

= Xenon =

Xenon is a chemical element with symbol Xe and atomic number 54 . It is a colorless , dense , odorless noble gas , that occurs in the Earth 's atmosphere in trace amounts . Although generally unreactive , xenon can undergo a few chemical reactions such as the formation of xenon hexafluoroplatinate , the first noble gas compound to be synthesized .

Xenon is used in flash lamps and arc lamps , and as a general anesthetic . The first excimer laser design used a xenon dimer molecule (Xe₂) as its lasing medium , and the earliest laser designs used xenon flash lamps as pumps . Xenon is also being used to search for hypothetical weakly interacting massive particles and as the propellant for ion thrusters in spacecraft .

Naturally occurring xenon consists of eight stable isotopes . There are also over 40 unstable isotopes that undergo radioactive decay . The isotope ratios of xenon are an important tool for studying the early history of the Solar System . Radioactive xenon @-@ 135 is produced by beta decay from iodine @-@ 135 (which is a product of nuclear fission) , and it acts as the most significant neutron absorber in nuclear reactors .

= = History = =

Xenon was discovered in England by the Scottish chemist William Ramsay and English chemist Morris Travers in September 1898 , shortly after their discovery of the elements krypton and neon . They found xenon in the residue left over from evaporating components of liquid air . Ramsay suggested the name xenon for this gas from the Greek word ????? [xenon] , neuter singular form of ????? [xenos] , meaning ' foreign (er) ' , ' strange (r) ' , or ' guest ' . In 1902 , Ramsay estimated the proportion of xenon in the Earth 's atmosphere as one part in 20 million .

During the 1930s , American engineer Harold Edgerton began exploring strobe light technology for high speed photography . This led him to the invention of the xenon flash lamp , in which light is generated by sending a brief electric current through a tube filled with xenon gas . In 1934 , Edgerton was able to generate flashes as brief as one microsecond with this method .

In 1939 , American physician Albert R. Behnke Jr. began exploring the causes of " drunkenness " in deep @-@ sea divers . He tested the effects of varying the breathing mixtures on his subjects , and discovered that this caused the divers to perceive a change in depth . From his results , he deduced that xenon gas could serve as an anesthetic . Although Russian toxicologist Nikolay V. Lazarev apparently studied xenon anesthesia in 1941 , the first published report confirming xenon anesthesia was in 1946 by American medical researcher John H. Lawrence , who experimented on mice . Xenon was first used as a surgical anesthetic in 1951 by American anesthesiologist Stuart C. Cullen , who successfully operated on two patients .

Xenon and the other noble gases were for a long time considered to be completely chemically inert and not able to form compounds . However , while teaching at the University of British Columbia , Neil Bartlett discovered that the gas platinum hexafluoride (PtF₆) was a powerful oxidizing agent that could oxidize oxygen gas (O₂) to form dioxygenyl hexafluoroplatinate (O₂ + [PtF₆] ?) . Since O₂ and xenon have almost the same first ionization potential , Bartlett realized that platinum hexafluoride might also be able to oxidize xenon . On March 23 , 1962 , he mixed the two gases and produced the first known compound of a noble gas , xenon hexafluoroplatinate . Bartlett thought its composition to be Xe + [PtF₆] ? , although later work has revealed that it was probably a mixture of various xenon @-@ containing salts . Since then , many other xenon compounds have been discovered , along with some compounds of the noble gases argon , krypton , and radon , including argon fluorohydride (HArF) , krypton difluoride (KrF₂) , and radon fluoride . By 1971 , more than 80 xenon compounds were known .

In November 1999 IBM scientists demonstrated a technology capable of manipulating individual atoms . The program , called IBM in atoms , used a scanning tunneling microscope to arrange 35 individual xenon atoms on a substrate of chilled crystal of nickel to spell out the three letter company acronym . It was the first time atoms had been precisely positioned on a flat surface .

= = Characteristics = =

Xenon has atomic number 54 ; that is , its nucleus contains 54 protons . At standard temperature and pressure , pure xenon gas has a density of 5.85 kg / m^3 , about 4.5 times the surface density of the Earth 's atmosphere , 1.217 kg / m^3 . As a liquid , xenon has a density of up to 3.1 g / mL , with the density maximum occurring at the triple point . Notably , liquid xenon has a high polarizability due to its large atomic volume , and thus is an excellent solvent . It can dissolve hydrocarbons , biological molecules , and even water . Under the same conditions , the density of solid xenon , 3.64 g / cm^3 , is higher than the average density of granite , 2.75 g / cm^3 . Using gigapascals of pressure , xenon has been forced into a metallic phase .

Solid xenon changes from face centered cubic (fcc) to hexagonal close packed (hcp) crystal phase under pressure and begins to turn metallic at about 140 GPa , with no noticeable volume change in the hcp phase . It is completely metallic at 155 GPa . When metallized , xenon looks sky blue because it absorbs red light and transmits other visible frequencies . Such behavior is unusual for a metal and is explained by the relatively small widths of the electron bands in metallic xenon .

Liquid or solid xenon nanoparticles can be formed at room temperature by implanting Xe + ions into a solid matrix . Many solids have lattice constants smaller than solid Xe . This results in compression of the implanted Xe to pressures that may be sufficient for its liquefaction or solidification .

Xenon is a member of the zero valence elements that are called noble or inert gases . It is inert to most common chemical reactions (such as combustion , for example) because the outer valence shell contains eight electrons . This produces a stable , minimum energy configuration in which the outer electrons are tightly bound .

In a gas filled tube , xenon emits a blue or lavenderish glow when the gas is excited by electrical discharge . Xenon emits a band of emission lines that span the visual spectrum , but the most intense lines occur in the region of blue light , which produces the coloration .

= = Occurrence and production = =

Xenon is a trace gas in Earth 's atmosphere , occurring at 87 ± 1 parts per billion (nL / L) , or approximately 1 part per 11.5 million , and is also found as a component in gases emitted from some mineral springs .

Xenon is obtained commercially as a by product of the separation of air into oxygen and nitrogen . After this separation , generally performed by fractional distillation in a double column plant , the liquid oxygen produced will contain small quantities of krypton and xenon . By additional fractional distillation steps , the liquid oxygen may be enriched to contain 0.1 to 2 % of a krypton / xenon mixture , which is extracted either via absorption onto silica gel or by distillation . Finally , the krypton / xenon mixture may be separated into krypton and xenon via distillation . Worldwide production of xenon in 1998 was estimated at $5,700 \text{ m}^3$. Because of its low abundance , xenon is much more expensive than the lighter noble gases . Approximate prices for the purchase of small quantities in Europe in 1999 were 10 ? / L for xenon , 1 ? / L for krypton , and 0.20 ? / L for neon ; the much more plentiful argon costs less than a cent per liter .

Within the Solar System , the nucleon fraction of xenon is 1.56×10^{-8} , for an abundance of approximately one part in 630 thousand of the total mass . Xenon is relatively rare in the Sun 's atmosphere , on Earth , and in asteroids and comets . The planet Jupiter has an unusually high abundance of xenon in its atmosphere ; about 2 to 6 times as much as the Sun . This high abundance remains unexplained and may have been caused by an early and rapid buildup of planetesimals ? small , subplanetary bodies ? before the presolar disk began to heat up . (Otherwise , xenon would not have been trapped in the planetesimal ices .) The problem of the low terrestrial xenon may potentially be explained by covalent bonding of xenon to oxygen within quartz , hence reducing the outgassing of xenon into the atmosphere .

Unlike the lower mass noble gases , the normal stellar nucleosynthesis process inside a star does

not form xenon . Elements more massive than iron @-@ 56 have a net energy cost to produce through fusion , so there is no energy gain for a star when creating xenon . Instead , xenon is formed during supernova explosions , by the slow neutron capture process (s @-@ process) of red giant stars that have exhausted the hydrogen at their cores and entered the asymptotic giant branch , in classical nova explosions and from the radioactive decay of elements such as iodine , uranium and plutonium .

= = Isotopes and isotopic studies = =

Naturally occurring xenon is made of eight stable isotopes , the most of any element with the exception of tin , which has ten . Xenon and tin are the only elements to have more than seven stable isotopes . The isotopes ^{124}Xe and ^{134}Xe are predicted to undergo double beta decay , but this has never been observed so they are considered to be stable . Besides these stable forms , there are over 40 unstable isotopes that have been studied . The longest lived of these isotopes is ^{136}Xe , which has been observed to undergo double beta decay with a half @-@ life of 2×10^{21} yr . ^{129}Xe is produced by beta decay of ^{129}I , which has a half @-@ life of 16 million years , while $^{131\text{m}}\text{Xe}$, ^{133}Xe , $^{133\text{m}}\text{Xe}$, and ^{135}Xe are some of the fission products of both ^{235}U and ^{239}Pu , and therefore used as indicators of nuclear explosions .

Nuclei of two of the stable isotopes of xenon , ^{129}Xe and ^{131}Xe , have non @-@ zero intrinsic angular momenta (nuclear spins , suitable for nuclear magnetic resonance) . The nuclear spins can be aligned beyond ordinary polarization levels by means of circularly polarized light and rubidium vapor . The resulting spin polarization of xenon nuclei can surpass 50 % of its maximum possible value , greatly exceeding the thermal equilibrium value dictated by paramagnetic statistics (typically 0 @-@ 001 % of the maximum value at room temperature , even in the strongest magnets) . Such non @-@ equilibrium alignment of spins is a temporary condition , and is called hyperpolarization . The process of hyperpolarizing the xenon is called optical pumping (although the process is different from pumping a laser) .

Because a ^{129}Xe nucleus has a spin of $1/2$, and therefore a zero electric quadrupole moment , the ^{129}Xe nucleus does not experience any quadrupolar interactions during collisions with other atoms , and thus its hyperpolarization can be maintained for long periods of time even after the laser beam has been turned off and the alkali vapor removed by condensation on a room @-@ temperature surface . Spin polarization of ^{129}Xe can persist from several seconds for xenon atoms dissolved in blood to several hours in the gas phase and several days in deeply frozen solid xenon . In contrast , ^{131}Xe has a nuclear spin value of $3/2$ and a nonzero quadrupole moment , and has t_1 relaxation times in the millisecond and second ranges .

Some radioactive isotopes of xenon , for example , ^{133}Xe and ^{135}Xe , are produced by neutron irradiation of fissionable material within nuclear reactors . ^{135}Xe is of considerable significance in the operation of nuclear fission reactors . ^{135}Xe has a huge cross section for thermal neutrons , 2×10^6 barns , so it acts as a neutron absorber or " poison " that can slow or stop the chain reaction after a period of operation . This was discovered in the earliest nuclear reactors built by the American Manhattan Project for plutonium production . Fortunately the designers had made provisions in the design to increase the reactor 's reactivity (the number of neutrons per fission that go on to fission other atoms of nuclear fuel) . ^{135}Xe reactor poisoning played a major role in the Chernobyl disaster . A shutdown or decrease of power of a reactor can result in buildup of ^{135}Xe and getting the reactor into the iodine pit .

Under adverse conditions , relatively high concentrations of radioactive xenon isotopes may be found emanating from nuclear reactors due to the release of fission products from cracked fuel rods , or fissioning of uranium in cooling water .

Because xenon is a tracer for two parent isotopes , xenon isotope ratios in meteorites are a powerful tool for studying the formation of the solar system . The iodine @-@ xenon method of dating gives the time elapsed between nucleosynthesis and the condensation of a solid object from the solar nebula . In 1960 , physicist John H. Reynolds discovered that certain meteorites contained an isotopic anomaly in the form of an overabundance of xenon @-@ 129 . He inferred that this was

a decay product of radioactive iodine ^{129}I . This isotope is produced slowly by cosmic ray spallation and nuclear fission, but is produced in quantity only in supernova explosions. As the half-life of ^{129}I is comparatively short on a cosmological time scale, only 16 million years, this demonstrated that only a short time had passed between the supernova and the time the meteorites had solidified and trapped the ^{129}I . These two events (supernova and solidification of gas cloud) were inferred to have happened during the early history of the Solar System, as the ^{129}I isotope was likely generated before the Solar System was formed, but not long before, and seeded the solar gas cloud with isotopes from a second source. This supernova source may also have caused collapse of the solar gas cloud.

In a similar way, xenon isotopic ratios such as $^{129}\text{Xe} / ^{130}\text{Xe}$ and $^{136}\text{Xe} / ^{130}\text{Xe}$ are also a powerful tool for understanding planetary differentiation and early outgassing. For example, The atmosphere of Mars shows a xenon abundance similar to that of Earth: 0.08 parts per million, however Mars shows a higher proportion of ^{129}Xe than the Earth or the Sun. As this isotope is generated by radioactive decay, the result may indicate that Mars lost most of its primordial atmosphere, possibly within the first 100 million years after the planet was formed. In another example, excess ^{129}Xe found in carbon dioxide well gases from New Mexico was believed to be from the decay of mantle-derived gases soon after Earth's formation.

== Compounds ==

After Neil Bartlett's discovery in 1962 that xenon can form chemical compounds, a large number of xenon compounds have been discovered and described. Almost all known xenon compounds contain the electronegative atoms fluorine or oxygen.

== Halides ==

Three fluorides are known: XeF_2 , XeF_4 , and XeF_6 .

XeF_2

XeF_4

XeF_6 is theorized to be unstable. The fluorides are the starting point for the synthesis of almost all xenon compounds.

The solid, crystalline difluoride XeF_2

XeF_2 is formed when a mixture of fluorine and xenon gases is exposed to ultraviolet light. Ordinary daylight is sufficient. Long-term heating of XeF_2

XeF_2 at high temperatures under an NiF_2

XeF_2 catalyst yields XeF_4

XeF_6 . Pyrolysis of XeF_6

XeF_6 in the presence of NaF yields high-purity XeF_4

XeF_4 .

The xenon fluorides behave as both fluoride acceptors and fluoride donors, forming salts that contain such cations as XeF^+ and Xe_2^{2+}

XeF_2^+

XeF_3^+ , and anions such as XeF_3^- ?

XeF_5^- , XeF_6^- ?

XeF_7^- , and XeF_8^{2-} ?

XeF_2 . The green, paramagnetic Xe_2^{2+}

XeF_2 is formed by the reduction of XeF_4

XeF_2 by xenon gas.

XeF_4

XeF_2 is also able to form coordination complexes with transition metal ions. Over 30 such complexes have been synthesized and characterized.

Whereas the xenon fluorides are well characterized, the other halides are not known, the only exception being the dichloride, XeCl_2 . Xenon dichloride is reported to be an endothermic,

colorless, crystalline compound that decomposes into the elements at 80 ° C, formed by the high @-@ frequency irradiation of a mixture of xenon, fluorine, and silicon or carbon tetrachloride. However, doubt has been raised as to whether XeCl

2 is a real compound and not merely a van der Waals molecule consisting of weakly bound Xe atoms and Cl

2 molecules. Theoretical calculations indicate that the linear molecule XeCl

2 is less stable than the van der Waals complex.

= = = Oxides and oxohalides = = =

Three oxides of xenon are known: xenon trioxide (XeO

3) and xenon tetroxide (XeO

4), both of which are dangerously explosive and powerful oxidizing agents, and xenon dioxide (XeO₂), which was reported in 2011 with a coordination number of four. XeO₂ forms when xenon tetrafluoride is poured over ice. Its crystal structure may allow it to replace silicon in silicate minerals.

The XeOO⁺ cation has been identified by infrared spectroscopy in solid argon.

Xenon does not react with oxygen directly; the trioxide is formed by the hydrolysis of XeF

6:

XeF

6 + 3 H

2O → XeO

3 + 6 HF

XeO

3 is weakly acidic, dissolving in alkali to form unstable xenate salts containing the HXeO⁺

4 anion. These unstable salts easily disproportionate into xenon gas and perxenate salts, containing the XeO₄²⁻

6 anion.

Barium perxenate, when treated with concentrated sulfuric acid, yields gaseous xenon tetroxide:

Ba

2XeO

6 + 2 H

2SO

4 → 2 BaSO

4 + 2 H

2O + XeO

4

To prevent decomposition, the xenon tetroxide thus formed is quickly cooled to form a pale @-@ yellow solid. It explodes above 35 ° C into xenon and oxygen gas.

A number of xenon oxyfluorides are known, including XeOF

2, XeOF

4, XeO

2F

2, and XeO

3F

2. XeOF

2 is formed by the reaction of OF

2 with xenon gas at low temperatures. It may also be obtained by the partial hydrolysis of XeF

4. It disproportionates at 20 ° C into XeF

2 and XeO

2F

2. XeOF

4 is formed by the partial hydrolysis of XeF

6, or the reaction of XeF

6 with sodium perxenate, Na

4XeO

6. The latter reaction also produces a small amount of XeO

3F

2. XeOF

4 reacts with CsF to form the XeOF ?

5 anion, while XeOF₃ reacts with the alkali metal fluorides KF, RbF and CsF to form the XeOF ?

4 anion.

== Other compounds ==

Recently, there has been an interest in xenon compounds where xenon is directly bonded to a less electronegative element than fluorine or oxygen, particularly carbon. Electron @-@ withdrawing groups, such as groups with fluorine substitution, are necessary to stabilize these compounds. Numerous such compounds have been characterized, including:

C

6F

5 ? Xe + ? N ? C ? CH

3, where C₆F₅ is the pentafluorophenyl group.

[C

6F

5]

2Xe

C

6F

5 ? Xe ? X, where X is CN, F, or Cl.

R ? C ? C ? Xe +, where R is C

2F ?

5 or tert @-@ butyl.

C

6F

5 ? XeF +

2

(C

6F

5Xe)

2Cl +

Other compounds containing xenon bonded to a less electronegative element include F ? Xe ? N (SO

2F)

2 and F ? Xe ? BF

2. The latter is synthesized from dioxygenyl tetrafluoroborate, O

2BF

4, at ? 100 ° C.

An unusual ion containing xenon is the tetraxenonogold (II) cation, AuXe₂ +

4, which contains Xe ? Au bonds. This ion occurs in the compound AuXe

4 (Sb

2F

11)

2, and is remarkable in having direct chemical bonds between two notoriously unreactive atoms, xenon and gold, with xenon acting as a transition metal ligand.

The compound Xe

2Sb

2F

11 contains a Xe - Xe bond , the longest element - element bond known (308 @ 71 pm = 3 @ 0871 Å) .

In 1995 , M. Räsänen and co - workers , scientists at the University of Helsinki in Finland , announced the preparation of xenon dihydride (HXeH) , and later xenon hydride - hydroxide (HXeOH) , hydroxenoacetylene (HXeCCH) , and other Xe - containing molecules . In 2008 , Khriachtchev et al. reported the preparation of HXeOXeH by the photolysis of water within a cryogenic xenon matrix . Deuterated molecules , HXeOD and DXeOH , have also been produced .

== Clathrates and excimers ==

In addition to compounds where xenon forms a chemical bond , xenon can form clathrates ? substances where xenon atoms or pairs are trapped by the crystalline lattice of another compound . One example is xenon hydrate (Xe ? 5 @ 75 H₂O) , where xenon atoms occupy vacancies in a lattice of water molecules . This clathrate has a melting point of 24 ° C. The deuterated version of this hydrate has also been produced . Another example is Xe hydride (Xe (H₂)₈) , in which xenon pairs (dimers) are trapped inside solid hydrogen . Such clathrate hydrates can occur naturally under conditions of high pressure , such as in Lake Vostok underneath the Antarctic ice sheet . Clathrate formation can be used to fractionally distill xenon , argon and krypton .

Xenon can also form endohedral fullerene compounds , where a xenon atom is trapped inside a fullerene molecule . The xenon atom trapped in the fullerene can be monitored via ¹²⁹Xe nuclear magnetic resonance (NMR) spectroscopy . Using this technique , chemical reactions on the fullerene molecule can be analyzed , due to the sensitivity of the chemical shift of the xenon atom to its environment . However , the xenon atom also has an electronic influence on the reactivity of the fullerene .

When xenon atoms are at their ground energy state , they repel each other and will not form a bond . When xenon atoms becomes energized , however , they can form an excimer (excited dimer) until the electrons return to the ground state . This entity is formed because the xenon atom tends to fill its outermost electronic shell , and can briefly do this by adding an electron from a neighboring xenon atom . The typical lifetime of a xenon excimer is 1 ? 5 ns , and the decay releases photons with wavelengths of about 150 and 173 nm . Xenon can also form excimers with other elements , such as the halogens bromine , chlorine and fluorine .

== Applications ==

Although xenon is rare and relatively expensive to extract from the Earth 's atmosphere , it has a number of applications .

== Illumination and optics ==

== Gas - discharge lamps ==

Xenon is used in light - emitting devices called xenon flash lamps , which are used in photographic flashes and stroboscopic lamps ; to excite the active medium in lasers which then generate coherent light ; and , occasionally , in bactericidal lamps . The first solid - state laser , invented in 1960 , was pumped by a xenon flash lamp , and lasers used to power inertial confinement fusion are also pumped by xenon flash lamps .

Continuous , short - arc , high pressure xenon arc lamps have a color temperature closely approximating noon sunlight and are used in solar simulators . That is , the chromaticity of these lamps closely approximates a heated black body radiator that has a temperature close to that observed from the Sun . After they were first introduced during the 1940s , these lamps began replacing the shorter - lived carbon arc lamps in movie projectors . They are employed in typical

35mm , IMAX and the new digital projectors film projection systems , automotive HID headlights , high @-@ end " tactical " flashlights and other specialized uses . These arc lamps are an excellent source of short wavelength ultraviolet radiation and they have intense emissions in the near infrared , which is used in some night vision systems .

The individual cells in a plasma display use a mixture of xenon and neon that is converted into a plasma using electrodes . The interaction of this plasma with the electrodes generates ultraviolet photons , which then excite the phosphor coating on the front of the display .

Xenon is used as a " starter gas " in high pressure sodium lamps . It has the lowest thermal conductivity and lowest ionization potential of all the non @-@ radioactive noble gases . As a noble gas , it does not interfere with the chemical reactions occurring in the operating lamp . The low thermal conductivity minimizes thermal losses in the lamp while in the operating state , and the low ionization potential causes the breakdown voltage of the gas to be relatively low in the cold state , which allows the lamp to be more easily started .

===== Lasers =====

In 1962 , a group of researchers at Bell Laboratories discovered laser action in xenon , and later found that the laser gain was improved by adding helium to the lasing medium . The first excimer laser used a xenon dimer (Xe₂) energized by a beam of electrons to produce stimulated emission at an ultraviolet wavelength of 176 nm . Xenon chloride and xenon fluoride have also been used in excimer (or , more accurately , exciplex) lasers . The xenon chloride excimer laser has been employed , for example , in certain dermatological uses .

===== Medical =====

===== Anesthesia =====

Xenon has been used as a general anesthetic . Although it is expensive , anesthesia machines that can deliver xenon are about to appear on the European market , because advances in recovery and recycling of xenon have made it economically viable .

Xenon interacts with many different receptors and ion channels and like many theoretically multi @-@ modal inhalation anesthetics these interactions are likely complementary . Xenon is a high @-@ affinity glycine @-@ site NMDA receptor antagonist . However , xenon distinguishes itself from other clinically used NMDA receptor antagonists in its lack of neurotoxicity and its ability to inhibit the neurotoxicity of ketamine and nitrous oxide . Unlike ketamine and nitrous oxide , xenon does not stimulate a dopamine efflux in the nucleus accumbens . Like nitrous oxide and cyclopropane , xenon activates the two @-@ pore domain potassium channel TREK @-@ 1 . A related channel TASK @-@ 3 also implicated in inhalational anesthetic actions is insensitive to xenon . Xenon inhibits nicotinic acetylcholine ?4?2 receptors which contribute to spinally mediated analgesia . Xenon is an effective inhibitor of plasma membrane Ca²⁺ + ATPase . Xenon inhibits Ca²⁺ + ATPase by binding to a hydrophobic pore within the enzyme and preventing the enzyme from assuming active conformations .

Xenon is a competitive inhibitor of the serotonin 5 @-@ HT₃ receptor . While neither anesthetic nor antinociceptive this activity reduces anesthesia @-@ emergent nausea and vomiting .

Xenon has a minimum alveolar concentration (MAC) of 72 % at age 40 , making it 44 % more potent than N₂O as an anesthetic . Thus it can be used in concentrations with oxygen that have a lower risk of hypoxia . Unlike nitrous oxide (N₂O) , xenon is not a greenhouse gas and so it is also viewed as environmentally friendly . Xenon vented into the atmosphere is being returned to its original source , so no environmental impact is likely .

===== Neuroprotectant =====

Xenon induces robust cardioprotection and neuroprotection through a variety of mechanisms of action . Through its influence on Ca^{2+} , K^{+} , KATP \ HIF and NMDA antagonism xenon is neuroprotective when administered before , during and after ischemic insults . Xenon is a high affinity antagonist at the NMDA receptor glycine site . Xenon is cardioprotective in ischemia @-@ reperfusion conditions by inducing pharmacologic non @-@ ischemic preconditioning . Xenon is cardioprotective by activating PKC @-@ epsilon & downstream p38 @-@ MAPK . Xenon mimics neuronal ischemic preconditioning by activating ATP sensitive potassium channels . Xenon allosterically reduces ATP mediated channel activation inhibition independently of the sulfonylurea receptor1 subunit , increasing KATP open @-@ channel time and frequency . Xenon upregulates hypoxia inducible factor 1 alpha (HIF1a) .

Xenon gas was added as an ingredient of the ventilation mix for a newborn baby at St. Michael 's Hospital , Bristol , England , whose life chances were otherwise very compromised , and was successful , leading to the authorisation of clinical trials for similar cases . The treatment is done simultaneously with cooling the body temperature to $33 \pm 5^{\circ}\text{C}$.

=== Doping ===

Inhaling a xenon / oxygen mixture activates production of the transcription factor HIF @-@ 1 @-@ alpha , which leads to increased production of erythropoietin . The latter hormone is known to increase red blood cell production and athletes ' performance . Xenon inhalation has been used for this purpose in Russia since at least 2004 . On August 31 2014 the World Anti Doping Agency (WADA) added Xenon (and Argon) to the list of prohibited substances and methods , although at this time there is no reliable drug test .

=== Imaging ===

Gamma emission from the radioisotope ^{133}Xe of xenon can be used to image the heart , lungs , and brain , for example , by means of single photon emission computed tomography . ^{133}Xe has also been used to measure blood flow .

Xenon , particularly hyperpolarized ^{129}Xe , is a useful contrast agent for magnetic resonance imaging (MRI) . In the gas phase , it can be used to image empty space such as cavities in a porous sample or alveoli in lungs . Hyperpolarization renders ^{129}Xe much more detectable via magnetic resonance imaging and has been used for studies of the lungs and other tissues . It can be used , for example , to trace the flow of gases within the lungs . Because xenon is soluble in water and also in hydrophobic solvents , it can be used to image various soft living tissues .

=== NMR spectroscopy ===

Because of the xenon atom 's large , flexible outer electron shell , the NMR spectrum changes in response to surrounding conditions , and can therefore be used as a probe to measure the chemical circumstances around it . For instance xenon dissolved in water , xenon dissolved in hydrophobic solvent , and xenon associated with certain proteins can be distinguished by NMR .

Hyperpolarized xenon can be used by surface chemists . Normally , it is difficult to characterize surfaces using NMR , because signals from the surface of a sample will be overwhelmed by signals from the far @-@ more @-@ numerous atomic nuclei in the bulk . However , nuclear spins on solid surfaces can be selectively polarized , by transferring spin polarization to them from hyperpolarized xenon gas . This makes the surface signals strong enough to measure , and distinguishes them from bulk signals .

=== Other ===

In nuclear energy applications , xenon is used in bubble chambers , probes , and in other areas where a high molecular weight and inert nature is desirable . A by @-@ product of nuclear weapon

testing is the release of radioactive xenon ^{133}Xe and xenon ^{135}Xe . The detection of these isotopes is used to monitor compliance with nuclear test ban treaties, as well as to confirm nuclear test explosions by states such as North Korea.

Liquid xenon is being used in calorimeters for measurements of gamma rays as well as a medium for detecting hypothetical weakly interacting massive particles, or WIMPs. When a WIMP collides with a xenon nucleus, it is predicted to impart enough energy to cause ionization and scintillation. Liquid xenon is useful for this type of experiment due to its high density which makes dark matter interaction more likely and permits a quiet detector due to self-shielding.

Xenon is the preferred propellant for ion propulsion of spacecraft because of its low ionization potential per atomic weight, and its ability to be stored as a liquid at near room temperature (under high pressure) yet be easily converted back into a gas to feed the engine. The inert nature of xenon makes it environmentally friendly and less corrosive to an ion engine than other fuels such as mercury or caesium. Xenon was first used for satellite ion engines during the 1970s. It was later employed as a propellant for JPL's Deep Space 1 probe, Europe's SMART-1 spacecraft and for the three ion propulsion engines on NASA's Dawn Spacecraft.

Chemically, the perxenate compounds are used as oxidizing agents in analytical chemistry. Xenon difluoride is used as an etchant for silicon, particularly in the production of microelectromechanical systems (MEMS). The anticancer drug 5-fluorouracil can be produced by reacting xenon difluoride with uracil. Xenon is also used in protein crystallography. Applied at pressures from 0.5 to 5 MPa (5 to 50 atm) to a protein crystal, xenon atoms bind in predominantly hydrophobic cavities, often creating a high quality, isomorphous, heavy atom derivative, which can be used for solving the phase problem.

== Precautions ==

Many oxygen-containing xenon compounds are toxic due to their strong oxidative properties, and explosive due to their tendency to break down into elemental xenon plus diatomic oxygen (O_2), which contains much stronger chemical bonds than the xenon compounds.

Xenon gas can be safely kept in normal sealed glass or metal containers at standard temperature and pressure. However, it readily dissolves in most plastics and rubber, and will gradually escape from a container sealed with such materials. Xenon is non-toxic, although it does dissolve in blood and belongs to a select group of substances that penetrate the blood-brain barrier, causing mild to full surgical anesthesia when inhaled in high concentrations with oxygen.

At 169 m/s, the speed of sound in xenon gas is lower than that in air due to the lower average speed of the heavy xenon atoms compared to nitrogen and oxygen molecules. Hence, xenon lowers the rate of vibration in the vocal tract when exhaled. This produces a characteristic lowered voice timbre, an effect opposite to the high-timbred voice caused by inhalation of helium. Like helium, xenon does not satisfy the body's need for oxygen. Xenon is both a simple asphyxiant and an anesthetic more powerful than nitrous oxide; consequently, many universities no longer allow the voice stunt as a general chemistry demonstration. As xenon is expensive, the gas sulfur hexafluoride, which is similar to xenon in molecular weight (146 versus 131), is generally used in this stunt, and is an asphyxiant without being anesthetic.

It is possible to safely breathe dense gases such as xenon or sulfur hexafluoride when they are in a mixture of at least 20% oxygen. Xenon at 80% concentration along with 20% oxygen rapidly produces the unconsciousness of general anesthesia (and has been used for this, as discussed above). Breathing mixes gases of different densities very effectively and rapidly so that heavier gases are purged along with the oxygen, and do not accumulate at the bottom of the lungs. There is, however, a danger associated with any heavy gas in large quantities: it may sit invisibly in a container, and if a person enters a container filled with an odorless, colorless gas, they may find themselves breathing it unknowingly. Xenon is rarely used in large enough quantities for this to be a concern, though the potential for danger exists any time a tank or container of xenon is kept in an unventilated space.