Group 18 elements

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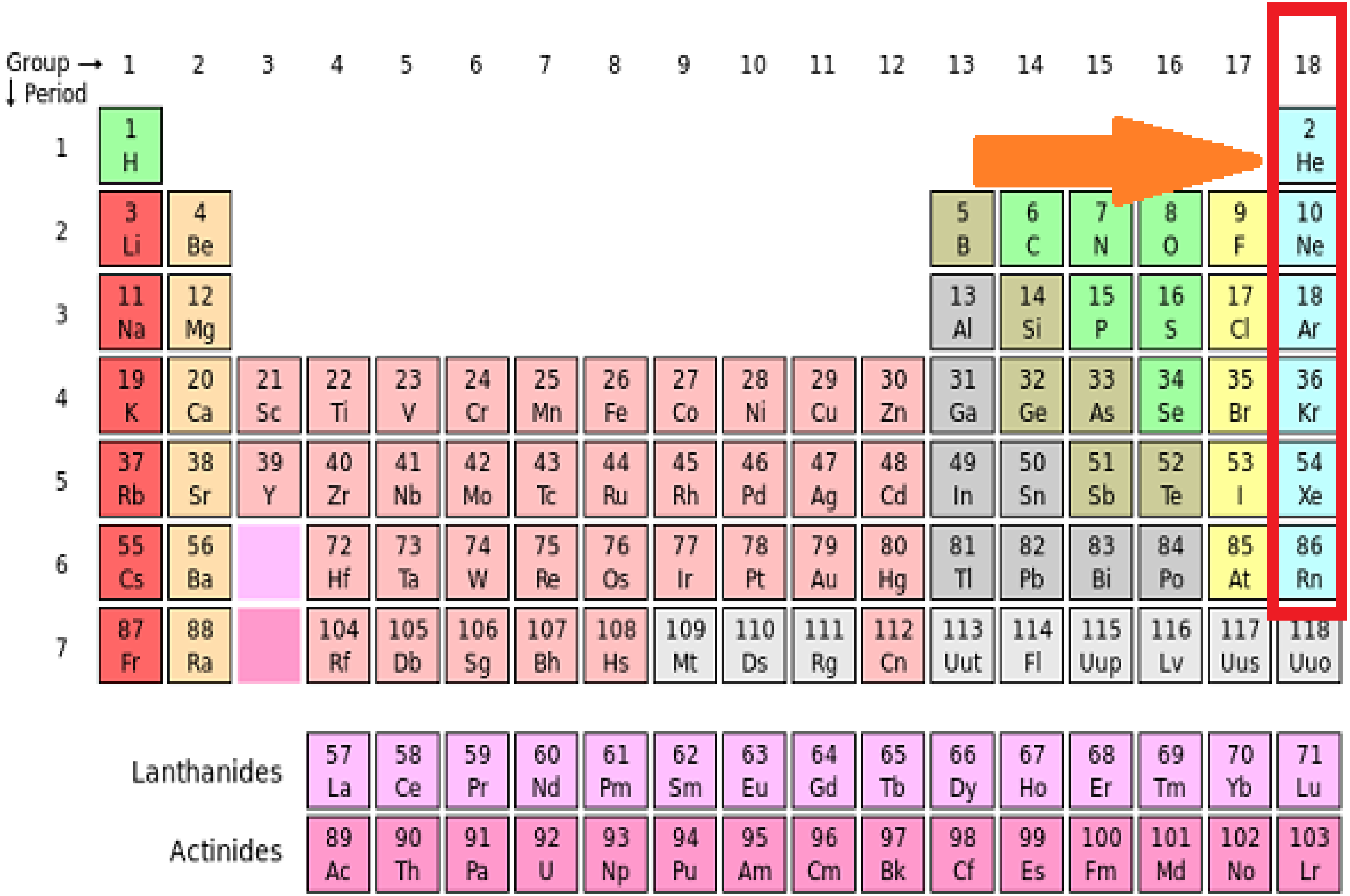
Definition of Noble Gases

The periodic table is divided into 18 vertical columns referred to as *groups* or *families*. On the far right side of the periodic table in group 18 is a unique group of elements known as the **noble gases**. The noble gases are a group of extremely nonreactive elements that all exist in the gas state.

They are often considered to be **inert**. Inertness refers to an element's tendency to resist change and reactions. For this reason, the noble gases were discovered later than many other elements. Scientists did not notice them because they were never found reacting with other elements in nature or in the lab.



Group → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
↓ Period
1 1 H 2 He
2 3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
3 11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
4 19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
5 37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
6 55 Cs 56 Ba 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
7 87 Fr 88 Ra 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 Ds 111 Rg 112 Cn 113 Uut 114 Fl 115 Uup 116 Lv 117 Uus 118 Uuo
Lanthanides 57 La 58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
Actinides 89 Ac 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr

List of Noble Gases

The noble gases include helium, neon, argon, krypton, xenon, and radon.

- Helium - This gas has the atomic number two and is the second most abundant element in the universe. It is a main part of most stars.
- Neon - Neon has the atomic number ten and is commonly used in lamps for the red-orange glow it gives off when exposed to electricity.
- Argon - Argon has the atomic number 18. It is most commonly used in welding as an inert gas to reduce the risk of fire and in lighting.
- Krypton - This gas has atomic number 36 on the periodic table and is most commonly used in photography and lighting.
- Xenon - Xenon has atomic number 54. It is most commonly used in lamps and has been used as an anesthetic.
- Radon - Radon is atomic number 86. It is formed by the radioactive decay of other elements and leeches up to the surface of Earth as it is formed. It is known to cause lung cancer when breathed in by those who encounter the gas on a regular basis.

Inert Gases

The noble gases were originally also referred to as "inert gases," since it was believed that they did not react with other elements to form compounds. In recent years, however, this term has fallen out of favor, although you will occasionally see it in older literature.

Scientists have discovered that, since the heavier noble gas atoms are held together less strongly by electromagnetic forces than are the lighter noble gases, such as helium, the outer electrons of these heavier atoms can be removed more easily. Because of this, many compounds of the gases xenon, krypton, and radon can, in fact, be formed. Of the six noble gases, only krypton, xenon, and radon have the ability to form stable compounds. These are used as oxidizing agents.

An **inert gas** is a gas which does not undergo chemical reactions under a set of given conditions. The noble gases often do not react with many substances. Inert gases are used generally to avoid unwanted chemical reactions degrading a sample. These undesirable chemical reactions are often oxidation and hydrolysis reactions with the oxygen and moisture in air. The term *inert gas* is context-dependent because several of the noble gases can be made to react under certain conditions.

Purified argon gases are most commonly used as inert gases due to their high natural abundance (78% N_2, 1% Ar in air) and low relative cost.

Unlike noble gases, an inert gas is not necessarily elemental and is often a compound gas. Like the noble gases the tendency for non-reactivity is due to the valence, the outermost electron shell, being complete in all the inert gases. This is a tendency, not a rule, as noble gases and other "inert" gases can react to form compounds.

The History

- The first person to discover the noble gases was ***Henry Cavendish*** in 1875. Cavendish distinguished these elements by chemically removing all oxygen and nitrogen from a container of air. The nitrogen was oxidized to nitrogendioxide by electric discharges and absorbed by a sodium hydroxide solution. The remaining oxygen was then removed from the mixture with an absorber. The experiment revealed that 1/120 of the gas volume remained un-reacted in the receptacle. The second person to isolate, but not typify, them was ***William Francis*** (1855-1925). Francis noted the formation of gas while dissolving uranium minerals in acid.

Electronic Configuration in the Noble Gases

The noble gas atoms, as do the atoms in most other groups on the periodic table, increase steadily in atomic radius from one period to the next due to an increasing number of electrons. The size of the atom is related to several properties. For example, the ionization potential decreases with an increasing radius because the valence electrons in the larger noble gases are farther away from the nucleus and so are not held as tightly together by the atom. Noble gases have the largest ionization potential among the elements of each period. This reflects the stability of their electron configuration and points again to their relative lack of chemical reactivity.

The Electron Configurations for Noble Gases

Helium $1s^2$

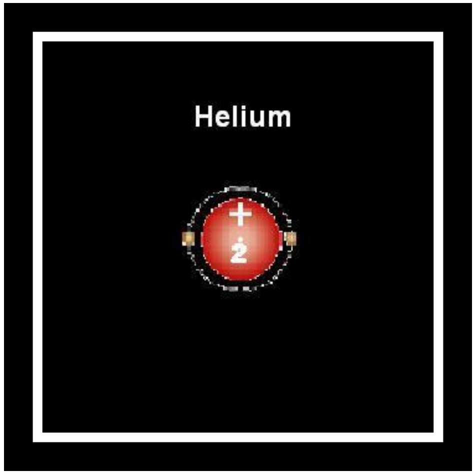
Neon $[He]\ 2s^2\ 2p^6$

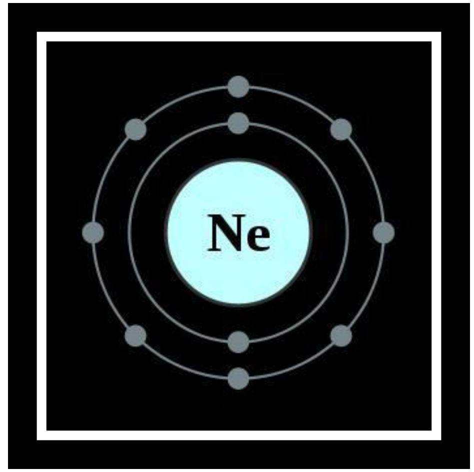
Argon $[Ne]\ 3s^2\ 3p^6$

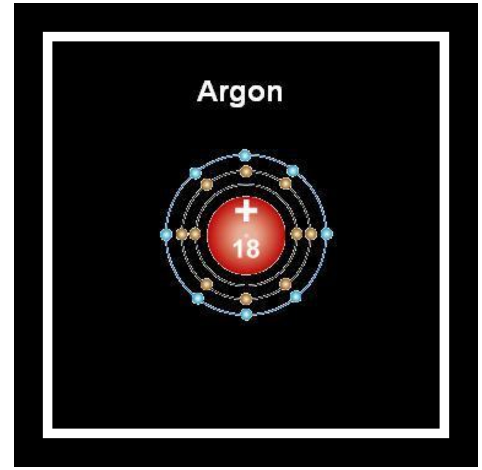
Krypton $[Ar]\ 3d^{10}\ 4s^2\ 4p^6$

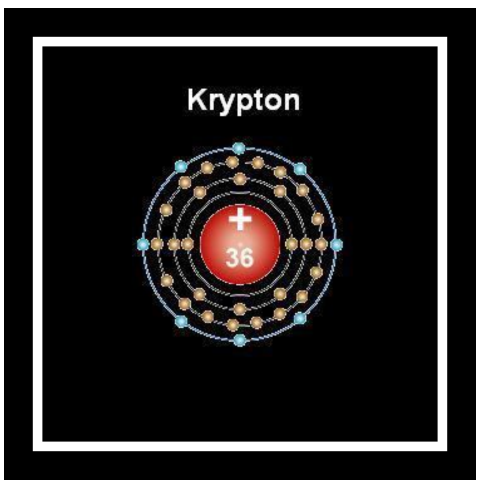
Xenon $[Kr]\ 4d^{10}\ 5s^2\ 5p^6$

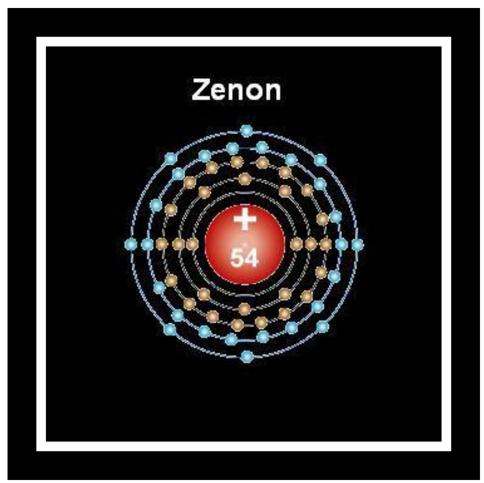
Radon $[Xe]\ 4f^{14}\ 5d^{10}\ 6s^2\ 6p^6$

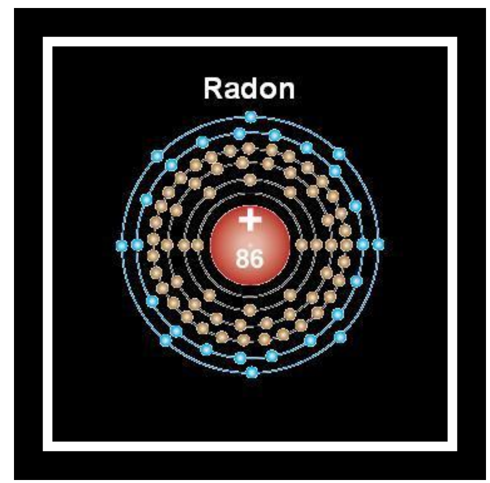

Helium
+
2


Ne


Argon
+
18


Krypton
+
36


Zenon
+
54


Radon
+
86

Trends within Group 18

	Atomic #	Atomic mass	Boiling point (K)	Melting point (K)	1st Ionization (E/kJ mol^{-1})	Density (g/dm^3)	Atomic radius (pm)
He	2	4.003	4.216	0.95	2372.3	0.1786	31
Ne	10	20.18	27.1	24.7	2080.6	0.9002	38
Ar	18	39.948	87.29	83.6	1520.4	1.7818	71
Kr	36	83.3	120.85	115.8	1350.7	3.708	88
Xe	54	131.29	166.1	161.7	1170.4	5.851	108
Rn	86	222.1	211.5	202.2	1037.1	9.97	120

The Atomic and Physical Properties

Atomic mass, boiling point, and atomic radii **INCREASE** down a group in the periodic table.

The first ionization energy **DECREASES** down a group in the periodic table.

The noble gases have the largest ionization energies, reflecting their chemical inertness.

Down Group 18, atomic radius and interatomic forces **INCREASE** resulting in an **INCREASED** melting point, boiling point, enthalpy of vaporization, and solubility.

The **INCREASE** in density down the group is correlated with the **INCREASE** in atomic mass.

Because the atoms **INCREASE** in atomic size down the group, the electron clouds of these non polar atoms become increasingly polarized, which leads to weak van Der Waals forces among the atoms. Thus, the formation of liquids and solids is more easily attainable for these heavier elements because of their melting and boiling points.

Because noble gases' outer shells are full, they are extremely stable, tending not to form chemical bonds and having a small tendency to gain or lose electrons.

Under standard conditions all members of the noble gas group behave similarly.

All are monotomic gases under standard conditions.

Noble gas atoms, like the atoms in other groups, **INCREASE** steadily in atomic radius from one period to the next due to the **INCREASING** number of electrons.

The size of the atom is positively correlated to several properties of noble gases. The ionization potential **DECREASES** with an **INCREASING** radius, because the valence electrons in the larger noble gases are further away from the nucleus; they are therefore held less tightly by the atom.

The attractive force **INCREASES** with the size of the atom as a result of an **INCREASE** in polarizability and thus a **DECREASE** in ionization potential.

Overall, noble gases have weak interatomic forces, and therefore very low boiling and melting points compared with elements of other groups.

The Chemical Properties

Noble gases are odorless, colorless, nonflammable, and monotonic gases that have low chemical reactivity.

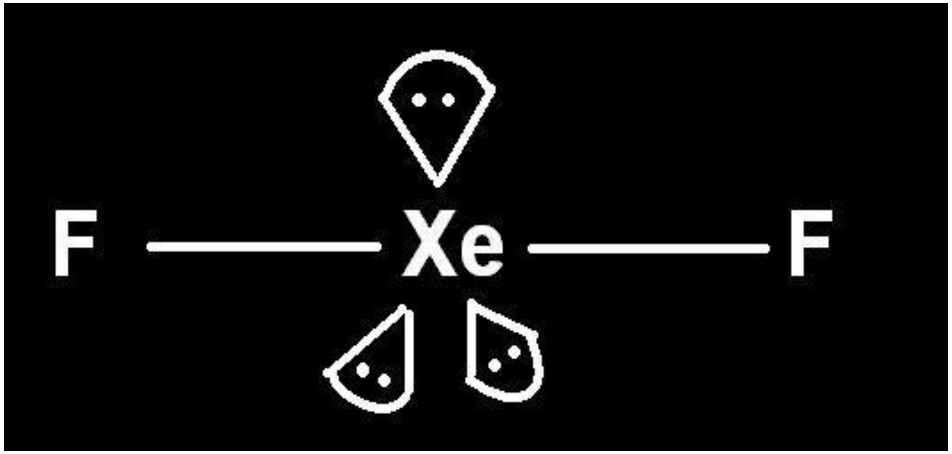
Noble Gas Compounds

The full valence electron shells of these atoms make noble gases **extremely stable** and **unlikely to form chemical bonds** because they have **little tendency to gain or lose electrons.**

Although noble gases do not normally react with other elements to form compounds, there are some exceptions. Xe may form compounds with fluoride and oxide.

Xenon Difluoride (XeF_2)

- Dense white crystallized solid
- Powerful fluorinating agent
- Covalent inorganic fluorides
- Stable xenon compound
- Decomposes on contact with light or water vapor
- Linear geometry
- Moisture sensitive
- Low vapor pressure



Xenon Tetrafluoride (XeF_4)

- Colorless Crystals
- Square planar geometry
- Discovered in 1963

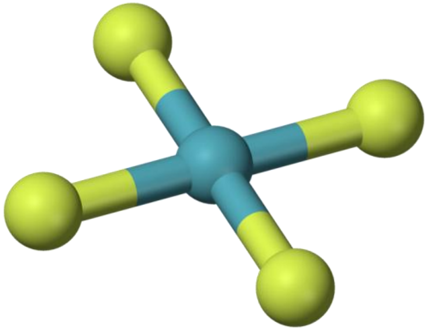


Figure: On Oct. 2, 1963, Argonne announced the creation of xenon tetrafluoride, the first simple compound of xenon, a noble gas widely thought to be chemically inert.

Xenon Hexafluoride (XeF_6)

- Strongest fluorinating agent
- Colorless solid
- Highest coordination of the three binary fluorides of xenon (XeF_2 and XeF_4)
- Formation is exergonic, and the compound is stable at normal temperatures
- Readily sublimes into intense yellow vapors
- Structure lacks perfect octahedral symmetry

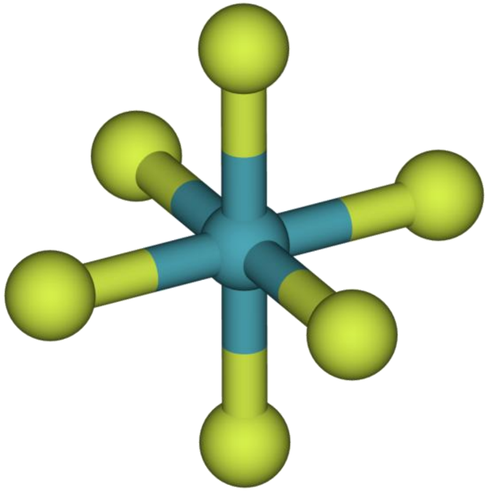
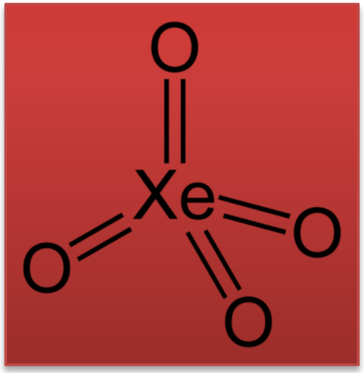


Figure: XeF_6 geometric structure with center Xe atom flanked by six F atoms. Figure used with permission from Wikipedia.

Xenon Tetroxide (XeO_4)

- Yellow crystalline solid
- Relatively stable
- Oxygen is the only element that can bring xenon up to its highest oxidation state of +8



Two other short-lived xenon compounds with an oxidation state of +8, XeO_3F_2 and XeO_2F_4, are produced in the reaction of xenon tetroxide with xenon hexafluoride.

Radon difluoride (RnF_2)

This is one of the few reported compounds of radon. Radon reacts readily with fluorine to form a solid compound, but this decomposes on attempted vaporization and its exact composition is uncertain. The usefulness of radon compounds is limited because of the noble gas's radioactivity.

The longest-lived isotope, ^{222}Ra, has a half-life of only 3.82 days.

Applications of Noble Gases

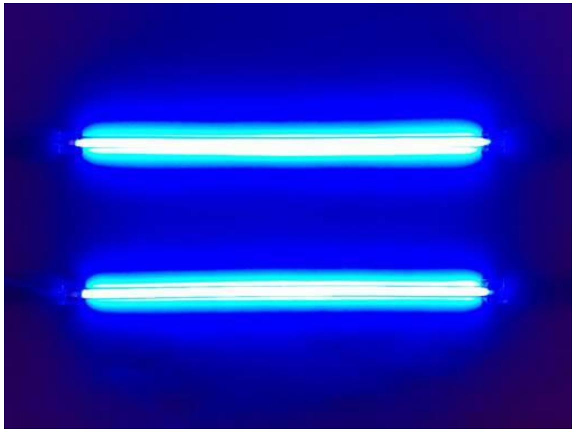
Helium

Helium is used as a component of breathing gases due to its low solubility in fluids or lipids. This is important because other gases are absorbed by the blood and body tissues when under pressure during scuba diving. Because of its reduced solubility, little helium is taken into cell membranes; when it replaces part of the breathing mixture, helium causes a decrease in the narcotic effect of the gas at far depths. The reduced amount of dissolved gas in the body means fewer gas bubbles form, decreasing the pressure of the ascent. **Helium** and **Argon** are used to shield welding arcs and the surrounding base metal from the atmosphere.

Helium is used in very low temperature cryogenics, particularly for maintaining superconductors (useful for creating strong magnetic fields) at a very low temperatures. Helium is also the most common carrier gas in gas chromatography.

Neon

Neon has many common and familiar applications: neon lights, fog lights, TV cine-scopes, lasers, voltage detectors, luminous warnings, and advertising signs. The most popular application of neon is the neon tubing used in advertising and elaborate decorations. These tubes are filled with neon and helium or argon under low pressure and submitted to electrical discharges. The color of emitted light is depends on the composition of the gaseous mixture and on the color of the glass of the tube. Pure Neon within a colorless tube absorbs red light and reflects blue light, as shown in the figure below. This reflected light is known as fluorescent light.



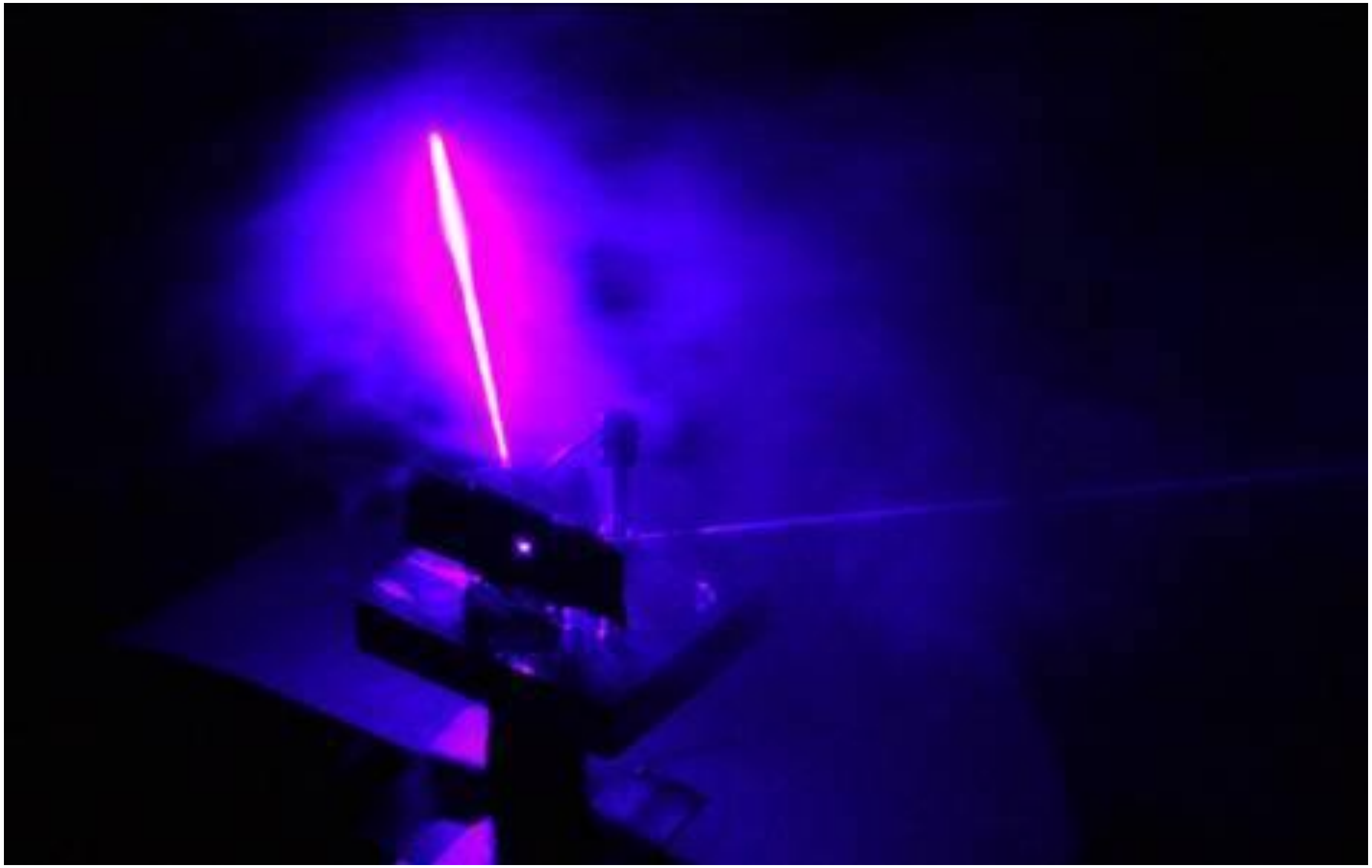
Argon

Argon has a large number of applications in electronics, lighting, glass, and metal fabrications. Argon is used in electronics to provide a protective heat transfer medium for ultra-pure silicon crystal semiconductors and for growing germanium. Argon can also fill fluorescent and incandescent light bulbs, creating the blue light found in "neon lamps." By utilizing argon's low thermal conductivity, window manufacturers provide a gas barrier needed to produce double-pane insulated windows. This insulation barrier improves the windows' energy efficiencies. Argon also creates an inert gas shield during welding, flushes out melted metals to eliminate porosity in casting, and provides an oxygen- and nitrogen-free environment for annealing and rolling metals and alloys.

Argon plasma light bulb

Krypton

Similarly to argon, krypton can be found in energy efficient windows. Because of its superior thermal efficiency, krypton is sometimes chosen over argon for insulation. It is estimated that 30% of energy efficient windows sold in Germany and England are filled with krypton; approximately 1.8 liters of krypton are used in these countries. Krypton is also found in fuel sources, lasers and headlights. In lasers, krypton functions as a control for a desired optic wavelength. It is usually mixed with a halogen (most likely fluorine) to produce excimer lasers. Halogen sealed beam headlights containing krypton produce up to double the light output of standard headlights. In addition, Krypton is used for high performance light bulbs, which have higher color temperatures and efficiency because the krypton reduces the rate of evaporation of the filament.



Krypton laser.

Xenon

Xenon has various applications in incandescent lighting, x-ray development, plasma display panels (PDPs), and more. Incandescent lighting uses xenon because less energy can be used to obtain the same light output as a normal incandescent lamp. Xenon has also made it possible to obtain better x-rays with reduced amounts of radiation. When mixed with oxygen, it can enhance the contrast in CT imaging. These applications have had great impact on the health care industries. Plasma display panels (PDPs) using xenon as one of the fill gases may one day replace the large picture tubes in television and computer screens.

Nuclear fission products may include several radioactive isotopes of xenon, which absorb neutrons in nuclear reactor cores. The formation and elimination of radioactive xenon decay products are factors in nuclear reactor control.

Radon

Radon is reported as the second most frequent cause of lung cancer, after cigarette smoking. However, it also has beneficial applications in radiotherapy, arthritis treatment, and bathing. In radiotherapy, radon has been used in implantable seeds, made of glass or gold, primarily used to treat cancers. It has been said that exposure to radon mitigates auto-immune diseases such as arthritis. Some arthritis sufferers have sought limited exposure to radioactive mine water and radon to relieve their pain. "Radon Spas" such as Bad Gastern in Austria and Onsen in Japan offer a therapy in which people sit for minutes to hours in a high-radon atmosphere, believing that low doses of radiation will boost up their energy.