

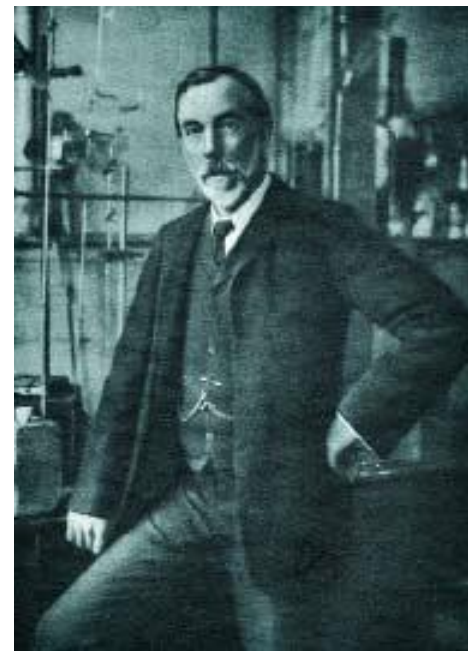
Nobel Gases Overview

Element	Ionization energy/kJ mol ⁻¹	T_m /K	T_b /K
He	2 372	0.95	4.2
Ne	2 081	25	27
Ar	1 520	84	87
Kr	1 351	116	120
Xe	1 170	161	165
Rn	1 037	202	211

The noble gases have a completely filled outer electron shell (s^2p^6 or s^2), so there is no driving force for these elements to engage in chemical bonding → **monoatomic and very inert.**

Nobel Gases Discovery

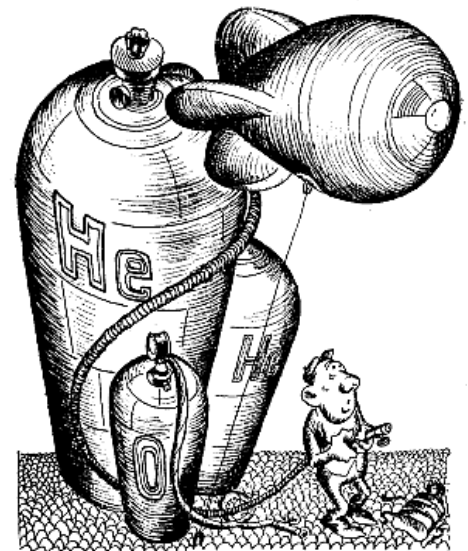
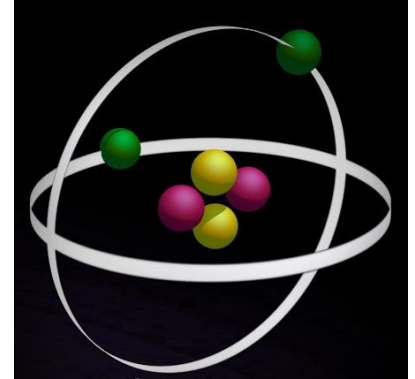
- In the early 1890s, Ramsay puzzled over a curious observation made by Lord Rayleigh, who found that the density of nitrogen collected from air samples always appeared greater than the density of the gas prepared chemically.
- Ramsay separated nitrogen from air and then passed the dried gas through red-hot magnesium, which absorbed the nitrogen and left behind the heavier component. Rayleigh removed nitrogen from air samples by forming nitrogen oxides using electric discharges. The studies proved that air indeed contains a new component.
- In August 1894 Rayleigh announced the discovery of a new element they named argon (Greek for lazy).
- Using liquefaction and fractional distillation methods, Ramsay succeeded in isolating from air three other new elements in the summer of 1898. He named them krypton ("hidden one"), neon ("new one"), and xenon ("the stranger").



Sir William Ramsay
Nobel Prize in Chemistry
in 1904

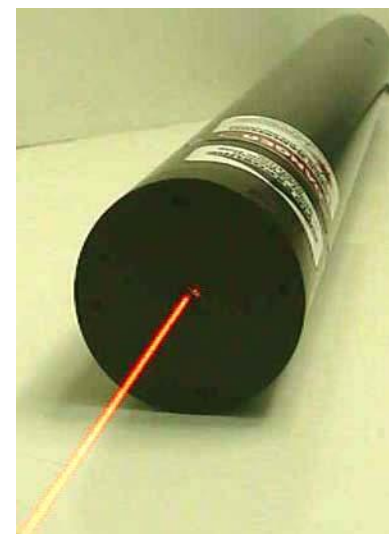
Helium

- He is the second most abundant element in the universe.
- He was discovered on the sun (yellow line in the sun's spectrum) before it was found on the earth.
- Helium makes up about 0.0005% of the earth's atmosphere. It is constantly lost to space but replaced by the decay of radioactive elements in the earth's crust.
- He has the lowest boiling point of all elements (-269 °C). Liquid helium is an important cryogenic material.
- Helium is extracted from natural gas (some sources contain up to 8 % He).
- He-O₂ mixtures are used for diving.



Neon

- From the Greek word for new, '*neos*'.
- Ne is the fourth most abundant element in the universe.
- The largest use for neon gas is in advertising signs.
- Ne is combined with He to make helium-neon lasers.



Yellow He-Ne laser.

Argon

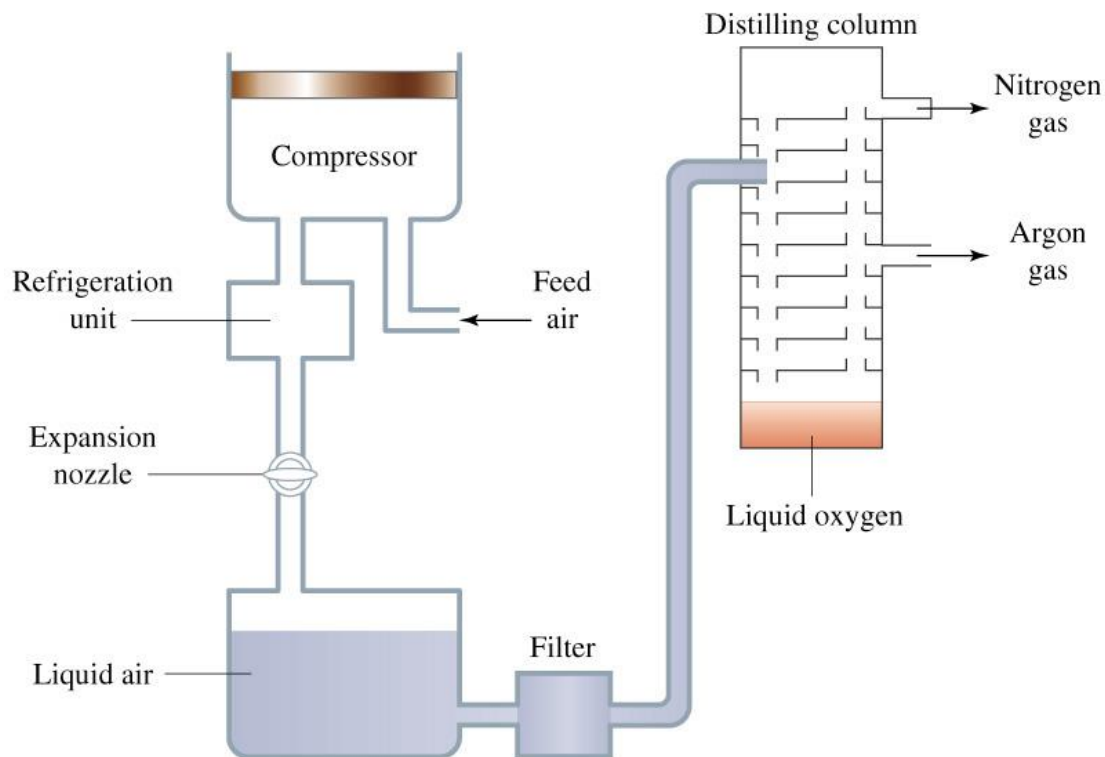
- From the Greek word for inactive, '*argos*'.
- Argon makes up **0.93 % of the earth's atmosphere**, making it the third most abundant gas.
- Argon is obtained from the air as a byproduct of the production of O_2 and N_2 .
- Argon is frequently used when an inert atmosphere is needed.



Composition of the atmosphere

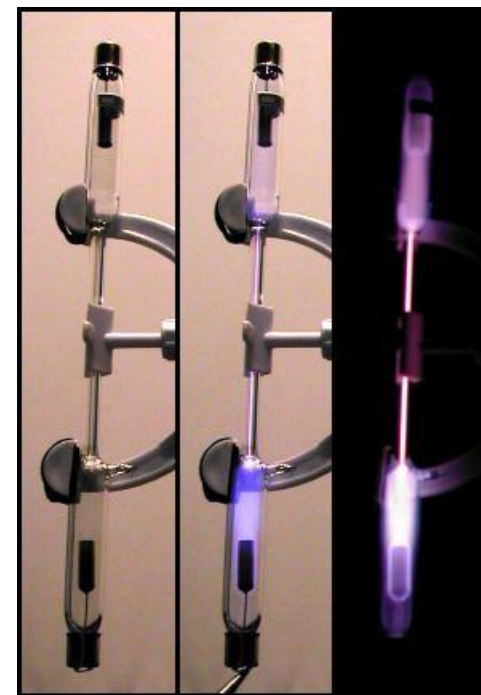
Technical Production of Argon

Clean air is compressed and then cooled. The liquid air is filtered to remove $\text{CO}_2(\text{s})$ and then distilled. Nitrogen is the most volatile component (bp. 77.4 K); it comes off as a gas. Argon (bp. 87.5 K) is removed from the middle of the column, and liquid oxygen (bp. 90.2 K) collects at the bottom of the column.



Krypton

- From the Greek word for hidden, '*kryptos*'.
- The earth's atmosphere contains about 0.0001 % Kr (1 ppm).
- The high cost of obtaining krypton from the air has limited its practical applications. Some fluorescent light bulbs are filled with a mixture of Kr and Ar.
- In 1960, the length of the meter was defined in terms of the orange-red spectral line of ^{86}Kr .



Photographs of Kr gas (left) and Kr plasma (right).

Xenon

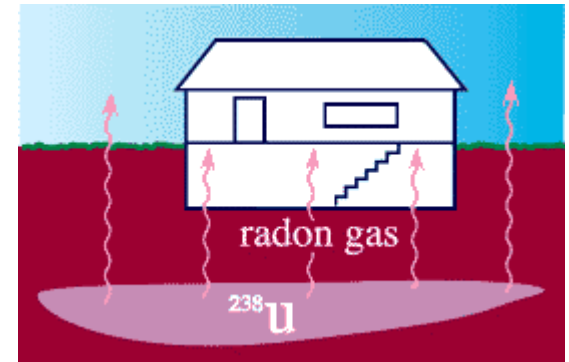
- From the Greek word for stranger, '*xenon*'.
- The earth's atmosphere contains about 0.0000087 % Xe.
- Xe produces a brilliant white flash of light when it is excited electrically and is widely used in lamps.
- Xe is commercially obtained by extraction from liquid air.



A Xenon lamp.

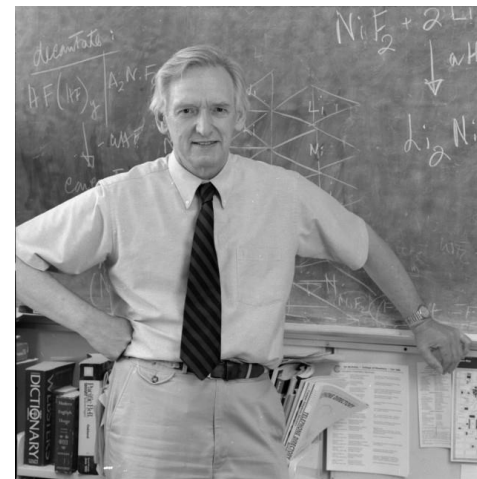
Radon

- Radon (Rn) was discovered in 1900 while studying radium's decay chain. Today, radon is still primarily obtained through the decay of radium (Ra).
- At normal room temperatures, Radon is a colorless, odorless, radioactive gas (α -decay, $t_{1/2} = 3.8$ d).
- Rn is a large contributor to our daily exposure of radiation. ^{222}Rn is a decay product of uranium and radium which is found in soils and rocks. Rn gas escapes from the soils and can be trapped in houses.
- The main hazard is from inhalation of the element and its decay products which are collected on dust in the air. Many deaths from lung cancer are caused by radon exposure.



History of Nobel Gas Compounds

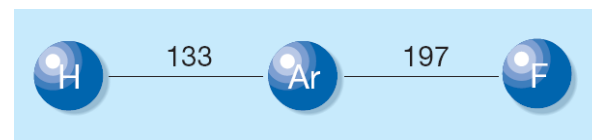
- Linus Pauling predicted in 1933 that molecules containing xenon and krypton should exist.
- In 1962 Neil Bartlett found that the strongly oxidizing agent PtF_6 is powerful enough to ionize oxygen to give the stable salt $(\text{O}_2)^+(\text{PtF}_6)^-$.
- The ionization energy of O_2 (1175 kJ/mol) is similar to that of Xe (1170 kJ/mol) $\rightarrow$ reaction with Xe was found to give a yellow solid.
- First published as $\text{Xe}^+(\text{PtF}_6)^-$; later found to be a mixture including the compound $(\text{XeF})^+(\text{PtF}_6)^-$.
- Soon after Bartlett's discovery, XeF_2 , XeF_4 and XeF_6 were prepared by reaction of the elements.



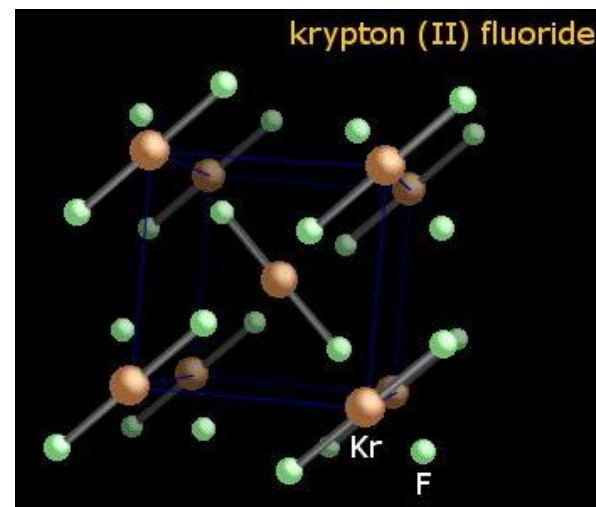
Neil Bartlett discovered the first noble gas compound in 1962.

He, Ne, Ar and Kr

- He and Ne are the only two elements for which no neutral chemical compounds are known.
- In 2000, the first stable argon compound, **HArF**, was synthesized at low temperatures and characterized by IR-spectroscopy.
- **KrF₂** from colorless crystals, which are stable at $-78\text{ }^{\circ}\text{C}$. It is formed from Kr and F₂ at $-183\text{ }^{\circ}\text{C}$ using electrical discharges.
- **KrF₂** is the strongest oxidizing agent that is known.

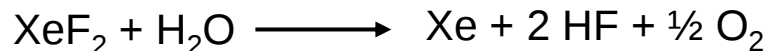


The first Ar compound
([*Nature* 2000, 406, 874](#))

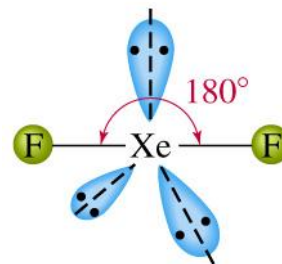
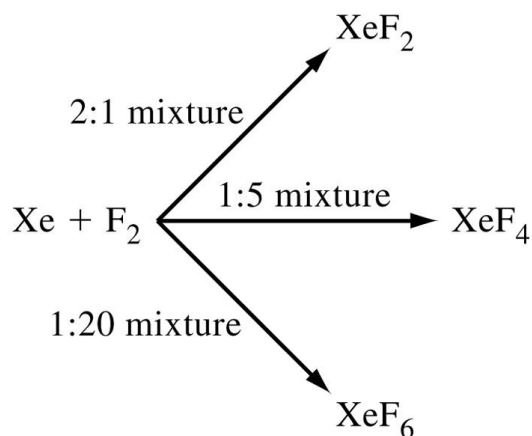


Xenon Fluorides

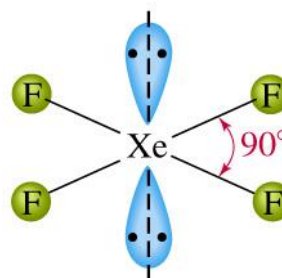
- All three Xe-Fluorides can be made from the elements using different stoichiometries.
- They are very strong oxidizing agents; XeF₂ can oxidize water:



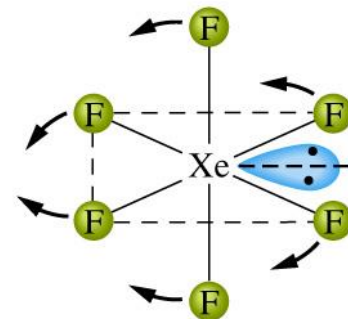
- The structures can be explained with the VSEPR theory.



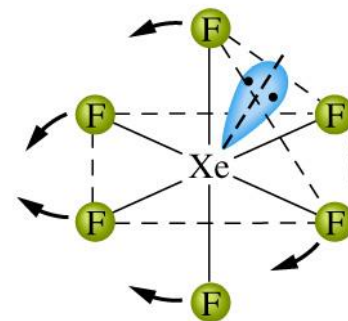
(a)



(b)



or



(c)

Important Xenon Compounds – Summary

