The noble gases (Group 18) are located in the far right of the periodic table and were previously referred to as the "inert gases" due to the fact that their filled valence shells (octets) make them extremely nonreactive. The noble gases were characterized relatively late compared to other element groups.

The History

The first person to discover the noble gases was Henry Cavendish in the late 18th century. Cavendish distinguished these elements by chemically removing all oxygen and nitrogen from a container of air. The nitrogen was oxidized to $\text{NO}_2$ 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.

Argon

In 1894, John William Strutt discovered that chemically-obtained pure nitrogen was less dense than the nitrogen isolated from air samples. From this breakthrough, he concluded that another, unknown gas was present in the air. With the aid of William Ramsay, Strutt managed to replicate and modify Cavendish's experiment to better understand the inert component of air in his original experiment. The researchers' procedure differed from the Cavendish procedure: they removed the oxygen by reacting it with copper, and removed the nitrogen in a reaction with magnesium. The remaining gas was properly characterized and the new element was named "argon," which originates from the Greek word for "inert."

Helium

Helium was first discovered in 1868, manifesting itself in the solar spectrum as a bright yellow line with a wavelength of 587.49 nanometers. This discovery was made by Pierre Jansen. Jansen initially assumed it was a sodium line. However, later studies by Sir William Ramsay (who isolated helium on Earth by treating a variety of rare elements with acids) confirmed that the bright yellow line from his experiment matched up with that in the spectrum of the sun. From this, British physicist William Crookes identified the element as helium.

Neon, Krypton, Xenon

These three noble gases were discovered by Morris W. Travers and Sir William Ramsay in 1898. Ramsay discovered neon by chilling a sample of the air to a liquid phase, warming the liquid, and capturing the gases as they boiled off. Krypton and xenon were also discovered through this process.

Radon

In 1900, while studying the decay chain of radium, Friedrich Earns Dorn discovered the last gas in Group 18: radon. In his experiments, Dorn noticed that radium compounds emanated radioactive gas. This gas was originally named niton after the Latin word for shining, "nitens". In 1923, the International Committee for Chemical Elements and International Union of Pure Applied Chemistry (IUPAC) decided to name the element radon. All isotopes of radon are radioactive. Radon-222
has the longest half-life at less than 4 days, and is an alpha-decay product of Radium-226 (part of the U-238 to Pb-206 radioactive decay chain).

The Electron Configurations for Noble Gases

- **Helium** \(1s^2\)
- **Neon** \([\text{He}]\ 2s^2\ 2p^6\)
- **Argon** \([\text{Ne}]\ 3s^2\ 3p^6\)
- **Krypton** \([\text{Ar}]\ 3d^{10}\ 4s^2\ 4p^6\)
- **Xenon** \([\text{Kr}]\ 4d^{10}\ 5s^2\ 5p^6\)
- **Radon** \([\text{Xe}]\ 4f^{14}\ 5d^{10}\ 6s^2\ 6p^6\)

Table 1: Trends within Group 18

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

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.

For covalently-bonded diatomic and polyatomic gases, heat capacity arises from possible translational, rotational, and vibrational motions. Because monatomic gases have no bonds, they cannot absorb heat as bond vibrations. Because the center of mass of monatomic gases is at the nucleus of the atom, and the mass of the electrons is negligible compared to the nucleus, the kinetic energy due to rotation is negligible compared to the kinetic energy of translation (unlike in di- or polyatomic molecules where rotation of nuclei around the center of mass of the molecule contributes significantly to the heat capacity). Therefore, the internal energy per mole of a monatomic noble gas equals its translational contribution, \( \frac{3}{2}RT \), where \( R \) is the universal gas constant and \( T \) is the absolute temperature.

For monatomic gases at a given temperature, the average kinetic energy due to translation is practically equal regardless of the element. Therefore at a given temperature, the heavier the atom, the more slowly its gaseous atoms move. The mean velocity of a monatomic gas decreases with increasing molecular mass, and given the simplified heat capacity situation, noble gaseous thermal conductivity decreases with increasing molecular mass.

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**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.
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.

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.

Outside Links

- Wikipedia article on XeF₂: http://en.wikipedia.org/wiki/XeF2
- Wikipedia article on XeF₄: http://en.wikipedia.org/wiki/XeF4
- Wikipedia article on XeF₆: http://en.wikipedia.org/wiki/XeF6
- Wikipedia article on XeO₄: http://en.wikipedia.org/wiki/XeO4
- History of Noble Gases: http://www.bbc.co.uk/dna/h2g2/A2342189
- Image of Helium: http://www.flw.com/datatools/periodic/e_model/2.gif
• Image of Krypton: http://www.flw.com/datatools/periodic/e_model/36.gif
• Image of Xenon: http://www.flw.com/datatools/periodic/e_model/54.gif
• Image of XeFs: http://www.faidherbe.org/site/cours/dupuis/images4/xef6.gif
• Image of helium balloons: http://www.carondelet.pvt.k12.ca.us/PeriodicTable/He/helium%20pic3.jpg
• Image of neon light: http://www.neonsdirect.co.uk/images/blue-neon-lights.jpg
• Image of argon plasma light bulb: http://www.vk2zay.net/article/file/17
• Image of krypton laser: http://www.ucd.ie/physics/preston/re...biophysics.jpg
• Image of xenon headlights: http://www.bmw.com/com/en/newvehicle...s_bi_xenon.jpg
• Image of radon bath: http://www.sibyllenbad.de/cms/medien...264-sb_199.jpg

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