Top page

| | | | |
|---|---|---|---|
| Sodium | Chlorine | Borax | Haber Process |
| Potassium uses | Hydrogen Peroxide | Alcohol | Ammonia |
| Ammonia: | Potassium Chloride | Ethyl alcohol | destructive |
| NitrogenFixation | productCatalysis | Vanadium | Nitric Acid |
| potassium nitrate | Sulfuric Acid | Pyrite | Nitrogen |
| Platinum | Soda | Biological energy…*fuel* | Solar Energy |
| *Synthesys* | *·METALLURGYGY* | Ash | Fermentatio***n*** |
| Reduction table | Aerosol Dispenser | carbide | SOAP |
| Limestone | ***Electric Furnace*** | ***crucible*** | ***Combustion,*** |
| Castor oil | ***Chromatography*** | Tannic acid | Spinel |
| Hydrogenation | Wood | Chromium | Chromite |
| ***Refractories*** | ***Potash*** | ***Fatty Acids*** | Stearic Acid |
| Calcination | Flax | ***lacquer*** | Acetic Anhydride |
| Acetylene | Carbon Tetrachloride | | |
| | | | |
| | | | |

percent of the U.S. gross national 20

# Chlorine

Chlorine, symbol Cl, greenish-yellow gaseous element. In group 17 (or VIIa) of the periodic table (*see* Periodic Law), chlorine is one of the halogens. The atomic number of chlorine is 17.

Elementary chlorine was first isolated in 1774 by the Swedish chemist Carl Wilhelm Scheele, who thought that the gas was a compound; it was not until 1810 that the British chemist Sir Humphry Davy proved that chlorine was an element and gave it its present name.

At ordinary temperatures, chlorine is a greenish-yellow gas that can readily be liquefied under pressure of 5170 torr, or 6.8 atmospheres, at 20° C (68° F). The gas has an irritating odor and in large concentration is dangerous; it was the first substance used as a poison gas in World War I (1914-1919) (*see* Chemical and Biological Warfare).

Free chlorine does not occur in nature, but its compounds are common minerals, and it is the 20th most abundant element in the earth's crust. Chlorine melts at -101° C (-149.8° F), boils at -34.05° C (-29.29° F) at one atmosphere pressure, and has a specific gravity of 1.41 at -35° C (-31° F); the atomic weight of the element is 35.453.

Chlorine is an active element, reacting with water, organic compounds, and many metals. Four oxides have been prepared: $Cl_2O$, $ClO_2$, $Cl_2O_6$, and $Cl_2O_7$. Chlorine will not burn in air, but it will support the combustion of many substances; an ordinary paraffin candle, for example, will burn in chlorine with a smoky flame. Chlorine and hydrogen can be kept together in the dark, but react explosively in the presence of light. Chlorine solutions in water are familiar in the home as bleaching agents.

Most chlorine is produced by the electrolysis of ordinary salt solution, with **sodium hydroxide** as a by-product. Because the demand for chlorine exceeds that for sodium hydroxide, some industrial chlorine is produced by treating salt with nitrogen oxides or by oxidizing hydrogen chloride. Chlorine is shipped as a liquid in steel bottles or tank cars. It is

Top page

used for bleaching paper pulp and other organic materials, destroying germ life in water, and preparing bromine, tetraethyl lead, and other important products.

# Limestone

Limestone (mineral), a common sedimentary rock composed primarily of the **mineral calcite (CaCO3)**. Limestone constitutes approximately 10 percent of the sedimentary rocks exposed on the earth's surface. It forms either by direct crystallization from water (usually seawater) or by accumulation of shell and shell fragments. In the first case, it carries a record of the chemical composition of seawater and it provides evidence of how that composition has changed with time. In the second case, limestone provides a record of the evolution of many important fossils. Limestone usually forms in shallow water less than 20 m (70 ft) deep and thus also provides important geological information on the variation in sea level in the past. Limestone rocks are frequently riddled with caves. **Limestone is an important building stone and is used to make *cement and concrete.***

Limestone Pinnacles, Guilin Spectacular limestone pinnacles rise along both sides of the Lei River in a mountainous region of southern China near the city of Guilin.Village Gallery/David Orbock

Limestone Limestone is a sedimentary rock composed of the mineral calcite. It is sometimes formed with the aid of marine organisms, such as shellfish and coral, that acquire calcium carbonate for their protective shells. When the organisms die, these shells form calcite deposits that harden into limestone over millions of years.Bruce Coleman, Inc./Gary Withey

**When a drop of dilute hydrochloric acid is placed on a piece of limestone, the acid reacts** with the calcite and forms bubbles of carbon dioxide. This "fizz" reaction is so characteristic of limestone than **many geologists carry a small bottle of dilute hydrochloric acid into the field for a rapid and easy identification of limestone.**

# Hydrogen Peroxide

Hydrogen Peroxide, chemical compound of hydrogen and oxygen with the formula $H_2O_2$. Pure, anhydrous hydrogen peroxide is a colorless, syrupy liquid with a specific gravity of 1.44. It blisters the skin and has a metallic taste. The liquid solidifies at -0.41° C (31.4° F). Concentrated solutions are unstable, and the pure liquid may explode violently if heated to a temperature above 100° C (302.4° F). It is soluble in water in all proportions, and the usual commercial forms are a 3% and a 30% aqueous solution. To retard the decomposition of the peroxide into water and oxygen, organic substances, such as acetanilide, are added to the solutions, and they are kept in dark bottles at low temperature.

Hydrogen peroxide is manufactured in large amounts by the electrolysis of aqueous solutions of sulfuric acid or of potassium bisulfate or ammonium bisulfate. It is also prepared by the action of acid on other peroxides, such as those of sodium and barium.

Hydrogen peroxide acts as both an oxidizing and a reducing agent. Its oxidizing properties are used in the bleaching of substances, such as hair, ivory, feathers, and delicate fabrics, which would be destroyed by other agents. It is also used medicinally, in the form of a 3% aqueous solution, as an antiseptic and throat wash. Hydrogen peroxide is used in restoring the original colors to paintings that have darkened through the conversion of the white lead used in the paintings to lead sulfide. The hydrogen peroxide oxidizes the black lead sulfide to white lead sulfate. It is also used as a source of oxygen in the fuel mixture for many rockets and torpedoes. As a reducing agent it reacts only with such easily reduced chemicals as silver oxide and potassium permanganate.

# Sodium

## I INTRODUCTION

Sodium, symbol Na, highly reactive, silvery-white, extremely soft metallic element. In group 1 (or Ia) of the periodic table (*see* Periodic Law), sodium is one of the alkali metals. The atomic number of sodium is 11. It was discovered in 1807 by the British chemist Sir Humphry Davy.

## II PROPERTIES AND OCCURRENCE

Elemental sodium is metal that is soft enough to be cut with a knife. It has a hardness of 0.4. It oxidizes immediately on exposure to air and reacts violently with water, forming sodium hydroxide and hydrogen. Sodium melts at about 98° C (208° F), boils at about 883° C (about 1621° F), and has a specific gravity of 0.97. The atomic weight of sodium is 22.99. Sodium is found in nature only in the combined state. It occurs in the ocean and in salt lakes as sodium chloride, NaCl, and less often as sodium carbonate, $Na_2CO_3$, and sodium sulfate, $Na_2SO_4$. Sodium is prepared commercially by the electrolytic decomposition of fused sodium chloride. Sodium ranks seventh in order of abundance of the elements in the earth's crust. It is a necessary constituent of plant and animal tissue.

## III USES

The element is used in the manufacture of tetraethyl lead and as a cooling agent in nuclear reactors (*see* Nuclear Energy). The most important compound of sodium is sodium chloride, known commonly as salt. Other important compounds include sodium carbonate, known as washing soda, and sodium bicarbonate, known as baking soda (*see* Soda). Sodium hydroxide, known commercially as soda lye or caustic soda, is used in the manufacture of soap, rayon, and paper, in oil refining, and in the textile and rubber industries. Sodium tetraborate is known commonly as borax. Sodium fluoride, NaF, is used as an antiseptic, as a poison for mice and roaches, and in ceramics. Sodium nitrate, known as Chile saltpeter, is used as a fertilizer. Sodium peroxide, $Na_2O_2$, is an important bleaching and oxidizing agent. Sodium thiosulfate, $Na_2S_2O_3 \cdot 5H_2O$, known as *hypo,* is used in photography as a fixing agent.

# Potassium Chloride

Potassium Chloride, drug used to maintain or restore potassium levels in patients with potassium deficiency, which can cause such problems as thirst, fatigue, low blood pressure, muscle cramps, nausea, and irregular heartbeat. Some diuretics (medications that increase urination) and heart drugs, as well as certain diseases, can cause potassium deficiency. Potassium chloride works by controlling the body’s water balance and regulating such processes as nerve transmission, muscle contraction, and normal heart rhythm. Potassium chloride is available over the counter in tablets, capsules, liquid, or powder forms that are taken orally with a meal or with fluids. Patients with such medical conditions

Top page

as diabetes, heart disease, liver disease, kidney disease, adrenal insufficiency, or ulcers should use this drug with caution. Potassium chloride is considered safe for pregnant or nursing women, but its suitability for youths under the age of 18 has not been determined. Possible side effects include diarrhea, nausea, vomiting, and abdominal pain. Potassium chloride has also been associated with the formation of stomach and intestinal ulcers, including bleeding and perforation. Patients who notice black or tar-colored stools should contact a doctor immediately. An overdose of potassium chloride can cause irregular heartbeat, muscle weakness, paralysis, or cardiac arrest.

Potassium chloride should not be taken with certain blood pressure drugs (ACE inhibitors), diuretics, digitalis, or antispasmodic drugs. It should not be combined with dietary salt substitutes without a doctor’s approval.

# Borax

Borax, or sodium tetraborate, chemical compound, $Na_2B_4O_7 \cdot 10H_2O$, crystallizing in the monoclinic system, with hardness 2 and specific gravity 1.7. When heated it swells, gives off water, and fuses easily, forming a glasslike mass. Mineral borax was discovered in ancient times in Tibet and was exported to Europe under the name tincal. In modern times, this source was replaced by extensive deposits of borax and related minerals in California; Stassfurt, Germany; Tuscany, Italy; and the Atacama Desert, Chile. The mineral kernite, or rasorite, $Na_2B_4O_7 \cdot 4H_2O$, is identical with borax except for water content, hardness (3), and specific gravity (1.95).

# Uses

Borax dissolves readily in water, forming an alkaline, antiseptic solution that is used as a disinfectant, detergent, and water softener. It is an excellent flux for soldering and welding because it dissolves the coating of metallic oxide to leave a clean metal surface. Borax beads are used in chemical laboratories for analytical purposes; when melted with borax, different metallic oxides form beads of differently colored borates. Borax also is used in the manufacture of ceramics, enamel, and glass. Pyrex glass contains 30% borax by weight. In making such products as paint, calcimine, and coated paper, borax is combined with the plastic casein.

Alcohol

## INTRODUCTION

Alcohol (Arabic *al-kuhul*), term applied to members of a group of chemical compounds and, in popular usage, to the specific compound ethyl alcohol, or ethanol. The Arabic word denotes kohl, a fine powder of antimony used as an eye makeup. The word *alcohol* originally denoted any fine powder; the alchemists of medieval Europe later applied it to essences obtained by distillation, and this led to the current usage.

Alcohols are a class of organic compounds containing the hydroxyl group, OH, attached to a carbon atom. Alcohols have one, two, or three hydroxyl groups attached to their molecules and are thus classified as monohydric, dihydric, or trihydric, respectively. Methanol and ethanol are monohydric alcohols. Alcohols are further classified as primary, secondary, or tertiary, according to whether one, two, or three other carbon atoms are bound to the carbon atom to which the hydroxyl group is bound. Alcohols, although analogous to inorganic bases, are neither acid nor alkaline. They are characterized by many common reactions, the most important of which is the reaction with acids to form substances called esters, which are analogous to inorganic salts. Alcohols are normal by-products of digestion and chemical processes within cells and are found in the tissues and fluids of animals and plants.

## WOOD ALCOHOL

***Methyl alcoho***l, or methanol, $CH_3$ OH, is the simplest of all the alcohols. It was formerly made by the destructive distillation of wood; however, almost all of the methanol produced today is synthetic, made from hydrogen and carbon monoxide. Methanol is used as a denaturant for grain alcohol (see below), as an antifreeze, as a solvent for gums and lacquers, and in the synthesis of many organic compounds, particularly formaldehyde. When taken internally, by either drinking the liquid or inhaling the vapors, methanol is extremely poisonous. Methanol melts at -97.8° C (-144.0° F), boils at 64.7° C (148.5° F), and has a specific gravity of 0.7915 at 20° C (68° F).

Top page

## III GRAIN ALCOHOL

**Ethyl alcohol**, or ethanol, $C_2 H_5OH$, is a clear, colorless liquid, with a burning taste and characteristic, agreeable odor. Ethanol is the alcohol in such beverages as beer, wine, and brandy. Because of its low freezing point, it has been used as the fluid in thermometers for temperatures below -40° C (-40° F), the freezing point of mercury, and for other special low-temperature purpose, such as for antifreeze in automobile radiators. Ethanol is normally concentrated by distillation of dilute solutions. Commercial ethanol contains 95 percent by volume of ethanol and 5 percent of water. Dehydrating agents remove the remaining water and produce absolute ethanol. Ethanol melts at -114.1° C (-173.4° F), boils at 78.5° C (173.3° F), and has a specific gravity of 0.789 at 20° C (68° F). Ethanol has been made since ancient times by the fermentation of sugars. All beverage ethanol and more than half of industrial ethanol is still made by this process. Starch from potatoes, corn, or other cereals can be the raw material. The yeast enzyme, zymase, changes the simple sugars into ethanol and carbon dioxide. The fermentation reaction, represented by the simple equation $C_6H_{12}O_6 \rightarrow 2C_2 H_5OH + 2CO_2$ is actually very complex because impure cultures of yeast produce varying amounts of other substances, including fusel oil, glycerin, and various organic acids. The fermented liquid, containing from 7 to 12 percent ethanol, is concentrated to 95 percent by a series of distillations. In the production of beverages such as whiskey and brandy, some of the impurities, which supply the flavor, are of great value. Much ethanol not intended for drinking is now made synthetically, either from acetaldehyde made from acetylene, or from ethylene made from petroleum. A small amount is made from wood pulp.

Ethanol can be oxidized to form first acetaldehyde and then acetic acid. It can be dehydrated to form ether. Other products made from ethanol include butadiene, used in making synthetic rubber; ethyl choride, used as a local anesthetic; and many other organic chemicals. Ethanol can also be mixed with gasoline to form the automobile fuel called gasohol. Ethanol is *miscible* (mixable) in all proportions with water and with most organic solvents. It is an excellent solvent for many substances and is used in making such products as perfumes, lacquer, celluloid, and explosives. Alcoholic solutions of nonvolatile substances are called tinctures; if the solute is volatile, the solution is called a spirit.

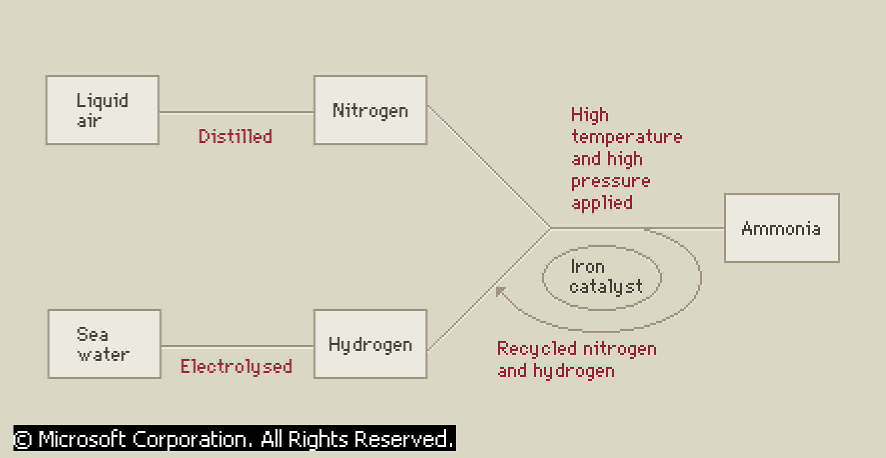
Most industrial ethanol is denatured to prevent its use as a beverage. Denaturing involves mixing ethanol with small amounts of poisonous or unpleasant substances to make the ethanol undrinkable. The removal of all these substances would involve a series of treatments more expensive than the federal excise tax on alcoholic beverages.

Top page

## IV HIGHER ALCOHOLS

Higher alcohols, those of greater molecular [illegible] OH group, are also important—as, for example, the trihydric alcohol known as glycerol.

# Haber Process



**Haber Process**

German chemist and Nobel laureate Fritz Haber developed an economical method of producing ammonia from air and seawater. In his process, nitrogren is separated from the other components of air through distillization. Hydrogen is obtained from seawater by passing an electric current through the water. The nitrogren and hydrogen are combined to form ammonia ($NH_3$).

# Ammonia

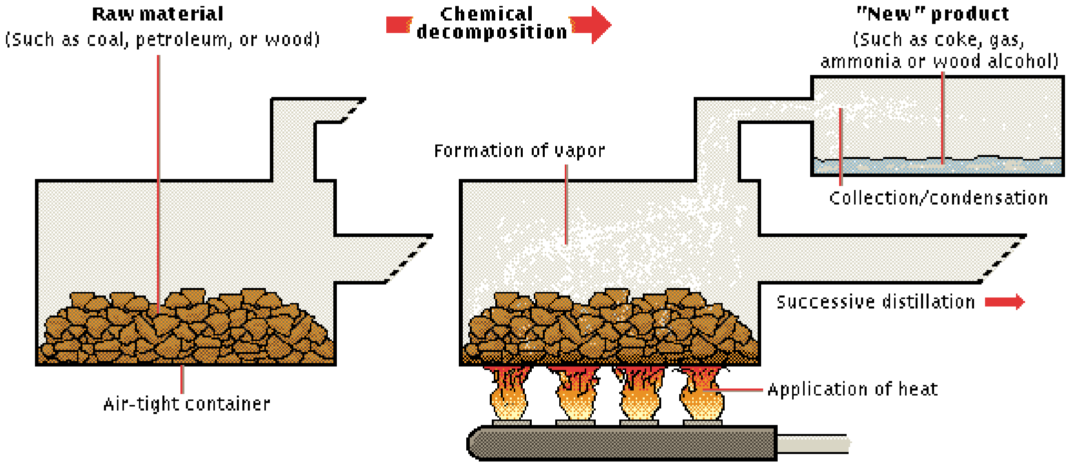
Ammonia, colorless, pungent gas, $NH_3$, highly soluble in water. A saturated aqueous (water) solution of ammonia contains 45 percent ammonia by weight at 0° C (32° F) and 30 percent at ordinary room temperatures. On solution in water, ammonia becomes ammonium hydroxide, $NH_4OH$, which is strongly basic and similar in chemical behavior to the hydroxides of the alkali metals (*see* Acids and Bases; Alkalies).

Ammonia was known to the ancients, who derived both the name and the substance from sal ammoniac, which was produced at the Temple of Jupiter Ammon in Libya by the distillation of camel dung. During the Middle Ages in Europe ammonia was obtained by heating the horns and hoofs of oxen and was called spirits of hartshorn. Free ammonia was obtained by the German alchemist Basil Valentine; its composition was determined by the French chemist Comte Claude Berthollet about 1777.

In the 19th century the principal source of ammonia was the destructive distillation of coal; it was an important by-product of the manufacture of fuel gases (*see* Gases, Fuel). Today most ammonia is produced synthetically from hydrogen and nitrogen (*see* Nitrogen Fixation). Ammonia is an important refrigerant (*see* Refrigeration) and is widely used in the chemical industries, especially in the manufacture of fertilizer, nitric acid, and explosives.

Ammonia melts at -77.7° C (-107.9° F), boils at -33.35° C (-28.03° F), and has a density of 0.68 at its boiling point and 1 atmosphere (1,013 millibars) of pressure.

## Destructive distillation



Destructive distillation is used to convert raw materials, for instance wood by-products, into useful chemicals. Standard distillation processes, such as desalinization, only perform a physical separation of the constituents. Destructive distillation, however, is a chemical change; the end products (methane, charcoal, and coal tar) cannot be turned back into wood.

**Nitrogen Fixation**, biological or industrial process by which molecular atmospheric nitrogen is converted into a chemical compound that is essential for plant growth and is also used in industrial chemical production.

***INDUSTRIAL FIXATION:*** The principal industrial nitrogen-fixation process today is the production of ammonia by passing a mixture of atmospheric nitrogen and hydrogen over a metallic catalyst (see Catalysis) at 500°-600° C (932°-1112° F). Ammonia is then oxidized to form nitric acid, which is in turn combined with ammonia to yield ammonium nitrate, used primarily in explosives and fertilizers (see Fertilizer). In another method, cyanamide, which is used as a fertilizer or in the production of cyanides, is produced by passing atmospheric nitrogen over heated calcium carbide in the presence of a catalyst.

# Catalysis

**Catalysis, alteration of the speed of a chemical reaction, through the presence of an additional substance**, known as a catalyst, that remains chemically unchanged by the reaction. Enzymes (*see* Enzyme), which are among the most powerful catalysts, play an essential role in living organisms, where they accelerate reactions that otherwise would require temperatures that would destroy most of the organic matter.

A catalyst in a solution with—or in the same phase as—the reactants is called a homogeneous catalyst. The catalyst combines with one of the reactants to form an intermediate compound that reacts more readily with the other reactant. The catalyst, however, does not influence the equilibrium of the reaction, because the decomposition of the products into the reactants is speeded up to a similar degree.

## Homogeneous catalysis

Catalysts are substances that trigger or speed up chemical reactions (without chemically altering the catalysts in the process). A catalyst combines with a reactant to form an intermediate compound that can more readily react with other reactants. An example of this is the formation of sulfur trioxide (SO3), which is an important ingredient for producing sulfuric acid (H2SO4). Without a catalyst, sulfur trioxide is made by combining sulfur dioxide (SO2) with molecular oxygen: 2SO2 + O2 → 2SO3. Because this reaction proceeds very slowly, manufacturers use nitrogen dioxide (NO2) as a catalyst to speed production of SO3:

Step One: NO2 (catalyst) + SO2 → NO + SO3 (SO3 is extracted and combined with steam to produce sulfuric acid)

Step Two: NO (from Step One) + O2 → NO2 (catalyst that is reused in step one) In the above reactions, nitrogen dioxide (NO2) acts as a catalyst by combining with sulfur dioxide (SO2) to form both sulfur trioxide (SO3) and nitrogen monoxide (NO). The sulfur trioxide is removed from the process (to be used in the production of sulfuric acid). Nitrogen monoxide (NO) is subsequently combined with molecular oxygen (O2) to produce the original catalyst, nitrogen dioxide (NO2), which can be continually reused to catalyze sulfur trioxide (SO3).

## contact, catalyst

A catalyst that is in a separate phase from the reactants is said to be a heterogeneous, or contact, catalyst. Contact catalysts are materials with the capability of adsorbing (*see* Adsorption) molecules of gases or liquids onto their surfaces. An example of heterogeneous catalysis is the use of finely divided platinum to catalyze the reaction of carbon monoxide with oxygen to form carbon dioxide. This reaction is used in catalytic converters mounted in automobiles to eliminate carbon monoxide from the exhaust gases. Some substances, called promoters, do not have catalytic ability by themselves but increase the effectiveness of a catalyst. For example, if alumina is added to finely divided iron, it increases the ability of the iron to catalyze the formation of ammonia from a mixture of nitrogen and hydrogen. **Materials that reduce the effectiveness of a catalyst**, on the other hand, are referred to as poisons. Lead compounds reduce the ability of **platinum** to act as a catalyst; therefore, an automobile equipped with a catalytic converter for emission control must be fueled with unleaded gasoline.

Catalysts are of major importance in today's industrial world. It has been estimated that about 20 percent of the U.S. gross national product is generated through the use of catalytic processes. One current area of active research in ***catalysis*** is that of enzymes. Natural enzymes have long been used by a few industries, but fewer than 20 such enzymes are presently available in industrial amounts. Biotechnologists are seeking ways in which to expand this resource and also to develop semisynthetic enzymes for highly specific tasks.

# Vanadium

### INTRODUCTION

Top page

Vanadium, symbol V, silver-white metallic element with an atomic number of 23. Vanadium is one of the transition elements of the periodic table (*see* Periodic Law). It was discovered in 1801 in Mexico by Andrés Manuel del Rio, but it was mistaken for a form of chromium. Vanadium was rediscovered in about 1830 by the Swedish chemist Nils Gabriel Sefström.

## II PROPERTIES AND OCCURRENCE

Vanadium takes a high polish and is one of the hardest of all metals. It melts at about 1890° C (about 3434° F), boils at about 3380° C (about 6116° F), and has a specific gravity of 5.96. The atomic weight of vanadium is 50.941. Vanadium is soluble in nitric and sulfuric acids and insoluble in hydrochloric acid, dilute sodium hydroxide, and dilute alcohol. Vanadium forms several acidic oxides, the most important of which are the dark green trioxide, $V_2O_3$, and the orange pentoxide, $V_2O_5$. Other important compounds include vanadium monosulfide, VS; vanadium trisulfide, $V_2S_3$; vanadium dichloride, $VCl_2$; vanadium trichloride, $VCl_3$; vanadium dihydroxide, $V(OH)_2$; and metavanadic acid, $HVO_3$.

Vanadium ranks about 19th in abundance of the elements in the earth's crust. It is never found in the pure state, but occurs in combination with various minerals throughout the world. Vanadium-ore minerals in the United States are roscoelite, found in Colorado; vanadinite, found in Arizona and New Mexico; and carnotite, found in Colorado and Utah. Major producers of vanadium include the United States, Russia, and South Africa.

## III USES

Because of its hardness and great tensile strength, the metal is used in many alloys such as ferrovanadium, nickel vanadium, and chrome vanadium. Chrome-vanadium steels are used in the production of springs and in transmission gears and other engine parts. Titanium-vanadium alloys are used for missile cases, jet-engine housings, and nuclear-reactor components. **As a catalyst, vanadium has largely replaced platinum** in the manufacture of sulfuric acid and is employed widely as a photographic developer, as a reducing agent, and as a drying agent in various paints.

Top page

# Nitric Acid

Nitric Acid, colorless, corrosive liquid that has the chemical formula $HNO_3$. Medieval alchemists called it *aqua fortis* (strong water). Commercially, nitric acid is made by the action of sulfuric acid on sodium nitrate. Nitric acid is also made by the catalytic oxidation of ammonia. Nitric acid is a strong acid and a strong oxidizing agent. When dropped on the skin, the acid produces a yellow coloration because of the reaction of the acid with certain proteins to form yellow xanthoproteic acid.

The concentrated nitric acid used commercially contains about 71 percent $HNO_3$; the rest is water. *Fuming nitric acid,* which also is widely used commercially, consists of nitric acid with gaseous nitrogen oxide in solution. It is red or brown in color and more active than other forms of nitric acid. Ordinary and fuming nitric acid have many applications. They are used in **chemical synthesis**, in the ***nitration of organic materials*** to form nitro compounds (compounds that contain an $NO_2$ group), and in the manufacture of dyes and explosives. Nitric acid melts at -42° C (-44° F) and boils at 83° C (181° F).

The salts of nitric acid are called *nitrates.* Potassium nitrate, or *saltpeter,* and sodium nitrate are the nitrates of greatest commercial importance. Nearly all nitrates are soluble in water; one of the exceptions is bismuth subnitrate, $BiONO_3 \cdot H_2O$, which is used in medicine for treating intestinal disorders. Amitol, a powerful explosive, is a mixture of ammonium nitrate and trinitrotoluene (TNT). The reaction of nitric acid with organic compounds yields many important nitrates, such as nitroglycerin and nitrocellulose. Calcium, sodium, potassium, and ammonium nitrates are used in fertilizers to provide a source of nitrogen for plant growth.

## *Potassium uses:*

Potassium metal is used in photoelectric cells. Potassium forms many compounds resembling corresponding sodium compounds, based on a valence of 1. A few of the element's most important compounds follow. Potassium bromide (KBr), a white solid formed by the reaction of potassium hydroxide and bromine, is used in photography, engraving, and lithography, and in medicine as a sedative. Potassium chromate ($K_2CrO_4$), a yellow crystalline solid, and potassium bichromate, or potassium dichromate ($K_2Cr_2O_7$), a red crystalline solid, are powerful oxidizing agents used in matches and fireworks, in textile dyeing, and in leather tanning. Potassium iodide (KI), a white crystalline compound that is very soluble in water, is used in photography for preparing gelatin emulsions and in medicine for the treatment of rheumatism and overactivity of the thyroid gland. Potassium nitrate ($KNO_3$), a white solid prepared by fractional crystallization of sodium nitrate and potassium chloride solutions, is used in matches, explosives, and fireworks, and in pickling meat. It occurs naturally as saltpeter. Potassium permanganate ($KMnO_4$), a purple crystalline solid, is used as a disinfectant and germicide and as an oxidizing agent in many important chemical reactions. Potassium sulfate ($K_2SO_4$), a white crystalline solid, is an important potassium fertilizer and is also used in the preparation of potassium alum. Potassium hydrogen tartrate ($KHC_4H_4O_6$), commonly known as cream of tartar, is a white solid used in baking powder and in medicine.

The term potash originally designated potassium carbonate, obtained by leaching wood ashes, but is now applied in general to a number of potassium compounds. Potassium carbonate ($K_2CO_3$), a white solid, also called potash or pearl ash, is obtained

Top page

from the ash of wood or other burned plant materials, and by reacting potassium hydroxide with carbon dioxide. It is used in making glass and soft soap. Potassium chlorate (KClO3), called chlorate of potash, a white crystalline compound, is formed by the electrolysis of potassium chloride solution. It is a powerful oxidizing agent and is used in matches, fireworks, and explosives, as a disinfectant, and as a source of oxygen. Potassium chloride (KCl), a white crystalline compound commonly called chloride of potash or muriate of potash, is a common constituent of potassium salt minerals, from which it is obtained by volatilization. It is an important potassium fertilizer and is also used in making other potassium compounds. Potassium hydroxide ***(KOH),*** called caustic potash, a white solid that is dissolved by the moisture in the air, is prepared by the electrolysis of potassium chloride or by the reaction of potassium carbonate and calcium hydroxide; it is used in the manufacture of soap and is an important chemical reagent. It dissolves in less than its own weight of water, liberating heat and forming a strongly alkaline solution.

# potassium nitrate (Saltpeter)

Saltpeter, white, translucent, lustrous mineral composed of potassium nitrate, $KNO_3$. It crystallizes in the orthorhombic system in prismatic crystals, which have a hardness of 2 and a specific gravity of 2.1, and these crystals exhibit perfect domal cleavage. The mineral, which is also called niter, forms delicate crusts on the surfaces of rocks and stone walls, and occurs as a component of surface soil in Spain, Iran, Egypt, and India. In the U.S. it occurs in loose soil of the limestone caves of Kentucky, Tennessee, and the Mississippi Valley. Saltpeter is of commercial importance as a fertilizer, in the manufacture of glass, as a food preservative, and in some medicines as a diuretic. Saltpeter was once used in gunpowder and is now found in explosives, fireworks, and matches. In addition, this substance is employed in fluxes used in metallurgy. It is important as a source of nitrogen in the manufacture of nitrogen-containing compounds, particularly nitric acid, and as an oxidizing agent in many industrial chemical processes. Chile saltpeter, or soda niter, is composed of sodium nitrate, $NaNO_3$. It occurs over vast areas in South America, particularly in Chile, in beds which vary in thickness from 15 cm to 3.6 m (6 in to 12 ft). The beds, called caliche, are interspersed with deposits of gypsum, sodium chloride and other salts, and sand. The caliche is quarried and purified in Chile before the Chile saltpeter is exported. In the U.S. small deposits are found in Nevada and California. Pure Chile saltpeter crystallizes in the rhombohedral system, forming white, semitransparent, lustrous crystals that are crystallographically similar to calcite. It has a hardness ranging from 1.5 to 2 and a specific gravity of 2.24 to 2.29, and exhibits perfect rhombohedral cleavage. Chile saltpeter ($NaNO_3$) deliquesces; that is, it absorbs water from the atmosphere, becomes moist, and gradually dissolves. It is used extensively as a fertilizer and in the manufacture of nitric acid. It is not used in the manufacture of gunpowder because of its deliquescence, but it is used in making the less abundant saltpeter.

## Sulfuric Acid

### INTRODUCTION

Sulfuric Acid, $H_2SO_4$, corrosive, oily, colorless liquid, with a specific gravity of 1.85. It melts at 10.36° C (50.6° F), boils at 340° C (644° F), and is soluble in all proportions in water. When sulfuric acid is mixed with water, considerable heat is released. Unless the mixture is well stirred, the added water may be heated beyond its boiling point and the

Top page

sudden formation of steam may blow the acid out of its container (*see* Acids and Bases). The concentrated acid destroys skin and flesh, and can cause blindness if it gets into the eyes. The best treatment is to flush away the acid with large amounts of water. Despite the dangers created by careless handling, sulfuric acid has been commercially important for many years. The early **alchemists prepared** it in large quantities by heating naturally occurring sulfates to a high temperature and dissolving in water the sulfur trioxide thus formed. About the 15th century a method was developed for obtaining the acid by distilling hydrated ferrous sulfate, or iron vitriol, with sand. In 1740 the acid was produced successfully on a commercial scale by burning sulfur and potassium nitrate in a ladle suspended in a large glass globe partially filled with water.

## II PROPERTIES

Sulfuric acid is a strong acid, that is, in aqueous solution it is largely changed to hydrogen ions ($H^+$) and sulfate ions ($SO_4^{2-}$). Each molecule gives two $H^+$ ions, thus sulfuric acid is dibasic. Dilute solutions of sulfuric acid show all the behavior characteristics of acids. They taste sour, conduct electricity, neutralize alkalies, and corrode active metals with formation of hydrogen gas. From sulfuric acid one can prepare both normal salts (*see* Salt) containing the sulfate group, $SO_4$, and acid salts containing the hydrogen sulfate group, $HSO_4$. Concentrated sulfuric acid, formerly called oil of vitriol, is a valuable desiccating agent. It acts so vigorously in this respect that it removes water from, and therefore chars, wood, cotton, sugar, and paper. It is **used in the manufacture** of ether, nitroglycerine, and dyes for its property as a desiccant. When concentrated sulfuric acid is heated, it behaves also as an oxidizing agent, capable, for example, of dissolving such relatively unreactive metals as copper, mercury, and lead to produce metal sulfate, sulfur dioxide, and water.

During the 19th century, the German chemist Baron Justus von Liebig discovered that sulfuric acid, when added to the soil, increased the amount of soil phosphorus available to plants. This discovery gave rise to an increase in the commercial production of sulfuric acid and led to improved methods of manufacture.

## III MANUFACTURE

Two processes for the production of sulfuric acid are in use today. In their initial steps, both require **the use of sulfur dioxide, which is produced by burning iron pyrites, $FeS_2$, or sulfur, in air.** The first of these methods, the lead-chamber process, employs as reaction vessels large lead-sheathed brick towers. In these towers, sulfur-dioxide gas, air, steam, and oxides of nitrogen react to yield sulfuric acid as fine droplets that fall to the bottom of the chamber. Almost all the nitrogen oxides are recovered from the outflowing gas and are brought back to the chamber to be used again. Sulfuric acid produced in this way, and labeled acid, is only about 62 to 70 percent $H_2SO_4$. The rest is water. About 20 percent of all sulfuric acid is now made by the lead-chamber process, but that percentage is diminishing.

**The second method of manufacturing sulfuric acid**, the contact process, which came into commercial use about 1900, depends on oxidation of sulfur dioxide to sulfur trioxide, $SO_3$, under the accelerating influence of a catalyst (*see* Catalysis). Finely divided platinum, the most effective catalyst, has two disadvantages: It is very expensive, and it is vitiated by certain impurities in ordinary sulfur dioxide that reduce its activity. Many sulfuric-acid producers use two catalysts in tandem; first, a more ***rugged but less effective one like***

Top page

***iron oxide or vanadium oxide to bring about the bulk reaction; then***, a smaller amount of platinum to finish the job. At 400° C (752° F), the conversion of sulfur dioxide to trioxide is nearly complete. The trioxide is dissolved in concentrated sulfuric acid, and at the same time a regulated influx of water maintains the concentration at a selected level usually about 95 percent. By reducing the flow of water, a product with more $SO_3$ than shown in the formula $H_2SO_4$ may be made. This product, called fuming sulfuric acid, or oleum, or Nordhausen acid, is needed in some organic chemical reactions.

## IV PRODUCTION

The uses of sulfuric acid are so varied that the volume of its production provides an approximate index of general industrial activity. American production of sulfuric acid exceeded 29 million tons annually in the early 1970s, a figure corresponding to a daily production of 1/3 kg (3/4 lb) per person throughout the year. ***The largest single use of sulfuric acid is for making fertilizers***, both superphosphate and ammonium sulfate. It is also used in making organic products, refining petroleum, making paints and pigments, processing metals, and making rayon. One of the few consumer products containing sulfuric acid as such is the lead storage battery, or car energizer.

# Pyrite

Pyrite, also iron pyrites or fool's gold, mineral composed of ***iron sulfide***, $FeS_2$, the most common sulfide mineral. It crystallizes in the isometric system (*see* Crystal) and frequently occurs as well-defined crystals as well as in massive formations. The mineral is brass yellow, is opaque, and has a metallic luster. The resemblance of pyrite to gold caused many prospectors to mistake it for gold, and it became known as fool's gold. It is distinguished from gold by its brittleness and by its hardness, which ranges between 6 and 6.5; the specific gravity is 4.95 to 5.1. Pyrite is a common mineral in sedimentary rocks and also occurs in igneous and metamorphic rocks. It is often associated with coal formations and sometimes occurs associated with gold or copper. Large deposits are found throughout the world; deposits in Spain and Portugal are particularly noteworthy. In the U.S. important deposits occur in Arizona, Colorado, New York, Pennsylvania, South Carolina, Tennessee, Utah, and Virginia. Pyrite is not mined as an iron ore, except in countries where iron-oxide ores are not available, because of the difficulty of removing the sulfur. It is used mainly in the commercial production of sulfuric acid and of copperas, or ferrous sulfate (*see* Sulfur). Marcasite, a mineral of the same composition as pyrite, is called white iron pyrites. It is opaque, with a metallic luster, and is pale—bronze yellow or almost white when freshly fractured. The hardness is the same as that of pyrite. The specific gravity varies from 4.85 to 4.90. Marcasite is distinguished from pyrite by the difference in color, crystal habit, and by chemical tests. It is more easily decomposed than pyrite and is much less common in occurrence. Marcasite is used, to a much lesser extent than pyrite, in making sulfuric acid.

Nitrogen

## I INTRODUCTION

Nitrogen, symbol N, gaseous element that makes up the largest portion of the earth's atmosphere. The atomic number of nitrogen is 7. Nitrogen is in group 15 (or Va) of the periodic table (*see* Periodic Law).

Top page

Nitrogen was isolated by the British physician Daniel Rutherford in 1772 and recognized as an elemental gas by the French chemist Antoine Laurent Lavoisier about 1776.

## II PROPERTIES

Nitrogen is a colorless, odorless, tasteless, nontoxic gas. It can be condensed into a colorless liquid, which can in turn be compressed into a colorless, crystalline solid. Nitrogen exists in two natural isotopic forms, and four radioactive isotopes have been artificially prepared. Nitrogen melts at -210.01° C (-346.02° F), boils at -195.79° C (-320.42° F), and has a density of 1.251 g/liter at 0° C (32° F) and 1 atmosphere pressure. The atomic weight of nitrogen is 14.007.

Nitrogen is obtained from the atmosphere by passing air over heated copper or iron. The oxygen is removed from the air, leaving nitrogen mixed with inert gases. Pure nitrogen is obtained by fractional distillation of liquid air; because liquid nitrogen has a lower boiling point than liquid oxygen, the nitrogen distills off first and can be collected.

Nitrogen composes about four-fifths (78.03 percent) by volume of the atmosphere. Nitrogen is inert and serves as a diluent for oxygen in burning and respiration processes. It is an important element in plant nutrition; certain bacteria in the soil convert atmospheric nitrogen into a form, such as nitrate, that can be absorbed by plants, a process called nitrogen fixation. Nitrogen in the form of protein is an important constituent of animal tissue. The element occurs in the combined state in minerals, of which saltpeter ($KNO_3$) and Chile saltpeter ($NaNO_3$) are commercially important products.

Nitrogen combines with other elements only at very high temperatures or pressures. It is **converted to an active form by passing through an electric discharge at low pressure**. The nitrogen so produced is very active, combining with alkali metals to form azides; with the vapor of zinc, mercury cadmium, and arsenic to form nitrides; and with many hydrocarbons to form hydrocyanic acid and cyanides, also known as nitriles. Activated nitrogen returns to ordinary nitrogen in about one minute.

In the combined state nitrogen takes part in many reactions; it forms so many compounds that a systematic scheme of compounds containing nitrogen in place of oxygen was created by the American chemist Edward Franklin. In compounds nitrogen exists in all the valence states between -3 and +5. Ammonia, hydrazine, and hydroxylamine represent compounds in which the valence of nitrogen is -3, -2, and -1, respectively. Oxides of nitrogen represent nitrogen in all the positive valence states.

## III USES

Most of the nitrogen used in the chemical industry is obtained by the fractional distillation of liquid air. It is then used to synthesize ammonia. From ammonia produced in this manner, a wide variety of important chemical products are prepared, including fertilizers, nitric acid, urea, hydrazine, and amines. In addition, an ammonia compound is used in the preparation of nitrous oxide ($N_2O$) a colorless gas popularly known as laughing gas. Mixed with oxygen, nitrous oxide is used as an anesthetic for some types of surgery.

Used as a coolant, liquid nitrogen has found widespread application in the field of cryogenics. With the recent advent of ceramic materials that become superconductive at the boiling point of nitrogen, the use of nitrogen as a coolant is increasing (*see* Superconductivity).

Platinum

## I INTRODUCTION

Top page

Platinum, symbol Pt, relatively rare, chemically inert metallic element that is more valuable than gold. The atomic number of platinum is 78. The element is one of the transition elements in group 10 (or VIIIb) of the periodic table (*see* Periodic Law).

Platinum is the most important of the group of elements called the platinum metals, the other members of which are ruthenium, rhodium, palladium, osmium, and iridium. Platinum metals were probably used in alloyed forms in ancient Greece and Rome and were first mentioned in European literature in the early 16th century. The separation of the other platinum metals from platinum and from each other was accomplished in the early 19th century.

## II PROPERTIES AND OCCURRENCE

Platinum is a grayish-white metal with a hardness of 4.3. It has a high fusing point, is malleable and ductile, expands slightly upon heating, and has high electrical resistance. Chemically the metal is relatively inert and resists attack by air, water, single acids, and ordinary reagents. It dissolves slowly in aqua regia, forming chloroplatinic acid ($H_2PtCl_6$); is attacked by halogens; and combines upon ignition with sodium hydroxide, sodium nitrate, or sodium cyanide. Platinum melts at about 1772° C (about 3222° F), boils at about 3827° C (about 6921° F), and has a specific gravity of about 21.45. The atomic weight of platinum is 195.09.

Platinum ranks about 72nd in natural abundance among the elements in crustal rock. Except for the mineral sperrylite, which is platinum arsenide and is found only sparingly in a few localities, platinum occurs in the metallic state, often alloyed with other platinum metals. Nuggets of the metal weighing up to 9.5 kg (21 lb) have been found.

## III USES

Because of its chemical inertness and high fusing point, platinum is valuable for laboratory apparatus, such as crucibles, tongs, funnels, combustion boats, and evaporating dishes. Small amounts of iridium are usually added to increase its hardness and durability. Platinum is also used for contact points in electrical apparatus and in instruments used for measuring high temperatures. Finely divided platinum in the form of platinum sponge or platinum black is used extensively as a catalyst in the chemical industry. A considerable amount of the platinum used in the United States goes into jewelry, in which it is often alloyed with gold. It is also used for dental fillings.

Platinum is mined all over the world; in the late 1980s the Union of Soviet Socialist Republics (USSR) and South Africa were the leading producers. Canada, with mines in Ontario, where platinum is associated with nickel ore, ranked third in world production. Other leading producers are Colombia and the United States.

## ***Density***

Density, amount of a substance contained within a specific area. In physics, density is the ratio of the mass of a substance to its volume, and it can be calculated by dividing the mass by the volume. Density is often expressed in units such as grams per cubic centimeter ($g/cm^3$) or pounds per cubic foot ($lb/ft^3$).

The density of a substance can vary under different conditions. Substances expand and contract as their temperature changes, and as a result their density also changes. Precise measurements of density therefore include the temperature at which they were taken. For example, 1 cu cm of water at 4°C (39°F) weighs 1 g, so water’s density at that temperature is 1 $g/cm^3$. Hot air balloons are able to fly because the density of air changes as its temperature changes. The balloon rises because the heated air inside its bag is less dense

Top page

than the cooler air outside. Pressure also affects the density of gases. If a given amount of gas is contained within a smaller volume, its density increases. Air at sea level, for example, is denser than air at the top of Mount Everest because the air pressure at sea level is higher and squeezes the air into a smaller volume.

**Scientists often indicate the *density of a substance* by using another measurement called specific gravity.**

***Specific gravity:*** is the density of a substance divided by the density of another substance that is used as a standard. For solids and liquids, water at 4°C (39°F) is usually the standard. Gold has a density of 19.3 g/cm$^3$, so its specific gravity is 19.3 g/cm$^3$ divided by 1 g/cm$^3$ (the density of water at 4°C), or 19.3.

Density can be measured in a number of ways. Solid objects can be weighed to determine their mass and then immersed in a liquid to determine their volume. The volume of liquid displaced by the object is equal to the object’s volume, and the mass divided by the volume is its density. The density of a liquid may be determined similarly. The liquid’s mass can be found by first weighing an empty container, then weighing the container with the liquid in it, and then subtracting the empty weight from the full weight. The liquid’s volume may be determined by instruments similar to the transparent measuring cups used in cooking. Gases may be weighed in airtight containers of known volume and weight. Since gases are more sensitive to changes in temperature and pressure than are liquids or solids, the temperature and pressure must be included in any measurement of the density of a gas.

The term *density* is also used in many other ways. Population density, for example, is the number of people living within a certain area. Photographic density refers to the blackness of an image on film or on a photographic plate. Particle density is the number of particles in a given volume divided by that volume. Charge density is the total electric charge contained in a volume divided by that volume.

## Soda

Soda, term applied to various compounds of sodium, and particularly to sodium carbonate ($Na_2CO_3$)**( صودا الطعام)** , and sodium bicarbonate ($NaHCO_3$) ( **بيكنك بودر**). Sodium carbonate, which has a specific gravity of 2.53 and a melting point of 851° C (1563.8° F), is a white powder with strong alkaline properties; it occurs in nature dissolved in the waters of inland lakes called *soda lakes.* It occurs also in some salt beds. Several hydrated forms of sodium carbonate are manufactured, chief among which are the decahydrate ($Na_2CO_3 \cdot 10H_2O$), called *washing soda* or *sal soda,* and the monohydrate ($Na_2CO_3 \cdot H_2O$), called *crystal carbonate.*

Sodium carbonate was originally prepared from the ashes of seaweed and was called *soda ash*, but it was not used on a large scale until the French chemist Nicolas Leblanc devised a method, called

***the Leblanc process***, for the production of the compound from ordinary table salt, sodium chloride. The Leblanc process was superseded by the less expensive *Solvay process*, invented by the Belgian chemist Ernest Solvay, in an attempt to use the ammonia obtained as a by-product in the coke industry. In the Solvay process, sodium chloride is treated with ammonia gas and then with carbon dioxide, resulting in the formation of sodium bicarbonate ($NaHCO_3$), and ammonium chloride. The sodium bicarbonate precipitate is filtered from the solution of ammonium chloride and is dried and heated to form sodium carbonate. Increasingly, however, rather than using synthetic processes such as the Solvay process, sodium carbonate is being obtained from natural sources, such as soda lakes.

***Sodium carbonate is used*** in the manufacture of glass and ceramics, in the pulping of wood to make paper, and in the manufacture of soap. It is also used in petroleum refining, as a water softener, as a cleaner and degreaser in washing compounds, and in the manufacture of other sodium-containing compounds, such as sodium hydroxide.

Sodium bicarbonate, or *baking soda,* is a white powder with a specific gravity of 2.16. It decomposes when heated in air above 55° C (131° F), losing carbon dioxide and water and forming sodium carbonate. It is an important constituent of baking powder and is also employed as a source of carbon dioxide in fire extinguishers. It is used medicinally to neutralize excessive acid in the stomach and industrially to moderate the alkalinity of sodium carbonate. It occurs naturally in many mineral springs and is manufactured by treating sodium carbonate with water and carbon dioxide. For other compounds of sodium, *see* Alkalies; Sodium.

## Biomass:

Biomass, contraction for biological mass, the amount of living material provided by a given area of the earth's surface. The term is most familiar from discussions of **biomass energy**, *that is, the fuel energy that can be derived directly or indirectly from biological sources*. Biomass energy from wood, crop residues, and dung remains the primary source of energy in developing regions. In a few instances it is also a major source of power, as in Brazil, where sugarcane is converted to ethanol fuel, and in **China's Sichuan province, where fuel gas is obtained from dung.** Various research projects aim at further development of biomass energy, but economic competition with petroleum has mainly kept such efforts at an early developmental stage.

**Liquid fuels such as alcohol,** ether, and oil can be produced from plants and plant-derived substances, known collectively as biomass. These liquid fuels, sometimes referred to as ***biofuels***, are derived from the chemical energy released by plants in photosynthesis.

***Biofuels*** can be *synthesized* from a variety of plants and grains. For example, soybeans and rapeseed can be processed into a diesel-like fuel. Corn and sugarcane can be fermented into alcohol. Other organic matter, such as wood, paper, and grass, can also be synthesized into alcohol when certain fermentation-triggering fungi (organisms that decompose organic matter) are added. Biomass alcohol is mixed with gasoline (in a 1:10 alcohol to gas ratio) in certain urban regions to reduce automobile emissions.

Biofuel

***Biofuel***, any solid, liquid, or gaseous fuel produced from *organic* (once-living) matter. Biofuel is produced either directly from plants or indirectly from industrial, commercial, domestic, or ag**ricultural wastes. There are three main methods for the development of biofuels:(1)** the burning of dry organic wastes (such as household refuse, industrial and agricultural wastes, straw, wood, and peat);(2) **the fermentation of wet wastes (such as animal dung)** in the **absence of oxygen** to produce *biogas (containing up to 60 percent methane)*, or (3)**the fermentation of sugarcane or corn to produce alcohol and esters**; and ***energy forestry*** (producing fast-growing wood for fuel).

***Fermentation*** produces two main types of biofuels: alcohols and esters. These could theoretically be used in place of fossil fuels but, because major alterations to engines would be required, biofuels are usually mixed with fossil fuels. The European Union will require 5.75 percent ethanol, derived from wheat, beet, potatoes, or corn, to be added to fossil fuels by 2010 and 20 percent by 2020. About a quarter of Brazil's transportation fuel in 2002 was ethanol.

Top page

***(In India)*** To decrease reliance on fuelwood, the government has promoted the use of biogas (a mixture of methane and carbon dioxide produced by decomposing organic matter) for cooking fuel.
See Energy Supply, World; Fuels, Synthetic; Gasohol.

## *Solar Energy*

Does not refer to a single energy technology but rather covers a diverse set of renewable energy technologies that are powered by the Sun’s heat. Some solar energy technologies, such as heating with solar panels, utilize sunlight directly. Other types of solar energy, such as hydroelectric energy and fuels from biomass (wood, crop residues, and dung), rely on the Sun’s ability to evaporate water and grow plant material, respectively. The common feature of solar energy technologies is that, unlike oil, gas, coal, and present forms of nuclear power, solar energy is inexhaustible. Solar energy can be divided into three main groups—heating and cooling applications, electricity generation, and fuels from biomass.

## *Synthesys*

CHEMISTRY formation of chemical compounds: the process of forming a complex compound through a series of one or more chemical reactions involving simpler substances

## *met·al·lur·gy* [méttʼl ùrjee]

**study of metals:** the study of the structure and properties of metals, their extraction from the ground, and the procedures for refining, alloying, and making things from them

## *Ash (residue)*

Ash (residue), solid residue of combustion. If combustion has been complete, the ash will be entirely inorganic.

*The ash from wood* or similar plant material generally consists principally of sodium carbonate and potassium carbonate; for centuries wood ash was the principal source of potassium for making such chemicals as saltpeter. As recently as World War I, it was an important potassium source for the U.S. The ash content of dry wood varies from 2 percent by weight for balsa to 0.2 percent for redwood (sequoia).

## *Ash: رماد*

The ash of animal bones consists primarily of calcium phosphate. For many years bones were a principal source of phosphorus, and ground bone, or bone meal, is still used as fertilizer for its phosphorus and calcium content. Mineral deposits of calcium phosphate are now exploited, but much of this was formed from the bones of prehistoric animals. *Ash from the burning of sea plants is a common source of iodine.*

The content of ash in coal varies from as little as 3 percent by weight for some subbituminous coal to as much as 28 percent for some cannel coal. Its composition may also vary greatly; coal ash contains sodium and potassium carbonates and large quantities of silicate in combination with a wide variety of metals. The composition of the ash determines the fusion point of the ash, that is, the temperature at which it forms clinker, or slag. This may vary from below 1093° C (2000° F) to above 1649° C (3000° F), the lower fusion temperatures generally being found in coal with high silica content.

All the inorganic constituents of food are referred to collectively as ash, although some of them can actually be volatilized by burning the food. Such ash contains the minerals essential to the maintenance of life, of which the most important are calcium, chlorine, iodine, iron, phosphorus, potassium, sodium, and sulfur.

## *Fermentation*

Top page

Fermentation, chemical changes in organic substances produced by the action of enzymes (*see* Enzyme). This general definition includes virtually all chemical reactions of physiological importance, and scientists today often restrict the term to the action of specific enzymes, called ferments, produced by minute organisms such as molds, bacteria, and yeasts. For example, lactase, (1)a ferment produced by bacteria usually found in milk, causes the milk to sour by changing lactose (milk sugar) into lactic acid. Probably the most important type of fermentation is (2) *alcoholic fermentation*, in which the action of zymase secreted by yeast converts simple sugars, such as glucose and fructose, into ethyl alcohol and carbon dioxide. Many other kinds of fermentation occur naturally, as in the formation of butyric acid when butter becomes rancid and of acetic acid when wine turns to vinegar.
Generally, fermentation results in the breakdown of complex organic substances into simpler ones through the action of catalysis. For example, by the action of diastase, zymase, and invertase, starch is broken down (hydrolyzed) into complex sugars, then simple sugars, and finally alcohol.

Glycerin, acetone, butyl alcohol, and butyric acid are now produced on a large commercial scale by special *fermentation* processes. Various fermentation productions of milk, such as acidophilus milk, Bulgarian milk, and yogurt, are widely consumed for their nutritive properties.

The action of certain bacteria on undigested carbohydrates causes fermentation in the human intestine. As a result, gases such as hydrogen sulfide and carbon dioxide may form in amounts large enough to cause distention and pain. Acids such as lactic acid and acetic acid may also form in the intestines of infants, causing diarrhea.

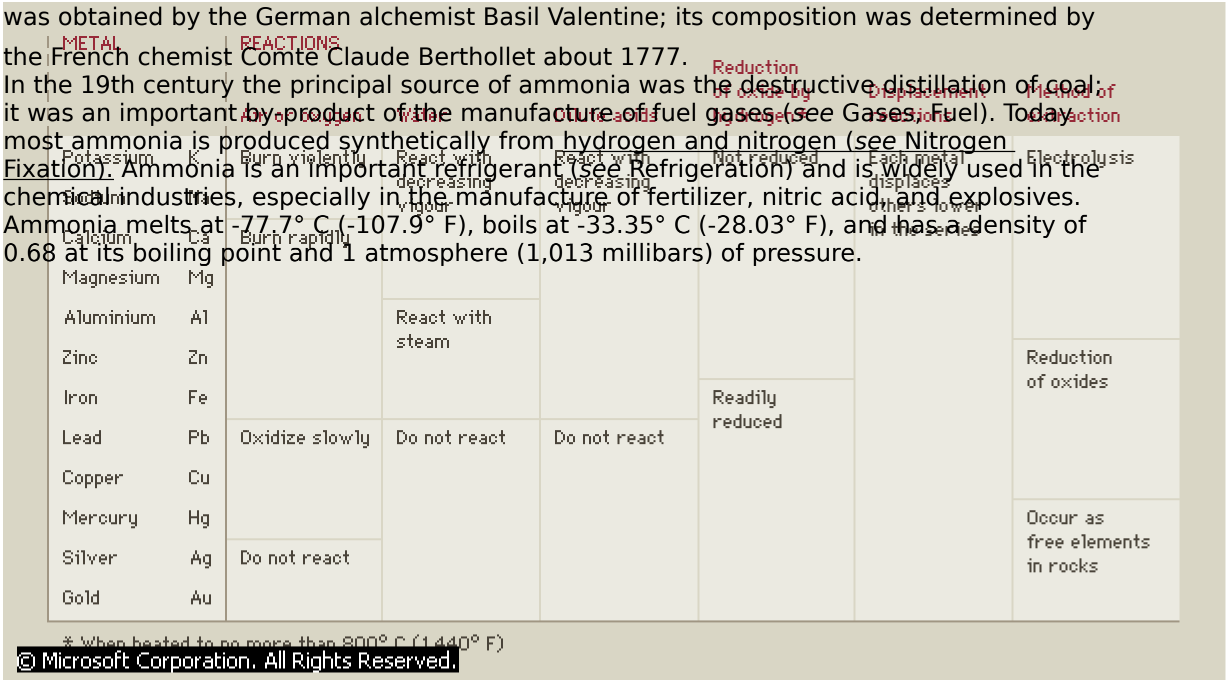
*See* Brewing; Zymology. See also articles on many of the enzymes, foods, and organic substances mentioned.

## Ammonia:

Ammonia, colorless, pungent gas, $NH_3$, highly soluble in water. A saturated aqueous (water) solution of ammonia contains 45 percent ammonia by weight at 0° C (32° F) and 30 percent at ordinary room temperatures. On solution in water, ammonia becomes ammonium hydroxide, $NH_4OH$, which is strongly basic and similar in chemical behavior to the hydroxides of the alkali metals (*see* Acids and Bases; Alkalies).

Ammonia was known to the ancients, who derived both the name and the substance from sal ammoniac, which was produced at the Temple of Jupiter Ammon in Libya (1) ***by the distillation of camel dung***. During the Middle Ages in Europe ammonia was obtained by (2)*heating the horns and hoofs of oxen* and was called spirits of hartshorn. Free ammonia was obtained by the German alchemist Basil Valentine; its composition was determined by the French chemist Comte Claude Berthollet about 1777.

In the 19th century the principal source of ammonia was the destructive distillation of coal; it was an important by-product of the manufacture of fuel gases (*see* Gases, Fuel). Today most ammonia is produced synthetically from hydrogen and nitrogen (*see* Nitrogen Fixation). Ammonia is an important refrigerant (*see* Refrigeration) and is widely used in the chemical industries, especially in the manufacture of fertilizer, nitric acid, and explosives. Ammonia melts at -77.7° C (-107.9° F), boils at -33.35° C (-28.03° F), and has a density of 0.68 at its boiling point and 1 atmosphere (1,013 millibars) of pressure.



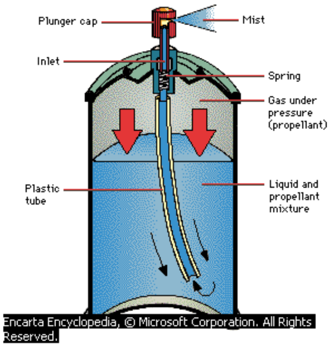
| METAL | | REACTIONS<br>Air or oxygen | Water | Dilute acids | Reduction of oxide by hydrogen* | Displacement reactions | Method of extraction |
|---|---|---|---|---|---|---|---|
| Potassium | K | Burn violently | React with decreasing vigour | React with decreasing vigour | Not reduced | Each metal displaces others lower in the series | Electrolysis |
| Sodium | Na | | | | | | |
| Calcium | Ca | Burn rapidly | | | | | |
| Magnesium | Mg | | | | | | |
| Aluminium | Al | | React with steam | | | | |
| Zinc | Zn | | | | | | Reduction of oxides |
| Iron | Fe | | | | Readily reduced | | |
| Lead | Pb | Oxidize slowly | Do not react | Do not react | | | |
| Copper | Cu | | | | | | |
| Mercury | Hg | | | | | | Occur as free elements in rocks |
| Silver | Ag | Do not react | | | | | |
| Gold | Au | | | | | | |

* When heated to no more than 800° C (1,440° F)

Top page

## Aerosol Dispenser:

Aerosol Dispenser container and valve designed to dispense a wide variety of substances in the form of fine sprays, foams, or liquid streams. The product to be dispensed, such as paint, cosmetics, or food, is sealed in the container with a propellant gas under pressure.
Certain propellants such as nitrous oxide or carbon dioxide remain gaseous when pressurized in these containers. Others, such as the chlorofluorocarbons, may liquefy (*see* Fluorine). In a two-phase system the product mixes with the liquid propellant that expands into a gas when released and breaks the product into tiny droplets. A three-phase system consists of a layer of product between layers of nonmixing liquefied propellant at the bottom and gaseous propellant at the top. In both systems depressing the push button on the valve allows the product to be forced up a tube and through the valve. The liquefied gas in the bottom of the container vaporizes to keep the pressure constant.



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In the 1970s chlorofluorocarbons came under scrutiny as a possible threat to the atmospheric ozone layer. These propellants have been banned in the United States and in several other countries for all but essential uses (*see* Atmosphere; Ozone Layer).

## calcium carbide:

**compound used in making acetylene:** a colorless or grayish-black powdery compound used in the generation of acetylene gas for welding.
Formula: $CaC_2$ *Also called* calcium acetylide
*Also called* carbide
*Also called* calcium carbide

## Carbides:

Carbides, compounds of carbon with metals or metalloids. These compounds have high melting points and are not readily volatilized. They are produced by heating appropriate mixtures to high temperatures in electric furnaces. The largest group of carbides is the acetyledic group, including the carbides of beryllium, calcium, strontium, sodium, potassium, copper, silver, gold, and nickel. The acetylides, the most important of which is calcium carbide, form acetylene by reaction with water or acids. Another group, consisting of aluminum, beryllium, and manganese carbides, is termed the methanides. These yield methane on reaction with water or acids.

Important metallic carbides include iron carbide, or cementite, the hardening constituent in steel; tungsten carbide, from which are made hard tools for the machining of tough metals; and boron carbide, a material almost as hard as diamond. An important nonmetallic carbide is silicon carbide, or carborundum, which is used as an abrasive.

## Electric Furnace,

electrically heated device used industrially for melting metals or firing ceramics. It is also known as an electrothermic furnace.

## *resistance furnace*

The simplest type of electric furnace is the resistance furnace, in which heat is generated by passing a current through a resistance element surrounding the furnace or by utilizing the resistance of the material being heated. The heating element in an externally heated furnace may take the form of a (1) **coil of metal wire wound around a tube of refractory material** or it may be a(2) **tube of metal or other resistive material such as carborundum**. Resistance furnaces are particularly useful in applications in which a small furnace, with precisely controlled temperatures, is needed. Small resistance furnaces are widely used in laboratories and in shops for the heat treatment of tools. **Larger furnaces :** are used for firing ceramics and melting brass. The highest temperature at which resistance furnaces are operated, for example, in the manufacture of graphite, is in the neighborhood of 4100° C (7366° F).

## electric-arc furnace

The **electric-arc furnace** is the most widely used type of electric furnace for the production of **quality alloy steels** and range in capacity from **227 kg (500 lb) to 181 metric tons.** In these furnaces the heat is generated by an arc struck between the metal being heated and one or more electrodes suspended above the metal. A typical form of arc furnace has three electrodes, fed by a three-phase power supply, giving three heating arcs. The electrodes are made either of graphite or of carbon.

## induction furnace,

A more recently developed type of electric furnace is the **induction furnace,** consisting of a crucible in which a metallic charge is heated by eddy currents induced magnetically. Around the crucible is wound a coil through which high-frequency alternating currents are passed. The magnetic field of this coil sets up eddy currents in the metal in the crucible. Induction furnaces have a number of advantages, chief among them being the speed at which metal can be melted. At comparatively low frequencies the induced eddy currents exert a stirring action on the molten metal. Because the higher frequencies are the most effective for heating, some induction furnaces have two coils, one for high-frequency current and one for low-frequency. The earlier types of induction furnaces operated at frequencies between 60 and 60,000 cycles per second, but some modern furnaces are designed to use frequencies of 1 million cycles or more per second.

## electrolytic furnace

A special type of furnace, called an electrolytic furnace, is used in the production of aluminum, magnesium, and sodium. In the electrolytic furnace, a salt is fused by the heat generated by the passage of a large electric current and is at the same time electrolyzed so that the pure metal is deposited at one electrode.

## *crucible*

METALLURGY **container for melting something:** a heat-resistant container in which ores or metals are melted

METALLURGY **bottom of furnace:** the hollow part at the bottom of a furnace where molten metal collects

## *coke*

**carbon fuel:** a solid residue consisting mainly of carbon, left after

Top page

the volatile elements have been driven from bituminous(asphalt) coal or other petroleum material. Coke is used as a fuel and in steelmaking.

*transitive and intransitive verb* (*past* **coked**, *past participle* **coked**, *present participle* **cok·ing**, *3rd person present singular* **cokes**)
**change into coke:** to change something, for example, bituminous coal, into coke, or to become coke or like coke

## *Combustion*,

Combustion, process of rapid oxidation or burning of a substance with simultaneous evolution of heat and, usually, light. In the case of common fuels, the process is one of chemical combination with atmospheric oxygen to produce as the principal products carbon dioxide, carbon monoxide, and water, together with products such as sulfur dioxide that may be generated by the minor constituents of the fuel (see Chemical Reaction; Fuel). The term combustion, however, also embraces oxidation in the broad chemical sense, and the oxidizing agent may be nitric acid, certain perchlorates, or even chlorine or fluorine. See separate articles on most of the fuels and chemicals mentioned in this article.

II ENERGY RELEASE

Rocket Blast Off A rocket blasts off from its launching pad at Cape Canaveral, Florida. Most of the rocket is filled with liquid fuel and a liquid oxidizing agent. The fuel and oxidizing agent mix and ignite in the combustion chamber; the presence of the oxidizing agent ensures that the fuel burns far more efficiently than it could if it depended on the surrounding air for oxygen.Photo Researchers, Inc./Jerry Cooke

Most combustion processes release energy, or heat, for the production of power, for use in industrial processes, and for domestic heating and lighting. Combustion is also a means of producing a desired oxidized product, as in the burning of sulfur to produce sulfur dioxide and ultimately sulfuric acid. In addition, it is a method for disposing of wastes.

The energy released by combustion causes a rise of temperature of the products of combustion. The temperature attained depends on the rate of release and dissipation of the energy and the quantity of combustion products. Air is the cheapest source of oxygen, but because air is three-quarters nitrogen by weight, nitrogen becomes the major constituent of the products of combustion, and the rise in temperature is substantially less than if pure oxygen were used. Theoretically, in any combustion, a minimum ratio of air to fuel is required for complete combustion. The combustion, however, can be made more readily complete, and the energy released maximized, by increasing the amount of air. An excess of air, however, reduces the ultimate temperature of the products and the amount of the released energy. Therefore, an optimum air-to-fuel ratio can almost always be determined, depending on the rate and extent of combustion and the final temperature desired. Air with enriched oxygen content or pure oxygen, as in the case of the oxyacetylene torch, may be used to produce high temperatures (see Acetylene). The rate of combustion may be increased by finely dividing the fuel to increase its surface area and hence its rate of reaction, and by mixing it with the air to provide the necessary amount of oxygen to the fuel. If energy must be released extremely fast, as in the case of rockets, the oxidizer may be incorporated directly into the fuel during the manufacture of the fuel (see

## *Castor Oil*

Castor Oil, colorless or yellow to yellowish-brown, thick, oily liquid obtained from the seeds of the castor-oil plant (see Castor Bean). Although it has a disagreeable taste, it is practically odorless. It is insoluble in water, but soluble in

Top page

organic solvents. The medicinal oil is prepared from husked seeds. Unhusked seeds, the source of industrial castor oil, yield from 45 to 55 percent oil. The oil is pressed from the seeds, purified, and then bleached.

In addition to its use as a simple purgative, castor oil is used as a plasticizer in nitrocellulose compositions, in cosmetics, and in insulation products. It is also used in the manufacture of waterproof lacquers and paints.

***Castor beans*** are used in the production of castor oil. The aqueous phase in the process of making castor oil yields a mixture consisting of 5 to 10 percent ricin. Separating the ricin from this mixture involves **chromatography**, a technique by which pure substances are separated from complex mixtures.

## *Chromatography*

Chromatography, in chemistry, **analytical technique used for the chemical separation of mixtures and substances**. The technique depends on the principle of selective adsorption (not to be confused with absorption), a type of adhesion. Chromatography was discovered in 1906 by the Italian-born Russian botanist Mikhail Tswett, but was not widely used until the 1930s. Tswett separated plant pigments (chlorophylls) by pouring petroleum-ether extract of green leaves over a column of powdered calcium carbonate in a vertical glass tube. As the solution percolated through the column the individual components of the mixture migrated downward at different rates of speed, so that the column became marked with horizontal bands of colors, called a chromatogram. Each band corresponded to a different pigment.

Column chromatography now uses a wide range of adsorbent solids, including silica, alumina, and silica gel. Liquids may also be adsorbed on these solids and in turn serve as adsorbents—a process called partition chromatography—which enables chemists to construct columns with very different properties for particular tasks. High performance liquid chromatography, a variant of this technique that is now in common use, employs liquids adsorbed on extremely small and uniform particles to provide very high sensitivity. A pump is required to drive a mixture through the column. Thin-layer chromatography is another form of column chromatography in which the adsorbent material is on a glass or plastic film.

In paper chromatography, a liquid sample flows down a vertical strip of adsorbent paper, on which the components are deposited in specific locations. Another technique, known as gas-liquid chromatography (gas-solid chromatography is a more rarely used variant), permits separation of mixtures of gas compounds or substances that can be vaporized by heat. The vaporized mixture is forced by an inert gas along a narrow, coiled tube packed with a material through which the components flow at different rates and are detected at the end of the tube. In ion chromatography, a gas may be broken down into ions (electrically charged molecular fragments) by passing it through a hydrogen flame, bombarding it with X rays or radioactive material, or using adsorbent substances that exchange ions with the material being analyzed. Gel permeation chromatography is another method, based on the filtering action of an adsorbent with pores of uniform size; molecules of high molecular weight are separated and detected by this method.

Chromatography is essential to the separation of pure substances from complex mixtures and is widely used in the analysis of foods, drugs, blood, petroleum products, and radioactive-fission products.

# Hydrogenation

Hydrogenation, reaction **involving the combination of hydrogen with unsaturated organic compounds** (*see* Hydrocarbons). Unsaturated organic compounds have at least one pair of carbon atoms connected by a double or triple bond. When an unsaturated compound is treated with hydrogen at a suitable temperature and in the presence of a catalyst (*see* Catalysis), such as finely-divided nickel, platinum, or palladium, **the multiple bond between the carbon atoms is broken and a hydrogen atom attaches itself to each carbon atom.**

For example, when ethylene ($C_2H_4$) is hydrogenated, the product is ethane ($C_2H_6$). Hydrogenation is also used with more complicated molecules, yielding a great variety of synthetic products that are important in the laboratory and for industry.

## *hydrogenation of vegetable oils*

The hydrogenation reaction is applied on a large industrial scale in a number of processes, the most important of which in the United States is the **hydrogenation of vegetable oils to produce many edible fats,** such as margarine. Oils are esters of fatty acids containing one or more double bond linkages between carbon atoms; solid fats are saturated compounds. **To convert the oils, which often have an unpleasant taste and odor, to fats with odor and taste sufficiently innocuous so that they can be used for cooking, the oils are hydrogenated.** The reaction is performed at a **temperature of about 200° C (about 392° F) in the presence of finely-divided nickel, and under a pressure of 3 to 4 atmospheres of hydrogen**. Large volumes of ***cheap and plentiful vegetable oils, such as soybean and cottonseed oil,*** are hydrogenated sufficiently to yield creamy solids that resemble lard at room temperatures. Such products are widely used in foods. Low-grade oils, such as fish oils, are hydrogenated and used in the manufacture of soap and wax.

## *The Bergius process*

***The hydrogenation process*** is also applied in the production **of synthetic gasoline. The Bergius process,** named after the German chemist Friedrich Bergius, is used on a **large scale in many parts of the world where petroleum resources are low.** It utilizes **coal and coal tar as a starting material.** The coal, *mixed with a heavy oil, is ground to a fine paste and heated with hydrogen, under pressure, in the presence of a catalyst composed of metallic sulfides*. The resulting oil is further hydrogenated, and a third hydrogenation yields gasoline. One ton of coal yields about 304 liters (about 80 gallons) of gasoline.

## *The Fischer-Tropsch process*

**The Fischer-Tropsch process,** named after its developers, the German chemists Franz Fischer and Hans Tropsch, was used extensively in Germany in the 1930s to produce synthetic petroleum and **diesel fuel.** It uses a mixture of **carbon monoxide** and **hydrogen gases** with a catalyst containing nickel, cobalt, or modified iron. **The process is currently used to produce the raw materials for manufacturing synthetic fats and soaps.**

## *Wood*

Wood is an ***important raw material in the chemical industry***. Each year an enormous quantity of wood is reduced to pulp and reconstituted mechanically to form paper. Some modern industries are based on extracting from wood its minor chemical constituents, such as tannins, pigments (see Paint and Varnish), gums, resins, and oils, and further modifying these constituents.

In addition to water, the principal constituent of wood is cellulose. Much of the large quantity of cellulose used today in making rayon and nitrocellulose is obtained from such comparatively pure sources as cotton, but an increasing quantity is being obtained from wood. The chief difficulty in using cellulose from wood lies in separating it from its impurities, the most important of which is lignin, a carbohydrate. Formerly, the lignin was discarded, but it was found to be a raw material for the manufacture of plastics and a suitable medium for the cultivation of yeast, which is an important livestock and poultry feed.

Wood may be used as a chemical raw material, without separating the cellulose from the lignin, by several different processes. In the Bergius process, wood is treated with hydrochloric acid in order to produce sugars, which are either used as cattle feed or fermented to produce alcohol. Wood may be converted into liquid fuels by hydrogenation. Wood has long been used also as a source of chemicals by destructive distillation. Most of these chemicals, however, including acetic acid, methyl alcohol, and acetone, are now made synthetically.

Certain new products consist essentially of a mixture of wood with certain chemicals; such a mixture will have mechanical properties similar to those of wood, but will be stronger and more resistant chemically. The most important methods of making these mixtures consist of impregnating the wood with certain chemicals, such as a mixture of phenol and formaldehyde, and then heating the impregnated wood so that the chemicals react within the cells of the wood to form a plastic. Wood treated with such resins is known as impreg. It has great resistance to decay and to insect and borer attack; its specific gravity is increased, but its strength is increased only slightly, if at all. A different product, called compreg, is made by compressing the impregnated wood in a hydraulic press at pressures of about 70 kg/sq cm (about 1000 lb/sq in) while the chemical reaction which forms the plastic is progressing. Such compressed impregnated wood may have a specific gravity up to about 1.35. The hardness is many times as great as that of the original wood, and the strength is somewhat greater, although the toughness may be less.
**Charcoal, made from charred wood, is also used for fuel.**

## *Tannic acid*

The ability of tannins to transform proteins into insoluble products resistant to decomposition leads to their use as tanning agents. Ferric salts react with tannins to give bluish-black products that are useful as inks. Tannins are used as mordants for dyeing cloth, as sizes for paper or silk, and as coagulants for rubber (see Dyeing). The precipitating properties of tannins are used in clarifying, or cleaning, wines and beer. Tannic acid is valuable as an external medicine because it is astringent[1] and styptic[2]

## *Chromite*

Chromite, only ore mineral of chromium, consisting o**f ferrous**[3] chromite, FeCr2O4, and belonging to the spinel group. It crystallizes in the isometric system (see Crystal) and has a hardness of 5.5 and a specific gravity, or relative density, of 4.1 to 4.8. It is found in irregular brownish-black or black grains or octahedral crystals. Chromite is one of the first minerals to crystallize from magma. It occurs principally in rocks containing various amounts of ferromagnetic minerals. It also

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[1] **pore-closing substance:** a substance used on the skin to draw tissue together

[2] **able to stop bleeding:** slowing down the rate of bleeding or stopping bleeding altogether, whether by causing the blood vessels to contract or by accelerating clotting

[3] **containing iron:** containing iron with a valence of two

Top page

occurs in the minerals serpentine and peridotite, as well as in glacial and alluvian deposits (see Alluvium). Large deposits of chromite are found in Kazakhstan, Turkey, and Zimbabwe, and also in Austria, Bosnia and Herzegovina, Serbia and Montenegro (formerly the Federal Republic of Yugoslavia), and the Former Yugoslav Republic of Macedonia

Chromium

## I INTRODUCTION

Chromium, symbol Cr, gray metallic element that can take on a high polish. The atomic number of chromium is 24; the element is one of the transition elements of the periodic table (*see* Periodic Law).

## II PROPERTIES AND OCCURRENCE

The element was discovered in 1797 by the French chemist Louis Nicolas Vauquelin, who named it chromium (Greek *chroma,* “color”) because of the many different colors of its compounds.

Chromium is a common element; overall it ranks about 21st in natural abundance among the elements in crustal rocks. Chromium has an atomic weight of 51.996; the element melts at about 1857° C (about 3375° F), boils at about 2672° C (about 4842° F), and has a specific gravity of 7.2.

Chromium can replace part of the aluminum or iron in many minerals, imparting to them their unique colors. Many precious stones owe their color to the presence of chromium compounds (*see* Gemstones). Workable ores are rare, however, chromite ($FeCr_2O_4$) being the only important one.

In chromites and chromic salts, chromium has a valence of +3. Most of these compounds are green, but some are red or blue. Chromic oxide ($Cr_2O_3$) is a green solid. In chromates and dichromates, chromium has a valence of +6. Potassium dichromate ($K_2Cr_2O_7$) is a red, water-soluble solid that, mixed with gelatin, gives a light-sensitive surface useful in photographic processes (*see* Photography). The chromates are generally yellow, the best known being lead chromate ($PbCrO_4$), an insoluble solid widely used as a pigment called chrome yellow. Chrome green is a mixture of chrome yellow and Prussian blue.

## III USES

More than half the production of chromium goes into metallic products, and about another third is used in refractories. It is an ingredient in several important catalysts. The chief use of chromium is to form alloys with iron, nickel, or cobalt. The addition of chromium imparts hardness, strength, and corrosion resistance to the alloy. In the stainless steels, chromium makes up 10 percent or more of the final composition. Because of its hardness, an alloy of chromium, cobalt, and tungsten is used for high-speed metal-cutting tools. When deposited electrolytically, chromium provides a hard, corrosion-resistant, lustrous finish. For this reason it is widely used as body trim on automobiles and other vehicles. The extensive use of chromite as a refractory is based on its high melting point, its moderate thermal expansion, and the stability of its crystalline structure.

# Spinel

Top page

Spinel, mineral composed of magnesium aluminate $MgAl_2O_4$. It crystallizes in the isometric system, usually in hexahedral crystals with a vitreous luster. Various amounts of impurities, such as iron, manganese, and chromium, impart different colors to the mineral, including red, lavender, blue, green, brown, or black. The clear red variety, which is almost pure magnesium aluminate, is known as ruby spinel or balas ruby. Spinel containing iron is dark in color and is known as pleonaste or ceylonite. Spinel containing chromium is yellowish- to greenish-brown and is known as picotite. The hardness of the mineral is 8; the specific gravity ranges from 3.5 to 4.1. Transparent and finely colored specimens are used as gemstones. Most spinel gemstones are the red, ruby-spinel variety. Ruby spinels are found in the sands of Sri Lanka and Madagascar. In the U.S. ordinary spinel occurs in New York and New Jersey. About 200 different synthetic spinels have been manufactured.

Chromium

## *Refractories.*

Magnesite-chrome basic refractory is being used as a melt-cast product in the steel industry to lower furnace-maintenance costs. High-temperature castable refractories are being employed for the roofs of electric-arc furnaces. They are also being used for jet aircraft and for missile-launching platforms. Silicon-carbide refractories are playing vital roles in high-temperature work.

## *Fatty Acids*

Fatty Acids, common name for a group of organic acids (see Chemistry, Organic) that includes the saturated (hydrogenated), straight-chain acids, with a single carboxyl (COOH) group, that are produced by **the hydrolysis of fats**—hence the name (see Fats and Oils). The group also includes all other saturated straight-chain acids and acids with a branched chain or cyclic structure. Formic acid, HCOOH, and acetic acid, CH3COOH, are the simplest fatty acids. Both have sour taste, irritate the skin, and have a sharp smell. Of more complicated structure are butyric, caproic, caprylic, and capric acids, all of which have *unpleasant odors.* Stearic, palmitic, oleic, and naphthenic acids are g*reasy materials with little odor.* **A growing source of fatty acids is tall oil, a by-product of the pinewood used to make paper pulp.**

Fatty acids are useful in preparing biodegradable detergents, thickeners for paints, and lubricants. Stearic acid is used to combine rubber with other substances, such as pigments, or materials that control the flexibility of rubber products; it is also used in the polymerization of styrene and butadiene in making artificial rubber. New uses for fatty acids include ore flotation and the manufacture of disinfectants, varnish driers, and heat stabilizers for vinyl resins. Fatty acids are also used in plastic products, such as coatings for wood and metal, and in automobile parts ranging from air-cleaner housings to upholstery.

## *Stearic Acid*

Stearic Acid, white crystalline, organic solid, CH3(CH2)16CO2H. It is insoluble in water but somewhat soluble in alcohol and ether. Together with lauric, myristic, and palmitic acids, it forms an important group of fatty acids. It occurs abundantly in most animal and vegetable oils and fats as an ester (see Esters)—glyceryl tristearate or stearin, C57H120O6—and constitutes the bulk of fats in food and the human body. The acid is **obtained by hydrolysis of the ester and may be prepared commercially by the hydrolysis of tallow.** It is used in lubricating mixtures, waterproofing materials, and varnish driers, and in the manufacture of paraffin wax candles. Combined with sodium hydroxide, stearic acid forms a soap, sodium stearate. See Fats and Oils.

Top page

Stearic acid melts at 70° C (158° F) and boils at 383° C (721° F).

## *Calcination*

Calcination, chemical and manufacturing process in which a material is heated, without melting, in order to drive off the material's volatile components. Calcination is industrially important in the production of lime from limestone and in the manufacture of portland cement and plaster of Paris (see Gypsum), and also as a first step in the extraction of metal from ores.

## *Lime*

Lime (substance), caustic solid substance, white when pure, obtained by calcining limestone and other forms of calcium carbonate. Pure lime, also called quicklime, burnt lime, and caustic lime, is composed of calcium oxide ($CaO$) but commercial preparations usually contain impurities, such as the oxides of aluminum, iron, silicon, and magnesium. When treated with water, lime liberates large amounts of heat and forms calcium hydroxide, sold commercially as a white powder called slaked lime or hydrated lime. Lime is used in the preparation of cement and mortar and as a neutralizer of acid soils in agriculture. It is also used in the manufacture of paper, glass, and whitewash, in leather tanning, sugar refining, and as a water-softening agent.

Limewater, which is an alkaline solution of slaked lime in water, is used principally in medicine as an antacid, as a neutralizer for acid poisoning, or for treatment of burns.

Flax

## I INTRODUCTION

Flax, common name for a family of plants, and for plants of a genus within that family. One species is grown extensively for its fiber and seed. The fiber products include linen threads and fabrics, and the seed is the source of linseed oil and meal. Other species are cultivated as ornamental plants or for pharmaceuticals.

Flax plants range in height from 30 to 100 cm (12 to 40 in) and have shallow taproots. Because the stems contain the fiber, the taller varieties, which are sparsely branched, are used for fiber production. The seed-producing varieties have shorter stems and are more heavily branched. Both fiber and seed flaxes have narrow, alternate, lancelike leaves. The flowers are completely symmetrical, with five sepals, five petals, ten stamens, and up to ten seeds. The seeds are borne in five double-celled carpels, which are part of the pistil. The flowers of most cultivated varieties range in color from deep to pale shades of blue. Some varieties, which may have white, violet, pink, or red blossoms, make effective ornamental plants. Flaxseeds are shiny and may be dark brown, yellow, or mottled in color.

## II ORIGIN

The use of flax fiber for cloth originated almost 10,000 years ago. Remnants of linen fishing nets and clothing and unworked flax have been found in Switzerland in the remains of Stone Age lake dwellings. The ancient Egyptians used linen shrouds, some of which are still preserved on mummies, and pictures of flax cultivation adorn the walls of various Egyptian tombs. Passages in the Bible refer to the manufacture of linen. Annual flax, which was

Top page

cultivated in Mesopotamia, Assyria, and Egypt for about 5000 years, **still grows wild in the regions** around the Persian Gulf, the Caspian Sea, and the Black Sea.

**In North America flax was grown as early as 1626, and linen was the most important textile fiber until the beginning of the Industrial Revolution. With the invention of the cotton gin in 1793, cotton became an extremely cheap raw material, and it largely displaced flax as a fiber source. Subsequently flax has been cultivated in the United States mainly for its seed.**

## III FIBER FLAX

Primarily a temperate-region plant, flax grows under a **wide range of temperature** and moisture conditions. High temperatures and high precipitation are, however, unfavorable for production of either flax or seed. Moderately fertile silt or clay loams are most satisfactory for cultivation.

Fiber flax is harvested by uprooting the plants, which then are piled in the fields to dry. The seed is removed to be used for feed or oilseed or to be retained for planting. The straw is retted, a process that promotes partial decomposition of the stem to permit separation of the fiber from the woody portions. In retting, the straw is spread on the ground in order to subject it to the action of rain, dew, and microorganisms, and to cyclic wetting, drying, freezing, and thawing. Another process, called water-retting, which is used in some countries, consists of immersing the straw in ponds, streams, or special tanks in which water and microorganisms promote decomposition.

The retted stems are crushed and broken and the fiber is separated from the woody fragments, called shives. This process yields relatively long and straight fibers, known as line fibers, and short, damaged or tangled fibers, called tow. Flax tow is used primarily in upholstery. Having high tensile strength, line fibers are used in the manufacture of various threads employed in the bookbinding and shoe industries and in such products as twine, fishnets, and laces. Flax fibers are also used extensively in various types of linen cloth and other fabrics.

France and Belgium produce high-quality fiber. Flax fiber is also produced in eastern Europe, and on a limited scale in Ireland and Canada. Small amounts of fiber flax have been cultivated in the United States, primarily in Michigan and Oregon, but little commercial production of flax fiber has taken place since 1950. The Soviet Union cultivated flax extensively; despite a large total yield, however, the quality of the fiber usually was inferior to that obtained from western Europe.

## IV SEED FLAX

Flax for seed is produced and harvested in about the same manner as wheat and other small grains. The crop is most productive on loamy soils with moderate to high fertility. In California, India, and Argentina, seed flax is planted in the fall and matures in about 150 days. In the northern United States and in Canada and the northern latitudes in Europe, the

Top page

crop is seeded in the spring and matures in 100 to 120 days. Yields and quality are best in relatively cool climates. High temperatures and drought during the time the seed is developing often reduce the crop yield and oil content.

Seed flax does not compete well with weeds. It is planted on clean firm seedbeds, usually on acreage previously planted with corn or a similar intertilled crop, in which weeds have been killed by cultivation. The inability of seed flax to compete with weeds or other plants has made it valuable as a so-called nurse crop, or companion crop, for plantings of alfalfa, clovers, and other forage legumes. Weeds in flax crops may be controlled by use of herbicide sprays.

Flax seed yields from 30 to 40 percent linseed oil by weight. The oil is used in the manufacture of paints, varnishes, linoleum, oilcloth, printing inks, soaps, and many other products. Since 1959 it also has been used as a coating for concrete pavements and bridge decks to prevent scaling and surface deterioration from heavy traffic, freeze-thaw cycles, and applications of salt or calcium chloride for snow and ice control. The oil cake, or linseed meal, which remains after the oil has been expressed, contains 30 to 40 percent crude protein and is a valuable feed for livestock.

In recent years the fiber from seed flax has been used in the manufacture of high-grade and special-purpose papers. Most U.S. cigarette paper is manufactured from the fiber of domestically grown seed flax.

**Scientific classification:** Flax plants make up the family Linaceae. The species grown extensively for its fiber and seed is classified as *Linum usitatissimum.*

**lac·quer** [lákər]
noun (plural lac·quers)

1. type of varnish: a varnish made from the sap of an eastern Asian tree and used to give a protective surface, especially to wood
2. glossy synthetic coating: a hard, glossy, clear or colored coating made up of resins or cellulose derivatives and a plasticizer in a volatile solvent

Acetic Anhydride, colorless, volatile, mobile (free-flowing) liquid, $(CH3CO)2O$, with an irritating odor. It is primarily employed as an intermediate in the manufacture of industrial chemicals, pharmaceuticals, perfumes, plastics, synthetic fibers, explosives, weed killers, and other chemical products. It is manufactured by the dehydration of acetic acid or by the oxidation of acetaldehyde. About 75 percent of the acetic anhydride produced annually in the United States is used for the manufacture of cellulose acetate, and about 1.5 percent is used for the manufacture of aspirin. Acetic anhydride melts at -73° C (-99.4° F), boils at 139.6° C (283.3° F), and has a density of 1.082 g per ml.

# Acetylene

Acetylene, colorless, odorless, flammable gas, HC:CH. As ordinarily prepared it has an unpleasant odor due to impurities. Acetylene, also known as ethyne, can be prepared from any of various organic compounds by heating them in the absence of air, but it is produced commercially by the reaction of calcium carbide with water or as a by-product of the production of ethylene. Although acetylene can be

Top page

liquefied at ordinary temperatures with high pressure, it is violently explosive as a liquid. Acetylene gas is usually stored in metal tanks, under pressure, dissolved in liquid acetone. When acetylene is bubbled through a solution of ammonia and cuprous chloride, copper acetylide, a reddish precipitate, is formed. This is used as a test for acetylene. **Copper acetylide** is explosive when dry.

Acetylene burns in air with a hot and brilliant flame. It was formerly much used as an illuminant and is now mainly used in the **oxyacetylene torch**, in which acetylene is burned in oxygen, producing a very hot flame used for welding and cutting metal. Acetylene is also used in chemical synthesis, particularly in the manufacture of vinyl chloride for plastics, acetaldehyde, and the neoprene type of synthetic rubber. Acetylene has a melting point of -81° C (-113.8° F) and a boiling point of -57° C (-70.6° F).

# Carbon Tetrachloride

Carbon Tetrachloride, heavy, colorless liquid, $CCl_4$, with a characteristic nonirritating odor. It has a freezing point of -22.92° C (-9.26° F), a boiling point of 76.72° C (170.10° F), and a density of 1.5947 g/ml at 20° C. It is made by treating carbon disulfide, $CS_2$, with chlorine, $Cl_2$, or sulfur monochloride, $S_2Cl_2$, or by the chlorination of hydrocarbons. Carbon tetrachloride is used to make compounds such as chlorofluoromethanes, used as refrigerants and aerosol-spray propellants. Carbon tetrachloride is also used **in fire extinguishers** and for dry **cleaning of fabrics.**