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# VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA

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AERONAUTICS · ASTRONOMY · BOTANY  
CHEMICAL ENGINEERING · CHEMISTRY  
CIVIL ENGINEERING · ELECTRICAL ENGINEERING  
ELECTRONICS · GEOLOGY · GUIDED MISSILES  
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NAVIGATION · NUCLEAR SCIENCE & ENGINEERING  
PHOTOGRAPHY · PHYSICS · RADIO & TELEVISION  
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## PREFACE

In this third edition the Van Nostrand SCIENTIFIC ENCYCLOPEDIA retains the character that established the unique position of the book in its earlier editions. It is a basic reference work on science and engineering and on mathematics and medicine, and the substantial increase in size of this third edition is clear evidence of the momentous advances that have occurred in these fields and of the thoroughness of their treatment here.

Specifically, the entries cover aeronautics, astronomy, botany, chemistry, chemical engineering, civil engineering, computer technology, electrical engineering, electronics and radio, geology, guided missiles, mathematics, mechanical engineering, medicine, metallurgy, meteorology, mineralogy, navigation, nuclear science and engineering, photography, physics, statistics, zoology, and such related areas as astrophysics, biochemistry, biophysics, nautical astronomy and others.

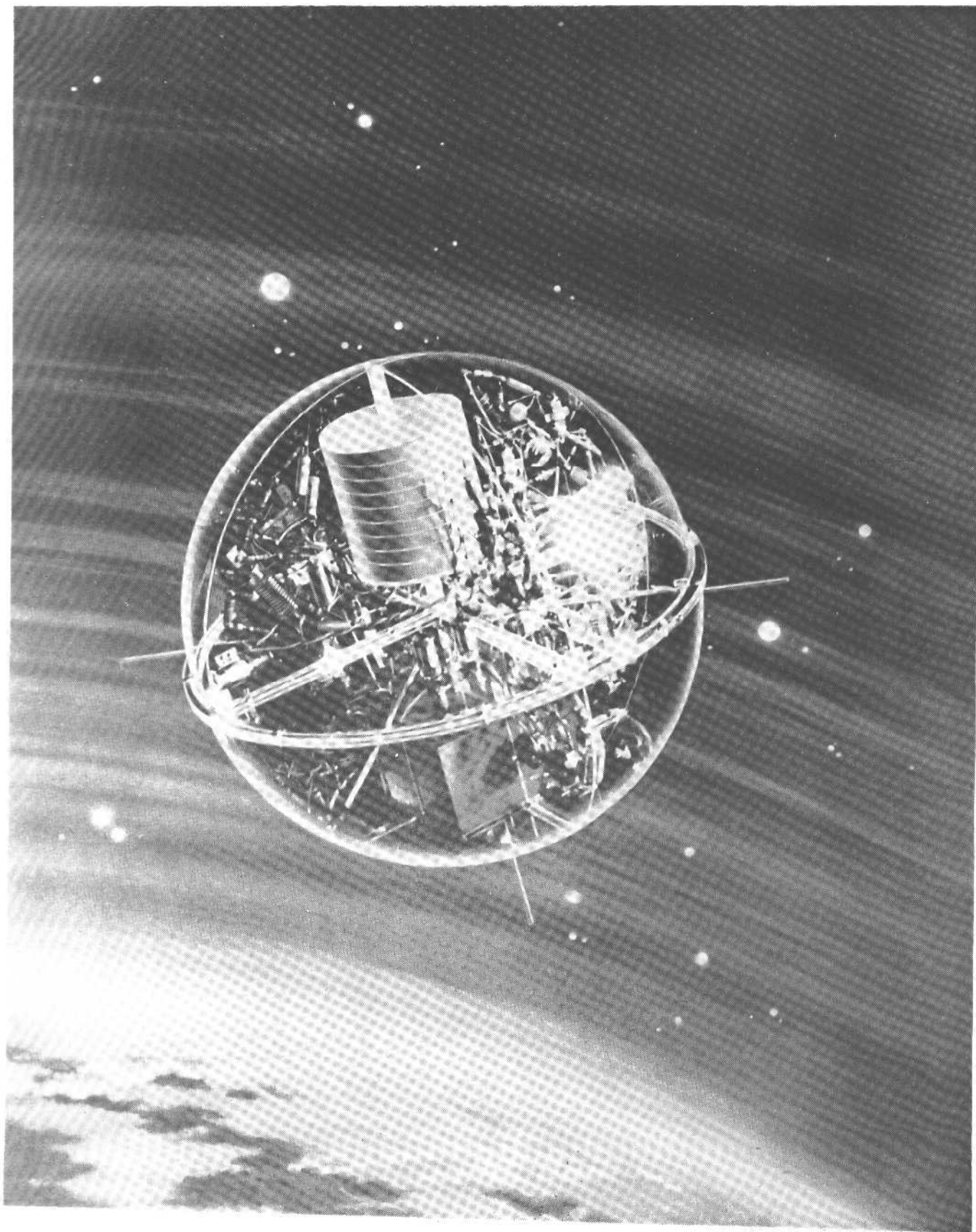
In order to obtain a unity impossible when many men contribute, the responsibility for the compilation of the data for each of these fields was left largely in the hands of a single contributor. However, acknowledgment must be made to many other authorities including those who laid the foundations of the early editions as well as those who contributed material and suggestions for this third edition.

The ENCYCLOPEDIA defines and explains about 15,000 terms of fundamental interest. These are arranged alphabetically and an extensive system of cross-indexing has been developed to enable the reader to find the substantive facts that bear directly on each included topic. By this system each term explained in the book is printed in bold face (black face) type whenever it is used significantly in the course of an article on another term. Whenever this bold face type appears within an article, the word or term appearing in this type is itself explained and described in its alphabetical position. This makes it possible for the reader or student to check every article that has a direct bearing on the topic in which he is interested. It leads him to the supplementary information relative to any particular subject and enables him to gain a comprehensive knowledge of each term by using these aids and consulting the given references.

Inevitably there are limits to any one-volume work. These limits necessarily restrict the length of the articles and the size and number of illustrations. However, the comprehensiveness of the book is noteworthy both in the scope of the terms covered and in the breadth of the treatment in the individual article. The meticulous work of the contributors, together with their systematic cross-referencing, have made possible the inclusion of a wealth of material within the covers of a single book.

An important feature of this ENCYCLOPEDIA is the progressive development of the discussion of each topic, beginning with a simple definition expressed in the plainest of terms and progressing to a final reflection of the more detailed aspects of the topic treated. Articles dealing with simple concepts are, of course, treated generally in simple terms. Those articles of a more highly technical nature may be of value both to the inquiring lay reader and to the trained technician if they will select their reading from the earlier or later portions of such an article.

The publishers, the contributors and the editors will appreciate the indulgence of the reader in the case of any significant omissions and in the case of errors. The exercise of judgment in the selection of material was unavoidable, and it was also necessary to maintain a limit of difficulty beyond which it was impractical to go in attempting to cover so broad a field within the physical confines of one useful volume.



Model of earth satellite. This plastic model of an earth satellite was put on exhibition at the Hayden Planetarium, New York, and was built by *Popular Science Monthly* after consultation with scientists assigned to the satellite project. For attachment to rocket, and further explanation, see Page 1455. (*International News Photos*)

# A

**A SUPPLY.** The source of the heating current for the cathode of an electronic tube. In the early days of radio the various voltages needed to operate a receiver were obtained from batteries, called A, B, and C batteries, supplying the filament, plate and grid voltages respectively. These letter designations have been carried over to the present-day sources, although the voltages are usually obtained now from an a-c source, either directly as in the case of the A supply or indirectly for B and C voltages. (See *Amplifiers and Radio Receivers*.)

**AA.** An Hawaiian term introduced into geological nomenclature by C. E. Dutton, in 1883, and signifying the jagged, scoriaceous, blocky and exceedingly rough surface of some basic lava flows.

**AARD-VARK.** Mammalia, Tubulidentata. *Orycteropus*. African animals of peculiar form and ancient lineage, including an Ethiopian and a South-African species. All are anteaters, feeding exclusively on ants and termites, nocturnal in habit, with acute hearing. The southern species has been called the ant-bear.

**AARD WOLF.** Mammalia, Carnivora. An African species, *Proteles cristatus*, superficially like the striped hyena, not common, nocturnal and sleeps by day under termite nests or in excavated or aard-vark holes. Teeth reduced in number and size, an insect eater, but can chew very rotten meat or newly born animals.

**AARITE.** Niccolite.

**AASVOGEL.** South-African vultures. The name was applied by the Dutch colonists and means carrion-bird.

**ABACA.** The sclerenchyma bundles from the sheathing leaf bases of *Musa textilis* (Manila hemp), a plant closely resembling the edible banana plant. These bundles are stripped by hand, after which they are cleaned by drawing over a rough knife. The fiber bundles are now whitish and lustrous, and from six to twelve feet long. Being coarse, extremely strong and capable of resisting tension, they are much used in the manufacture of ropes and cables. Since the fibers swell only slightly when wet, they are particularly suited for rope which will be used in water. Waste manila fibers from rope manufacture and other sources are used in the making of a very tough grade of paper, known as manila paper. The fibers may be obtained from both wild and cultivated plants, the latter yielding a product of better grade. The cultivated plants, propagated by seeds, by cuttings of the thick rhizomes or by suckers, are ready for harvest at the end of three years, after which a crop may be expected approximately every three years.

**ABALONE.** Mollusca, Gasteropoda. *Haliotis*. Marine species, mostly of the Pacific and Indian Oceans. The single broad shallow shell has a richly colored iridescent inner surface and is an important source of mother-of-pearl and blister pearls for costume jewelry. The flesh is palatable. It is eaten on the west coast of America, but much larger quantities are dried in California for shipment to the Orient.

**ABAMPERE.** The cgs electromagnetic unit of current. It is that current which, when flowing in straight parallel wires

1 cm apart in free space, will produce a force of 2 dynes per cm length on each wire. One abampere is ten amperes.

**ABBE CONDENSER.** A compound lens used for directing light through the object of a compound microscope. All the light enters the object at an angle with the axis of the microscope.

**ABBE NUMBER.** The reciprocal of the dispersive power of a material.

**ABBE SINE CONDITION.** The relationship  $n'y \sin \theta = n'y' \sin \theta'$ , where  $n, n'$  are indices of refraction,  $y, y'$  are distances from optical axis, and  $\theta, \theta'$  are angles light rays make with the optical axis. A failure of an optical surface to satisfy the sine condition is a measure of the coma of the surface.

**ABCOULOMB.** Units and Dimensions.

**ABDOMEN.** The abdomen is the posterior division of the body in many arthropods. It is the posterior portion of the trunk in vertebrates. In the vertebrates this region of the body contains most of the alimentary tract, the excretory system, and the reproductive organs. It contains part of the coelom and in mammals is separated from the thorax by the diaphragm.

The abdominal cavity of the human body is subdivided into the abdomen proper and the pelvic cavity.

The walls of the abdominal cavity are lined with a smooth membrane called the peritoneum, which also provides partial or complete covering for the organs within the cavity.

The abdomen proper is bounded above by the diaphragm; below it is continuous with the pelvic cavity; posteriorly it is bounded by the spinal column, and the back muscles; and on each side by muscles and the lower portion of the ribs. In front, the abdominal wall is made up of layers of fascia and muscles. The abdomen is divided into nine regions whose boundaries may be indicated by lines drawn on the surface. The mid-section above the navel between the angle of the ribs is known as the epigastric region; that portion around the navel, as the umbilical; below the navel and above the pubic bone, as the hypogastric region. It is further divided into right and left upper quadrants on each side above the navel, and right and left lower quadrants on each side below the navel. The lumbar region extends on either side of the navel posteriorly and laterally.

The principal organs of the abdominal cavity are the stomach, duodenum, jejunum, ileum, and colon or large intestine, the liver, gall bladder and biliary system, the spleen, pancreas and their blood and lymphatic vessels, lymph glands, and nerves, the kidneys and ureters.

The pelvic portion of the abdomen contains the sigmoid colon and rectum, a portion of the small intestine, the bladder, in the male the prostate gland and seminal vesicles, in the female the uterus, Fallopian tubes and ovaries.

**ABEL EQUATION.** A mass point moves along a smooth curve in a vertical plane and under the influence of gravity alone. Given the time,  $t$ , required for the particle to fall from a point,  $x$ , to the lowest point on the curve as a function of  $x$ , what is the equation of the curve? The problem leads to a Volterra integral equation of the first kind

$$f(x) = \int_0^x \frac{\phi(t) dt}{\sqrt{2g(x-t)}}$$



where  $g$  is the acceleration of gravity. The solution is

$$\phi(x) = \frac{\sqrt{2g}}{\pi} \int_0^x \frac{f'(t)dt}{\sqrt{x-t}}$$

and the equation of the curve is

$$y = \int_0^x \sqrt{|\phi^2(t) - 1|} dt.$$

A closely related problem is that of the **brachistochrone**, where the path is required for a minimum time of descent. Such matters were of considerable interest to many seventeenth and eighteenth century mathematicians; the one described here was solved by the Norwegian, N. H. Abel (1802-1829).

A more general case of the Abel equation is

$$f(x) = \int_0^x (x-y)^{-\alpha} \phi(y) dy$$

where  $f(x)$  is continuously differentiable for  $x \geq 0$  and  $0 < \alpha < 1$ . The solution is

$$\phi(y) = \frac{\sin \alpha \pi}{\pi} \left[ \int_0^y (y-x)^{\alpha-1} f'(x) dx + f(0) y^{\alpha-1} \right].$$

A first-order differential equation

$$y' = f_0(x) + f_1(x)y + f_2(x)y^2 + f_3(x)y^3$$

is also known as an Abel equation. When the  $f_i(x)$  are given explicitly, the equation can often be converted into one of simpler type and solved in terms of elementary functions. In the general case the solution involves **elliptic functions**.

**ABERRATION OF LIGHT.** The apparent change of position of an object, due to the speed of motion of the observer, is known as the aberration of light. Care must be taken not to confuse this effect with that of **parallax**.

If a **telescope**, assumed to be stationary, is pointed at a source of light, the light which enters the object glass centrally and in the direction of the optic axis will pass through the telescope along that axis and emerge through the center of the eyepiece. If the telescope is in motion relative to the source, in any direction other than parallel to the optic axis, the light which enters centrally will emerge off the center of the eyepiece. If this light is to emerge centrally the telescope must be tilted forward in the plane containing the direction of motion of the instrument and the source. The amount of tilt will depend on the direction of the source and the ratio of the speed of the telescope to the speed of light.

This aberrational effect was first announced by Bradley in 1726. He noticed that stars had apparent periodic motions with a period of one **sidereal year**, and that the character of the apparent motion depended upon the **celestial latitude** of the star. He correctly interpreted the effect as due to the motion of the earth about the sun. Statistical discussions of the observations of a large number of stars have shown that the maximum value of this aberration due to the earth's **orbital motion** is  $20''.47$ . This is known as the "aberration angle" or as the "constant of aberration." An aberrational effect of about  $0''.3$ , at maximum, is observed due to the rotation of the earth on its axis.

In 1871, Airy made a series of observations for determination of the aberration constant using a telescope filled with water. Since the value of the **index of refraction** of water is about  $1\frac{1}{2}$ , Airy expected that the value of the aberration would be  $27''.3$  when using the water-filled tube. He found, however, that the value was  $20''.5$  no matter what substance was placed in the telescope. The result of this so-called "Airy's Experiment" caused much discussion, but was eventually explained on the basis of the **Michelson-Morley experiment** and the **theory of relativity**.

All observations, in which the positions of the stars are involved, must be corrected for aberration of light if the results are to be accurate to within  $20''$ . Both the motion of the earth about the sun and the rotation of the earth must be considered. The magnitude of the correction depends upon the **celestial coordinates** of the star, the position of the observer on the earth, and the date and time of observation.

**ABERRATION, OPTICAL.** The failure of an optical system to form an image of a point as a point, of a straight line as a straight line, and of an angle as an equal angle. (See **spherical aberration**, **astigmatism**, **coma**, **curvature of field**, **distortion** (of the image), and **chromatic aberration**.)

**ABFARAD.** Units and Dimensions.

**ABHENRY.** Units and Dimensions.

**ABIogenesis.** The origin of living matter or living organisms from non-living material—spontaneous generation.

The ancients believed that living things, such as insects and mice, sprang from decaying organic matter or even from mud in situations where they were sometimes seen in large numbers. Careful experiments finally showed that such highly organized creatures were produced only by others like themselves but the discovery of microorganisms again raised the question. In the experiments conducted by Pasteur and other scientists, it was at last proved that thoroughly sterilized materials gave rise to no living things unless they were later contaminated. Modern biology admits the possibility that an exceedingly simple type of living substance may arise from non-living materials but recognizes that living things as we know them are too complex to develop abruptly in this way. Even the origin of simple living substance has not actually been demonstrated.

**ABLATION.** This term is used in geology to denote the wasting away of the surface of **glaciers**, or less commonly, the wasting away of rocks. Ablation deposits are the masses of **detritus** left after surface melting of glacial ice.

**ABNEY EFFECT.** A shift in hue which is the result of a variation in **purity** and, therefore, in **saturation**. The Abney effect may be represented by **chromaticity loci**, of specified **luminance**, with the hue and **brightness** constant, when **purity** and, therefore, **saturation** are varied. It is a relationship, of psychophysical nature, between psychophysical specifications and color sensation attributes.

**ABOHM.** Units and Dimensions.

**ABORAL OR APICAL SYSTEM.** Part of the nervous system of the **echinoderms**. Unlike most nervous tissue it is developed from the middle germ layer.

**ABORT.** This term has two common meanings in medicine:  
1. To check a disease or a condition during its early stages.  
2. To expel the **fetus** before it has become capable of a separate existence, i.e., during the first 28 weeks of pregnancy.

**ABORTION.** The expulsion of the fetus from the **uterus** during the first 28 weeks of **pregnancy**, before it has become capable of separate existence. Abortion may be spontaneous, or induced, and induced abortion may be either therapeutic or criminal. The induction of abortion in the absence of a therapeutic aim is illegal in all Christian countries; the Roman Catholic church forbids it absolutely. Therapeutic abortion is commonly considered necessary for the sake of the mother in severe **toxemia of pregnancy**, in heart disease when failure is likely, when there is possibility of reactivation of quiescent **tuberculosis**, with malignant and other disease of the uterus, and in **insanity**: for the sake of the fetus when the mother

has had rubella in the first three months of pregnancy, or where hemolytic disease appears inevitable. Incomplete abortion implies the expulsion of only a part of the contents of the uterus; in missed abortion the contents separate from their attachments but are not expelled. Expulsion of the fetus after the 28th week but before full term is called **premature labor**.

**ABRASION.** All metallic and non-metallic surfaces, no matter how smooth, consist of minute serrations and ridges which induce a cutting or tearing action when two surfaces in contact move with respect to each other. This wearing of the surfaces is termed abrasion. Undesirable abrasion may occur in bearings and other machine elements, but abrasion is also adapted to surface finishing and machining, where the material is too hard to be cut by other means, or where precision is a primary requisite.

**ABRASIVES.** Substances which are employed to grind, wear off, lap, rub down, polish, etc., the surface of objects in order to give them a different size, shape, or finish are termed abrasives.

Grinding, cutting, drilling, and polishing of various materials are often done with a wheel, sheet, or blast of abrasives harder than the material being treated. In the selection of an abrasive, the size of the individual grains and their specific hardness become important factors which determine the appearance of the finished surface or edge. The selected grains may be bonded to a surface, such as sandpaper or emery paper, or formed into special shapes, especially wheels of various widths and diameters, or spotted on the face of drills as in drilling oil wells. Abrasives may be classified according to their principal applications as follows:

- a. Loose grains and powders mixed with soap.
- b. Coated abrasives—sandpaper, etc.: emery, flint, garnet, fused alumina, or other materials bonded with hide glue or resins to paper, cloth, etc.
- c. Abrasive wheels and endless belts: various natural and manufactured abrasives of different grit sizes cemented to leather-covered wooden wheels or belts and used for polishing, buffing, and lapping.
- d. Sharpening sticks: hones, oilstones, whetstones.
- e. Buhrstones, grindstones, millstones, and pulpstones used for grinding cement, flour, grain, pigments, logs, etc.
- f. Bonded grinding wheels: fine or crushed abrasives such as emery, fused alumina, silicon carbide, and other abrasives screened for size are bonded, using clays, glue, hydraulic cement, magnesium oxychloride, resinoids, rubber, shellac, silicates, or other adhesives, and fired.

The particles of an abrasive should have the following characteristics: (1) suitable hardness as measured by Mohs' scale, (2) suitable toughness, (3) enough resistance to breaking, (4) correct form (generally sharp corners are needed but in some instances a rounded particle is more suitable), (5) proper size, (6) a higher melting point than the material to be ground or worked, and (7) capable of mixing with a fat or other material employed in making an abrasive composition or of being wetted by an adhesive if used.

Many naturally occurring materials are used for this purpose, and for the harder abrasives specially manufactured materials are commonly utilized. The natural abrasives most used are sand, quartz, emery, diatomite, tripoli, pumice, and diamonds.

Sand, sandstone, quartzite and quartz, flint, and garnet are most used in sand-blasting of metals, in sawing-stones, grindstones, pulpstones, whetstones, in the grinding of ores in mills, and as sheets on paper or cloth. Emery and corundum are similarly used, practically all being imported as crude material and processed in this country.

Diatomite is used principally in polishes, but also as filter aid due to its high porosity, and as filler in special cases such as in plastics. It is highly resistant to heat, has low absorptive power for moisture, is chemically inert, has excellent electrical properties, and produces a good surface finish. It is stated that four leading brands of silver polishes contain 15 to 19% of diatomite as the sole abrasive. The principal states producing diatomite are California and Oregon. Tripoli is used for abrasive purposes, as an oil well drilling mud, and also for foundry facing, and for filler in concrete. The production is centered around Newton County, Missouri, and adjacent Ottawa County, Oklahoma, and in Alexander County, southern Illinois. Pumice is used in cleansing and scouring mixtures and in hand soaps, and also for acoustic plaster and as an admixture for concrete.

Diamonds for abrasive purposes come from Brazil—these are called carbonadoes or black diamonds—and from the Union of South Africa—these are called bort. A beryllium-copper alloy is used successfully for cast-setting diamond core bits and reaming shells. These drilling bits are tough, strong, and hard, and the bond between the alloy and the diamonds is very close. Many small stones can be spaced over a comparatively small drill face.

Manufactured or "artificial" abrasives have made possible rapid working of very hard materials. Aluminum oxide glass ("Alundum") and silicon carbide crystals ("Carborundum") have proved outstandingly important. Tungsten carbide has attracted much attention as a very hard abrasive. It is typical of several metallic carbides, nitrides, and borides that have been suggested as abrasives. Some information on this point is contained in the following table:

HARDNESS AND MELTING POINT OF VARIOUS CARBIDES, NITRIDES, AND BORIDES

> Greater than. (For Mohs' Scale Values, see **Hardness**)

METAL	CARBIDES		NITRIDES		BORIDES	
	Hardness (Mohs' value)	Melting Point (°C.)	Hardness (Mohs' value)	Melting Point (°C.)	Hardness (Mohs' value)	Melting Point (°C.)
Chromium .....	>7	1890			8	
Columbium .....		3500	>8		>9	
Molybdenum .....	7-9	2700			>9	
Tantalum .....	>9	3875	>8	3100	>9	
Titanium .....	>8	3150	>8	2950	>9	
Tungsten .....	>9	2850			>9	
Vanadium .....	>9	2830		2050	>9	
Zirconium .....	>8	3530	>8	2980	>9	3000

TABLE OF HARDNESS OF METALS AND OTHER SURFACES, AND OF ABRASIVES COMMONLY EMPLOYED FOR POLISHING, CUTTING DOWN, AND COLOR BUFFING

(For Mohs' Scale Values, see Hardness)

METAL OR SURFACE	HARDNESS MOHS' SCALE	ABRASIVE FOR POLISHING	ABRASIVE FOR CUTTING DOWN	ABRASIVE FOR COLOR BUFFING
Lead .....	1.5			
Tin .....	1.8		Tin Oxide	Crocus Martis
Magnesium .....	2.0			
Cadmium .....	2.0			
Zinc .....	2.5	Aluminum Oxide; Emery	Tripoli	Lime
Bismuth .....	2.5			
Gold .....	2.5		Tripoli	Rouge
Silver .....	2.7		Hard Rouge	Soft Rouge
Aluminum .....	2.9	Aluminum Oxide	Tripoli	Silica
Copper .....	3.0	Emery	Silica	Lime
Arsenic .....	3.5			
Brass .....	3.5	Aluminum Oxide	Tripoli	Silica; Lime
Antimony .....	3.8			
Nickel .....	4.0	Aluminum Oxide; Emery	Tripoli	Lime
Steel .....	4.7	Aluminum Oxide	Emery	Lime
		Crocus Martis		
		Silicon Carbide		
Nickel Silver .....	4.2	Emery	Tripoli	Lime; Rouge
Platinum .....	4.3	Green Rouge		
Iron .....	4.5	Crocus Martis		
Monel Metal .....	4.5	Aluminum Oxide; Emery	Tripoli	Unfused Alumina
Palladium .....	4.8			
Nickel .....	5.0			Sheffield Lime
Cobalt .....	5.5			
Ruthenium .....	6.5			
Iridium .....	6.5			
Silicon (cryst.) .....	7.0			
Osmium .....	7.0			
Stainless Steel .....	7.0	Green Rouge	Unfused Alumina	Chromium Oxide
		Fused Alumina	Emery	
		Silicon Carbide		
Chromium .....	Up to 9.0	Green Rouge	Chromium Oxide	Unfused Alumina
Boron (cryst.) .....	9.5			
Hard Rubber .....			Pumice	Tripoli
Molded Resins .....			Tripoli	Unfused Alumina

Factors influencing the Hardness of Metals in general:

1. Degree of purity, particularly metallic impurities; carbon content in case of steels.
2. Mechanical and thermal pretreatment.
3. Oxide skin.

**ABSAROKITE.** A geologic term proposed by Iddings in 1805 for a porphyritic basalt containing phenocrysts of olivine and augite in a ground mass of smaller labradorite crystals. Type locality, Absaroka Range, Yellowstone Park.

**ABSCCESS.** A localized collection of pus usually formed in response to an infectious agent. *Staphylococci* and *streptococci* are the common bacteria producing abscesses, although any organism may do so.

Abscesses may be single or multiple, primary or metastatic (see *Metastasis*), and may involve any organ or tissue in the body. The wall of an abscess is made up of inflammatory tissue which acts as a barrier to the spread of infection; the abscess cavity contains pus which consists of white blood cells, debris of tissue destruction, and bacteria, living and dead.

The physical signs associated with a superficially situated abscess are those of inflammation, swelling, increased heat, redness and tenderness over the involved area. Treatment in uncomplicated cases is usually surgical incision and drainage at the proper time. *Chemotherapy* is usually necessary.

**ABSCISSION.** This term is applied to the process whereby leaves, leaflets, fruits or other plant parts become detached from the plant. Leaf abscission is a characteristic phenomenon of many species of woody dicots and is especially conspicuous during the autumn period of leaf fall. The onset of abscission seems to be regulated by plant hormones. Three main stages

can be distinguished in the usual process of leaf abscission. The first is the formation of an abscission layer which is typically a transverse zone of parenchymatous cells located at the base of the petiole. The cells of this layer may become differentiated weeks or even months before abscission actually occurs. The second step is the abscission process proper which occurs as a result of a dissolution of the middle lamellae of the cells of the abscission layer. This results in the leaf remaining attached to the stem only by the vascular elements which are soon broken by the pressure of wind or the pull of gravity and the leaf falls from the plant. In the final stage of the process the exposed cells of the leaf scar are rendered impervious to water by lignification and suberization of the walls (see *Lignin*; *Suberin*). Subsequently other layers of corky cells develop beneath the outer layer. These layers eventually become a part of the periderm of the stem. The broken xylem elements of the leaf scar become plugged with gums or tyloses and the phloem elements become compressed and sealed off.

In some kinds of plants an abscission layer is only imperfectly formed and in many others, especially herbaceous species, no abscission layer develops at the base of the petiole. In a few herbaceous species, of which coleus, begonia, and fuchsia are examples, an abscission layer develops. In the majority of herbaceous species, however, and in some woody species, there is no true abscission process. In such herbaceous plants most or all of the leaves are retained until the death of the plant. In the woody plants falling in this category (ex-

ample: shingle oak, *Quercus imbricaria*) the leaves are shed only by mechanical disruption from the plant. Abscission of the fruits of apple and doubtless of many other species occurs in much the same manner as abscission of leaves. The abscission of apple fruits can be artificially retarded by spraying with certain plant regulators.

**ABSOLUTE HUMIDITY.** The mass of water vapor in a specified volume. It can be expressed in any convenient units: ounces per cu. yd., grams per cu. meter. Example: 22 grams per cu. meter. (See **Humidity**.)

**ABSOLUTE MAGNITUDE.** The apparent brightness of a star, or any other luminous object, depends both upon the intrinsic brightness of the object and also upon its distance from the observer. In the case of the stars the apparent brightness, expressed as **stellar magnitude**, may be determined by any one of the standard methods of **stellar photometry**. In case the distance of the star is known the intrinsic brightness may be immediately calculated. Conversely, if we have any method available for determining the intrinsic brightness of a star independently of a knowledge of the distance, this distance may be computed from the ratio between the apparent and intrinsic brightness.

The absolute magnitude of a star is the apparent brightness, expressed on the magnitude scale, that a star would have if it were situated at a distance of ten parsecs from the sun or, in other words, if the stellar parallax of the star were  $\frac{1}{10}$  of a second. Analytically, the absolute magnitude,  $M$ , of a star is connected with the apparent magnitude,  $m$ , and the stellar parallax,  $\pi''$ , by:

$$M = m + 5 + 5 \log \pi''.$$

On this scale we find the sun, with apparent magnitude  $-26.72$  and parallax  $206265''$ , to have an absolute magnitude of  $4.85$ . **Antares** with parallax  $0''.009$  and apparent magnitude  $1.22$  is found to have an absolute magnitude of  $-4.0$ . On the basis of these absolute magnitudes and the defining relation of the magnitude scale, we find the brightness ratio of Antares to the sun to be 3470 or the star Antares is actually 3470 times as bright as the sun.

**ABSOLUTE SPACE-TIME.** A fundamental concept underlying **Newtonian mechanics** is that there exists a preferred reference system to which all measurements should be referred. This is known as absolute space-time. The assumption of such a system is replaced in **relativistic mechanics** by the principle of equivalence. (See **Equivalence**, **Principle of**.)

**ABSOLUTE TEMPERATURE SCALE.** Temperature Scale, Absolute.

**ABSOLUTE UNITS.** Units and Dimensions.

**ABSOLUTE ZERO.** Since permanent gases behave within limitations according to the **Gay-Lussac Law**, which states that the volume of a gas is proportional to its temperature in degrees Celsius (Centigrade) plus  $273.16$ , we should expect its volume at  $-273.16^\circ \text{C}$ , to be zero. Such behavior is not observed for various reasons, one of which is that no gas justifies the name "permanent" at such low temperatures—all gases may be liquefied at temperatures above  $-273.16^\circ \text{C}$ . Nevertheless, the occurrence of this figure in the expression for the expansion of permanent gases suggests that it has a peculiar significance. This suggestion is given weight by the anomalous properties of substances at temperatures approaching  $-273.16^\circ \text{C}$ . (See **super-conductivity**; and entries under **helium**, **liquid**.) Guided by these considerations, as well as many others (e.g., see **thermodynamics**), we are led to regard  $-273.16^\circ \text{C}$ , as the lowest temperature that can be reached, i.e., as the absolute zero of temperature. It is logical, therefore, to use this temperature as the zero of a temperature scale instead of the arbitrarily chosen ice point at  $0^\circ \text{C}$ . Such a scale is the **Kelvin temperature scale**.

**ABSORBANCE.** The common logarithm of the **absorptance**. It may be applied to the total radiation, the visible radiation or to a particular part of the spectrum (**spectral absorbance**).

**ABSORBANCY.** The common logarithm of the reciprocal of the **transmittancy**.

**ABSORBENT COTTON.** Absorbent cotton is prepared from the fibers of the cotton plant. These fibers are treated in such a way as to remove the natural waxy substances and the small amount of mineral matter present. Subsequent washing yields the product known commercially as absorbent cotton, which can absorb as much as eighteen times its own weight of water, and which has many commercial and medical uses.

**ABSORBER.** In general, a medium, substance or functional part that takes up matter or energy. In radiation and particle physics, an absorber is a body of material introduced between a source of radiation and a detector to (1) determine the energy or nature of the radiation; (2) to shield the detector from the radiation; or (3) to transmit selectively one or more components of the radiation, so that the radiation undergoes a change in its energy spectrum. Such an absorber may function through a combination of processes of true absorption, scattering and slowing-down. (See also **Absorption**.)

**ABSORPTANCE.** The ratio of the radiant flux absorbed in a body of material to the radiant flux incident upon it. Commonly, the material is in the form of a parallel-sided plate and the radiation in the form of a parallel beam incident normally on the surface of the plate. Properly, transmission measurements should be corrected for reflection and scattering losses to determine the absorptance. The absorptance may be measured for any radiation, for visible light (**optical absorptance**) or as a function of the wavelength of the radiation (**spectral absorptance**).

**ABSORPTIOMETER.** A device equipped with a simple dispersing system or with filters by which a determination may be made of the concentration of substances by their absorption of nearly monochromatic radiation at a selected wavelength. Note that this is one of the meanings given under **colorimeter**.

**ABSORPTION.** There are at least four common uses of the term absorption in science and engineering. 1. The process whereby the total number of particles emerging from a body of matter is reduced relative to the number entering, as a result of interaction of the particles with the body. 2. The process whereby the kinetic energy of a particle is reduced while traversing a body of matter. This loss of kinetic energy of corpuscular radiation is also referred to as moderation, slowing, or stopping. The absorption of mechanical energy by dynamometers, which convert the mechanical energy to heat or electricity, has led to the use of the term "absorption dynamometers" to distinguish these machines. 3. The process whereby some or all of the energy of sound waves or electromagnetic radiations is transferred to the substance on which they are incident or which they traverse. 4. The process of "attraction into the mass" of one substance by another so that the absorbed substance disappears physically.

This fourth use of the term absorption occurs frequently. In physiology, it denotes the process by which materials enter the living substance of which the organism is composed. Materials including food and oxygen are taken into special organs by ingestion and respiration but they must pass through the cell wall to become an integral part of the organism by absorption. The basic physical forces involved are those of osmosis, under which it is considered, and diffusion. The absorption of gases plays an important part in engineering. It is the frequent cause of **corrosion** by condensate (due to the high content of dissolved oxygen). Gaseous absorption is the basis of the absorption system of refrigeration. In this system a gas (or vapor) is absorbed

in a suitable medium and is then separated by distillation, followed in some cases by liquefaction under pressure. The principles involved in the absorption of gases in liquids are treated in the article on **Solutions and Solubility**, and in the article on **Dissolving**. Vaporized solvents can be recovered from vapor-air mixtures by absorption in liquids. The vapor is brought into close contact with a liquid absorbent at the proper temperature in such a way that the vaporized solvent is extracted as completely as possible from the atmosphere. Such liquid absorption is usually carried out by means of scrubbing towers or spray chambers. Depending upon whether the solvent to be recovered is either water soluble or oil soluble, the liquid absorbent may either be an aqueous solution or water itself, or an oil-dissolving material like mineral oil.

Absorption is particularly important in industrial hygiene and air pollution analyses. In such methods the air to be tested is passed through an absorbing solution, the pollutant reacts with the reagents in the absorbing solution and thus is absorbed from the air stream. The adsorption of materials is a related phenomenon that is treated in the article on **Adsorption**. (See also **Gas Absorption**.)

**ABSORPTION BAND.** A region of the **absorption spectrum** in which the **absorptivity** passes through a maximum or inflection.

**ABSORPTION CELL.** A vessel used to hold substances for the determination of their absorption spectra. (See **Absorption Spectrum**.)

**ABSORPTION COEFFICIENT.** 1. For the absorption of one substance or phase in another, as in the absorption of a gas in a liquid, the absorption coefficient is the volume of gas dissolved by a specified volume of solvent; thus a widely used coefficient is the quantity  $\alpha$  in the expression  $\alpha = V_0/Vp$ , where  $V_0$  is the volume of gas reduced to standard conditions,  $V$  is the volume of liquid and  $p$  is the partial pressure of the gas. 2. In the case of sound, the absorption coefficient (which is also called the acoustical absorptivity) is defined as the fraction of the incident **sound energy** absorbed by a surface or medium, the surface being considered part of an infinite area. 3. In the most general use of the term absorption coefficient, applied to electromagnetic radiation and atomic and sub-atomic particles, it is a measure of the rate of decrease in intensity of a beam of photons or particles in its passage through a particular substance. One complication in the statement of the absorption coefficient arises from the cause of the decrease in intensity. When light, x-rays, or other electromagnetic radiation enters a body of matter, it experiences in general two types of attenuation. Part of it is subjected to **scattering**, being reflected in all directions, while another portion is absorbed by being converted into other forms of energy. The scattered radiation may still be effective in the same ways as the original, but the absorbed portion ceases to exist as radiation or is re-emitted as secondary radiation. Strictly, therefore, we have to distinguish the true absorption coefficient from the **scattering coefficient**; but for practical purposes it is sometimes convenient to add them together as the total attenuation or **extinction coefficient**.

Accurate measurements upon radiation which has traversed various thicknesses of matter has established that any infinitely thin layer perpendicular to the direction of propagation cuts down the flux density by a fraction of its value proportional to the thickness of the layer, whence by integration (when permissible) the flux density after having penetrated the medium to a distance  $x$  is

$$I = I_0 e^{-\alpha x};$$

in which  $I_0$  is the flux density just after entrance into the medium (i.e., for  $x = 0$ ). (See the **Bouguer law**.) For true absorption, the constant  $\alpha$  is the absorption coefficient. For scattering, which obeys the same law,  $\alpha$  is the scattering coefficient. And for the total attenuation, including both,

it is the **extinction coefficient**, which is the sum of the absorption and the scattering coefficients.

The absorption coefficient may be computed for total radiation which enters the absorbing material, for the visible luminous radiation or as a function of wavelength, being in that case, the **spectral absorption coefficient**. The absorption coefficient divided by the density of the absorbing medium is called the mass absorption coefficient.

**ABSORPTION CURVE.** The graphical relationship between thickness of absorbing material and intensity of transmitted radiation.

**ABSORPTION DISCONTINUITY.** A discontinuity appearing in the **absorption coefficient** of a substance for a particular type of radiation when expressed as a function of the energy (or frequency or wavelength) of this radiation. An absorption discontinuity is often associated with anomalies in other variables such as the **refractive index**.

**ABSORPTION EDGE.** The wavelength corresponding to an abrupt discontinuity in the intensity of an **absorption spectrum**, notably an x-ray absorption spectrum, which gives the appearance of a sharp edge in the photograph of such a spectrum.

**ABSORPTION SPECTRUM.** The **spectrum** of radiation which has been filtered through a material medium. When white light traverses a transparent medium, a certain portion of it is absorbed, the amount varying, in general, progressively with the frequency, of which the **absorption coefficient** is a function. Analysis of the transmitted light may, however, reveal that certain frequency ranges are absorbed to a degree out of all proportion to the adjacent regions; that is, with a distinct selectivity. These abnormally absorbed frequencies constitute, collectively, the "absorption spectrum" of the medium, and appear as dark lines or bands in the otherwise continuous spectrum of the transmitted light. The phenomenon is not confined to the visible range, but may be found to extend throughout the spectrum from the far infra-red to the extreme ultra-violet and into the x-ray region.

A study of such spectra shows that the lines or bands therein accurately coincide in frequency with certain lines or bands of the emission spectra of the same substances. This was formerly attributed to **resonance** of electronic vibrations, but is now more satisfactorily explained by **quantum theory** on the assumption that those quanta of the incident radiation which are absorbed are able to excite atoms or molecules of the medium to some (but not all) of the energy levels involved in the production of the complete emission spectrum.

A very familiar example is the spectrum of sunlight, which is crossed by innumerable dark lines—the **Fraunhofer lines**—from which so much has been learned about the constitution of the sun.

A noteworthy characteristic of selective absorption is found in the existence of certain anomalies in the refractive index in the neighborhood of absorption frequencies; discussed under **Dispersion**.

**ABSORPTION TOWER.** **Gas Absorption**.

**ABSORPTIVITY.** **Thermal Radiation**.

**ABSORPTIVITY, OPTICAL.** The **transmissivity** subtracted from unity.

**ABUNDANCE RATIO.** The proportions of the various isotopes making up a particular specimen of an **element**.

**ABUTMENT.** A bridge abutment is the foundation that supports the end of the bridge superstructure and holds the abutting earth in place. Abutments are generally constructed of **reinforced concrete**. The simple abutment consists of a **footing**, a **breast** or cross wall, a bridge seat, a back wall, and

usually companion wing walls. The footing transfers the loads to the supporting soil, consequently the area in contact with the soil must be large enough to insure a safe bearing pressure. The breast wall must be large enough to withstand safely the combined effects of the bridge loads, its own weight and the pressure of the soil back of the abutment. The bridge seat is the surface which supports the end bearings of the bridge. The back wall supports the earth above the bridge seat. The wing walls are usually attached to both ends of the breast wall and are used to retain the side slopes of the fill at the end of the abutment.

#### ABVOLT. Units and Dimensions.

**ABYSSAL FAUNA.** The animals found in the depths of the ocean below 600 fathoms. The abysses are characterized by darkness, low unchanging temperature, great pressure, the presence of ooze, and the absence of plant life due to the lack of light. Grotesque form and the extensive development of light-producing organs are frequent among abyssal animals.

**ABYSSAL ROCKS.** Proposed by Brögger as a general term for deep-seated igneous rocks, or those which have crystallized from magmas far below the surface of the earth, very slowly and under great pressure. Granite is a typical abyssal rock. The term Plutonic is synonymous.

#### A-C. Alternating Currents.

#### A-C CIRCUITS. Alternating Current Circuits.

**ACACIA.** Leguminosae: tribe Mimosae. A very large genus of trees and shrubs, particularly abundant in Africa and Australia. The small flowers are aggregated into ball-like or elongate clusters, which are quite conspicuous. The leaves are rather diverse in shape; quite commonly they are dissected into compound pinnate forms; in other instances, especially in Australia species, they are reduced even to a point where only the flattened petiole (see Leaf), called a phyllode, remains. This petiole grows with the edges vertical, a fact which some have been led to construe as a protective adaptation against too intense sunlight on the surface. Several species, particularly those growing in Africa and tropical Asia, yield products of commercial value. For example, from *Acacia Senegal* gum arabic is obtained; and from *A. Catechu*, a brown or black dye called cutch. Many species are valuable timber trees. Certain tropical American species are of particular interest because of the curious pairs of thorns, which are united at their base. These thorns are often hollowed out and used as nests by species of stinging ants.

#### ACANTHITE. Argentite.

**ACANTHOCEPHALA** (Thorny-headed worms). Worms, slender and hollow (pseudocoelom) with recurved hooks on invaginate proboscis, no digestive tracts, and adults parasitic in intestine of vertebrates with larva in intermediate arthropod host. They are usually regarded as a class of roundworm (Nemathelminthes), but ranking as a separate phylum is now favored.

**ACANTHUS.** Acanthaceae. *Acanthus* is a small genus of Mediterranean plants largely grown for ornamental purposes. The flowers are white or various shades of red. The leaves of these plants are the source of the more or less conventionalized architectural design called the acanthus.

**ACARINA.** The order of Arachnida which includes the mites and ticks.

**ACCELERATED FLIGHT.** When the velocity of an airplane along its flight path contains elements of acceleration, the structure receives increments of inertia loading which may prove to be far more severe upon the structure than the

loading imposed by the static weight of the airplane and its contents. Consequently, accelerated flight has been the subject of extensive analytical and experimental investigation. Acceleration of rectilinear velocity, as by increasing engine power in straight level flight, is of small import, since radial accelerations resulting from curvilinear flight at constant speed are so large as to be the critical influence. Cases of curved flight paths capable of accelerations of several  $g$  (acceleration of gravity, i.e., 32.2 ft. per sec.<sup>2</sup>) are quick pull-ups (or "zooms") from high-speed rectilinear flight, spins, steeply banked turns, loops. The magnitude of the effect of accelerated flight is well illustrated by considering the centrifugal force on an airplane following a curved flight path in the vertical plane. With a constant tangential speed of 120 m.p.h. the airplane will experience a radial acceleration of 4  $g$  (4 times the acceleration of gravity) even though the radius of curvature be about 240 feet. (See Load Factor.)

**ACCELERATING CHAMBER.** Any evacuated envelope in which charged particles are accelerated.

**ACCELERATING TUBE.** An accelerating chamber of general tubular construction, either toroidal as in a betatron or cylindrical with a large length-to-diameter ratio as in an electrostatic accelerator or linear electron accelerator. It may be sealed off or continuously evacuated.

**ACCELERATION.** The rate of change of the velocity with respect to the time is called acceleration. It is expressed mathematically by  $\frac{dv}{dt}$ , the vector derivative of the velocity,  $v$  with respect to the time,  $t$ . If the motion is in a straight line whose position is clearly understood, it is convenient to treat the velocity  $v$  and the acceleration  $\frac{dv}{dt}$  as scalars with appropriate algebraic signs; otherwise they must be treated by vector methods.

Acceleration may be rectilinear or curvilinear, depending upon whether the path of motion is a straight line or a curved line. A body which moves along a curved path has acceleration components at every point. One component is in the direction of the tangent to the curve and is equal to the rate of change of the speed at the point. For uniform circular motion this component is zero. The second component is normal to the tangent and is equal to the square of the tangential speed divided by the radius of curvature at the point. This normal component which is directed toward the center of curvature also equals the square of the angular velocity multiplied by the radius of curvature. The acceleration due to gravity is equal to an increase in the velocity of about 32.2 ft. per sec. per sec. at the earth's surface and is of prime importance since it is the ratio of the weight to the mass of a body. For examples of acceleration in both curved and linear motion, see Kinematics.

#### ACCELERATION OF GRAVITY. Gravitation and Gravity.

#### ACCELERATORS, RUBBER. Rubber and Accelerators.

**ACCELEROMETER.** The accelerometer is an instrument for determining the acceleration of the system with which it moves. Work in accelerometry is becoming increasingly important as means of transport continue to provide higher motive speeds for the use of mankind. The principal instrument in this field of work is the accelerometer. It has been used in airplane work to study the stresses that the airplane structure undergoes, and to determine how long these stresses last. The records can also be used to study pilots' ability, especially in landings and acrobatic maneuvers. Other uses for this instrument are the study of the oscillations of automobile springs, the pickup and braking power of automobiles, the side load on tires or rails when rounding curves, and study of vibrations of various sorts. The accelerometer should have



a natural period of vibration which is considerably higher than that of any shocks it may experience. In addition, it should give a graphic, easily interpreted record, and it should be rugged, strong, and accurate. Not all these characteristics can be met by one design, and accelerometers suitable for measuring the accelerations produced in certain flight maneuvers are unsatisfactory for measuring landing shock accelerations. One style of the accelerometer is the seismograph type. Unfortunately, this instrument records displacements against an axis of time sequence, and accelerations are not read directly. The slope of the displaced curve is the rate of change of displacement with time; in other words, the velocity. If the velocity is determined and plotted, a similar measurement of slope gives the rate of change of velocity with time, and this is the acceleration. Thus the record of a seismograph type of accelerometer must be differentiated twice in order to obtain accelerations, for:

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt}$$

$$\text{Hence: } a = \frac{d^2s}{dt^2}$$

While this type of instrument has its certain uses, it has been superseded for most accelerometry work by more practical designs.

The term accelerometer is also applied to a **transducer** which gives an indication, usually in the form of a proportional voltage, of the acceleration to which it is subjected.

#### ACCEPTOR ELEMENTS. Transistor.

**ACCEPTOR ENERGY LEVEL.** An acceptor impurity atom in a crystal is equivalent to an excess negative charge, since its atomic core is insufficiently charged to neutralize its share of the covalent bonding electrons. Consequently, it can attract a positive charge, such as a hole in the electron distribution, forming bound states which lie just above the top of the valence band. The promotion of an electron to one of these levels frees a hole for conduction, as in a p-type semiconductor. (See Semiconductor; Transistor.)

**ACCEPTOR IMPURITY.** An impurity, in a semiconductor, which may induce hole conduction. Such an impurity is capable of accepting an electron from the valence band, forming an acceptor energy level.

**ACCESS TIME.** 1. The time interval, characteristic of a memory or storage device (see Computer), between the instant at which information is requested of the memory and the instant at which this information begins to be available in useful form. 2. The time interval between the instant at which information is available for storage and the instant at which it is effectively stored.

**ACCESSORY NIDAMENTAL GLAND.** A gland of the female reproductive system in the squids and allied species.

**ACCOMMODATION.** The mechanism whereby the equatorial diameter of the lens of the eye may be decreased and its thickness increased to focus clearly on the retina the image of a near object.

**ACCOMMODATION COEFFICIENT.** A quantity defined by the equation:

$$a = \frac{T_2 - T_1}{T_2 - T_3}$$

where  $T_1$  is the temperature of gas molecules striking a surface which is at temperature  $T_2$ , and  $T_3$  is the temperature of the gas molecules as they leave the surface,  $a$  is the accom-

modation coefficient. It is, therefore, a measure of the extent to which the gas molecules leaving the surface are in thermal equilibrium with it.

#### ACCOUCHEMENT. Childbirth.

**ACCOUCHEUR.** An obstetrician or midwife.

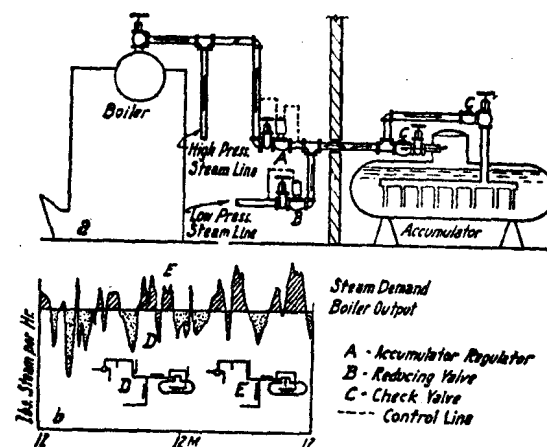
**ACCRETION.** Term in mineralogy and geology defining the process by which inorganic bodies grow larger by the addition of material onto the external surface.

**ACCUMULATOR, HYDRAULIC.** The hydraulic accumulator is a hydraulic device consisting of a cylinder and piston which is actuated by weight, springs, or compressed fluid. On the opposite side of the piston a fluid such as water, oil, air, etc., is stored, and consequently, is available to do work when the pressure on it is reduced. This work is obtained by virtue of the fact that while the fluid is discharged rapidly, giving large hydraulic power for short periods of time, it may be refilled by a comparatively small and low-powered pump working a much longer period of time.

One successful type of accumulator consists of a closed cylinder containing a rubber bag filled with air or gas. Fluid is pumped into the cylinder under pressure, compressing the air or gas in the bag. When the release valve is opened the air or gas in the bag expands to eject the fluid from the cylinder.

Another type of hydraulic accumulator is the pumped storage plant, now being looked on with considerable favor by electric power systems for the economic carrying of variable load. As employed in conjunction with steam generating stations, steam turbine-driven centrifugal pumps raise water from a lower to an upper pool with off-peak power. During the peak-load periods this water is released to the lower pool through a hydraulic turbo-generator as rapidly as is needed to give the required power. The hydraulic storage of power of this nature is essentially a high head development, low head equipment and hydraulic losses being too expensive. In favorable locations the over-all efficiency of conversion and storage may not need to be greater than 50% in order to justify the project.

**ACCUMULATOR, STEAM.** The steam accumulator is an effective means for smoothing out irregular steam demand into a uniform boiler output. Its operation is based upon the fact that the heat contained in water in a liquid form



The Ruths steam accumulator.

varies with the pressure of the water. Thus in a tank of water under pressure with the water at the saturation temperature, a decrease of pressure on the tank will be accompanied by a release of some of the heat energy held by the water, and a consequent flashing of a portion of the water into steam. This process can be continued with the produc-

tion of steam at ever-decreasing pressures until the lower pressure limit is reached. Since the heat required to evaporate a pound of water is much more than the heat of the liquid at the commonly used pressures, only 20-40% of the weight of water in a charged accumulator tank can be converted into steam.

An accumulator installation is shown by the diagram on facing page (page 8). The irregular steam demand is assumed to be that of an industrial process using considerable quantities of low-pressure steam, while the desired boiler output is shown as the straight line. The accumulator must absorb steam during the valleys which occur below the steady boiler output line and supply steam during the peaks. The direction of steam flow when charging the accumulator is shown at *D*, while at *E* is the flow diagram for accumulator discharging.

**AC-DC RECEIVERS.** These are radio receivers designed without transformers in the power supply so they may be connected to either alternating-current or direct-current circuits. The heaters or filaments of the various tubes are connected in series with the proper series or parallel resistors to adjust the current to the correct value. The d-c voltage for the plates is obtained from a rectifier-filter circuit connected directly to the line. A simple half-wave vacuum tube type is shown. Metallic rectifiers such as those using germa-

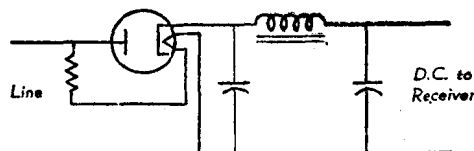


Plate supply of a-c-d-c receiver.

nium, selenium, or silicon are often used as well. Such supplies prevent the use of a direct ground to the receiver chassis since the 120-volt line has one side grounded and there is always the possibility of connecting the receiver plug so it would short the line if the receiver were grounded.

**ACERDISE.** See boehmite under **Lepidocrocite**.

**ACETAL(S).** Organic compounds of the general formula  $RCH(OR')(OR'')$ . They are formed by the reaction of aldehydes with alcohols in the presence of small amounts of acids or certain inorganic salts. They are stable toward alkali, are volatile and insoluble in water but are decomposed into aldehyde by the action of acids. The last reaction is often used as a source of aldehydes.

**ACETALDEHYDE.** Acetaldehyde ( $CH_3 \cdot CHO$ ) is a colorless, odorous liquid, boiling point  $20^\circ C$ ., miscible with water, alcohol, or ether in all proportions. Acetaldehyde reacts with many chemicals in a marked manner, (1) with ammonio-silver nitrate ("Tollen's solution"), to form metallic silver, either as a black precipitate or as an adherent mirror film on glass, (2) with alkaline cupric solution ("Fehling's solution") to form cuprous oxide, red to yellow precipitate, (3) with rosaniline (fuchsine, magenta), which has been decolorized by sulfurous acid ("Schiff's solution"), the pink color of rosaniline is restored, (4) with sodium hydroxide, upon warming, a yellow to brown resin of unpleasant odor separates (this reaction is given by aldehydes immediately following acetaldehyde in the series, but not by formaldehyde, furfuraldehyde or benzaldehyde), (5) with anhydrous ammonia, to form aldehyde-ammonia ( $CH_3 \cdot CHO \cdot NH_2$ ), white solid, melting point  $97^\circ C$ ., boiling point  $111^\circ C$ ., with decomposition, (6) with concentrated sulfuric acid, heat is evolved, and with rise of temperature, paraldehyde ( $(C_2H_4O)_3$  or



colorless liquid, boiling point  $124^\circ C$ ., slightly soluble in water, is formed, (7) with acids, below  $0^\circ C$ ., forms metaldehyde

( $C_2H_4O$ )<sub>x</sub>, white solid, sublimates at about  $115^\circ C$ . without melting but with partial conversion to acetaldehyde, (8) with dilute hydrochloric acid or dilute sodium hydroxide, aldol ( $CH_3 \cdot CHOH \cdot CH_2 \cdot CHO$ ) slowly forms, (9) with phosphorus pentachloride, forms ethylidene chloride ( $CH_3 \cdot CHCl_2$ ), colorless liquid, boiling point  $58^\circ C$ ., (10) with ethyl alcohol and dry hydrogen chloride, forms acetal, 1,1-diethoxyethane ( $CH_3 \cdot CH(OC_2H_5)_2$ ), colorless liquid, boiling point  $104^\circ C$ ., (11) with hydrocyanic acid, forms acetaldehyde cyanhydrin ( $CH_3 \cdot CHOH \cdot CN$ ), readily converted into alpha-hydroxypropionic acid ( $CH_3 \cdot CHOH \cdot COOH$ ), (12) with sodium hydrogen sulfite, forms acetaldehyde sodium bisulfite ( $CH_3 \cdot CHOH \cdot SO_3Na$ ), white solid, from which acetaldehyde is readily recoverable by treatment with sodium carbonate solution, (13) with hydroxylamine hydrochloride forms acetaldoxime ( $CH_3 \cdot CH : NOH$ ), white solid, melting point  $47^\circ C$ ., (14) with phenylhydrazine, forms acetaldehyde phenylhydrazone ( $CH_3 \cdot CH : N \cdot NH \cdot C_6H_5$ ), white solid, melting point  $98^\circ C$ ., (15) with magnesium methyl iodide in anhydrous ether ("Grignard's solution"), yields, after reaction with water, isopropyl alcohol ( $(CH_3)_2CHOH$ ), a secondary alcohol, (16) with semicarbazide, forms acetaldehyde semicarbazone ( $CH_3 \cdot CH : N \cdot NH \cdot CO \cdot NH_2$ ), white solid, melting point  $162^\circ C$ ., (17) with chlorine, forms trichloroacetaldehyde ("chloral") ( $CCl_3 \cdot CHO$ ), (18) with hydrogen sulfide, forms thio-acetaldehyde ( $CH_3 \cdot CHS$  or  $(CH_3 \cdot CHS)_3$ ). Acetaldehyde stands chemically between ethyl alcohol on one hand—to which it can be reduced—and acetic acid on the other hand—to which it can be oxidized. These reactions of acetaldehyde, coupled with its ready formation from acetylene by mercuric sulfate solution as a catalyzer, open up a vast field of organic chemistry with acetaldehyde as raw material: acetaldehyde hydrogenated to ethyl alcohol; oxygenated to acetic acid, thence to acetone, acetic anhydride, vinyl acetate, vinyl alcohol. Acetaldehyde is also formed by the regulated oxidation of ethyl alcohol by such a reagent as sodium dichromate in sulfuric acid (chromic sulfate also produced). Reactions (1), (3), (14) and (16) above are most commonly used in the detection of acetaldehyde. (See **Aldehyde(s)**.)

**ACETANILIDE.** Aniline.

**ACETIC ACID AND ACETATES.** Acetic acid ( $H \cdot C_2H_3O_2$  or  $CH_3 \cdot COOH$ ) is a colorless liquid, melting point  $16.6^\circ C$ ., boiling point  $118^\circ C$ ., miscible with water, alcohol, or ether in all proportions. Acetic acid solution reacts with alkalis to form acetates, e.g., sodium acetate, calcium acetate; similarly, with some oxides, e.g., lead acetate; with carbonates, e.g., sodium acetate, calcium acetate, magnesium acetate; with some sulfides, e.g., zinc acetate, manganese acetate. Ferric acetate solution, upon boiling, yields red precipitate of basic ferric acetate. Acetic acid solution attacks many metals, liberating hydrogen and forming acetate, e.g., magnesium, zinc, iron. Acetic acid is an important organic substance, with alcohols forming esters (acetates); with phosphorus trichloride forming acetyl chloride ( $CH_3 \cdot CO \cdot Cl$ ), which is an important reagent for transfer of the acetyl ( $CH_3CO-$ ) group; forming acetic anhydride, also an acetyl reagent; forming acetone and calcium carbonate when passed over lime and a catalyzer (barium carbonate) or when calcium acetate is heated; forming methane (and sodium carbonate) when sodium acetate is heated with sodium hydroxide; forming mono-, di-, trichloroacetic (or bromoacetic) acids by reaction with chlorine (or bromine) from which hydroxy- and amino-, aldehydic, dibasic acids, respectively, may be made; forming acetamide when ammonium acetate is distilled. Acetic acid dissolves sulfur and phosphorus, is an important solvent for organic substances, and causes painful wounds when it comes in contact with the skin. Normal acetates are soluble, basic acetates insoluble. The latter are important in their compounds with lead, copper ("verdigris"). Acetic acid is made (1) by destructive distillation of wood. Dilute acid is obtained in the aqueous distillate, recovered by neutralization with calcium hydroxide, and then evaporation and recovery of calcium



acetate; (2) from calcium or sodium acetate, acetic acid of high strength is made by distillation with concentrated **sulfuric acid**; (3) by the action of bacteria on dilute ethyl alcohol, containing the proper food materials for the bacteria, dilute acetic acid (vinegar) is produced. The vinegar contains, besides acetic acid and water, the materials characteristic of the alcohol and the process used; (4) by the reaction of acetaldehyde and air over a suitable catalyzer. Acetic acid is used as has been suggested by its reactions, (1) in the preparation of many organic substances, notably, **cellulose acetate**, as a non-inflammable photographic film and also as a textile fiber; (2) in the preparation of many acetates and basic acetates and carbonates (white lead in conjunction with carbon dioxide); (3) as a weak, moderately cheap acid; (4) as a solvent when concentrated for organic chemicals; (5) in pharmaceutical preparations, dyeing, rubber, artificial leather.

Esters (acetates of various alcohols) of note are:

Methyl acetate ( $\text{CH}_3\text{COOCH}_3$ ), boiling point  $57^\circ\text{C}$ .  
Ethyl acetate ( $\text{CH}_3\text{COOC}_2\text{H}_5$ ), boiling point  $77^\circ\text{C}$ .  
Propyl acetate ( $\text{CH}_3\text{COOC}_3\text{H}_7$ ), boiling point  $102^\circ\text{C}$ .  
Butyl acetate ( $\text{CH}_3\text{COOC}_4\text{H}_9$ ), boiling point  $125^\circ\text{C}$ .  
Amyl acetate ( $\text{CH}_3\text{COOC}_5\text{H}_{11}$ ), boiling point  $149^\circ\text{C}$ .  
Glycol monoacetate ( $\text{CH}_3\text{COOCH}_2\cdot\text{CH}_2\text{OH}$ ), boiling point  $182^\circ\text{C}$ .

Glycol diacetate ( $\text{CH}_3\text{COOCH}_2\cdot\text{CH}_2\text{COOCH}_3$ ), boiling point  $190^\circ\text{C}$ .

Glyceryl monoacetate (monoacetin) ( $\text{CH}_2\text{OH}\cdot\text{CHOH}\cdot\text{CH}_2\text{OOCCH}_3$ ) decomposes upon heating.

Glyceryl diacetate (diacetin) ( $\text{CH}_2\text{OH}\cdot\text{CHOOCCH}_3\cdot\text{CH}_2\text{OOCCH}_3$ ), melting point  $40^\circ\text{C}$ , boiling point  $176^\circ\text{C}$ . at 40 mm. pressure.

Glyceryl triacetate (triacetin) ( $\text{CH}_3\text{OOCCH}_3\cdot\text{CHOOCCH}_3\cdot\text{CH}_2\text{OOCCH}_3$ ), melting point  $-78^\circ\text{C}$ , boiling point  $259^\circ\text{C}$ .

Glucose pentacetate ( $\text{C}_6\text{H}_8(\text{OH})(\text{COOCH}_3)_5$ ), melting point  $113^\circ\text{C}$ , sublimes.

Cellulose triacetate ( $\text{C}_6\text{H}_5(\text{OH})_2(\text{COOCH}_3)_3$ ).

Cellulose tetracetate ( $\text{C}_6\text{H}_5(\text{OH})(\text{COOCH}_3)_4$ ), softens at about  $150^\circ\text{C}$ .

Cellulose pentacetate ( $\text{C}_6\text{H}_5(\text{COOCH}_3)_5$ ).

Cetyl acetate ( $\text{CH}_3\text{COOC}_{16}\text{H}_{33}$ ), melting point  $22^\circ\text{C}$ , boiling point  $200^\circ\text{C}$ . at 15 mm. pressure.

Phenyl acetate ( $\text{CH}_3\text{COOC}_6\text{H}_5$ ), boiling point  $195^\circ\text{C}$ .

Acetates may be detected by formation of foul-smelling cacodyl (poisonous) on heating with dry arsenic trioxide. Other tests for acetate are the lanthanum nitrate test in which a blue or bluish-brown ring forms when a drop of 2.5%  $\text{La}(\text{NO}_3)_3$  solution, a drop of 0.01 N iodine solution, and a drop of 0.1% ammonium hydroxide solution are added to a drop of a neutral acetate solution; the ferric chloride test in which a reddish color is produced by the addition of 1 N ferric chloride solution to a neutral solution of acetate; and the ethyl acetate test in which ethyl alcohol and sulfuric acid are added to the acetate solution and warmed to form the odorous compound.

**ACETOACETIC ACID ESTER.** This is an important organic liquid of the formula  $\text{CH}_3(\text{CO})\text{CH}_2\cdot\text{COOC}_2\text{H}_5$ , which is used as a starting point for the synthesis of **ketones** of the type  $\text{CH}_3(\text{CO})\text{CHR}'\text{R}''$  and acids of the type  $\text{R}'\text{R}''\text{CHCOOH}$  where  $\text{R}'$  and  $\text{R}''$  are hydrocarbon radicals. The ethyl ester of acetoacetic acid is made by treating ethyl acetate (see **Esters**) with sodium.

**ACETONE.** Acetone ( $\text{CH}_3\cdot\text{CO}\cdot\text{CH}_3$ ) is a colorless, odorous liquid, boiling point  $56^\circ\text{C}$ , miscible in all proportions with water, alcohol, or ether. Acetone reacts with many chemicals in a marked manner, (1) with **phosphorus pentachloride**, yields acetone chloride ( $(\text{CH}_3)_2\text{CCl}_2$ ), (2) with **hydrogen chloride** dry, yields both mesityl oxide ( $\text{CH}_3\text{COCH}:\text{C}(\text{CH}_3)_2$ ), liquid, boiling point  $132^\circ\text{C}$ , and phorone ( $(\text{CH}_3)_2\text{C}:\text{CHCOCH}:\text{C}(\text{CH}_3)_2$ ), yellow solid, melting point  $28^\circ\text{C}$ , (3) with concentrated **sulfuric acid**, yields mesitylene ( $\text{C}_6\text{H}_3(\text{CH}_3)_3$ ) (1,3,5), (4) with **ammonia**, yields acetone amines, e.g., dia-

etoneamine ( $\text{C}_6\text{H}_{12}\text{ONH}$ ), (5) with **hydrogen cyanide**, yields acetone cyanhydrin ( $(\text{CH}_3)_2\text{CHOH}\cdot\text{CN}$ ), readily converted into alpha-hydroxy acid ( $(\text{CH}_3)_2\text{CHOH}\cdot\text{COOH}$ ), (6) with sodium hydrogen sulfite, forms acetone sodium bisulfite ( $(\text{CH}_3)_2\text{COH}\cdot\text{SO}_3\text{Na}$ ), white solid, from which acetone is readily recoverable by treatment with sodium carbonate solution, (7) with **hydroxylamine hydrochloride**, forms acetoxime ( $(\text{CH}_3)_2\text{C}:\text{NOH}$ ), solid, melting point  $60^\circ\text{C}$ , (8) with **phenylhydrazine**, yields acetonephenylhydrazone ( $(\text{CH}_3)_2\text{C}:\text{NNHC}_6\text{H}_5\cdot\text{H}_2\text{O}$ ), solid melting point  $16^\circ\text{C}$ , anhydrous compound, melting point  $42^\circ\text{C}$ , (9) with **semicarbazide**, forms acetonesemicarbazone ( $(\text{CH}_3)_2\text{C}:\text{NNHCONH}_2$ ), solid, melting point  $189^\circ\text{C}$ , (10) with **magnesium methyl iodide** in anhydrous ether ("**Grignard's solution**"), yields, after reaction with water, trimethylcarbinol ( $(\text{CH}_3)_3\text{COH}$ ), a tertiary alcohol, (11) with ethyl thioalcohol and hydrogen chloride dry, yields mercaptol ( $(\text{CH}_3)_2\text{C}(\text{SC}_2\text{H}_5)_2$ ), (12) with **hypochlorite**, **hypobromite**, or **hypoiodite** solution, yields chloroform ( $\text{CHCl}_3$ ), bromoform ( $\text{CHBr}_3$ ) or iodoform ( $\text{CHI}_3$ ), respectively, (13) with most reducing agents, forms isopropyl alcohol ( $(\text{CH}_3)_2\text{CHOH}$ ), a secondary alcohol, but with **sodium amalgam** forms pinacone ( $(\text{CH}_3)_2\text{COH}\cdot\text{COH}(\text{CH}_3)_2$ ), (14) with **sodium dichromate** and sulfuric acid, forms **acetic acid** ( $\text{CH}_3\text{COOH}$ ) plus **carbon dioxide** ( $\text{CO}_2$ ). When acetone vapor is passed through a tube at a dull red heat, **ketene** ( $\text{CH}_2:\text{CO}$ ) and **methane** ( $\text{CH}_4$ ) are formed. Acetone is made (1) by heating calcium acetate at  $400^\circ\text{C}$ , calcium carbonate being simultaneously formed, (2) by passing **acetic acid** vapor over a heated catalyzer, e.g., **barium carbonate**, **manganese carbonate**, (3) by fermentation of **starch** by specific bacteria, normal-butyl alcohol being simultaneously produced, (4) in the **water condensate** (approximately 0.5% acetone) in the destructive distillation of wood, and, (5) in the urine of persons having **diabetes**. Acetone may be detected by the addition of acetic acid and sodium nitroprusside (trace). The appearance of a violet color in the interface between this solution and a layer of ammonium hydroxide indicates acetone. Acetone is used (1) as a solvent, e.g., for **acetylene**, (2) as a solvent for **cellulose** and **glyceryl esters** in the manufacture of celluloid, smokeless powders, airplane dopes, varnishes, (3) in the preparation of **chloroform**, **iodoform**, **sulfonal**.

**ACETOPHENONE.** Aldehydes, Ketones and Related Compounds.

**ACETYL CHLORIDE.** Chlorine.

**ACETYLENE.** Acetylene, ethyne ( $\text{C}_2\text{H}_2$  or  $\text{CH}:\text{CH}$ ) is a colorless gas, of characteristic odor, moderately poisonous, boiling point  $-84^\circ\text{C}$ , density, 1.17 grams per liter at  $0^\circ\text{C}$ . and 760 mm. (specific gravity 0.91, air equal to 1.00), slightly soluble in water or alcohol, very soluble in acetone (300 volumes of acetylene in 1 volume acetone at 12 atmospheres pressure), burns when ignited in air with a luminous sooty flame, requiring a specially devised burner for illumination purposes, forms an explosive mixture with air over a wide range (about 3% to 80% acetylene), explosive when compressed to 2 or more atmospheres, but safe when dissolved in acetone, of high fuel value (1455 B.T.U. per cubic foot). Acetylene reacts (1) with **chlorine**, to form acetylene tetrachloride ( $\text{C}_2\text{H}_2\text{Cl}_4$  or  $\text{CHCl}_2\cdot\text{CHCl}_2$ ) or acetylene dichloride ( $\text{C}_2\text{H}_2\text{Cl}_2$  or  $\text{CHCl}:\text{CHCl}$ ), (2) with **bromine**, to form acetylene tetrabromide ( $\text{C}_2\text{H}_2\text{Br}_4$  or  $\text{CHBr}_2\cdot\text{CHBr}_2$ ) or acetylene dibromide ( $\text{C}_2\text{H}_2\text{Br}_2$  or  $\text{CHBr}:\text{CHBr}$ ), (3) with **hydrogen chloride** (bromide, iodide), to form ethylene monochloride ( $\text{C}_2\text{H}_3\text{Cl}$ ) (monobromide, monoiodide), and 1,1-dichloroethane, ethylidene chloride ( $\text{CH}_3\cdot\text{CHCl}_2$ ) (dibromide, diiodide), (4) with water in the presence of a **catalyzer**, e.g., mercuric sulfate, to form **acetaldehyde** ( $\text{CH}_3\cdot\text{CHO}$ ), (5) with **hydrogen**, in the presence of a catalyzer, e.g., finely divided nickel heated, to form **ethylene** ( $\text{C}_2\text{H}_4$ ) or **ethane** ( $\text{C}_2\text{H}_6$ ), (6) with metals, such as copper or nickel, when moist, also lead or zinc, when moist and unpurified. Tin is