

= Caesium =

Caesium or cesium is a chemical element with symbol Cs and atomic number 55 . It is a soft , silvery @-@ gold alkali metal with a melting point of 28 @. @ 5 ° C (83 @. @ 3 ° F) , which makes it one of only five elemental metals that are liquid at or near room temperature . Caesium is an alkali metal and has physical and chemical properties similar to those of rubidium and potassium . The metal is extremely reactive and pyrophoric , reacting with water even at ? 116 ° C (? 177 ° F) . It is the least electronegative element . It has only one stable isotope , caesium @-@ 133 . Caesium is mined mostly from pollucite , while the radioisotopes , especially caesium @-@ 137 , a fission product , are extracted from waste produced by nuclear reactors .

The German chemist Robert Bunsen and physicist Gustav Kirchhoff discovered caesium in 1860 by the newly developed method of flame spectroscopy . The first small @-@ scale applications for caesium were as a " getter " in vacuum tubes and in photoelectric cells . In 1967 , based on Einstein defining the speed of light as the most constant dimension in the universe , the International System of Units isolated two specific wave counts from an emission spectrum of caesium @-@ 133 to co @-@ define the second and the meter . Since then , caesium has been widely used in highly accurate atomic clocks .

Since the 1990s , the largest application of the element has been as caesium formate for drilling fluids . It has a range of applications in the production of electricity , in electronics , and in chemistry . The radioactive isotope caesium @-@ 137 has a half @-@ life of about 30 years and is used in medical applications , industrial gauges , and hydrology . Although the element is only mildly toxic , it is a hazardous material as a metal and its radioisotopes present a high health risk if released into the environment .

= = Characteristics = =

= = = Physical properties = = =

Caesium is a very soft (it has the lowest hardness of all elements , 0 @. @ 2 Mohs) , very ductile , pale metal , which darkens in the presence of trace amounts of oxygen . It has a melting point of 28 @. @ 4 ° C (83 @. @ 1 ° F) , making it one of the few elemental metals that are liquid near room temperature . Mercury is the only elemental metal with a known melting point lower than caesium . In addition , the metal has a rather low boiling point , 641 ° C (1 @, @ 186 ° F) , the lowest of all metals other than mercury . Its compounds burn with a blue or violet colour .

Caesium forms alloys with the other alkali metals , as well as with gold , and amalgams with mercury . At temperatures below 650 ° C (1 @, @ 202 ° F) , it does not alloy with cobalt , iron , molybdenum , nickel , platinum , tantalum or tungsten . It forms well @-@ defined intermetallic compounds with antimony , gallium , indium and thorium , which are photosensitive . It mixes with all the other alkali metals (except lithium) ; the alloy with a molar distribution of 41 % caesium , 47 % potassium , and 12 % sodium has the lowest melting point of any known metal alloy , at ? 78 ° C (? 108 ° F) . A few amalgams have been studied : CsHg

2 is black with a purple metallic lustre , while CsHg is golden @-@ coloured , also with a metallic lustre .

= = = Chemical properties = = =

Caesium metal is highly reactive and very pyrophoric . In addition to igniting spontaneously in air , it reacts explosively with water even at low temperatures , more so than other members of the first group of the periodic table . The reaction with solid water occurs at temperatures as low as ? 116 ° C (? 177 ° F) . Because of its high reactivity , the metal is classified as a hazardous material . It is stored and shipped in dry saturated hydrocarbons , such as mineral oil . Similarly , it must be handled under inert gas , such as argon . However , a caesium @-@ water explosion is often less

powerful than a sodium @-@ water explosion with a similar amount of sodium . This is because caesium explodes instantly upon contact with water , leaving little time for hydrogen to accumulate . Caesium can be stored in vacuum @-@ sealed borosilicate glass ampoules . In quantities of more than about 100 grams (3 @.@ 5 oz) , caesium is shipped in hermetically sealed , stainless steel containers .

The chemistry of caesium is similar to that of other alkali metals , but is more closely similar to that of rubidium , the element above caesium in the periodic table . As expected for an alkali metal , its only common oxidation state is + 1 . Some small differences arise from the fact that it has a higher atomic mass and is more electropositive than other (nonradioactive) alkali metals . Caesium is the most electropositive chemical element . The caesium ion is also larger and less " hard " than those of the lighter alkali metals .

== = Compounds == =

The vast majority of caesium compounds contain the element as the cation Cs^+ , which binds ionically to a wide variety of anions . One noteworthy exception is provided by the caeside anion (Cs^-) . Other exceptions include the several suboxides (see section on oxides below) .

Returning to more normal compounds , salts of Cs^+ are almost invariably colourless unless the anion itself is coloured . Many of the simple salts are hygroscopic , but less so than the corresponding salts of the lighter alkali metals . The phosphate , acetate , carbonate , halides , oxide , nitrate , and sulfate salts are water @-@ soluble . Double salts are often less soluble , and the low solubility of caesium aluminium sulfate is exploited in the purification of Cs from its ores . The double salt with antimony (such as CsSbCl_4) , bismuth , cadmium , copper , iron , and lead are also poorly soluble .

Caesium hydroxide (CsOH) is hygroscopic and a very strong base . It rapidly etches the surface of semiconductors such as silicon . CsOH has been previously regarded by chemists as the " strongest base " , reflecting the relatively weak attraction between the large Cs^+ ion and OH^- ; it is indeed the strongest Arrhenius base , but a number of compounds that cannot exist in aqueous solution , such as n @-@ butyllithium and sodium amide , are more basic .

A stoichiometric mixture of caesium and gold will react to form yellow caesium auride ($\text{Cs} + \text{Au}^-$) upon heating . The auride anion here behaves as a pseudohalogen . The compound reacts violently with water , yielding caesium hydroxide , metallic gold , and hydrogen gas ; in liquid ammonia it can be reacted with a caesium @-@ specific ion exchange resin to produce tetramethylammonium auride . The analogous platinum compound , the red caesium platinide (Cs_2Pt) , contains the platinide ion that behaves as a pseudochalcogen .

== = Complexes == =

Like all metal cations , Cs^+ forms complexes with Lewis bases in solution . Because of its large size , Cs^+ usually adopts coordination numbers greater than six @-@ coordination , which is typical for the lighter alkali metal cations . This trend is already apparent by the 8 @-@ coordination in CsCl , vs. the halite motif adopted by the other alkali metal chlorides . Its high coordination number and softness (tendency to form covalent bonds) are the basis of the separation of Cs^+ from other cations , as is practiced in the remediation of nuclear wastes , where $^{137}\text{Cs}^+$ is separated from large amounts of nonradioactive K^+ .

== = Halides == =

Caesium fluoride (CsF) is a hygroscopic white solid that is widely used in organofluorine chemistry as a source of the fluoride anion . Caesium fluoride has the halite structure , which means that the Cs^+ and F^- pack in a cubic closest packed array as do Na^+ and Cl^- in sodium chloride . It is noteworthy as caesium and fluorine have the lowest and highest electronegativities respectively among all the known elements .

Caesium chloride (CsCl) crystallizes in the simple cubic crystal system . Also called the " caesium chloride structure " , this structural motif is composed of a primitive cubic lattice with a two @-@ atom basis , each with an eightfold coordination ; the chloride atoms lie upon the lattice points at the edges of the cube , while the caesium atoms lie in the holes in the center of the cubes . This structure is shared with CsBr and CsI , and many other compounds that do not contain Cs . In contrast , most other alkaline halides adopt the sodium chloride (NaCl) structure . The CsCl structure is preferred because Cs + has an ionic radius of 174 pm and Cl^- 181 pm .

== == Oxides == ==

More so than the other alkali metals , caesium forms numerous binary compounds with oxygen . When caesium burns in air , the superoxide CsO_2

is the main product . The " normal " caesium oxide (Cs_2O)

forms yellow @-@ orange hexagonal crystals , and is the only oxide of the anti @-@ CdCl_2 type . It vaporizes at 250°C (482°F) , and decomposes to caesium metal and the peroxide Cs_2O_2

at temperatures above 400°C (752°F) . Aside from the superoxide and the ozonide CsO_3 , several brightly coloured suboxides have also been studied . These include Cs_7O , Cs_4O , Cs_{11}O

Cs_3O , Cs_3O

Cs_{11}O , Cs_3O

Cs_3O (dark @-@ green) , CsO , Cs_3O

Cs_3O , as well as Cs_7O

Cs_3O . The latter may be heated under vacuum to generate Cs_2O . Binary compounds with sulfur , selenium , and tellurium also exist .

Cs_2 , as well as Cs_7O

Cs_7O . The latter may be heated under vacuum to generate Cs_2O . Binary compounds with sulfur , selenium , and tellurium also exist .

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== == Isotopes == ==

Caesium has a total of 39 known isotopes that range in their mass number (i.e. number of nucleons in its nucleus) from 112 to 151 . Several of these are synthesized from lighter elements by the slow neutron capture process (S @-@ process) inside old stars , as well as inside supernova explosions (R @-@ process) . However , the only stable caesium isotope is ^{133}Cs , which has 78 neutrons . Although it has a large nuclear spin ($7/2^+$) , nuclear magnetic resonance studies can be done with this isotope at a resonating frequency of 11 @-@ 7 MHz .

The radioactive ^{135}Cs has a very long half @-@ life of about 2 @-@ 3 million years , longest of all radioactive isotopes of caesium . ^{137}Cs and ^{134}Cs have half @-@ lives of 30 and two years , respectively . ^{137}Cs decomposes to a short @-@ lived $^{137\text{m}}\text{Ba}$ by beta decay , and then to nonradioactive barium , while ^{134}Cs transforms into ^{134}Ba directly . The isotopes with mass numbers of 129 , 131 , 132 and 136 , have half @-@ lives between a day and two weeks , while most of the other isotopes have half @-@ lives from a few seconds to fractions of a second . There are at least 21 metastable nuclear isomers . Other than $^{134\text{m}}\text{Cs}$ (with a half @-@ life of just under 3 hours) , all are very unstable and decay with half @-@ lives of a few minutes or less .

The isotope ^{135}Cs is one of the long @-@ lived fission products of uranium which form in nuclear reactors . However , its fission product yield is reduced in most reactors because its predecessor , ^{135}Xe , is an extremely potent neutron poison and transmutes frequently to stable ^{136}Xe before it can decay to ^{135}Cs .

Because of its beta decay (to $^{137\text{m}}\text{Ba}$) , ^{137}Cs is a strong emitter of gamma radiation . Its half @-@ life makes it the principal medium @-@ lived fission product along with ^{90}Sr ? both are responsible for radioactivity of spent nuclear fuel after several years of cooling up to several hundred years after use . For example , ^{137}Cs together with ^{90}Sr currently generate the largest source of

radioactivity generated in the area around the Chernobyl disaster . It is not feasible to dispose of ^{137}Cs through neutron capture (due to the low capture rate) and as a result it must be allowed to decay .

Almost all caesium produced from nuclear fission comes from beta decay of originally more neutron rich fission products , passing through various isotopes of iodine and of xenon . Because iodine and xenon are volatile and can diffuse through nuclear fuel or air , radioactive caesium is often created far from the original site of fission . With the commencement of nuclear weapons testing around 1945 , ^{137}Cs was released into the atmosphere and then returned to the surface of the earth as a component of radioactive fallout .

== Occurrence ==

Caesium is a relatively rare element as it is estimated to average approximately 3 parts per million in the Earth 's crust . This makes it the 45th most abundant of all elements and the 36th of all the metals . Nevertheless , it is more abundant than such elements as antimony , cadmium , tin and tungsten , and two orders of magnitude more abundant than mercury or silver , but 3 % as abundant as rubidium ? with which it is so closely associated , chemically .

Due to its large ionic radius , caesium is one of the " incompatible elements " . During magma crystallization , caesium is concentrated in the liquid phase and crystallizes last . Therefore , the largest deposits of caesium are zone pegmatite ore bodies formed by this enrichment process . Because caesium does not substitute for potassium as readily as does rubidium , the alkali evaporite minerals sylvite (KCl) and carnallite (KMgCl

$3 \cdot 6\text{H}$

2O) may contain only 0 .002 % caesium . Consequently , Cs is found in few minerals . Percentage amounts of caesium may be found in beryl (Be

3Al

2 (SiO

3)

6) and avogadrite ((K , Cs) BF

4) , up to 15 wt % Cs_2O in the closely related mineral pezzottaite (Cs (Be_2Li) $\text{Al}_2\text{Si}_6\text{O}_{18}$) , up to 8 .4 wt % Cs_2O in the rare mineral londonite ((Cs , K) Al

4Be

4 (B , Be)

12O

28) , and less in the more widespread rhodizite . The only economically important source mineral for caesium is pollucite Cs (AlSi

2O

6) , which is found in a few places around the world in zoned pegmatites , and is associated with the more commercially important lithium minerals lepidolite and petalite . Within the pegmatites , the large grain size and the strong separation of the minerals create high grade ore for mining .

One of the world 's most significant and richest sources of the metal is the Tanco Mine at Bernic Lake in Manitoba , Canada . The deposits there are estimated to contain 350 ,000 metric tons of pollucite ore , which represent more than two thirds of the world 's reserve base . Although the stoichiometric content of caesium in pollucite is 42 .6 % , pure pollucite samples from this deposit contain only about 34 % caesium , while the average content is 24 wt % . Commercial pollucite contains over 19 % caesium . The Bikita pegmatite deposit in Zimbabwe is mined for its petalite , but it also contains a significant amount of pollucite . Notable amounts of pollucite are also mined in the Karibib Desert , Namibia . At the present rate of world mine production of 5 to 10 metric tons per year , reserves will last for thousands of years .

== Production ==

The mining of pollucite ore is a selective process and is conducted on a small scale in comparison

with most metal mining operations . The ore is crushed , hand sorted , but not usually concentrated , and then ground . Caesium is then extracted from pollucite mainly by three methods : acid digestion , alkaline decomposition , and direct reduction .

In the acid digestion , the silicate pollucite rock is dissolved with strong acids , such as hydrochloric (HCl) , sulfuric (H₂SO₄) , hydrobromic (HBr) , or hydrofluoric (HF) acids . With hydrochloric acid , a mixture of soluble chlorides is produced , and the insoluble chloride double salts of caesium are precipitated as caesium antimony chloride (Cs₄SbCl₇) , caesium iodine chloride (Cs₂I₂Cl₂) , or caesium hexachloroantimonate (Cs₂(CsCl)₆) . After separation , the pure precipitated double salt is decomposed , and pure CsCl is obtained after evaporating the water . The method using sulfuric acid yields the insoluble double salt directly as caesium alum (CsAl (SO₄)₂ · 12H₂O) . The aluminium sulfate in it is converted to the insoluble aluminium oxide by roasting the alum with carbon , and the resulting product is leached with water to yield a Cs₂SO₄ solution .

The roasting of pollucite with calcium carbonate and calcium chloride yields insoluble calcium silicates and soluble caesium chloride . Leaching with water or dilute ammonia (NH₄OH) yields then a dilute chloride (CsCl) solution . This solution can be evaporated to produce caesium chloride or transformed into caesium alum or caesium carbonate . Albeit not commercially feasible , direct reduction of the ore with potassium , sodium or calcium in vacuum can produce caesium metal directly .

Most of the mined caesium (as salts) is directly converted into caesium formate (HCOO⁻ Cs⁺) for applications such as oil drilling . To supply the developing market , Cabot Corporation built a production plant in 1997 at the Tanco mine near Bernic Lake in Manitoba , with a capacity of 12 000 barrels (1 900 m³) per year of caesium formate solution . The primary smaller scale commercial compounds of caesium are caesium chloride and its nitrate .

Alternatively , caesium metal may be obtained from the purified compounds derived from the ore . Caesium chloride , and the other caesium halides , as well , can be reduced at 700 to 800 ° C (1 292 to 1 472 ° F) with calcium or barium , followed by distillation of the caesium metal . In the same way , the aluminate , carbonate , or hydroxide may be reduced by magnesium . The metal can also be isolated by electrolysis of fused caesium cyanide (CsCN) . Exceptionally pure and gas free caesium can be made by the thermal decomposition at 390 ° C (734 ° F) of caesium azide CsN₃ , which is produced from aqueous caesium sulfate and barium azide . In vacuum applications , caesium dichromate can be reacted with zirconium forming pure caesium metal without other gaseous products .

Cs₂Cr₂O₇ + 2 Zr → 2 Cs + 2 ZrO₃ + Cr₂O₃

The price of 99 . 8 % pure caesium (metal basis) in 2009 was about US \$ 10 per gram (\$ 280 per ounce) , but its compounds are significantly cheaper .

= = History = =

In 1860 , Robert Bunsen and Gustav Kirchhoff discovered caesium in the mineral water from Dürkheim , Germany . Due to the bright blue lines in its emission spectrum , they chose a name derived from the Latin word caesius , meaning sky @-@ blue . Caesium was the first element to be discovered spectroscopically , only one year after the invention of the spectroscope by Bunsen and Kirchhoff .

To obtain a pure sample of caesium , 44 @,@ 000 litres (9 @,@ 700 imp gal ; 12 @,@ 000 US gal) of mineral water had to be evaporated to yield 240 kilograms (530 lb) of concentrated salt solution . The alkaline earth metals were precipitated either as sulfates or oxalates , leaving the alkali metal in the solution . After conversion to the nitrates and extraction with ethanol , a sodium @-@ free mixture was obtained . From this mixture , the lithium was precipitated by ammonium carbonate . Potassium , rubidium and caesium form insoluble salts with chloroplatinic acid , but these salts show a slight difference in solubility in hot water . Therefore , the less @-@ soluble caesium and rubidium hexachloroplatinate ((Cs , Rb) 2PtCl_6) could be obtained by fractional crystallization . After reduction of the hexachloroplatinate with hydrogen , caesium and rubidium could be separated by the difference in solubility of their carbonates in alcohol . The process yielded 9 @.@ 2 grams (0 @.@ 32 oz) of rubidium chloride and 7 @.@ 3 grams (0 @.@ 26 oz) of caesium chloride from the initial 44 @,@ 000 liters of mineral water .

The two scientists used the caesium chloride thus obtained to estimate the atomic weight of the new element at 123 @.@ 35 (compared to the currently accepted one of 132 @.@ 9) . They tried to generate elemental caesium by electrolysis of molten caesium chloride , but instead of a metal , they obtained a blue homogeneous substance which " neither under the naked eye nor under the microscope " showed the slightest trace of metallic substance " ; as a result , they assigned it as a subchloride (Cs

2Cl) . In reality , the product was probably a colloidal mixture of the metal and caesium chloride . The electrolysis of the aqueous solution of chloride with a mercury anode produced a caesium amalgam which readily decomposed under the aqueous conditions . The pure metal was eventually isolated by the German chemist Carl Setterberg while working on his doctorate with Kekulé and Bunsen . In 1882 , he produced caesium metal by electrolysing caesium cyanide , and thus avoiding the problems with the chloride .

Historically , the most important use for caesium has been in research and development , primarily in chemical and electrical fields . Very few applications existed for caesium until the 1920s , when it came to be used in radio vacuum tubes . It had two functions ; as a getter , it removed excess oxygen after manufacture , and as a coating on the heated cathode , it increased its electrical conductivity . Caesium did not become recognized as a high @-@ performance industrial metal until the 1950s . Applications of nonradioactive caesium included photoelectric cells , photomultiplier tubes , optical components of infrared spectrophotometers , catalysts for several organic reactions , crystals for scintillation counters , and in magnetohydrodynamic power generators . Caesium also was , and still is , used as a source of positive ions in secondary ion mass spectrometry (SIMS) .

Since 1967 , the International System of Measurements has based its unit of time , the second , on the properties of caesium . The International System of Units (SI) defines the second as the duration of 9 @,@ 192 @,@ 631 @,@ 770 cycles at the microwave frequency of the spectral line corresponding to the transition between two hyperfine energy levels of the ground state of caesium @-@ 133 . The 13th General Conference on Weights and Measures of 1967 defined a second as : " the duration of 9 @,@ 192 @,@ 631 @,@ 770 cycles of microwave light absorbed or emitted by the hyperfine transition of caesium @-@ 133 atoms in their ground state undisturbed by external fields " .

= = Applications = =

= = = Petroleum exploration = = =

The largest current end use of nonradioactive caesium is in caesium formate based drilling fluids for the extractive oil industry . Aqueous solutions of caesium formate ($\text{HCOO}^- \text{Cs}^+$) made by reacting caesium hydroxide with formic acid were developed in the mid 1990s for use as oil well drilling and completion fluids . The function of a drilling fluid is to lubricate drill bits , to bring rock cuttings to the surface , and to maintain pressure on the formation during drilling of the well . Completion fluids assist the emplacement of control hardware after drilling but prior to production by maintaining the pressure .

The high density of the caesium formate brine (up to $2.3 \text{ g} \cdot \text{cm}^{-3}$, or 19.2 pounds per gallon) , coupled with the relatively benign nature of most caesium compounds , reduces the requirement for toxic high density suspended solids in the drilling fluid a significant technological , engineering and environmental advantage . Unlike the components of many other heavy liquids , caesium formate is relatively environment friendly . The caesium formate brine can be blended with potassium and sodium formates to decrease the density of the fluids down to that of water ($1.0 \text{ g} \cdot \text{cm}^{-3}$, or 8.3 pounds per gallon) . Furthermore , it is biodegradable and reclaimable , and may be recycled , which is important in view of its high cost (about \$ 4,000 per barrel in 2001) . Alkali formates are safe to handle and do not damage the producing formation or downhole metals as corrosive alternative , high density brines (such as zinc bromide ZnBr_2 solutions) sometimes do ; they also require less cleanup and reduce disposal costs .

=== Atomic clocks ===

Caesium based atomic clocks observe electromagnetic transitions in the hyperfine structure of caesium ^{133}Cs atoms and use it as a reference point . The first accurate caesium clock was built by Louis Essen in 1955 at the National Physical Laboratory in the UK . They have been improved repeatedly over the past half century , and form the basis for standards compliant time and frequency measurements , and have been regarded as " the most accurate realization of a unit that mankind has yet achieved . " These clocks measure frequency with an error of 2 to 3 parts in 10^{14} , which would correspond to a time measurement accuracy of 2 nanoseconds per day , or one second in 1.4 million years . The latest versions are accurate to better than 1 part in 10^{15} , which means they would be off by about 1 second in 20 million years , . Caesium clocks are also used in networks that oversee the timing of cell phone transmissions and the information flow on the Internet .

=== Electric power and electronics ===

Caesium vapour thermionic generators are low power devices that convert heat energy to electrical energy . In the two electrode vacuum tube converter , it neutralizes the space charge that builds up near the cathode , and in doing so , it enhances the current flow .

Caesium is also important for its photoemissive properties by which light energy is converted to electron flow . It is used in photoelectric cells because caesium based cathodes , such as the intermetallic compound K_2CsSb , have low threshold voltage for emission of electrons .

The range of photoemissive devices using caesium include optical character recognition devices , photomultiplier tubes , and video camera tubes . Nevertheless , germanium , rubidium , selenium , silicon , tellurium , and several other elements can substitute caesium in photosensitive materials .

Caesium iodide (CsI) , bromide (CsBr) and caesium fluoride (CsF) crystals are employed for scintillators in scintillation counters widely used in mineral exploration and particle physics research , as they are well suited for the detection of gamma and X ray radiation . Caesium , being a heavy element , provides good stopping power , contributing to better detectivity . Caesium compounds may also provide a faster response (CsF) and be less hygroscopic (CsI) .

Caesium vapor is used in many common magnetometers . The element is also used as an internal

standard in spectrophotometry . Like other alkali metals , caesium has a great affinity for oxygen and is used as a " getter " in vacuum tubes . Other uses of the metal include high @-@ energy lasers , vapour glow lamps , and vapor rectifiers .

= = = Centrifugation fluids = = =

Because of their high density , solutions of caesium chloride , caesium sulfate , and caesium trifluoroacetate (Cs (O₂CCF₃))

are commonly used in molecular biology for density gradient ultracentrifugation . This technology is primarily applied to the isolation of viral particles , subcellular organelles and fractions , and nucleic acids from biological samples .

= = = Chemical and medical use = = =

There are relatively few chemical applications for caesium . Doping with caesium compounds is used to enhance the effectiveness of several metal @-@ ion catalysts used in the production of chemicals , such as acrylic acid , anthraquinone , ethylene oxide , methanol , phthalic anhydride , styrene , methyl methacrylate monomers , and various olefins . It is also used in the catalytic conversion of sulfur dioxide into sulfur trioxide in the production of sulfuric acid .

Caesium fluoride enjoys niche use in organic chemistry as a base , or as an anhydrous source of fluoride ion . Caesium salts sometimes replace potassium or sodium salts in organic synthesis , such as cyclization , esterification , and polymerization . It has also been used in thermoluminescent radiation dosimetry (TLD) : When exposed to radiation , it acquires crystal defects that , when heated , revert with emission of light proportionate to the received dose . Thus , measuring the light pulse with a photomultiplier tube can allow the accumulated radiation dose to be quantified .

= = = Nuclear and isotope applications = = =

Caesium @-@ 137 is a very common radioisotope used as a gamma @-@ emitter in industrial applications . Its advantages include a half @-@ life of roughly 30 years , its availability from the nuclear fuel cycle , and having ¹³⁷Ba as a stable end product . The high water solubility is a disadvantage which makes it incompatible with large pool irradiators for food and medical supplies . It has been used in agriculture , cancer treatment , and the sterilization of food , sewage sludge , and surgical equipment . Radioactive isotopes of caesium in radiation devices were used in the medical field to treat certain types of cancer , but emergence of better alternatives and the use of water @-@ soluble caesium chloride in the sources , which could create wide @-@ ranging contamination , gradually put some of these caesium sources out of use . Caesium @-@ 137 has been employed in a variety of industrial measurement gauges , including moisture , density , leveling , and thickness gauges . It has also been used in well logging devices for measuring the electron density of the rock formations , which is analogous to the bulk density of the formations .

Isotope 137 has also been used in hydrologic studies analogous to those using tritium . It is a daughter product of nuclear fission reactions . With the commencement of nuclear testing around 1945 , and continuing through the mid @-@ 1980s , caesium @-@ 137 was released into the atmosphere , where it is absorbed readily into solution . Known year @-@ to @-@ year variation within that period allows correlation with soil and sediment layers . Caesium @-@ 134 , and to a lesser extent caesium @-@ 135 , have also been used in hydrology as a measure of caesium output by the nuclear power industry . While they are less prevalent than either caesium @-@ 133 or caesium @-@ 137 , these isotopes have the advantage of being produced solely from anthropogenic sources .

= = = Other uses = = =

Caesium and mercury were used as a propellant in early ion engines designed for spacecraft propulsion on very long interplanetary or extraplanetary missions . The ionization method was to strip the outer electron from the propellant upon contact with a tungsten electrode that had voltage applied . Concerns about the corrosive action of caesium on spacecraft components have pushed development in the direction of the use of inert gas propellants , such as xenon ; this is easier to handle in ground @-@ based tests and has less potential to interfere with the spacecraft . Eventually , xenon was used in the experimental spacecraft Deep Space 1 launched in 1998 . Nevertheless , Field Emission Electric Propulsion thrusters which use a simple system of accelerating liquid metal ions such as of caesium to create thrust have been built .

Caesium nitrate is used as an oxidizer and pyrotechnic colorant to burn silicon in infrared flares , such as the LUU @-@ 19 flare , because it emits much of its light in the near infrared spectrum . Caesium has been used to reduce the radar signature of exhaust plumes in the SR @-@ 71 Blackbird military aircraft . Caesium , along with rubidium , has been added as a carbonate to glass because it reduces electrical conductivity and improves stability and durability of fibre optics and night vision devices . Caesium fluoride or caesium aluminium fluoride are used in fluxes formulated for the brazing of aluminium alloys that contain magnesium .

Magnetohydrodynamic (MHD) power @-@ generating systems were researched , but failed to gain widespread acceptance . Caesium metal has also been considered as the working fluid in high @-@ temperature Rankine cycle turboelectric generators . Caesium salts have been evaluated as antishock reagents to be used following the administration of arsenical drugs . Because of their effect on heart rhythms , however , they are less likely to be used than potassium or rubidium salts . They have also been used to treat epilepsy .

= = Health and safety hazards = =

Nonradioactive caesium compounds are only mildly toxic . Exposure to large amounts can cause hyperirritability and spasms , due to the chemical similarity of caesium to potassium , but such amounts would not ordinarily be encountered in natural sources and nonradioactive caesium is not a significant environmental hazard . The median lethal dose (LD50) value for caesium chloride in mice is 2 @. @ 3 g per kilogram , which is comparable to the LD50 values of potassium chloride and sodium chloride . However , in large quantities caesium competes with potassium in various biological processes . Accordingly , excess caesium intake can lead to hypokalemia , arrhythmia , and acute cardiac arrest . The principal use of nonradioactive caesium , as caesium formate in petroleum drilling fluids , takes advantage of its low toxicity compared to less costly alternatives .

Caesium metal is one of the most reactive elements and is highly explosive when it comes in contact with water . The hydrogen gas produced by the reaction is heated by the thermal energy released at the same time , causing ignition and a violent explosion . This can occur with other alkali metals , but caesium is so potent that this explosive reaction can even be triggered by cold water . The autoignition temperature of caesium is also ? 116 ° C , so it is highly pyrophoric , and ignites explosively in air to form caesium hydroxide and various oxides . Caesium hydroxide is a very strong base , and will rapidly corrode glass .

The isotopes 134 and 137 are present in the biosphere in small amounts from human activities and which differs between locations . Radiocaesium does not accumulate in the body as effectively as many other fission products (such as radioiodine and radiostrontium) . About 10 % of absorbed radiocaesium washes out of the body relatively quickly in sweat and urine . The remaining 90 % has a biological half @-@ life between 50 and 150 days . Radiocaesium follows potassium and tends to accumulate in plant tissues , including fruits and vegetables . Plants absorb caesium differently , some do not absorb it much , and some take it large amounts , sometimes displaying great resistance to it . It is also well @-@ documented that mushrooms from contaminated forests accumulate radiocaesium (caesium @-@ 137) in their fungal sporocarps . Accumulation of caesium @-@ 137 in lakes has been a high concern after the Chernobyl disaster . Experiments with dogs showed that a single dose of 3 @. @ 8 millicuries (140 MBq , 4 @. @ 1 ?g of caesium @-@ 137) per kilogram is lethal within three weeks ; smaller amounts may cause infertility and cancer .

The International Atomic Energy Agency and other sources have warned that radioactive materials , such as caesium ^{137}Cs , could be used in radiological dispersion devices , or " dirty bombs " .