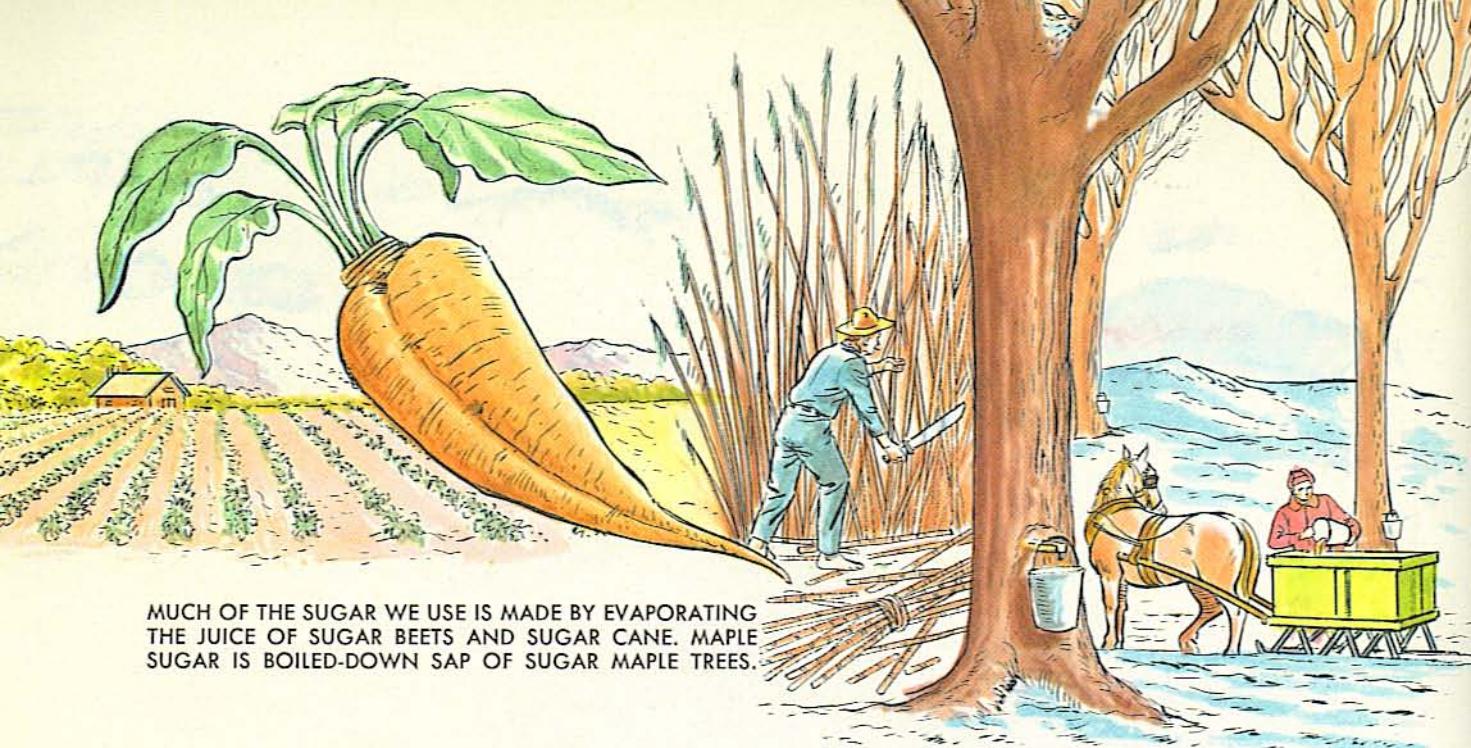


CRACKING OIL

POUR A FEW ml HOUSEHOLD OIL IN TEST TUBE. PLACE WAD OF STEEL WOOL NEAR MOUTH OF TUBE. CLOSE IT WITH STOPPER THAT HAS A GLASS TUBE WITH JET TIP. HEAT STEEL WOOL. A LITTLE LATER, ALSO HEAT THE OIL. OIL IS CRACKED INTO GAS THAT BURNS WHEN IGNITED.

1 POUR A LITTLE TURPENTINE INTO A BOTTLE CAP. PLACE A SMALL WICK IN IT.

2 PLACE BOTTLE CAP ON PIECE OF PAPER. IGNITE TURPENTINE. IT BURNS INCOMPLETELY, GIVING OFF A BLACK SMOKE OF CARBON WHICH YOU CAN COLLECT IN A JAR.

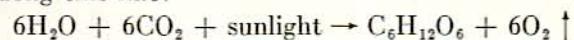


Carbohydrates—Sweet and Bland

USUALLY, when we talk about "hydrates" we mean chemicals that contain water. But when we talk about carbohydrates we mean organic compounds of carbon, hydrogen, and oxygen in which the proportion between hydrogen and oxygen is the same as in water (H_2O) — that is, twice as much hydrogen as oxygen. And so we find carbohydrates that have 22 atoms of hydrogen and 11 atoms of oxygen to 12 atoms of carbon ($C_{12}H_{22}O_{11}$), or 12 hydrogen and 6

oxygen to 6 carbon ($C_6H_{12}O_6$), or 10 and 5 to 6 carbon atoms ($C_6H_{10}O_5$).

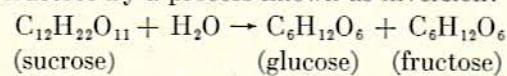
Carbohydrates are produced by plants by a remarkable process called photosynthesis—"putting things together with the help of light." When green leaves are exposed to sunlight, the chlorophyll in them combines the hydrogen from water with carbon dioxide from the air, while setting oxygen free—along this line:



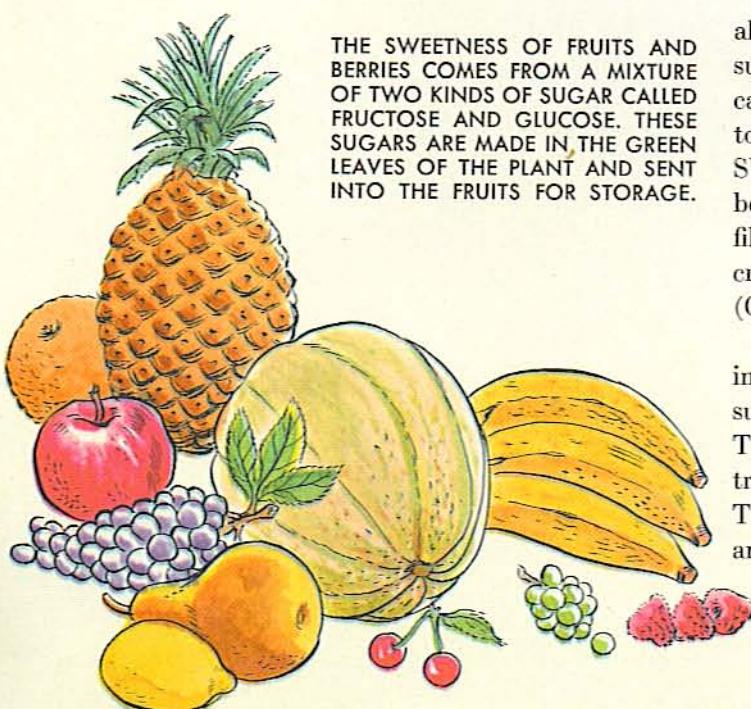
Carbohydrates are of tremendous importance to all of us. They make up a large part of our food supply in the form of sugars and starches. Another carbohydrate called cellulose helps to clothe us (cotton, linen) and shelter us (wood).

SUGARS—Most of our sugar comes from sugar beets or sugar cane. The juice is pressed out, cleared, filtered, and evaporated. The result is pure, white crystals of a sugar with the chemical name sucrose ($C_{12}H_{22}O_{11}$).

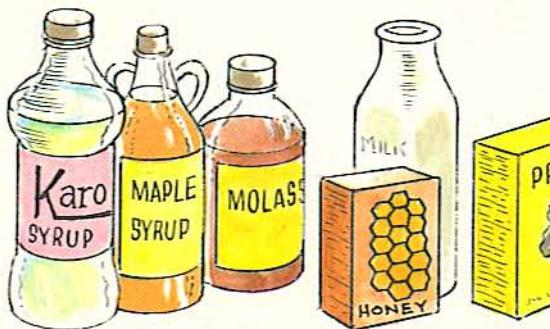
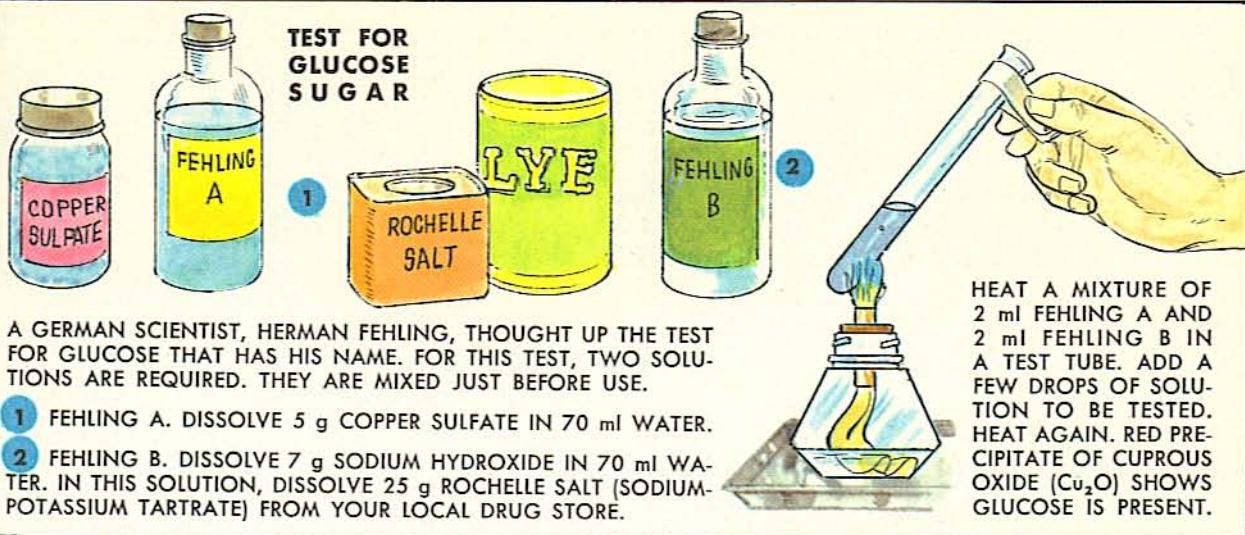
Another sugar called glucose ($C_6H_{12}O_6$) is found in ripe fruits, often in the company of still another sugar of the same formula called fructose ($C_6H_{12}O_6$). These two sugars can be made in the laboratory by treating the more complicated sucrose with an acid. The sucrose picks up water and splits into glucose and fructose by a process known as inversion:



(CONTINUED ON PAGE 86)

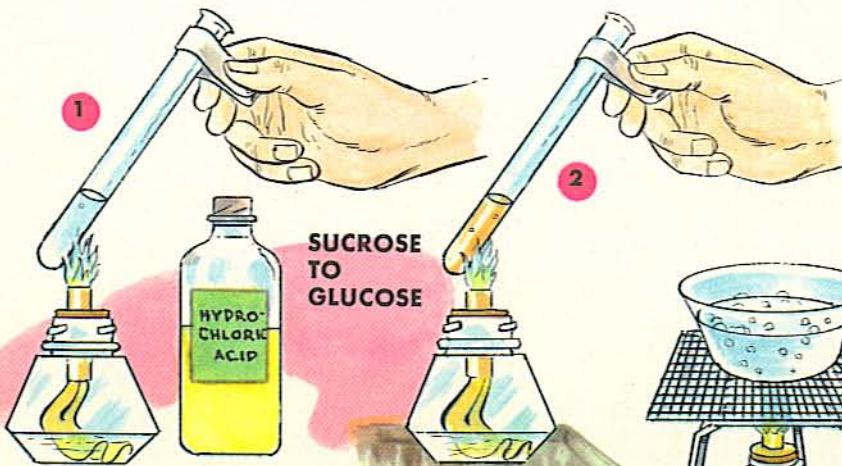
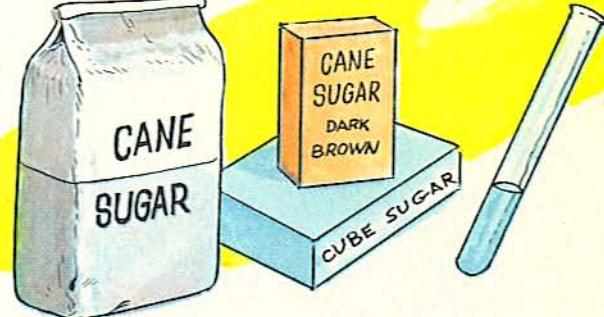


TEST FOR GLUCOSE SUGAR



USE FEHLING TEST TO FIND OUT IF DIFFERENT SWEET-TASTING FOODS CONTAIN GLUCOSE SUGAR: CORN SYRUP, MAPLE SYRUP, MOLASSES, HONEY. ALSO TRY JUICES OF VARIOUS FRUITS: PRUNES, ORANGES, LEMONS, BERRIES. SEVERAL CONTAIN GLUCOSE AND GIVE RED PRECIPITATE. SUGAR IN MILK (LACTOSE) GIVES Cu_2O PRECIPITATE.

TEST CANE SUGAR WITH FEHLING. YOU DO NOT GET RED PRECIPITATE. CANE SUGAR IS NOT GLUCOSE BUT ANOTHER SUGAR CALLED SUCROSE.



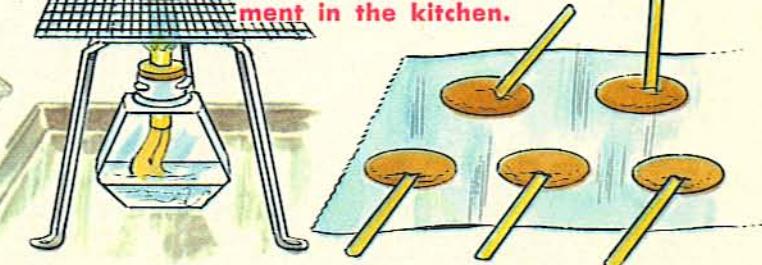
1 DISSOLVE 1 g CANE SUGAR IN 10 ml WATER IN A TEST TUBE. ADD 10 DROPS HYDROCHLORIC ACID. HEAT GENTLY FOR A FEW MINUTES WITHOUT BOILING.

2 HEAT FEHLING SOLUTION IN ANOTHER TEST TUBE. ADD A FEW ml SUGAR SOLUTION. HEAT AGAIN. YOU GET RED PRECIPITATE. GLUCOSE HAS BEEN FORMED.

MAKING SUGAR CANDY

IT IS EASY TO MAKE LOLLIPOPS. OVER LOW HEAT AND WHILE STIRRING, DISSOLVE $\frac{1}{2}$ CUP SUGAR IN 2 TABLESPOONS WATER AND 2 TABLESPOONS LIGHT SYRUP. THEN CONTINUE HEATING WITHOUT STIRRING UNTIL A SAMPLE DROPPED INTO COLD WATER FORMS BRITTLE THREAD. SPOON OUT TABLESPOONFULS ONTO A SHEET OF GREASED ALUMINUM FOIL. PUSH STICK IN EACH BLOB. REMOVE WHEN COLD.

Perform this experiment in the kitchen.



Carbohydrates—Continued

STARCHES—Starch is distributed in most plant parts. It is a carbohydrate with very large molecules. Take a look at its formula: $(C_6H_{10}O_5)_x$. At first glance it looks quite simple. But note that little x —it stands for “any number of times.” A single molecule of starch may weigh 6,000 times as much as a single molecule of glucose.

You can break this polysaccharide (“many-sugar”) into the monosaccharide (“single-sugar”) glucose by treating it with an acid.

CELLULOSE is the building material of the plant world. It makes up the cell walls of leaves and stalks,



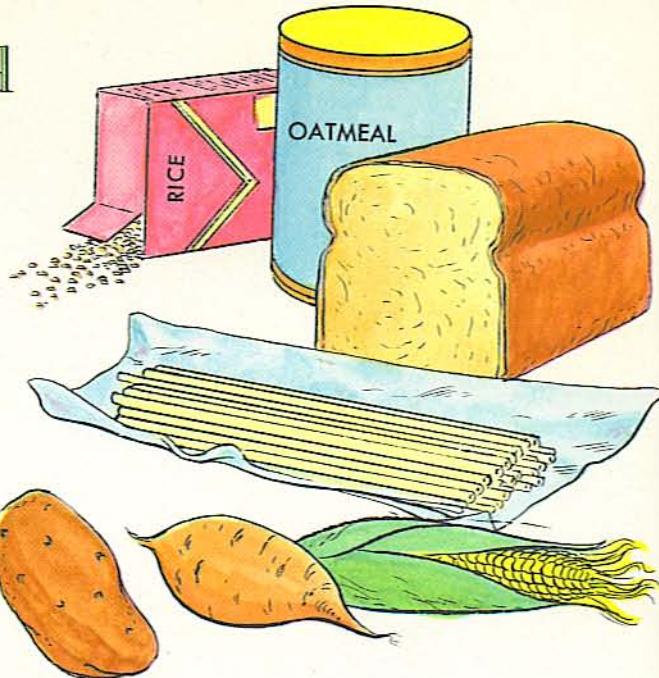
A GROWING PLANT IS THE MOST ASTONISHING CHEMICAL FACTORY ON EARTH. THE GREEN SUBSTANCE IN LEAVES—CALLED CHLOROPHYLL—with the help of sunlight is able to combine water (taken in by the roots) with carbon dioxide from the air (taken in through the leaves) to form sugar first and then starch.

cross section of leaf



2 PICK OFF A LEAF. REMOVE BLACK PAPER STRIPS. DIP IN BOILING WATER FOR A MOMENT TO KILL THE LEAF. THEN DROP IT INTO DENATURED ALCOHOL IN A CUSTARD CUP. PLACE CUSTARD CUP IN A POT OF BOILING WATER. AS ALCOHOL GETS HOT, IT EXTRACTS THE CHLOROPHYLL FROM THE LEAF. KEEP LEAF IN ALCOHOL UNTIL ALL CHLOROPHYLL IS OUT.

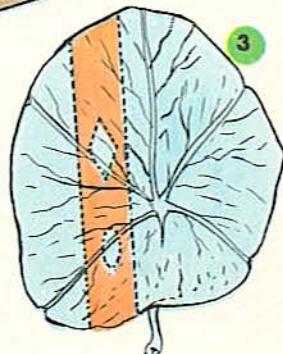
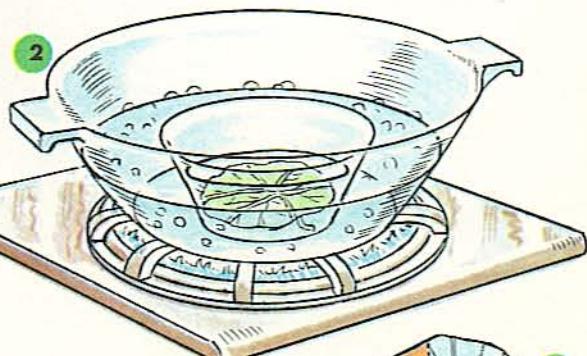
3 PLACE LEAF IN IODINE TEST SOLUTION. PARTS EXPOSED TO SUN TURN BLUE. THIS PROVES PRESENCE OF STARCH. UNEXPOSED PARTS BECOME BROWN.



wood and fibers. Cotton is 95 per cent cellulose. The paper on which this book is printed is specially treated cellulose. So is the cellophane around your candy and the rayon that goes into ladies' dresses. For more about cellulose in natural fibers and rayon, see pages 102-103.

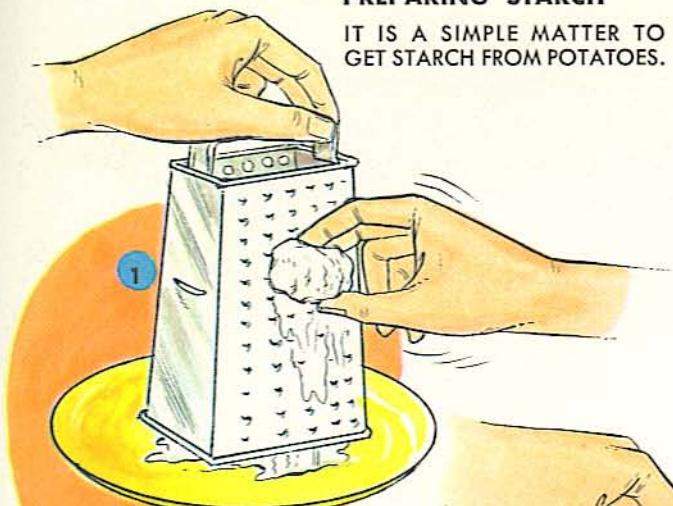
EXPERIMENTS WITH PHOTOSYNTHESIS

1 POT UP A NASTURTIUM OR GERANIUM PLANT AND PLACE IT IN THE DARK FOR A COUPLE OF DAYS. THEN FASTEN STRIPS OF BLACK PAPER ACROSS BOTH SIDES OF ONE OR MORE LEAVES. NOW EXPOSE THE GROWING PLANT TO THE SUNLIGHT FOR TWO HOURS.



PREPARING STARCH

IT IS A SIMPLE MATTER TO GET STARCH FROM POTATOES.



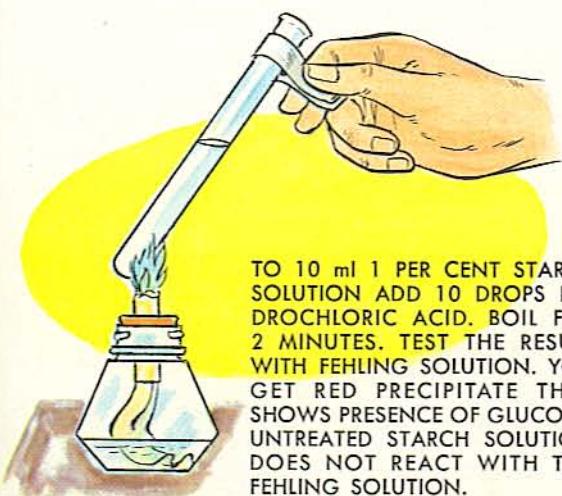
1 PEEL A COUPLE OF POTATOES. GRATE THEM UP ON FINE SIDE OF GRATER.

2 PLACE POTATO PULP ON DOUBLE LAYER OF CHEESE CLOTH. FOLD UP AND TIE. DIP BAG IN POT OF WATER. SQUEEZE. DIP AND SQUEEZE UNTIL MOST STARCH IS OUT.



EXPERIMENTS WITH STARCH

TO MAKE 1 PER CENT STARCH SOLUTION, STIR $\frac{1}{2}$ g STARCH IN 5 ml COLD WATER. ADD 45 ml MORE WATER. BRING TO BOIL WHILE STIRRING, THEN COOL SOLUTION.



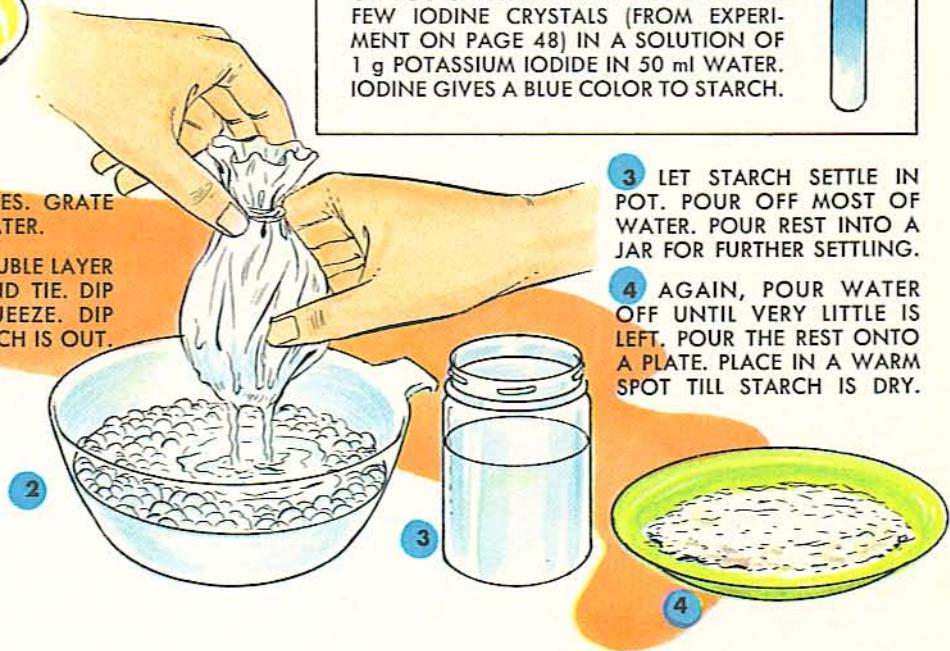
TO 10 ml 1 PER CENT STARCH SOLUTION ADD 10 DROPS HYDROCHLORIC ACID. BOIL FOR 2 MINUTES. TEST THE RESULT WITH FEHLING SOLUTION. YOU GET RED PRECIPITATE THAT SHOWS PRESENCE OF GLUCOSE. UNTREATED STARCH SOLUTION DOES NOT REACT WITH THE FEHLING SOLUTION.

TEST FOR STARCH



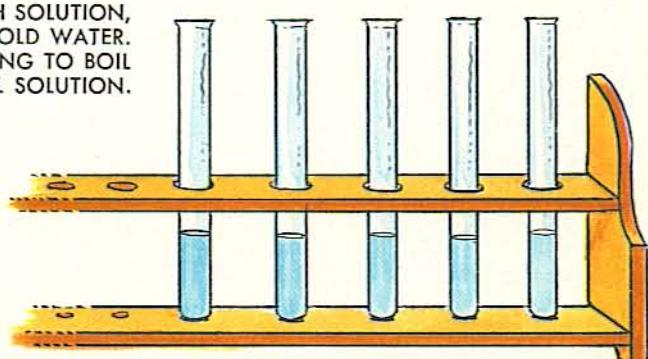
SOLUTION FOR TESTING STARCH CAN BE MADE BY DILUTING 5 ml REGULAR TINCTURE OF IODINE WITH 45 ml WATER.

OR YOU CAN MAKE IT BY DISSOLVING A FEW IODINE CRYSTALS (FROM EXPERIMENT ON PAGE 48) IN A SOLUTION OF 1 g POTASSIUM IODIDE IN 50 ml WATER. IODINE GIVES A BLUE COLOR TO STARCH.

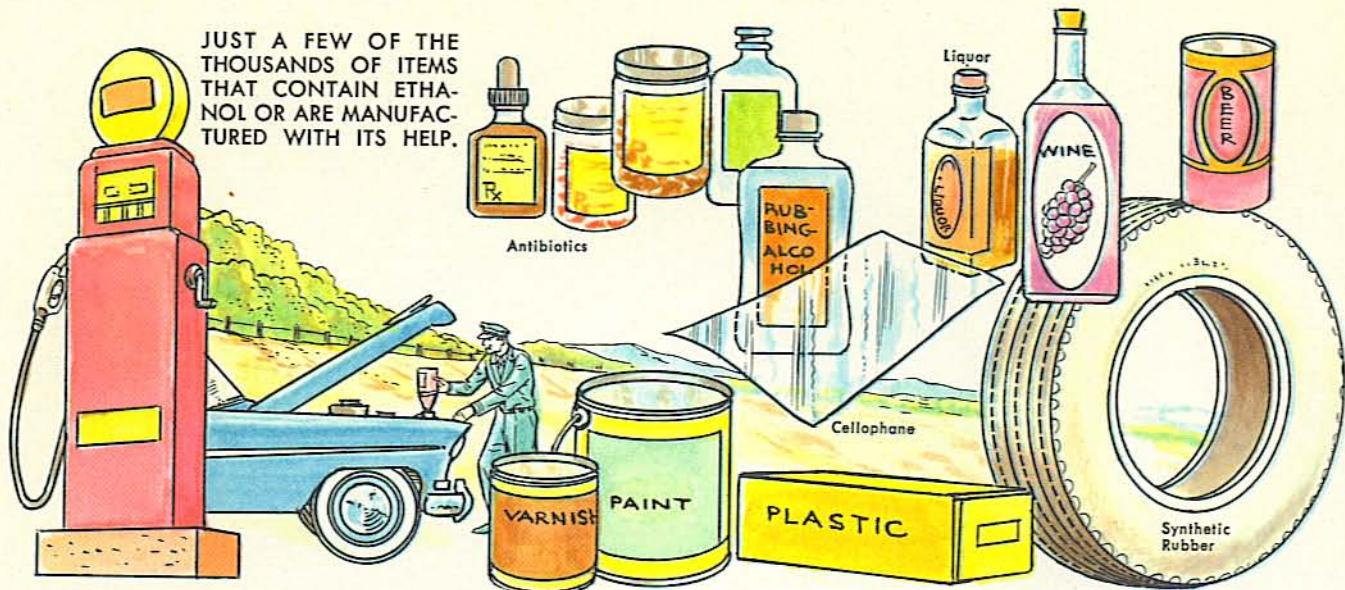


3 LET STARCH SETTLE IN POT. POUR OFF MOST OF WATER. POUR REST INTO A JAR FOR FURTHER SETTLING.

4 AGAIN, POUR WATER OFF UNTIL VERY LITTLE IS LEFT. POUR THE REST ONTO A PLATE. PLACE IN A WARM SPOT TILL STARCH IS DRY.



LINE UP FIVE TEST TUBES, EACH CONTAINING 5 ml WATER AND 1 DROP IODINE TEST SOLUTION. IN ANOTHER TEST TUBE, ADD 2 DROPS OF SALIVA (SPIT-
TLE) TO 5 ml STARCH SOLUTION. PLACE THIS IN GLASS OF WARM (NOT HOT) WATER. WITH 2-MINUTE INTERVALS, DROP 3 DROPS SALIVA-STARCH MIXTURE INTO A TEST TUBE WITH IODINE SOLUTION. SHAKE. COLOR GETS LESS AND LESS BLUE. SALIVA DIGESTS THE STARCH AND TURNS IT INTO A SUGAR, MALTOSE.

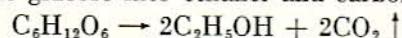


Many Kinds of Alcohols

TO MOST PEOPLE, alcohol is the strong stuff in beer, wine, and hard liquor. But to a chemist, this is just one of many alcohols.

Alcohols may be considered hydrocarbons in which one or more hydrogen (H) atoms are replaced by hydroxyl (OH) groups. Their names are made up from the names of the hydrocarbons to which they are related by giving these an “-ol” ending. In this way, CH_4 , methane, becomes CH_3OH , methanol (also called methyl alcohol); C_2H_6 , ethane, becomes $\text{C}_2\text{H}_5\text{OH}$, ethanol (also known as ethyl or grain alcohol); and so on. Methanol (CH_3OH) was originally called wood alcohol because it was made by the destructive distillation of wood. It is very poisonous and is therefore used to “denature” ethanol, making this unfit for drinking.

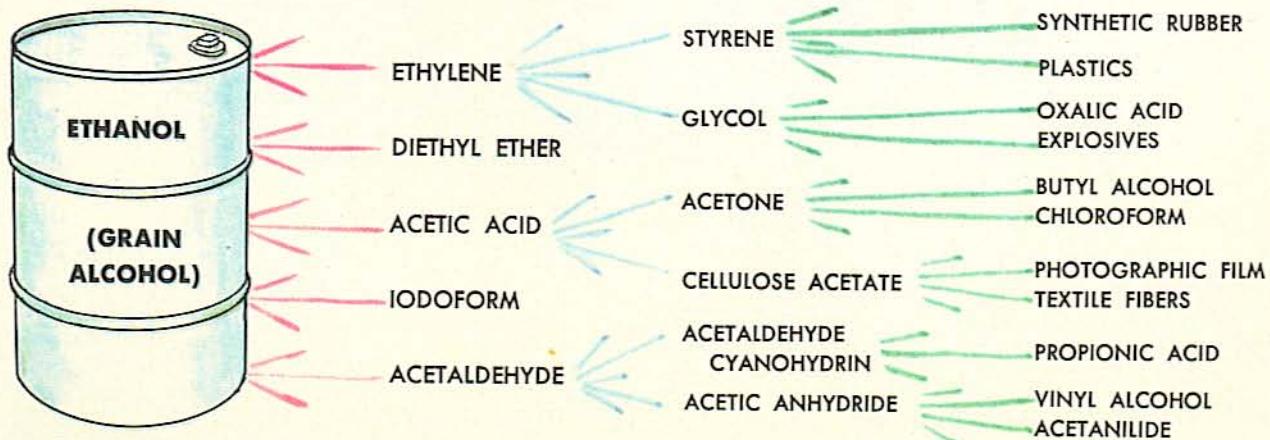
Ethanol ($\text{C}_2\text{H}_5\text{OH}$) is produced today, to a great extent, in the same way in which it was made thousands of years ago, by a process called fermentation. In this, the tiny plant cells of yeast are made to grow in the solution of a simple sugar, such as glucose ($\text{C}_6\text{H}_{12}\text{O}_6$). In growing, the yeast cells give off a substance called zymase. This acts as a catalyst and turns the glucose into ethanol and carbon dioxide:



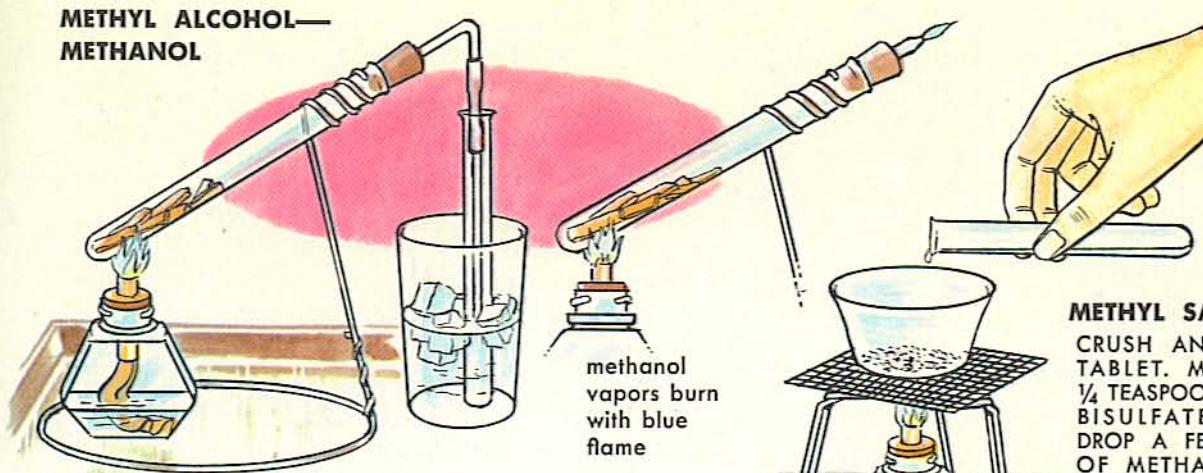
The ethanol is finally separated from the watery liquid by distillation.

Glycerol ($\text{C}_3\text{H}_5(\text{OH})_3$) is still another alcohol which you probably know better under the name of glycerin. Glycerol may be considered a product of propane (C_3H_8) in which not one but three H atoms have been replaced by OH.

THE “FAMILY TREE” OF ETHANOL—WITH SOME OF ITS CHILDREN, GRANDCHILDREN, AND GREAT-GRANDCHILDREN.



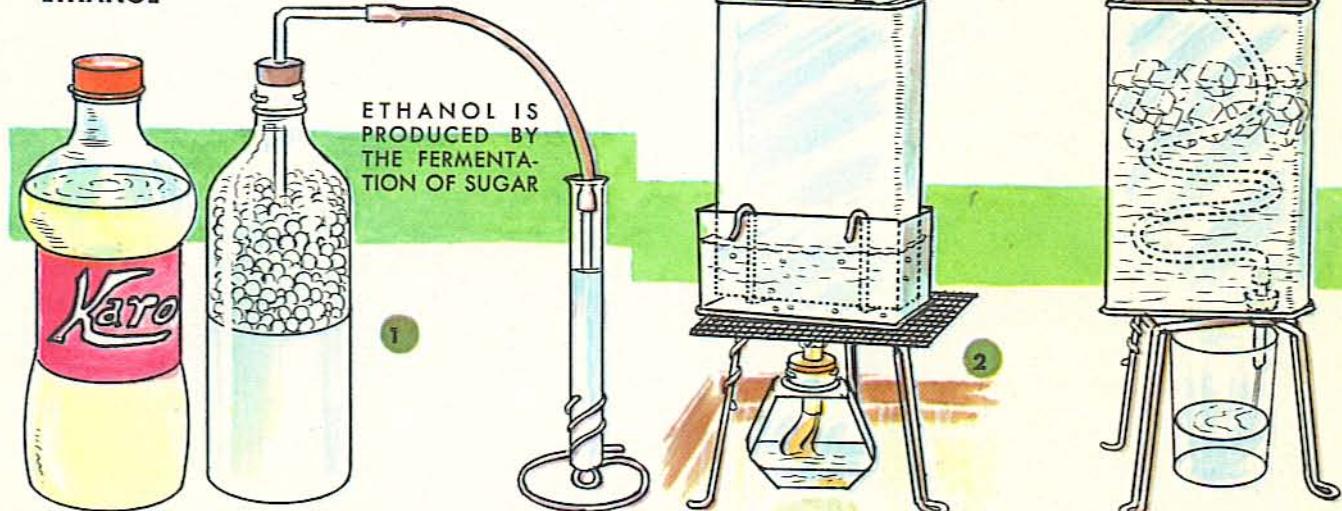
METHYL ALCOHOL— METHANOL



METHANOL CAN BE PRODUCED BY DRY DISTILLATION OF WOOD. FILL A TEST TUBE ONE THIRD FULL OF SLIVERS OF WOOD. HEAT. LEAD VAPORS THROUGH L-SHAPED GLASS TUBE INTO TEST TUBE IN MIXTURE OF WATER AND ICE.

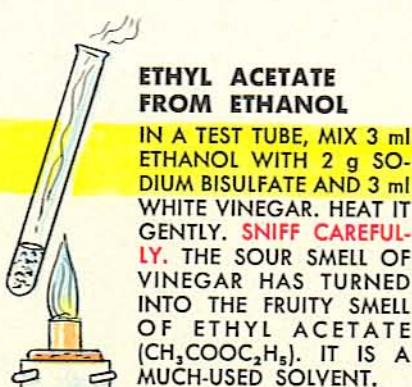
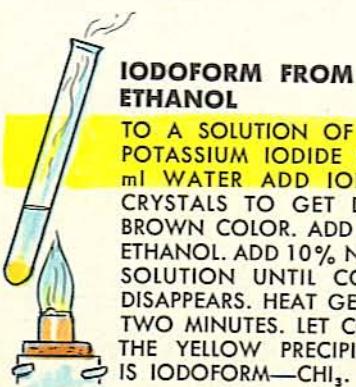
METHYL SALICYLATE
CRUSH AN ASPIRIN TABLET. MIX WITH $\frac{1}{4}$ TEASPOON SODIUM BISULFATE. HEAT. DROP A FEW DROPS OF METHANOL (OR DENATURED ALCOHOL) ONTO HOT MIXTURE. YOU GET SMELL OF WINTERGREEN OIL—METHYL SALICYLATE.

ETHYL ALCOHOL— ETHANOL



1 IN A PINT BOTTLE MIX $\frac{1}{4}$ CUP CORN SYRUP WITH 1 CUP WARM WATER. ADD $\frac{1}{2}$ PACKAGE YEAST THAT HAS BEEN SOFTENED IN LUKEWARM WATER. PLACE BOTTLE IN A WARM SPOT. SHORTLY THE LIQUID BEGINS TO BUBBLE. LEAD THE GAS INTO LIME WATER. GAS IS CO_2 . IN A FEW DAYS, GAS DEVELOPMENT SLOWS DOWN.

2 FILTER HALF OF THE FERMENTED LIQUID INTO A 1-PINT SCREW-TOP CAN. SET UP APPARATUS FOR DISTILLATION AS DESCRIBED ON PAGE 61 WITH THE EXCEPTION THAT HEATING IS DONE ON A WATER BATH MADE FROM HALF A QUART CAN WITH WATER. DISTILL OFF A FEW ml ETHANOL AT LOWEST POSSIBLE HEAT.



Carboxylic Acids



TANNIC ACID, USED FOR TANNING, IS FOUND IN THE BARK OF A NUMBER OF TREES AND IN GALL APPLES ON OAK TREES.



ACETIC ACID IS WHAT MAKES VINEGAR TASTE SOUR. VINEGAR MEANS "SOUR WINE." THAT IS WHAT IT USED TO BE.



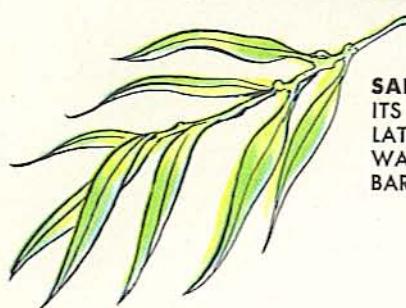
CAN YOU THINK of anything more refreshing than a glass of cold lemonade on a hot summer's day? Or anything better than cranberry sauce for adding a tangy taste to the Thanksgiving dinner?

The tartness of lemonade and cranberry sauce comes from organic acids.

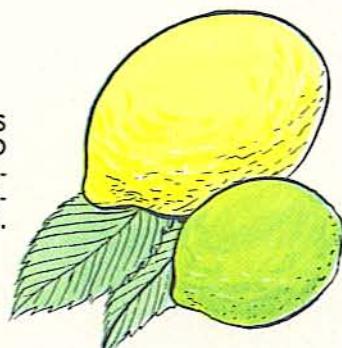
These acids are found ready-made in nature in great numbers. Some of them occur as free acids (citric acid, tannic acid, malic acid), others as esters (products of acids and alcohols, such as fats and oils and the flavors of many fruits and the odors of many flowers). Still other of these organic acids are produced by the action of bacteria (acetic acid from wine or cider, lactic acid when milk turns sour, butyric acid in rancid butter).

Some organic acids can be extracted directly from the plant parts in which they are found. But to get them in pure and concentrated form it is usually necessary to turn them into sodium or calcium salts and then free the acids from the salts with a stronger acid. Many of the acids which were formerly obtained from plant parts can now be made artificially in the laboratory.

Organic acids have one thing in common. They all contain a combination of one carbon atom, one oxygen atom, and one hydroxyl group (OH). This COOH combination, called a carboxyl group (from a joining-up of the words *carbon* and *hydroxyl*), has given the organic acids their scientific name, carboxylic acids. When these acids form salts it is the H in the carboxyl group that is replaced by a metal, as, for instance, when CH_3COOH (acetic acid) forms CH_3COONa (sodium acetate).



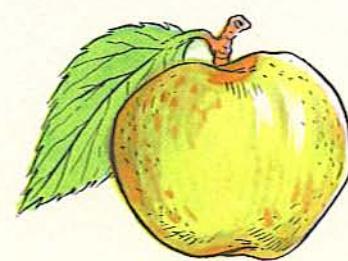
SALICYLIC ACID GOT ITS NAME FROM *SALIX*, LATIN FOR WILLOW. IT WAS FIRST MADE FROM BARK OF WILLOW TREES.



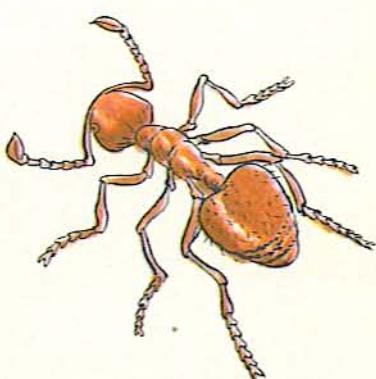
CITRIC ACID GIVES THE TART TASTE TO CITRUS FRUITS—LEMONS, LIMES, GRAPEFRUITS, AND ORANGES.



OXALIC ACID ORIGINALLY CAME FROM THE WOOD SORREL PLANT—*OXALIS*. NOW IT IS MADE ARTIFICIALLY.

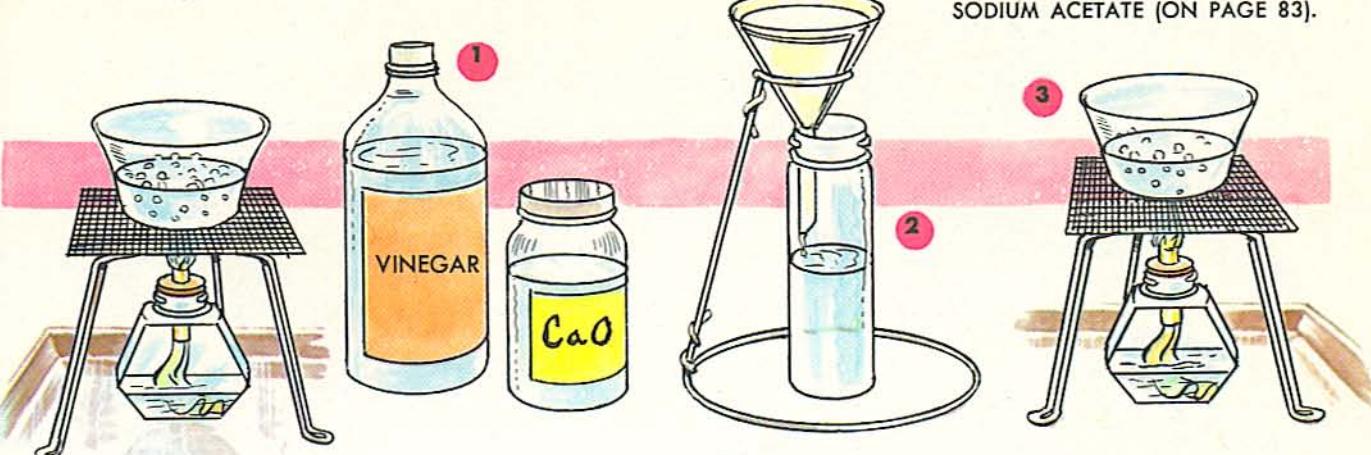


MALIC ACID IS FOUND IN MANY UNRIPE FRUITS—GREEN APPLES, PLUMS, CURRANTS, AND A GREAT NUMBER OF OTHERS. NAME COMES FROM LATIN *MALUS*—APPLE TREE.



FORMIC ACID IS THE HIGHLY IRRITATING ACID THAT ANTS (*FORMICA*) PUMP INTO YOU WHEN THEY BITE YOU.

ACETIC ACID



VINEGAR IS DILUTED ACETIC ACID. SEVERAL OF ITS SALTS—ACETATES—CAN BE MADE FROM VINEGAR. USE LIME FOR MAKING THE CALCIUM SALT— $(CH_3COO)_2Ca$.

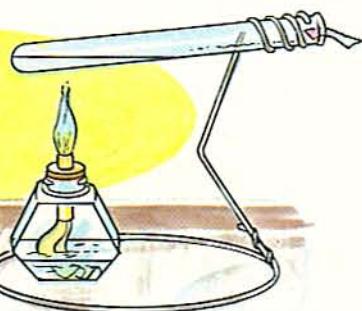
1 WARM 50 ml WHITE VINEGAR IN A CUSTARD CUP. ADD CALCIUM OXIDE UNTIL NO MORE DISSOLVES.

2 FILTER SOLUTION TO REMOVE UNDISSOLVED CALCIUM OXIDE. FILTRATE CONTAINS CALCIUM ACETATE.

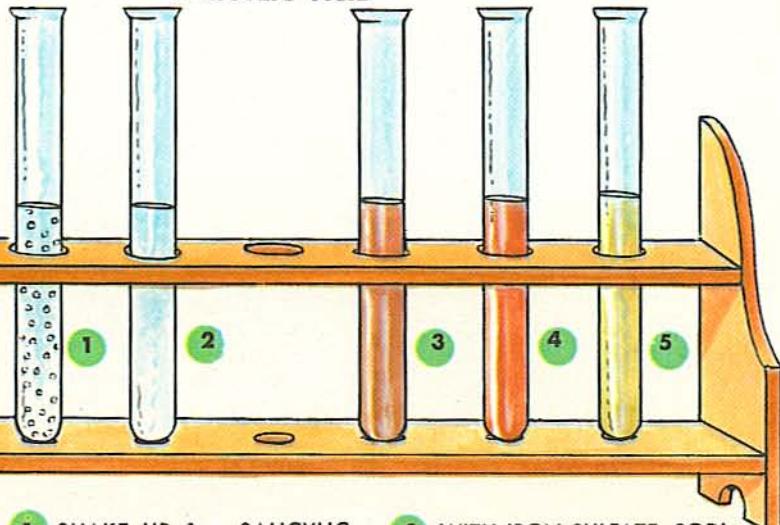
3 EVAPORATE SOLUTION UNTIL ALMOST DRY. DO NOT OVERHEAT—if you do, the acetate breaks up into calcium carbonate and acetone (CH_3COCH_3).

YOU CAN AGAIN DRIVE ACETIC ACID OUT OF ITS CALCIUM SALT.

MIX CALCIUM ACETATE WITH AN EQUAL AMOUNT OF SODIUM BI-SULFATE. PLACE IN DRY TEST TUBE. HEAT GENTLY. YOU GET SHARP ODOR OF ACETIC ACID. MOISTENED BLUE LITMUS PAPER AT MOUTH OF TUBE TURNS RED.



SALICYLIC ACID



1 SHAKE UP 1 g SALICYLIC ACID WITH 10 ml WATER. IT DOES NOT GO INTO SOLUTION.

2 ADD 10 PER CENT NaOH SOLUTION BY THE DROP UNTIL ALL SALICYLIC ACID IS DISSOLVED. YOU NOW HAVE A SODIUM SALICYLATE SOLUTION.

3 WITH IRON SULFATE, SODIUM SALICYLATE GIVES RED-BROWN FERROUS SALICYLATE.

4 A FERRIC SALT GIVES WINE-RED FERRIC SALICYLATE.

5 COPPER SULFATE GIVES THE GREEN COPPER SALICYLATE.

TANNIC ACID

TANNIC ACID IS FOUND IN TEA.

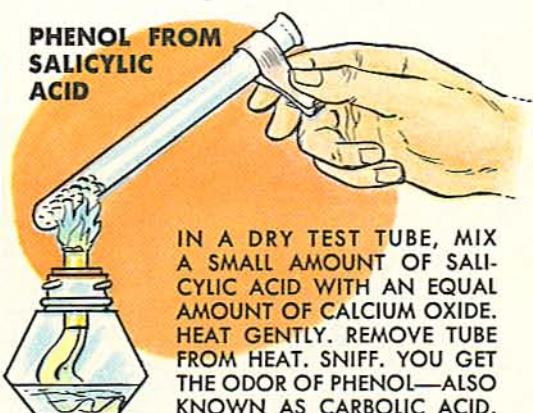


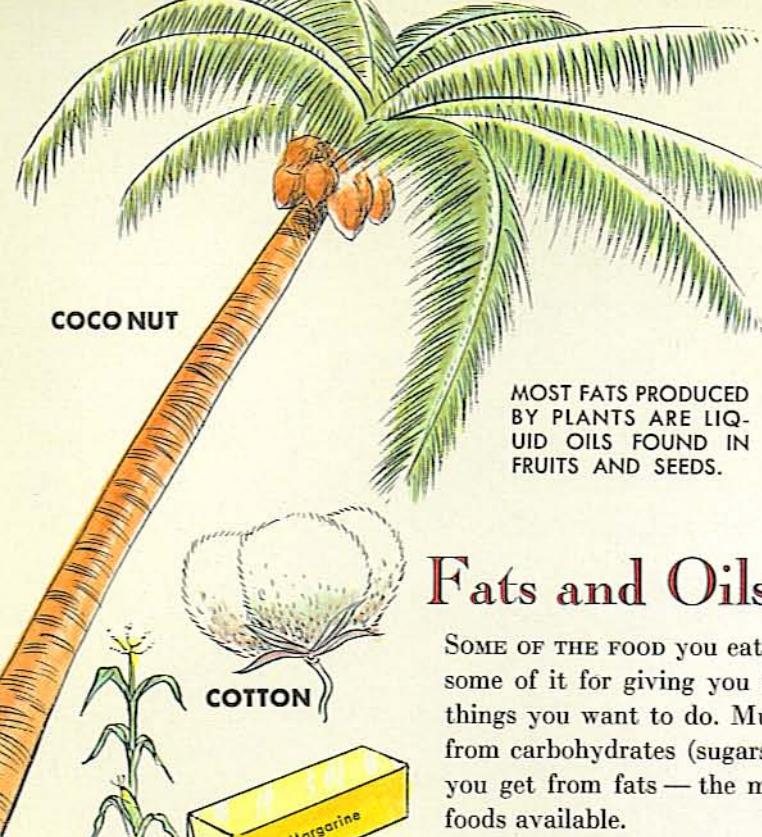
1 BOIL 1/4 TEASPOON TEA IN 50 ml WATER. THEN LET IT STAND TO STEEP AND COOL. POUR OFF THE CLEAR LIQUID.

2 DISSOLVE A CRYSTAL OF IRON SULFATE IN 5 ml WATER AND ADD TO THE TEA. YOU WILL GET A BLACK PRECIPITATE OF IRON TANNATE.

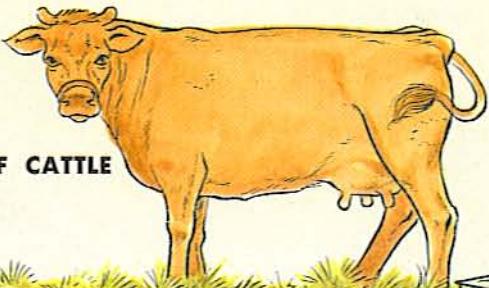


PHENOL FROM SALICYLIC ACID

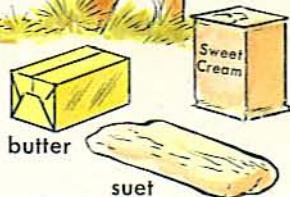




MOST FATS PRODUCED BY PLANTS ARE LIQUID OILS FOUND IN FRUITS AND SEEDS.



FATS FROM ANIMALS ARE MOST COMMONLY SOLID AT USUAL ROOM TEMPERATURE.

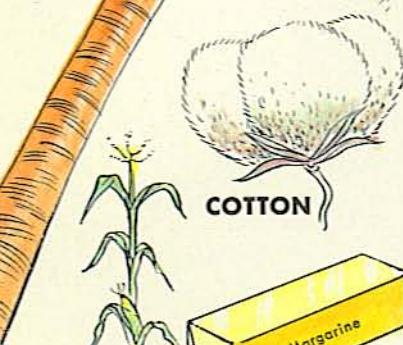


Fats and Oils for Energy

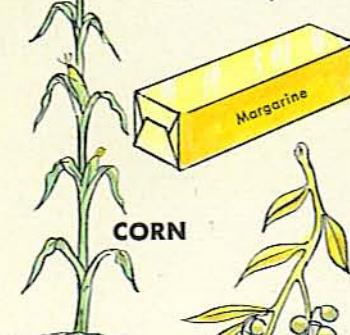
SOME OF THE FOOD you eat is used for your growth, some of it for giving you the energy to do all the things you want to do. Much of this energy comes from carbohydrates (sugars and starches). The rest you get from fats — the most concentrated energy foods available.

All fats are esters, that is, combinations of fatty acids with the alcohol, glycerol (glycerin). Some fats (butter, lard) are solid at usual room temperature, others are liquid (olive oil, corn oil). But when heated, the solid fats melt, and, when cooled, the liquid fats turn solid.

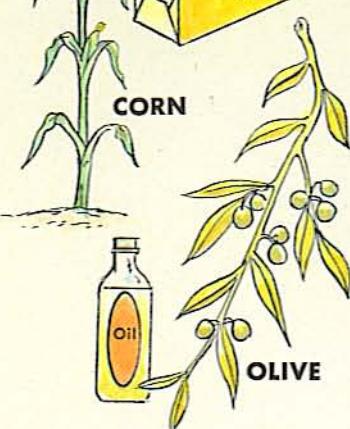
Fats and oils are used for many other things in addition to their use as food. Soap and candles are made from fats. So are paints and varnishes, printers' inks and some of the detergents.



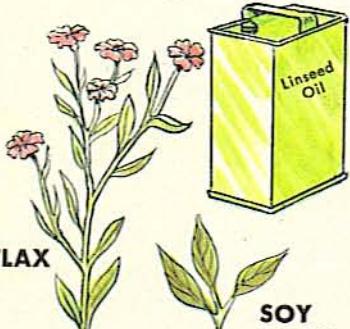
COTTON



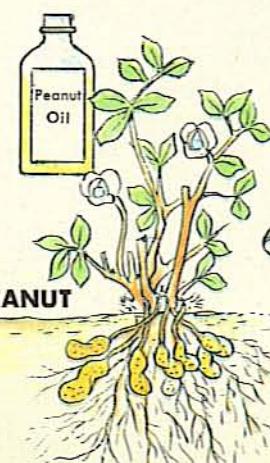
CORN



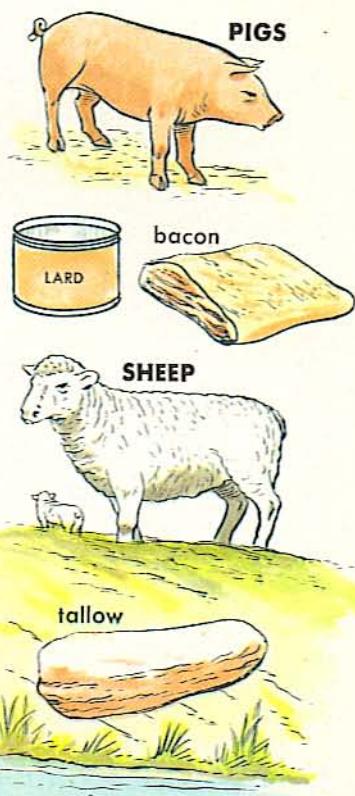
OLIVE



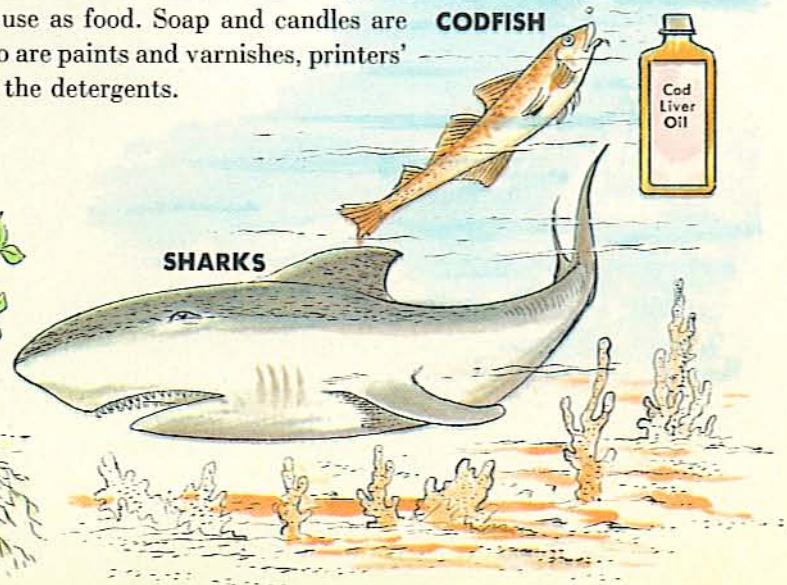
**SOY
BEAN**



PEANUT



CODFISH



EXTRACTING FAT



1 SHAVE A SMALL SQUARE OF BAKER'S CHOCOLATE OR BITTER CHOCOLATE INTO FINE BITS.

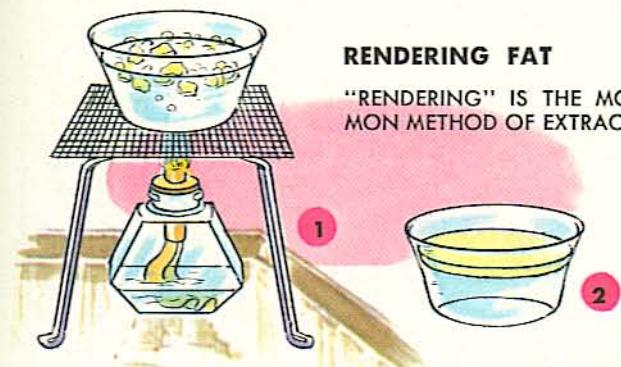
2 IN A CUSTARD CUP, POUR CARBON TETRACHLORIDE OVER THE CUT-UP CHOCOLATE AND STIR.

3 FILTER CHOCOLATE-TETRACHLORIDE MIXTURE. LET FILTRATE STAND UNTIL CARBON TETRACHLORIDE HAS EVAPORATED AND YELLOW-WHITE COCOA BUTTER IS LEFT.

Be careful not to breathe fumes.

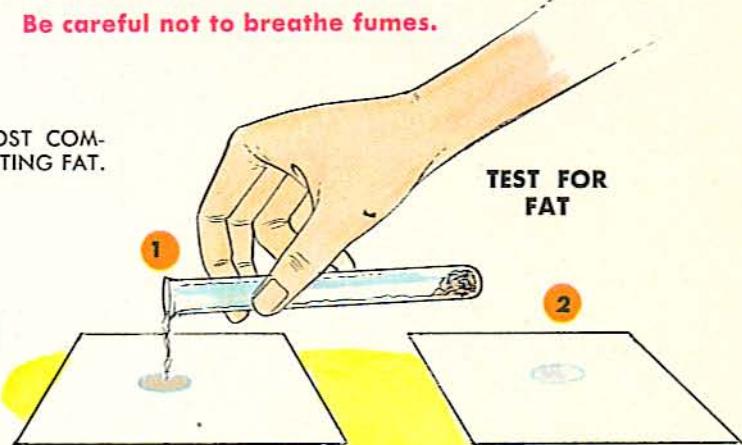
RENDERING FAT

"RENDERING" IS THE MOST COMMON METHOD OF EXTRACTING FAT.



1 CUT UP A SMALL AMOUNT OF SUET—THE FAT FROM A PIECE OF BEEF. DROP IT INTO HOT WATER. BOIL WATER FOR TEN MINUTES OR MORE.

2 REMOVE THE RENDERED-OUT SUET. PLACE CUSTARD CUP IN REFRIGERATOR. AFTER COOLING YOU CAN LIFT OFF THE FAT AS A SOLID DISK.



1 CRUSH A COUPLE OF PEANUTS. DROP THEM IN A TEST TUBE. COVER THEM WITH CARBON TETRACHLORIDE AND LET STAND ABOUT 5 MINUTES. POUR A FEW DROPS ON A PIECE OF PAPER. LET CARBON TETRACHLORIDE EVAPORATE.

2 LOOK AT THE PAPER AGAINST THE LIGHT. THE ALMOST TRANSPARENT "GREASE SPOT" IS A TEST FOR FAT.

TEST FOR GLYCEROL (GLYCERIN)

IN A DRY TEST TUBE ADD $\frac{1}{4}$ TEASPOON SODIUM BISULFATE TO 1 ml VEGETABLE OIL AND HEAT GENTLY. WAFT THE IRRITATING ODOR TOWARD YOU AND SNIFF CAUTIOUSLY. THE SMELL IS FROM ACROLEIN WHICH IS PRODUCED BY BREAKING DOWN THE GLYCERIN IN THE FAT.



THE NaHSO_4 SETS THE GLYCEROL FREE, THEN IMMEDIATELY DESTROYS IT. GLYCEROL LOSES WATER AND TURNS INTO ILL-SMELLING ACROLEIN:

$$\text{C}_3\text{H}_5(\text{OH})_3 \rightarrow \text{C}_3\text{H}_4\text{O} + 2\text{H}_2\text{O}$$

FATTY ACIDS



DISSOLVE $\frac{1}{2}$ TEASPOON SOAP POWDER OR FLAKES IN 50 ml WARM WATER. ADD 10 ml HYDROCHLORIC ACID. YOU WILL GET LUMPS OF THE FATTY ACIDS OF WHICH SOAP IS THE SODIUM SALT—MOSTLY STEARIC AND PALMITIC ACIDS. STEARIC ACID IS ADDED TO PARAFFIN IN THE MAKING OF CANDLES.



IN THE OLD-FASHIONED SOAP KETTLE, ONLY A FEW GALLONS OF SOAP COULD BE MADE AT ONE TIME.

IN MODERN SOAP PANS, SEVERAL STORIES HIGH, UP TO 100 TONS OF FAT CAN BE TURNED INTO SOAP.

Soap and Soap Making

WHENEVER YOUR HANDS get dirty, it is an easy matter to get them clean. All you need is water and plenty of $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COONa}$ — $\text{C}_{17}\text{H}_{35}\text{COONa}$ for short, the sodium salt of stearic acid, a substance more generally known as soap.

Soap has been used for cleaning for thousands of years. No one knows who invented it — but the method for making it was passed down from father to son, from mother to daughter. The early soap makers first had to burn wood to get potash (K_2CO_3 — see page 59) or dried seaweed to get soda ash (Na_2CO_3). This was treated with lime to make potassium or sodium hydroxide (KOH or NaOH — see page 45), and this, in turn, was boiled with fat to make soap. Very much the same method is used today — except that the boiling is done in tremendous soap pans under steam pressure.



STRONG SOAP BUBBLES RESULT WHEN YOU ADD GLYCERIN TO THE SOAP SOLUTION. HERE IS A RECIPE: 5 g SOAP, 100 ml WATER, AND 10 ml GLYCERIN.

THIS IS THE WAY SCIENTISTS BELIEVE THAT SOAP ACTS: ONE END OF THE SOAP MOLECULE IS SOLUBLE IN WATER, THE OTHER END IN OIL. WHEN OIL IS SHAKEN UP IN SOAPY WATER, THE OIL DROPS ARE SURROUNDED BY THE SOAP MOLECULES DIPPING THE OIL-DISSOLVING ENDS INTO THE OIL. THE WATER-SOLUBLE ENDS HOLD THE OIL DROPLETS SUSPENDED.

MAKING SOAP

MAKE A WATER BATH BY POURING 1 INCH WATER INTO A TIN CAN.



1 MELT 10 g SHORTENING ("CRISCO" OR SIMILAR PRODUCT) IN A CUSTARD CUP ON THE WATER BATH.

2 DISSOLVE 5 g SODIUM HYDROXIDE (NaOH) IN 15 ml WATER. ADD 15 ml DENATURED ALCOHOL (TO SPEED UP THE ACTION). POUR THIS SOLUTION INTO THE MELTED SHORTENING WHILE STIRRING. CONTINUE HEATING AND STIRRING UNTIL A SMALL SAMPLE DISSOLVES COMPLETELY IN $\frac{1}{2}$ TEST TUBE WATER. THE SOAP MAKING (SAPONIFICATION) IS THEN COMPLETED.

TESTING SOAP AND DETERGENTS

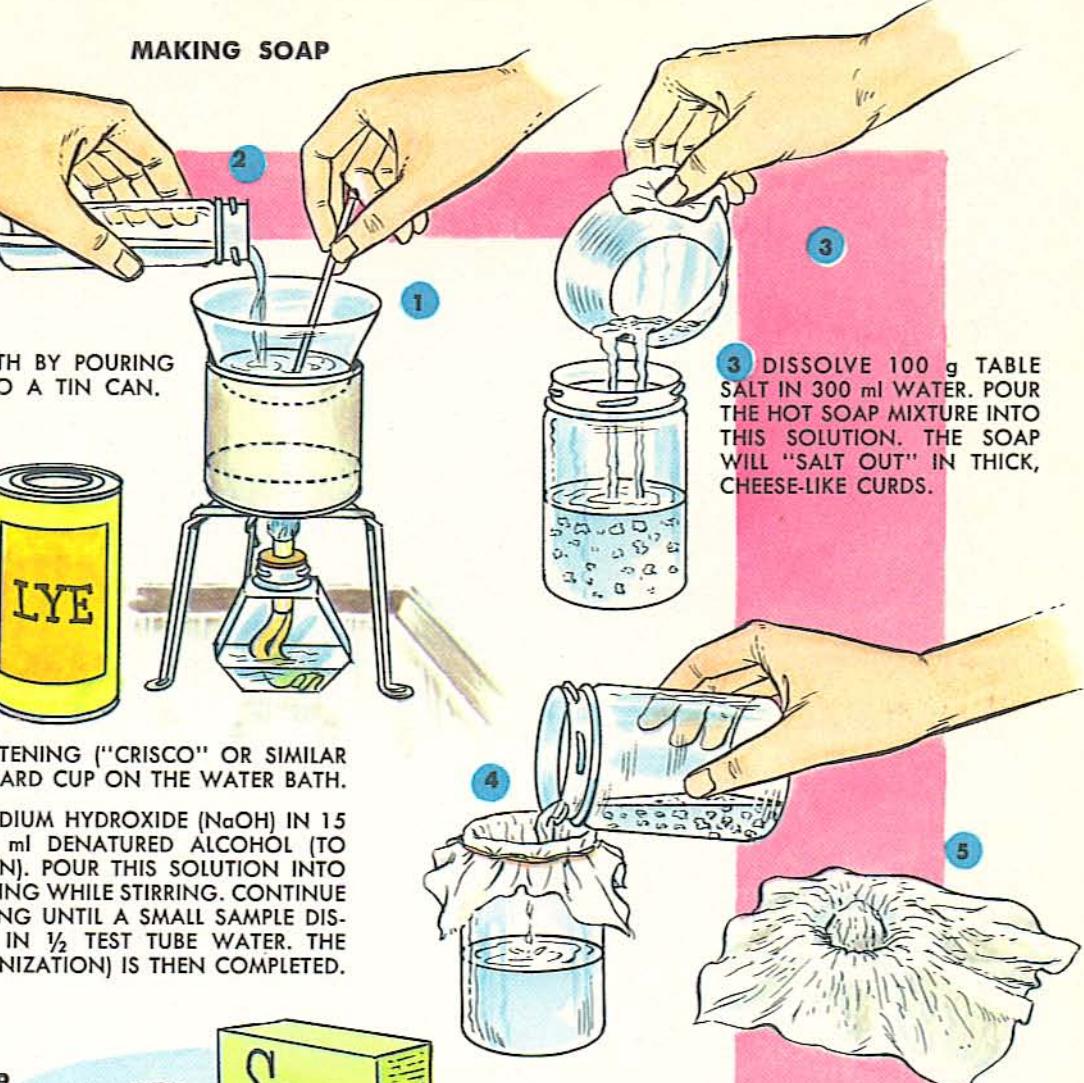
DISSOLVE 1 g OF YOUR HOME-MADE SOAP IN 50 ml LUKE-WARM WATER. ALSO MAKE SOLUTIONS IN 50 ml WATER OF 1 g TOILET SOAP, 1 g SOAP FLAKES, 1 g SOAP POWDER, 1 g POWDERED DETERGENT, AND 1 ml LIQUID DETERGENT.



1 POUR 10 ml OF THE SOAP AND DETERGENT SOLUTIONS INTO SEPARATE TEST TUBES. TEST EACH SOLUTION FOR ACID AND BASE WITH LITMUS PAPER AND PHENOLPHTHALEIN.

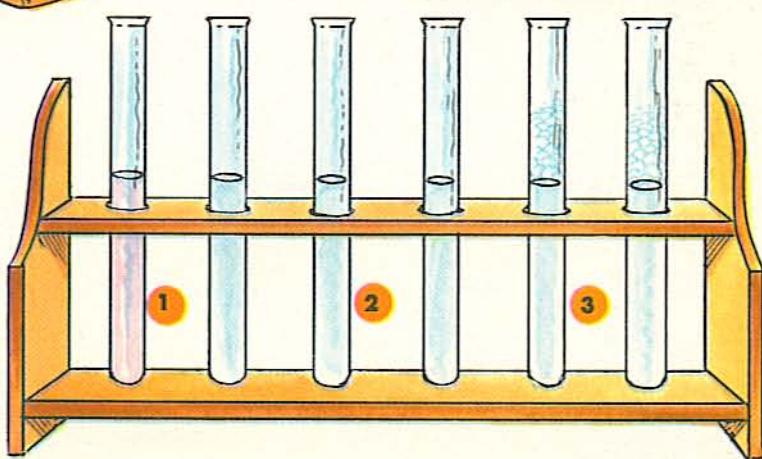
2 SHAKE 5 DROPS OF OIL INTO EACH SOLUTION. NOTE THE DIFFERENCE IN THE WAY THE SOLUTIONS MAKE EMULSION WITH OIL.

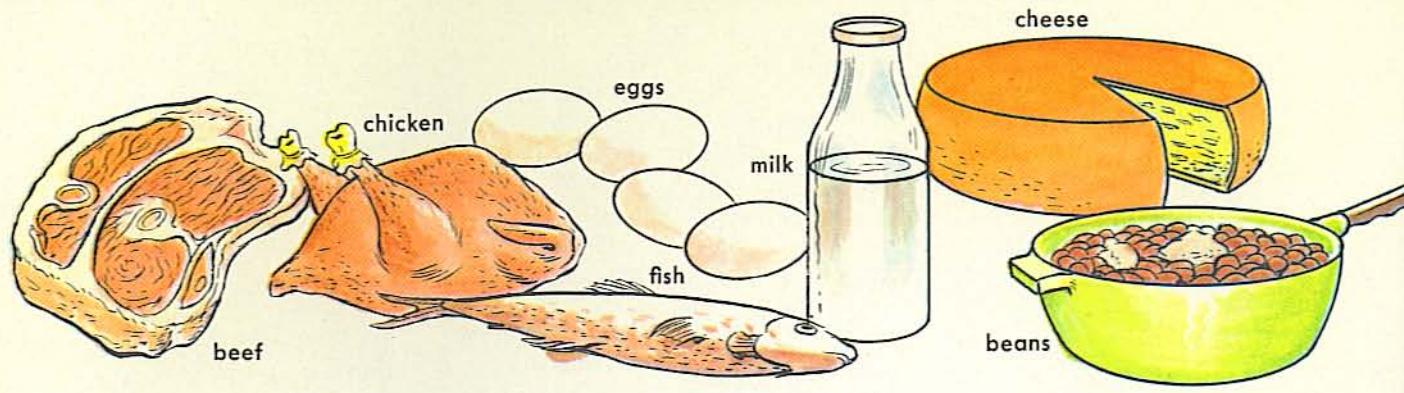
3 AGAIN, POUR 10 ml OF EACH SOLUTION INTO SEPARATE TEST TUBES. ADD 5 ml LIME-WATER TO EACH. SHAKE AND NOTICE THE DIFFERENCE IN THE AMOUNT OF FOAM MADE BY EACH SOLUTION IN THIS "HARD" WATER.



4 TIE A PIECE OF CHEESE CLOTH OVER THE TOP OF A JAR. POUR THE SALT SOLUTION WITH THE SOAP CURDS INTO CHEESE CLOTH AND LET SALT SOLUTION DRAIN OFF. WASH THE SOAP BY POURING TWO TEST TUBES OF ICE-COLD WATER THROUGH IT TO REMOVE MOST OF THE SALT THAT'S STILL ON IT.

5 FINALLY, SQUEEZE OUT THE WATER AND SPREAD OUT THE CHEESE CLOTH TO LET THE SOAP DRY.





Proteins—the Body-Building Foods

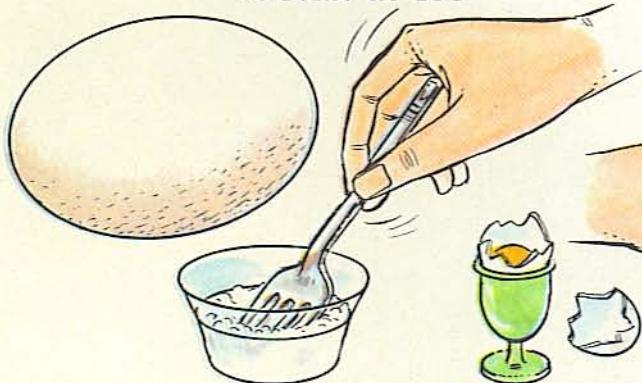
AT ALMOST every meal, we look forward especially to the proteins: ham and eggs for breakfast, hamburgers or frankfurters for lunch, steak or chicken for dinner. We drink milk mostly for the sake of its proteins. Even many of our desserts are protein products — from ice cream to Jell-O.

While most other foodstuffs, such as carbohydrates and fats, consist of carbon, hydrogen, and oxygen,

the proteins also contain nitrogen and, for the most part, sulfur. Their molecules are "giants" compared with the molecules of other chemical compounds. One of them, albumin in egg, has this estimated formula: $C_{696}H_{1125}O_{200}N_{190}S_{18}$.

Not all proteins are edible. You would hardly think of eating hair and nails, furs and feathers — yet these are all proteins. (CONTINUED ON PAGE 99)

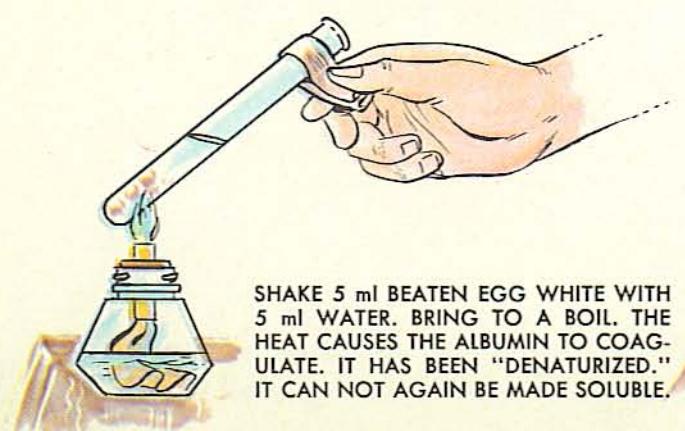
PROTEIN IN EGG



CRACK AN EGG. SEPARATE WHITE FROM YOLK BY LETTING WHITE FLOW INTO A CUP WHILE RETAINING YOLK IN EGG SHELL. BEAT WHITE WITH FORK.

THE PROTEIN IN EGG IS CALLED ALBUMIN

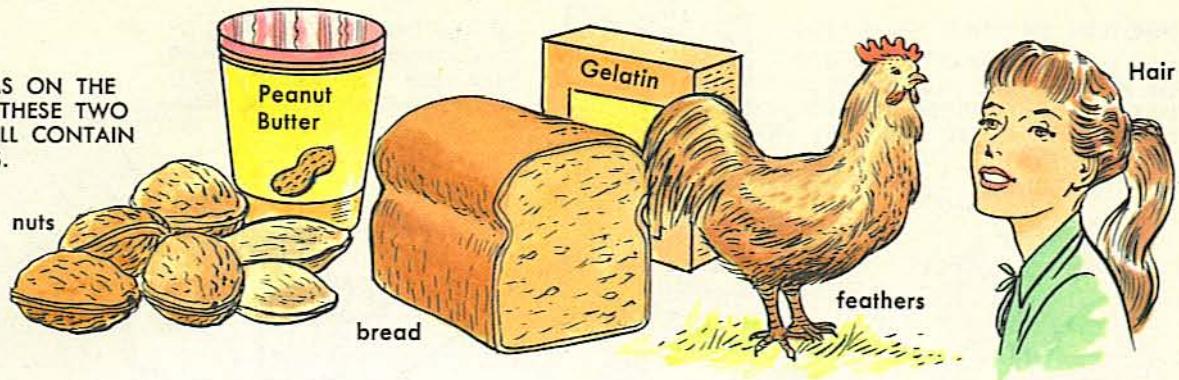
SHAKE 5 ml EGG WHITE WITH 5 ml WATER. ADD 5 ml DENATURED ALCOHOL. THE ALCOHOL CAUSES THE ALBUMIN TO COAGULATE OUT IN WHITE FLECKS.



SHAKE 5 ml BEATEN EGG WHITE WITH 5 ml WATER. BRING TO A BOIL. THE HEAT CAUSES THE ALBUMIN TO COAGULATE. IT HAS BEEN "DENATURIZED." IT CAN NOT AGAIN BE MADE SOLUBLE.

FILL CUSTARD CUP HALF FULL OF WATER. BRING TO A BOIL. POUR IN THE EGG WHITE THAT IS LEFT. IT COAGULATES INTO A FIRM WHITE MASS. THIS METHOD IS USED IN COOKING. IT IS CALLED "POACHING."

THE ITEMS ON THE TOP OF THESE TWO PAGES ALL CONTAIN PROTEINS.



WHAT DOES ALBUMIN CONSIST OF?

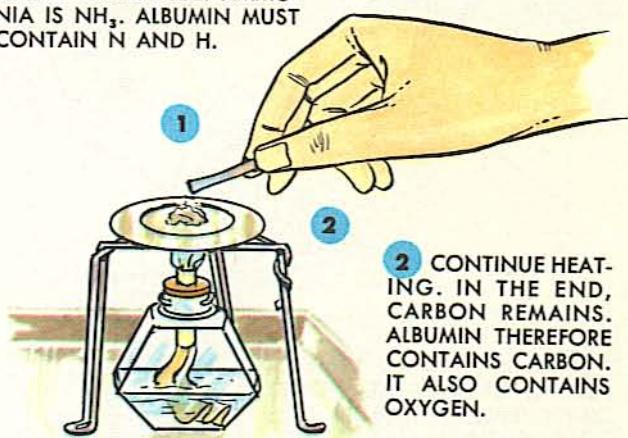


1 DROP A SMALL PIECE OF COAGULATED EGG WHITE INTO A TEST TUBE. COVER IT WITH 5 ml 10% NaOH SOLUTION. HEAT. WHITE GOES IN SOLUTION.

2 POUR A FEW DROPS OF THE EGG WHITE SOLUTION ONTO A BRIGHT SILVER COIN. IN A FEW MINUTES SILVER COIN TURNS BROWNISH-BLACK FROM SILVER SULFIDE, PROVING THAT ALBUMIN CONTAINS SULFUR.

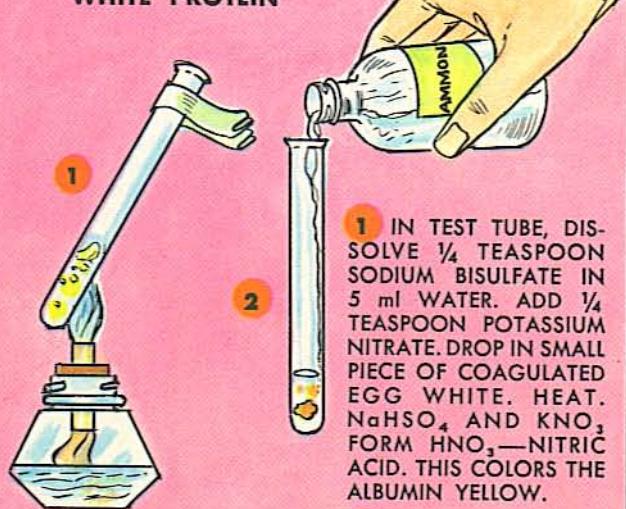
1 PLACE A SMALL PIECE OF COAGULATED EGG WHITE ON A PIECE OF TIN. HEAT. VAPORS SMELL OF AMMONIA AND TURN WETTED RED LITMUS PAPER BLUE. AMMONIA IS NH₃. ALBUMIN MUST CONTAIN N AND H.

ALBUMIN IS FOUND IN EGGS, BLOOD, MILK, AND GRAIN.



2 CONTINUE HEATING. IN THE END, CARBON REMAINS. ALBUMIN THEREFORE CONTAINS CARBON. IT ALSO CONTAINS OXYGEN.

TEST FOR SOLID WHITE PROTEIN

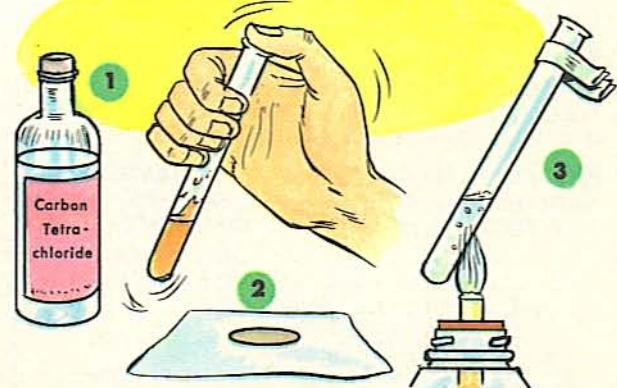


1 IN TEST TUBE, DISSOLVE $\frac{1}{4}$ TEASPOON SODIUM BISULFATE IN 5 ml WATER. ADD $\frac{1}{4}$ TEASPOON POTASSIUM NITRATE. DROP IN SMALL PIECE OF COAGULATED EGG WHITE. HEAT. NaHSO₄ AND KNO₃ FORM HNO₃—NITRIC ACID. THIS COLORS THE ALBUMIN YELLOW.

2 ADD HOUSEHOLD AMMONIA. THE YELLOW ALBUMIN TURNS BRIGHT ORANGE.

TEST CHEESE, WOOL, CHICKEN, LIMA BEANS THE SAME WAY.

WHAT DOES EGG YOLK CONTAIN?



Be careful not to breathe fumes.

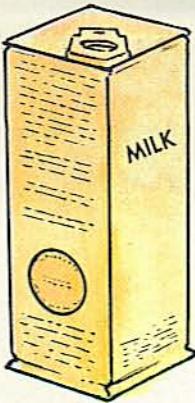
1 SHAKE 5 ml OF THE YOLK WITH 5 ml CARBON TETRACHLORIDE TO FIND OUT IF IT CONTAINS FAT.

2 POUR A LITTLE OUT ON PAPER. LET CARBON TETRACHLORIDE EVAPORATE. GREASE SPOT REMAINS.

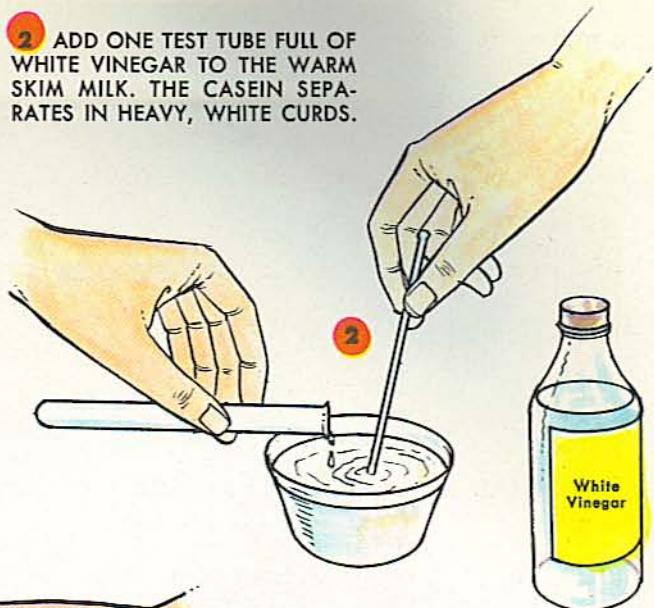
3 HEAT THE MIXTURE. YOU GET A WHITE COAGULATION. YOLK AND WHITE BOTH CONTAIN ALBUMIN.

PROTEIN IN MILK

MILK IS AN IMPORTANT SOURCE OF PROTEIN. THE PROTEIN IN MILK IS CALLED CASEIN. CHEESE IS SPECIALLY TREATED CASEIN.



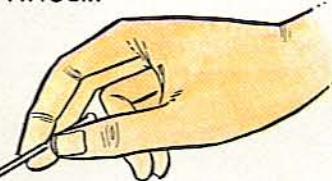
2 ADD ONE TEST TUBE FULL OF WHITE VINEGAR TO THE WARM SKIM MILK. THE CASEIN SEPARATES IN HEAVY, WHITE CURDS.



1 POUR $\frac{1}{2}$ CUP SKIM MILK (OR MIXTURE OF 8 TEASPOONS SKIM MILK POWDER AND $\frac{1}{2}$ CUP WATER) INTO A CUSTARD CUP. HEAT GENTLY UNTIL IT FEELS JUST SLIGHTLY WARM WHEN YOU TEST IT WITH A FINGER.



3 TIE A PIECE OF CHEESE CLOTH OVER A JAR. POUR THE CURDLED MILK INTO THE CHEESE CLOTH. LET LIQUID (WHEY MIXED WITH VINEGAR) RUN OUT. KEEP THE LIQUID.



4 FOLD CHEESE CLOTH UP AROUND THE CASEIN. DIP THE BAG IN WATER AND SQUEEZE SEVERAL TIMES TO WASH OUT WHEY AND VINEGAR.



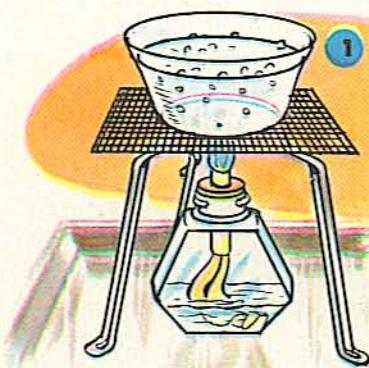
5 SQUEEZE THE CASEIN ALMOST DRY. SPREAD OUT THE CHEESE CLOTH TO LET THE CASEIN DRY.



WHAT ELSE IS IN MILK?

1 POUR THE VINEGAR-MIXED WHEY INTO A CUSTARD CUP AND BRING IT TO A BOIL. YOU WILL SEE TINY WHITE FLECKS. THESE ARE ALBUMIN COAGULATED OUT BY THE HEAT.

2 FILTER THE WHEY. TEST THE FILTRATE WITH FEHLING SOLUTION (SEE PAGE 85). MILK SUGAR GIVES RED Cu_2O PRECIPITATE.



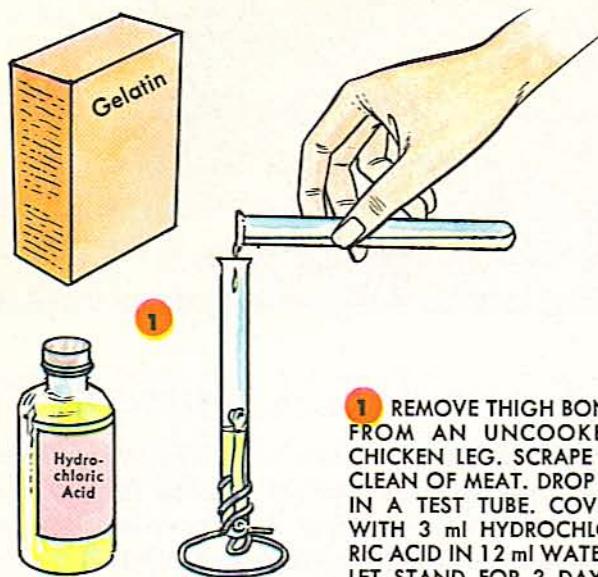
MAKING CASEIN GLUE

SOFTEN 4 g CASEIN WITH 4 ml WATER. SHAKE UP 1 g CALCIUM OXIDE IN 4 ml WATER. POUR THE CALCIUM OXIDE MIXTURE INTO THE CASEIN WHILE STIRRING. THE RESULTING SMOOTH PASTE IS AN EXCELLENT GLUE FOR PAPER AND FOR WOOD.



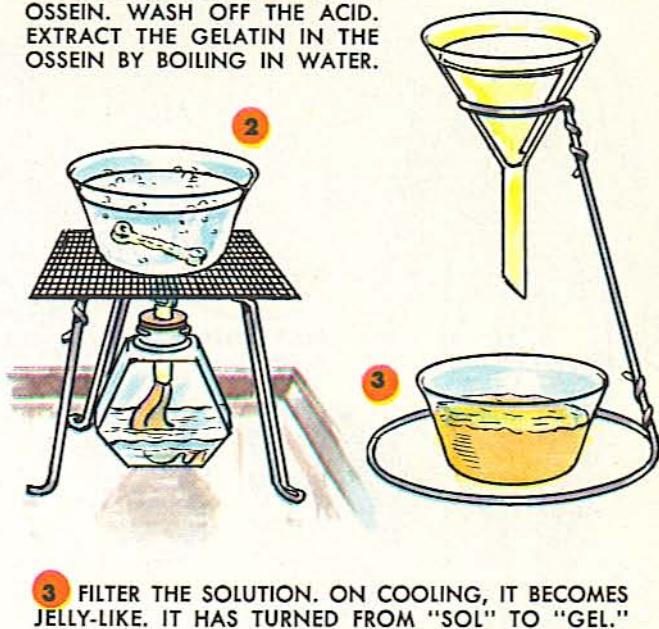
GELATIN IS A PROTEIN

GELATIN IS MADE FROM ANIMAL BONES AND HIDES.



1 REMOVE THIGH BONE FROM AN UNCOOKED CHICKEN LEG. SCRAPE IT CLEAN OF MEAT. DROP IT IN A TEST TUBE. COVER WITH 3 ml HYDROCHLORIC ACID IN 12 ml WATER. LET STAND FOR 3 DAYS.

2 THE DILUTED HYDROCHLORIC ACID DISSOLVES THE CALCIUM SALTS IN THE BONE, LEAVING A FLEXIBLE SUBSTANCE CALLED OSSEIN. WASH OFF THE ACID. EXTRACT THE GELATIN IN THE OSSEIN BY BOILING IN WATER.



3 FILTER THE SOLUTION. ON COOLING, IT BECOMES JELLY-LIKE. IT HAS TURNED FROM "SOL" TO "GEL."

Proteins—Continued

You are certain to be familiar with three common, pure proteins: albumin in eggs, casein in milk, and gelatin.

ALBUMIN — Egg white contains around 13 per cent albumin — from Latin *albus*, white.

When you shake up egg white with water, you get what looks like an almost clear solution. But this is not a "true" solution such as you get when you dissolve salt or sugar — it is another kind of "solution" called a "colloidal dispersion." For more about colloidal dispersions, see pages 100-101.

As long as egg white is kept cool, it stays transparent and almost liquid. But what happens when you heat it? You know from frying or boiling an egg: It hardens — coagulates — into a solid white mass which you can not again "dissolve" in water. The chemist's term for this change is "denaturation" — the egg white has changed its nature.

CASEIN — Casein is another protein that goes into your diet. Some of the casein you drink (milk), some of it you eat (ice cream and cheese).

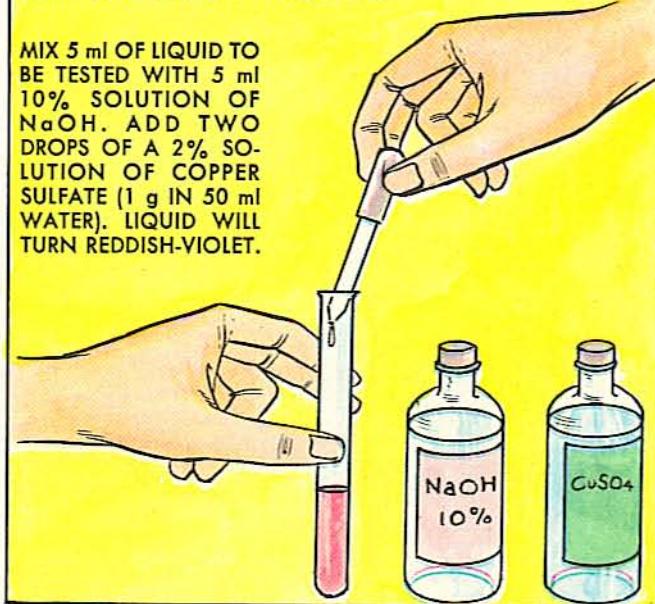
In cheese making, the casein is separated from the liquid part of the milk — the whey. It is then pressed and stored until ripe. The flavors of cheeses are caused mostly by esters created during the ripening.

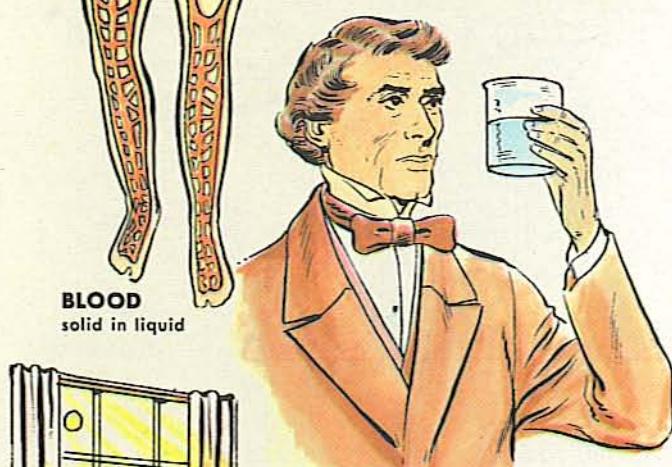
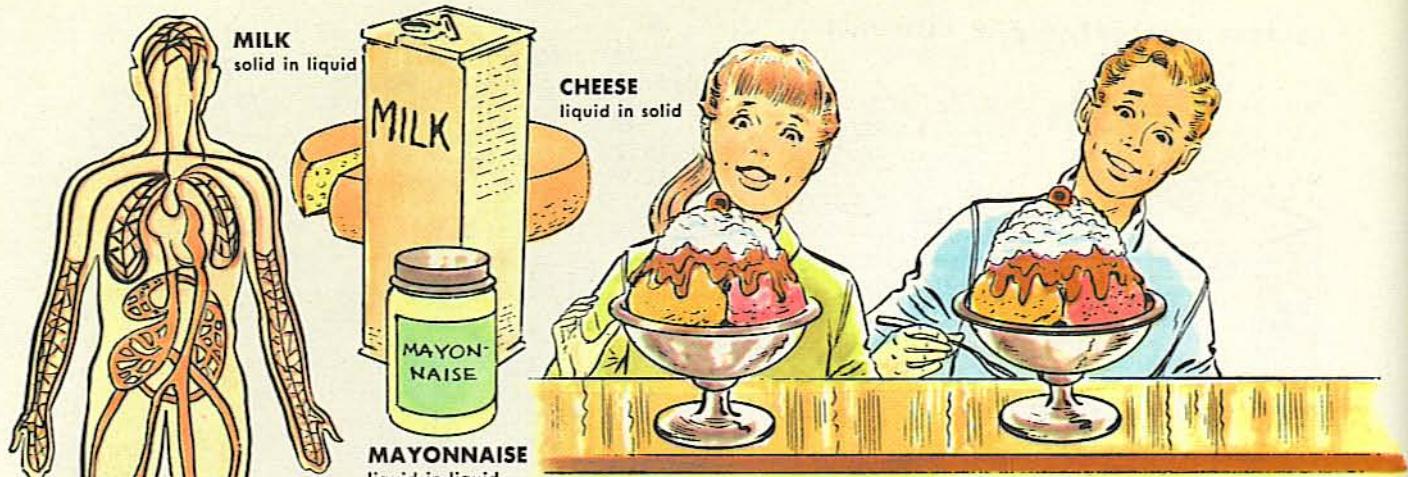
GELATIN — Gelatin is a protein made from animal skins and bones, horns and hooves.

Gelatin behaves in a peculiar manner with water. In cold water it merely swells, but in hot water it "dissolves" readily, forming a colloidal dispersion. As long as you keep this dispersion warm, it remains in a liquid form that is called a "sol." When cooled, it turns into a jelly-like form called a "gel."

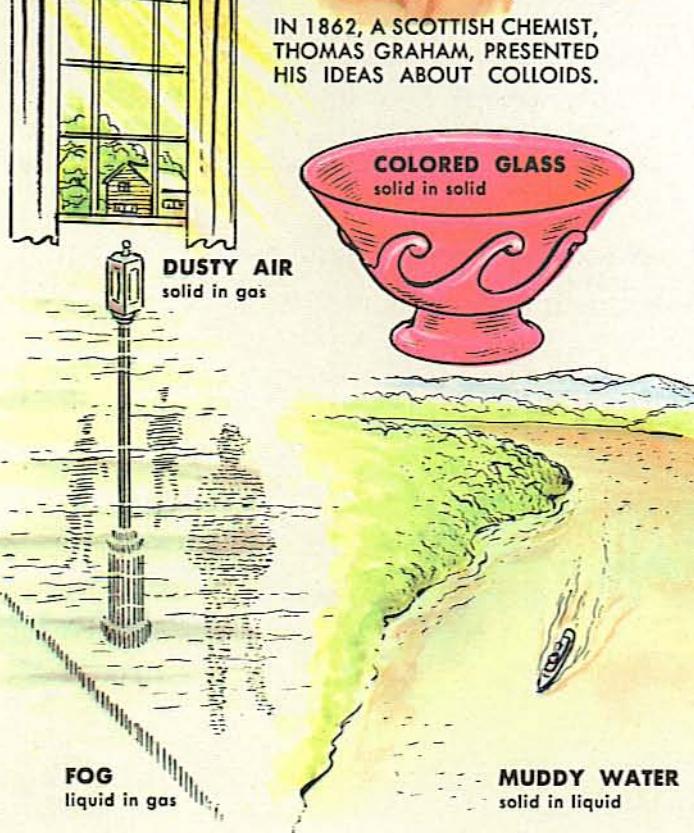
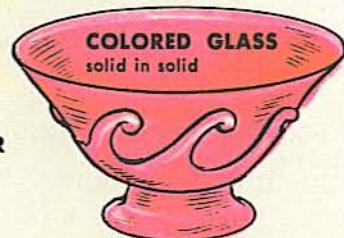
TEST FOR LIQUID PROTEINS

MIX 5 ml OF LIQUID TO BE TESTED WITH 5 ml 10% SOLUTION OF NaOH. ADD TWO DROPS OF A 2% SOLUTION OF COPPER SULFATE (1 g IN 50 ml WATER). LIQUID WILL TURN REDDISH-VIOLET.





IN 1862, A SCOTTISH CHEMIST,
THOMAS GRAHAM, PRESENTED
HIS IDEAS ABOUT COLLOIDS.



Colloidal Dispersions

WOULD YOU WALK up to a soda fountain and order "a triple, chocolate-flavored colloidal dispersion"? No? Yet that's what you do when you ask for a chocolate sundae. Ice cream is a colloidal dispersion of solids in a liquid; so is chocolate syrup. Whipped cream is a colloidal dispersion of air in a liquid.

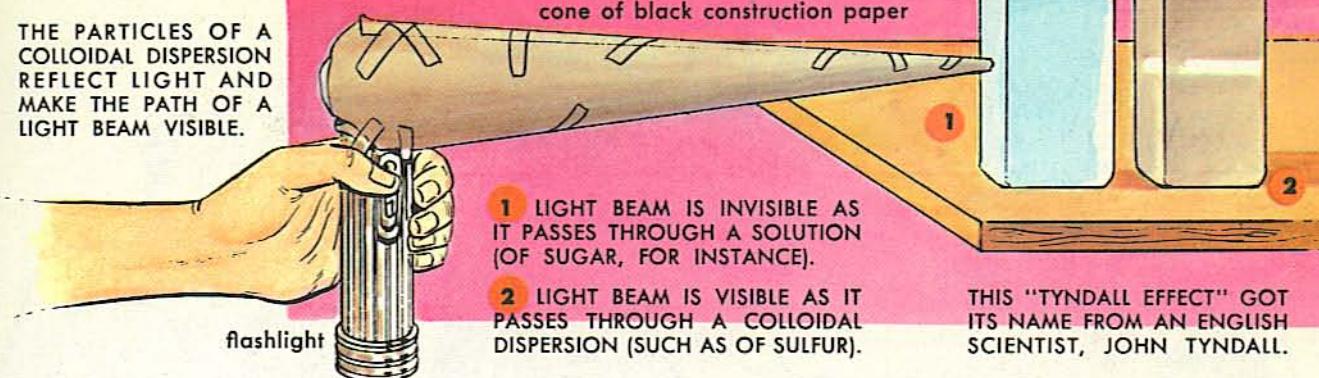
It was a Scot, Thomas Graham, who explained colloids, in 1862. He noticed that some solutions passed through parchment paper, others didn't. He discovered that most of those that filtered through were of chemicals that formed crystals — he called them "crystalloids." The others he called "colloids" — from Greek *kolloides*, glue-like.

When a colloid is mixed with water, it does not form a solution but a dispersion. In a solution, the molecules of the dissolved chemical are too small to be seen even with the strongest microscope. In a colloidal dispersion, the much larger particles can be seen in an ultra-microscope — and you can see them as a light effect when you pass a light beam through the dispersion.

Colloidal dispersions can be formed by gases, liquids, and solids. Eight combinations are possible:

LIGHT TEST FOR COLLOIDS

THE PARTICLES OF A COLLOIDAL DISPERSION REFLECT LIGHT AND MAKE THE PATH OF A LIGHT BEAM VISIBLE.



gases in liquids and in solids; liquids in gases, in other liquids, and in solids; solids in gases, in liquids, and in other solids. The illustrations show some of these possibilities — you can think of many others.

The colloidal state is important to life. It is the way in which we get most of our food, the way we digest it, and the way the blood carries nourishment throughout our bodies.

IN PEPTIZATION, LARGE PARTICLES ARE BROKEN DOWN INTO SMALLER PARTICLES OF COLLOIDAL SIZE.

1 SHAKE UP 1 g STARCH WITH 100 ml COLD WATER. IF LEFT UNDISTURBED, STARCH QUICKLY SETTLES TO BOTTOM.

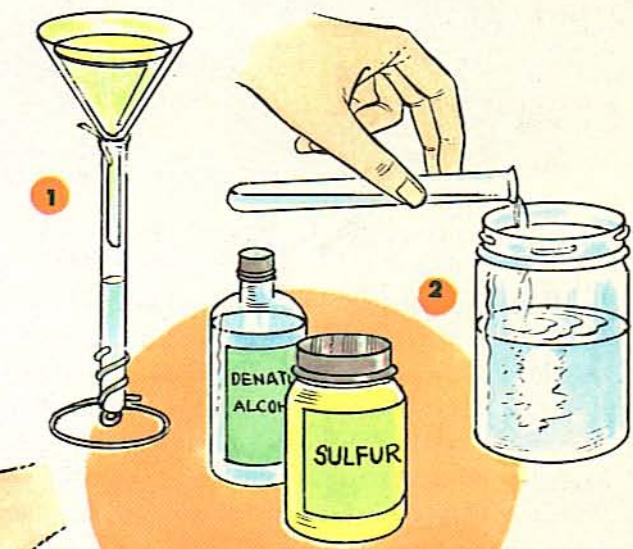
2 POUR THE MIXTURE OF STARCH AND WATER INTO A CUSTARD CUP. BRING TO A BOIL, THEN COOL. STARCH HAS NOW FORMED A COLLOIDAL DISPERSION.



IN COAGULATION, MANY MOLECULES OF A SUBSTANCE JOIN TOGETHER INTO PARTICLES OF COLLOIDAL SIZE.

1 SHAKE 1 g FLOWERS OF SULFUR WITH 10 ml DENATURED ALCOHOL. A SMALL AMOUNT OF SULFUR GOES IN SOLUTION. FILTER OUT THE UNDISSOLVED SULFUR.

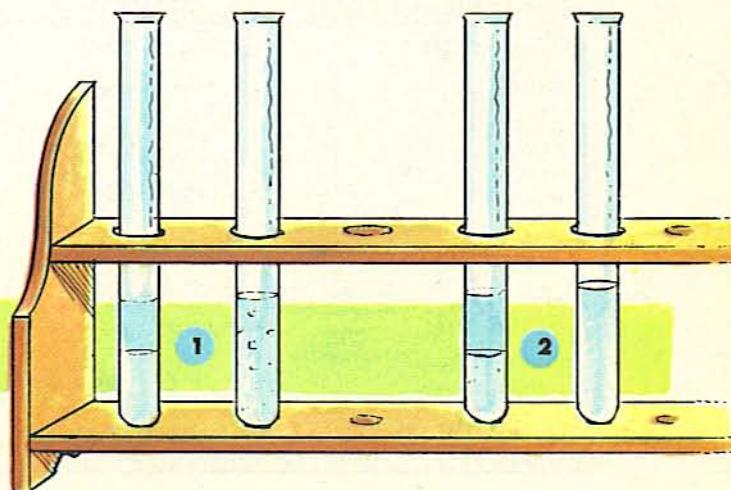
2 POUR THE ALCOHOLIC SOLUTION OF SULFUR INTO A LARGE AMOUNT OF WATER. YOU WILL SEE A WHITE CLOUD OF FINELY DISPERSED COLLOIDAL SULFUR.



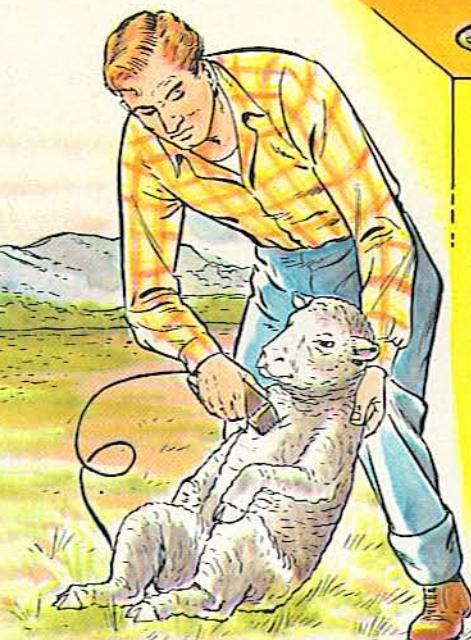
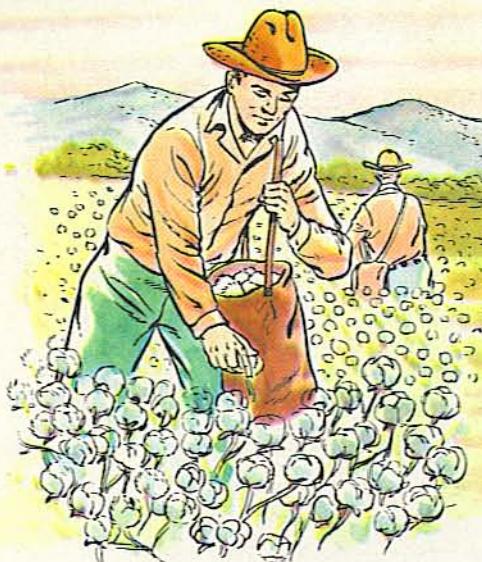
IN EMULSIFICATION, ONE LIQUID IS DISPERSED IN ANOTHER. EMULSIONS CAN BE TEMPORARY OR PERMANENT.

1 SHAKE 5 ml KEROSENE AND 5 ml WATER TOGETHER IN A TEST TUBE. LET STAND FOR A SHORT TIME. LIQUIDS SEPARATE. THE EMULSION WAS TEMPORARY.

2 SHAKE 5 ml KEROSENE WITH SOLUTION OF $\frac{1}{2}$ g SOAP IN 5 ml WARM WATER. THEN LET STAND. LIQUIDS DO NOT SEPARATE. THIS IS A PERMANENT EMULSION.



VEGETABLE FIBERS COME FROM PLANTS: COTTON, FLAX (LINEN).



WOOL AND SILK (FROM SILK WORMS) ARE ANIMAL FIBERS.



ARTIFICIAL FIBERS ARE VERY POPULAR: NYLON, DACRON, ORLON.

Natural and Artificial Fibers

IT WOULD BE TOUGH to get along without fibers in the modern world. Fibers are spun into thread, and the thread is made into cloth for clothing and bed-sheets, curtains and towels, and many other things around the house. Fibers also go into such articles as string and rope, rugs and auto tires. Some of these fibers come from the plant and animal worlds, others

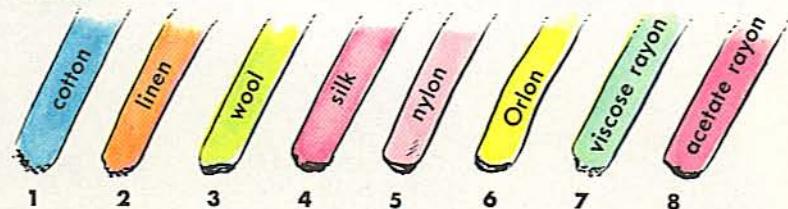
are manufactured synthetically with coal or petroleum for their starting point.

Fibers belong in different groups of chemical compounds. Animal fibers are proteins; vegetable fibers are cellulose. Artificial fibers such as nylon, Orlon and Dacron are very complex chemical compounds and have enormously long molecules.



BURNING TEST FOR FIBERS

CUT HALF-INCH STRIPS OF DIFFERENT FABRICS. IGNITE EACH STRIP IN TURN. NOTICE HOW FABRIC BURNS, THE SMELL, AND ASH LEFT BEHIND.



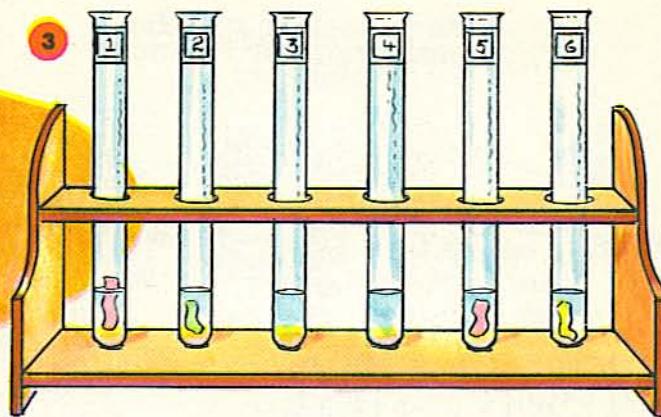
KIND	FLAME	SMELL	ASH
1 COTTON	Rapid, yellow flame	Like burning paper	Small, fine, gray
2 LINEN	Fairly fast, yellow flame	Like cotton	Like cotton
3 WOOL	Slow, sizzling flame	Like burning hair	Hollow, black bead, easy to crush
4 SILK	Small, slow flame	Like wool	Shiny, round bead, easy to crush
5 NYLON	Melts; no flame	Like celery	Melts to black bead, hard to crush
6 ORLON	Melts and burns	Like broiled fish	Black bead, hard to crush
7 VISCOS RAYON	Rapid, yellow flame	Like cotton	Like cotton
8 CELLULOSE ACETATE	Rapid flame with small sparks; melts	Like vinegar	Black bead, hard to crush

CHEMICAL TESTS FOR FIBERS

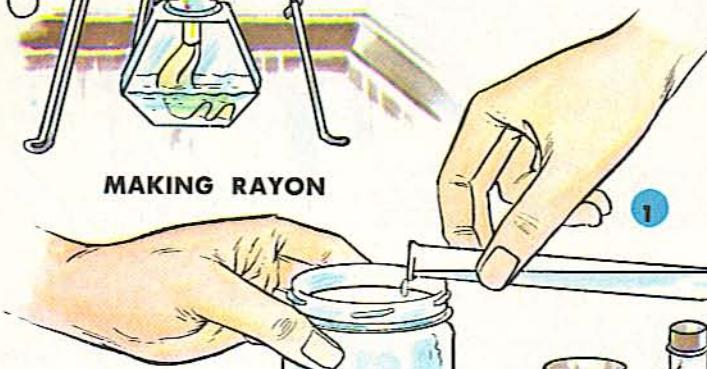


1 POUR 5 ml 10% NaOH SOLUTION INTO EACH OF SIX TEST TUBES AND DROP IN STRIPS OF SIX KINDS OF CLOTH. MARK EACH TEST TUBE SO YOU KNOW WHAT IS IN EACH.

- 2 PLACE TEST TUBES IN A CAN OF HOT WATER. BOIL FOR TEN MINUTES.
- 3 PLACE TEST TUBES IN STAND. NOTE RESULT. WOOL AND SILK HAVE DISSOLVED, THE OTHERS NOT.



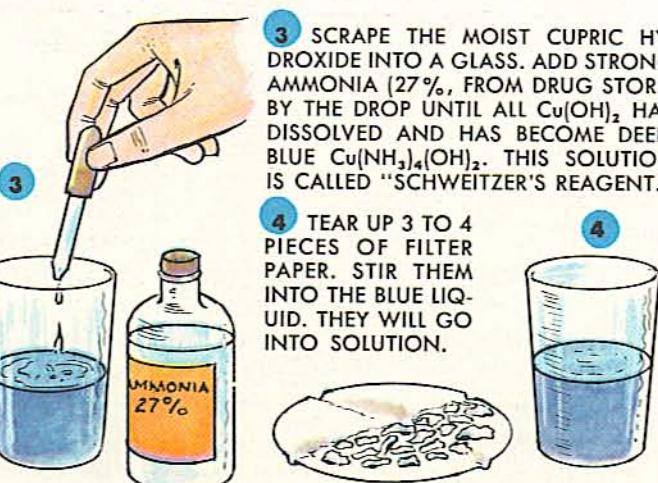
TRY SAME EXPERIMENT WITH STRONG HCl. SILK AND RAYON DISSOLVE. BUT THE WOOL DOES NOT.



MAKING RAYON

RAYON IS MADE BY "DIGESTING" CELLULOSE IN CUPRAMMONIUM AND THEN SETTING IT FREE AGAIN.

1 TO MAKE CUPRAMMONIUM SOLUTION, FIRST DISSOLVE 10 g COPPER SULFATE IN 100 ml WATER IN A PINT JAR. ADD 10% NaOH SOLUTION UNTIL NO MORE LIGHT-BLUE CUPRIC HYDROXIDE FORMS. LET STAND. POUR WATER OFF PRECIPITATE. RE-FILL THE JAR WITH WATER. AGAIN LET STAND. AGAIN POUR WATER OFF PRECIPITATE. REPEAT THIS WASHING PROCESS HALF A DOZEN TIMES.



3 SCRAPE THE MOIST CUPRIC HYDROXIDE INTO A GLASS. ADD STRONG AMMONIA (27%, FROM DRUG STORE) BY THE DROP UNTIL ALL $\text{Cu}(\text{OH})_2$ HAS DISSOLVED AND HAS BECOME DEEP-BLUE $\text{Cu}(\text{NH}_3)_4(\text{OH})_2$. THIS SOLUTION IS CALLED "SCHWEITZER'S REAGENT."

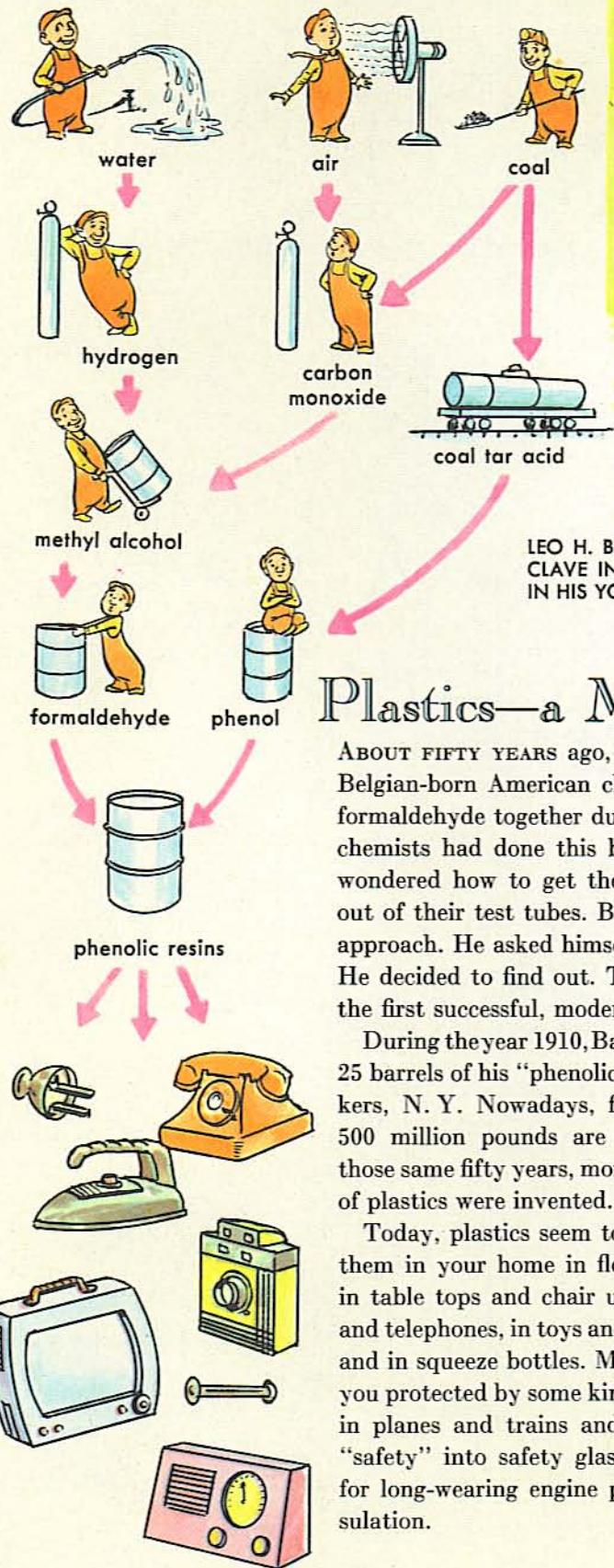
4 TEAR UP 3 TO 4 PIECES OF FILTER PAPER. STIR THEM INTO THE BLUE LIQUID. THEY WILL GO INTO SOLUTION.

MAKE APPARATUS AS SHOWN BELOW, WITH GLASS TUBE ENDING IN FINE JET TIP. POUR PAPER SOLUTION INTO BOTTLE.



5 PLACE THE JET TIP JUST BELOW THE SURFACE OF A MIXTURE OF 10 ml HYDRO-CHLORIC ACID AND 500 ml WATER. BLOW. AS BLUE LIQUID STREAMS OUT INTO THE DILUTED ACID, IT TURNS INTO WHITISH STRAND OF RAYON THAT SETTLES ON BOTTOM.

THE MAKING OF A TYPICAL THERMOSETTING PLASTIC PHENOLICS



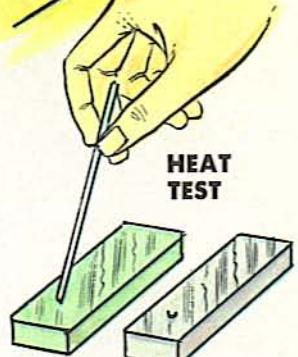
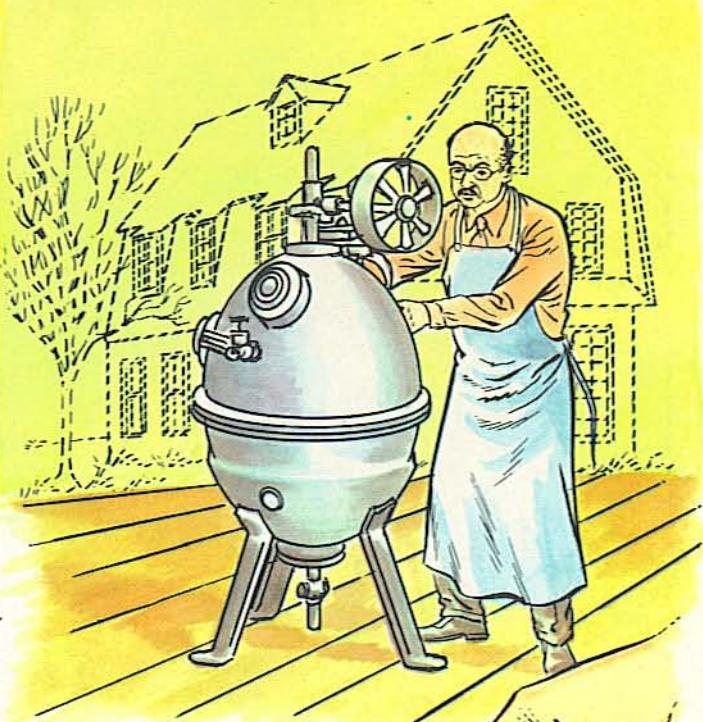
LEO H. BAEKELAND WITH THE AUTO-CLAVE IN WHICH HE MADE BAKELITE IN HIS YONKERS, N. Y., LABORATORY.

Plastics—a Modern Giant

ABOUT FIFTY YEARS ago, Dr. Leo H. Baekeland, a Belgian-born American chemist, mixed phenol and formaldehyde together during an experiment. Other chemists had done this before Baekeland and had wondered how to get the messy goo that resulted out of their test tubes. But Baekeland had another approach. He asked himself, "What is it good for?" He decided to find out. The result was Bakelite—the first successful, modern plastic.

During the year 1910, Baekeland produced less than 25 barrels of his "phenolic" plastic in a barn in Yonkers, N. Y. Nowadays, fifty years later, close to 500 million pounds are produced yearly. During those same fifty years, more than a dozen other types of plastics were invented.

Today, plastics seem to be everywhere. You find them in your home in flooring and wall coverings, in table tops and chair upholstery, in TV cabinets and telephones, in toys and games, in rigid containers and in squeeze bottles. Much of your food comes to you protected by some kind of plastic. They are used in planes and trains and cars. A plastic puts the "safety" into safety glass. Other plastics are used for long-wearing engine parts and for electrical insulation.



HEAT TIP OF GLASS ROD SLOWLY IN FLAME OF ALCOHOL BURNER. PRESS HOT TIP AGAINST PLASTIC. IT MAKES A DENT IN THERMOPLASTIC, NOT IN THE THERMOSETTING.



HOLD SMALL PIECE OF A PLASTIC IN FLAME. NOTE HOW IT BURNS.

MOST THERMOSETTING PLASTICS GIVE OFF STRONG ODOR BUT DO NOT BURN. MOST THERMOPLASTICS BURN BUT SOME OF THEM STOP BURNING WHEN REMOVED FROM FLAME.

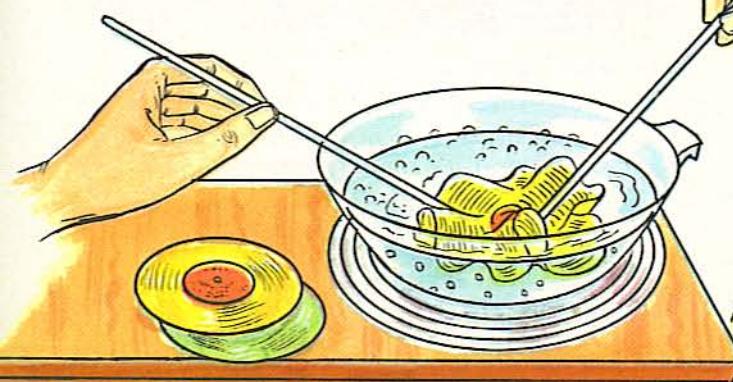
Plastics are made from a few simple raw materials — some just from water, air, and coal, others with the help of petroleum or natural gas, limestone and salt. The plastics chemist breaks down the comparatively simple molecules of these materials, then builds them up anew into very complex molecules.

Plastics may be divided into two main groups according to their special properties. One group consists of the thermosetting plastics. These can be molded by heat and pressure, but can not be remelted and remolded. They are along the lines of egg white which, once set by heat, stays set. The phenolics and ureas are important thermosetting plastics.

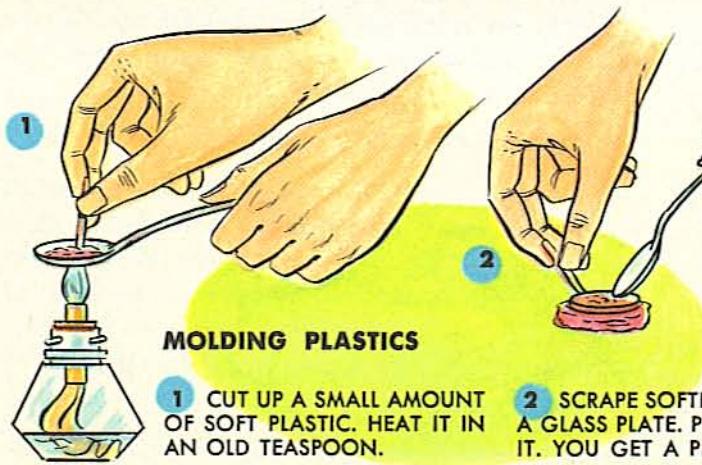
The other group contains the thermoplastics. These are soft when heated, hard when cooled, but can be softened and hardened repeatedly. You can compare them to sulfur and candle wax. The polyethylenes, polystyrenes, vinyls, and acrylics are in the thermoplastics "family."

HEAT SHAPING. THERMOPLASTICS BECOME SOFT WHEN HEATED. YOU CAN THEN SHAPE THEM AT WILL.

BRING A POT OF WATER TO A BOIL. DROP IN AN OLD VINYL RECORD. WHEN SOFT, SHAPE IT WITH TWO LONG STICKS. IT BECOMES HARD AGAIN WHEN IT IS REMOVED FROM THE HOT WATER AND COOLED.



1

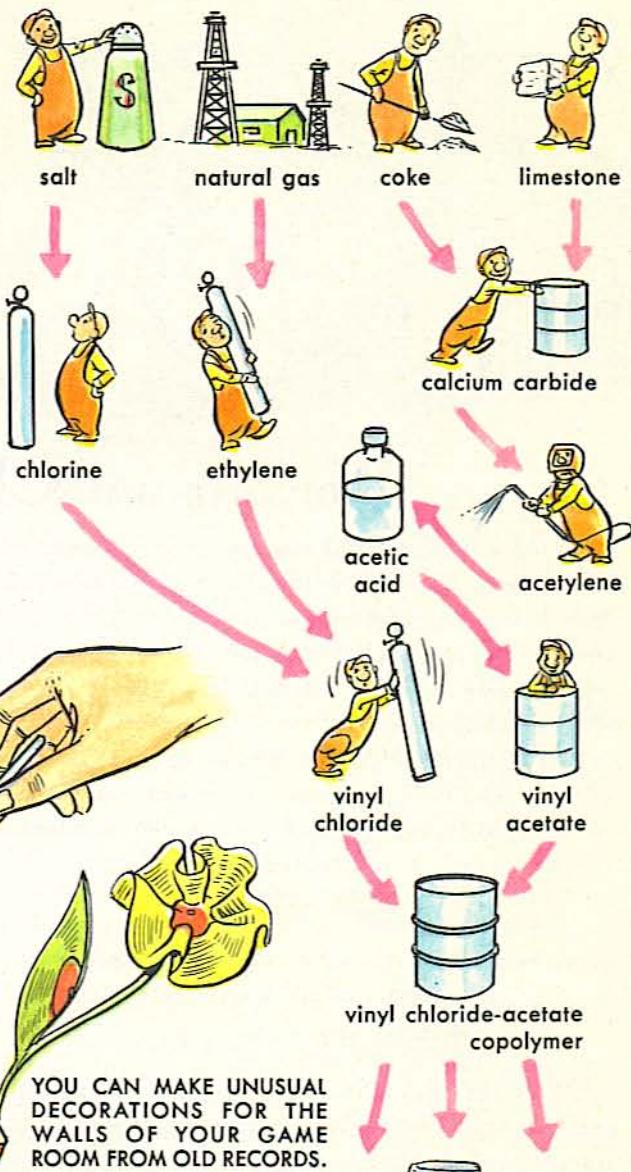


MOLDING PLASTICS

1 CUT UP A SMALL AMOUNT OF SOFT PLASTIC. HEAT IT IN AN OLD TEASPOON.

2 SCRAPE SOFTENED PLASTIC ONTO A GLASS PLATE. PRESS A PENNY INTO IT. YOU GET A PERFECT MOLD.

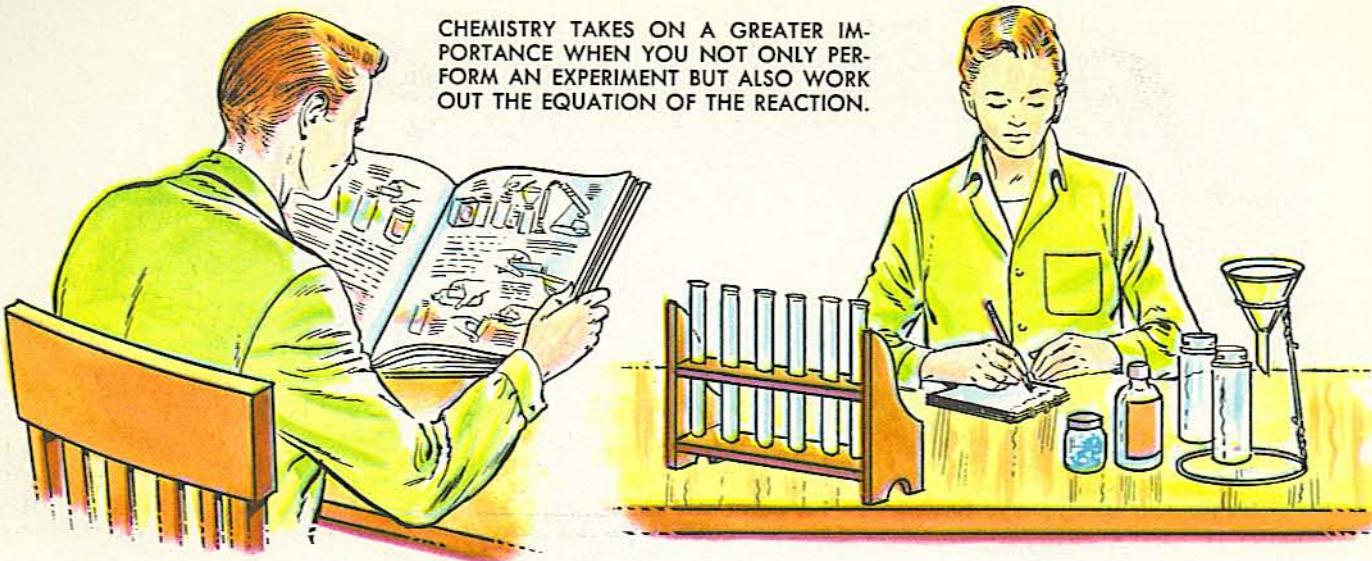
THE MAKING OF A TYPICAL THERMOPLASTIC VINYL



YOU CAN MAKE UNUSUAL DECORATIONS FOR THE WALLS OF YOUR GAME ROOM FROM OLD RECORDS.



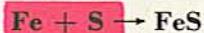
CHEMISTRY TAKES ON A GREATER IMPORTANCE WHEN YOU NOT ONLY PERFORM AN EXPERIMENT BUT ALSO WORK OUT THE EQUATION OF THE REACTION.



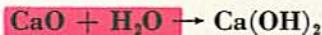
Working out Chemical Equations

YOU HAVE DONE a great number of experiments by now. You have worked with gases, liquids, and solids. You have precipitated and decanted, filtered and distilled. As you think back over the experiments you will discover that they fall into four main groups of chemical reactions.

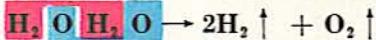
The simplest of these reactions is the DIRECT COMBINATION. In this, two or more substances combine to form a single more complex substance, as when iron and sulfur form iron sulfide:



or when quicklime (calcium oxide) reacts with water to make slaked lime (calcium hydroxide):



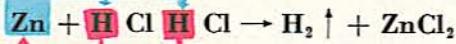
DECOMPOSITION is the opposite of chemical combination. In this, a substance is broken down into simpler substances. This was the case when you separated the two elements found in water:



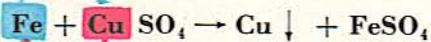
or when you made oxygen from hydrogen peroxide:



In a SINGLE DISPLACEMENT, one element takes the place of another in a compound, as when you made hydrogen from zinc and hydrochloric acid:



or when you set copper free by dropping a nail in a solution of copper sulfate:



In a DOUBLE DISPLACEMENT, the two compounds change partners with each other. Think of the time when you precipitated silver chloride from solutions of salt and silver nitrate:



or when you mixed Epsom salt and washing soda:



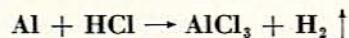
In studying the chemical shorthand above, you notice that, in every instance, there is an equal number of atoms of each element on either side of the arrow that indicates that a reaction takes place. Because of this equal arrangement, these chemical descriptions are called equations.

Many of these equations are scattered throughout this book. Many more are found in advanced chemistry textbooks. But very often, a chemist has to work out an equation from scratch.

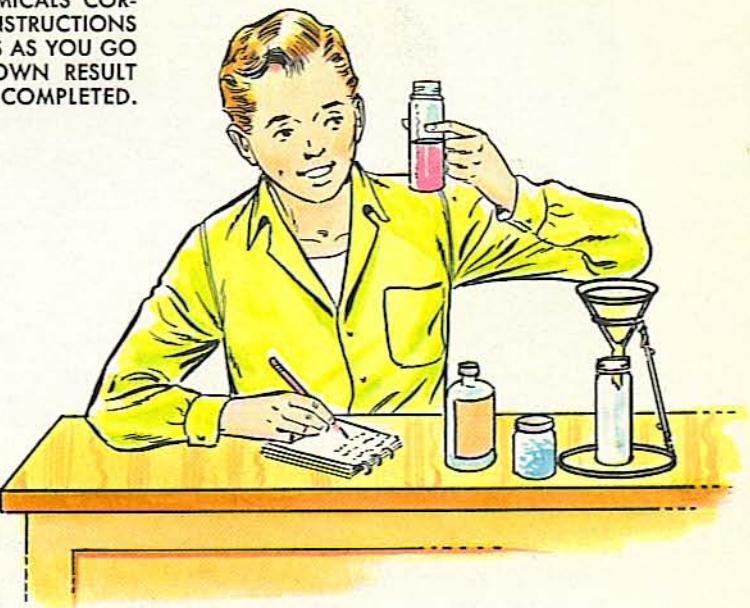
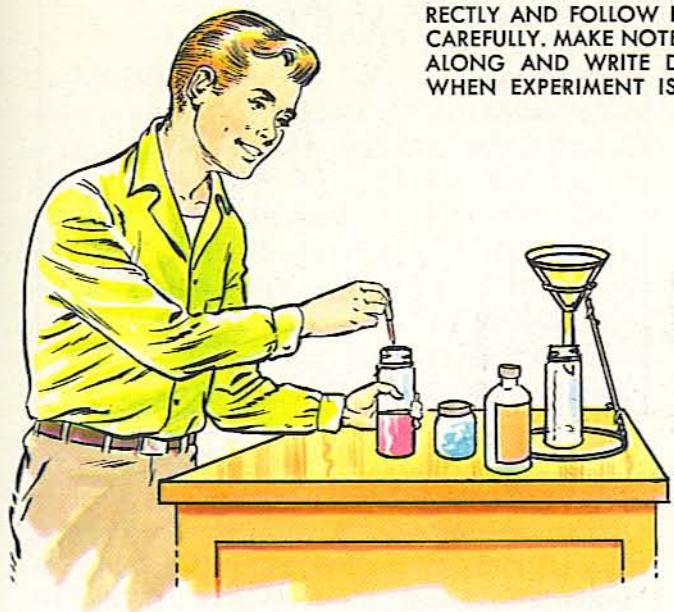
Let's say you want to figure out the equation for dissolving aluminum foil in hydrochloric acid. You write out a trial equation:



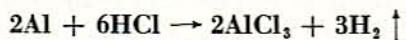
But is AlCl correct? Look at the valence chart on page 75. Aluminum has three valence bonds, chlorine only one. One Al atom therefore takes on three Cl atoms, and aluminum chloride must be AlCl_3 . H isn't right, either. Hydrogen exists in the free state only in molecules containing two atoms (H_2). So you change the equation to this:



MEASURE OUT ALL CHEMICALS CORRECTLY AND FOLLOW INSTRUCTIONS CAREFULLY. MAKE NOTES AS YOU GO ALONG AND WRITE DOWN RESULT WHEN EXPERIMENT IS COMPLETED.

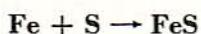


Now you need an amount of HCl that will give you Cl by the 3's and H by the 2's. 6HCl will do this. So you write in 6HCl and change the rest until the equation balances:



Equations tell you what happens — but they tell far more than that.

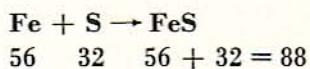
Take the simple equation:



APPROXIMATE ATOMIC WEIGHTS FOR CALCULATIONS

Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
ALUMINUM	Al	27	MAGNESIUM	Mg	24
BORON	B	11	MANGANESE	Mn	55
CALCIUM	Ca	40	NITROGEN	N	14
CARBON	C	12	OXYGEN	O	16
CHLORINE	Cl	36	POTASSIUM	K	39
COPPER	Cu	64	SILICON	Si	28
HYDROGEN	H	1	SILVER	Ag	108
IODINE	I	127	SODIUM	Na	23
IRON	Fe	56	SULFUR	S	32
LEAD	Pb	207	ZINC	Zn	65

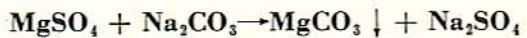
This not only tells you that iron and sulfur make iron sulfide but also that it takes one iron atom and one sulfur atom to produce one molecule of FeS. Further, by inserting the atomic weights for the two elements from the chart on page 107, the equation tells you how much iron and sulfur are needed and how much iron sulfide you should get:



You can use the atomic weight numerals to indicate numbers of grams or any other unit of weight. By dividing by 16 you get the number of grams you used for experiment on page 22.

Now take a more complicated equation.

Let's say you want to produce magnesium carbonate. The chart of solubilities on page 108 tells you that MgCO_3 is insoluble. You should therefore be able to precipitate it from a soluble magnesium salt — the sulfate, for instance — and soluble sodium carbonate:



Now you need to know how much MgSO_4 and how much Na_2CO_3 you need, and how much MgCO_3 you will get.

Before you start figuring from the equation above, check the chart on page 108, top right. Here you will discover that each molecule of magnesium sulfate has seven molecules of water of hydration ($7\text{H}_2\text{O}$) attached to it, and each sodium carbonate molecule,

(CONTINUED ON PAGE 108)

SOLUBILITY OF SALTS AND HYDROXIDES

NITRATES—**SOLUBLE**—WITHOUT EXCEPTIONS.
 ACETATES—**SOLUBLE**—WITHOUT EXCEPTIONS.
 CHLORIDES—**SOLUBLE**—EXCEPT Ag, Hg (MERCURIOUS), AND Pb.
 SULFATES—**SOLUBLE**—EXCEPT Pb, Ba, Sr (Ca, Ag AND Hg SLIGHTLY SOLUBLE).
 NORMAL CARBONATES, PHOSPHATES, SILICATES,
 SULFIDES—**INSOLUBLE**—EXCEPT Na, K, NH₄.
 HYDROXIDES—**INSOLUBLE**—EXCEPT Na, K, NH₄, Ba. (Ca AND Sr SLIGHTLY SOLUBLE.)

WATER OF HYDRATION (WATER OF CRYSTALLIZATION)

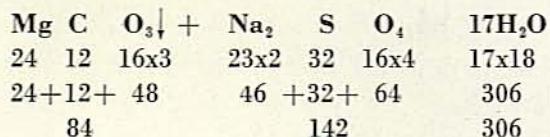
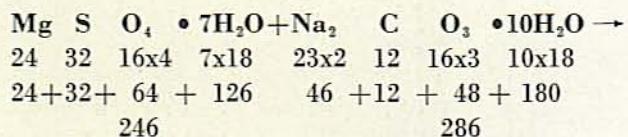
AgNO ₃	NH ₄ Al(SO ₄) ₂ ·12H ₂ O
CaCl ₂ ·6H ₂ O	NH ₄ Cl
(CaSO ₄) ₂ ·H ₂ O	Na ₂ B ₄ O ₇ ·10H ₂ O
CuSO ₄ ·5H ₂ O	Na ₂ CO ₃ ·10H ₂ O
FeCl ₃ ·6H ₂ O	NaCl
FeCl ₂ ·4H ₂ O	NaHCO ₃
FeSO ₄ ·7H ₂ O	NaHSO ₄ ·H ₂ O
KAl(SO ₄) ₂ ·12H ₂ O	NaOH
KNO ₃	Na ₂ SO ₄ ·10H ₂ O
MgSO ₄ ·7H ₂ O	Na ₂ S ₂ O ₃ ·5H ₂ O

Equations—Continued

ten molecules of water (10H₂O). These do not enter into the chemical reaction—but you have to include them in the weight of the chemicals.

Write the atomic weight below each element. Then figure the molecular weight of each compound by adding the atomic weights of all the atoms found in the molecule.

This is what you get:



(When a formula contains subscripts—the small numerals that indicate how many of a kind—be certain to multiply the atomic weight by the number indicated by the subscript. In cases where the formula is preceded by a large number, be sure to multiply the molecular weight by this number.)

Your finished calculation tells you that 246 g (or 24.6 g or .246 g) of magnesium sulfate crystals and 286 g (or 28.6 g or .286 g) of sodium carbonate crystals will give you 84 g (or 8.4 g or .84 g) magnesium carbonate.

When you get even deeper into chemical mathematics you will be able to figure out the percentage of elements in a compound for which you know the formula, or the formula of a compound when you know the percentage of elements, or the numbers of liters of a gas you prepare in a chemical reaction.

CHEMISTRY AS A HOBBY WILL GIVE YOU MANY HOURS OF ENJOYMENT.



CHEMISTRY AS A SCIENCE TRAINS YOUR REASONING AND OBSERVATION.

What's Ahead in Chemistry?

THE CHEMICAL WONDERS of today are amazing enough — but they are like nothing compared to the wonders the future holds in store for the welfare of all humanity.

FOOD — The fertilizers of tomorrow will greatly increase the crops grown on farms throughout the world. Insect and disease-destroying chemicals will make cattle and poultry healthier and better producers of meat, milk, and eggs. Chemicals unknown today will make it possible to keep food fresh without refrigeration in any climate.

HOMES — The houses of the future will be built of more durable materials than any we have today. Floors and wall covering will last almost indefinitely. New paints will add never-fading colors.

CLOTHING — Many more man-made fibers will be added to those we use today — fibers with longer wear; fabrics that are cool in summer, warm in winter, easy to keep clean.

HEALTH — The miracle drugs of today have wiped out diseases that ranked among our greatest killers just a few years ago. In years to come many more diseases will disappear from the surface of the world under the onslaught of still more effective drugs created in the chemical laboratory.

TRAVEL — Much of the travel of the future will be at supersonic speeds. Planes and rockets will require materials that can stand tremendous heat and new fuels capable of producing enormous energy. Chemistry will provide them.

ATOMIC ENERGY — The force hidden in the atom will be turned into light and heat and power for everyday uses. Chemists of the future, working with their brother-scientists, the physicists, will find new ways of harnessing and using the atoms of numerous elements — some of them unknown to the scientists of today.

Do you want to share in the making of that astonishing and promising future?

If you have enjoyed performing the experiments in this book, figuring out formulas and equations, jotting down observations, you are the kind of person who has the qualifications for making a successful career in chemistry.

If you care to look further into the matter, speak to your science teacher about it and drop a line to one or all three of the organizations mentioned below and ask for their pamphlets on becoming a chemist:

American Chemical Society,

1155 16th Street, N. W., Washington 6, D. C.

American Institute of Chemical Engineers,

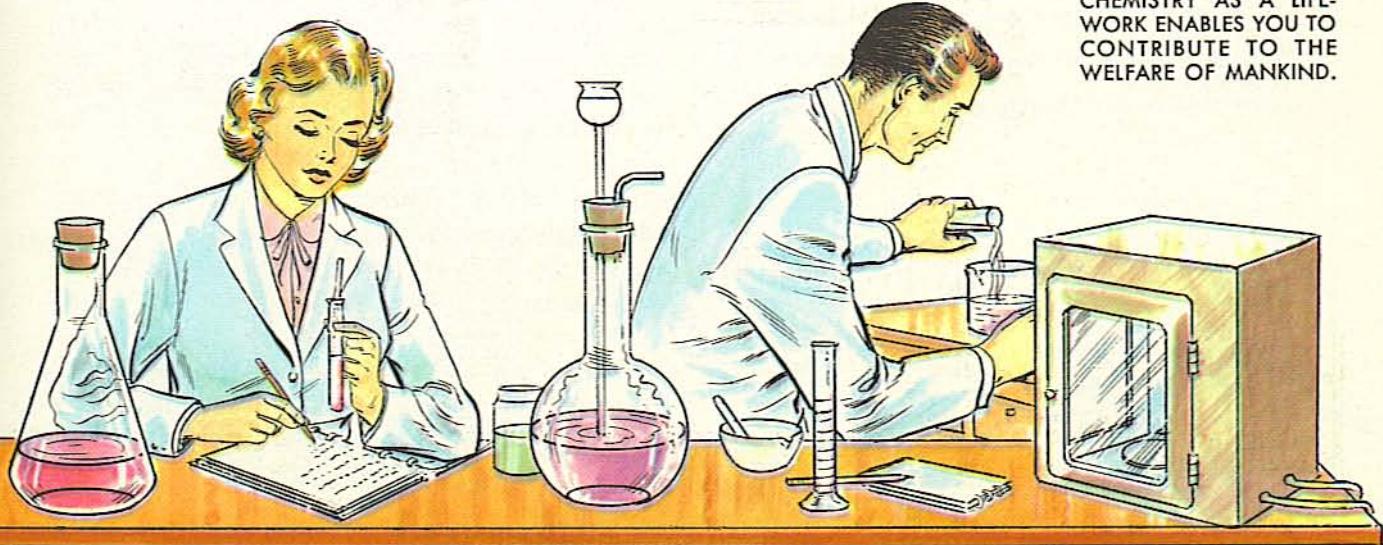
25 West 45th Street, New York 36, N. Y.

Manufacturing Chemists' Association,

1625 I Street, N. W., Washington 6, D. C.

But whatever you decide for the future, keep up your interest in chemistry as a hobby. In addition to giving you fun and enjoyment, your chemical hobby will sharpen your powers of observation and reasoning and train your mind for whatever occupation you decide upon for a lifework.

CHEMISTRY AS A LIFE-WORK ENABLES YOU TO CONTRIBUTE TO THE WELFARE OF MANKIND.



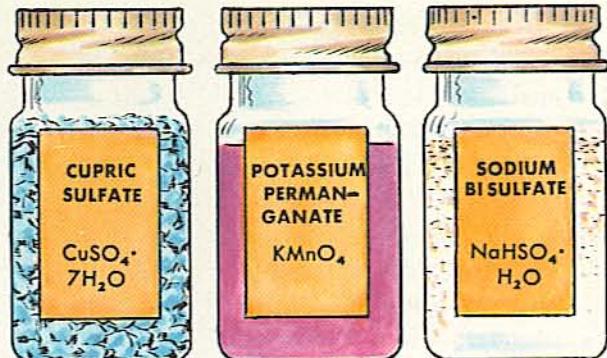
Where to Get Chemicals and Equipment

A GREAT MANY of the experiments in this book can be performed with equipment found around the house: water glasses, custard cups, jars, bottles, cans, and funnel. For the rest, the following pieces of regular chemical laboratory equipment are needed:

- 6 test tubes, regular, 150 mm x 16 mm
- 3 test tubes, Pyrex, 150 mm x 16 mm
- 1 test tube brush, small
- 3 wide-mouth bottles, 4 ozs.
- 6 ft. glass tubing, 6 mm outside diameter
- 3 ft. rubber tubing, $\frac{3}{16}$ " inside diameter
- 2 No. 0 rubber stoppers, one hole
- 1 No. 5 rubber stopper, one hole
- 3 No. 5 rubber stoppers, two holes
- 1 triangular file, 4"
- 1 glass stirring rod, 5"
- 1 pkg. filter paper, 12.5 cm, 50 pieces
- 1 vial litmus paper strips, blue
- 1 vial litmus paper strips, red

If you can not secure this equipment locally, write to one of the companies below asking for price list or catalog, including cost of catalog where called for. When you receive the answer, mail your order and the correct amount by bank check or money order.

- Science Mail Co., 17-33 Murray St., Whitestone 57, N. Y.
(Price list free)
- Winn Chemical Co., 124 West 23rd St., New York 11, N. Y.
(Catalog 25¢)
- N. Y. Scientific Supply Co., 28 West 30th St., New York 1, N. Y. (Catalog 50¢)
- Home Lab Supply, 511 Homestead Ave., Mount Vernon, N. Y.
(Price list free)
- Biological Supply Co., 1176 Mt. Hope Ave., Rochester 20, N. Y. (Catalog 25¢)
- A. C. Gilbert Co., P. O. Box 1610, New Haven 6, Conn.
(Price list free)
- Bio-Chemical Products, 30 Somerset St., Belmont, Mass.
(Catalog 25¢)
- Laboratory Sales, P. O. Box 161, Brighton, Mass.
(Catalog 25¢)
- The Porter Chemical Co., Hagerstown, Md. (Price list free)
- Tracey Scientific Laboratories, P. O. Box 615, Evanston, Ill.
(Catalog 25¢)
- National Scientific Co., 13 South Park Ave., Lombard, Ill.
(Catalog 35¢)
- Hagenow Laboratories, Manitowoc, Wis. (Catalog 20¢)



CHEMICALS FOR HOME EXPERIMENTS ARE AVAILABLE IN JARS OF UNIFORM SIZE, ALL PROPERLY LABELED.

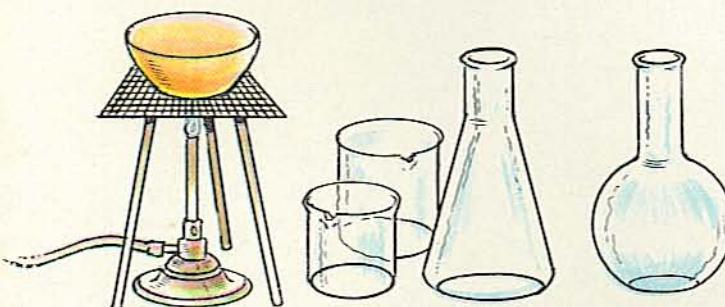
WHENEVER YOU NEED a chemical for one of the experiments described in this book, check the list of common chemicals on page 111 to find out where to buy it.

All of these chemicals are, of course, available through chemical supply houses. The trouble is that many of these houses do not sell to individuals but only to schools and established laboratories. Also, the chemicals usually come in a standard amount of $\frac{1}{4}$ lb. — or even 1 lb. — where, in home experiments, you would need 1 ounce or less. The same is often the case when you buy chemicals in a local store. The minimum-sized packages or jars may be so large that you couldn't possibly use up the contents in a year of experiments. You will probably also have to repack what you actually need into glass jars of suitable size for efficiency and to fit your storage space.

Because of this and the inconvenience of having to shop around, you may find it advantageous to buy your chemicals by the kit, in uniform-sized screw-top glass containers. Such kits are available in the science department of many hobby and model supply stores.

Chem-Kit No. 1 contains the ten chemicals marked ■ on the opposite page. Chem-Kit No. 2 contains the ten chemicals marked □. The kits contain sufficient amounts of chemicals to perform each experiment many times over.

You can also make up your own set of chemicals in amounts suitable for home experiments by getting them from one of the companies listed to the left. Be certain to add the cost of the catalog when you write for one and to send the correct amount when you order.



IF YOU DECIDE TO USE REGULAR LABORATORY WARE IN YOUR HOME LAB, GET PRICE LIST FROM SUPPLIER.

Common Chemicals and Their Formulas

CHEMICAL NAME	FORMULA	COMMON NAME	WHERE TO BUY
ACETIC ACID	$\text{CH}_3\text{COOH} + \text{H}_2\text{O}$	5% solution: white vinegar	Grocery
AMMONIUM CHLORIDE	NH_4Cl	sal ammoniac	Drug store
AMMONIUM HYDROXIDE	$\text{NH}_4\text{OH} + \text{H}_2\text{O}$	10% solution: household ammonia 27% solution: strong ammonia	Grocery Drug store
BORIC ACID	H_3BO_3	boric acid	Drug store
CALCIUM CARBONATE	CaCO_3	chunks: marble, limestone powder: precipitated chalk	Builders' supplies Drug store
CALCIUM HYDROXIDE	$\text{Ca}(\text{OH})_2$	slaked lime, garden lime	Hardware store
CALCIUM OXIDE	CaO	quicklime	Builders' supplies
CALCIUM SULFATE	$(\text{CaSO}_4) \cdot \text{H}_2\text{O}$ $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	plaster of Paris gypsum	Hardware store Chemical supplies
CARBON TETRACHLORIDE	CCl_4	carbon tet	Hardware store
COPPER SULFATE	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	blue vitriol	Drug store
FERROUS SULFATE	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	iron sulfate, green vitriol, copperas	Drug store
GLUCOSE	$\text{C}_6\text{H}_{12}\text{O}_6 + \text{H}_2\text{O}$	solution: corn syrup	Grocery
HYDROCHLORIC ACID	$\text{HCl} + \text{H}_2\text{O}$	25% solution: muriatic acid	Hardware store
HYDROGEN PEROXIDE	$\text{H}_2\text{O}_2 + \text{H}_2\text{O}$	3% solution: peroxide	Drug store
IRON, METAL, POWDER	Fe	powdered iron	Chemical supplies
MAGNESIUM, METAL	Mg	magnesium ribbon	Chemical supplies
MAGNESIUM SULFATE	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	Epsom salts	Drug store
MANGANESE DIOXIDE	MnO_2	pyrolusite	Hardware store (flashlight battery)
NAPHTHALENE	C_{10}H_8	moth balls	Hardware store
PHENOLPHTHALEIN	$\text{C}_6\text{H}_4\text{COOC}(\text{C}_6\text{H}_4\text{OH})_2$	phenolphthalein	Drug store
POTASSIUM ALUMINUM SULFATE	$\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$	alum, potassium alum	Drug store
POTASSIUM FERROCYANIDE	$\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$	potassium ferrocyanide	Chemical supplies
POTASSIUM IODIDE	KI	potassium iodide	Drug store
POTASSIUM NITRATE	KNO_3	saltpeter, niter	Drug store
POTASSIUM PERMANGANATE	KMnO_4	potassium permanganate	Drug store
SALICYLIC ACID	$\text{C}_6\text{H}_4\text{OHCOOH}$	salicylic acid	Drug store
SILVER NITRATE	AgNO_3	lunar caustic	Drug store
SODIUM BICARBONATE	NaHCO_3	baking soda, bicarb	Grocery
SODIUM BISULFATE	$\text{NaHSO}_4 \cdot \text{H}_2\text{O}$	82% of Sani-Flush®	Grocery
SODIUM CARBONATE	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$	sal soda, crystal washing soda concentrated washing soda	Grocery Grocery
SODIUM CHLORIDE	NaCl	salt, table salt	Grocery
SODIUM HYDROXIDE	NaOH	lye, caustic soda, Drano®	Grocery
SODIUM HYPOCHLORITE	$\text{NaClO} + \text{H}_2\text{O}$	5% solution: laundry bleach, Clorox®	Grocery
SODIUM POTASSIUM TARTRATE	$\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$	Rochelle salt	Drug store
SODIUM SILICATE	$\text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$	solution: water glass	Hardware store
SODIUM TETRABORATE	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$	borax	Drug store
SODIUM THIOSULFATE	$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	hypo	Photo store
SUCROSE	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$	cane sugar	Grocery
SULFUR	S	powder: flowers of sulfur block: sulfur candle	Drug store Hardware store
ZINC, METAL	Zn	zinc	Hardware store (flashlight battery)
ZINC CHLORIDE	$\text{ZnCl}_2 + \text{H}_2\text{O}$	tinners' fluid	Hardware store

Note: Chemicals marked □—many of them liquids—are most easily secured in local stores. Chemicals marked ■ are found in Chem-Kit No. 1, chemicals marked ■ in Chem-Kit No. 2 (see opposite page).

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