CHAPTER 10

THE ATMOSPHERE AND THE INERT GASES

The Composition of the Atmosphere

The atmosphere is the mixture of gases which surrounds the earth. A small portion of the atmosphere is called air although the distinction may not be well-marked. In ancient time air was considered to be an element. But in 1775, Lavoisier established that air is a mixture of nitrogen and oxygen together with other gases. Nitrogen, oxygen and a number of inert gases are present in the atmosphere besides carbondioxide, water vapour and dust. Traces of hydrogen, hydrogen sulphide, ammonia, oxides of nitrogen, sulphur dioxide and other gases are also present. The composition varies according to location on the earth's surface and altitude. The average composition of dry air at sea-level by volume is given in Table 10.1.

Table 10.1. Composition of the atmosphere.

Component	*Percent by volume*	*Remarks*
Nitrogen	77.16	
Oxygen	20.60	
Argon	0.94	
Carbondioxide	0.04	variable
Moisture	0.140	variable
Neon	0.0018	
Helium	0.0005	
Krypton	0.0001	
Xenon	0.000005	
Hydrogen	Traces	
Ozone	Traces	
Dust particles & other gases	Traces	Variable

The percentage composition of dry and pure air does not vary much with location on the earth's surface or with altitude. However, density of air and pressure varies greatly with altitude. Thus, the average pressure of air at sea-level is 760 mm. Hg, but at 15000 feet it is about 400 mm. Hg, at 10 miles it is 40 mm. and at 30 miles altitude it is only 0.1 mm. Similarly, density of air decreases with altitude.

Detection of the Presence of Main Constituents of Air

(a) Oxygen

Oxygen can be detected by a number of chemical methods :—

(i) By burning a number of metals and non-metals in air, it is found that the oxides of the elements are formed. Thus, phosphorus burns in air to form P_2O_5. Similarly, when air is passed over heated copper, formation of CuO takes place.

(ii) When a jar filled with NO gas is exposed to air, reddish brown fumes of NO_2 is formed showing the presence of oxygen in air.

(iii) Oxygen is essential for life. Without oxygen no living being could exist on earth.

(b) Carbondioxide

(i) A vessel containing a sample of clear lime water, when exposed to air, becomes covered with a white crust. When air is passed through lime water, it turns milky. Lime water absorbs carbondioxide from air to form insoluble calcium carbonate by the reaction,

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$

Carbondioxide may be released from this calcium carbonate by dilute acids.

(ii) Plants absorb CO_2 from air in presence of moisture and sunlight with the help of chlorophyl in the green leaves. The process is known as photosynthesis.

(c) Moisture

(i) A sample of caustic soda exposed in air turns into liquid after some time due to absorption of water vapour present in air.

(ii) Fused calcium chloride also absorbs water vapour when exposed to air and turns into liquid.

(iii) Water vapour is responsible for the formation of clouds which condenses into rain.

(d) Nitrogen

After the chemical removal of water vapour and carbondioxide from air by passing it through soda lime which absorbs both CO_2 and H_2O, and then burning the air with phosphorus or passing it through heated copper which takes up oxygen, the residual gas contains mostly nitrogen. The residual colourless gas is non-inflammable. Nitrogen combines with heated magnesium to form magnesium nitride:

$$N_2 + 3Mg = Mg_3N_2$$

(e) Inert gases

These are left as ultimate residue after removal of all other constituents.

Liquid Air

Before air is liquefied, it is freed from moisture and carbondioxide because these gases are solidified easily on cooling and may clog the pipes of the liquid air machine. Dust, water vapour and carbondioxide are removed from the air successively through a dust catcher, fused calcium chloride and slaked lime. The purified air is then subjected to a pressure of about 200 atmospheres and cooled to remove the heat produced by compression. The cooling is generally done by means of a mixture of salt and ice, or by cold water in the jacket containing the pipe (Fig. 10—1).

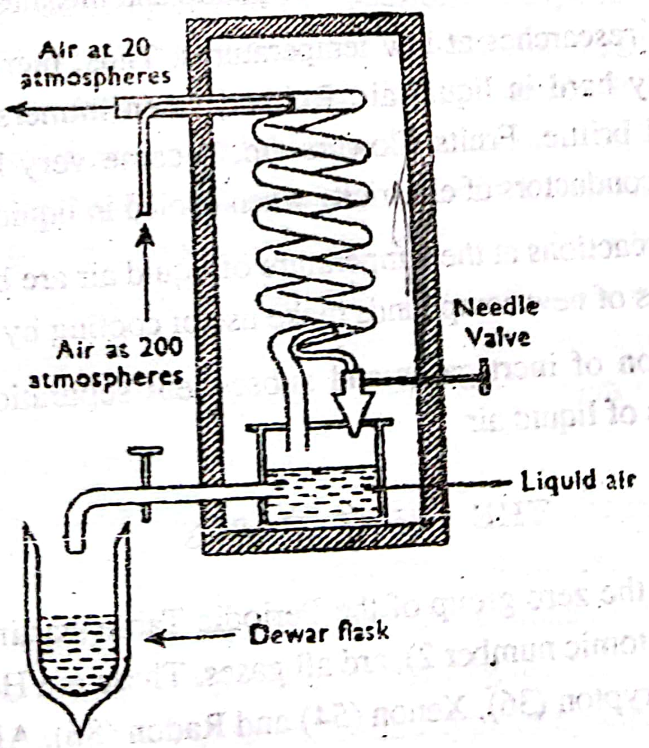


Fig. 10—1. A liquid air machine.

The cold compressed air is passed into the liquefying chamber through a needle valve where it expands suddenly to a pressure of about 20 atmospheres. This sudden expansion is accompanied by the absorption of heat and cools the air to a large extent due to Joule–Thomson effect. This cooled air is circulated round the spiral tube through the jacket, thereby further cooling the compressed air in the small inner coil of the liquefier. As the process continues, the air that escapes from the valve is colder than before, and finally the critical temperature is reached when the air becomes liquid.

Properties of liquid air

(i) Liquid air is a mobile liquid with a faint blue tinge.

(ii) Evaporates rapidly in the open with the absorption of a large quantity of heat. It is stored in Dewar flasks.

(iii) Liquid air is a mixture and, therefore, has no fixed boiling point. It boils at about –190°C (b.p. of oxygen, –182.5°C and nitrogen, –195.8°C).

(iv) Physical properties of many substances are changed in liquid air.

Applications of liquid air

(i) Manufacture of commercial oxygen, nitrogen and inert gases. Liquid oxygen is a fuel for rockets and jet-propelled planes and missiles.

(ii) Scientific researches at low temperatures. Thus, mercury freezes and becomes extremely hard in liquid air. Rubber, when immersed in liquid air, becomes hard and brittle. Fruits, flowers etc. become very hard. All metals become very good conductors of electricity when cooled in liquid air.

(iii) Chemical reactions at the temperature of liquid air are being carried out. Synthetic procedures of new compounds make use of cooling by liquid air.

(iv) Liquefaction of inert gases and subsequent separation by fractional distillation make use of liquid air.

THE INERT GASES

The elements of the zero group of the Periodic Table starting from helium, the second element (atomic number 2), are all gases. These are Helium (2), Neon (10), Argon (18), Krypton (36), Xenon (54) and Radon (86). All these gaseous elements are generally known as inert gases since normally they do not react with other substances and exist only in the free state. The atoms of these gases do not even form diatomic molecules, but remain as separate atoms in the gaseous state. These are also called *Noble gases* because of their property of remaining aloof from other elements. These are also known as *Rare gases* because of their presence in the atmosphere in extremely minute amounts (total of about 1% only).

The Discovery of the Inert Gases

The discovery of inert gases is a thrilling episode in the history of chemistry. Until the end of the nineteenth century it was taken for granted that the atmosphere had been fully explored and none thought for a moment of searching for a new element in the air. In 1785, Cavendish had observed that when an electric spark was struck between two electrodes in an enclosed volume of mixture of oxygen and common air, the nitrogen of the air combined with oxygen which could be absorbed in alkali solutions. But a small volume of the air, about $\frac{1}{120}$th part, could not be converted to nitrous acid and remained as residue. This important experiment of Cavendish had also passed into oblivion.

About a century later, Rayleigh in 1892, performed experiments for accurate determinations of the densities of gases, such as nitrogen, oxygen etc. Although the oxygen which he prepared by three different methods from chemical compounds or isolated from air had the same density, the results with nitrogen were puzzling. The atmospheric nitrogen was found to be slightly heavier (to the extent of about 0.5%) than the nitrogen prepared by chemical methods, such as from ammonium nitrite, urea, oxides of nitrogen or nitric acid. The normal density of chemical nitrogen is 1.2505 *g./l* whereas the atmospheric nitrogen has a density of 1.2572 *g. /l.* Rayleigh repeated the experiment of Cavendish and confirmed the presence of unabsorbed residue.

It was known that each element gives its characteristic spectrum and from the spectral lines one can identify the elements. The spectrum analysis is a sort of finger print method for the identification of elements. Rayleigh was rather astonished to find that residual gas left after sparking nitrogen and oxygen did not give the spectrum of nitrogen but an unfamiliar type of spectrum.

Willium Ramsay gained permission from Rayleigh to investigate into the chemistry of the atmospheric air. He passed air over red hot copper in order to remove oxygen and the residual nitrogen was passed over heated magnesium to find out whether it would be completely absorbed or not. After the gas was passed back and forth over heated magnesium taking all precautions to exclude dust, water vapour and carbondioxide, everything was absorbed except about $\frac{1}{80}$th part of the original volume. The experiments of Ramsay on chemical nitrogen and atmospheric nitrogen are given schematically as follows :-

$$\text{Air} \xrightarrow[-CO_2]{-H_2O} N_2 + O_2 \xrightarrow[-O_2\,(CuO)]{\text{heated Cu}} N_2 \xrightarrow[-N_2(Mg_3N_2)]{\text{heated Mg}} \text{Residual gas}$$

$$\begin{array}{c} NH_4NO_2 \\ \downarrow \\ NO + Cu \rightarrow \text{Chemical } N_2 \xrightarrow[-O_2 \text{ (if any)}]{\text{heated Cu}} N_2 \xrightarrow[-N_2\,(Mg_3N_2)]{\text{heated Mg}} \text{No residual gas at all} \\ \uparrow \\ NH_3 + Cl_2 \end{array}$$

Rayleigh and Ramsay examined the spectrum of the residual gas and observed groups of green and red lines never observed before in the spectrum of any gas, A detailed study of this residual gas was made. The density of the purified residual gas was found to be 19.94 (H=1), its atomic weight was determined and chemical properties were investigated and was found to have no chemical activity. In 1894, Ramsay and Rayleigh announced the discovery of a new element, the first inert gas, and it was named Argon, "the lazy one", because of its chemical inactivity. Later on, it was proved that this residual gas was not pure argon but contained a number of other gases also.

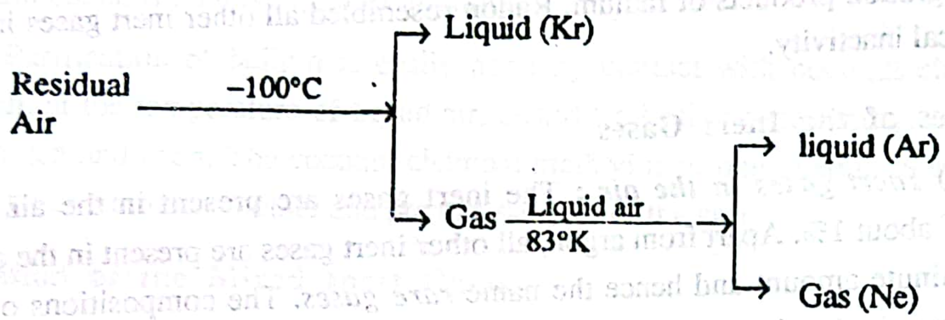
In the year 1868, the French astronomer Janssen came to India to observe a total eclipse of the sun. He examined the chromosphere of the sun by means of a spectroscope and noticed a bright yellow line D_3, which did not coincide with D_1 and D_2 lines of sodium. Lockyer concluded that the new line did not belong to any element then known to exist in terrestrial substances. He named it Helium (helios for the sun) and for about two decades helium was regarded as hypothetical element which might possibly exist only in the sun.

Xe - র‍্যামজে ট্রেভার্স

জ্যানসেন He - 1868
র‍্যামজে Ar - 1894
Ne - 1898

Kr - 1898 র‍্যামজে ট্রেভার্স
Radon - 1900 Dorn

In 1888, Hillebrand noticed that when the mineral uraninite or *cleveite* is heated with acid, an inert gas is evolved which he believed to be nitrogen and thus missed a great discovery. Ramsay repeated the experiments and obtained a sample of the gas by heating cleveite with dilute sulphuric acid. Nitrogen present in the gas was removed by the sparking method over caustic alkali. Ramsay identified the spectrum of this gas and confirmed the presence of helium in the minerals. Thus the terrestrial helium was discovered.



Ramsay and Travers observed that helium obtained from different minerals differed in density and by diffusion method separated the gases into two fractions differing in densities to a great extent. The heavier fraction gave the spectrum similar to that of argon and the lighter fraction was helium. Thus argon was also discovered in minerals.

After the discovery of argon and helium their positions in the Periodic Table presented a problem. It was suggested that helium with atomic weight 4 might possibly belong to a new group of elements. The possibility of the existence of one element between helium and argon and at least two or more of higher atomic weights were suggested. Since argon was discovered in the residual gas obtained after removing the oxygen and nitrogen, Ramsay and Travers suspected the presence of other gases of similar nature in the residual gas. Starting with liquid air, by fractional evaporation and spectral analysis of the fractions, they first discovered a new inert gas in 1898 which was named Krypton (meaning hidden). After working on the density of this gas, it was found that the new element belonged between bromine and rubidium.

Continuing their search for the lighter gas, the residual air or mainly argon in the liquid state was subjected to fractional distillation under reduced pressure.

The more volatile fraction gave a complex spectrum with many brilliant red lines. The blaze of crimson light brought honour and fame to Ramsay and Travers. The new gas was named Neon (the new one) in 1898.

Ramsay and Soddy, in 1903, made the sensational discovery that helium was also produced by the atomic disintegration of radium. Later on, it was shown that many radio-elements on disintegration produce helium.

Dorn, in 1900, discovered radium emanation (Radon) as one of the disintegration products of radium. Radon resembled all other inert gases in the chemical inactivity.

Sources of the Inert Gases

(1) Inert gases in the air **:** The inert gases are present in the air to a total of about 1%. Apart from argon, all other inert gases are present in the air in very minute amount and hence the name *rare gases*. The compositions of the inert gases in the air are :

Argon	0.932%
Neon	0.0015%
Helium	0.0005%
Krypton	0.0001%
Xenon	0.00001%

(2) Other sources of inert gases **:** Some minerals, such as uraninite, monazite, thorianite, cleveite etc. contain helium and also some argon which are evolved when the minerals are heated.

(3) The most important source of helium is the natural gas (mainly methane) from some petroleum springs.

(4) Inert gases are also present in some hot springs having their sources at great depths.

Isolation of Inert Gases

Helium: 1. Helium may be isolated from various sources and purified. The most important source of helium is the natural gas from petroleum springs in the U.S.A. and Canada. Helium is obtained from the natural gas by cooling to a very low temperature whereby all other gases present become solid or liquid and helium is left in the gaseous state.

2. Helium may be obtained from monazite by strong heating or by heating the mineral with dilute sulphuric acid. Helium thus obtained contains mainly other gases as impurity.

3. From hot springs helium may be collected by simple devices. This helium contains mainly argon as impurity.

Purification of helium is easily done by contact with coconut charcoal which, at the temperature of liquid air, absorbs all other gases except helium, hydrogen and neon. The coconut charcoal method is also applied to isolate the inert gases from one another and prepare samples of the gases.

Isolation of the Mixed Inert Gases

The mixed gases are allowed to come in contact with coconut charcoal in a bulk kept immersed in a cold bath in Dewar flask.

After about half an hour the unabsorbed gases are pumped off (Fig. 10—2).

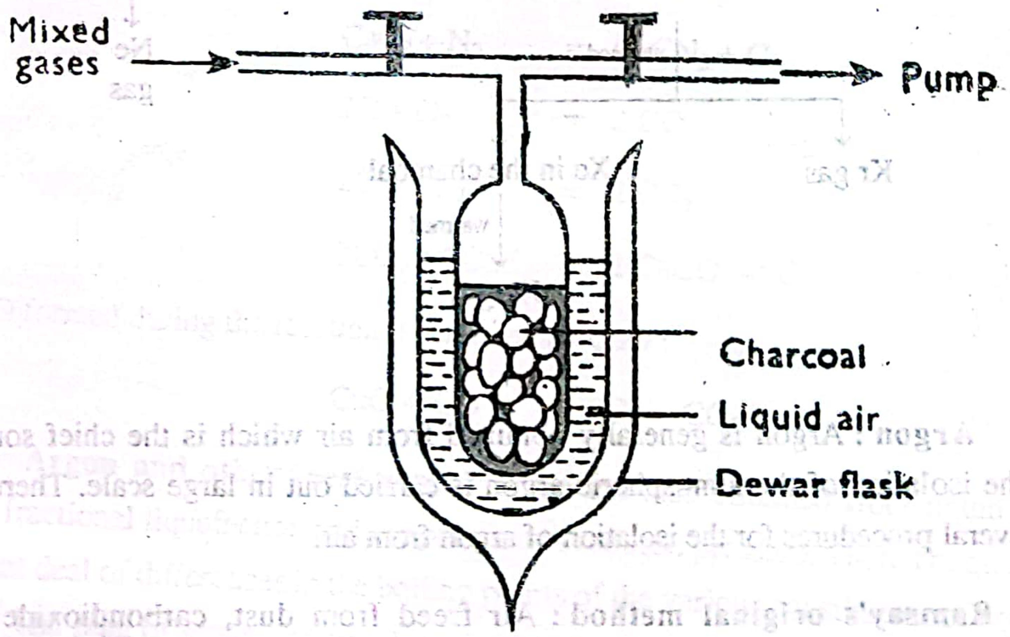
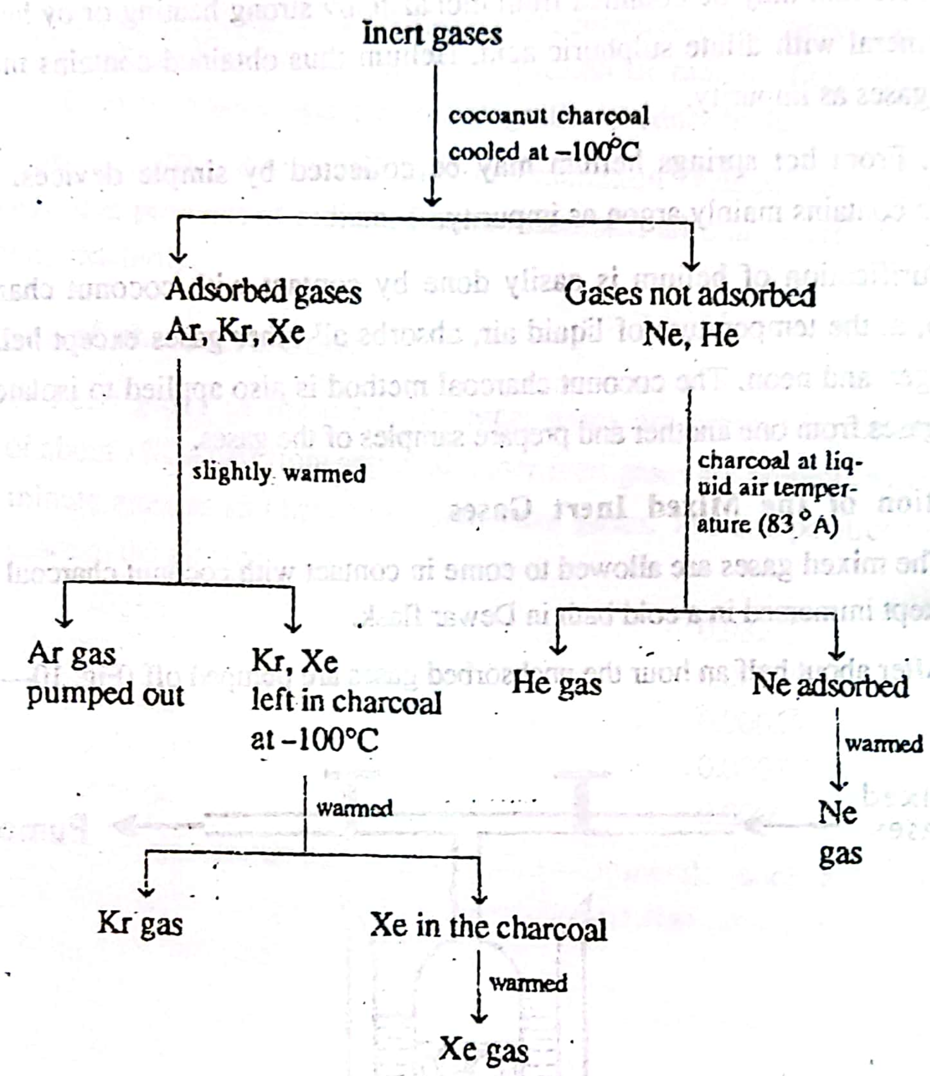


Fig. 10-2. Purification of inert gases (He) by coconut charcoal.

The plan of isolation of inert gases by this method is as follows :-



Argon : Argon is generally obtained from air which is the chief source. The isolation of the atmospheric argon is carried out in large scale. There are several procedures for the isolation of argon from air.

1. Ramsay's original method : Air freed from dust, carbondioxide and water vapour, is passed through a tube containing heated copper which removes oxygen (as CuO) and the issuing gas is then passed through heated magnesium which removes nitrogen (as Mg_3N_2). The residual gas contains mainly argon and other inert gases and is purified.

2. Rayleigh's method : A mixture of 11 volumes of oxygen and 9 volumes of air is subjected to electric discharge from a transformer of 6000-8000 volts, thereby nitrogen and oxygen of air combine to form nitric oxide. A fountain of caustic soda solution is discharged through a tube in the inside of the vessel to dissolve the nitric oxide formed. Impure argon was obtained by removing excess oxygen by means of alkaline pyrogallol solution.

3. Calcium carbide process : A mixture of 90 parts calcium carbide and 10 parts calcium chloride is taken in an iron retort and heated to redness (800°C). Air is passed through the heated mixture. The issuing gas is passed over red hot copper oxide (CuO) to convert CO to CO_2 and then through solid KOH to absorb CO_2 and moisture. Final traces of moisture is removed by means of P_2O_5. The gas, rich in argon, is stored in gas holders. The reactions that occur, remove oxygen and nitrogen as follows :

$$CaC_2 + N_2 = CaCN_2 + C$$

$$2C + O_2 = 2\,CO$$

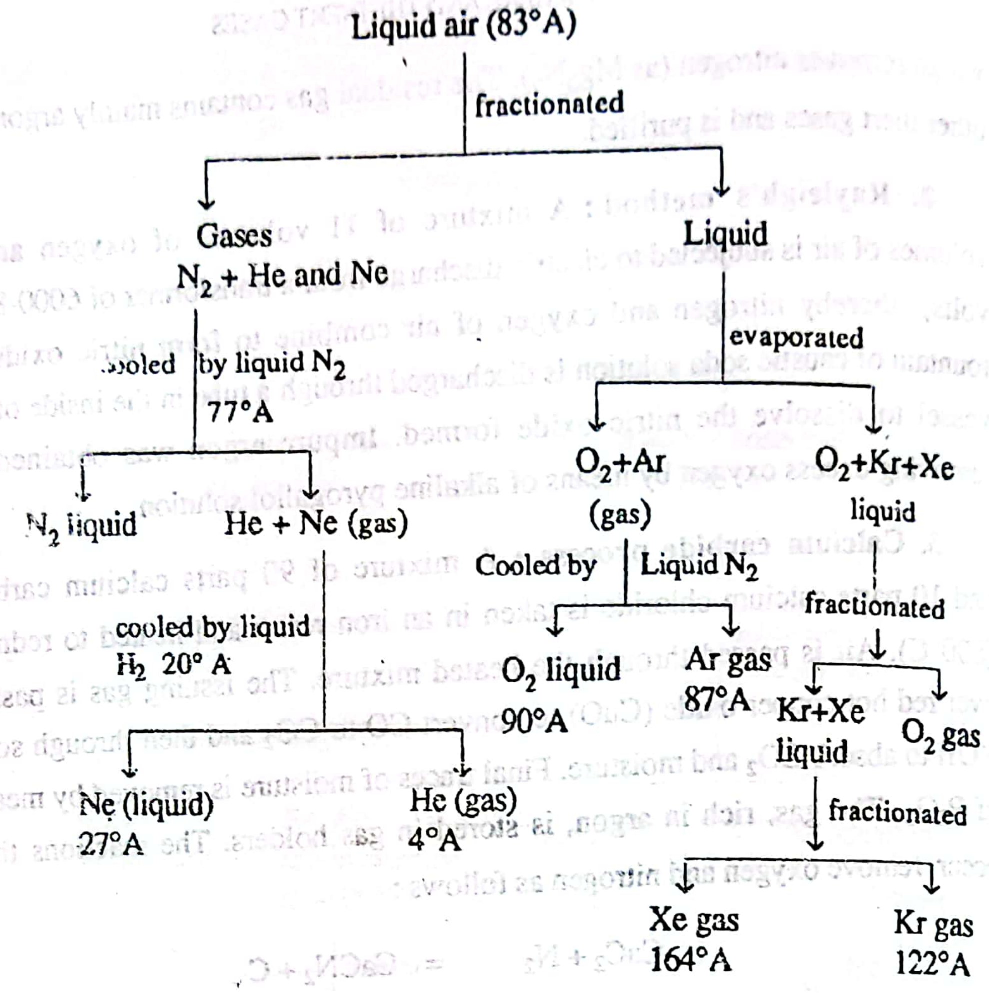
$$2C + 2O_2 = 2\,CO_2$$

$$3CO_2 + 2CaC_2 = 2\,CaCO_3 + 5C$$

CO formed during the reaction is removed by CuO :

$$CuO + CO = Cu + CO_2$$

Argon and other inert gases : These are also obtained from liquid air by fractional liquefaction and evaporation at reduced pressure. There are quite a great deal of differences in the boiling points of the various constituents of liquid air. The plan of separation of all the inert gases may be outlined as follows and industrially used for the separation of all the inert gases.



Radon : Radon resembles in all other properties to the family of inert gases. It differs only in its radioactivity and undergoes spontaneous disintegration.

Radon is continually formed by the radioactive change of radium metal and its compounds under all conditions by the loss of He atoms or α-particles. The equation for the change is,

$$_{88}Ra^{226} \;=\; _{86}Rn^{222} \;+\; _{2}He^{4}$$

Radon is best produced from an aqueous solution of a radium salt. Radium salt is dissolved in water and the solution is allowed to stand. On boiling the solution, radon is evolved along with some helium, oxygen and hydrogen.

The Monoatomic Character of the Inert Gases.

(1) The weights of 22.414 litres of the inert gases at N.T.P. have been found to be :

He	4.003 g.
Ne	20.183 g.
Ar	39.94 g.
Kr	83.80 g.
Xe	131.30 g.
Rn	222.00 g.

The above figures, therefore, give the molecular weights of the different inert gases. But these are also their respective atomic weights. It has already been stated that ordinarily the inert gases are devoid of chemical activity.

(2) The monoatomic nature was also proved by the measurement of specific heats of the gases. A gas molecule if it is diatomic or more complex molecule, by virtue of its three forms of motion, i.e., translational, vibrational and rotational, would require greater amount of energy to raise its temperature by 1°C than a molecule which is capable of only one kind of motion, e.g., translational motion. The inert gases have lower specific heats than hydrogen or oxygen and it is concluded that they occur as individual atoms. It has been shown that all the gases in which the ratio between the specific heat at constant pressure, C_p, and specific heat at constant volume, C_v, (C_p/C_v) is equal to about 1.667, are monoatomic. The ratio for diatomic gases is about 1.4 and for triatomic gases 1.3. Experimental determinations of C_p/C_v of all the inert gases have given values ranging from 1.64 to 1.68. Hence the inert gases are monoatomic.

The electronic structures of the inert gases indicate that all the gases have electronic structures which are paired and have completely filled s or s and p orbitals as given in Table 10.2.

Table 10.2. Electronic structure of the inert gases.

At. No.	*Elements*	*Electronic configurations*
2	He	$1s^2$
10	Ne	$1s^2 2s^2 2p^6$
18	Ar	$1s^2 2s^2 2p^6 3s^2 3p^6$
36	Kr	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
54	Xe	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6$
86	Rn	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^6$

Thus it may be concluded that an electronic structure represents an stable system in which all the electrons are paired and s and p orbitals in the outermost energy levels are completely filled. The elements possessing such electron arrangements must have a very stable atom and hence devoid of chemical activity. This fact is proved by the ionization potential of the inert gases as shown in Fig. 3—1.

Properties of the Inert Gases

1. Physical Properties

(i) All the inert gases are colourless, odourless and tasteless. They are somewhat soluble in water. Helium is the least soluble of all gases. All the gases can be liquefied and helium is the most difficult to liquefy. Liquid helium has been obtained first by Onnes in 1907 by the Joule-Thomson effect on the gas cooled previously to 15°A. The colourless liquid has very low density and has the lowest boiling point of all liquids, 4°A. Solid helium has been obtained by cooling liquid helium to 1°A under pressure. Liquid helium exists in two forms: He-I and He-II having a transition point but no triple point. Metals in liquid helium become superconductors of electricity. Liquid He-II has lowest viscosity and can flow upward along the surface of a glass container.

(4) Radon gas glows strongly emitting heat and energy. Liquid and solid radon are colourless but glow with a bluish tinge in the dark.

The physical properties of the inert gases are summarized in Table 10.3.

Table 10.3. Physical properties of the inert gases.

Properties	He	Ne	Ar	Kr	Xe	Rn
1. Atomic Number	2	10	18	36	54	86
2. Electrons in the outermost levels	s^2	s^2p^6	s^2p^6	s^2p^6	s^2p^6	s^2p^6
3. Atomic wt.	4.0	20.2	40	83.8	131	222
4. Atomic radius Å	0.93	1.60	1.91	2.0	2.2	—
5. Melting point °C	−272	−249	−187	−157	−112	−71
6. Boiling point °C	−269	−246	−186	−153	−107	−62
7. Critical temp. °C	−286	−220	−117	−63	−15	−104
8. Critical pressure (atmospheres)	2.26	26.9	48.0	54.3	58.2	62.4
9. C_p/C_v	1.65	1.64	1.65	1.69	1.67	—
10. Colour of spectra	Yellow	Red	Orange	Green	Blue	—

A comparison of the boiling points of the inert gases with other substances of comparable molecular weights is given in Table 10.4 to show the extremely low values for the inert gases.

Table 10.4. Comparison of the boiling points (b.p.) and molecular weights (M.W.) of the inert gases with other comparable substances.

Substances	*M.W.*	*b.p. (K)*
He	4	4.2
H_2	2	20.3
Ne	20	27
CH_4	16	92
Ar	40	87
HCl	37	189
Kr	84	121
CF_4	88	135
Xe	131	164
n-C_9H_{20}	128	424
Rn	222	211
ICl_3	233	350

II. Chemical Properties

The electronic configuration and the nature of the inert gases: The chemical activity and the valence of an element depends upon the electronic configuration, particularly upon the type, the number and the arrangement of the electrons in the outermost energy level. The number of electrons in the outermost level of the inert gases is 8 derived from s^2p^6 arrangement. In the case of helium it is 2 having $1s^2$ electrons. Since these arrangements represent completed electronic level and account for chemical inactivity because of no tendency to alter the electronic arrangements by transfer or sharing of electrons, therefore, the inert gases do not even combine among themselves to form molecules but exist in monoatomic conditions.

The atoms of the inert gases have no electron affinity and do not gain ~~electrons from~~ reducing agents. They have higher ionization potential than those of any other elements and thus do not tend to lose electrons to oxidizing agents. On the other hand, many ions assume the stable electronic arrangement of the inert gases.

Compound of the Inert Gases

In spite of the inert character of the inert gases, attempts have always been made to force them to enter into chemical combination by using unusual conditions with success. The tendency of compound formation by inert gases increases as the atomic number increases. Inert gas with higher atomic number have d orbitals available which participate in bond formation. He, Ne and Ar show less tendency to form compounds in view of low bond energies of their compounds. Xe, by far, gives large number of compounds while Rn chemistry is rather complicated because of its radioactive nature.

(1) Boothe and Wilson on the basis of thermal analysis showed the existence of a series of argon-boron trifluoride compounds at low temperatures :

$Ar : BF_3$, $Ar : 2BF_3$, $Ar : 3BF_3$ and so on.

These compounds have similar bonds as in the following molecules :

$NH_3 : BF_3$ and $(CH_3)_2O : BF_3$

(2) The dipole interaction of H_2O molecule may polarize an inert gas and hydrate formation has been claimed having the following formula and exists at low temperatures and high pressures :

Ar : [illegible] $Kr : xH_2O$ $Xe : xH_2O$ where x is 1 to 6.

(3) [illegible] (from helium) of some metals have been made, such as HgHe, $HgHe_2$, WHe_2, FeHe etc. These "compounds" may be alloys in which small helium atoms occupy the interstitial positions in the crystal lattice and may not be true chemical compound.

(4) The inert gases become incorporated into the crystals of hydroquinone the molecule of which acts like a *cage*. These types of compounds are known as *clathrates* or cage compounds. They break up when the crystals are melted or dissolved in water; thereby the free gas is released.

(5) More recently xenon has been shown to form definite compounds particularly with the most electronegative element fluorine. XeF_4 has been isolated in pure crystalline form. Other fluorides such as XeF_2 and XeF_6, have also been made. Oxygen is also shown to form compounds with xenon. XeO_3, $XeOF_4$ and XeO_2F_2 have been isolated from the reaction products of xenon fluoride and water : $XeF_6 + H_2O \rightarrow XeOF_4 + 2HF$ and

$$XeOF_4 + 2H_2O \rightarrow XeO_3 + 4HF.$$

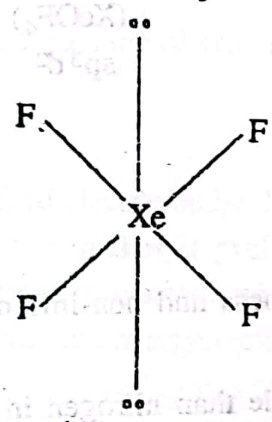


Fig. 10—3. Structure of XeF_4.

The structure of stable XeF_4 molecule has been found to be square planar with Xe—F bond = 1.93 Å. Since there are four pairs of electrons (8 electrons) in the outermost energy level of Xe, the formation of XeF_4 crystals can be explained on the basis of octahedral arrangement using sp^3d^2 hybridized orbitals of Xe having two axial positions occupied by two electron pairs as given in Fig. 10–3.

The formation of Xe—F bonds in XeF_4 may be shown as follows on the basis of electron arrangements :—

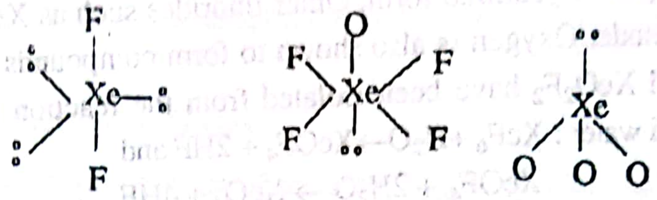
Xe—$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6$

Xe—Outermost energy level—$5s^2\ 5p^6$

	$5s^2$	$5p^6$			$5d^0$				
Xe (ground state)—	↑↓	↑↓	↑↓	↑↓	—	—	—	—	—
Xe (excited states)—	↑↓	↑↓	↑	↑	↑	↑	—	—	—
XeF_4—	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓			
			F	F	F	F			

sp^3d^2

Other compounds of Xe are formulated as follows :



(XeF_2) sp^3d ($XeOF_4$) sp^3d^2 (XeO_3) p^3d

Uses of the Inert Gases

1. Uses of Helium :

(a) Because of its lightness and non-inflammability, helium is used for filling observation balloons.

(b) Helium is less soluble than nitrogen in the blood. Hence mixture of helium and oxygen are used by sea divers. This overcomes the disadvantage of using air at high pressure for respiration, because the nitrogen of air gets dissolved in the blood at high pressure and on surfacing the pressure is released but the dissolved nitrogen forms a pathological condition known as *bends* due to the formation of bubbles of nitrogen in the blood giving sudden pain.

(c) Mixtures of helium and oxygen are also used in the treatment of respiratory diseases such as asthma.

(d) Helium is used for inflating tyres of large aeroplanes.

(e) It is also used as an inert atmosphere for the melting and welding of easily oxidizable metals.

(j) Liquid helium produces lowest temperature and is used for scientific research.

(g) It is used in tube lights, vacuum drying etc.

2. Uses of Neon :

(a) Neon is used in neon lamps and signs. When an electric current is passed through neon under low pressure, it emits a brilliant orange-red glow which penetrates through mists and fogs. This is, therefore, used as beacon lights for air pilots.

(b) Neon is now-a-days extensively used in advertisement signs by coloured lights and in fluorescent tubes. The colour of neon in a lamp or tube may be changed by mixing with argon and mercury vapour and by using tubes made of glasses of special compositions. Lights of different shades can thus be obtained.

(c) Neon is used in television sets, radio-photography, sound movies etc. where ready responses to changes in electrical potential are required.

(d) Neon is also used for stimulation of growth of plants and flowers in the green houses.

3. Uses of Argon :

(a) Argon is used in gas-filed electric bulbs. It lowers the heat conductivity and complete chemical inertness makes it preferable to nitrogen. Thus the volatilization of tungsten filament is reduced and prolongs the life of the lamp. Ordinary tube lights contain a mixture of argon and mercury vapour

(b) With oxygen argon is used in welding to create an inert atmosphere. Argon is now widely used for welding of aluminium and stainless steel.

(c) Geiger-Counters are also filled with argon.

4. Uses of Krypton and Xenon :

(a) Krypton-xenon photographic flash tube has been developed for taking high speed photographic exposures. In cinematography, krypton flash is used to produce intense light.

(b) Krypton mixed with neon gives blue light in the electric tubes.

(c) Xenon imparts green colour to the electronic tube lights.

(d) Krypton is used in ionization chambers for cosmic ray measurements.

(e) Xenon has recently been used for making Bubble Chambers for detecting γ-rays, neutrons and other nuclear particles.

5. Uses of Radon :

Radon differs from other inert gases in its radioative properties. Because of this property radon is used in the radiotherapy of malignant growth. It is particularly suitable in the non-surgical treatment of cancer. Radon is much more radioactive than radium and the therapeutic preparation of radon in small tubes is technically known as *seeds*.

QUESTIONS AND PROBLEMS

1. How were helium. neon, and argon discovered.? What are the properties and uses of these gases ?
2. (a) Name the inert gases. Explain why they are inert and discuss their position in the Periodic Table of elements.
   (b) What are the important applications of the inert gases?
3. (a) Give a short account of the discovery of inert gases of the atmosphere. Why are these so called?
   (b) Discuss the important properties of the inert gases and mention some of their uses.
4. (a) What are inert gases? Show that the Bond Orders in He_2 and Ne_2 are zero.
   (b) Write a short account of the discovery of inert gases.
   (c) Explain why inert gases are chemically inactive.
   (d) Mention four uses of inert gases.
5. Give a short historical accounts of the discovery of Argon and Helium. How can they be separated and to what industrial use they have been put? Discuss the position of inert gases in the Periodic Table.
6. Describe the methods employed indicating the physico-chemical principle involved in the separation of rare gases of the atmosphere. Indicate their importance in chemistry.
7. What physical principles are employed in the liquefaction of air? What are the uses of liquid air?
8. Relate the chemical inactivity of the inert gases to their electronic structure.
9. How is argon obtained in a pure state? State its uses.
10. Give a brief account of the discovery of inert gases, their properties and uses.
11. Discuss the important properties of the inert gases and mention some of their uses.
12. Write notes on :- Discovery of inert gases and its impact on periodic classification.
13. Discuss "Elements of zero group are highly inert".
14. Why the tendency for compound formation of inert gases increases as the atomic number of elements increases ?
15. Write equation for the reaction of XeF_4 with H_2O.
16. Explain why $XeBr_2$ has not been prepared.
17. Compare the structure of ICl_2^- and $XeCl_2$.
18. $O_2^+PtF_6^-$ isolated by Bartlett gave rise to the preparation of $Xe^+PtF_6^-$. Compare the ionization energies of O2 (278.5 Kcal/mole) and of Xe (279.7 Kcal/mole) and the oxidation potential of O2 (g) and Xe(g) are 12·2 ev and 12'12 ev respectively to justify the reason of formation of the inert gas compounds.