Xenon is an element under the Noble gases group and is on period 7 of the periodic table. This element is most notable for its bright luminescence in light bulbs. Xenon is unique for being the first noble gas element to be synthesized into a compound.

**General Facts**

- **Element number:** 54
- **Atomic symbol:** Xe
- **Atomic weight:** 131.29
- **Electron configuration:** [Kr]5s^24d^105p^6
- **Melting point:** 161.4 K
- **Boiling point:** 165.03 K
- **Density:** 0.005887 grams per cubic centimeter
- **Phase at room temperature:** Gas
- **Family:** Group 18 Nobles Gases
- **Electrons per shell:** 2, 8, 18, 18, 8
- **Ionization energy:**
  - 1st: 1170.4 kJ·mol\(^{-1}\)
  - 2nd: 2046.4 kJ·mol\(^{-1}\)
  - 3rd: 3099.4 kJ·mol\(^{-1}\)

**Origin and History**

Xenon was first discovered in England by chemists Sir William Ramsay and Morris William Travers on July 12, 1898, after discovering Krypton and Neon. Since Xenon is an odorless and colorless gas that exists only in trace amounts in the atmosphere, it is very difficult to take notice of it. Xenon and other noble gases were discovered by evaporating liquified
air and collecting the residue. By cooling the air to below the boiling point (from gas to liquid), the air would condense to a liquid. The liquid air is then gradually warmed up, vaporizing lighter gases such as oxygen and nitrogen. Xenon gas can then be confined separately from the atmosphere. Collecting xenon is expensive because there is less than 1 parts per million in volume of the Earth's atmosphere.

Xenon is most commonly used in light bulbs and as a general anesthetic. When it is trapped inside of a bulb, electricity discharged through the gaseous xenon would emit a bright light of the entire spectrum. These light bulbs are very common in automobile headlights, such as the Audi A4 light bulbs. Other common uses of Xenon are in X-rays, plasma display panels, and anesthetics.

HID Xenon lights are brighter, stable and more economically friendly than regular halogen light bulbs. They do not look like regular halogen bulbs because halogen bulbs contain a bright filament. Instead, the xenon bulbs contain electrically charged xenon gas and metal halide; whenever they collide, the bulb becomes illuminated.

Crystal Lattice Structure

As a solid noble gas, solid xenon is structured as face centered cubic (FCC). This is also known as the CCP, which is the cubic closest packing. This crystal lattice structure is the closest that atoms can be packed into a cube. In the FCC structure, there is one atom at each corner and one atom at each face of the cube. The structure fits four atoms in each lattice cube. Face centered cubic structures are the most dense.

Xenon as a Noble Gas

Located in group 18 of the periodic table, the noble gases have a full valence electron shell. Because their valence shells are filled, the elements of group 18 are chemically stable. These elements all carry the common characteristic of being odorless monatomic gases under STP.

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<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic number</th>
<th>Atomic Mass (g)</th>
<th>Boiling Point (K)</th>
<th>1st Ionization Energies (kJ/ mol)</th>
<th>Atomic Radii pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>He</td>
<td>2</td>
<td>4.003</td>
<td>4.216</td>
<td>2372.3</td>
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<tr>
<td>Ne</td>
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<td>20.18</td>
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<td>18</td>
<td>39.948</td>
<td>87.29</td>
<td>1520.4</td>
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<tr>
<td>Kr</td>
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<td>89.3</td>
<td>120.85</td>
<td>1350.7</td>
<td>116</td>
</tr>
<tr>
<td>Xe</td>
<td>54</td>
<td>131.29</td>
<td>166.1</td>
<td>1170.4</td>
<td>140</td>
</tr>
</tbody>
</table>
Periodic Trends

- **Atomic radii:** Increases down the table. Reason: The radii is constantly increasing because the nucleus is gaining more protons, therefore affording to attract more electrons. For example, with an atomic number of 2, helium can only hold 2 electrons. On the other hand, Xenon has an atomic number of 54, which allows the element to hold 54 electrons. This brings the electron cloud to the 5p orbital.

- **Boiling point:** Increases down the table. As you go down the periodic table of the noble gases, there are more electrons, creating more Van Der Waals forces. We know that boiling points depend on the strength of the bonds. The stronger the bonds, the more energy it needs to drive structure to entropy, therefore having a higher boiling point.

- **Ionization energies:** Increases going up the table because it's harder to remove electrons from smaller atoms.

Xenon’s Isotopes

Xenon has the second most stable isotopes (next to tin). There are a total of nine naturally existing isotopes. Xenon isotopes differ because they have a different number of neutrons, adding to the atomic mass of protons and neutrons. There are also over 18 radioactive isotopes of xenon -- radioactive isotopes are chemically unstable, therefore they are highly reactive. Radioactive isotopes essentially have the same characteristics as the element because they are still neutral atoms. Isotopes have the same amount of protons and electrons, so the structure of the atom hardly changes. Isotopes are also specified mainly by their mass number. For instance, Xe with an atomic number of 54 and 78 neutrons is labeled as Xe-132.

Why are Isotopes important?

Isotopes are necessary for radioactive decay. Radioactive decay is the breakdown of the nucleus due to instability. In the nucleus, the neutrons surround the protons in order to keep the nucleus stable. The unstable isotopes undergo radioactive decay because there is an imbalance of neutrons attach to neutrons rather than neutrons attach to protons. This instability decays a neutron into a proton and an electron. We know that the number of proton determines the element, however under this decay, we have an additional proton that changes the entire element. This process is called Beta Radiation. This process helps us find the half life of unstable atoms. The half life is the time it takes for half of the atom to decay. Half lives help us date the time of certain matter. Some isotopes have really long half lives, while some end in milliseconds. Xenon isotopes such as Xe-129, Xe-130, and Xe-136 are used as tools to measure the dating of the solar system with half lives.

Xenon Compounds and their Molecular Structure

Noble gases have always been believed to be inert with other group 18 elements. However, in 1962 the first noble gas compound was produced by Neil Bartlett, combining xenon, platinum and fluorine. It is now possible to produce xenon compounds in which the oxidation states range from +2 to +8(!). Most of the known xenon compounds contain the strongly
reducing fluorine or oxygen atoms. Xenon Halides: a binary compound consisting of a halogen and an element with a higher ionization

**Xenon Difluoride (XeF₂)**

- White crystallized solid
- Covalent inorganic fluorides
- Stable compound
- Decomposes on contact with light or water vapor
- Linear structure
- Moister sensitive
- Low vapor pressure

\[ \text{Xe} + \text{F}_2 \rightarrow \text{XeF}_2 \]

**Xenon Tetrafluoride (XeF₄)**

- Colorless Crystals
- Square planar structure

\[ \text{Xe} + 2\text{F}_2 \rightarrow \text{XeF}_4 \]

**Xenon Hexafluoride (XeF₆)**

- Strongest fluorinating agent
- Colorless solid
- Exergonic and stable at normal temperatures
- Sublimes into yellow vapors
- Structure lacks perfect octahedral symmetry

\[ \text{Xe} + 3\text{F}_2 \rightarrow \text{XeF}_6 \]

Fluorine is the ONLY ELEMENT that directly reacts with Xenon. So how do we get XeO₃? Xenon Halides are reactive with other compounds such as water.

\[ \text{XeF}_2 + 3\text{H}_2\text{O} \rightarrow \text{XeO}_3 + 6\text{HF} \]

The Xe has a total of 8 outside shell electrons while the Fluorine 7 valence electrons. Xe’s outside shell electrons are very far away from the center, therefore Xenon cannot possibly pay attention/attract all of the electrons. Fluorine is smaller, therefore it has a stronger positive attraction to the few electrons it has left. Fluorine is the only element that reacts with Xe because it is the most electronegative. In other words, it is the only element that is strong enough to pull electrons out of the stable xenon.
Practice Problems

1. Why does Xenon react directly with fluorine?
2. How was xenon gas discovered?
3. Would Xenon react with oxygen? Write out the balanced equation for XeO₃ Xenon trioxide.
4. Describe the process of radioactive decay.
5. Why are xenon headlights better than halogen headlights? (answers on bottom of the page)

References

- Nossov, Andrei. "Application of continuously circulating flow of hyperpolarized (HP) ^{129}Xe-NMR on mesoporous materials." *PCCP.* 2003, 4473, 4478

Answers to Practice Problems

1. Xenon reacts directly with fluorine because fluorine is a very powerful oxidizing agent (hence it gets reduced and it gains an electron from Xenon). Xenon has larger radii; therefore the electron attraction to the nucleus is weaker in comparison to the smaller noble gases. Fluorine on the other hand is very tiny and highly electronegative, so it would steal an electron from fluorine, forming a compound.
2. William Ramsay and Morris Travers discovered Xenon gas by capturing xenon vapors from boiling liquid air.
3. Xenon does not react directly with oxygen. Xenon reacts with water molecules in order to form xenon oxides.
4. The process of radioactive decay is the deterioration of an atom through the instability of isotopes. The instability of isotopes forms the neutrons into a proton and an electron, therefore changing the entire element.
5. Generally speaking, typical lights rely on an ignited filament, however a xenon bulb has a chamber filled xenon gas and metal halides. When there is an electrical discharge, the xenon gas collides with the metal halides to produce a powerful light.

Contributors

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