

energy of the innermost electron, is close to that: 74,971 eV. See ATOMIC STRUCTURE AND SPECTRA.

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Atomic time

Time based on the frequency determined by the energy of quantum transitions. Atomic time is obtained from the continuous operation of atomic clocks since mid-1955. The only relativistic correction to atomic time is for gravitational potential (related to height above sea level). See ATOMIC CLOCK.

Basic principles. An atom which drops from an energy level, E_2 , to a lower one, E_1 , emits radiation of frequency $f = (E_1 - E_2)/h$, where h is Planck's constant. The second in the International System of Units (SI) was defined in 1967 as the duration of 9,192,631,770 cycles of the radiation from a selected transition of cesium-133. See ATOMIC STRUCTURE AND SPECTRA; QUANTUM MECHANICS.

International Atomic Time. International Atomic Time (TAI) is generated by the International Bureau of Weights and Measures (BIPM) in Sevres, France. It is based on approximately 200 commercial atomic clocks and up to 8 laboratory-built, cesium primary-frequency standards at approximately 44 laboratories around the world. The clock data are collected through use of the Global Positioning System (GPS) with a process called common-view time transfer. The primary physical frequency standards, with accuracy as good as 2.2 parts in 10^{15} , provide the accuracy and long-term stability of TAI, which reproduces the SI second to better than 1 part in 10^{14} . The highest-accuracy standards now use laser-cooled atoms. The function of the commercial clocks is to provide redundancy and short-term stability. See ATOMIC CLOCK; SATELLITE NAVIGATION SYSTEMS.

TAI is a highly precise atomic time used, for example, in determining variations in the Earth's speed of rotation, computing orbits, and tracking celestial objects, including spacecraft. TAI provides not only the SI unit of time but also the unit of length, the meter, now defined as the distance that light travels in $1/299,792,458$ of a second in vacuum. See PHYSICAL MEASUREMENT.

Civil time. Universal Time 1 (UT1), based on the Earth's rotation, is losing about 1 s per year relative to TAI. This loss rate is slowly increasing because of tidal friction and irregular variations in the Earth's rotational speed. Coordinated Universal Time (UTC) was formed to provide civil time related to TAI. Legal time based on a standard time zone generally differs

from UTC by an integer number of hours.

The BIPM keeps UTC an exact number of seconds from TAI and within 0.9 s of UT1 by adding a leap second to UTC as needed, usually to the last minute of December or June. The International Earth Rotation Service, in Paris, informs the BIPM when a leap second change should be made. Twenty-two leap seconds have been inserted over a period of 27 years (1972-1999). See EARTH ROTATION AND ORBITAL MOTION.

The cesium clock has proven to be highly accurate and very stable over long time intervals. Some commercial clocks can match laboratory standards in stability but not in accuracy. Research to build even more accurate clocks involves laser-cooled ions and atoms and the use of energy transitions corresponding to frequencies in the optical region. See LASER COOLING.

Relativistic effects. The theory of relativity predicts two effects important for atomic time. Relative to coordinate time in an inertial frame, a standard clock runs slower the faster it moves relative to that frame, and a clock at rest in the frame runs slower the lower it is in a gravitational potential. Thus, if two standard clocks are at the same elevation on the Earth, the one closer to the Earth's Equator will run slower than a clock closer to a pole, due to the greater rotational velocity of points on the Earth's surface nearer the Equator. A standard clock lower in elevation above mean sea level will run slower than a higher clock, if they are at the same latitude. Defining gravitational potential as the sum, W , of the potential due to gravity and the potential due to Earth's centrifugal force, the rate of TAI is defined in terms of the rate a standard clock would run on the surface of constant gravitational potential which best approximates mean sea level. This surface is called the geoid. A primary frequency reference for TAI must be corrected for the offset, ΔW , of the gravitational potential at the location of the standard from the value on the geoid, according to $\Delta W/c^2$, where c is the speed of light. The change in gravitational potential is approximately equal to gb , where g is the acceleration due to gravity near the Earth, and b is the height above the geoid. The frequency bias for a standard is about $+1.1$ parts in 10^{16} per meter (3.3 parts in 10^{17} per foot) above the geoid. No other relativistic terms are currently applied. Other relativistic terms to consider include the effects of Earth tides (parts in 10^{16}), and effects associated with frame dragging (parts in 10^{21}). See EARTH, GRAVITY FIELD OF; GEODESY.

Relativistic effects must also be considered in the long-distance comparison of clocks that contribute to TAI. These effects are primarily some form of the Sagnac effect. This can be understood as a change in the delay of a signal traveling at the speed of light between clocks on the Earth, due to the Earth's rotation. See DYNAMICAL TIME; RELATIVITY; TIME.

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Atomization

The process whereby a bulk liquid is transformed into a multiplicity of small drops. This transformation, often called primary atomization, proceeds through the formation of disturbances on the surface of the bulk liquid, followed by their amplification due to energy and momentum transfer from the surrounding gas.

Spray formation processes are critical to the performance of a number of technologies and applications. These include combustion systems (gas turbine engines, internal combustion engines, incinerators, furnaces, rocket motors), agriculture (pesticide and fertilizer treatments), paints and coatings (furniture, automobiles), consumer products (cleaners, personal care products), fire suppression systems, spray cooling (materials processing, computer chip cooling), medicinals, (pharmaceutical), and spray

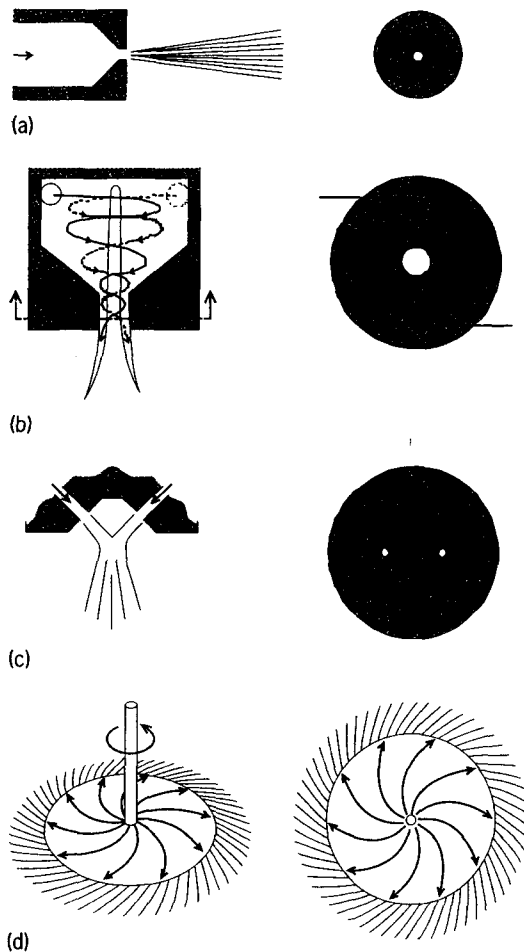


Fig. 1. Single-fluid atomizers. Diagrams on right are cross sections. (a) Pressure atomizer. (b) Pressure-swirl atomizer. (c) Impinging-jet atomizer. (d) Rotary atomizer.

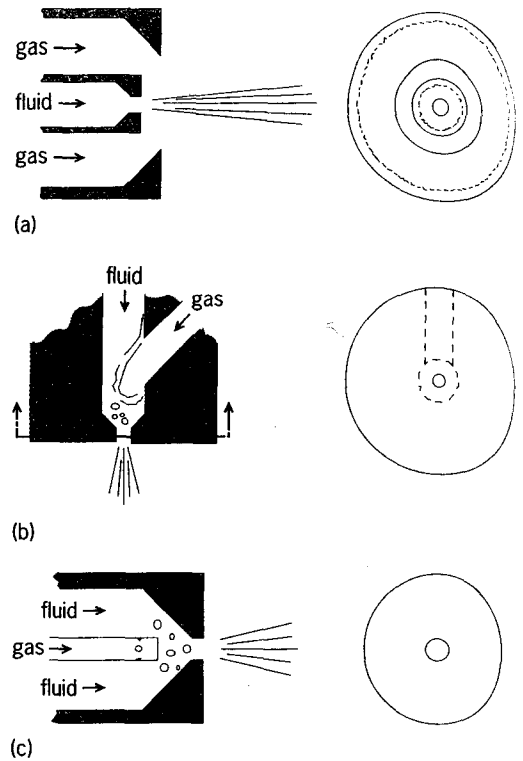


Fig. 2. Twin-fluid atomizers. Diagrams on right are cross sections. (a) External-mix atomizer. (b) Y-jet internal-mix atomizer. (c) Effervescent internal-mix atomizer.

drying (foods, drugs, materials processing). Current concerns include how to make smaller drops (especially for internal combustion engines), how to make larger drops (agricultural sprays), how to reduce the number of largest and smallest drops (paints and coatings, consumer products, medicinals, spray drying), how to distribute the liquid mass more uniformly throughout the spray, and how to increase the fraction of liquid that impacts a target (paints and coatings, spray cooling, fire suppression).

Spray devices (that is, atomizers) are often characterized by how disturbances form. The most general distinction is between systems where one or two fluids flow through the atomizer. The most common types of single-fluid atomizers (Fig. 1) are pressure (also called plain-orifice, hydraulic, or pneumatic), pressure-swirl, rotary, ultrasonic (sometimes termed whistle or acoustic), and electrostatic; other types include impinging jet, fan, and jet-swirl. Twin-fluid atomizers (Fig. 2) include internal-mix and external-mix versions, where these terms describe the location where atomizing fluid (almost always a gas) first contacts fluid to be sprayed (almost always a liquid).

While primary atomization is important, because of its role in determining mean drop size and the spectrum of drop sizes, subsequent processes also play key roles in spray behavior. They include further drop breakup (termed secondary atomization), drop transport to and impact on a target, drop evaporation (and perhaps combustion), plus drop collisions and coalescence. In addition, the spray interacts with