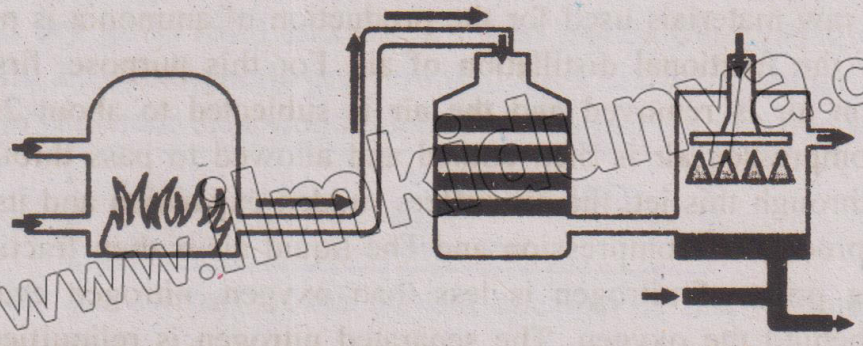
CHAPTER 19

Nitrogen and Sulphur

Student Learning Outcomes

After studying this chapter, students will be able to:

- Recognize that atmospheric oxides of nitrogen (NO and NO_2) can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, which is a component of photochemical smog.
- Describe the role of NO and NO_2 in the formation of acid rain both directly and in their catalytic role in the oxidation of atmospheric sulphur dioxide.
- State the symbol equation for the production of ammonia in the Haber process, $N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$
- State the sources of the hydrogen (methane) and nitrogen (air) in the Haber process.
- State the typical conditions in the Haber process as 450°C, 20000kPa/20 atm and an iron catalyst.
- State the symbol equation for the conversion of sulphur dioxide to sulphur trioxide in the Contact process, $2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$
- State the sources of the sulphur dioxide (burning sulphur or roasting sulphide ores) and oxygen (air) in the Contact process.
- State the typical conditions for the conversion of sulphur dioxide to sulphur trioxide in the Contact process as 450°C, 200kPa/atm and a vanadium(V) oxide catalyst Oxides.
- Describe the amphoteric oxides as oxides that react with acids and bases to produce a salt and water.
- Classify oxides as acidic, including SO_2 and CO_2, basic, including CuO and CaO, or amphoteric, limited to Al_2O_3 and ZnO, related to metallic and non-metallic character.
- Properties of metal
- Identify the general chemical properties of metals, limited to their reactions with dilute acids, cold water, steam and oxygen.
- Arrange metals in order of reactivity given relevant information.



Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

19.1 Ammonia

19.2 Sulphuric Acid

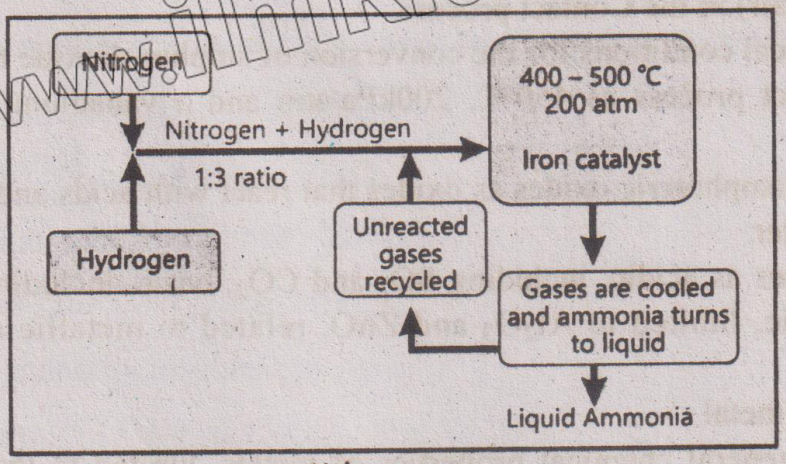
Q.1: Explain the production of ammonia on industrial scale.

Ans. Haber Process:

Ammonia is produced industrially by Haber process discovered by a German Chemist F.J. Haber. In this process, a mixture of nitrogen and hydrogen, in the ratio of 1:3 by volume is heated at 400-500°C under 200 atmospheric pressure and in the presence of catalyst Fe/Al_2O_3 to give ammonia.

$$N_{2\,(g)} + 3H_{2\,(g)} \underset{\text{Catalyst}}{\overset{400\text{-}500\,^{\circ}c}{\rightleftharpoons}} 2NH_{3\,(g)}$$

The equilibrium mixture obtained in the above reaction contains 35% ammonia by volume. This mixture is cooled by refrigeration coils where ammonia gas changes to liquid ammonia at –33.4 °C and is removed from the mixture. The other components of the mixture, hydrogen and nitrogen gases, are then recycled back into the reaction chamber.



Haber process

Q.2: How nitrogen and hydrogen used in Haber process are obtained?

Ans. Source of Nitrogen:

One of the raw materials used for the production of ammonia is nitrogen gas and it is obtained by the fractional distillation of air. For this purpose, first of all carbon dioxide present in air is removed and the air is subjected to about 200 atmospheric pressure. This compressed air is then cooled and allowed to pass through a spiral jet. While escaping through this jet, the air suffers sudden expansion and its temperature is decreased. This process of compression and The liquid air is then fractionally distilled. Since the boiling point of nitrogen is less than oxygen, nitrogen evaporates first at -196°C leaving behind the oxygen. The separated nitrogen is reliquified and stored in

specially designed cylinders.

Source of Hydrogen:

The second raw material, hydrogen, is produced by heating methane in the limited amount of oxygen that is not enough to completely oxidize methane to carbon dioxide and water. With less oxygen available, the reaction products contain primarily hydrogen and carbon monoxide and a relatively small amount of carbon dioxide. The carbon monoxide obtained is then reacted with water to form carbon dioxide and more hydrogen gas.

$$CH_{4(g)} + H_2O_{(g)} \longrightarrow CO_{(g)} + 3H_{2(g)}$$
$$CO_{(g)} + H_2O_{(g)} \longrightarrow CO_{2(g)} + H_{2(g)}$$

Q.3: Describe the contact process for the production of sulphuric acid.

Ans. Contact Process:

Sulphuric acid is one of the most important chemical compounds known. It is very commonly used in the laboratory and almost every manufacturing process makes use of this acid directly or indirectly at some stage.

Sulphuric acid is prepared industrially by the contact process. The process involves the following steps.

Preparation of Sulphur dioxide gas:

Sulphur dioxide gas is produced either by burning elemental sulphur in air or roasting a sulphur ore, iron pyrite, in excess of air.

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$
$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

Sulphur dioxide produced above is then passed through purifying chambers and sprayed with steam. This process removes dust impurities as well as arsenic compounds present in the gas. This step is important because arsenic compounds poison the catalyst used later on. The moist gases (SO_2 and O_2) are then dried by passing through a drying tower in which concentrated sulphuric acid is being sprayed. Oxygen used in this reaction is obtained by the fractional distillation of air.

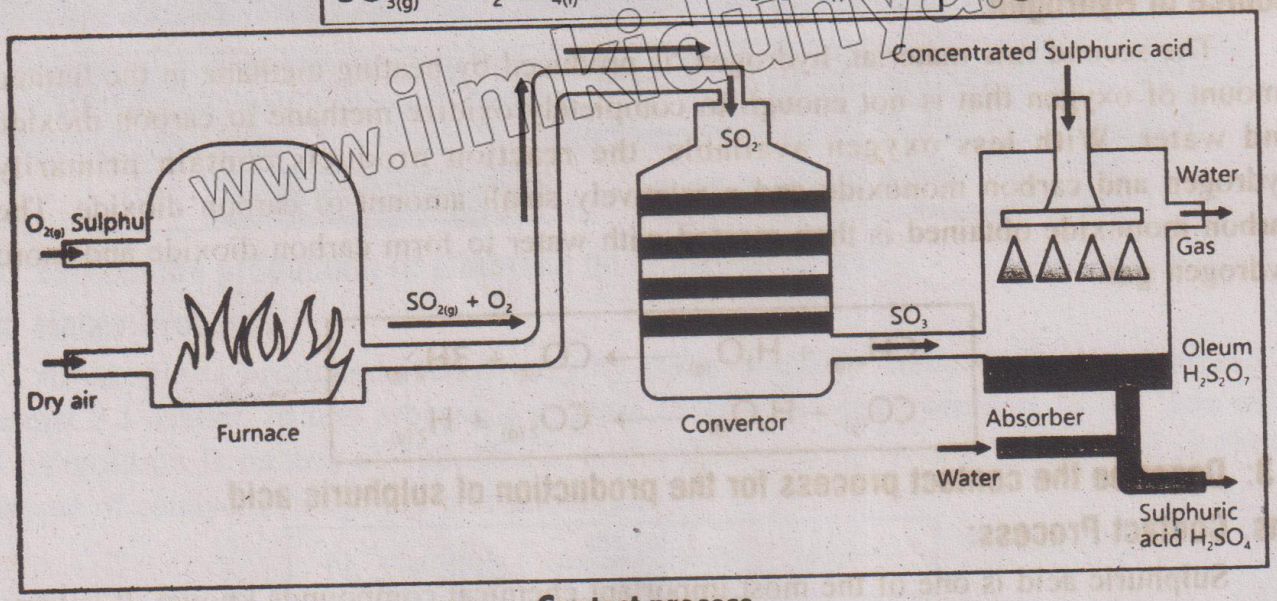
Oxidation of Sulphur dioxide:

The clean and dry gases (SO_2 and O_2) are then passed over vanadium (V) oxide catalyst at 450°C and 2-3 atmospheric pressure through a contact chamber. Although the reaction is reversible yet under these conditions 98% SO_2 gas is converted to SO_3.

$$2SO_{2(g)} + O_{2(g)} \xrightarrow[\text{450 °C, 2-3 atomsphere}]{V_2O_5} 2SO_{3(g)}$$

Sulphur trioxide gas formed in the contact chamber is then absorbed into 98% sulphuric acid to give oleum.

$$SO_{3(g)} + H_2SO_{4(l)} \longrightarrow H_2S_2O_{7(l)}$$ oleum



Contact process

The oleum is then mixed with an appropriate amount of water to produce sulphuric acid with desired concentration.

$$H_2S_2O_{7(l)} + H_2O_{(l)} \longrightarrow 2H_2SO_{4(l)}$$

19.3 Oxides

19.4 Metals

Q.4: Explain the formation and properties of acidic and basic oxides.

Ans. Oxides

Binary compounds of elements with oxygen are called oxides. Oxygen shows an oxidation state of –2 in there oxides.

Metal Oxides: Metal oxides are commonly basic and amphoteric.

Non-metallic oxides: Non-metallic oxides are acidic in nature.

Formation of Basic and Acidic Oxides: Both basic and acidic oxides are formed when metals and non-metals are heated respectively in the presence of air or oxygen.

Metal oxides are typically ionic compounds in which electrons are transferred from metals to oxygen.

Non-metal oxides are covalent compounds where electrons are shared between non-metals and oxygen atoms.

Properties of Basic Oxides: Oxygen reacts with metals to give oxides which when dissolved in water produce hydroxides. They change red litmus blue. When treated with acids they give salts.

$$O_{2(g)} + 4Na_{(s)} \longrightarrow 2Na_2O_{(s)}$$

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

$$O_{2\,(g)} + 2Ca_{(s)} \longrightarrow 2CaO_{(s)}$$
$$CaO_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O_{(l)}$$

$$O_{2\,(g)} + 2Cu_{(s)} \longrightarrow 2CuO_{(s)}$$
$$CuO_{(s)} + 2HCl_{(aq)} \longrightarrow CuCl_{2(aq)} + H_2O_{(l)}$$

Properties of Acidic Oxides: Oxygen combines with non metals (S, C, N) to give acidic oxides. These oxides react with water to give acids which turn blue litmus red.

$$O_{2(g)} + S_{(s)} \longrightarrow SO_{2\,(g)}$$
Sulphur dioxide
$$SO_{2\,(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3(l)}$$
Sulphurous Acid

$$O_{2\,(g)} + C_{(s)} \longrightarrow CO_{2\,(g)}$$
$$CO_{2\,(g)} + H_2O_{(l)} \longrightarrow H_2CO_{3\,(aq)}$$
Carbonic Acid

Acidic oxides react with bases to give salts.

$$SO_{2\,(g)} + 2NaOH_{(aq)} \longrightarrow Na_2SO_3 + H_2O$$
Sodium sulphite
$$CO_{2(g)} + Ca(OH)_{2\,(aq)} \longrightarrow CaCO_{3(s)} + H_2O_{(l)}$$

Q.5: What are neutral oxides? Explain the formation and properties of amphoteric oxide?

Ans. Neutral Oxides:

Neutral oxides are those oxides which on contact with water produce neither an acid nor a base. Their aqueous solutions have no action on blue or red litmus paper. Examples are carbon monoxide (CO), nitric oxide (NO) and nitrous oxide (N_2O).

Amphoteric Oxide:

Amphoteric oxides are usually formed when oxygen reacts with less electropositive metals.

$$O_{2(g)} + 2Zn_{(s)} \longrightarrow 2ZnO_{(s)}$$
$$3O_{2(g)} + 4Al_{(3)} \longrightarrow 2Al_2O_{3(:)}$$

These oxides behave both as an acid and a base. Zinc oxide and aluminium oxide behave as bases in the presence of an acid.

$$ZnO_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_2O_{(l)}$$
$$Al_2O_{3(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)}$$

These oxides behave as acids in the presence of an alkali.

$$ZnO_{(s)} + 2NaOH_{(aq)} + H_2O_{(l)} \longrightarrow \underset{\text{Sodium zincate}}{Na_2Zn(OH)_{4(aq)}}$$

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \longrightarrow \underset{\text{Sodium aluminate}}{2NaAl(OH)_{4\,(aq)}}$$

These oxides are insoluble in water and have no action on litmus paper.

Q.6: Give reaction of metals with cold water, steam, oxygen and dilute acids.

Ans. Metals: Nearly three fourth elements shown in the periodic table are called metals. Metals have a tendency to lose electrons and form cations.

Reaction of metals with cold water:

Most of the elements present in the first and second group of the periodic table react vigorously with cold water producing their respective hydroxides and hydrogen gas.

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH_{(aq)} + H_{2(g)}$$

Magnesium, however, reacts with cold water slowly giving magnesium hydroxide and hydrogen gas.

$$Mg_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2\,(s)} + H_{2\,(g)}$$

Reactions of metals with steam: The more reactive the metal, the more readily it reacts with steam. Reactive metals like lithium, sodium, potassium and calcium react violently with steam and the reaction can be dangerous.

Beryllium and aluminum react with steam at high temperatures (around 700°C) to give their respective oxides and hydrogen.

$$Be_{(s)} + H_2O_{(g)} \longrightarrow BeO_{(s)} + H_{2\,(g)}$$

Magnesium, iron and Zn have a moderate reaction with steam producing their respective oxides and hydrogen gas.

$$Mg_{(s)} + H_2O_{(g)} \longrightarrow MgO_{(s)} + H_{2\,(g)}$$

Reactions of metals with Oxygen: Metals react with oxygen to give metal oxides. The ease of reaction and the type of oxide which is formed, depends upon the reactivity of metals and the conditions used.

Sodium burns in air with yellow flame producing both sodium oxide and sodium per oxide.

$$4Na_{(s)} + O_{2(g)} \longrightarrow 2Na_2O_{(s)}$$

$$2Na_{(s)} + O_{2(g)} \longrightarrow Na_2O_{2\,(s)}$$

Magnesium, calcium, strontium and barium burn in oxygen with colour of the flame characteristic to each metal giving their respective oxides.

$$Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$$

Metal	Colour of flame
Mg	Intense white flame
Ca	White flame with a tinge of red
Sr	Crimson flame
Ba	A pale green flame

Strontium flame

Barium flame

Reactions of metals with dilute acids: The more reactive the metal the more vigorous is its reaction with dilute acids. Sodium and potassium are very dangerous and react violently with dilute acids giving their respective salts and hydrogen gas.

$$2Na_{(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_{2(g)}$$

All group 2 elements react with dilute acids giving their salts, and hydrogen gas. The reaction generally becomes more vigorous as we move down the group.

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2(g)}$$

19.5 Reactivity Series of Metals

19.6 Role of Oxides of Nitrogen in Spreading Air Pollution

Q.7: Write a note on the reactivity series of metals.

Ans. Reactivity Series of Metals:

Based on their reactions with water and acids, the metals can be arranged in decreasing order of their reactivities. Such an arrangement is called the reactivity series of metals.

According to this reactivity series, calcium and metals above it react with cold water to give metal hydroxides and hydrogen gas. The metals below calcium do not react with cold water, instead they react with steam to give metal oxides and hydrogen gas.

Only metals above hydrogen will be able to liberate H_2 upon reacting with dilute acids. Unreactive metals below hydrogen do not react with dilute acids. The more reactive the metal, the more vigorous its reaction will be with dilute acids. Similarly reactive metals, like potassium and sodium, react with oxygen easily whereas the less reactive metals like silver, copper and iron react with oxygen much more slowly.

Reactivity Series of Metals
Most Reactive
k
Na
Li
Ba
Sr
Ca
Mg
Al
C
Mn
Zn
Fe
H
Cu
Ag
Au
Least Reactive

The metals at the top of the series are powerful reducing agents since they are easily oxidized. However, the reducing ability of metals decreases going down the series.

$$Zn_{(s)} + CuSO_{4\,(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)}$$

Q.8: Describe the role of nitrogen in the formation of PAN and the acid rain.

Ans. Role of Nitrogen in the formation of PAN and the Acid Rain:

Primary Pollutants: The primary pollutants in the atmosphere include oxides of nitrogen, sulphur and carbon and various hydrocarbons etc.

Secondary Pollutants: These primary pollutants are then converted into secondary pollutants through various reactions going on in the atmosphere. The main secondary pollutants are ozone, per oxyacetyl nitrate (PAN), sulphuric acid etc. All these compounds are toxic and their concentration in the atmosphere must be controlled.

Harmful oxides of Nitrogen: Oxides of nitrogen which are harmful when present in the atmosphere include NO and NO_2, collectively represented by NO_x. They are generated in the atmosphere through both natural and man-made sources.

Natural Sources of NO_x: Natural sources for the production of NO_x include electrical discharges during lightning which can cause atmospheric nitrogen and oxygen to react forming nitric oxide. This nitric oxide is rapidly converted into nitrogen dioxide by oxygen present in air.

$$N_{2(g)} + O_{2(g)} \xrightarrow{\text{Electric arc}} 2NO_{(g)}$$

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2\,(g)}$$

Man-Made Sources of NO_x: Combustion of fossil fuels in vehicles, various industrial processes and electricity power plants are the main man-made sources which generate NO in the atmosphere. Apart from these, agricultural activities and fertilizers also contribute to NO_x emission.

Emission of (NO_x) and (VOCs) in the Atmosphere: Heavy traffic during morning and evening hours together with industrial processes emit a huge amount of oxides of nitrogen (NO_x) and most volatile organic compounds (VOCs) in the atmosphere.

Production of (PAN): Ultraviolet radiation present in sunlight interacts with the oxides of nitrogen and VOCs through a complex series of chemical reactions to produce secondary pollutants like ozone, aldehydes and peroxyacetyl nitrate (PAN).

Formation of Acid Rain: Oxides of nitrogen are also responsible for the formation of another type of pollutant called acid rain. Especially NO reacts with water and other chemicals presents in air, to produce vapours of nitric acid and nitrous acid.

$$2NO_{2\,(g)} + H_2O_{\,(l)} \longrightarrow HNO_{3(g)} + HNO_{2\,(g)}$$

These acidic vapours then mix with water vapours present in air and fall to earth as acid rain.

Oxides of nitrogen (NO_x) can also act as catalyst to convert, another primary pollutant, sulphur dioxide present in air, to sulphuric acid which is another major

component of acid rain.

$$2SO_{2\,(g)} + O_{2\,(g)} \xrightarrow{\text{Oxides of nitrogen}} 2SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(g)} \longrightarrow H_2SO_{4\,(g)}$$

Acid rain has a pH less than 5.6. Acid rain is damaging for the ecosystem, it can corrode materials and can lead to respiratory problems.

19.1 Quick Check!

1. Why is ammonia gas turned into a liquid after its production?

Ans. Ammonia is turned into a liquid (at approximately –33.4°C) to easily separate it from the mixture of unreacted nitrogen and hydrogen remain as gases, allowing them to be recycled back into the reaction chamber to increase efficiency.

2. Why high pressure is maintained in the production of ammonia?

Ans. Since the formation of ammonia involves 4 moles of reactants turning into 2 moles of product, maintaining a high pressure of 200 atm forces the equilibrium to the right, significantly increasing the yield of ammonia.

19.2 Quick Check!

1. How SO_2 is prepared from FeS_2?

Ans. Sulphur dioxide (SO_2) is prepared by roasting iron pyrite, in excess of air.

The chemical reaction is:

$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

2. Why SO_2 and oxygen are purified before they react to produce SO_3.

Ans. The gases must be purified to remove dust, impurities as well as arsenic compounds present in the gas. This step is important because arsenic compounds poison the catalyst (vanadium (v) oxide) (V_2O_5), used later on.

19.3 Quick Check!

1. Why lead oxide is called an amphoteric oxide?

Ans. Lead oxide is called an amphoteric oxide because it can react with both acids and strong bases to form salts and water, demonstrating both acidic and basic characteristics.

2. Why non-metals form covalent oxides?

Ans. Non-metals have high electronegativites. When they react with oxygen (also a non-metal), they share electrons to reach stability rather than transferring them, resulting in covalent bonds.

19.4 Quick Check!

1. Write the equation for the reaction between Ba and H_2O.

Ans. $Ba + 2H_2O \longrightarrow Ba(OH)_2 + H_2$

2. How do aluminum and zinc react with water?

Ans. Aluminum and Zinc do not react with cold water due to a protective oxide layer on their surface. However, they react with steam at high temperatures to form their respective oxides and hydrogen.

19.5 Quick Check!

1. Which will react faster with HCl, Zn or Fe?

Ans. Zinc (Zn) will react faster with HCl because it is placed higher than Iron (Fe) in the reactivity series, making it more reactive.

2. Name one metal which will displace Zn from its salt.

Ans. Any metal above Zinc (Zn) in the series, such as magnesium (Mg), Aluminum (Aℓ), or sodium (Na), will displace Zinc from its salt.

19.6 Quick Check!

1. What are the harmful effects of oxides of nitrogen on human health?

Ans. **(i)** Oxides of nitrogen can lead to severe respiratory problems, including inflammation of the airways, coughing, and wheezing.

(ii) They also contribute to the formation of secondary pollutants like ozone and PAN, which are toxic to humans.

2. How do oxides of nitrogen pollute environment?

Ans. Oxides of nitrogen pollute the environment by:

- Acting as catalyst to form acid rain (Contributing to sulphuric acid formation).
- Reacting with water to form nitric acid rain.
- Contributing to the formation of smog and secondary pollutants like ozone and peroxyacetyl nitrate (PAN) in the presence of sunlight.

INTERESTING INFORMATION

- 13% of total nitrogen fixation in the environment is contributed by the Haber process.
- Air pollution is responsible for about seven to eight million deaths annually. It is a significant risk to child health.
- Water is an amphoteric substance. It can act as both an acid and a base, depending on the other substance it reacts with.
- Sulphuric acid is called the "king of chemicals" because it is used in almost every industry.
- If two pieces of uncoated metal touch in space, they become permanently stuck together. It does not happen on Earth because the atmosphere puts a thin layer of oxide between the surfaces which acts as a barrier preventing adhesion.

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

19.1 Ammonia

19.2 Sulphuric Acid

1. What is the ratio by volume of nitrogen to hydrogen used in the Haber process?

(a) 1:1 (b) 1:3 (c) 3:1 (d) 2:3

2. **Which catalyst is used in the synthesis of ammonia?**
(a) Vanadium (v) oxide (b) Platinum
(c) Iron with Al_2O_3 (d) Nickel

3. **At what temperature is nitrogen separated from liquid air during fractional distillation?**
(a) –196°C (b) –33.4°C (c) 450°C (d) 0°C

4. **Which of these is a raw material for the production of hydrogen in the Haber process?**
(a) Iron pyrite (b) Carbon dioxide (c) Methane (CH_4) (d) Sulphur

5. **What is the chemical formula of oleum?**
(a) H_2SO_4 (b) SO_3 (c) $H_2S_2O_7$ (d) $H_2S_2O_8$

6. **Which catalyst is employed in the contact process for the oxidation of SO_2?**
(a) Iron (b) Magnesium
(c) Vanadium (V) oxide (d) Copper

7. **What percentage of the total nitrogen fixation in the environment is contributed by the Haber process?**
(a) 80% (b) 13% (c) 98% (d) 35%

8. **Which compound is known as the "king of chemicals"?**
(a) Ammonia (b) Nitric acid (c) Methane (d) Sulphuric acid

9. **The roasting of Iron Pyrite (FeS_2) produces which gas?**
(a) SO_2 (b) NH_3 (c) CO_2 (d) H_2

10. **What pressure is typically maintained in the Haber process?**
(a) 100 atm (b) 200 atm (c) 300 atm (d) 400 atm

11. **What is the primary use of the Ammonia produced globally?**
(a) Plastics (b) Refrigerants (c) Explosives (d) Fertilizers

19.3 Oxides

19.4 Metals

12. **Which type of oxide is formed when oxygen reacts with a non-metal like sulphur or carbon?**
(a) Basic oxide (b) Acidic oxide
(c) Neutral oxide (d) Amphoteric oxide

13. **What is the characteristic flame colour of Barium (Ba) when it burns in oxygen?**
(a) Intense white (b) Crimson (c) Pale green (d) White with red

14. **It is an example of a neutral oxide.**
(a) ZnO (b) Na_2O (c) CO (d) Al_2O_3

15. **Which metal produces a crimson flame when burned?**
(a) Calcium (b) Strontium (c) Magnesium (d) Potassium

16. **Which of the following metals reacts most violently with dilute acids?**
(a) Sodium (b) Zinc (c) Iron (d) Magnessium

17. **It is an amphoteric substance.**
(a) Water (b) Carbon dioxide
(c) Sodium hydroxide (d) Hydrochloric acid

19.5 Reactivity Series of Metals

19.6 Role of Oxides of Nitrogen in Spreading Air Pollution

18. Which gas is rapidly converted into nitrogen dioxide (NO_2) by oxygen in the air?

(a) Nitric oxide (NO) (b) Nitrous oxide (N_2O)
(c) Ammonia (NH_3) (d) Nitrogen (N_2)

19. Peroxyacetyl nitrate (PAN) is formed by the reaction of sunlight with NOx and.

(a) Carbon dioxide (b) Volatile organic compounds
(c) Water vapour (d) Oxygen

20. Which metal cannot displace hydrogen from dilute acids?

(a) Iron (Fe) (b) Zinc (Zn) (c) Lead (Pb) (d) Gold (Au)

Answers

1.	(b)	2.	(c)	3.	(a)	4.	(c)	5.	(c)	6.	(c)	7.	(b)
8.	(d)	9.	(a)	10.	(b)	11.	(d)	12.	(b)	13.	(c)	14.	(c)
15.	(b)	16.	(a)	17.	(a)	18.	(a)	19.	(b)	20.	(d)		

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques (Knowledge, Understanding, Application, Analytical & Conceptual)

19.1 Ammonia

19.2 Sulphuric Acid

1. What are the main industrial uses of ammonia?

Ans. Ammonia is primarily used to manufacture nitrogenous fertilizers (about 80%), such as urea. It is also used in the production of plastics, pharmaceuticals, and as a refrigerant.

2. Who discovered Haber process for the production of ammonia?

Ans. Haber process was discovered by a German chemist F.J. Haber for the production of ammonia.

3. What are the optimum conditions for the Haber process?

Ans. The conditions are a temperature of 400-500°C under 200 atmospheric pressure, and the presence of catalyst Fe/Al_2O_3.

4. State the balanced chemical equation for the synthesis of ammonia.

Ans. $N_{2(g)} + 3H_{2(g)} \xrightleftharpoons[\text{Catalyst}]{400\text{-}500\ ^\circ c} 2NH_{3(g)}$

5. How is nitrogen obtained for the Haber process?

Ans. Nitrogen for the Haber process is obtained from the fractional distillation of liquid air. Since the boiling point of nitrogen is less than oxygen, nitrogen evaporates first at –196°C leaving behind the oxygen. The separated nitrogen is reliquified and

stored in specially designed cylinders.

6. How much nitrogen fixation in the environment is contributed by the Haber process?

Ans. 13% of total nitrogen fixation in the environment is contributed by the Haber process.

7. How is sulphuric acid prepared industrially?

Ans. Sulphuric acid is prepared industrially by the contact process.

8. Why must SO_2 and O_2 be purified before entering the contact chamber?

Ans. They must be purified to remove dust and arsenic compounds, as there impurities can poison the catalyst used later on.

9. Why is sulphuric acid called the "king of chemicals"?

Ans. Sulphuric acid is called the "king of chemicals" because it is used in almost every industry.

10. What catalyst and conditions are used to convert SO_2 to SO_3?

Ans. A vanadium (V) oxide (V_2O_5) catalyst is used at a temperature of 450°C and 2-3 atmospheric pressure to convert SO_2 to SO_3.

19.3 Oxides

19.4 Metals

11. What are oxides?

Ans. Oxides: Binary compounds of elements with oxygen are called oxides.

12. Differentiate between basic and acidic oxides.

Ans. Basic oxides: Usually formed by metals. They dissolve in water to produce hydroxides. They change red litmus blue.

Acidic Oxides: Usually formed by non-metals (S, C, N). They dissolve in water to give acids which turn blue litmus red.

13. What are neutral oxides?

Ans. Neutral Oxides: Neutral oxides are those oxides which on contact with water produce neither an acid nor a base.

Examples: Carbon monoxides (CO), nitric oxide (NO) and nitrous oxide (N_2O).

14. Define amphoteric oxides.

Ans. Amphoteric oxides: Amphoteric oxides are usually formed when oxygen reacts with less electropositive metals. They behave both as an acid and a base. They also behave as acids in the presence of an alkali.

Examples: Zinc oxide (Zn) and Aluminum oxide (Al_2O_3).

15. Give a reaction showing ZnO behaving as a base.

Ans. Zinc oxide (ZnO) behaves as a base the presence of an acid.

$$ZnO_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_2O_{(l)}$$

16. Give a reaction showing Al_2O_3 behaving as an acid.

Ans. When Al_2O_3 reacts with an alkali like (NaOH), It behaves as an acid.

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3\,H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4\,(aq)}$$

17. Water is an amphoteric substance. Comment on it.

Ans. Water is an amphoteric substance. It can act as both an acid and a base, depending on the other substance it reacts with.

18. How do group 1 metals (Na, k) react with cold water?

Ans. They react vigorously with cold water to produce their respective hydroxides and hydrogen gas.

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

$$2K_{(s)} + 2H_2O_{(l)} \longrightarrow 2KOH_{(aq)} + H_{2(g)}$$

19. How does magnesium react with water?

Ans. Magnesium reacts with cold water slowly giving magnesium hydroxide and hydrogen gas.

$$Mg_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2\,(s)} + H_{2\,(g)}$$

20. What are the characteristic flame colours of Mg, Ca, Sr, and Ba?

Ans. **Magnesium (Mg):** Intense white flame
Calcium (Ca): White flame with a ting of red.
Strontium (Sr): Crimson flame
Barium (Ba): A pale green flame

19.5 Reactivity Series of Metals

19.6 Role of Oxides of Nitrogen in Spreading Air Pollution

21. Which metals can liberate hydrogen gas from dilute acids?

Ans. Only metals placed above hydrogen in the reactivity series can liberate hydrogen gas upon reacting with dilute acids.

22. Which metals react with oxygen easily and which metals react with oxygen slowly?

Ans. Reactive metals, like potassium and sodium, react with oxygen easily whereas the less reactive metals like silver, copper and iron react with oxygen much more slowly.

23. Which metals in the reactivity series are powerful and why?

Ans. The metals at the top of the series are powerful reducing agents since they are easily oxidized.

24. How the reducing ability of metals decreases in the reactivity series?

Ans. The reducing ability of metals decreases going down the series.

25. What does primary pollutants in the atmosphere include?

Ans. The primary pollutants in the atmosphere include oxides of nitrogen, sulphur and carbon and various hydrocarbons.

26. Differentiate between primary and secondary pollutants.

Ans. **Primary pollutants:** Pollutants emitted directly into the atmosphere are called primary pollutants, such as oxides of nitrogen (NO_x), sulphur and carbon and

various hydrocarbons.

Secondary Pollutants: Secondary pollutants are formed when primary pollutants react in the atmosphere, such as ozone (O_3), peroxyactyl nitrate (PAN), and sulphuric acid.

27. How is nitric oxide (NO) produced naturally?

Ans. It is produced during lightening when electrical discharges cause atmospheric nitrogen and oxygen to react.

$$N_{2(g)} + O_{2(g)} \xrightarrow{\text{Electric arc}} 2NO_{(g)}$$

28. What is the role of NO_2 in the formation of acid rain?

Ans. Nitrogen dioxide reacts with water and other chemicals in the air to produce vapours of nitric acid (HNO_3) and nitrous acid (HNO_2), which contribute to acid rain.

29. What are negative impacts of an acid rain?

Ans.
- Acid rain is damaging for the ecosystem.
- It can corrode materials.
- It can lead to respiratory problems.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ **Choose and tick the correct answer from the given choices.**

1. The reason for maintaining higher temperature for the production of ammonia is:

(a) activation energy of the reaction is very high.
(b) activation energy of the reaction is very low.
(c) nitrogen and hydrogen are both gases.
(d) at low temperature nitrogen and hydrogen change into liquids.

2. The contact process used for the industrial production of H_2SO_4 is sensitive to the impurities present in SO_2 and O_2 because the impurities:

(a) affect the capability of the catalyst (b) affect the purity of H_2SO_4
(c) do not let SO_2 to react with oxygen
(d) decrease the rate of reaction appreciably

3. Which of the following oxides is neutral in character?

(a) Al_2O_3 (b) SO_2 (c) CO_2 (d) NO

4. Sodium is considered more reactive than magnesium because:

(a) It is more electropositive than magnesium
(b) It reacts with water slowly. (c) It is present in second group
(d) It is the less metallic

5. Secondary pollutants present in the atmosphere are:

(a) Oxides of nitrogen (b) Oxides of Sulphur

(c) Ozone and PAN (d) Oxides of Carbon

6. **SO_3 is absorbed in H_2SO_4 rather than H_2O during the production of sulphuric acid because:**
   (a) SO_3 does not react with H_2O
   (b) Reaction of SO_3 with H_2O is highly exothermic producing mist of H_2SO_4 which is difficult to condense.
   (c) It gives better yield of H_2SO_4
   (d) reaction of SO_3 with H_2O can cause explosion.

7. **Oxides formed when oxygen reacts with metals:**
   (a) Acidic (b) Basic
   (c) Both basic and amphoteric (d) Neutral

8. **Major components of acid rain are:**
   (a) H_2SO_4 and HNO_3 (b) H_2SO_3 and HNO_2
   (c) H_2SO_4 and HCl (d) Acetic acid and HNO_3

Answers

1. (a) 2. (a) 3. (d) 4. (a) 5. (c) 6. (b) 7. (b) 8. (a)

B. Short Answer Questions

19.1 How is nitrogen obtained from air?

Ans. Nitrogen is obtained by the fractional distillation of liquid air. Since the boiling point of nitrogen is less than oxygen, nitrogen evaporates first at –196°C leaving behind the oxygen. The separated nitrogen is reliquified and stored in specially designed cylinders.

19.2 How is hydrogen produced from methane?

Ans. Hydrogen is produced by heating methane in the limited amount of oxygen that is not enough to completely oxidize methane to carbon dioxide and water. With less oxygen available, the reaction products contain primarily hydrogen and carbon monoxide and a relatively small amount of carbon dioxide. The carbon monoxide obtained is then reacted with water to form carbon dioxide and more hydrogen gas.

$$CH_{4(g)} + H_2O_{(g)} \longrightarrow CO_{(g)} + 3H_{2(g)}$$

$$CO_{(g)} + H_2O_{(g)} \longrightarrow CO_{2(g)} + H_{2(g)}$$

19.3 Which conditions are used to oxidize SO_2 to SO_3?

Ans. In the contact process, the oxidation occurs at 450°C, a pressure of 2-3 atmosphere, in the presence of a catalyst vanadium (V) oxide (V_2O_5).

19.4 Why CO_2 is called an acidic oxide while CO is called a neutral oxide?

Ans. Carbon dioxide (CO_2) is an acidic oxide because it dissolves in water to form carbonic acid (H_2CO_3) and reacts with bases to form salts.

On the other hand carbon monoxide (CO) is a neutral oxide because it does not react with acids or bases and has no effect on litmus paper.

19.5 How do magnesium and calcium differ with each other towards their reactions with water?

Ans. Calcium reacts vigorously with cold water to produce calcium hydroxide and hydrogen.

$$Ca_{(s)} + H_2O_{(\ell)} \longrightarrow Ca(OH)_{2(s)} + H_{2(g)}$$

Magnesium reacts with cold water slowly giving magnesium hydroxide and hydrogen gas.

$$Mg_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2(s)} + H_{2(g)}$$

19.6 How are the reactivities of metals determined?

Ans. The relative reactivates of metals are determined by comparing how vigorously they react with water, dilute acids and oxygen. Metals are then arranged in decreasing order of their reactivity.

19.7 Which secondary pollutants are produced by oxides of nitrogen?

Ans. Oxides of nitrogen (NO_x) react with other compounds and sunlight to produce ozone (O_3), peroxyacetyl nitrate (PAN), sulphuric acid and acid rain.

C. Constructed Response Questions

19.1 Why ammonia is regarded as an important chemical?

Ans. Ammonia (NH_3) is considered one of the most important chemical for several reasons.

- **Agriculture:** About 80% of the ammonia produced world-wide is used to manufacture nitrogenous fertilizers, such as urea and various ammonium salts. These are essential for increasing crop yields to feed the global population.
- **Industrial Applications:** Ammonia is a key raw material in the production of plastics and pharmaceuticals.
- **Refrigeration:** Due to its thermodynamic properties, ammonia is widely used as an industrial refrigerant.
- **Nitrogen Fixation:** The Haber process, which produces ammonia, contributes to 13% of the total nitrogen fixation in the environment.

19.2 How SO_2 present in the atmosphere is converted to SO_3?

Ans. In the atmosphere, the conversion of sulphur dioxide (SO_2) to sulphur trioxide (SO_3) does not happen efficiently on its own; it requires a catalyst.

- **Catalyst Role:** Oxides of nitrogen (NO_x) present in the air act as catalysts for this reaction.
- **Reaction:** $2SO_{2(g)} + O_{2(g)} \xrightarrow{NO_x} 2SO_{3(g)}$
- **Impact:** Once SO_3 is formed, it reacts with water vapour in the air to produce sulphuric acid (H_2SO_4), which is a major component of acid rain.

19.3 The burning of fossil fuels in a car engine is responsible for the production of oxides of nitrogen. Explain.

Ans. The burning of fossil fuels in a car engine is responsible for the production of oxides of nitrogen is discussed below.

- **High Temperature Environment:** Inside a car engine, the combustion of fossil fuels creates extremely high temperatures.
- **Thermal Reaction:** This intense heat provides the necessary activation energy

for atmospheric nitrogen (N_2) and oxygen (O_2) to react directly.

- **Sequence:** They first form nitric oxide (NO), which then rapidly reacts with more oxygen in the air to form nitrogen dioxide (NO_2).
- **Equation:** $N_{2(g)} + O_{2(g)} \xrightarrow{\text{High Temp}} 2NO_{(g)}$

19.4 The metals present at the top of the reactivity series are regarded as more reactive than those present at the bottom. Comment on this statement.

Ans. Reactivity of Metals: The reactivity of a metal is defined by its ability to lose electrons and form positive ions.

Reactivity Series of Metals: Based on their reactions with water and acids, the metals can be arranged in decreasing order of their reactivities. Such an arrangement is called the reactivity series of metals.

Top of the Series: Metals like potassium (K) and sodium (Na) are at the top because they are highly electropositive.

They lose their valence electrons very easily and react vigorously with water, oxygen and acids.

Reducing Agents: Because they are easily oxidized (lose electrons), metals at the top are considered powerful reducing agents.

Bottom of the Series: Metals like silver (Ag) and gold (Au) are at the bottom because they are very stable and do not lose electrons easily, making them "least reactive".

19.5 How fossil fuels produce SO_2?

Ans. Sulphur dioxide is a by-product of energy production and industrial processes.

- **Impurities:** Most fossil fuels, particularly coal and heavy oils, naturally contain small amounts of sulphur compounds as impurities.
- **Combustion:** When these fuels are burned (combusted) in power plants, factories, or home heating systems, the sulphur reacts with oxygen.
- **Reaction:** $S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$
- **Ore Roasting:** Additionally, roasting sulphide ores like iron pyrite (FeS_2) in excess air also releases large quantities of SO_2.

D. Descriptive Questions

19.1 Explain the production of ammonia on industrial scale.

Ans. For answer see Q1

19.2 Describe the contact process for the production of sulphuric acid.

Ans. For answer see Q3

19.3 Explain the formation and properties of acidic and basic oxides.

Ans. For answer see Q4

19.4 Differentiate between first and second group metals based on their reactivities with oxygen and water.

Ans. For answer see Q6

19.5 Describe the role of oxides of nitrogen in the formation of PAN and the acid rain.

Ans. For answer see Q8