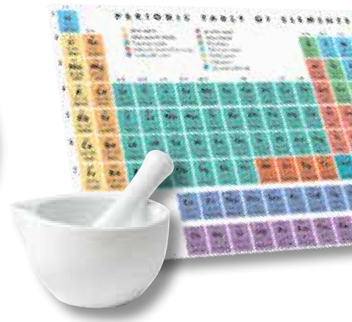
MERIT BADGE SERIES



CHEMISTRY





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MERIT BADGE SERIES

CHEMISTRY

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Requirements

Always check www.scouting.org for the latest requirements.

1. Do EACH of the following:
    a. Describe three examples of safety equipment used in a chemistry laboratory and the reason each one is used.
    b. Describe what a safety data sheet (SDS) is and tell why it is used.
    c. Obtain an SDS for both a paint and an insecticide. Compare and discuss the toxicity, disposal, and safe-handling sections for these two common household products.
    d. Discuss the safe storage of chemicals. How does the safe storage of chemicals apply to your home, your school, your community, and the environment?
2. Do EACH of the following:
    a. Predict what would happen if you placed an iron nail in a copper sulfate solution. Then, put an iron nail in a copper sulfate solution. Describe your observations and make a conclusion based on your observations. Compare your prediction and original conclusion with what actually happened. Write the formula for the reaction that you described.
    b. Describe how you would separate sand (or gravel) from water and then demonstrate. Also describe how you would separate table salt from water, oil from water, and gasoline from motor oil. Name the practical processes that require these kinds of separations and how the processes may differ depending on what you want to keep.
    c. Describe the difference between a chemical reaction and a physical change.

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3. Construct a Cartesian diver. Describe its function in terms of how gases in general behave under different pressures and different temperatures. Describe how the behavior of gases affects a backpacker at high altitudes and a scuba diver underwater.

4. Do EACH of the following:

   a. Cut a round onion into small chunks. Separate the onion chunks into three equal portions. Leave the first portion raw. Cook the second portion of onion chunks until the pieces are translucent. Cook the third portion until the onions are caramelized, or brown in color. Taste each type of onion. Describe the taste of raw onion versus partially cooked onion versus caramelized onion. Explain what happens to molecules in the onion during the cooking process.

   b. Describe the chemical similarities and differences between toothpaste and an abrasive household cleanser. Explain how the end use or purpose of a product affects its chemical formulation.

   c. In a clear container, mix a half-cup of water with a tablespoon of oil. Explain why the oil and water do not mix. Find a substance that will help the two combine, and add it to the mixture. Describe what happened, and explain how that substance worked to combine the oil and water.

5. Discuss with your counselor the 5 classical areas of chemistry (organic, inorganic, physical, analytical and biological), and two others from the following list. Explain what they are, and how they impact your daily life.

   a. Agricultural chemistry

   b. Atmospheric chemistry

   c. Environmental chemistry and green chemistry

   d. Flavor chemistry, fragrance chemistry, and food chemistry

   e. Medicinal and natural products chemistry

   f. Photochemistry

   g. Polymer chemistry

   h. Or another area of your choosing

6. Do EACH of the following:
   a. Name two government agencies that are responsible for tracking the use of chemicals for commercial or industrial use. Pick one agency and briefly describe its responsibilities.
   b. Define pollution. Explain the chemical impacts on ozone and global climate change. Pick a current environmental problem. Briefly describe what people are doing to resolve this issue and to increase understanding of the problem
   c. Using reasons from chemistry, describe the effect on the environment of ONE of the following:
      1) The production of aluminum cans
      2) Burning fossil fuels
      3) Single-use items, such as water bottles, bags, straws, or paper
   d. Briefly describe the purpose of phosphates in fertilizer and in laundry detergent. Explain how the use of phosphates in fertilizers affects the environment. Explain why phosphates have been removed from laundry detergents.

7. Do ONE of the following:
   a. Visit a laboratory and talk to a chemist. Ask what that chemist does and what training and education are needed to work in that career.
   b. Using resources found at the library and in periodicals, books, and the internet (with your parent's permission), learn about two different kinds of work done by chemists, chemical engineers, chemical technicians, or industrial chemists. For both positions, find out the education and training requirements.
   c. Visit an industrial plant that makes chemical products or uses chemical processes and describe the processes used. What, if any, by-products are produced and how are they handled?
   d. Visit a county farm agency or similar governmental agency and learn how chemistry is used to meet the needs of agriculture in your county.

Contents

Introduction to Chemistry

Why does baking soda foam and bubble when vinegar is poured on it? What happens when dry ice vaporizes and makes a spooky fog for a scary movie? How can charcoal for the outside grill be made of carbon when diamonds are also made of carbon?

Chemistry answers these questions and many more by studying the substances that make up our world and universe. How substances react with each other, how they change, how certain forces connect molecules, and how molecules are made are all parts of chemistry. Stretch your imagination to envision molecules that cannot be seen—but can be proven to exist—and you become a chemist.

Exploding Chemistry

Try this experiment as your introduction to chemistry. Put on safety goggles. Break an effervescent antacid tablet in half. Drop the pieces into an empty camera-film container or non-child-proof pill container with a snap-on (not screw-on) lid. Fill the container half-full of water and quickly press the cap on. Hold the container away from your face, pointing at the ceiling. Do you hear anything? What happened? Only chemistry can explain it.

Chemistry and Chemicals

Chemistry is one of the physical sciences. *Science* is the study by which people try to understand and explain our world and the universe in a rational, logical manner. Chemistry is sometimes called the *central science* because its properties are important to biologists, physicists, geologists, and astronomers alike. Chemistry is present throughout modern society in medicine, manufacturing, and agriculture.

What Is Chemistry?

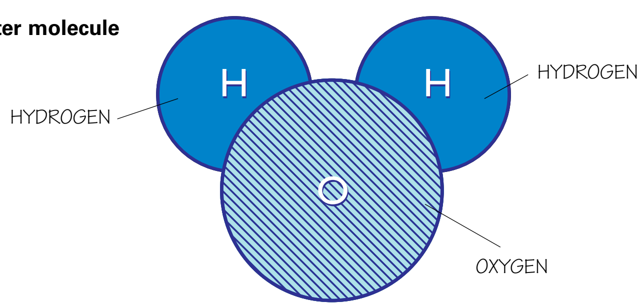
Chemistry is the science of the study of matter. *Matter* is anything that has mass and occupies space. Chemistry includes the study of substances; their structures, properties, and reactions; and the energy changes of those reactions.

Two million atoms can fit on the tip of a pin.

The Building Blocks of Our World

Chemicals are made of *molecules,* and molecules are made of *atoms.* Look at water. It is a chemical. A water molecule is two hydrogen atoms attached to one oxygen atom.

Water molecule



Hydrogen and oxygen are elements found in the periodic table.

IUPAC Periodic Table

INTERNATIONAL UNION OF
PURE AND APPLIED CHEMISTRY

1	2	3	4	5	6	7	8	9
1 **H** hydrogen 1.0080 ± 0.0002								
3 **Li** lithium 6.94 ± 0.06	4 **Be** beryllium 9.0122 ± 0.0001							
11 **Na** sodium 22.990 ± 0.001	12 **Mg** magnesium 24.305 ± 0.002							
19 **K** potassium 39.098 ± 0.001	20 **Ca** calcium 40.078 ± 0.004	21 **Sc** scandium 44.956 ± 0.001	22 **Ti** titanium 47.867 ± 0.001	23 **V** vanadium 50.942 ± 0.001	24 **Cr** chromium 51.996 ± 0.001	25 **Mn** manganese 54.938 ± 0.001	26 **Fe** iron 55.845 ± 0.002	27 **Co** cobalt 58.933 ± 0.001
37 **Rb** rubidium 85.468 ± 0.001	38 **Sr** strontium 87.62 ± 0.01	39 **Y** yttrium 88.906 ± 0.001	40 **Zr** zirconium 91.224 ± 0.002	41 **Nb** niobium 92.906 ± 0.001	42 **Mo** molybdenum 95.95 ± 0.01	43 **Tc** technetium [97]	44 **Ru** ruthenium 101.07 ± 0.02	45 **Rh** rhodium 102.91 ± 0.01
55 **Cs** caesium 132.91 ± 0.01	56 **Ba** barium 137.33 ± 0.01	57-71 lanthanoids	72 **Hf** hafnium 178.49 ± 0.01	73 **Ta** tantalum 180.95 ± 0.01	74 **W** tungsten 183.84 ± 0.01	75 **Re** rhenium 186.21 ± 0.01	76 **Os** osmium 190.23 ± 0.03	77 **Ir** iridium 192.22 ± 0.01
87 **Fr** francium [223]	88 **Ra** radium [226]	89-103 actinoids	104 **Rf** rutherfordium [267]	105 **Db** dubnium [268]	106 **Sg** seaborgium [269]	107 **Bh** bohrium [270]	108 **Hs** hassium [269]	109 **Mt** meitnerium [277]

57 **La** lanthanum 138.91 ± 0.01	58 **Ce** cerium 140.12 ± 0.01	59 **Pr** praseodymium 140.91 ± 0.01	60 **Nd** neodymium 144.24 ± 0.01	61 **Pm** promethium [145]	62 **Sm** samarium 150.36 ± 0.02
89 **Ac** actinium [227]	90 **Th** thorium 232.04 ± 0.01	91 **Pa** protactinium 231.04 ± 0.01	92 **U** uranium 238.03 ± 0.01	93 **Np** neptunium [237]	94 **Pu** plutonium [244]

of the Elements

Key:
atomic number
Symbol
name
abridged standard atomic weight

10	11	12	13	14	15	16	17	18
								2 **He** helium 4.0026 ± 0.0001
			5 **B** boron 10.81 ± 0.02	6 **C** carbon 12.011 ± 0.002	7 **N** nitrogen 14.007 ± 0.001	8 **O** oxygen 15.999 ± 0.001	9 **F** fluorine 18.998 ± 0.001	10 **Ne** neon 20.180 ± 0.001
			13 **Al** aluminium 26.982 ± 0.001	14 **Si** silicon 28.085 ± 0.001	15 **P** phosphorus 30.974 ± 0.001	16 **S** sulfur 32.06 ± 0.02	17 **Cl** chlorine 35.45 ± 0.01	18 **Ar** argon 39.95 ± 0.16
28 **Ni** nickel 58.693 ± 0.001	29 **Cu** copper 63.546 ± 0.003	30 **Zn** zinc 65.38 ± 0.02	31 **Ga** gallium 69.723 ± 0.001	32 **Ge** germanium 72.630 ± 0.008	33 **As** arsenic 74.922 ± 0.001	34 **Se** selenium 78.971 ± 0.008	35 **Br** bromine 79.904 ± 0.003	36 **Kr** krypton 83.798 ± 0.002
46 **Pd** palladium 106.42 ± 0.01	47 **Ag** silver 107.87 ± 0.01	48 **Cd** cadmium 112.41 ± 0.01	49 **In** indium 114.82 ± 0.01	50 **Sn** tin 118.71 ± 0.01	51 **Sb** antimony 121.76 ± 0.01	52 **Te** tellurium 127.60 ± 0.03	53 **I** iodine 126.90 ± 0.01	54 **Xe** xenon 131.29 ± 0.01
78 **Pt** platinum 195.08 ± 0.02	79 **Au** gold 196.97 ± 0.01	80 **Hg** mercury 200.59 ± 0.01	81 **Tl** thallium 204.38 ± 0.01	82 **Pb** lead 207.2 ± 1.1	83 **Bi** bismuth 208.98 ± 0.01	84 **Po** polonium [209]	85 **At** astatine [210]	86 **Rn** radon [222]
110 **Ds** darmstadtium [281]	111 **Rg** roentgenium [282]	112 **Cn** copernicium [285]	113 **Nh** nihonium [286]	114 **Fl** flerovium [290]	115 **Mc** moscovium [290]	116 **Lv** livermorium [293]	117 **Ts** tennessine [294]	118 **Og** oganesson [294]

63 **Eu** europium 151.96 ± 0.01	64 **Gd** gadolinium 157.25 ± 0.03	65 **Tb** terbium 158.93 ± 0.01	66 **Dy** dysprosium 162.50 ± 0.01	67 **Ho** holmium 164.93 ± 0.01	68 **Er** erbium 167.26 ± 0.01	69 **Tm** thulium 168.93 ± 0.01	70 **Yb** ytterbium 173.05 ± 0.02	71 **Lu** lutetium 174.97 ± 0.01
95 **Am** americium [243]	96 **Cm** curium [247]	97 **Bk** berkelium [247]	98 **Cf** californium [251]	99 **Es** einsteinium [252]	100 **Fm** fermium [257]	101 **Md** mendelevium [258]	102 **No** nobelium [259]	103 **Lr** lawrencium [262]

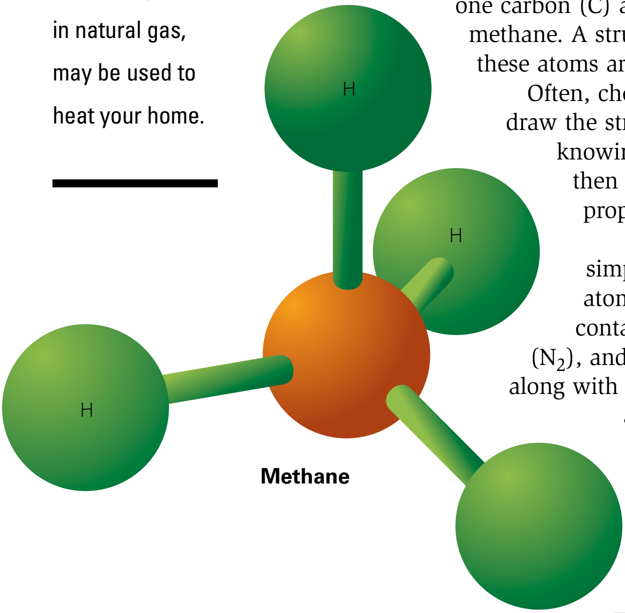
For notes and updates to this table, see www.iupac.org. This version is dated May 4, 2022.

Elements are considered *pure substances* because they are made up of only one type of substance. Often we encounter mixtures of several chemicals. Milk, for example, is mostly water. Yet, milk also contains other chemicals such as calcium, fats, proteins, carbohydrates, vitamins, and minerals. You can pick up the container of any commercial food or household product—like cereal, deodorant, or vitamins—and read the list of ingredients. All these ingredients are chemicals. Even the bottle and label are chemicals.

Compounds

When writing chemical formulas, chemists show the number of each type of atom in the *compound*. For example, the molecular formula of methane is CH_4, which means that there are four hydrogen (H_4) atoms and one carbon (C) atom in each molecule of methane. A structural formula shows how these atoms are arranged.

Methane, the main compound in natural gas, may be used to heat your home.



Methane

Often, chemists need to know how to draw the structures of compounds. By knowing the structures, they can then understand many of the properties of the compounds.

Some molecules are very simple, containing only a few atoms. The air we breathe contains oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2), along with other gases. Other molecules are more complicated. Some contain dozens of atoms, while others contain hundreds or even millions of atoms. Table sugar is sucrose ($C_{12}H_{22}O_{11}$).

The deoxyribonucleic acid (DNA) within our cells that contains our genetic code is composed of only carbon, hydrogen, nitrogen, oxygen, and phosphorus, but it contains millions of these atoms in specific combinations.

What Are Chemicals?

When people hear the word *chemicals,* they may feel afraid. They unconsciously may think that all chemicals are poisonous, but not all chemicals are even dangerous. Remember that water (H_2O) is a chemical.

Everything in your house is made from chemicals, including the food you eat and the clothes you wear. Even your body is made of chemicals. To live and breathe, you must continuously carry out many chemical reactions within your body. You eat complex molecules of carbohydrates, fats, and proteins. Your body uses these molecules for energy and to make new biomolecules for tissues such as muscle, hair, and nails.

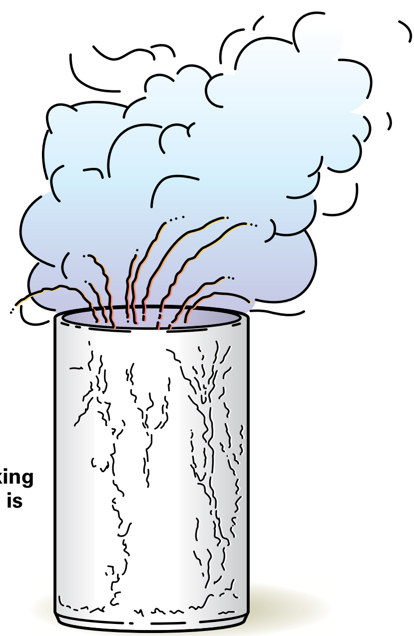
Chemical Reaction or Physical Change

In a *chemical reaction,* the atoms in a molecule are combined or rearranged with atoms in another molecule to form a new compound that has different physical and chemical properties.

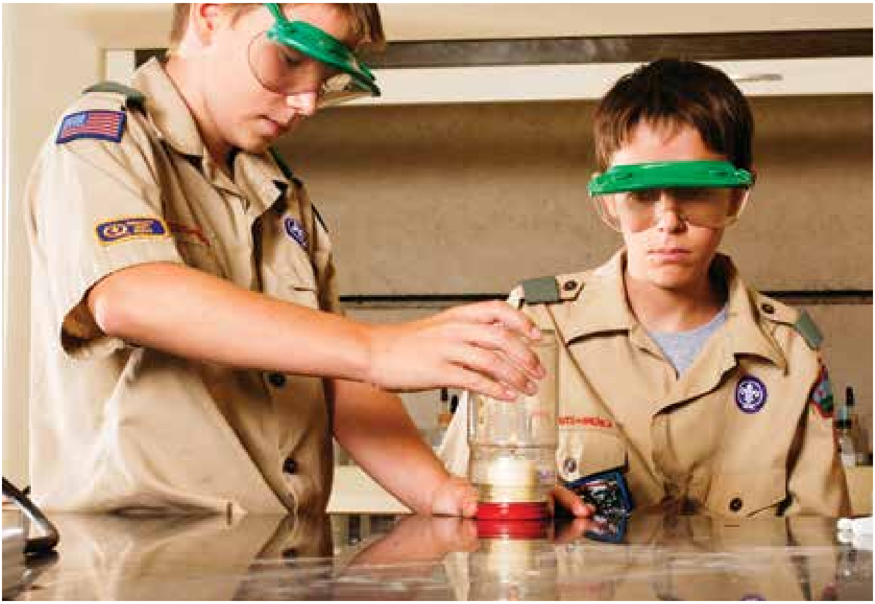
Combustion

Combustion is one way to tell if a chemical change has taken place. Try this experiment with a flame—one sign of chemical change. Look for another clue of a chemical change.

Step 1—Put on safety goggles. Stand a short candle (2 or 3 inches tall) in a bowl, with water about a half-inch deep. You may attach clay to the candle and bowl to help keep the candle upright. Light the candle. Hold a cold, dry glass cup (not plastic) upside down over the burning candle. Does moisture collect on the inside of the glass?



Three clues a chemical reaction is taking place are: (1) flame is present; (2) gas is given off; and (3) color changes.



Step 2—Set the glass upside down over the candle. Note how and when the level of the water in the glass rises. Does the water now occupy about one-fifth of the volume of the glass?

WHAT HAPPENED?

The three things necessary for combustion to occur are heat, fuel, and oxygen. Dry air is about 21 percent oxygen and 78 percent nitrogen by volume, with small amounts of other gases such as carbon dioxide and hydrogen. The flame in this experiment actually goes out before all the oxygen is consumed, while the heat of the flame causes the gases to expand. When the flame goes out, the temperature in the glass drops, causing the gases to contract and the water level to rise quickly. What is left in the glass is mostly nitrogen.

Chemists use equations to show the reactant and product molecules. Candle wax is often a variety of waxes with long chains of carbons and hydrogens. An equation for the combustion of paraffin, a common wax, is:

$$\text{Reactants} \rightarrow \text{Products}$$

$$C_{31}H_{64} + 47O_2 \rightarrow 31CO_2 + 32H_2O + \text{heat}$$

Physical Change

Ice melting and water evaporating are examples of *physical change*. In contrast to chemical reactions, physical change does not form new compounds. Water is still H_2O whether it is a liquid, solid, or gas. The change from one state to another does not change water's molecular structure.

Every spring, physical change occurs naturally when solid ice on mountaintops melts, flows as water downhill, and evaporates to water vapor. This can be represented by the equation

H_2O (s) → H_2O (l) → H_2O (g)
Solid → Liquid → Gas

(s) = solid, (l) = liquid, (g) = gas

Dry ice is frozen carbon dioxide. At room temperature, it changes directly from a solid to a gas. The surface temperature of dry ice is very cool at –109 degrees Fahrenheit.

The pressure of an ice skate melts the ice just below the blade so that ice skaters actually glide on water.

Can Blaster

Find an adult to help you with this experiment. Warn people in your area that this experiment will be noisy.

Step 1—Put on safety goggles to protect your eyes.

Step 2—Fill a bowl with ice water and pour ¼ cup water into an empty aluminum soda can. The smaller the opening in the top of the can, the better.

Step 3—Put on oven mitts, then set the can on a stove burner. Turn the burner on high. Once steam begins to rise from the can, heat it for three more minutes. **Caution:** Keep your hands away from the hot steam!

Step 4—Turn off the heat. Wearing oven mitts and using tongs, quickly remove the can, turn it upside down, and submerge it in the ice water.

WHAT HAPPENED?

The volume of a liquid expands by a factor of more than 1,000 when it becomes a gas. Imagine the steam inside the can pushing out the air molecules as it starts to boil. The molecules of steam in their high-energy state spread out, with most escaping out of the top of the can.

When the can is inverted in the ice water, the water vapor becomes trapped in the can. The ice water quickly cools the can and the steam inside. The gas steam contracts by a factor of more than 1,000 when it liquefies. Suddenly, the pressure inside the can drops and the can implodes. Bang!

Safety and Chemistry

Some chemicals are safe enough to be eaten—such as sugar, cooking oil, and baking soda. Other chemicals are so potentially dangerous that you need to wear gloves and safety goggles when you handle them. Examples of dangerous chemicals are bathroom cleaners, drain cleaners, and acids. Many chemicals must be stored safely to avoid possible fires or poisonings. Flammable materials should be stored away from heat and flame, which are sources of ignition.

Storage in Your Home

If you have younger brothers and sisters, make sure your parents place childproof locking devices on kitchen and bathroom cabinets. Before storing a chemical at home, read the label. If the label recommends keeping the chemical out of reach of children, store it in a high or locked cabinet. Chemicals such as drain cleaners and bleach have warning labels.

Never store a chemical in a container that was not made for it.

Storage in Your School

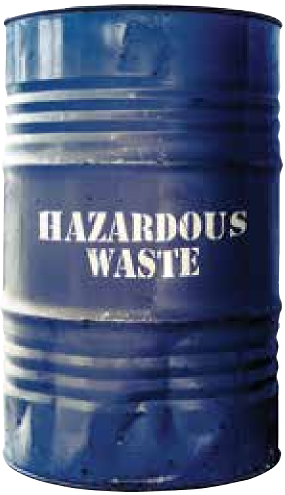
At most schools, all chemicals are stored in a common area, often organized by hazard classification. Schools try to select less-toxic chemicals and minimize chemical use to reduce waste and safety risk. Teachers working with chemicals receive training in safe storage, proper use, potential hazards, and disposal. Schools have a chemical spill plan in case of an accident.

Storage in Your Community

Businesses in your community use chemicals that can be toxic if not stored or used correctly. A spilled chemical on a business property could be washed by rain into a local stream, which could drain into a town's water supply. Government regulates the proper use, storage, and disposal of chemicals.

Safety Data Sheet (SDS)

What would you do if you accidentally splattered a chemical in your eyes? You should read the container's label and follow the instructions. The label might tell you to rinse your eyes thoroughly and seek medical attention. In the hospital's emergency room, the nurse would ask what you splattered in your eyes. A bug killer called Bug-B-Dead might be all you knew. The nurse would know the chemicals were pesticides, but which one? A safety data sheet is important in these situations.



Safe use and storage of chemicals is critical for protecting the environment for everyone. Unsafe storage in one environment can affect other environments.

By U.S. law, all chemical manufacturers and importers of hazardous substances—like pesticides, household cleaners, or even paint—must write an SDS to tell users about potential hazards. An SDS gives both consumers and emergency personnel the correct procedures for using a particular substance.

A government agency called the Occupational Safety and Health Administration (OSHA) monitors exposure to chemicals in the workplace and SDS reporting.

An SDS allows the hazardous chemical manufacturer to alert the chemical user and emergency personnel about important safety information. Although formats can differ, U.S. law requires an SDS to include certain data.

With your parent or guardian's permission, find an SDS for an insectides and a paint by searching online for "sds insecticide" and "sds paint." On both SDS reports, look for the following information:

- **Toxicity and health effects**—both immediate upon exposure and long-term exposure effects
- **First aid**—what to do if the product gets in a person's eyes or on the skin, or is breathed into the lungs or swallowed
- **Reactivity**—if the substance will react with itself or other products, and the chemicals released if the product is burned
- **Storage**—temperature, location, and handling to minimize risk
- **Disposal**—directions and legal limitations
- **Protective equipment**—safety equipment for personal protection
- **Spill and leak**—procedures or actions to take in the event of a spill or leak
- **Physical data**—for example, its melting point, boiling point, *flash point*, and flammability (if it will burn)

Flash point refers to the lowest temperature at which chemical vapors will ignite when exposed to flame.

A safety data sheet (SDS) contains 16 sections. While all sections must be included to comply with international regulations, the Occupational Safety and Health Administration will not enforce the content of sections 12 through 15. Sections 1 through 11 and 16 are described below:

Section 1: Identification. This section identifies the chemical on the SDS, lists its recommended uses, and provides the manufacturer's name, address, and emergency telephone contact information.

Section 2: Hazard(s) Identification. This section identifies the hazards of the chemical and provides appropriate warning information.

Section 3: Composition/Information on Ingredients. This section identifies the ingredients in the product.

Section 4: First-Aid Measures. This section describes the initial care that should be given by untrained responders to someone who has been exposed to the chemical.

Section 5: Fire-Fighting Measures. This section provides recommendations for fighting a fire caused by the chemical.

Section 6: Accidental Release Measures. This section provides recommendations on the appropriate response to spills, leaks, or releases.

Section 7: Handling and Storage. This section provides guidance on safe handling and storage practices.

Section 8: Exposure Controls/Personal Protection. This section identifies exposure limits and indicates personal protective measures to minimize exposure.

(continued on page 24)

Icons like these placed on chemicals can tell you a little about them, such as if the chemical is hazardous *(top)*, a biohazard *(center)*, or flammable *(bottom)*.

These abbreviations commonly used in the SDS are important to know:

LEL: Lower explosive limit. The point at which a material becomes too "lean" to burn.

PEL: Permissible exposure limits. Tells how much of the product you can safely be exposed to without suffering undue harm.

TLV: Threshold limit value. Similar to PEL.

TWA: Time weighted average. The amount of the material to which the "average" human can safely be exposed over an eight-hour working day.

UEL: Upper explosive limit. The point at which a material becomes too "rich" to burn.

SAFETY DATA SHEET

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifier

Product name : FIRETEX M71V2

Product code : M71V2

1.2 Relevant identified uses of the substance or mixture and uses advised against

Material uses : Paint or paint related material.
: Industrial use only.

1.3 Details of the supplier of the safety data sheet

Sherwin-Williams Protective & Marine
Tower Works
Kestor Street
Bolton
BL2 2AL
United Kingdom
+44 (0) 1204 521771

e-mail address of person responsible for this SDS : hse.pm.emea@sherwin.com

1.4 Emergency telephone number

National advisory body/Poison Centre

Telephone number : 0844 892 0111

Supplier

Telephone number : +(44)-870-8200 418

Hours of operation : Emergency contact available 24 hours a day

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Product definition : Mixture

Classification according to Regulation (EC) No. 1272/2008 [CLP/GHS]

Flam. Liq. 3, H226
STOT SE 3, H335 and H336 (Respiratory tract irritation and Narcotic effects)
Asp. Tox. 1, H304
Aquatic Chronic 2, H411

The product is classified as hazardous according to Regulation (EC) 1272/2008 as amended.

Classification according to Directive 1999/45/EC [DPD]

The product is classified as dangerous according to Directive 1999/45/EC and its amendments.

Classification : R10
Xi; R37
R66, R67
N; R51/53

Physical/chemical hazards : Flammable.

Section 9: Physical and Chemical Properties. This section identifies physical and chemical properties associated with the material.

Section 10: Stability and Reactivity. This section describes the reactivity hazards of the material and chemical stability information.

Section 11: Toxicological Information. This section identifies the toxicological and health effects information or states that such information is not available.

Section 16: Other Information. This section includes other information not covered in previous sections, including when the SDS was prepared or last revised.


Conforms to Regulation (EC) No. 1907/2006 (REACH), Annex II, as amended by Regulation (EU) No. 453/2010

FIRETEX M71V2
M71V2

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Bolton
BL2 2AL
United Kingdom
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Physical/chemical hazards	: Flammable.

Date of issue/Date of revision : 29, May, 2015. *Date of previous issue* : 29, Apr, 2015. *Version* : 1.01 1/15

Safety Equipment

Chemistry experiments are fun as long as everyone is safe. Make sure your experiment is safe by learning about recommended safety equipment.

Safety Goggles

When working with chemicals, wear splashproof goggles to protect your eyes from spilled or splattered chemicals. Remember that goggles worn around your neck or forehead do not protect your eyes. Some state laws require every person in the laboratory to wear goggles.

Fire Blanket

Most clothing is flammable. If someone's clothing catches on fire, wrap the person in a fire blanket to cut off the supply of oxygen to the flames, just like snuffing out a candle.

Safety Gloves

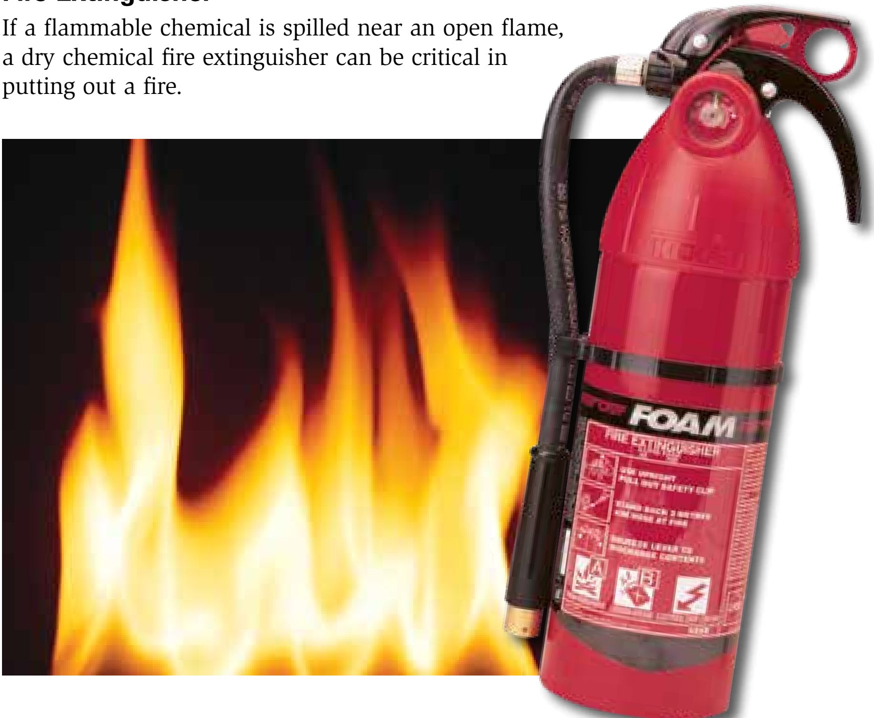
Disposable gloves like those used in the medical or dental profession are safety gloves. Some chemicals, like acids, are unsafe for skin contact. Although some substances can soak through gloves, this extra layer of protection can save hands from a chemical burn.

First-Aid Kit

For minor cuts, burns, and abrasions, have a first-aid kit handy. The supplies in a first-aid kit also can work for temporary assistance until proper medical attention is available.

Fire Extinguisher

If a flammable chemical is spilled near an open flame, a dry chemical fire extinguisher can be critical in putting out a fire.



Quick Safety Tips

- Always have access to a telephone to contact medical personnel if needed.
- Do not work alone or without your parent's permission.
- Follow the experiment's instructions exactly.

Knowing both where the safety equipment is located and how to use it are extremely important. If your clothing catches fire, you will not have the time to search for the fire blanket or read its instructions before major injury occurs.

Analytical Chemistry

Often, a chemist or chemical technician is given a sample and asked one of two questions: *What is in it?* or *How much of some specified material is in it?*

Finding answers to these two questions is what analytical chemistry is about. The first question deals with qualitative analysis: *What is in the sample?* The second question deals with quantitative analysis: *How much is in it?*

Quantitative Analysis

Suppose you are an analytical chemist given a mystery clear acid. Your boss asks, "How much acid is in the solution?" You can find the answer by carrying out a chemical reaction. If it is an acid, it will react with a base.

Concentration is the measure of how much of a substance is mixed with a set volume.

Acid—any substance that can produce a hydrogen ion (H^+) in water; tastes sour, like lemon juice.
Base—any substance that can accept a hydrogen ion (H^+) in water; tastes bitter and feels slippery in water.

For example, vinegar contains acetic acid. Baking soda, or sodium bicarbonate, is a base. These two ingredients produce gas when reacting, similar to the acid indigestion tablet experiment in the introduction.

Drop a dirty penny in a glass of cola. Let the penny stay in the cola overnight. How does the penny look in the morning? The acid in the cola is strong enough to clean the coin.

To see how bases react with acids, try this experiment. Pour about a quarter cup of vinegar into a bowl. Drop a teaspoon of baking soda into it. Stir. Repeat these last two steps, adding baking soda and stirring, until no more bubbling occurs. How many teaspoons did it require? The foam is due to the release of the product gas, which is carbon dioxide.

When the solution no longer has an excess of either acetic acid or sodium bicarbonate, the base has neutralized the acid. The chemical formula that illustrates this experiment is as follows.

$HC_2H_3O_2$	+	$NaHCO_3$	→	$NaC_2H_3O_2$	+	H_2O	+	CO_2
Acetic acid		Sodium bicarbonate		Sodium acetate		Water		Carbon dioxide

Qualitative Analysis

Now ask the other kind of question analytical chemists ask. Instead of *how much,* ask *what* is in the sample.

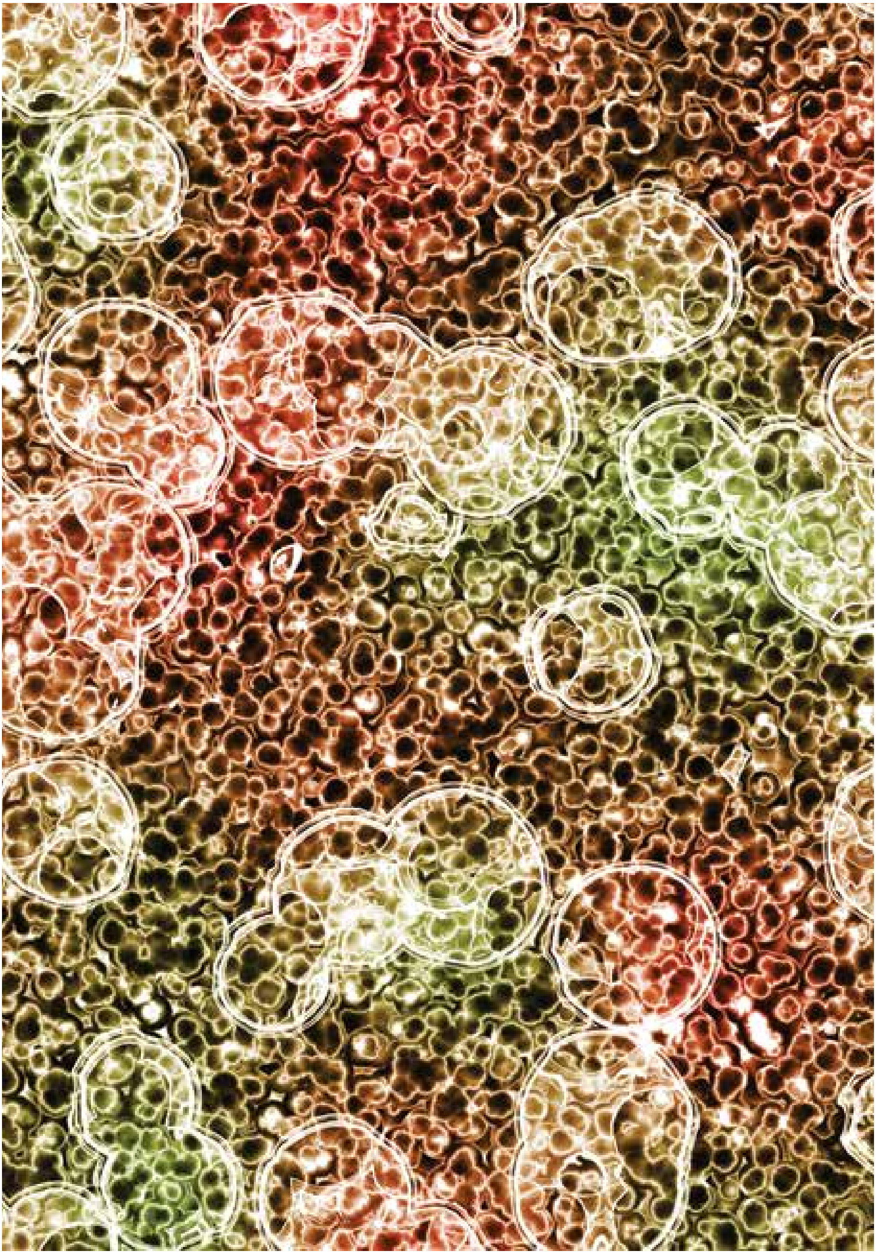
Toothpaste vs. Abrasive Cleanser

Rub some toothpaste between two fingers. Now do the same with an abrasive household cleaner and a drop of water. How are they the same? Like many household items, the labels list the ingredients. Copy the table below and fill in the blank.

Type of ingredient	Toothpaste	Household cleaner
Abrasive (often carbonate or phosphate)		
Surfactant (detergent like sodium lauryl sulfate)		
Solvent (water)		
Fluoride (enamel hardener)		
Additives (perfume, color, flavor)		

Both items clean by using abrasive action and a detergent. The most common abrasive in toothpaste is hydrated silica, which is similar in composition to sand. The most common detergent in both toothpaste and the cleanser is sodium lauryl sulfate. It is a surfactant; we will learn about surfactants in the section "Other Organic Compounds" on page 66.

Two important differences are the pH of the two products and the presence of fluoride in the toothpaste. Fluoride reacts with tooth enamel to make it a harder surface, which is therefore less prone to tooth decay. Fluoride also fights cavity-causing bacteria. The pH of the toothpaste is kept near biological pH (pH 7.4) to keep it from irritating mouth tissues. The pH of the abrasive cleanser, however, can be much higher to help it clean better.



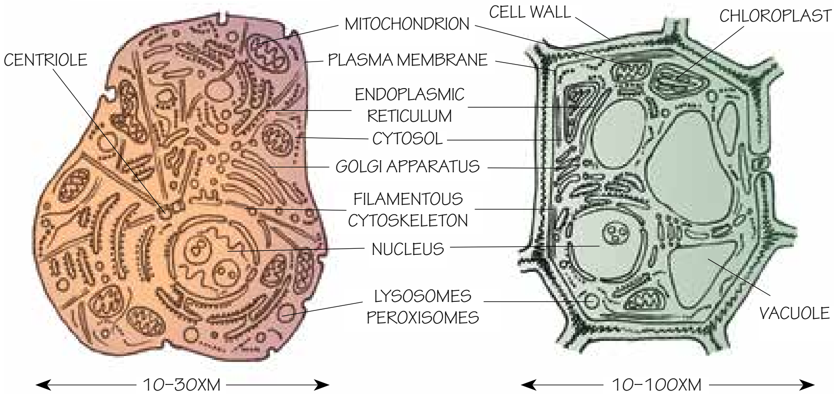
Biochemistry

Biochemistry is the study of the chemical basis of life. But what is life? The simplest unit of life is the *cell.* All living organisms—from the smallest bacterium to the largest mammal—are made of one or more cells.

Typical animal and plant cells

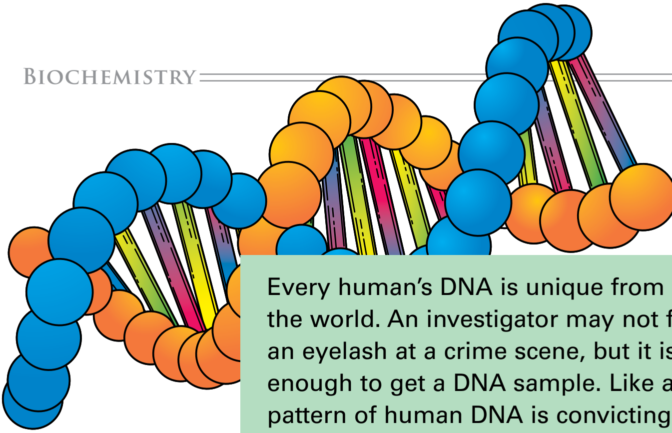
Animal cell—thin section of a generalized animal cell

Plant cell—thin section of a generalized cell from a higher plant



Many biochemists study proteins to understand the reactions necessary for life. Proteins are important in biochemistry because some of them *catalyze* (make faster) the reactions that need to occur for a cell to survive.

There are many different types of proteins. Most are distinct to specific cell types or organisms. This distinction has helped biochemists and medical personnel identify and treat many diseases.



Every human's DNA is unique from anyone else in the world. An investigator may not find more than an eyelash at a crime scene, but it is more than enough to get a DNA sample. Like a fingerprint, the pattern of human DNA is convicting evidence.

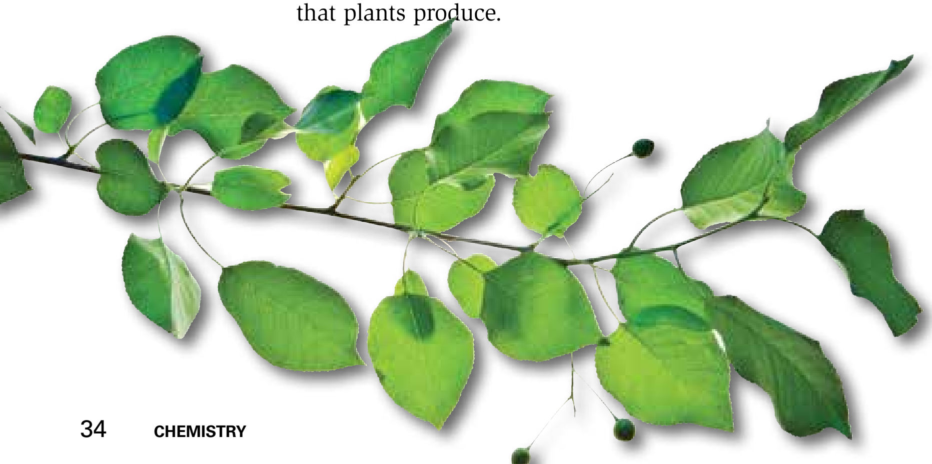
Photosynthesis

Plants, algae, and some bacteria have the unique ability to use sunlight to chemically convert carbon dioxide and water into sugars, oxygen, and energy—a form of photochemistry. This chemical reaction can be written as:

$$6CO_2 + 6H_2O \xrightarrow{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

$6CO_2$	+	$6H_2O$	→	$C_6H_{12}O_6$	+	$6O_2$
Carbon dioxide		Water	Sunlight	Sugar		Oxygen

Why are these reactions so vital? The above formula gives a clue. Plants use carbon dioxide to make sugars. During this process, plants release oxygen into the atmosphere. Animals cannot make sugars from carbon dioxide. So, they eat plants to get the sugars and other compounds that they cannot make independently but that are necessary for life. Animals also need oxygen to break down the carbohydrates in food to have energy for life. This would not be possible without the oxygen that plants produce.



Agricultural Chemistry

Although we take most of it for granted, chemistry's benefits to agriculture are phenomenal. There are fertilizers, fungicides, pesticides, growth stimulators, and weed killers. Chemicals for inhibiting the sprouting of potatoes and onions and for delaying the ripening of fruits are used in large quantities. Lime is important for neutralizing acid in soils, thereby improving crop growth.

The U.S. Department of Agriculture, through its regional laboratories and Agricultural Research Service, sponsors research work in the development of agricultural chemicals. These developments are passed on to farmers through county agents.

Visit a county farm agency, county agricultural extension office, or similar government agency to learn how chemistry is used to meet the needs of agriculture in your county. The internet is useful for locating agency telephone numbers and addresses.

Fertilizers

Plants need more than carbon dioxide and water to survive. They need a great many mineral nutrients. Because plants cannot move around, they must rely on their surroundings for the needed nutrients. If these nutrients become depleted, the plants can die. To prevent crop loss, many farmers and gardeners add commercial fertilizers to their soils.

Fertilizers usually are labeled with three numbers such as 10-6-4, or other similar figures. The numbers refer to the amounts of three important plant nutrients: nitrogen, phosphorus, and potassium. The first number is the percentage of nitrogen, as calculated by the amount of the element nitrogen (N). The second number is the percentage of phosphorus, as calculated by the amount of phosphorus pentoxide (P_2O_5). The third number is the percentage of potassium, as calculated by the amount of potassium oxide (K_2O).

Why do plants need nitrogen, phosphorus, and potassium to grow?

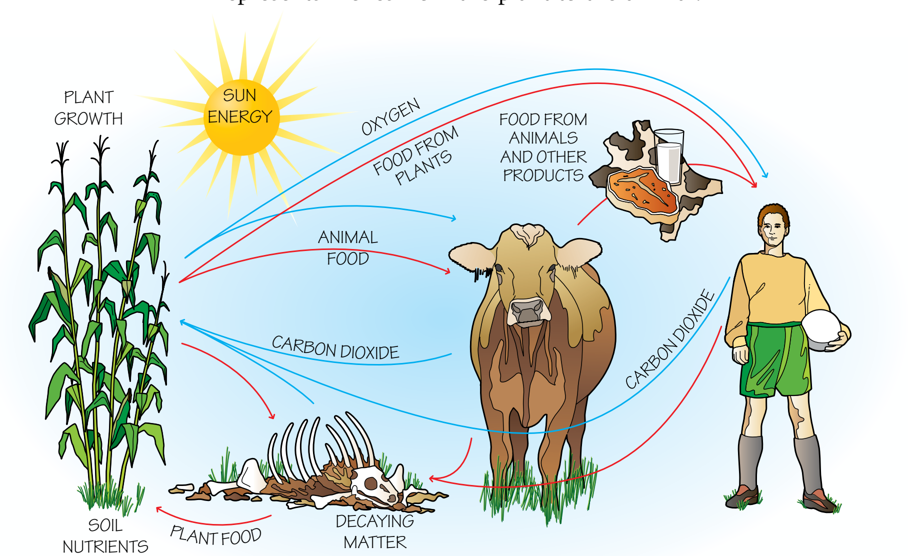
Nitrogen is an important part of proteins and nucleic acids. In addition, each molecule of *chlorophyll* contains four nitrogen atoms. Most plants cannot use nitrogen from the air (atmospheric nitrogen) as a source to obtain the nitrogen they need.

Phosphorus is another important element for plants. It typically is found in nucleic acids, proteins, and the "energy currency" of organisms, a compound called adenosine triphosphate. ATP is an essential part of enzymes that converts sugars to starch (an energy storage form) and to cellulose (a structural building block of plants).

Potassium contributes to the strength and rigidity of a plant. If there is not enough potassium, the leaves and stalks will sag.

Carbon Dioxide–Oxygen Cycle

Both carbon dioxide and oxygen continually move in cycles in nature. In the process of photosynthesis, plants use the carbon dioxide from the atmosphere and give off oxygen. When an animal eats a plant, the carbon dioxide that this food represents moves from the plant to the animal.



The carbon dioxide–oxygen cycle

The Chemistry of Cooking

There are several reasons to cook our food: It is easier to chew and digest, it is safer from food poisoning, and it may taste better. "Chemistry of Cooking" can also be called *food chemistry,* which is an important field of chemistry that impacts our daily lives.

Onion Chemistry

Onions are an ancient vegetable. The ancient Egyptians used onions for medicine and in mummification. Today, all around the world, onions are used primarily for their great flavor. What happens when you cook onions? Why do people prefer onions cooked instead of raw? Cooking is chemistry in action.

ONION TASTE TEST

Ask an adult to help with this cooking experiment and use hot pads at the stove.

Raw onion. Use a knife to cut an onion into chunks. Taste a piece of the raw onion.

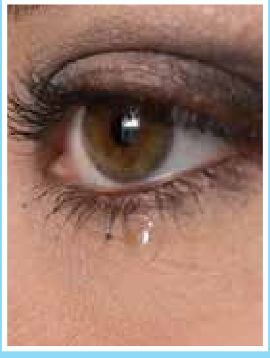
Translucent onion. Line a pan with a few tablespoons of cooking oil. Warm the oil over medium heat on a stove burner. Add onion chunks. Cook and stir for about three minutes, until the onion becomes translucent (kind of see-through). Remove half the onions and cool. Taste a translucent onion. How does it taste different from the raw onion?

Caramelized onion. Continue cooking and stirring the remaining onions in the pan for another 10 minutes over medium heat. The onion will become brown, or caramelized. Remove the onion from the heat and allow it to cool. Taste the caramelized onion. How does it taste compared with the raw and translucent onion? Why?

HOW IT WORKS

In the raw onion, you taste the bitter *thiosulfates*. The thiosulfates are volatile, which means they evaporate easily. When onion is heated in cooking, most of the thiosulfates evaporate and the *enzyme* that produces them is killed—so the translucent onion does not taste as bitter.

When the onion is further cooked to caramelization, it turns brown. The heat converts the onion's carbohydrates into simple sugars that, like fructose and glucose, make the onion taste sweet.



How can onions make you cry? *Propanethial sulfoxide* (a tear-inducing chemical known as a *lachrymator*) vaporizes from an onion when it is cut. This sulfur compound floats in the air. When some of it makes contact with the eye's nerve cell membrane, it produces sulfuric acid. It is no wonder that your eyes make tears to wash out this toxic acid.

Carbohydrates

Carbohydrates are the sugars and starches in foods. They come mainly from vegetables. The cellulose of wood and other fibrous plants is a carbohydrate that humans do not have the enzyme to digest.

There are two main ways to cook carbohydrates: toasting and boiling. When toasted on a hot fire, the carbohydrates in foods such as breads break down to give carbon and release water and other decomposition products. With a cooler fire, the sugars are changed into a light brown caramel, which has a pleasant flavor. With this type of fire, some of the starches in bread are changed to sugars.

In cooking vegetables and cereals by boiling, some of the changes are physical. The starch granules absorb water and may burst. Some *hydrolysis* (reaction with water) occurs and there is some conversion of starches to sugars. The woody stems of green vegetables, made of tough fibers, become tender and easier to chew because swelling softens these fibers.

Proteins

Proteins come from lean meats, fish, eggs, milk, nuts, and some vegetables like beans and peas. Proteins are made from amino acids. It is important to eat enough proteins because there are some amino acids that humans cannot make.

When cooking proteins, it is better to use low rather than high temperatures. Boiling and baking are better than frying, broiling, or steaming. A poached egg, for example, is more digestible than a fried or scrambled egg.

Fats

We get the fats we need from meats, butter, oleomargarine (made from vegetable oils), and oily vegetable materials such as olives and nuts. The right way to fry and cook fat is to do it slowly. This prevents the formation of acrolein, carbon, and other bad-tasting and indigestible compounds.

Mix a package of baker's yeast with about a half cup of very warm tap water. Stir in a spoonful of sugar. Pour it in an empty soda bottle and seal the top with a balloon. Let the bottle sit in a warm place for an hour. Did something change?

Baking

In baking bread, cooks rely on the generation and expansion of carbon dioxide to make the dough rise. Moisture and heat help to break up the starch granules and make them easy to digest. Fat used in making pastry coats the starch molecules so that they do not stick together. This gives the pastry a flaky texture.

One way to produce carbon dioxide in baking is to add baker's yeast, which gets the necessary energy for life by breaking down sugars. Yeast needs three things to grow: moisture, food, and warmth. The by-products of the yeast reaction are carbon dioxide and alcohol, which vaporizes in baking.

The other method to produce carbon dioxide in baking is to react an acid with the bicarbonate. This chemical reaction is like the vinegar and baking soda experiment.

Inorganic Chemistry

Inorganic chemistry is the study of all elements and their compounds *except carbon compounds*. (You will understand why carbon is excluded when you study organic chemistry.) Metals are among the most useful inorganic materials. In general, metals can be recognized by their shininess, hardness, and ability to conduct heat and electricity. Jewelry, paper clips, keys, and coins are made of metals. Metal wires carry electricity in your home. Some metals are elements, but many are *alloys,* meaning they are made of two or more elements. Some common alloys and their compositions are shown in the table.

Alloy	Composition
Sterling silver	92 percent silver (Ag), 8 percent copper (Cu)
18-karat gold	75 percent gold (Au), 25 percent copper (Cu)
Brass	67 percent copper (Cu), 33 percent zinc (Zn)
Bronze	90 percent copper (Cu), 10 percent tin (Sn)
Carbon steel	99 percent iron (Fe), 1 percent carbon (C)
Stainless steel	70 percent iron (Fe), 20 percent chromium (Cr), 10 percent nickel (Ni)
Dental amalgam	Silver (Ag), tin (Sn), mercury (Hg)

Iron

Iron is the most widely used metal. Iron and its alloys, like carbon steel and stainless steel, are useful because of their strength and hardness. Iron alloys are used in tools, nails, automobile frames and bodies, structural steel, and machinery.

Corrosion and Rust

Iron is easily attacked by oxygen gas and water vapor in air. It is converted to reddish-brown iron oxide, commonly called *rust.* As the outer layer of iron oxidizes, it splinters away from the surface, exposing the next layer of iron to oxidation. Corrosion costs billions of dollars a year in prevention, control, and replacement of weakened structures. Look around you—everywhere there is evidence of corrosion. The process of *rusting* is shown by the equation:

$$4Fe\ (s) + 2H_2O + 3O_2 \rightarrow 2Fe_2O_3\ (s) \times 2H_2O$$

Paint, varnish, or enamel can cover iron to protect the metal from rusting. Coating iron in zinc (Zn) is called *galvanization.* Metal garbage cans commonly are galvanized and corrode slowly. Zinc, similar to aluminum, forms a protective film by oxidation and resists corrosion.

Aluminum

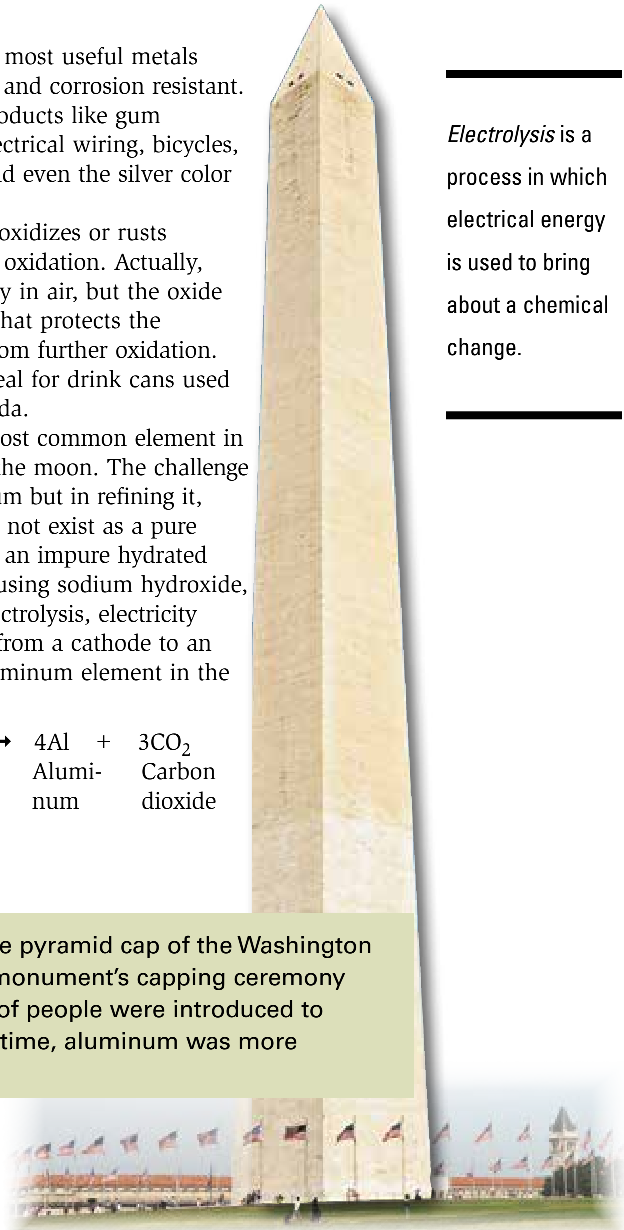
Aluminum is one of the most useful metals known. It is lightweight and corrosion resistant. Aluminum is used in products like gum wrappers, soda cans, electrical wiring, bicycles, car, trucks, airplanes, and even the silver color of fireworks.

Unlike iron, which oxidizes or rusts easily, aluminum resists oxidation. Actually, aluminum oxidizes easily in air, but the oxide forms a tight, thin film that protects the underlying aluminum from further oxidation. This quality makes it ideal for drink cans used for acidic carbonated soda.

Aluminum is the most common element in the crusts of Earth and the moon. The challenge is not in finding aluminum but in refining it, because aluminum does not exist as a pure element. When bauxite, an impure hydrated oxide ore, is refined by using sodium hydroxide, it produces alumina. Electrolysis, electricity passing through a fluid from a cathode to an anode, separates the aluminum element in the refining process:

$2Al_2O_3$	+	$3C$	$\rightarrow$	$4Al$	+	$3CO_2$
Alumina		Carbon anode		Alumi-num		Carbon dioxide

Electrolysis is a process in which electrical energy is used to bring about a chemical change.



Aluminum forms the pyramid cap of the Washington Monument. At the monument's capping ceremony in 1884, thousands of people were introduced to the material. At the time, aluminum was more valuable than gold.

Activity Series of Metals

When added together to a salt (sulfate) compound, any element on the metal activity series can displace any element listed below it. Based on the activity series chart, form a *hypothesis,* or a guess based on knowledge, of what would happen if an iron nail were soaked in copper sulfate.

Activity Series

Most Active

Decreasing Activity

- lithium (Li)
- potassium (K)
- calcium (Ca)
- sodium (Na)
- magnesium (Mg)
- aluminum (Al)
- manganese (Mn)
- zinc (Zn)
- chromium (Cr)
- iron (Fe)
- nickel (Ni)
- tin (Sn)
- lead (Pb)
- hydrogen (H)
- antimony (Sb)
- bismuth (Bi)
- copper (Cu)
- silver (Ag)
- mercury (Hg)
- platinum (Pt)
- gold (Au)

Least Active

Do this experiment. Wearing safety goggles, place a clean iron nail in a clear cup. A long nail works best. (Make sure the nails are not galvanized or plastic-coated. If they are, simply use some 80-grit sandpaper to remove the coatings.) Get some copper sulfate ($CuSO_4$), which is sold as root killer at hardware stores. (Note: not all root killers contain $CuSO_4$, so check the label.) Dissolve a half-teaspoon of the copper sulfate in one-third cup of water. Pour the light blue copper sulfate solution in the cup with the nail, preferably leaving the top of the nail out of the solution for comparison.

$$Fe\ (s) + CuSO_4\ (aq) \rightarrow Cu\ (s) + FeSO_4\ (aq)$$

(aq) = aqueous

Copper sulfate is sold as a root killer at hardware or gardening stores in many states but is banned in others. (Find out why it is banned.) Copper sulfate can still be purchased on-line but you must have your parent's (or guardian's) help to do it.

On the surface of the nail, iron (Fe) loses electrons to copper ions. The iron ions combine with the sulfate to produce iron sulfate ($FeSO_4$), while the copper ions gain the electrons to become copper metal. The surface of the nail should show a red-brown or copper color. The blue copper sulfate solution will become a lighter blue.

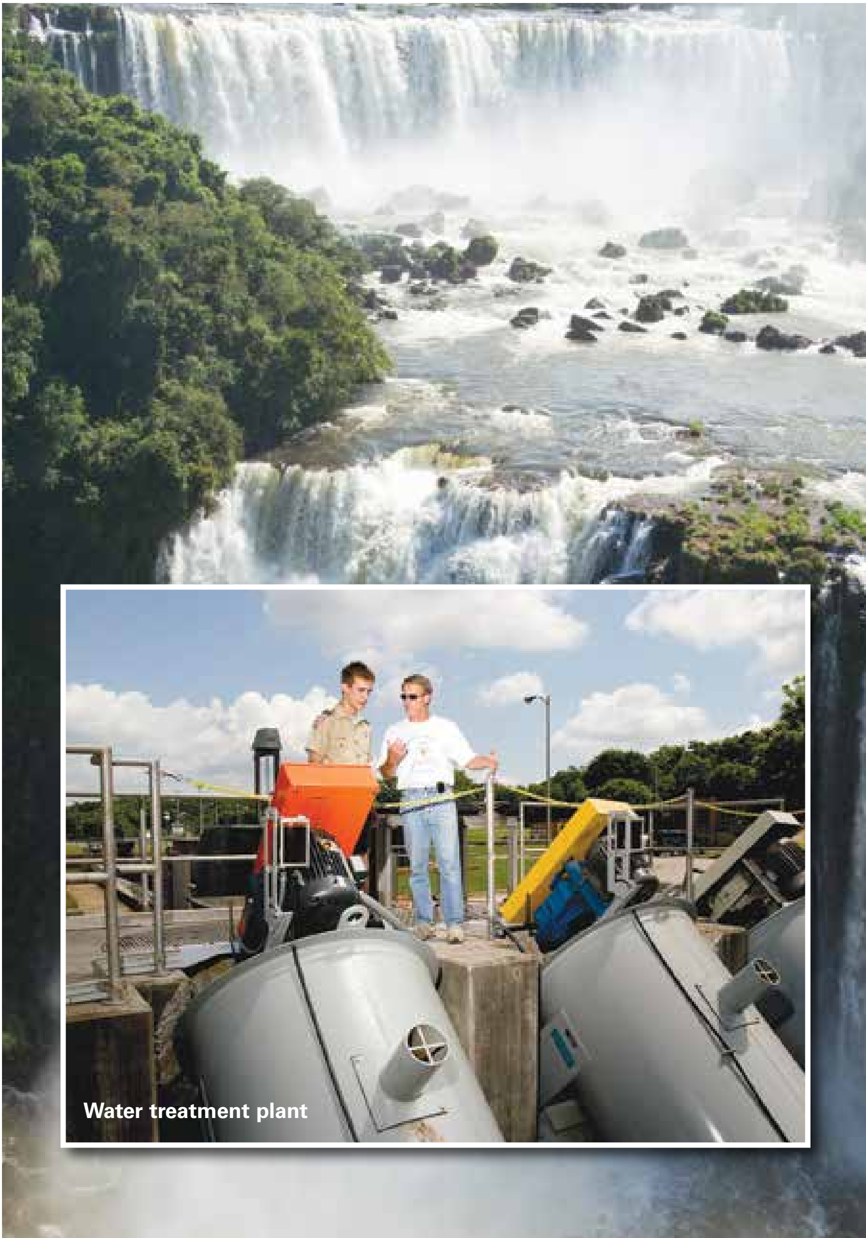
Metals transfer electrons in a predictable fashion. The chemical process of transferring electrons can be related to the behavior of metals and metal ions by arranging them in the *activity series*. The most active and least stable metal is placed at the top. The least active and most stable metal is at the bottom. Hydrogen gas behaves like a metal and is placed in the middle. Metals below it cannot liberate hydrogen gas.

$$Zn\ (s) + 2HCl\ (aq) \rightarrow H_2\ (g) + ZnCl_2\ (aq)$$

Each metal in the activity series is capable of *displacing* from solution the metal ions in any salt of any metal below it in the series. In the experiment, since iron is above copper in the series, the iron displaced the copper ions in the copper sulfate.

- If your nail was galvanized, then zinc, not iron, is in contact with the copper sulfate. The larger the interval between elements, the more vigorous the reaction. Would zinc be more or less reactive?
- Would gold (Au) be expected to displace copper ions from a solution of copper sulfate? Why? Why not?
- Try a similar experiment with a nail and some pennies in a glass of lemon juice. What happens to the copper in the pennies?

The major particles of atoms are *electrons* (negative charge), *protons* (positive charge), and *neutrons* (neutral or no charge).



Water treatment plant

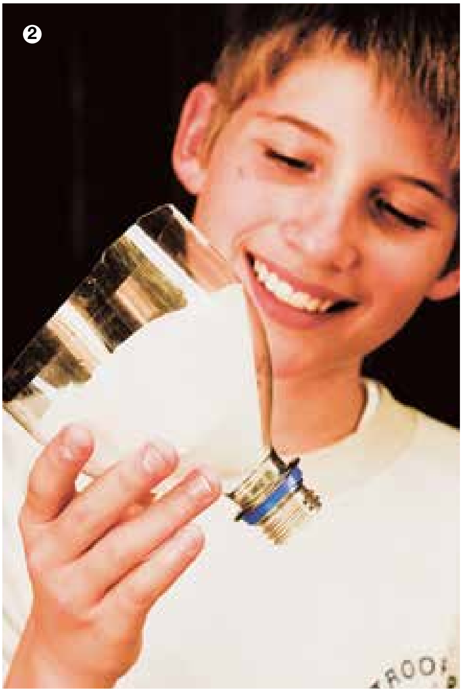
Separation

How does water mix with sand, salt, and oil? You can find out by separating them. Some chemists operate water treatment plants where water from streams and lakes is cleaned before it is sent to your home for you to drink.

Sand and Water

One part of water treatment is *filtration,* a process that works like a net to catch particles that are too large to pass through. You can demonstrate the process with an experiment.

Step 1—Make a funnel by cutting the top off a plastic bottle.



Step 2—Put the bottle-top funnel, cut side up, in a clear container. Place a coffee filter or folded paper towel in the funnel.

Step 3—Add two spoonfuls of sand (or gravel) to a glass of water. Stir to mix. Some of the sand will settle to the bottom. Holding the funnel and paper with one hand, pour the sand and water into the filter. The sand will be trapped in the filter.

In a water treatment plant, the water passes through a settling tank, where the largest and heaviest particles sink to the bottom. Then the water flows through a filter, typically with layers of gravel, charcoal, and sand, to remove the smaller particles.

Disappearing Act

Fill two drinking glasses to the top with water so that the glasses are almost overflowing. Add a spoonful of sand to one. Gently stir, trying not to make it overflow. Now add a second spoonful of sand. Did it overflow? Did the sand settle to the bottom? Now repeat the experiment by adding table salt, instead of sand, to the second glass. When you stirred the salt, did it seem to disappear? How many spoonfuls of salt could you add before the glass overflowed?

Dissolving

Table salt, which chemists call sodium chloride (NaCl), is a sodium ion bonded to a chlorine ion. When sodium chloride is mixed in water, the sodium ions with a positive charge are attracted to the oxygen atom in water. The chloride ions with a negative charge are attracted to the positive hydrogen in water. In this way, salt dissolves in water, unlike sand. So the *volume*, or space taken up, of the water does not change when salt is added, until no more salt can dissolve in the water. Salt dissolved in water becomes a *solution*.

Ions are atoms that carry an electrical charge.

Have you ever had bubbles in your nose when you drank a carbonated soft drink? The bubbles are carbon dioxide originally dissolved in the drink under pressure. When you opened the can and drank the soft drink at a lower pressure, the carbon dioxide was released.

Lost at Sea and Thirsty

If some thirsty chemists lost at sea landed on a deserted island, they could make drinking water by removing the dissolved sea salt from the ocean water. But how? Filtration will not work. The chemists would use the different boiling points of water and salt for separation. Water has a much lower boiling point than salt.

To understand separation using boiling points, try this experiment.

Step 1—With adult help, fill a teakettle half full of water. Add ¼ cup of salt. Close the top and swirl it to stir. Taste a teaspoonful. Yuck!

The *boiling point* is the temperature at which a substance boils at atmospheric pressure.

Step 2—Fit a bendable straw into the end of another bendable straw. Put one end of the straw through the vent hole on the teakettle. Set the teakettle on the stove, but do not turn the burner on yet.

Step 3—Use a fork to make a small hole in a disposable aluminum pie pan. Thread the straw through the pie pan hole. Set the pie pan on top of a glass so the straw extends down in the glass, but the pie pan does *not* cover the entire top of the glass.

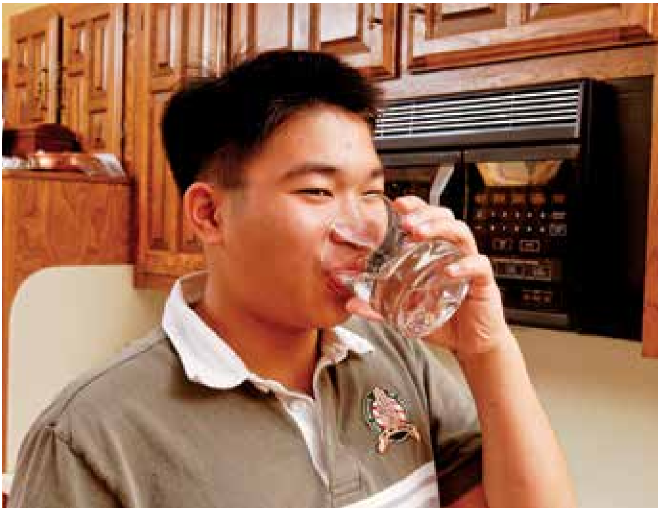
Step 4—Fill three resealable bags with ice. Set one on the pie pan, wrapping it around the straw. Set the other two ice bags around the outside of the glass.

Distillation is the process in which a liquid mixture of two or more substances is separated by adding and removing heat.

Step 5—Turn the burner on high heat until steam appears, then reduce heat to medium. When you have collected a large enough sample, taste the water in the glass. Yum! That is distilled water like you can buy bottled and sold at the grocery store.

WHAT HAPPENED?

Heating the teakettle brought the water to its boiling point temperature, where it began to boil—making steam. The steam passed through the straw and was cooled by the ice. The cooled steam condensed, became a liquid, and dripped down into the glass. This is distillation.



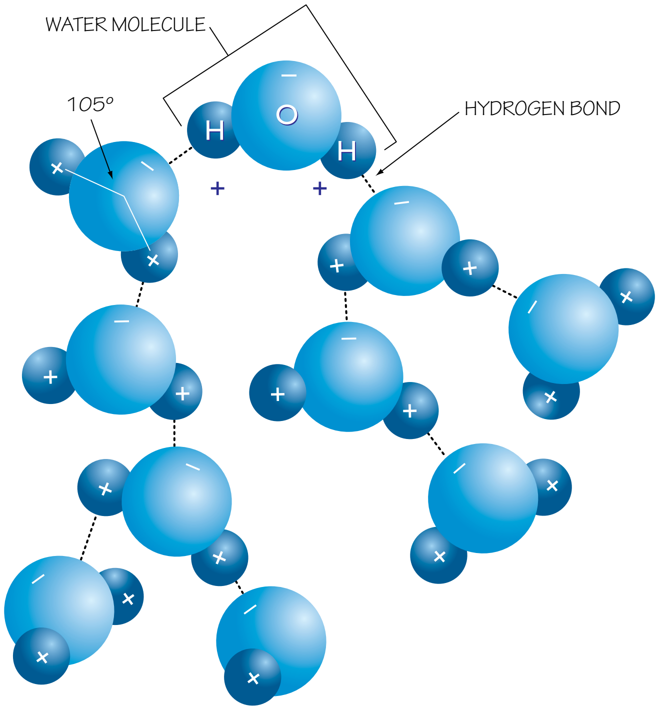
Oil and Water Separation

Density is the mass per unit volume of a substance.

Try this. Fill an empty 2-liter bottle with 3 or 4 inches of cooking oil, baby oil, or mineral oil. Add approximately the same amount of water and a few drops of food coloring. Tightly screw on the cap. Shake the bottle. The oil and water begin to separate as soon as you stop shaking the bottle.

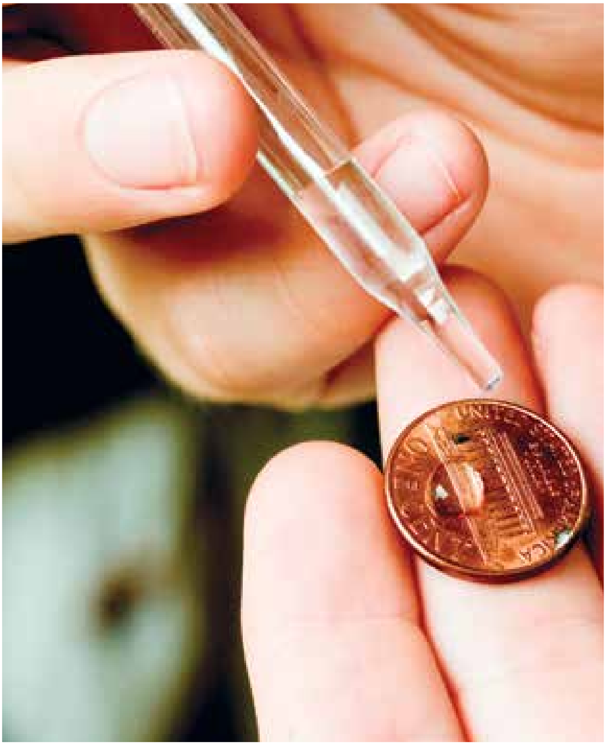
WHAT HAPPENED?

The oil separates out on top because it is lighter and has a lower density. However, even more factors are causing this separation. To understand what is happening, imagine the molecular level.



Polarity and Cohesion

Water is a *polar molecule,* with the oxygen negatively charged and the hydrogen positively charged. In magnets opposites attract, as positive attracts negative. You can think of a water molecule as a magnet where opposite charges attract, although it does not have magnetic poles like a magnet. When water molecules are in liquid phase, they turn so the positive side of one molecule is close to the negative side of another molecule. This attraction causes *cohesion*—water pulling together.

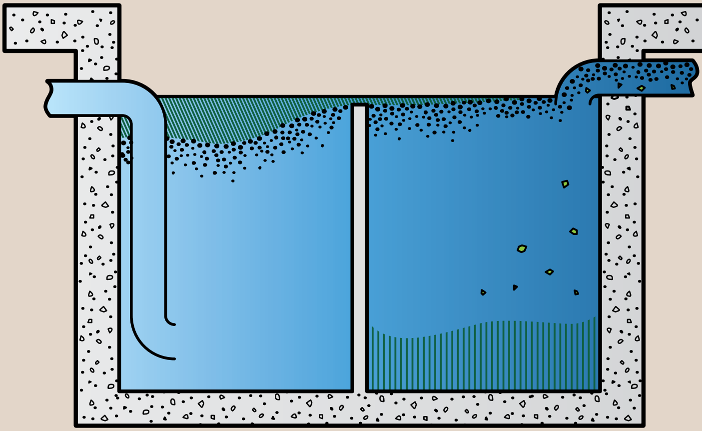


Guess the number of drops of water from a medicine dropper that can sit on the head of a penny before it overflows. Now try it and count the drops. The bubble forms on top of the penny because the water is attracted to itself—it is cohesive.

Oil, which is *nonpolar,* does not dissolve in water. After mixing by shaking the bottle, the oil and water quickly form separate layers as the water molecules pull together.

When crude oil comes out of the ground at an oil well, it carries water with it. You know your car cannot run on water—the water must be separated from the oil. An oil-water separator is like a large bottle on its side with a *weir,* or wall, that divides the separator. The water and oil fill up the area behind the wall in the first half.

The oil separates to make a layer on top of the water. Some of the oil layer spills over the top of the weir to the second section and is drained out. The water drains from the bottom of the first section.



Oil-Water Cup

Fill a disposable plastic cup with half oil and half water. Let the oil and water separate into two layers. Poke a hole with a pencil near the bottom of the cup. Watch the water flow out of the drain hole, as it would in an oil-water separator.

Organic Chemistry

All life—whether plant, animal, or fungi—depends on two things: water and carbon compounds. Organic chemistry is the study of these vital carbon compounds and their reactions. Organic chemistry is often called the chemistry of life and ranges from the simple, such as methane, to the very complex, such as hemoglobin or DNA. In this section, you will be looking at the basis of organic chemistry and how it affects people's daily lives.

Hydrocarbons are compounds made of hydrogen and carbon, the simplest being methane.

What Are Organic Chemicals?

People use the products of organic chemistry every day. *Hydrocarbons,* such as gasoline or natural gas, provide energy for our homes and cars. Pharmaceuticals from aspirin to antibiotics, and even illegal drugs like cocaine, are organic. Even plastics are organic. Many household items such as sugar and mothballs (naphthalene) are pure *organic compounds.* These chemicals are neither bad nor good, but simply a part of the world around us.

Organic compounds can exist as gases, liquids, or solids. A common example of an organic gas is natural gas, or methane (CH_4). Gasoline is a common organic liquid. Plastics are probably the most common form of organic solids.

Reactions of Organic Compounds

Organic acids and bases behave much like their inorganic counterparts. One example of an organic acid is acetic acid, the compound that gives vinegar its sharp taste and smell. In the analytical chemistry experiment, you noticed bubbles from this reaction. The carbonic acid decomposes to water and carbon dioxide, which bubbles out of solution. The reaction is:

$$CH_3COOH + NaHCO \rightarrow CH_3COONa + H_2CO_3 \rightarrow CH_3COONa + H_2O + CO_2$$

Plumbing tip. Use this tip to clean out a slow-draining pipe. Pour a cup of baking soda, and then a cup of vinegar, down the drain. Wait five minutes. Flush the drain with boiling water. The bubbling of the carbon dioxide and the acid in the vinegar help to break up deposits, which are flushed away by the hot water.

Oil and Gas Production

Most of the organic compounds we use come from crude oil. That is why conserving oil is important—not just so that we will have gasoline, but so we will have the full range of organic products that we use every day, from ibuprofen to plastic wrap and coffee cups.

Separating Gasoline

After the water and natural gas are separated from crude oil at the wellhead, the crude travels to a refinery. The crude oil is a mixture of different hydrocarbons. In the refining process, the crude oil is separated into several products called *fractions.* A distillation tower filled with *packing,* or trays, separates the products by distillation. Similar to the distillation of salt water, heat is added to boil the bottom product and cooling is used to condense the top product.

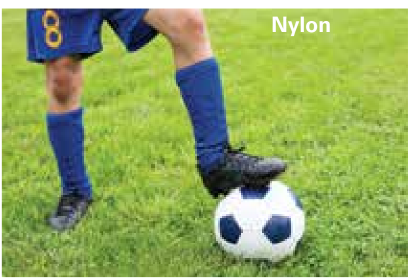
Motor Oil Separation

In your garage, you might find motor oil and gasoline. Gas-powered weed cutters operate on a mixture of gasoline and motor oil. These are not pure compounds but mixtures of hydrocarbons—compounds that contain varying amounts of carbon and hydrogen. Because they have different boiling points, they can be separated by distillation.

Plastics and Polymer Chemistry

A natural gas plant separates ethane and propane, among other hydrocarbons, from the raw natural gas stream. The product left behind consists primarily of methane for home and industrial heating. The ethane, propane, and heavier hydrocarbons can be cracked in an ethylene plant. The ethylene product then is food for the polyethylene plant, which produces polyethylene or plastic pellets. The pellets can be melted and molded into a variety of plastic products.

There are many kinds of plastics. Those that are easily recycled are stamped with a code number inside a triangle.


Nylon

Polystyrene

Polyvinyl chloride (PVC)

Polyethylene terephthalate

Polyethylene

Plastics, Polymers, and Recycling

Plastics are organic materials that people deal with every day. They range from hard plastic parts in cars, appliances, and furniture to resealable sandwich bags. *Polymers* are different from the materials already discussed in that they are made of long chains of molecules. This gives them many of their good properties. Polymers are formed by chemically linking many units of smaller molecules together. Most of these smaller units are products of the petrochemical industry.

It is obvious that most of the modern world's lifestyle is based on organic chemistry. Will this change in the future? As petroleum reserves are used up, the raw materials needed to make drugs, plastics, and other products will need to come from other sources. If we can lessen our need for oil, gasoline, and other fuels, we will greatly extend the life of these raw material sources. Chemical research is under way to find other sources, such as plants, to provide the necessary materials.

Drug Synthesis

Drugs or pharmaceuticals have become an integral part of everyday life. Most drugs, whether prescription or illegal, have been synthesized by organic chemists. But many of these materials were first isolated from natural sources using medicinal and natural products chemistries.

Prescription drug production

One of the great dangers of destroying the world's rain forests, which contain the greatest genetic diversity of the world, is that this source for new drugs will be destroyed.

Medicines used for cardiac problems and heart and lung surgeries were developed from compounds discovered in the rain forest.

The Food and Drug Administration protects the public health by monitoring dietary supplements, drugs, vaccines, animal feed, and even radiation-emitting products like microwaves.

Once a new drug has been discovered and shown to be effective, the organic chemist must design a synthesis, or series of chemical reactions in the laboratory, to duplicate the natural compound.

Other Organic Compounds

Closely related to medicines are the chemicals used in everyday foods. An extremely pure chemical available around the house is sucrose, or table sugar. Another example is vinegar. One area of active research is noncaloric sweeteners like saccharin, aspartame, and sucralose.

Stubborn Oil

Fill a clear empty plastic bottle half full of water. Add a tablespoon of oil and screw on the cap. Shake the bottle. As discovered in the oil and water separation experiment, oil and water do not mix.

Surface Tension

Surface water molecules are strongly attracted to the molecules on their sides and directly below them. Water molecules are not attracted to air. The water molecules on the surface exert all their strong attractive forces, called *cohesion,* on the molecules beside them and directly below them. This strong force is known as *surface tension.*

Tip: Remember the word *surfactant* because it disrupts the *surface* tension.

Here is the challenge: Find a mystery ingredient to add to the bottle so the oil and water will stay mixed after shaking. If you added soap or detergent to the oil and water, good for you. Those are both *surfactants.* See how surfactants break the surface tension of water by trying this activity.

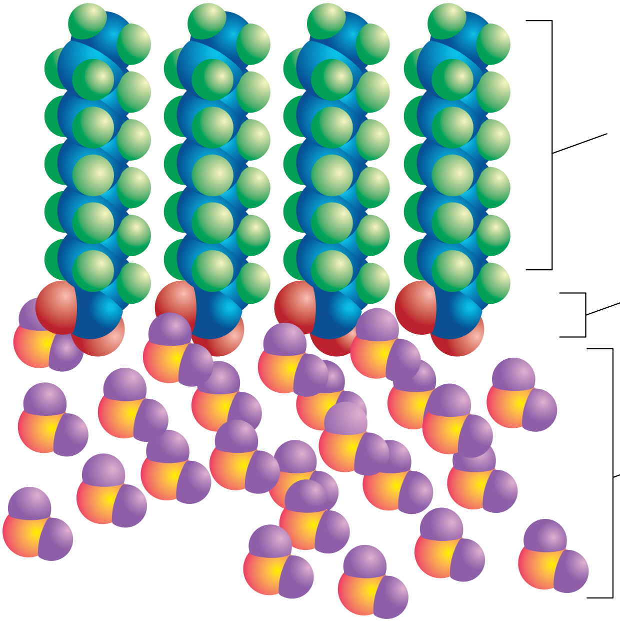
Fill a bowl with water, then sprinkle baby powder or deodorant shoe powder on the water surface. The powder floats on top because of surface tension. Add one drop of dishwashing liquid. What happens?

Detergent comes from the Latin word *detergere,* which means “to clean.”

When dropped on water, soap molecules line up on the surface with their nonpolar tails up. The polar heads of the surfactant are attracted to the water molecules which are also polar. The soap molecules push the powder floating on the surface to the edges of the bowl.

Goat Fat

The ancient Romans stirred goat fat and wood ashes in a pot over a fire to make soap. People continued to make soap by a similar process until commercial soap making became common in the early 1900s.

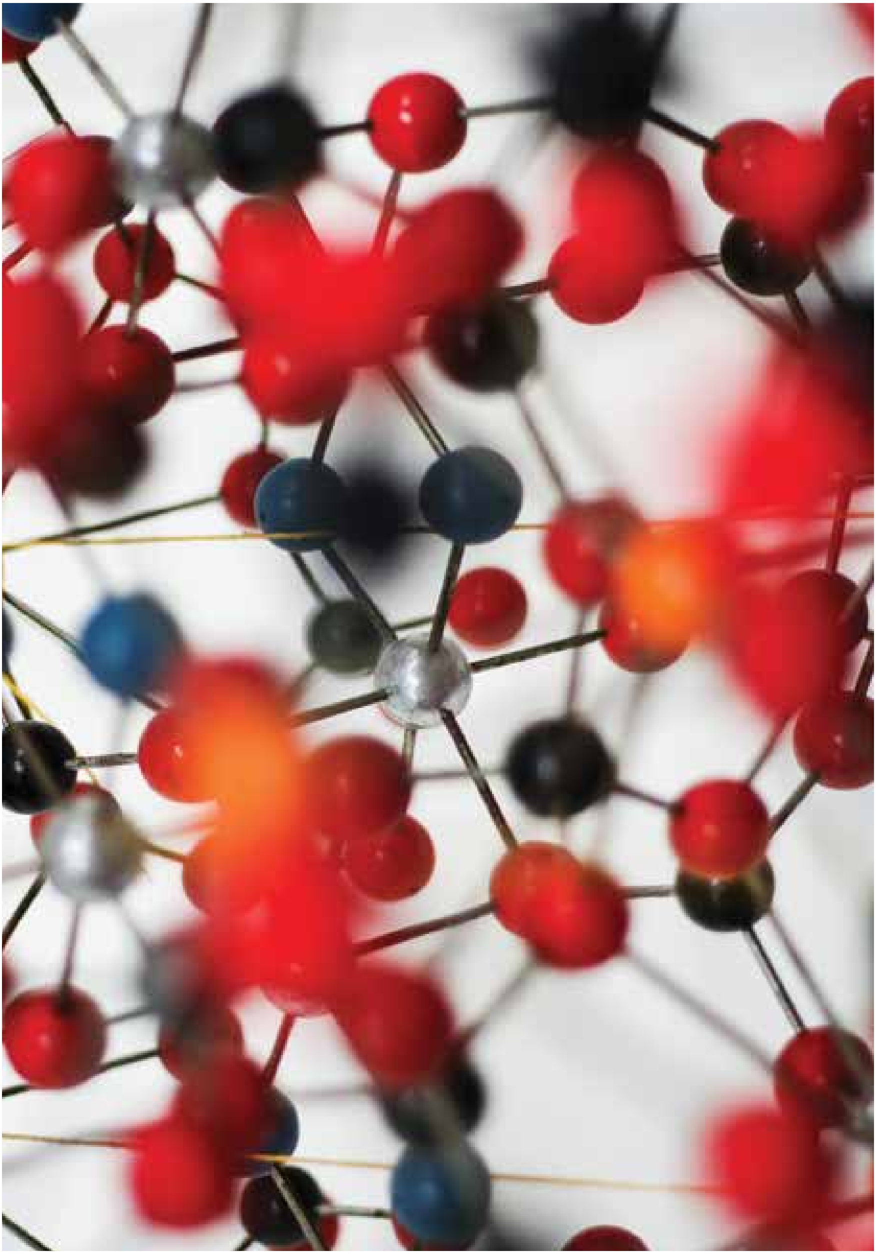


Monolayer of soap on water

When you added a soap—a surfactant—and shook the bottle in the stubborn oil experiment, why did the oil change from one large droplet on the surface of the water to bubbles and small droplets on the surface?

Besides changing the surface tension of the water, the soap formed *micelles* with the oil. With shaking, hundreds of micelles form. They vary in size, and the oil ball forms with the tails of the soap chain pointing inward in the oil and the negatively charged heads on the outside edge sticking out in the water.

Micelles are small ball-shaped globules usually floating in a liquid and in great number.



Physical Chemistry

The branch of chemistry called *physical chemistry* is where physics and chemistry meet. Physical chemists often try to quantitatively describe and measure chemical events and the characteristics of atoms and molecules. Physical chemical methods can determine the distance between atoms in a molecule, their spatial arrangement (relationship to one another in space), and the strength of the bond that holds them together. These methods often involve the use of electromagnetic radiation, but you can study the interactions between molecules by using some common objects.

Cartesian Diver

Make a physical chemistry toy with a diver that will float and dive over and over. This invention is called a Cartesian diver.

Step 1—Use a writing pen lid, preferably transparent, as the diver. Add some clay or sticky tack to the tip of the lid. (A medicine dropper or pipette also will work.) Put the pen lid, with the hole side down so that air is trapped inside, in a glass of water. If it floats with the tip of the lid just above the water, go to the next step. Otherwise add or remove clay until it floats as needed.

Step 2—Fill a clean clear plastic soft drink bottle to the very top with water. Float the pen lid in the bottle. Screw on the bottle cap tightly.

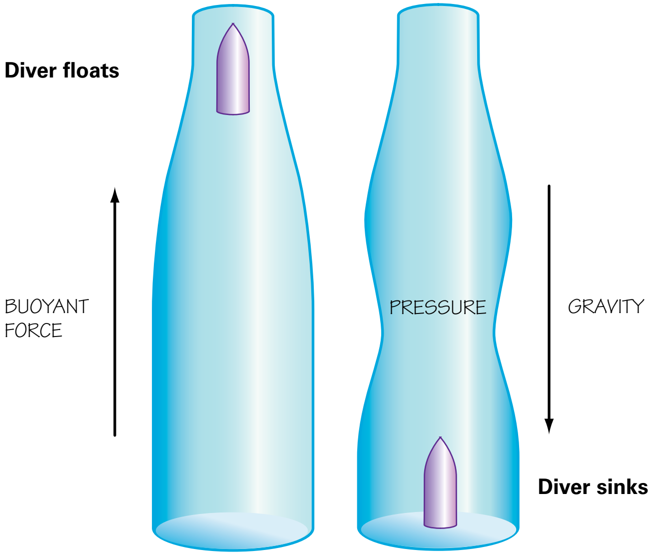
Step 3—Squeeze the sides of the bottle. The diver should sink to the bottom.

Step 4—Relax your grip on the bottle. Now what did the diver do?

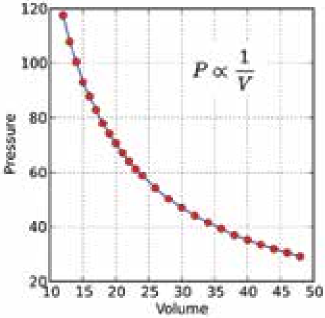
Physical chemistry studies the spatial distance between molecules, which explains the ability of a gas to change volume by compressing.

Why Did the Diver Sink?

If you used a transparent pen lid, squeeze the bottle and watch the bubble inside the diver closely. When the bottle is squeezed, the water pressure increases and the air bubble becomes smaller.



Liquids are called *incompressible* because their volume does not change as the pressure changes. Unlike a liquid, in a gas the molecules are far apart. When the pressure increases, the air molecules move closer together and take up less room. The relationship is expressed by Boyle's Law, in which the pressure (P) of a gas is inversely proportional to its volume (V) at a constant temperature. (For more information on gas behavior, research Boyle's and the Ideal Gas Equation.)



The diver, like a boat, floats because of *buoyancy,* the force equal to the weight of the water displaced by the volume of the diver. When the pressure increases, and the trapped air bubble compresses, the air displaces less water. At this point, the pull of gravity exceeds the buoyant force, so the diver sinks.

Backpack Hiker

Have you ever backpacked in the mountains? While you were hiking, did you notice it was more difficult to breathe? The *atmosphere,* or the air around us, stays close to 21 percent oxygen anywhere in the world. What is different at the high altitude is the low pressure. Imagine at the lower pressure that the air molecules float farther apart. When you inhale air at high altitudes, a smaller number of oxygen molecules fill your lungs. So at high altitudes, you must breathe faster to supply the same amount of oxygen to your blood, as you would at a lower altitude.

Scuba Diver

As a scuba diver descends to the ocean floor, the water pressure increases. The weight of water above the diver pushes down on the lower water, increasing the pressure. How does this affect the diver?

The high-pressure water squeezes the diver's chest. Divers need to breathe high-pressure air to fill their lungs. At a higher pressure, the body accumulates nitrogen in the blood and tissues. When the diver returns to the surface and the pressure decreases, the body releases the excess nitrogen when exhaling—if the diver ascends slowly enough. If the diver comes to the surface too quickly, several things go wrong—including some of the nitrogen vaporizing in the blood. These nitrogen bubbles in the muscle tissue are extremely painful and often make the diver bend over in pain. That is why decompression sickness is often called the bends.

Density

Chemists use the word *density* to describe the relationship of the mass or weight of an object to its volume or size. A pingpong ball and a golf ball have a similar volume, but the pingpong ball is less dense than the golf ball because it has a lower mass.

When an object of less density is placed in a surrounding medium of greater density, it will float. A helium balloon floats in air. When an object of greater density is placed in a surrounding medium of less density, it will sink. A golf ball sinks in water.

Pollution

The term *pollution* is commonplace in today's society. Hardly a day goes by without a news report about pollution and its effect on the environment. In the past, as people pressed forward with advances in technology, living standards, and conveniences, little thought was given to the possibility that by-products might harm the environment.

Today people are concerned about environmental contamination from pollution. It is becoming more important to understand pollution, materials that poison the environment, how to stop pollution, and how to clean up polluting materials.

Many current problems—air and water pollution, toxic wastes, and waste disposal—were partially caused by the improper use of chemistry. Hope lies in our chemists, who can help to solve these problems and perhaps reverse much of the damage that has been done.

If you choose option 7c, ask whether any by-products are produced at the plant you visit. Find out how by-products are produced and how they are handled.

Government Agencies

Science is interwoven in the structure of our society and government. Government agencies were formed to protect the people and environment from chemicals and to monitor the responsible use of chemicals.

The Environmental Protection Agency (EPA) protects human health and the air, water, and land upon which our health depends. Congress enacts the environmental laws, but it is the EPA's responsibility to develop and enforce these regulations. The EPA conducts research before setting national standards and delegating them to states and tribes to implement. The state-level environmental agencies issue permits.

Look for the ASTM label in your bike helmet.

If a company plans to build a new refinery, it first must obtain an emissions permit from the state in which the refinery is to be built. This permit details the amount and types of chemicals the refinery can release into the air, water, and soil.

The EPA is part of the larger U.S. Public Health and Services Department, which includes several agencies working with chemicals, such as the FDA, Centers for Disease Control, and the National Institute of Safety and Health. The following agencies and departments are also responsible for chemicals: U.S. Army Corps of Engineers, Department of Energy, Department of Defense, National Security Agency, Central Intelligence Agency, National Science Foundation, National Institutes of Standards and Technology, and American Society for Testing and Materials (ASTM).

Air Pollution

Most organisms need to breathe. The air plays a critical role in the carbon dioxide–oxygen cycle between plants and animals. Despite the importance of clean air, however, we continually dump wastes into it. Atmospheric and environmental chemistry study the causes and effects of changes to the environment.

The most common air pollutants in the United States are liquid and solid particles like smoke, soot, and dust, and gases like carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, and ozone. These pollutants cause many problems, ranging from health problems in humans to decreased productivity

Power plants, factories, and cars all contribute to pollution, as do some natural sources like volcanoes. The Taal Volcano in the Philippines is pictured on page 77.

of plants. Most of the carbon monoxide comes from the incomplete burning of fossil fuels like gas and coal.

Sulfur oxides come from several sources. Natural sources include volcanoes and decaying vegetable and animal matter in the oceans and on land. An unnatural source is the burning of coal.

There are many sources of liquid and solid particulate pollution. Volcanoes and forest fires are two natural sources. Humans contribute much more from activities like grinding and spraying, which cause dust, and burning fossil fuels like coal, diesel, and gasoline. In general, the smaller the particle, the longer it will stay airborne. This is a big problem because particulate pollution can be carried across the United States or even to countries overseas.

Ozone

Three oxygen atoms bond together to make an ozone (O_3) molecule. Ozone is found in nature primarily in a thin layer of atmosphere about 20 miles above Earth. Scientists are concerned about the hole in the ozone layer over Antarctica—where there are very low levels of ozone. In the upper atmosphere, the ozone layer reacts with harmful skin cancer–causing ultraviolet radiation from the sun and keeps it from reaching Earth.

Ozone acts like a sunscreen protecting Earth from ultraviolet radiation. Unfortunately, chlorofluorocarbons work as a catalyst to break down ozone into oxygen. One CFC molecule can destroy as many as 100,000 ozone molecules by reacting over and over. Aerosol spray cans now use harmless chemicals instead of CFCs. Freon-free and/or CFC-free air conditioners and refrigerators are the technology of the future.

Although ozone in the stratosphere protects us, breathing ozone is harmful for plants and animals, especially people who have breathing problems like asthma. In cities, ozone is produced by the interaction of hydrocarbons and nitrogen oxides under the influence of sunlight. It is a major and dangerous component of smog.

Ozone is a twofold problem. We need ozone in the upper atmosphere to protect us, but it is endangered by CFCs. At the same time, we do not want ozone at sea level, where it harms plant and animal life, yet it is here.

Global Climate Change

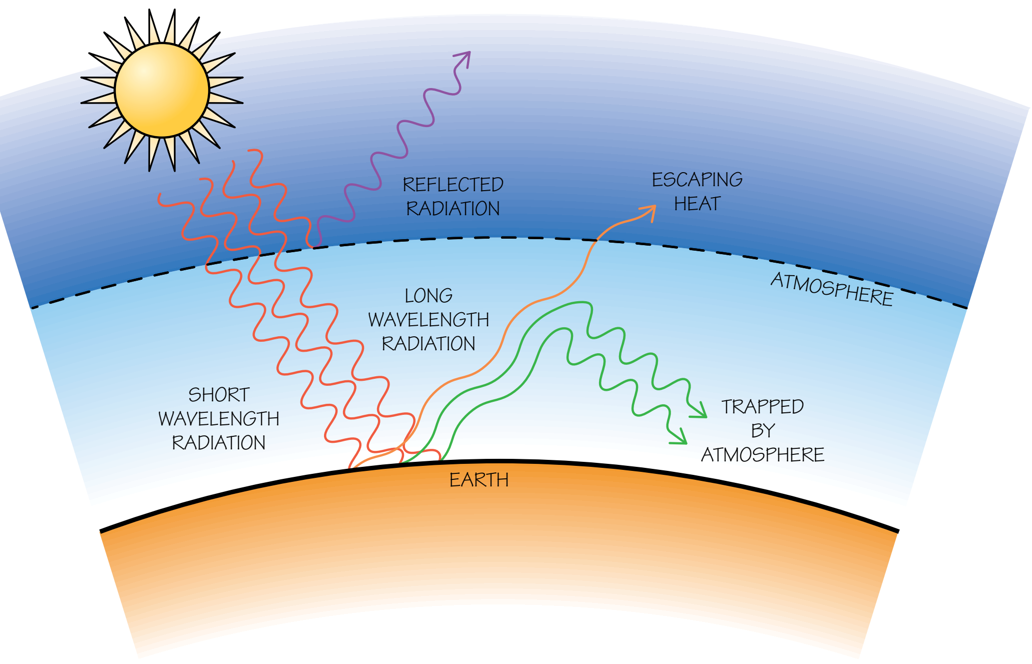
Carbon dioxide is not normally a pollutant. Animals and humans exhale carbon dioxide, and plants remove it from the atmosphere in the process of *photosynthesis.* As a greenhouse gas, carbon dioxide (only 0.04 percent of the air), traps heat many times more than oxygen. Many scientists believe that the burning of fossil fuels and the continual shrinking size of tropical rain forests have disrupted the natural balance of carbon dioxide in the atmosphere. Methane, CFCs, and nitrous oxide are also greenhouse gases. The latest scientific evidence (as of 2022) indicates that increases in these greenhouse gases are contributing to *global climate change.*

The word *smog* is *fog* and *smoke* combined.

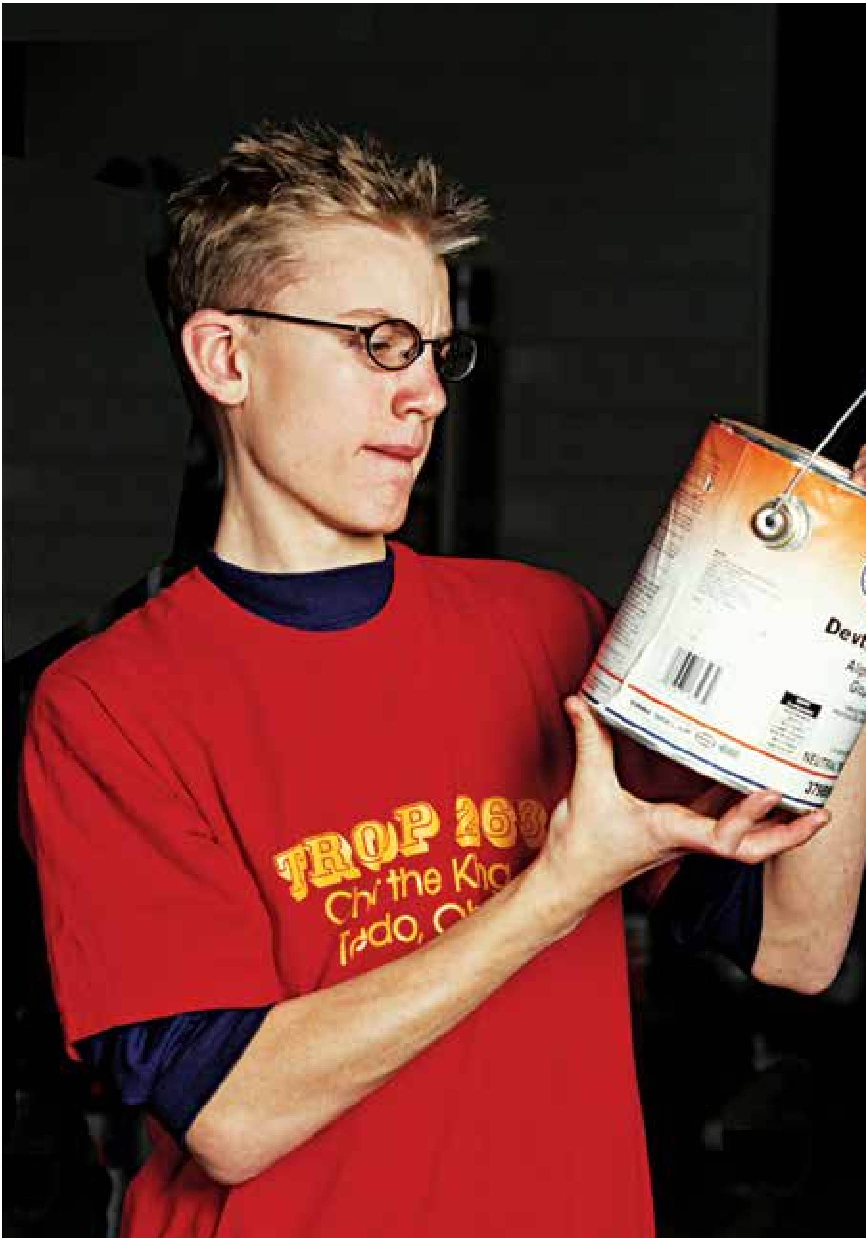
The Greenhouse Effect

The analogy that Earth is a greenhouse is appropriate. Earth's atmosphere lets in visible light and infrared radiation (heat energy), and then traps some of the heat energy so that Earth stays warm. Without the greenhouse gases trapping heat, the whole Earth would be as cold as the Arctic all year.

Significant changes in Earth's temperatures could have dramatic consequences, and there is no easy solution to the problem. We could try to reduce the amount of carbon dioxide we add to the environment. We could try to replace the lost vegetation, especially the rain forests. We can perhaps develop technologies to remove some of the excess carbon dioxide from the atmosphere. In any case, the possibility of global climate change presents challenges and opportunities.



The greenhouse effect



Green Chemistry

The chemical industry often gets blamed for creating pollution and other environmental problems, but *green chemistry* actually uses chemical tecÚiques to prevent pollution. The goal is to reduce or eliminate both the use and the creation of hazardous substances.

Green chemistry is not a separate branch of science like organic chemistry. Instead, it's an approach to chemistry that focuses on improving the environment. Scientists have developed 12 principles of green chemistry; they include designing chemical processes that don't create dangerous waste products, using raw materials that are renewable, and developing chemicals and products that are nontoxic and that degrade after use.

The EPA promotes green chemistry through several programs, including the Presidential Green Chemistry Challenge. Each year, this program honors people and companies who have developed successful green chemistry processes or products.

Here are some projects that have won the Presidential Green Chemistry Challenge:

- The pressure-treated lumber used in picnic tables, playground equipment, and decks once contained arsenic and another dangerous compound called hexavalent chromium. A company developed an environmentally advanced wood preservative that contains no hazardous chemicals and creates no hazardous waste when it is produced.
- Antifoulants are added to marine paint to prevent algae and barnacles from sticking to a ship's surface, which can make it harder for the ship to move through the water. Unfortunately, traditional antifoulants are toxic to marine animals—and to the humans who eat them. One company came up with an Earth-friendly alternative that rapidly degrades in the environment and is much less toxic than other antifoulants.
- Farmers use chemical pesticides to help plants fight pests and disease. One company improved on this fight by creating an agricultural chemical that actually stimulates a plant's own natural defenses but produces no hazardous wastes.

Water Pollution

Other sources of water pollution include erosion of croplands, nitrates from agricultural fertilizer, agricultural pesticides, and even boats.

Imagine a pyramid with swarms of *plankton* (tiny water organisms) at the bottom and humans at the top. The plankton become contaminated with small amounts of a pollutant. A fish will eat a lot of plankton, thereby concentrating the pollutant in its body. A larger fish will eat many smaller fish, and so on, until pollutant concentrations at the top of the pyramid reach levels that are harmful to waterbirds and to people. This is how a little water pollution can have a big impact.

Manufacturing plants are the leading source of controllable water pollutants in the United States. These pollutants include metals and organic compounds of all sorts. Some of the released wastes are degraded by naturally occurring bacteria, but many resist degradation. Treating this waste has led to a new area of biochemistry, called *bioremediation.*

The second largest source of water pollution is domestic, or household, waste. The technology to treat wastewater is constantly improving. We now can remove most suspended solids, bacteria, and other harmful materials from wastewater, making the water safe for reuse.

When rainwater runs off fertilized grass or an agricultural field, some of the phosphate is carried with it. In this way, even though phosphates have been removed from laundry detergent, phosphates are still being washed into rivers and lakes, contributing to excessive algae growth.

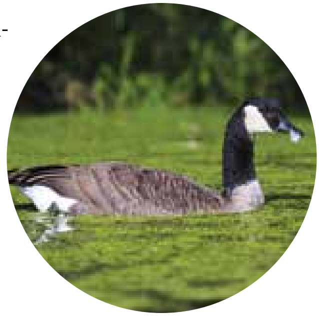
Phosphates

Look at the ingredients list on a box of detergent. You will discover lots of things go into detergent. One ingredient is a builder, or a water softener. The builder binds firmly to the ions in hard water so that the surfactant can attach to dirt and oils. The builder's job is to build up the power of the surfactant.

Until recently, most laundry detergents used phosphate builders. Phosphates are low-cost, low-toxicity, and effective water softeners. They seemed the perfect builder, until a surprising thing happened. Algae in some lakes grew out of control, covering the top of the water. Fish depend on oxygen from the air above the lake to dissolve in the water for them to breathe. When the algae die and decay, they use large amounts of oxygen. Fish suffocated because water, covered with decaying algae, had too little oxygen for them to breathe.

Chemists found that phosphates are excellent nutrients for algae. The laundry detergent phosphates from washing machine drainage dumped into rivers, streams, and lakes, prompting out-of-control algae growth.

Today, phosphates have been removed from laundry detergents, and stronger legislative action is being taken to control these substances that harm the environment. Yet, at this time, phosphates are still widely used in fertilizers.



Algae take away lots of oxygen from animals.

Solid Wastes

Trash typically has been disposed of in two ways: by dumping it in landfills or by burning it. Both methods are still used today, but neither is perfect because dumping is unsanitary and burning causes air pollution.

New technologies may help to reduce air pollution from burning trash. Sanitary landfills are another possible solution. However, landfills can have some major problems. We are running out of land to make landfills. And, if poorly managed, landfills can leak wastes that pollute water.

Another possible solution to the solid waste problem is recycling. By recycling, we have less waste to dispose of, and we are able to get multiple uses out of paper, cans, and glass.

Recycling

Recycling helps our planet and us. It reduces our dependence on crude oil, lowers our energy needs, reduces the amount of waste that must be disposed of, and reduces pollution.

Different polymers have different properties that determine their uses. Probably one of the most familiar plastics is blown polystyrene, or plastic foam. This material is used for hot-beverage cups, egg cartons, and disposable plates. It has enough heat resistance to stand up to boiling water.

The problem with polystyrene is it will take up to 400 years for its long chain molecules to decompose in a landfill. Plastic foam has become a symbol of our waste disposal problems.

Many polymers can be melted and formed into new objects. Some commonly recycled plastics are polyethylene, plastic soda bottles, and milk jugs. Recycling recovers most of the raw material and energy that goes into making an object.

Aluminum Cans

Recycling aluminum cans saves the wilderness from mining and reduces landfills, but the biggest impact is the saved energy. On average, electrolysis uses three times as much electrical energy as required to recycle the same amount of aluminum.

Natural Resources Saved by Recycling 1 Ton of Paper

Natural Resources	Amount Saved	Equivalent
Water	7,000 gallons	200 bathtubs full
Landfill space	3.3 cubic yards	10-foot-square area in a room
Oil	3 barrels	Six 20-gallon tanks of gasoline
Trees	17 trees	How many trees does your yard have?
Electricity	4,000 KW-hours	Six months of electricity for a home

Glass

Glass is one of the longest-lasting materials, taking over one million years to decompose. However, a kilogram of cullet (recycled glass) can replace 1.2 kg of raw materials when used to make new glass products. Cullet also helps manufacturers save on energy costs. For every 10% of cullet included in the glassmaking mixture, the energy needed to keep the furnace at temperatures high enough to generate molten glass falls by nearly 3%. Running furnaces at lower temperatures extends furnace life and reduces operating costs. As a result, the price of the final glass products is also reduced.

Careers in Chemistry

Did you enjoy the work you did to earn the Chemistry merit badge? If so, you might like to learn more about careers in chemistry and related fields. To prepare for a career in any branch of chemistry, a high school student should take as many science and mathematics courses as possible.

Chemist at work

Chemist

A chemist is a professional who normally has at least a bachelor's degree in chemistry, which prepares one to work in many different positions: industry, business, government, research institutions, and teaching.

Training Required

Chemists with a bachelor's degree in chemistry attended a college or university and took about a quarter to a third of their courses in chemistry, with several supporting courses in physics, mathematics, and computer science. Many chemists stay in school after earning a bachelor's degree and earn advanced degrees. The master's degree typically requires two years of study, and the doctorate requires at least four years beyond the undergraduate degree.

Industrial Chemist

Scarcely anything used by society is untouched by chemistry. Chemical companies big and small employ chemists, as do pharmaceutical companies, large manufacturers, utilities, and biotechnology companies, to name a few. Most chemists work in industry. Chemical businesses often have many career opportunities like technical sales and service, manufacturing, marketing, and research and development. Industrial research and

Many large chemical and petroleum companies hire ndustrial chemists.

development focuses on inventing or improving new products such as medicines, composites, lubricants, coatings, herbicides, pigments, sunscreens, and a host of other chemical products and manufactured goods we use every day.

Chemical Engineer

A chemical engineer is a professional with a broad background in chemistry combined with training in manufacturing princi-ples, physical design, and economics. Computers are a vital tool for the chemical engineer. These professionals often com-mand higher salaries than chemists and many other engineers.

They may work in all areas of manufacturing, government, and private consulting. A chemical engineer's first position could be in a refinery, chemical plant, or an engineering firm.

There are positions in which chemists and chemical engineers are interchangeable. Chemical engineers can advance in company management or be private consultants. Chemical engineers have many doors open to them; they also can move on to careers in law or medicine.

Training Required

The student who enrolls in an engineering college takes basic engineering courses for the first two years and basic chemistry courses. In the third or fourth year, in addition to some of the advanced courses that a chemistry major would take, there are specialized courses in chemical engineering. The student would also have courses in physics, mathematics, and computer science.

Chemical Technician

Chemical technicians are trained mainly in chemistry laboratory methods. They have knowledge of chemistry but not the extensive knowledge of theory that the chemist and chemical engineer have.

Chemical technicians have many responsibilities in manufacturing plants, often as members of teams that include chemists, chemical engineers, craftspeople, production employees, and maintenance workers. They may install or operate the machinery used to make chemicals. They may analyze products from a new process under testing, or they may be part of teams that run hundreds of analyses every day in a manufacturing plant.

Chemical technicians may join chemists in research and development or help chemical engineers run pilot plants. Their training and skills fit them for many positions in the chemical industry. They have the flexibility to handle different responsibilities in a plant as needed. Chemical technicians are not limited to the chemical industry, but could be useful anywhere there is a call for their skills: in other industries that use chemicals; in hospital laboratories testing medical samples or hospital materials; or in federal, state, and local government agency laboratories.

Training Required

Two or three years of study beyond high school are needed to qualify for the associate's degree given by many junior colleges and technical institutes. Students training as chemical technicians take courses in chemistry with emphasis on laboratory procedures, test methods, and instruments used for analysis. Besides chemistry, students usually take mathematics, English composition, technical report writing, and perhaps a few broadening courses—political science or sociology, for example.

Other Careers in Chemistry

Students who find that the laboratory is not for them but enjoy writing may find that technical writing or science reporting is a good career that combines their interests and talents. A career as a science librarian also is a specialty that may be appropriate. A chemist or chemical engineer with a doctorate may spe-cialize in research and development. Chemists teach in high schools, technical institutes, colleges, and universities.

Chemists interested in law may become patent attorneys. This specialty is best served by an undergraduate degree in chemistry, followed by a law degree.

Another career that builds on an undergraduate degree in chemistry is high-level management in industrial companies. The aspiring manager would need a master's degree in business administration. Chemists finding their interests and talents pointing this way after they begin an industrial career can take night-school courses until they complete their degree requirements.

A bachelor's degree in chemistry or chemical engineering can lead to interesting careers that overlap many other disciplines. For example, a career in biochemistry, biotechnology, or medical research could begin with an undergraduate degree in chemistry. There are many opportunities in environmental chemistry, clinical chemistry, geochemistry, and related areas in which chemistry is applied to other disciplines. Chemistry students who think they may be interested in these careers learn about them by taking appropriate science electives as part of their undergraduate studies.

Chemistry Resources

Scouting Literature

Astronomy, Cooking, Electricity, Energy, Engineering, Environmental Science, Fingerprinting, Fire Safety, Forestry, Gardening, Geology, Inventing, Medicine, Metalwork, Mining in Society, Nuclear Science, Oceanography, Painting, Plant Science, Pottery, Public Health, Pulp and Paper, Soil and Water Conservation, Space Exploration, Sustainability, Textile, and *Veterinary Medicine* merit badge pamphlets

With your parent's permission, visit the Boy Scouts of America's official retail website, www.scoutshop.org, for a complete listing of all merit badge pamphlets and other helpful Scouting materials and supplies.

Books

Balbes, Lisa M. *Nontraditional Careers for Chemists: New Formulas in Chemistry.* Oxford University Press, 2006.

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Organizations and Websites

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WebElements™ Periodic table
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Baccia Bollas—page 73

Daniel Giles—page 50 *(water treatment plant)*

Randy Piland—pages 6, 7 *(experiment)*, 14, 16–17 *(all)*, 30 *(Scouts)*, 38 *(Scout)*, 47–48 *(all)*, 51–52 *(all)*, 58, 70, 76 *(exhaust pipe)*, and 77

Notes