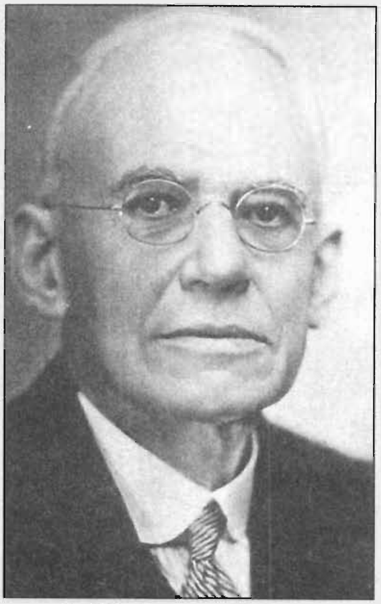
The Inert and the Noble

In 1869, when D I Mendeleev worked out the periodic table of elements, only 63 elements were known. Based on the periodicity of the properties of elements, Mendeleev could guess that many elements remained to be discovered and allotted suitable vacant places for them. Three such elements, called eka-aluminium, eka-boron and eka-silicon by Mendeleev, and now named gallium, scandium and germanium respectively, were eventually discovered, vindicating the periodic law. But an entire group of elements was missing in the original periodic table. These are the inert gas or noble gas elements. The first member of this series was identified in 1868 from the spectral lines from the sun, and appropriately named *helium*. The credit for isolating helium and most of the remaining inert gases goes to William Ramsay (Oct. 2, 1852 – July 23, 1916).

Ramsay's discovery was based on the hypothesis that the existence of some heavier gas in atmospheric nitrogen was responsible for its higher density compared to that of chemically generated nitrogen. After a few months of research he isolated argon, at the same time as Rayleigh. Following this discovery Ramsay demonstrated the existence of the lighter inert gas helium, on earth. Beginning in April 1895, Ramsay and his chief collaborator Morris W Travers isolated the other inert gases, krypton, neon and xenon by evaporating liquid air and collecting fractions, which were then analyzed spectroscopically. Although it was F E Dorn who discovered radon, the last inert gas, it was Ramsay who determined its atomic weight in 1904. Fittingly, Ramsay was awarded the 1904 Nobel Prize in Chemistry '*for his discovery of the inert gaseous elements in air and his determination of their place in the periodic system*'. The same year Rayleigh was awarded the Nobel Prize in Physics '*for his investigations of the densities of the most important gases and for his discovery of argon in connection with these studies*'.



Morris William Travers (Jan. 24, 1872 – Aug. 25, 1961), who was the principal coworker during these discoveries, later came to India as the first Director of Indian Institute of Science, Bangalore and was also the first Chairman of the Department of General Chemistry. In his later career, Travers worked in cryogenics, which is one of the principal uses for inert gases he helped to discover. He also published a biography of Ramsay in 1956.

Morris William Travers
(Jan. 24, 1872 – Aug. 25, 1961)

Some important properties of the inert gases are given below:

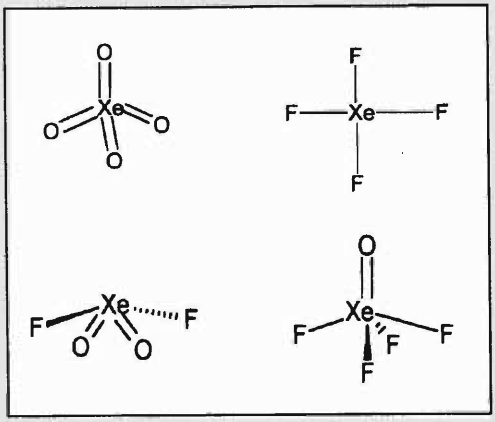
Name	Atomic Number	Boiling point (°C)	Ionization Potential (kJ/mol)
Helium (He)	2	–268.9	2372
Neon (Ne)	10	–246.1	2080
Argon (Ar)	18	–185.9	1520
Krypton (Kr)	36	–153.4	1351
Xenon (Xe)	54	–108.1	1169
Radon (Rn)	86	–62.0	1037

The extreme reluctance of these elements to combine with themselves (all of them are monatomic), or other elements earned them the name inert or noble gases. The inert nature is a direct result of their electronic structures with completely filled shells of electrons (ns^2 for He and ns^2, np^6 for others). Hence, their 'chemistry' is unique. Initially, several clathrates of argon, krypton and xenon were discovered. These are molecular compounds formed by the inclusion of an atom into a cage or enclosure formed by another molecule(s) without involving a traditional bond. For example, hydroquinone molecule hydrogen bonds to form a cage, which is an excellent host for noble gases and a variety of other small molecules.

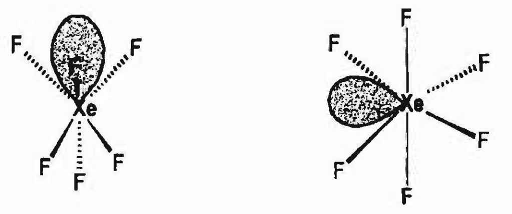
However, inert gases can be forced to react if we remove an electron from the closed shell. This in turn depends on the ionization potential of the element. As with other elements, this tendency increases with atomic number. Recognizing this fact, N Bartlett succeeded in making a complex with a xenon-fluorine covalent bond:

$$Xe + 2\,PtF_6 \rightarrow [XeF]^+ [PtF_6]^- + PtF_5$$

Soon after this discovery, a series of complexes with fluorine were made. The chemistry of xenon is probably the best investigated, for it forms numerous compounds that are stable at ambient conditions. Although radon should behave similarly, its radioactive nature is a deterrent to extensive investigations.



The structures of these compounds can be correctly explained using VSEPR (valence shell electron pair repulsion) theory. Thus, the shapes of XeO_4, XeF_4, XeF_2 XeO_2F_2, etc., are textbook exercises for the applicability of VSEPR theory.



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However, the structure of XeF_6 remains an enigma. This molecule although discovered in 1963, has merited attention even recently! VSEPR predicts it to be a distorted octahedron, but all structural studies on this molecule, electron diffraction and spectroscopic elucidation, point to an octahedral structure! One possible explanation for this discrepancy is the rapid interconversion between two distorted structures at a rate that is faster than that used in the spectroscopic tools to examine the compound.

Another interesting molecule that has come to light recently is HXeSH. It is remarkable because xenon is bonded to sulfur, which is not highly electronegative. It raises visions of organoxenon chemistry, a pleasing possibility considering the fact that Ramsay began his career as an organic chemist.

Helium is probably the most useful of the inert gases. It is also the most abundant, as it can be isolated from naturally occurring gas deposits. It is used in 'lighter than air' balloons. Its insolubility in blood allows it to be used as a safe diluent for oxygen in the breathing mixture of deep-sea divers. The inert gases are excellent fillers in electric light bulbs, vapor lamps and lasers. The characteristic colors of 'neon' signs are in fact the spectroscopic signatures of the elements, which enabled Ramsay to identify them. Argon and helium provide an inert shield to inhibit oxidation during arc welding.

Low temperature physics makes extensive use of inert gases. Liquefying helium is a particularly challenging problem, which won for H K Onnes the 1913 Nobel Prize in Physics. Liquid helium is a particularly interesting fluid because of the many unusual phenomena which it shows, including superfluidity. Liquid helium has many practical applications. It is used wherever superconductors are required. All high field NMR spectrometers have magnets that are cooled with liquid He!

Recently, helium has found a medical use. Beams of ionized helium atoms have been used to shrink tumors of the eye, a procedure that produces only minor side effects.

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