

9

NITROGEN AND PHOSPHOROUS

WHAT WE HAVE LEARNT

- Ammonia combines with hydrogen chloride to give ammonium chloride.
- Acids are proton donors. Bases are proton acceptors.
- Concentration, temperature, pressure and presence of a catalyst affect the speed of chemical reactions.

NITROGEN AND PHOSPHOROUS

Nitrogen is the most abundant element present in the atmosphere. This element is placed in p block and belongs to the 15th group of the periodic table. Nitrogen, phosphorous, arsenic, antimony and bismuth are the elements in this group. Nitrogen and phosphorous are of much industrial importance. These elements are essential for the manufacture of chemical manures. Other members of this group also have certain uses.

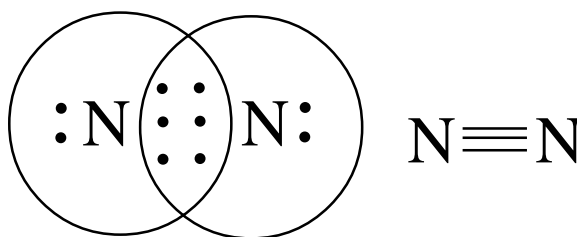
The element nitrogen is an important constituent of the human body. Proteins are made of amino acids which contain nitrogen. Nitrogen does not react with other substances in the soil and atmosphere as it is inert. Through the action of some micro organisms, the atmospheric nitrogen turns into nitrates and then back to nitrogen. This is called nitrogen cycle and from this process, life-cells get nitrogen which is essential for them. Ammonia is a nitrogen compound and it is used largely in laboratories. The chemistry of nitrogen and ammonia are dealt with in this chapter.

You know the position of nitrogen in the periodic table. Complete the following table.

Atomic number of nitrogen	
Subshell electronic configuration	
Period, group, block	
Physical state	
Colour	
Molecular formula	
Normal oxidation state	
Electronegativity	

Table 9.1

The nitrogen bond can be represented as follows:

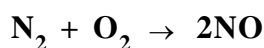


Did you observe the triple bond between the two nitrogen atoms? What type of chemical bonding is this? High energy is required to break this triple bond. Now you can explain why nitrogen is inert under normal conditions.

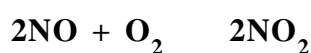
Nitrogen in atmosphere and soil

Plants need nitrogen to produce protein molecules. But from where do they get nitrogen? The reactivity of nitrogen is very low. At ordinary temperatures it does not take part in chemical reactions. So, plants cannot use atmospheric nitrogen. Plants can get this essential element only from the soil. But the presence of nitrogen compounds in the soil is very low. As a result, the nitrogen in the soil gets used up very quickly. This is why nitrogen manures are necessary. The chief ingredient of nitrogen fertilizers is ammonia and it is prepared from atmospheric nitrogen.

When lightning occurs, high temperature is produced in the atmosphere. As a result, atmospheric nitrogen and oxygen combine to form nitric oxide.



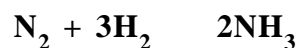
The nitric oxide thus formed combines with atmospheric oxygen producing nitrogen dioxide.



The oxides of nitrogen present in the atmosphere dissolve in rain water, reach the earth and produce certain salts of nitrogen in the soil. This helps the plants to grow. Thus, we can say that lightning is a blessing to vegetation.

Ammonia (NH₃)

Nitrogen combines with hydrogen to form ammonia which is an important industrial compound.



Mix a little calcium hydroxide (Ca(OH)₂) and ammonium chloride (NH₄Cl) in a watch glass using a glass rod. Smell the gas evolved. This pungent smelling gas is ammonia. Has it any colour? Introduce a moist red litmus paper into this gas. Note the change. What happens if a glass rod dipped in hydrochloric acid is brought in contact with this gas? Record your observations in your science diary. During the putrefaction of certain bio-materials, the characteristic smell of ammonia is produced.

Laboratory preparation of ammonia

Ammonia is prepared in the laboratory by heating a mixture of ammonium chloride (NH₄Cl) and calcium hydroxide (Ca(OH)₂). The apparatus for the preparation is shown below.

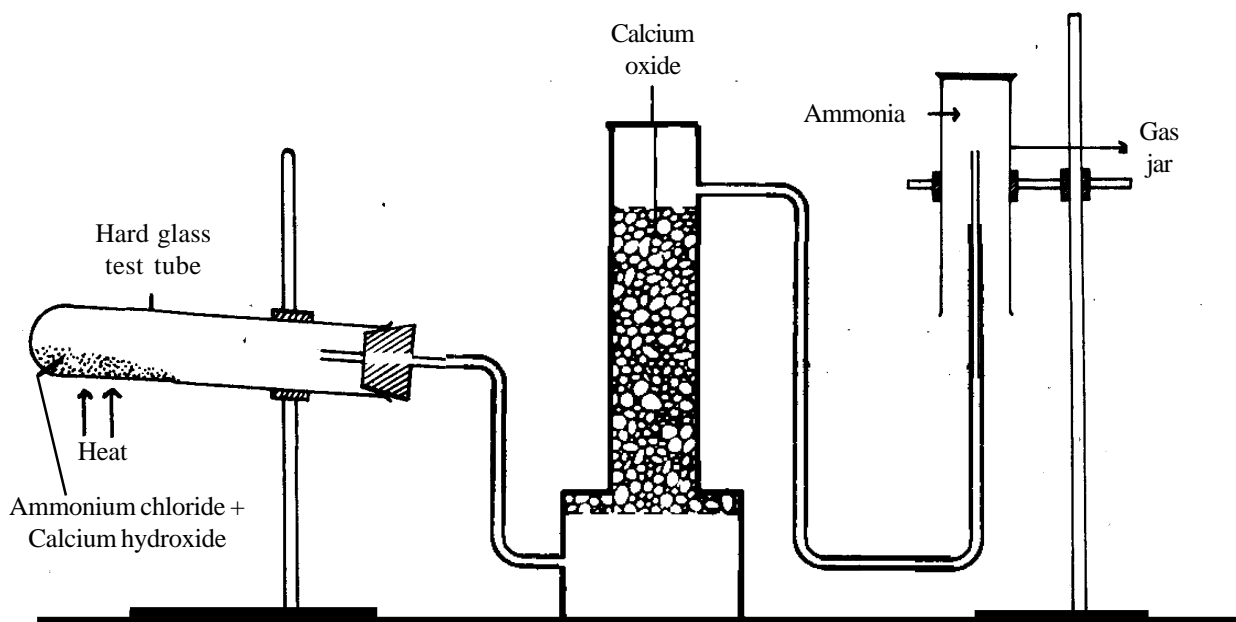
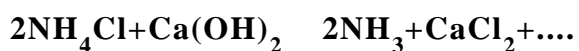


Figure 9.1

Write down the chemical equation of the above reaction.



Observe the above diagram carefully and answer the following:

- Why should we pass ammonia through the drying tower before collecting the gas?
- What is the drying agent used?
- Why is the gas jar placed mouth downwards? Is the density of ammonia higher or lower than that of air?
- Why is the hard glass test tube kept slightly inclined?

Record your answers in your science diary.

Fountain experiment

Do the fountain experiment using ammonia gas. See the diagram below.

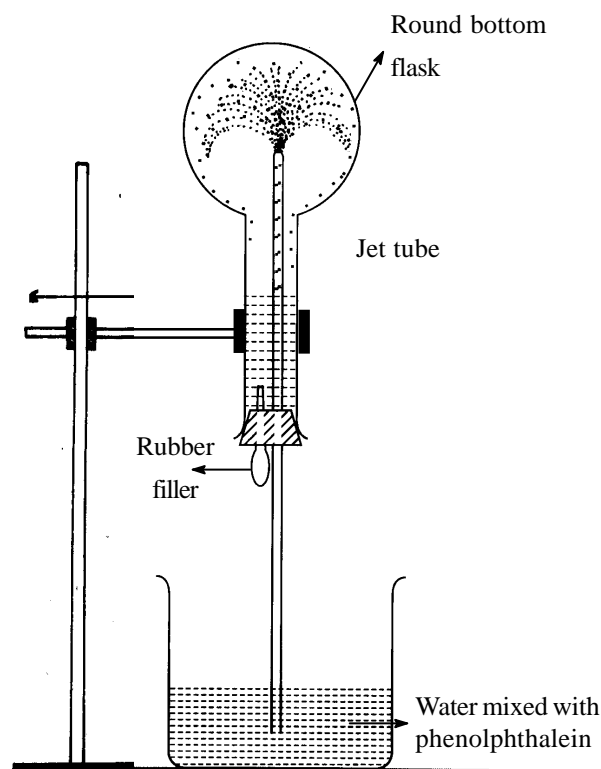


Figure 9.2

Add two drops of phenolphthalein into the water taken in the vessel. When water is dropped into the flask using a filler, a fountain is seen. How is it formed? Note the change in colour of the water fountain.

In the science diary write your observations regarding the physical properties of ammonia.

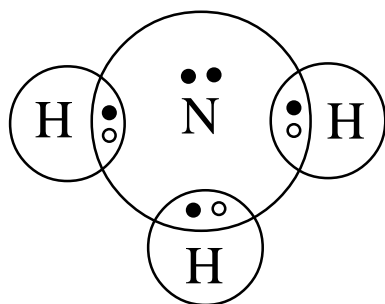
- **State**
- **Colour**
- **Smell**
- **Solubility**
- **Density**

Basic property

You have already seen that ammonia changes red litmus into blue. Also, you have observed the colour change in the fountain experiment. What property of ammonia is shown here?

You have learnt that the presence of OH^- ions is the cause of basic nature. Are there any OH^- ions in dry ammonia? Why does it show basic property?

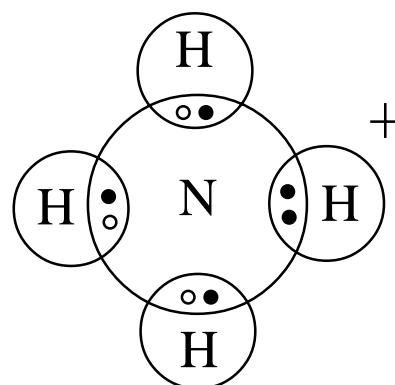
The chemical bonding in ammonia molecule can be represented as follows:



Has nitrogen completed its octet? Does nitrogen use all the electrons in its outer shell for chemical bonding? How many pairs of electrons are there in nitrogen that are not taking part in chemical bonding?

The pair of electrons that is not involved in chemical bonding is called the lone pair.

Let us study what happens when ammonia reacts with H^+ ions in acids. The lone pair in ammonia bonds with H^+ ions in acids forming ammonium ions (NH_4^+).



Here ammonia receives H^+ ions and hence it acts as a base. Ammonia combines with H^+ ions because it has a lone pair. When a molecule which shares its lone pair in chemical bonding, that molecule which gives off its electrons is called Lewis base.

The molecule or atom which accepts the lone pair is called Lewis acid.

Write down the reactions of ammonia with the acids given below:



Test for ammonia

You know what happens when a glass rod dipped in hydrochloric acid is brought in contact with ammonia. You can identify ammonia and its salts using Nessler's reagent. Take a little Nessler's reagent in a test tube and add 3 or 4 drops of ammonia solution. What do you see?

Uses of ammonia

List the chemicals that can be prepared using ammonia.

- Manufacture of nitric acid
- As a refrigerant
- As a source of nitrogen
- Manufacture of nylon, plastic, rayon, dyes etc.

What are the other uses?

Reversible and irreversible reactions

Take 5 grams of ammonium chloride in a test tube and heat it. Show a moist red litmus paper at the top of the test tube. Note the colour change. Bring a glass rod dipped in hydrochloric acid to the top of the test tube. What do you see? Do you recognise the gas with the basic property? Now, show a glass rod dipped in ammonia solution to the top of the test tube. What change is seen? Presence of which gas is indicated? We have seen a gas that is acidic in nature.

Write down the equation showing the decomposition of ammonium chloride.

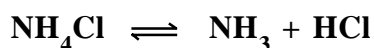


See the white particles that are deposited on the inner sides of the test tube.

You know that ammonia reacts with hydrogen chloride. What are the products formed when ammonium chloride decomposes? These products recombine inside the test tube. Now you know how ammonium chloride particles are formed in the sides of the test tube. Write the chemical equation of this reaction.



The decomposition of ammonium chloride on heating and the recombination of the product thus formed may be written in a single equation.



A process in which reactants combine to form products is called a forward reaction. A process in which the products recombine to form reactants is called a backward reaction.

In the above equation the upper arrow shows the forward reaction and lower arrow shows the backward reaction.

Are the above reactions different from the reactions you have studied before? What change came about in the reactants? Did the products change? This is a change that occurs in the forward and backward direction simultaneously. This type of reactions are called reversible reactions.

Are all chemical reactions of the same type?

Look at the following chemical equation.



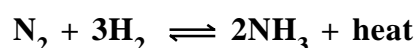
Can we prepare sodium hydroxide and hydrochloric acid (reactants) by treating sodium chloride with water? Discuss.

Such reactions are called irreversible reactions. They take place only in one direction.

Find out more examples for irreversible and reversible reactions.

Ammonia and chemical equilibrium

We have already seen that the reaction in which nitrogen and hydrogen combine to form ammonia has much industrial importance. This process of preparing ammonia for the manufacture of chemical manures is known as Haber process. See the following equation.



One mole of nitrogen and 3 moles of hydrogen combine to form 2 moles of ammonia. That is, 28 g of nitrogen combining with 6 g of hydrogen should give 34 g of ammonia. But, actually this yield is not obtained. Only half of the amount expected is formed in the system. Part of the ammonia produced decomposes and produces the reactants. This is why we cannot change the whole reactants to products. Is there any method to get a maximum yield of ammonia?

In the beginning, the system contains only the reactants. What will be the concentration of the products then? What is the direction of the reaction? Forward or backward? What will be the rate of the backward reaction? As the reaction proceeds how does the

Haber and ammonia

The German scientist Fritz Haber developed the method of industrial production of ammonia. Haber was searching for an abundantly available nitrogen compound that can be used in the manufacture of explosives and fertilizers. This led him to the invention of Haber process. In early days, nitroglycerine which can be prepared using sodium nitrate was used to prepare explosives. When nitroglycerine became scarce scientists began to explore nitrogen compounds for the same use. Haber was trying to make ammonia by combining nitrogen and hydrogen. He discovered that if pressure, temperature and catalysts are properly regulated, the inactive nitrogen will react with hydrogen to form ammonia. In 1905, Haber prepared ammonia using atmospheric nitrogen. This led to an industrial revolution in the manufacture of ammonia. Thus, industries related to explosives and manures, grew up around the world.

concentration of the reactants and products change? What happens to the rate of backward reaction? Write down the changes in the forward and backward reactions as the reaction goes on.

Compare your conclusions with the graph shown below.

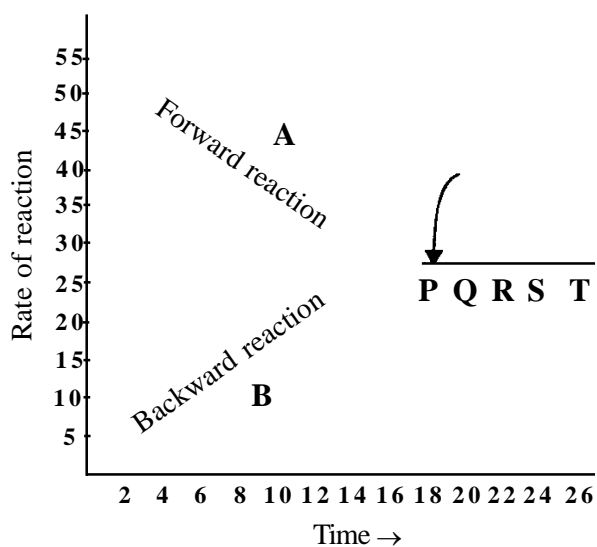


Figure 9.3

In this graph A denotes the forward reaction and B the backward reaction. What will be the speed of forward reaction at point P? Similarly, what will be the speed of backward reaction at P?

Tabulate the time taken and rate of the forward and backward reactions at points P, Q, R, S, T.

Point	Time	Rate of forward reaction	Rate of backward reaction

Table 9.2

The state when the rate of both the forward and backward reaction becomes equal is called equilibrium. At equilibrium, the rate of forward reaction will be the same as that of the backward reaction. After the attainment of equilibrium, will there be any change in the concentration of the reactants or the products? Can you explain?

Still the system contains both the reactants and products. Even then, why does not concentration of the products increase as a result of forward reaction? The backward reaction does not make any change in the concentration of the system. Why? Can you write down the features of the state of equilibrium?

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Since the formation of ammonia is a reversible reaction, the system attains equilibrium. There will not be any change in the concentrations of both the reactants and products after the system attains equilibrium. To make the process economically viable maximum quantity of NH_3 is to be made. The state of equilibrium should be changed for this.

You have already learnt the factors that affect the rate of chemical reactions. Write them down.

- pressure (only in the case of gases)
-
-

Le Chatelier principle

In the production of ammonia, both the reactants and the products are gases. So, pressure has its effect in this reaction. As in the case of concentration, temperature and pressure can affect the equilibrium.

Henry Le Chatelier put forward a principle regarding the effect of concentration, temperature and pressure on equilibrium.

If a system in equilibrium is subjected to a change of pressure, temperature or concentration, the equilibrium is shifted in such a way as to cancel the effect of that change. This is known as Le Chatelier principle.

Discuss how Le Chatelier's principle can be applied in the manufacture of ammonia.

Chemical equilibrium and concentration

If the concentration of one of the reactants is increased, what will happen to the forward reaction of a system at equilibrium? What will happen if the concentration of the product is increased?

Is it not clear that the rate of forward reaction increases if the concentration of the product is reduced?

Tabulate your observations when the concentration of a system at equilibrium is changed.

Concentration of reactants increases	Speed of forward reaction increases
Concentration of products increases	
Concentration of reactants decreases	
Concentration of product decreases	

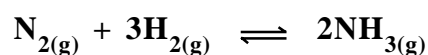
Table 9.3

If the concentration of the products decreases, in which direction should the reaction proceed so as to increase the concentration of the products?

In the manufacture of ammonia, if ammonia is liquefied and removed from the reaction site, will it increase or decrease the rate of forward reaction?

Chemical equilibrium and pressure

You know that the influence of pressure is limited to gases only. Take the manufacture of ammonia as an example.



Here, what happens to the total number of molecules in forward and backward reactions?

Forward reaction

4 molecules of reactants **2 molecules of product**

Backward reaction

2 molecules of product **4 molecules of reactants**

How is the molecules present in fixed volume of gas related to pressure? Will the pressure of a gas increase or decrease with the increase in the number of molecules?

When the pressure of the system is increased during the preparation of ammonia, naturally the system readjusts to cancel the effect of pressure. That is, the reaction will speed up in the direction where there is a decrease in pressure.

Which reaction (forward or backward) should be speeded up so as to decrease the pressure? Why? The changes that occur when the pressure of the system is increased, is tabulated below.

Forward reaction	speed increases
Total number of molecules	decreases
Volume	decreases
Quantity of ammonia	increases

Table 9.4

If the pressure of the system is reduced, what happens? Complete the following table:

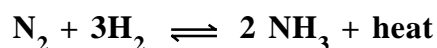
Forward reaction
Total number of molecules
Volume
Quantity of ammonia

Table 9.5

Is it not clear why pressure is increased up to 1000 atmospheric pressure during the manufacture of ammonia?

Chemical equilibrium and temperature

You know that energy changes occur during chemical reactions. In the preparation of ammonia, the forward reaction is exothermic. What about the backward reaction? Indicate your answers in the equation.



When temperature of a system is increased the system tries to cancel its effect by making the process of absorbing heat (endothermic reaction) faster.

How does this affect the production of ammonia? Which reaction is endothermic? Forward or backward? What happens to the system when the temperature is decreased?

The decrease in temperature favours forward reaction, but at low temperatures nitrogen is inert. So the reaction should be carried out at the optimum temperature of 500°C.

Chemical equilibrium and catalyst

You know what is a catalyst. Spongy iron is used as a positive catalyst in the manufacture of ammonia through the reaction of hydrogen and nitrogen. When iron is used at the beginning of the reaction, what change takes place in the forward reaction? What about the yield? What will happen when the yield of ammonia is increased?

When catalyst is used, what change in time will take place in attaining equilibrium?

Now is it clear that when a catalyst is used, the system attains the equilibrium faster.

What happens if a catalyst is used in a system which has already attained equilibrium? Formation of more products increases the backward reaction. As the forward reaction increases, backward reaction also automatically increases. That is, there will not be any change in the state of equilibrium.

Phosphorous

Phosphorus is a member of the nitrogen family and it is more reactive than nitrogen. It is a non-metal. This element is essential for the growth of plants and animals. It is also used in the manufacture of manures.

Phosphorus shows allotropy. White phosphorus and red phosphorus are its allotropes.

Dissolve a small piece of white phosphorus in carbon disulphide. Dip a filter paper in it and expose it to air. What do you see? The solvent carbon di sulphide is highly volatile. See the reaction of the remaining phosphorus with air.

Why is white phosphorus kept in water? What is the solvent of white phosphorus? What is the smell of white phosphorus? Is this smell familiar to you? What about its colour? Is it white as its name indicates? Expose a small piece of phosphorus in a dark room. This element is called 'phosphorous' as it means "something

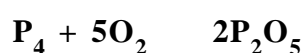
which carries light". White phosphorous is highly poisonous and it must be handled very carefully.

You might have noticed the material used on the sides of match boxes. This is red phosphorous - an allotrope of phosphorous. Compare its colour, smell, reaction with air, solubility and reactivity with white phosphorous and list the details.

Red phosphorous is prepared by heating white phosphorous in a vacuum steel retort at 540 K for a long time. At 470 K and at high pressure, white phosphorous turns to another allotrope called black phosphorous.

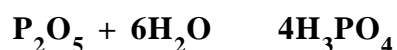
Phosphorous pentoxide

Take some hot water in a trough. Place a very light metal sheet on the surface of water. Take a small piece of white phosphorous and place it upon the metal sheet with the help of a tongs. You see the phosphorous burning within a short time. Immediately place a glass tumbler upside down on the metal sheet where the white phosphorous is placed. Note the changes and write them down. The smoke that fills the tumbler is phosphorous pentoxide. See the chemical equation.



This compound dissolves in water. Check the solution with blue litmus. What is the reason for the colour change?

Phosphoric acid (H_3PO_4) has much industrial importance and this acid is prepared by dissolving phosphorous pentoxide in water.



Uses

Phosphoric acid is used in the manufacture of phosphatic fertilizers that are essential for the growth of plants.

A mixture of red phosphorous, glass powder and gum is used for making match boxes. A combination of potassium chlorate, manganese dioxide and antimony sulphide is fixed using a gum to one end of the stick dipped in wax.

Other important uses of phosphorous are given below.

- **Manufacture of smoke shield bombs**
- **To prepare rat poison (zinc phosphide)**
- **For making alloys of metals**
- **In the manufacture of certain pesticides.**

Prepare a note on the importance of phosphorous and present it in the class.

SUMMARY

- N_2 is inert due to the presence of triple bond.
- Ammonia is prepared in the laboratory by heating a mixture of NH_4Cl and $Ca(OH)_2$.
- The density of ammonia is low and it dissolves in water. This solution shows basic nature.
- The reason for the basic nature of ammonia is the lone pair at the nitrogen atom.
- Molecule/atom that gives off lone pair is called Lewis base.
- Reversible reactions attain equilibrium.
- Chemical equilibrium is the state of a reversible system in which the concentration of reactants and products remains unchanged.
- If a system at equilibrium is subjected to a change in pressure, temperature or concentration, the system shows a tendency to cancel the effect of that change.
- Phosphorous is more reactive than nitrogen.
- White phosphorous, red phosphorous and black phosphorous are the allotropes of phosphorous.

MORE ACTIVITIES FOR YOU

1. Presence of nitric acid can be detected in rain water when lightning occurs. Can you explain?
2. Nitrogen is a chemically inert gas. But it is essential for the sustenance of life. Prepare a note on this and present in the class.
3. The ingredients of water gas can be separated by passing the water gas mixed with steam over red hot iron. Out of this, by oxidising one gas and applying high pressure, it can be dissolved in water. In this process, what is the remaining gas X? X is mixed with another gas in the atmosphere and the industrially important gas Y is prepared.
 1. Which is the atmospheric gas used in the preparation of Y?
 2. What is the gas X?
 3. What is the gas Y?
 4. What happens when the gas Y is passed over hot cupric oxide? Write the chemical equation.
4. Ammonia is manufactured by the reaction of nitrogen and hydrogen in a certain ratio.
 - Write the balanced chemical equation of this reaction.
- What is the amount of hydrogen in a mixture of 400 litres of the gases used in the manufacture of ammonia?
- If the reactants are completely used up, what will be the volume of ammonia?
- Production of ammonia is exothermic. What does 'exothermic' mean?
- From the gaseous system, to remove ammonia two methods are used. Find out the two methods. Also mention two physical properties of ammonia which forms the basis of the two methods.
5. Name a gas that forms alkali when dissolved in water.
6. Name a compound which on heating decomposes without producing any residue.
7. Let the following chemical reactions be conducted.

Reaction A : Nitrogen+metal
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Reaction B : X + H₂O ammonia+ another compound

Reaction C : ammonia+metallic oxide metal + water + nitrogen

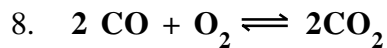
 - I. The metal used in the reaction A is magnesium.

a. Write the conditions for the reaction.

b. Write the chemical formula of the compound X

II. Write the balanced equation of the reaction B

III. What property of ammonia is shown in reaction C?



How does each of the conditions given below affect the forward reaction? Explain using Le Chatelier principle.

1. **Increased temperature**

2. **Reduced pressure**

3. **Increased concentration of Oxygen.**

9. $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$. Using Le Chatelier principle, explain the changes that occur in this reaction.

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