# Xenon

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**Xenon** is a chemical element with symbol **Xe** and atomic number 54. It is a colorless, dense, odorless noble gas found in the Earth's atmosphere in trace amounts.[10] 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.[11][12][13]

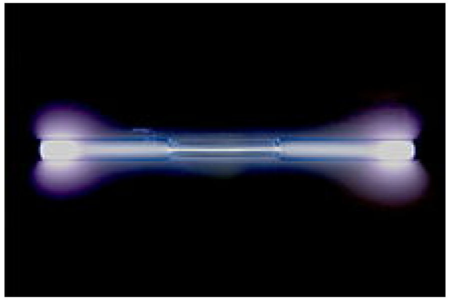
Xenon is used in flash lamps[14] and arc lamps,[15] and as a general anesthetic.[16] The first excimer laser design used a xenon dimer molecule ($Xe_2$) as the lasing medium,[17] and the earliest laser designs used xenon flash lamps as pumps.[18] Xenon is used to search for hypothetical weakly interacting massive particles[19] and as the propellant for ion thrusters in spacecraft.[20]

Naturally occurring xenon consists of eight stable isotopes. More than 40 unstable xenon isotopes undergo radioactive decay, and the isotope ratios of xenon are an important tool for studying the early history of the Solar System.[21] Radioactive xenon-135 is produced by beta decay from iodine-135 (a product of nuclear fission), and is the most significant neutron absorber in nuclear reactors.[22]

## 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 5.761 kg/m$^3$, about 4.5 times the density of the Earth's atmosphere at sea level, 1.217 kg/m$^3$.[45] As a liquid, xenon has a density of up to 3.100 g/mL, with the density maximum occurring at the triple point.[46] 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

**Xenon, $_{54}$Xe**

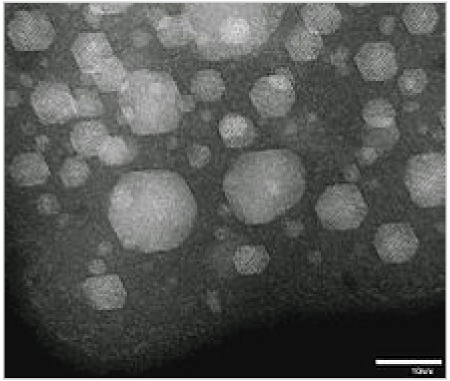


A xenon-filled discharge tube glowing light blue

Spectral lines of xenon

| | |
|---|---|
| **General properties** | |
| **Name, symbol** | xenon, Xe |
| **Appearance** | colorless gas, exhibiting a blue glow when placed in an electric field |
| **Xenon in the periodic table** | |
| **Atomic number** (*Z*) | 54 |
| **Group, block** | group 18 (noble gases), p-block |
| **Period** | period 5 |
| **Element category** | noble gas |
| **Standard atomic weight** (±) ($A_r$) | 131.293(6)[3] |
| **Electron configuration** | [Kr] $4d^{10}$ $5s^2$ $5p^6$ |
| per shell | 2, 8, 18, 18, 8 |
| **Physical properties** | |

even water.[47] Under the same conditions, the density of solid xenon, 3.640 g/cm$^3$, is greater than the average density of granite, 2.75 g/cm$^3$.[46] Under gigapascals of pressure, xenon forms a metallic phase.[48]



Liquid (featureless) and crystalline solid Xe nanoparticles produced by implanting $Xe^+$ ions into aluminium at room temperature.

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 width of the electron bands in that state.[49][50]

Xenon flash (animated version)

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.[51]

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.[52]

| | |
|---|---|
| **Phase** | gas |
| **Melting point** | 161.40 K (−111.75 °C, −169.15 °F) |
| **Boiling point** | 165.051 K (−108.099 °C, −162.578 °F) |
| **Density** at stp (0 °C and 101.325 kPa) | 5.894 g/L |
| when liquid, at b.p. | 2.942 g/cm$^3$[4] |
| **Triple point** | 161.405 K, 81.77 kPa[5] |
| **Critical point** | 289.733 K, 5.842 MPa[5] |
| **Heat of fusion** | 2.27 kJ/mol |
| **Heat of vaporization** | 12.64 kJ/mol |
| **Molar heat capacity** | 21.01[6] J/(mol·K) |

**Vapor pressure**

| **P** (Pa) | **1** | **10** | **100** | **1 k** | **10 k** | **100 k** |
|---|---|---|---|---|---|---|
| **at T** (K) | 83 | 92 | 103 | 117 | 137 | 165 |

**Atomic properties**

| | |
|---|---|
| **Oxidation states** | **0**, +1, +2, +4, +6, +8 (rarely more than 0; a weakly acidic oxide) |
| **Electronegativity** | Pauling scale: 2.6 |
| **Ionization energies** | 1st: 1170.4 kJ/mol<br>2nd: 2046.4 kJ/mol<br>3rd: 3099.4 kJ/mol |
| **Covalent radius** | 140±9 pm |
| **Van der Waals radius** | 216 pm |

**Miscellanea**

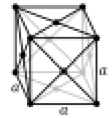
| | |
|---|---|
| **Crystal structure** | face-centered cubic (fcc) |

In a gas-filled tube, xenon emits a blue or lavenderish glow when excited by electrical discharge. Xenon emits a band of emission lines that span the visual spectrum,[53] but the most intense lines occur in the region of blue light, producing the coloration.[54]

# Isotopes and isotopic studies

Naturally occurring xenon is composed of eight stable isotopes. This is more than any other element except tin, which has ten.[69] The isotopes $^{124}Xe$ and $^{134}Xe$ are predicted by theory to undergo double beta decay, but this has never been observed so they are considered stable.[70] In addition, more than 40 unstable isotopes that have been studied. The longest lived of these isotopes is $^{136}Xe$, which undergoes double beta decay with a half-life of 2.11 × $10^{21}$ yr.[71] $^{129}Xe$ is produced by beta decay of $^{129}I$, which has a half-life of 16 million years. $^{131m}Xe$, $^{133}Xe$, $^{133m}Xe$, and $^{135}Xe$ are some of the fission products of $^{235}U$ and $^{239}Pu$,[68] and are used to detect and monitor 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.[72] 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).[73]



| | |
|---|---|
| **Speed of sound** | gas: 178 m·s$^{-1}$<br>liquid: 1090 m/s |
| **Thermal conductivity** | 5.65×10$^{-3}$ W/(m·K) |
| **Magnetic ordering** | diamagnetic[7] |
| **CAS Number** | 7440-63-3 |
| **History** | |
| **Discovery and first isolation** | William Ramsay and Morris Travers (1898) |

**Most stable isotopes of xenon**

| iso | NA | half-life | DM | DE (MeV) | DP |
|---|---|---|---|---|---|
| $^{124}$Xe | 0.095% | is stable with 70 neutrons | | | |
| $^{125}$Xe | syn | 16.9 h | ε | 1.652 | $^{125}$I |
| $^{126}$Xe | 0.089% | is stable with 72 neutrons | | | |
| $^{127}$Xe | syn | 36.345 d | ε | 0.662 | $^{127}$I |
| $^{128}$Xe | 1.910% | is stable with 74 neutrons | | | |
| $^{129}$Xe | 26.401% | is stable with 75 neutrons | | | |
| $^{130}$Xe | 4.071% | is stable with 76 neutrons | | | |
| $^{131}$Xe | 21.232% | is stable with 77 neutrons | | | |
| $^{132}$Xe | 26.909% | is stable with 78 neutrons | | | |
| $^{133}$Xe | syn | 5.247 d | $\beta^-$ | 0.427 | $^{133}$Cs |
| $^{134}$Xe | 10.436% | is stable with 80 neutrons | | | |
| $^{135}$Xe | syn | 9.14 h | $\beta^-$ | 1.16 | $^{135}$Cs |
| $^{136}$Xe | 8.857% | 2.165×10$^{21}$ y[8] | $\beta^-\beta^-$ | 2.45783[9] | $^{136}$Ba |

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 the hyperpolarization persists for long periods even after the engendering light and vapor have been removed. Spin polarization of $^{129}$Xe can persist from several seconds for xenon atoms dissolved in blood[74] to several hours in the gas phase[75] and several days in deeply frozen solid xenon.[76] 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.[77]

Some radioactive isotopes of xenon (for example, $^{133}$Xe and $^{135}$Xe) are produced by neutron irradiation of fissionable material within nuclear reactors.[11] $^{135}$Xe is of considerable significance in the operation of nuclear fission reactors. $^{135}$Xe has a huge cross section for thermal neutrons, $2.6\times10^6$ barns,[22] and operates 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).[78] $^{135}$Xe reactor poisoning was a major factor in the Chernobyl disaster.[79] A shutdown or decrease of power of a reactor can result in buildup of $^{135}$Xe, with reactor operation going into a condition known as the iodine pit.

Under adverse conditions, relatively high concentrations of radioactive xenon isotopes may emanate from cracked fuel rods,[80] or fissioning of uranium in cooling water.[81]

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. This isotope is produced slowly by cosmic ray spallation and nuclear fission, but is produced in quantity only in supernova explosions. Because the half-life of $^{129}$I is comparatively short on a cosmological time scale (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, because the $^{129}$I isotope was likely generated shortly before the Solar System was formed, seeding the solar gas cloud with isotopes from a second source. This supernova source may also have caused collapse of the solar gas cloud.[82][83]

In a similar way, xenon isotopic ratios such as $^{129}Xe/^{130}Xe$ and $^{136}Xe/^{130}Xe$ are a powerful tool for understanding planetary differentiation and early outgassing.[21] For example, the atmosphere of Mars shows a xenon abundance similar to that of Earth (0.08 parts per million[84]) but Mars shows a greater abundance of $^{129}Xe$ than the Earth or the Sun. Since 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.[85][86] In another example, excess $^{129}Xe$ found in carbon dioxide well gases from New Mexico is believed to be from the decay of mantle-derived gases from soon after Earth's formation.[68][87]

## Source

- Wikipedia: Xenon (https://en.wikipedia.org/wiki/Xenon)