

moisture helps to keep abscisic acid at relatively low levels, and high soil nitrogen leads to high levels of auxin in the plant. Auxin-type chemical regulators are frequently used to retard abscission. Acceleration of abscission can be obtained by low soil nitrogen (leading to low auxin), by moisture stress (leading to high abscisic acid), by ethylene-releasing chemicals, or by mildly toxic chemicals.

To delay abscission of leaves, fruits, and other plant parts, the auxin-type regulator, naphthaleneacetic acid, or related compounds are commonly used. Some notable applications are the spraying of apple orchards and pear orchards to prevent abscission of nearly mature fruit and the dipping of cut holly to prevent abscission of berries and leaves during shipment.

To accelerate abscission a variety of chemicals find use in one or another practice. Cotton is chemically defoliated to facilitate mechanical harvest. To promote leaf abscission, chemicals such as magnesium chlorate, tributylphosphorotrithioate, and merphos have been widely used. In some regions, young nursery plants are defoliated to facilitate earlier digging and shipping. Certain varieties of apples, peaches, and similar fruits must be thinned to ensure that the remaining fruit can reach marketable size. Naphthaleneacetamide and related compounds are the most frequently used to thin fruit. Although these chemicals are of the auxin type, the dosages applied to the flowers and young fruit are somewhat toxic and lead to abortion and abscission of a portion of the young fruit. The slightly toxic insecticide carbaryl is also used in fruit thinning. Efficient harvesting of mature fruit often depends on some chemical promotion of abscission. Ethaphon and other compounds that can release ethylene are often used, although they sometimes show undesirable side effects of subsequent growth. For the harvesting of oranges in Florida, various combinations of cycloheximide, 5-chloro-3-methyl-4-nitro-1*H*-pyrazole, and chlorothalonil have been very effective in promoting abscission. See PLANT PHYSIOLOGY.

Fredrick T. Addicott

**Bibliography.** F. T. Addicott, *Abscission*, 1988; L. G. Nickell, *Plant Growth Regulators*, 1982.

## Absolute zero

The temperature at which an ideal gas would exert no pressure. The Kelvin scale of temperatures is defined in terms of the triple point of water,  $T_3 = 273.16^\circ$  (where the solid, liquid, and vapor phases coexist) and absolute zero. Thus, the Kelvin degree is  $1/273.16$  of the thermodynamic temperature of the triple point. Temperature is measured most simply via the constant-volume ideal-gas thermometer, in which a small amount of gas is introduced (in order to limit the effect of interactions between molecules) and then sealed off. The gas pressure  $P$  referenced to its value at

the triple point  $P(T_3)$  is measured, and temperature  $T$  may be inferred from Eq. (1). The ideal-

$$T(K) = 273.16 \lim_{P \rightarrow 0} \frac{P(T)}{P(T_3)} \quad (1)$$

gas law applies if the molecules in a gas exert no forces on one another and if they are not attracted to the walls. With helium gas, the constant-volume gas thermometer can be used down to a temperature on the order of 1 K. Absolute zero is the temperature at which the pressure of a truly ideal gas would vanish. See GAS THERMOMETER; TEMPERATURE MEASUREMENT.

In order that a temperature be assigned to a particular specimen, there must exist mechanisms for the free transfer of energy within the system. Measurement of the distribution of speeds of particles can serve to define the temperature through the Maxwell distribution. The most probable speed gets smaller as the temperature decreases. According to classical physics, all motion would cease at absolute zero; however, the quantum-mechanical uncertainty principle requires that there be a small amount of residual motion (zero-point motion) even at absolute zero. See KINETIC THEORY OF MATTER; QUANTUM MECHANICS; UNCERTAINTY PRINCIPLE.

The Kelvin scale can be obtained by measurements of the efficiency of an ideal heat engine operating between reservoirs at two fixed temperatures. According to the second law of thermodynamics, the maximum possible efficiency  $\epsilon$  is given by Eq. (2), where  $T_1$  and  $T_2$  are the tem-

$$\epsilon = 1 - \frac{T_1}{T_2} \quad (2)$$

peratures of the low- and the high-temperature reservoirs respectively. All comparisons between the gas-thermometer scales and the thermodynamic scales have shown the equivalence of the two approaches. See CARNOT CYCLE; THERMODYNAMIC PRINCIPLES.

Temperature can also be defined from the Boltzmann distribution. If a collection of spin  $1/2$  magnetic ions is placed in a magnetic field, the ratio of the occupancy of the lower to the higher energy state is given by Eq. (3). Here  $k$

$$\frac{N_L}{N_H} = \exp \frac{|\Delta E|}{kT} \quad (3)$$

is Boltzmann's constant,  $|\Delta E|$  is the magnitude of the difference in energy between the states, and  $T$  is the Kelvin temperature. Thus, at high temperatures the two states have nearly equal occupation probability, while the lower energy state is progressively favored at lower temperatures. At absolute zero, only the lower energy level is occupied. By measuring the populations of the two states, the temperature of the spins can be inferred. This relation allows for the possibility of negative temperatures when the population of the higher energy state exceeds that of the lower state.

From the point of view of energy content, negative temperatures correspond to an energy of the spin system that exceeds that of an infinite positive temperature, and thus they are hotter than ordinary temperatures. *See* BOLTZMANN CONSTANT; BOLTZMANN STATISTICS; NEGATIVE TEMPERATURE.

Negative temperatures notwithstanding, the third law of thermodynamics states that the absolute zero of temperature cannot be attained by any finite number of steps. The lowest (and hottest) temperatures that have been achieved are on the order of a picokelvin ( $10^{-12}$ K). These are spin temperatures of nuclei which are out of equilibrium with the lattice vibrations and electrons of a solid. The lowest temperatures to which the electrons have been cooled are on the order of 10 microkelvins in metallic systems. *See* LOW-TEMPERATURE PHYSICS; TEMPERATURE. Jeevak M. Parpia; David M. Lee

## Absorption

Either the taking up of matter in bulk by other matter, as in the dissolving of a gas by a liquid; or the taking up of energy from radiation by the medium through which the radiation is passing. In the first case, an absorption coefficient is defined as the amount of gas dissolved at standard conditions by a unit volume of the solvent. Absorption in this sense is a volume effect: The absorbed substance permeates the whole of the absorber. In absorption of the second type, attenuation is produced which in many cases follows Lambert's law and adds to the effects of scattering if the latter is present. *See* ATTENUATION; SCATTERING OF ELECTROMAGNETIC RADIATION.

**Energy.** Absorption of electromagnetic radiation can occur in several ways. For example, microwaves in a waveguide lose energy to the walls of the guide. For nonperfect conductors, the wave penetrates the guide surface, and energy in the wave is transferred to the atoms of the guide. Light is absorbed by atoms of the medium through which it passes, and in some cases this absorption is quite distinctive. Selected frequencies from a heterochromatic source are strongly absorbed, as in the absorption spectrum of the Sun. Electromagnetic radiation can be absorbed by the photoelectric effect, where the light quantum is absorbed and an electron of the absorbing atom is ejected, and also by Compton scattering. Electron-positron pairs may be created by the absorption of a photon of sufficiently high energy. Photons can be absorbed by photoproduction of nuclear and subnuclear particles, analogous to the photoelectric effect. *See* ABSORPTION OF ELECTROMAGNETIC RADIATION; COMPTON EFFECT; ELECTRON-POSITRON PAIR PRODUCTION; PHOTOEMISSION.

Sound waves are absorbed at suitable frequencies by particles suspended in the air (wavelength of the order of the particle size), where the sound energy is transformed into vibrational energy of the

absorbing particles. *See* SOUND ABSORPTION.

Absorption of energy from a beam of particles can occur by the ionization process, where an electron in the medium through which the beam passes is removed by the beam particles. The finite range of protons and alpha particles in matter is a result of this process. In the case of low-energy electrons, scattering is as important as ionization, so that range is a less well-defined concept. Particles themselves may be absorbed from a beam. For example, in a nuclear reaction an incident particle *X* is absorbed into nucleus *Y*, and the result may be that another particle *Z*, or a photon, or particle *X* with changed energy comes out. Low-energy positrons are quickly absorbed by annihilating with electrons in matter to yield two gamma rays. *See* NUCLEAR REACTION. McAllister H. Hull, Jr.

**Matter.** The absorption of matter is a chemical engineering unit operation. In the chemical process industries and in related areas such as petroleum refining and fuels purification, absorption usually means gas absorption. This is a unit operation in which a gas (or vapor) mixture is contacted with a liquid solvent selected to preferentially absorb one, or in some cases more than one, component from the mixture. The purpose is either to recover a desired component from a gas mixture or to rid the mixture of an impurity. In the latter case, the operation is often referred to as scrubbing. The gas, once absorbed in the liquid, is in a completely dissolved state and therefore has become a full-fledged member of the liquid phase. In the chemical industry, gas absorption is the second-most common separation operation involving gas-liquid contacting. Only fractional distillation is employed more frequently.

When the operation is employed in reverse, that is, when a gas is utilized to extract a component from a liquid mixture, it is referred to as gas desorption, stripping, or sparging.

In gas absorption, either no further changes occur to the gaseous component once it is absorbed in the liquid solvent, or the absorbed component (solute) will become involved in a chemical reaction with the solvent in the liquid phase. In the former case, the operation is referred to as physical gas absorption, and in the latter case as gas absorption with chemical reaction. Examples of simple, or physical, gas absorption include the absorption of light oil (benzene, toluene, xylenes) from coke oven by-product gases by scrubbing with a petroleum oil, and recovery of valuable solvent vapors, such as acetone or those used in drycleaning processes, from gas streams by washing the gas with an appropriate solvent for the vapors. Examples of gas absorption with chemical reaction include scrubbing the flue gases from coal-fired generating stations with aqueous sodium carbonate solution to remove sulfur dioxide (a potential cause of acid rain), recovery of ammonia from coke oven by-product gases by scrubbing with dilute sulfuric acid, and the purification of natural gas