# 5 Compounds of Non - Metals


## ♥♥♥Ammonia ($NH_3$)

Ammonia is an important raw material for the production of nitrogenous fertilisers which are essential for the growth of plants.

### 1.♥♥♥ Preparation of Ammonia in the class room.

| Experiment | Observation | Inference |
|---|---|---|
| Take a little ammonium chloride ($NH_4Cl$) in a watch glass and add a little calcium hydroxide ($Ca(OH)_2$) to it. Stir well. | Pungent smell | A Colourless pungent smelling gas is produced |
| Show wet blue and red litmus papers over the watch glass one by one. | Red litmus paper turns blue | The gas is basic |

## 2. ♥♥♥ Preparation of Ammonia in the Laboratory

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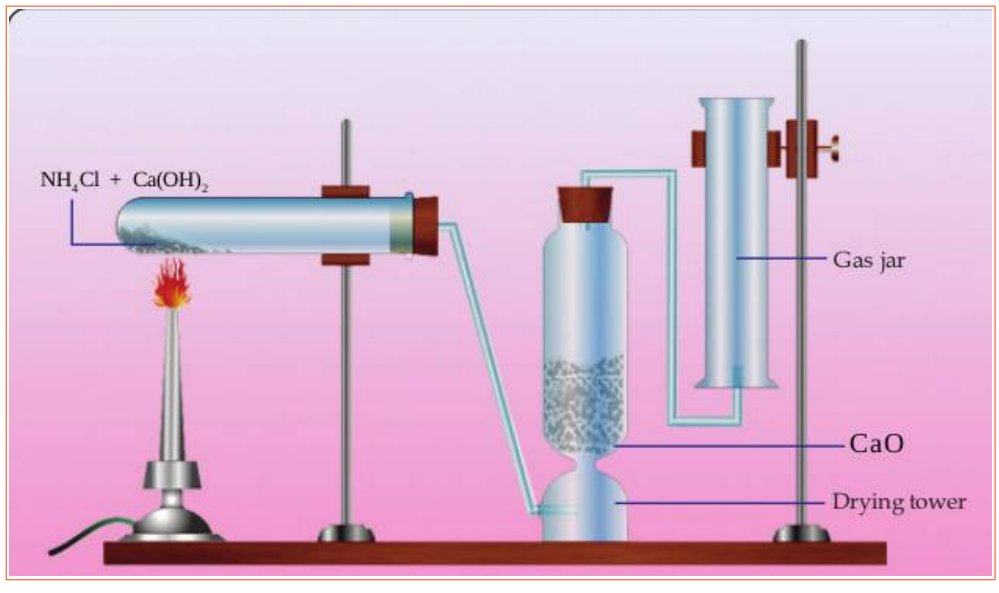



$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3$$

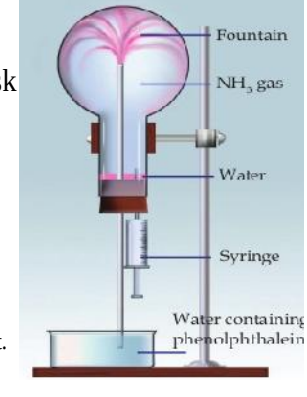
**1.** Why is ammonia gas passed through quick lime (CaO) ?

**Answer :** It is passed through a drying tower containing quick lime (CaO) ***to remove the moisture present in it.***

**2.** Note that the gas jar used for collecting ammonia is kept inverted. Give reason.

**Answer :** Ammonia is lighter than air(Density of ammonia is less than that of air)

### ♥♥♥ Properties of Ammonia




Arrange the apparatus as shown in the figure. Dip the jet tube in the beaker containing water, in which some phenolphthalein is added. Using a syringe add a few drops of water into the flask in which ammonia is taken.

**(a)** What do you observe?

**Answer :** Water rushes into the flask and spreads like a fountain. The entering water changes its colour to pink.

**(b)** What inference can be made about the solubility of ammonia in water ?

**Answer :** Ammonia is highly soluble in water.

**(c)** Why does water rush into the flask?

**Answer :** When ammonia dissolves in water , the pressure inside the flask decreases. Hence water rushes into it.

**(d)** Why does water entering the flask change its colour?

**Answer :** Ammonia dissolves in water forming a basic compound called ammonium hydroxide . Phenolphthalein shows pink colour in basic / alkaline solutions.

**(e)** Which property of ammonia is responsible for this change in colour?

**Answer :** Basic property

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**(f)** Complete the chemical equation given below and find the product obtained when ammonia is dissolved in water.

$NH_3 + H_2O \rightarrow$ .....

**Answer :** $NH_3 + H_2O \rightarrow NH_4OH$

**3.**♥♥♥ Put a tick mark to those which are applicable to ammonia in the table given below.

| | |
|---|---|
| Colour | Yes/No |
| Odour | Pungent smell/No smell |
| Nature | Acidic/Basic |
| Solubility in water | Less/Very high |
| Density of Ammonia | Less than that of air/More than that of air |

**Answer :**

| | |
|---|---|
| **Colour** | Yes/ **No** √ |
| **Odour** | **Pungent smell** √ /No smell |
| **Nature** | Acidic / **Basic** √ |
| **Solubility in water** | Less/**Very high** √ |
| **Density of Ammonia** | **Less than that of air** √ / More than that of air |

4. ♥♥♥ When an Ammonia tanker leaks, water is sprayed to reduce its intensity. What is the reason for this?

**Answer :** Ammonia gas is highly soluble in water. It prevents the spreading of ammonia .
Direct inhalation of ammonia is dangerous **.**

**5.** ♥♥♥ What is the difference between liquid ammonia and liquor ammonia ?

**Answer :**

| **Liquid Ammonia** | **Liquor Ammonia** |
|---|---|
| Ammonia gas can be liquefied easily by applying pressure. **Liquefied ammonia** is known as liquid ammonia. | ***A highly concentrated aqueous solution of ammonia*** is called Liquor ammonia. |

**6.** ♥♥♥ List the important ***uses of ammonia.***

- For the manufacture of chemical fertilisers like ammonium sulphate, ammonium phosphate, urea etc.
  ( About 80% of the ammonia produced by industry is used in **agriculture** as **fertilizer**)
- As a refrigerant in ice plants.
- To clean tiles and window panes.
- For purification of **water** supplies
- In the manufacture of plastics, explosives, textiles, **pesticides**, dyes and other chemicals.

**7.** ♥♥♥ a. Identify the pungent smelling gas evolved, when ammonium chloride is heated ?

**Answer :** The ***pungent smelling gas*** evolved ***is ammonia***. It turns a wet ***red litmus blue.***
This shows that ***ammonia is basic*** in nature.

b. After a while , the wet litmus paper changes again to red . Give reason.

**Answer :**When ammonium chloride is heated , ammonia and hydrogen chloride are formed . Ammonia , being lighter and basic , comes out first . It turns the wet ***red litmus blue.*** Then the **denser HCl** comes out . **It is acidic** in nature. It ***turns the blue litmus paper red .***

***c.*** Identify the white powder sticking to the sides of the test-tube. Justify your answer.
It is ammonium chloride. It is formed due to the reaction between $NH_3$ and HCl gases which come out.

**8.**♥♥♥ Let us do another experiment to make this clear. A glass rod dipped in concentrated hydrochloric acid is shown inside
a jar which is filled with ammonia gas.

●What have you observed?

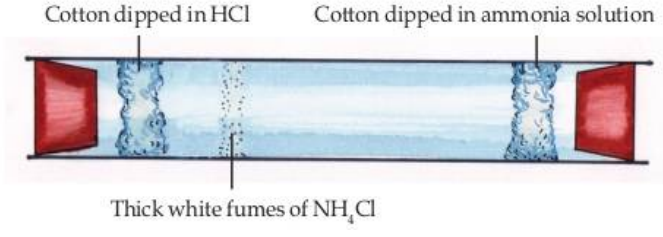
**Answer :** Dense white fumes are formed . This is due to the formation of ammonium chloride.

● Complete the chemical equation and find out the product.

$NH_3 + HCl \rightarrow$ .....

**Answer :** $NH_3 + HCl \rightarrow$ **$NH_4Cl$** (Ammonium chloride)

**9.**♥♥♥ Take a glass tube. Place a piece of cotton dipped in HCl at one end and another piece dipped in ammonia solution at the other end of the glass tube, such that these are well inside the glass tube. Close both ends of the glass tube tightly using corks. Observe the changes inside the glass tube.




Do you observe the thick white fumes? It is due to the combination of HCl gas and $NH_3$ gas.
Heat the region of the glass tube where the white powder of ammonium chloride has been stuck.The white powder disappears . It is due to the decomposition of ammonium chloride to ammonia and hydrogen chloride.

**Summary**

● **When ammonium chloride is heated , ammonia gas and hydrogen chloride gas are formed.**

$NH_{3\,(g)} + HCl_{\,(g)} \rightarrow NH_4Cl_{(s)}$

● When ammonia gas and hydrogen chloride gas are cooled , they combine to form ammonium chloride.

$NH_4Cl_{\,(s)} \rightarrow NH_{3\,(g)} + HCl_{\,(g)}$

● We can combine these equations into

$NH_4Cl_{(s)} \rightleftharpoons NH_{3\,(g)} + HCl_{\,(g)}$

This sign $\rightleftharpoons$ is to be read as reversible is to be read as reversible

Reactions taking place in both directions are called **reversible reactions.**

In a reversible reaction the reaction in which the ***reactants change to products is called the forward reaction*** and that in which the ***products change back to reactants is called the backward reaction.***

**10**♥♥♥.Examine the chemical equations given below and write the forward and backward reactions in each.

$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$
$2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$
$H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

**Answer :**

| **Reaction** | **Forward reaction** | **Backward reaction** | |
|---|---|---|---|
| $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$ | $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ | $N_2(g) + 3H_2(g) \leftarrow 2NH_3(g)$ | $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$ |
| $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$ | $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ | $2SO_2(g) + O_2(g) \leftarrow 2SO_3(g)$ | $2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$ |
| $H_2(g) + I_2(g) \leftrightarrow 2HI(g)$ | $H_2(g) + I_2(g) \rightarrow 2HI(g)$ | $H_2(g) + I_2(g) \leftarrow 2HI(g)$ | $2HI(g) \rightarrow H_2(g) + I_2(g)$ |

The chemical equation of the neutralisation reaction between sodium hydroxide and hydrochloric acid is given below.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

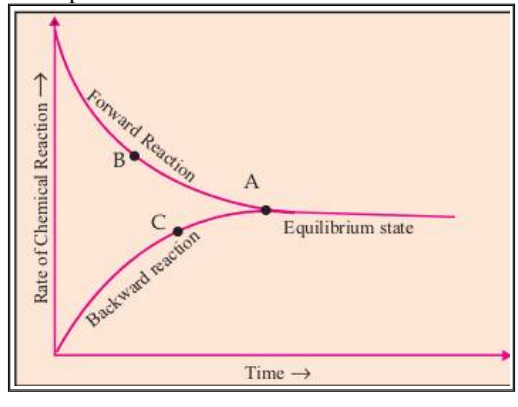
Here the products cannot be converted into reactants. Such ***chemical reactions in which reactants give products, but the products do not give back the reactants are called irreversible reactions.***

More examples:

$C + O_2 \rightarrow CO_2$
$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$
$MgSO_4 + BaCl_2 \rightarrow BaSO_4 + MgCl_2$
$KOH + HCl \rightarrow KCl + H_2O$

## ♥♥♥ Chemical Equilibrium

Analyse the following graph of a reversible process.




●What happens to the rates of forward and backward reactions as time progresses?

**Answer :** As time progresses , the rate of forward reaction decreases and that of backward reaction increases

●Identify the point from the graph at which the rates of both forward and backward reactions become equal.

**Answer : A**

♥♥♥ ***Chemical equilibrium*** is the stage at which the rate of the forward reaction becomes equal to the rate of the backward reaction in a reversible chemical reaction.

♥♥♥ ***The characteristics of equilibrium*** identified through the experimental observations conducted so far are given below:

- At the equilibrium both the reactants and the products coexist.
- The rates of forward and backward reactions become equal at equilibrium.
- Chemical equilibrium is dynamic at the molecular level.
- Chemical equilibrium is attained in closed systems.
- ♥♥♥ At equilibrium forward and backward reaction occur simultaneously at the same rate.

***Hence, chemical equilibrium is said to be dynamic at the molecular level .***

♥♥♥ *Le Chateliers' Principle*

When the concentration, pressure or temperature of a system at equilibrium is changed, the system will readjust itself so as to nullify the effect of that change and attain a new state of equilibrium.

## ♥♥♥ Influence of concentration on Equilibrium

Ammonia is industrially prepared by Haber process. Its chemical equation is given below

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Observe carefully the action and change in the rate of the reaction , under the following conditions .

♥♥♥ **( Each raw should carefully be analysed )**

| Action | Change in concentration | Change in rate* | | |
|---|---|---|---|---|
| More nitrogen is added | Increases the concentration of reactant | Rate of forward reaction increases | OR | Rate of backward reaction decreases |
| More hydrogen is added | Increases the concentration of reactant | Rate of forward reaction increases | OR | Rate of backward reaction decreases |
| More ammonia is added | Increases the concentration of product | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| Nitrogen is removed | Decreases the concentration of reactant | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| Hydrogen is removed | Decreases the concentration of reactant | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| Ammonia is removed | Decreases the concentration of product | Rate of forward reaction increases | OR | Rate of backward reaction decreases |

*** Comparitive change**

Given below is the stage of a reaction for the preparation of Sulphuric acid.

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

♥♥♥ Observe carefully the action and change in the rate of the reaction , under the following conditions .

| Action | Change in concentration | Change in rate* | | |
|---|---|---|---|---|
| More $SO_2$ is added | Increases the concentration of reactant | Rate of forward reaction increases | OR | Rate of backward reaction decreases |
| More $O_2$ is added | Increases the concentration of reactant | Rate of forward reaction increases | OR | Rate of backward reaction decreases |
| More $SO_3$ is added | Increases the concentration of product | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| $SO_2$ is removed | Decreases the concentration of reactant | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| $O_2$ is removed | Decreases the concentration of reactant | Rate of forward reaction decreases | OR | Rate of backward reaction increases |
| $SO_3$ is removed | Decreases the concentration of product | Rate of forward reaction increases | OR | Rate of backward reaction decreases |

* Comparitive change

| Action | Change in concentration | Change in rate* | |
|---|---|---|---|
| Reactants are added | Increases the concentration of reactants | Rate of forward reaction increases | Rate of backward reaction decreases |
| Products are removed | Decreases the concentration of products | | |
| Reactants are removed | Decreases the concentration of reactants | Rate of forward reaction decreases | Rate of backward reaction increases |
| Products are added | Increases the concentration of products | Rate of forward reaction decreases | |

* Comparitive change

## ♥♥♥ Pressure and Chemical Equilibrium

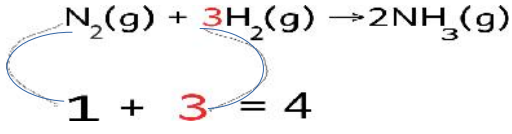
***Pressure*** has a significant influence in the case of ***gases only.***
Let us examine the influence of pressure in the manufacture of ammonia.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

***Here, both reactants and products are gases.***

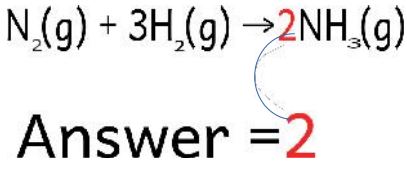
● In this equation what is the total number of moles of the reactant molecules?

**Answer :**




● What about the products?

**Answer :**




Forward reaction : 4 mole reactant molecules → 2 mole product molecules (volume decreases)
Backward reaction : 2 mole product molecules → 4 mole reactant molecules (volume increases)

In a gaseous system, decrease in the number of molecules helps to decrease the pressure.
***According to Le Chateliers' principle, when pressure of a system at equilibrium is increased the system will try to attain equilibrium by reducing pressure.***

● In the manufacture of ammonia, the reaction in which direction results in the decrease in the number of molecules?

**Answer :** From left to right (Forward direction)

● What happens when the pressure of the system is increased?

**Answer :** *According to Le Chateliers' principle, when pressure of a system at equilibrium is increased, the system will try to attain equilibrium by reducing pressure.* ***Here*** *it is done by increasing the rate of forward reaction ( By decreasing the rate of backward reaction)*

● What happens if the pressure of the system is decreased?

**Answer :** *According to Le Chateliers' principle, when pressure of a system at equilibrium is decreased, the system will try to attain equilibrium by increasing pressure.* ***Here*** *it is done by decreasing the rate of forward reaction.( By increasing the rate of backward reaction)*

● In the manufacture of ammonia, why is a high pressure of 150-300 atm used?

**Answer :** To increase the rate of production of ammonia . *According to Le Chateliers' principle, when pressure of a system at equilibrium is increased ,the system will try to attain equilibrium by reducing pressure.* ***Here*** *it is done by increasing the rate of forward reaction (By decreasing the rate of backward reaction)*

◘ Analyse the chemical equation for the gaseous reaction given below:

$$H_2(g) + I_2(g) \rightarrow 2\,HI(g)$$

● What is the total number of moles of reactants?

**Answer :** 1+1 = 2

● What about the products

**Answer :** 2

Here there is no change in the number of moles of the reactants and the products.

*In a reversible reaction* ***if there is no change in the number of gaseous molecules in the reactant and product side, pressure will not have any effect*** *on the chemical equilibrium.*

**11.** ♥♥♥ What happens when pressure in the following system at equilibrium is changed?

$$2\ SO_3(g) \rightarrow 2\ SO_2(g) + O_2(g)$$

**Answer:**

| | |
|---|---|
| Total number of gaseous moles of reactants | 2 |
| Total number of gaseous moles of products | 2+1 =3 |
| What happens when pressure is increased | ***The reaction proceeds faster to the side having lesser number of gaseous moles.***<br><br>*According to Le Chateliers' principle, when pressure of a system at equilibrium is increased, the system will try to attain equilibrium by reducing pressure. Here it is done by increasing the rate of backward reaction (By decreasing the rate of forward reaction)* |
| What happens when pressure is decreased | ***The reaction proceeds faster to the side having greater number of gaseous moles.***<br><br>*According to Le Chateliers' principle, when pressure of a system at equilibrium is decreased, the system will try to attain equilibrium by increasing pressure. Here it is done by increasing the rate of forward reaction (By decreasing the rate of backward reaction)* |

## ♥♥♥ Temperature and Equilibrium

Consider the reaction

$$N_2\,(g) + 3H_2\,(g) \rightarrow 2\,NH_3\,(g) + \text{Heat}$$

● Which is the endothermic reaction in this? ( Forward reaction/Backward reaction) ?

**Answer :** Backward reaction

On ***increasing the temperature***, the system tries to reduce it by ***increasing the rate of endothermic reaction***. As a result the product ammonia decomposes to form $N_2$ and $H_2$ .

Hence, according to Le Chateliers' principle, for the formation of a larger amount of $NH_3$ , the temperature has to be reduced. But ***at low temperature the number of molecules having threshold energy will be less***. Therefore ***the rates*** of forward and backward reactions ***get very much reduced***, the ***system will take more time to reach equilibrium***. Hence in the manufacture of ***ammonia, 450ºC*** is taken as the ***optimum temperature.***

## ♥♥♥Catalyst and Equilibrium

Catalysts are substances which alter the rate of reaction without undergoing a permanent chemical change to itself. Positive catalysts increase the rate of reaction. (Negative catalysts decrease the rate of reactions)

***In a reversible reaction , a catalyst accelerates the forward and backward reactions simultaneously . Hence the system attains equilibrium quickly.***

***It is not beneficial to add a catalyst in a system which has already attained equilibrium.***
***At equilibrium,the rate of forward reaction is equal to the rate of backward reaction. Since the catalyst accelerates the forward and backward reactions simultaneously it does not have any effect in equilibrium***