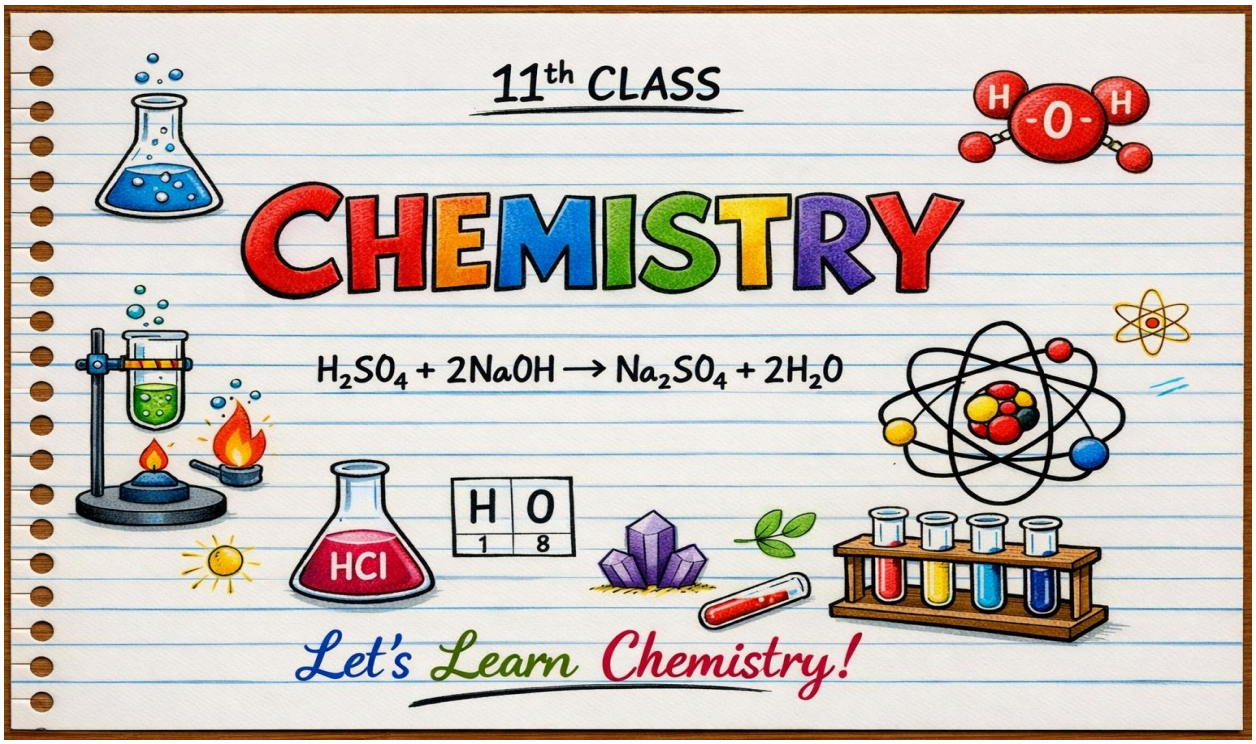


## Class: 11th

## subject: Chemistry

## Unit 12: NITROGEN AND SULFUR

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## ❖ Important MCQs:

**1. Nitrogen belongs to which group of the periodic table?**

(a) Group 13

(b) Group 14

(c) Group 15 ✅

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(d) Group 16

**2. The electronic configuration of nitrogen is:**

(a) $1s^2\ 2s^2\ 2p^5$

(b) $1s^2\ 2s^2\ 2p^3$ ✅

(c) $1s^2\ 2s^2\ 2p^6$

(d) $1s^2\ 2s^1\ 2p^4$

**3. The bond enthalpy of N≡N triple bond is:**

(a) 498 kJ/mol

(b) 945 kJ/mol

(c) 944 kJ/mol ✅

(d) 900 kJ/mol

**4. Nitrogen is chemically inert mainly due to:**

(a) Large atomic size

(b) High electronegativity

(c) Strong triple bond and high bond enthalpy ✅

(d) Presence of lone pair only

**5. The N≡N bond is non-polar because:**

(a) Different atoms are present

(b) Same atoms share electrons equally ✅

(c) High electronegativity difference

(d) Weak bonding

**6. Liquid nitrogen is mainly used for:**

(a) Heating reactions

(b) Rapid cooling purposes ✅

(c) Fuel production

(d) Oxidation reactions

**7. Nitrogen gas is produced in the laboratory by heating:**

(a) $NH_3$ solution

(b) $NH_4NO_2$ solution slowly

(c) $NH_4NO_2$ solution (ammonium nitrite) slowly heated ✅

(d) $NaNO_3$ solution

**8. Correct decomposition of ammonium nitrite is:**

(a) $NH_4NO_2 \longrightarrow N_2 + H_2O$

(b) $NH_4NO_2 \longrightarrow N_2 + 2H_2O$ ✅

(c) $NH_4NO_2 \longrightarrow NO_2 + H_2$

(d) $NH_4NO_2 \longrightarrow NH_3 + NO_2$

**9. Nitrogen requires how many electrons to complete its octet?**

(a) 1

(b) 2

(c) 3 ✅

(d) 5

**10. Nitrogen's low reactivity is also due to:**

(a) Polar covalent bond

(b) Non-polar covalent bond between identical atoms ✅

(c) Ionic bonding

(d) Weak single bond

**11. Ammonia is mainly used as:**

(a) Fuel gas

(b) Fertilizer ✅

(c) Oxidizing agent

(d) Solvent only

**12. Industrial production of ammonia is done by:**

(a) Contact process

(b) Haber-Bosch process ✅

(c) Solvay process

(d) Ostwald process

**13. In Haber process, nitrogen and hydrogen react in the ratio:**

(a) 1:1

(b) 1:2

(c) 1:3 ✅

(d) 2:3

**14. Ammonia acts as a Brønsted-Lowry base by:**

(a) Donating $OH^-$ ions

(b) Accepting $H^+$ ions ✅

(c) Producing electrons

(d) Losing electrons

**15. When ammonia reacts with water, it forms:**

(a) $NH_4Cl$

(b) $NH_4OH$ solution (ammonium hydroxide) ✅

(c) $HNO_3$

(d) $NO_2$

**16. Ammonia solution is weak because:**

(a) It is fully ionized

(b) It has high basicity constant

(c) It has low Kb and equilibrium lies to left ✅

(d) It is ionic compound

**17. Shape of ammonia ($NH_3$) molecule is:**

(a) Linear

(b) Tetrahedral

(c) Trigonal pyramidal ✅

(d) Planar triangular

**18. Ammonium ion ($NH_4^+$) has which shape?**

(a) Linear

(b) Trigonal planar

(c) Tetrahedral ✅

(d) Bent

**19. Laboratory preparation of ammonia involves heating $NH_4Cl$ with:**

(a) HCl

(b) NaOH

(c) $Ca(OH)_2$ ✅

(d) NaCl

**20. A confirmatory test for ammonia gas is:**

(a) Turns blue litmus red

(b) Has fruity smell

(c) Turns moist red litmus paper blue ✅

(d) Produces white smoke only

**21. Which statement best explains why $N_2O_5$ is unstable?**

(a) Weak ionic bonding

(b) It decomposes rapidly into $NO_2$ and $O_2$

(c) It has metallic bonding

(d) It contains hydrogen bonds

Answer: (b) ✅

**22. The oxidation state of nitrogen in $NO_2$ is:**

(a) +1

(b) +2

(c) +4 ✅

(d) +5

**23. NO is rapidly oxidized in air to form:**

(a) $N_2O$

(b) $NO_2$ ✅

(c) $N_2O_5$

(d) $NH_3$

**24. Which oxide of nitrogen exists in equilibrium with $N_2O_4$?**

(a) NO

(b) $NO_2$ ✅

(c) $N_2O$

(d) $N_2O_5$

**25. Lightning produces NO due to:**

(a) Reduction of oxygen

(b) Direct combination of $N_2$ and $O_2$ at high temperature ✅

(c) Decomposition of ammonia

(d) Combustion of nitrogen

**26. The major environmental concern of NOx gases is:**

(a) Global warming only

(b) Formation of acid rain and photochemical smog ✅

(c) Ozone layer repair

(d) Soil fertility increase

**27. Which condition favors photochemical smog formation?**

(a) Low temperature and darkness

(b) Sunlight and high NOx concentration ✅

(c) Rainy atmosphere

(d) High humidity only

**28. Photochemical smog is characterized by the presence of:**

(a) $SO_2$ and CO

(b) $O_3$ and PANs ✅

(c) $CO_2$ and $CH_4$

(d) $N_2$ and $H_2$

**29. PAN acts as a strong:**

(a) Reducing agent

(b) Oxidizing agent causing eye irritation and plant damage ✅

(c) Neutral gas

(d) Fuel gas

**30. Formation of PAN involves which intermediate?**

(a) Alkyl radical

(b) Acyl peroxy radical (RC(O)OO·) ✅

(c) Hydrogen radical

(d) Nitrogen radical

**31. The role of VOCs in smog formation is to:**

(a) Reduce $NO_2$

(b) Participate in radical chain reactions forming ozone and PANs ✅

(c) Neutralize ozone

(d) Remove oxygen from air

**32. Which oxide of nitrogen is least stable and exists as equilibrium mixture?**

(a) $N_2O$

(b) NO

(c) $NO_2$ / $N_2O_4$ system ✅

(d) $N_2O_5$

**33. Denitrifying bacteria in soil produce:**

(a) $NO_2$

(b) $N_2O$ gas ✅

(c) $NH_3$

(d) $HNO_3$

**34. The main oxidizing component of photochemical smog is:**

(a) $CO_2$

(b) $O_3$ (ozone) ✅

(c) $N_2$

(d) $SO_2$

**35. Classical (London) smog mainly consists of:**

(a) Ozone and PAN

(b) $SO_2$ and smoke particles ✅

(c) NOx and VOCs

(d) $CO_2$ and water vapor

**36. Photochemical smog is mainly formed due to reaction of:**

(a) $SO_2$ and $CO_2$

(b) NOx and VOCs in sunlight ✅

(c) CO and $O_2$

(d) $N_2$ and $H_2$

**37. Photochemical smog is called Los Angeles smog because:**

(a) It was first discovered there

(b) It commonly occurs there due to heavy traffic and sunlight ✅

(c) It contains only nitrogen

(d) It is harmless

**38. The nature of photochemical smog is:**

(a) Reducing

(b) Neutral

(c) Oxidizing ✅

(d) Basic

**39. Major component responsible for oxidizing nature of smog is:**

(a) $CO_2$

(b) $O_3$ (ozone) ✅

(c) $N_2$

(d) $SO_2$

**40. Which compound initiates ozone formation in smog?**

(a) $NO_2$ decomposition by sunlight ✅

(b) CO oxidation

(c) $SO_2$ reduction

(d) $N_2$ hydrolysis

**41. VOCs in photochemical smog mainly come from:**

(a) Water

(b) Hydrocarbons from fuels ✅

(c) Oxygen gas

(d) Nitrogen gas

**42. PAN belongs to which class of compounds?**

(a) Alcohols

(b) Peroxyacyl nitrates ✅

(c) Aldehydes

(d) Ketones

**43. General formula of PAN formation involves reaction with:**

(a) NO

(b) $NO_2$ ✅

(c) $CO_2$

(d) $H_2O$

**44. Which intermediate is formed before PAN formation?**

(a) Alkane

(b) Peroxyacyl radical ✅

(c) Amine

(d) Alcohol

**45. PAN causes:**

(a) Cooling of atmosphere

(b) Eye irritation and plant damage ✅

(c) Oxygen production

(d) Water purification

**46. The main purpose of a catalytic converter is to:**

(a) Increase fuel consumption

(b) Reduce harmful exhaust gases ✅

(c) Produce nitrogen gas only

(d) Store gases

**47. Catalytic converter has a structure similar to:**

(a) Solid block

(b) Honeycomb-like structure ✅

(c) Liquid surface

(d) Powder form

**48. Which metals are used in catalytic converters?**

(a) Fe, Cu, Zn

(b) Na, K, Ca

(c) Pt, Pd, Rh ✅

(d) Al, Si, Mg

**49. Catalytic converter converts harmful gases into:**

(a) CO, $NO_2$

(b) $CO_2$, $N_2$, $H_2O$ ✅

(c) $NH_3$, $CH_4$

(d) $SO_2$, CO

**50. Which of the following is NOT removed by catalytic converter?**

(a) CO

(b) NO

(c) Hydrocarbons

(d) $CO_2$ ✅

**51. Nitrification is the process of conversion of:**

(a) $NO_3^- \longrightarrow N_2$

(b) $NH_4^+ \longrightarrow NO_2^-$ and $NO_3^-$ ✅

(c) $N_2 \longrightarrow NH_3$

(d) $NO_2^- \longrightarrow NH_3$

**52. Denitrification involves the conversion of:**

(a) $NH_4^+ \longrightarrow NO_2^-$

(b) $NO_2^- \longrightarrow NO_3^-$

(c) $NO_3^- \longrightarrow N_2$ ✅

(d) $N_2 \longrightarrow NH_3$

**53. Which ion is an intermediate in nitrification?**

(a) $NH_3$

(b) $NO_2^-$ ✅

(c) $CO_2$

(d) $SO_4^{2-}$

**54. Nitrification mainly occurs in:**

(a) Air

(b) Soil by bacteria ✅

(c) Water only

(d) Plants only

**55. Denitrification is carried out by:**

(a) Plants

(b) Animals

(c) Denitrifying bacteria ✅

(d) Fungi only

**56. Sulfur belongs to which group of periodic table?**

(a) Group 14

(b) Group 15

(c) Group 16 (Chalcogens) ✅

(d) Group 17

**57. The chalcogen family includes:**

(a) N, P, As

(b) O, S, Se ✅

(c) Na, K, Ca

(d) Cl, Br, I

**58. Sulfur forms $S_8$ molecule due to:**

(a) Ionic bonding

(b) Double bonding

(c) Catenation (self-linking ability) ✅

(d) Metallic bonding

**59. Shape of $S_8$ molecule is:**

(a) Linear

(b) Planar

(c) Crown-like ring ✅

(d) Tetrahedral

**60. Common oxidation states of sulfur are:**

(a) -1, +1, +3

(b) -2, 0, +2, +4, +6 ✅

(c) +1, +2 only

(d) 0, +3, +5

**61. In $SO_2$, oxidation state of sulfur is:**

(a) +2

(b) +3

(c) +4 ✅

(d) +6

**62. Formation of $SO_3$ requires:**

(a) Low energy

(b) No catalyst

(c) High energy conditions ✅

(d) Only water

**63. Under acidic conditions, which form of sulfur is more stable?**

(a) Oxidized form ($SO_4^{2-}$)

(b) Reduced form ($H_2S$) ✅

(c) Neutral sulfur

(d) $SO_2$ only

**64. Under basic conditions, which sulfur form is more stable?**

(a) $H_2S$

(b) $SO_4^{2-}$ (+6 oxidation state) ✅

(c) $S_8$

(d) $SO_2$

**65. In contact process, which catalyst is used for formation of $SO_3$?**

(a) Iron

(b) Nickel

(c) Vanadium ($V_2O_5$) ✅

(d) Copper

**66. Sulfur burns in air to produce:**

(a) $SO_3$

(b) $SO_2$ with blue flame ✅

(c) $H_2S$

(d) $CS_2$

**67. Formation of $SO_3$ from sulfur requires:**

(a) Low temperature

(b) No catalyst

(c) High temperature and catalyst ✅

(d) Only water

**68. When sulfur reacts with metals like Ag, Cu, Zn, it forms:**

(a) Oxides

(b) Sulfides (tarnishing) ✅

(c) Carbonates

(d) Nitrides

**69. In reactions with less electronegative elements, sulfur acts as:**

(a) Reducing agent

(b) Oxidizing agent ✅

(c) Neutral substance

(d) Catalyst

**70. Sulfur converts cyanide ($CN^-$) into:**

(a) Nitrate

(b) Thiocyanate ($SCN^-$) ✅

(c) Ammonia

(d) Sulfate

**71. Reaction of sulfur with fluorine produces:**

(a) $SF_2$

(b) $SF_4$ and $SF_6$ ✅

(c) $SO_2$

(d) $H_2S$

**72. Sulfur hexafluoride ($SF_6$) is:**

(a) Highly reactive gas

(b) Liquid

(c) Very unreactive gas used as insulator ✅

(d) Acidic gas

**73. Reaction of sulfur with chlorine forms initially:**

(a) $SCl_4$

(b) $S_2Cl_2$ (yellow liquid) ✅

(c) $SO_2$

(d) HCl

**74. Vulcanization of rubber involves:**

(a) Oxygen bridges

(b) Nitrogen bridges

(c) Sulfur (S–S) cross links ✅

(d) Hydrogen bonds

**75. Main purpose of vulcanization is to:**

(a) Reduce strength

(b) Increase rubber strength and elasticity ✅

(c) Change color only

(d) Decrease durability

**76. Which sulfur compound is commonly used as fertilizer?**

(a) NaCl

(b) $CaSO_4 \cdot 2H_2O$ (Gypsum) ✅

(c) $CO_2$

(d) $NH_3$

**77. In gunpowder, sulfur acts as:**

(a) Oxidizer

(b) Fuel (helps burning faster) ✅

(c) Catalyst

(d) Inhibitor

**78. Composition of gunpowder includes:**

(a) $KNO_3$, charcoal, sulfur ✅

(b) NaCl, carbon, sulfur

(c) $H_2SO_4$, carbon, oxygen

(d) $NH_3$, sulfur, oxygen

**79. Sulfur-containing organic compounds include:**

(a) Alcohols only

(b) Thiols, thioethers, sulfoxides, sulfones ✅

(c) Alkanes only

(d) Alkenes only

**80. Mercaptans (thiols) are used as:**

(a) Fertilizers

(b) Odorants in natural gas ✅

(c) Fuels

(d) Oxidizers

**81. About 85% of sulfur is used for the production of:**

(a) $SO_2$

(b) $H_2SO_4$ (sulfuric acid) ✅

(c) $H_2S$

(d) $SO_3$

**82. Structure of sulfuric acid is:**

(a) Linear

(b) Planar

(c) Tetrahedral ✅

(d) Octahedral

**83. Industrial preparation of sulfuric acid is done by:**

(a) Haber process

(b) Contact process ✅

(c) Solvay process

(d) Ostwald process

**84. First step of contact process involves:**

(a) Formation of $SO_3$

(b) Combustion of sulfur to $SO_2$ ✅

(c) Absorption in water

(d) Cooling of gases

**85. Pyrite used in contact process is:**

(a) $Fe_2O_3$

(b) $FeS_2$ ✅

(c) $FeSO_4$

(d) $FeCO_3$

**86. Purpose of purification unit in contact process is to:**

(a) Cool gases

(b) Remove impurities like dust and $As_2O_3$ ✅

(c) Add oxygen

(d) Increase pressure

**87. Arsenic oxide impurities are removed by:**

(a) Water

(b) Activated carbon

(c) Ferric hydroxide $Fe(OH)_3$ ✅

(d) Sulfur

**88. Catalyst used in contact process is:**

(a) Fe

(b) Ni

(c) $V_2O_5$ (vanadium pentoxide) ✅

(d) Cu

**89. Optimal temperature in contact tower is around:**

(a) 100°C

(b) 200°C

(c) 420–450°C ✅

(d) 700°C

**90. Direct mixing of $SO_3$ with water is avoided because:**

(a) Reaction is slow

(b) It produces toxic gas

(c) Reaction is highly exothermic and forms acid mist ✅

(d) No reaction occurs

**91. Oleum is:**

(a) Pure $H_2SO_4$

(b) $SO_3$ dissolved in $H_2SO_4$ ✅

(c) $SO_2$ in water

(d) Dilute acid

**92. Sulfuric acid is:**

(a) Non-polar

(b) Weak acid

(c) Hygroscopic (absorbs water) ✅

(d) Non-corrosive

**93. Concentrated $H_2SO_4$ acts as:**

(a) Only acid

(b) Only base

(c) Dehydrating agent ✅

(d) Neutral substance

**94. Dehydration of ethanol by $H_2SO_4$ produces:**

(a) Methane

(b) Ethene ($C_2H_4$) ✅

(c) Ethanol

(d) $CO_2$

**95. Reaction of NaCl with $H_2SO_4$ produces:**

(a) $NH_3$

(b) HCl gas ✅

(c) $CO_2$

(d) $SO_2$

**96. Metals above hydrogen in electrochemical series react with dilute $H_2SO_4$ to produce:**

(a) $SO_2$

(b) $H_2$ gas and metal sulfate ✅

(c) $CO_2$

(d) $N_2$

**97. Hot concentrated $H_2SO_4$ reacts with metals to produce:**

(a) $H_2$ gas

(b) $SO_2$ gas ✅

(c) $N_2$ gas

(d) $O_2$ gas

**98. Sulfuric acid is called "King of Chemicals" because:**

(a) It is cheapest

(b) It is most reactive

(c) Its consumption indicates industrial progress ✅

(d) It is rare

**99. Major use of sulfuric acid is in:**

(a) Fuel production

(b) Fertilizer industry ✅

(c) Water purification only

(d) Textile only

**100. Sulfuric acid is used in lead storage batteries in concentration:**

(a) 10%

(b) 20%

(c) 35.67% ✅

(d) 80%

## ❖ Important Short Questions:

**1. Why is nitrogen gas chemically inert?**

**Answer:**

Nitrogen gas is chemically inert due to the presence of a very strong triple bond (N≡N) with high bond enthalpy, which requires a large amount of energy to break. It is also non-polar, so it does not easily react.

**Example:** $N_2$ does not react with oxygen at room temperature but reacts only at very high temperature (e.g., during lightning).

**2. What is the bond enthalpy of nitrogen molecule?**

**Answer:**

The bond enthalpy of nitrogen molecule (N≡N) is 944 kJ/mol, which makes the bond very strong and difficult to break.

**Example:** High energy is required to convert $N_2$ into ammonia in Haber process.

**3. What is the electronic configuration of nitrogen?**

**Answer:**

The electronic configuration of nitrogen is $1s^2\ 2s^2\ 2p^3$. It has 5 valence electrons.

**Example:** Nitrogen forms three covalent bonds to complete its octet in $NH_3$.

**4. How is ammonia prepared industrially?**

**Answer:**

Ammonia is prepared industrially by the Haber process, where nitrogen reacts with hydrogen under high pressure and temperature in the presence of iron catalyst.

**Example:** $N_2 + 3H_2 \rightleftharpoons 2NH_3$

**5. What are the conditions required for the Haber process?**

**Answer:**

- Temperature: ~450°C
- Pressure: 200 atm
- Catalyst: Finely divided iron (Fe)

**Example:** These conditions increase yield of $NH_3$.

**6. Why is ammonia considered a weak base?**

**Answer:**

Ammonia is a weak base because it partially ionizes in water and has a low base dissociation constant (Kb).

**Example:** $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ (reversible reaction)

**7. What is the shape of $NH_3$ molecule?**

**Answer:**

$NH_3$ has a trigonal pyramidal shape due to one lone pair on nitrogen.

**Example:** Ammonia looks like a pyramid with nitrogen at the top and three hydrogen atoms at the base.

**8. What is the shape of $NH_4^+$ ion?**

**Answer:**

$NH_4^+$ ion has a tetrahedral shape because all four bonds are identical after lone pair donation.

**Example:** Ammonium ion has equal bond angles of 109.5°.

**9. How is ammonia prepared in the laboratory?**

**Answer:**

Ammonia is prepared by heating ammonium chloride ($NH_4Cl$) with calcium hydroxide ($Ca(OH)_2$).

**Reaction:** $NH_4Cl + Ca(OH)_2 \longrightarrow NH_3 + CaCl_2 + H_2O$

**Example:** Ammonia gas is collected by downward displacement of air.

**10. What is the identification test for ammonia gas?**

**Answer:**

Ammonia gas turns moist red litmus paper blue due to its basic nature. It also has a pungent smell.

Example: $NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$ (produces $OH^-$ ions causing basic behavior)

**11. What are NOx gases?**

**Answer:**

NOx gases are a group of nitrogen oxides, mainly nitric oxide (NO) and nitrogen dioxide ($NO_2$). These gases are produced during high-temperature combustion processes such as in vehicle engines and power plants. They are harmful air pollutants and contribute to smog formation.

**Example:** Smoke coming from cars and buses releases NOx gases into the air.

**12. What is photochemical smog?**

**Answer:**

Photochemical smog is a type of air pollution formed when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight. It produces harmful chemicals like ozone and PAN. It is also called Los Angeles smog and is oxidizing in nature.

**Example:** In big cities like Karachi or Los Angeles, the hazy brown air in hot sunny weather is photochemical smog.

**13. What is the main component of photochemical smog?**

**Answer:**

The main component of photochemical smog is ozone ($O_3$), along with PAN and nitrogen dioxide. Ozone at ground level is harmful and affects breathing.

**Example:** High ozone levels in polluted air can cause coughing and eye irritation.

**14. What is PAN?**

**Answer:**

PAN stands for Peroxyacetyl Nitrate. It is a toxic chemical formed in photochemical smog from reactions involving NOx and hydrocarbons. It is very harmful to human eyes and plant leaves.

**Example:** PAN causes damage to crops and reduces agricultural productivity.

**15. What happens to $NO_2$ in sunlight?**

**Answer:**

In sunlight, $NO_2$ breaks down into nitric oxide (NO) and atomic oxygen. The atomic oxygen then reacts with oxygen gas ($O_2$) to form ozone ($O_3$), which is a major part of smog.

**Example:** In sunny traffic areas, $NO_2$ from car exhaust helps form ozone pollution.

**16. What is the function of a catalytic converter?**

**Answer:**

A catalytic converter is used in vehicles to reduce harmful gases from exhaust. It converts carbon monoxide (CO), nitrogen oxides (NOx), and

hydrocarbons into less harmful gases like carbon dioxide ($CO_2$), nitrogen ($N_2$), and water ($H_2O$).

**Example:** In cars, it helps reduce air pollution from engine exhaust.

**17. Which metals are used in catalytic converters?**

**Answer:**

Platinum (Pt), Palladium (Pd), and Rhodium (Rh) are used as catalysts. These metals speed up chemical reactions without being consumed.

**Example:** These metals help convert NOx into nitrogen gas in car exhaust systems.

**18. What is nitrification?**

**Answer:**

Nitrification is a biological process in the nitrogen cycle where ammonium ions ($NH_4^+$) are converted into nitrites ($NO_2^-$) and then nitrates ($NO_3^-$) by soil bacteria. These nitrates are used by plants as nutrients.

**Example:** Fertile soil contains nitrates produced by nitrifying bacteria.

**19. What is denitrification?**

**Answer:**

Denitrification is the process in which nitrate ions ($NO_3^-$) are converted back into nitrogen gas ($N_2$) by bacteria. This nitrogen gas is released into the atmosphere, completing the nitrogen cycle.

**Example:** Waterlogged soil releases nitrogen gas due to denitrification.

**20. To which group does sulfur belong?**

**Answer:**

Sulfur belongs to Group 16 of the periodic table, also called the chalcogen family. Elements in this group include oxygen, sulfur, selenium, and tellurium.

**Example:** Oxygen and sulfur behave similarly because they are in the same group.

**21. What is catenation in sulfur?**

**Answer:**

Catenation is the ability of sulfur atoms to form chains or ring structures by bonding with each other. This happens due to strong S–S bonds.

**Example:** Sulfur exists as $S_8$ molecules forming a crown-shaped ring.

**22. What is the shape of $S_8$ molecule?**

**Answer:**

$S_8$ molecule has a crown-shaped ring structure where eight sulfur atoms are linked together in a puckered ring form.

Example: Solid sulfur in laboratory is found in $S_8$ ring form.

**23. What is the oxidation state of sulfur in $SO_2$?**

**Answer:**

In $SO_2$, sulfur has an oxidation state of +4. This is calculated based on oxygen being more electronegative.

**Example:** $SO_2$ is produced when sulfur burns in air with a blue flame.

**24. How is sulfuric acid prepared industrially?**

**Answer:**

Sulfuric acid is prepared by the Contact process. In this process, sulfur is burned to form $SO_2$, which is then converted to $SO_3$ using $V_2O_5$ catalyst. $SO_3$ is then absorbed in $H_2SO_4$ to form oleum, which is diluted to make sulfuric acid.

**Example:** Factories use this process to produce large amounts of $H_2SO_4$ for fertilizers.

**25. What is oleum?**

**Answer:**

Oleum is a mixture of sulfur trioxide ($SO_3$) dissolved in concentrated sulfuric acid ($H_2SO_4$). It is also called fuming sulfuric acid and is used to prepare highly concentrated $H_2SO_4$.

**Example:** Industrial plants use oleum to safely produce strong sulfuric acid.

## ❖ Important Long Questions:

### 🌟 Q.1 Explain the reactivity of nitrogen ($N_2$). Why is it chemically inert?

**Answer:**

Nitrogen gas ($N_2$) is chemically inert under normal conditions due to its very stable structure and strong bonding between the two nitrogen atoms.

#### 1. Strong Triple Bond (N≡N)

- In nitrogen molecule, two nitrogen atoms are joined by a triple covalent bond (N≡N) which consists of one sigma bond and two pi bonds. This bond is extremely strong and stable.

#### 2. High Bond Enthalpy

- The bond enthalpy of nitrogen molecule is +944 kJ $mol^{-1}$, which is very high.
- A large amount of energy is required to break this bond, so nitrogen does not react easily at normal conditions.

### 3. Non-Polar Nature

- Nitrogen molecule is non-polar because both atoms are identical and share electrons equally. There is no electronegativity difference, so the molecule has no partial charges and shows low reactivity.

### 4. Stable Electronic Configuration

- Each nitrogen atom has the electronic configuration $1s^2\ 2s^2\ 2p^3$. By forming a triple bond, both atoms complete their octet and become highly stable.

### 5. High Activation Energy Requirement

Due to strong bonding, nitrogen requires very high energy to react. It only reacts under special conditions such as:

- High temperature (e.g., lightning)
- High pressure and catalyst (e.g., Haber process)

**Summary:**

Nitrogen is chemically inert because of its strong triple bond, high bond enthalpy (+944 kJ $mol^{-1}$), non-polar nature, and high stability, which makes it very difficult to break and react under normal conditions.

**Example:**

Nitrogen does not react with oxygen at room temperature, but during lightning it reacts to form nitrogen oxides (NOx).

## 🌟 Q.2 Describe the Haber Process for the industrial preparation of ammonia.

**Answer:**

The Haber Process is an industrial method used for the production of ammonia ($NH_3$) from nitrogen and hydrogen gases. It is one of the most important industrial processes because ammonia is widely used in fertilizers.

### 1. Chemical Equation:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + Heat$

This is a reversible reaction and occurs with the release of heat (exothermic reaction).

### 2. Conditions of Haber Process:

**(i) Temperature:**

- About 450°C
- High temperature increases reaction rate but reduces yield, so a moderate temperature is used.

**(ii) Pressure:**

- About 200 atm
- High pressure favors the formation of ammonia because fewer gas molecules are produced.

**(iii) Catalyst:**

- Finely divided iron (Fe)
- It increases the rate of reaction without affecting the yield.

**(iv) Promoter:**

- Molybdenum (Mo) is used to increase catalyst efficiency.

## 3. Working Principle:

- Nitrogen and hydrogen gases are mixed in a ratio of 1:3.
- The mixture is passed over iron catalyst at high temperature and pressure.
- Ammonia is formed continuously but removed by cooling so that equilibrium shifts forward (Le Chatelier's Principle).

## 4. Importance of Haber Process:

- Produces ammonia on a large industrial scale
- Ammonia is used in fertilizer production (ammonium sulfate, urea)
- Important for agricultural productivity
- Used in production of nitric acid and explosives

**Summary:**

The Haber Process is a very important industrial method for ammonia production, carried out under high pressure (200 atm), moderate

temperature (450°C), and iron catalyst to achieve good yield and fast reaction.

**Example:**

Ammonia produced by Haber process is mainly used to make fertilizers like ammonium nitrate and urea, which increase crop production.

### 🌟 Q.3 Explain the formation of photochemical smog and the role of NOx and VOCs.

**Answer:**

Photochemical smog is a type of air pollution formed in the atmosphere when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight. It is commonly found in large cities with heavy traffic and is also called Los Angeles smog. It is oxidizing in nature and harmful to living organisms.

### 1. Formation of Photochemical Smog:

Photochemical smog is formed through a series of chemical reactions:

**Step 1: Breakdown of Nitrogen Dioxide ($NO_2$)**

In sunlight, nitrogen dioxide absorbs energy and splits:

$$NO_2 \xrightarrow{sunlight} NO + O$$

## Step 2: Formation of Ozone ($O_3$)

The atomic oxygen reacts with oxygen gas:

$$O + O_2 \rightarrow O_3$$

👉 This ozone ($O_3$) is a major harmful component of smog.

### 2. Role of NOx (Nitrogen Oxides):

- NOx gases (NO and $NO_2$) are produced from vehicle exhausts, power plants, and industrial burning.
- $NO_2$ starts the smog formation by breaking in sunlight.
- NOx also helps in the formation of secondary pollutants like PAN.

### 3. Role of VOCs (Volatile Organic Compounds):

- VOCs are gases released from fuel vapors, petrol, and chemical industries.
- They react with NOx and ozone to form harmful substances like PAN and aldehydes.
- VOCs increase the toxicity and density of smog.

### 4. Harmful Effects of Photochemical Smog:

- Causes irritation in eyes and throat
- Damages lungs and breathing system
- Reduces visibility in atmosphere
- Harms plants and reduces crop yield

**Summary:**

Photochemical smog is formed due to the reaction of NOx and VOCs in sunlight, producing ozone and other toxic chemicals like PAN, which cause serious environmental and health problems.

**Example:**

In big cities during summer, a brown haze is seen in the air due to photochemical smog, especially during heavy traffic hours.

### 🌟 Q.4 Describe the Contact Process for the manufacture of sulfuric acid.

**Answer:**

The Contact Process is an industrial method used for the large-scale production of sulfuric acid ($H_2SO_4$). It is called the "Contact Process" because sulfur dioxide gas comes in contact with a solid catalyst ($V_2O_5$) during the reaction. Sulfuric acid is one of the most important industrial chemicals used in fertilizers, batteries, and many chemical industries.

This process consists of five main steps, each with an important role.

### 1. Formation of Sulfur Dioxide ($SO_2$):

In the first step, sulfur dioxide gas is prepared as the starting material. It is produced by burning sulfur in air or by roasting iron pyrite ore.

**Equations:**

$S + O_2 \longrightarrow SO_2$

$4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

👉 In this step, sulfur combines with oxygen to form $SO_2$ gas, which is the main raw material for sulfuric acid production.

### 2. Purification of $SO_2$ Gas:

The $SO_2$ gas obtained from furnaces contains impurities like dust, arsenic compounds, and moisture. These impurities must be removed because they can damage or poison the catalyst.

👉 **In purification units:**

- Dust is removed by filters
- Arsenic compounds are removed by special purifiers
- Moisture is removed by drying agents

✔ This step ensures that only pure $SO_2$ gas enters the next stage.

### 3. Catalytic Oxidation of $SO_2$ to $SO_3$:

In this most important step, sulfur dioxide is converted into sulfur trioxide.

**Equation:**

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

👉 This reaction is:

- Reversible
- Exothermic

**Conditions:**

- Catalyst: Vanadium pentoxide ($V_2O_5$)
- Temperature: 450°C
- Pressure: 1–2 atm

👉 The catalyst increases the speed of reaction without being used up.

### 4. Absorption of $SO_3$:

Sulfur trioxide cannot be directly mixed with water because it forms a fine acid mist, which is difficult to handle and unsafe.

So instead, $SO_3$ is absorbed in concentrated sulfuric acid.

**Equation:**

$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$ (Oleum)

👉 This step produces oleum, also known as fuming sulfuric acid.

### 5. Formation of Sulfuric Acid ($H_2SO_4$):

In the final step, oleum is carefully diluted with water to produce sulfuric acid of required concentration.

**Equation:**

$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

👉 This allows safe and controlled production of concentrated sulfuric acid.

**Summary:**

The Contact Process is an efficient industrial method for producing sulfuric acid. It involves preparation of $SO_2$, purification, catalytic oxidation using $V_2O_5$, absorption in $H_2SO_4$ to form oleum, and final dilution to produce $H_2SO_4$. Each step is important for high yield and safety.

**Example:**

Sulfuric acid produced by this process is widely used in:

- Fertilizers (ammonium sulfate, superphosphate)
- Car batteries
- Chemical manufacturing industries

**🌟 Q.5 Explain the catalytic converter and its role in reducing air pollution.**

**Answer:**

A catalytic converter is an important device used in vehicles (cars, buses, motorcycles) to reduce harmful gases released from engine

exhaust. It helps in controlling air pollution by converting toxic gases into less harmful substances.

It is usually fitted in the exhaust system of vehicles.

### 1. Structure of Catalytic Converter:

The catalytic converter has a honeycomb-like structure made of ceramic or metal. This structure provides a large surface area for reactions.

- The inner surface is coated with a thin layer of alumina ($Al_2O_3$)
- This layer supports the catalytic metals
- Exhaust gases pass through many small channels, increasing contact with catalyst

👉 This design makes the reaction more efficient.

### 2. Metals Used:

The following noble metals are used as catalysts:

- Platinum (Pt)
- Palladium (Pd)
- Rhodium (Rh)

👉 These metals are used because they:

- Speed up chemical reactions
- Are not consumed in the reaction
- Work at high temperatures

## 3. Working / Reactions in Catalytic Converter:

The catalytic converter performs three main reactions:

**(i) Conversion of Carbon Monoxide (CO):**

CO is a poisonous gas. It is converted into carbon dioxide.

$2CO + O_2 \longrightarrow 2CO_2$

**(ii) Conversion of Nitrogen Oxides (NOx):**

NOx gases are converted into nitrogen gas.

$2NO \longrightarrow N_2 + O_2$

**or overall:**

$2NO + 2CO \longrightarrow N_2 + 2CO_2$

**(iii) Conversion of Hydrocarbons:**

Unburnt hydrocarbons are converted into carbon dioxide and water.

$CxHy + O_2 \longrightarrow CO_2 + H_2O$

## 4. Role in Reducing Air Pollution:

- Removes poisonous gases like CO and NOx
- Reduces formation of smog and acid rain
- Improves air quality in cities
- Protects human health and environment

**Summary:**

A catalytic converter is an essential pollution-control device in vehicles. It uses Pt, Pd, and Rh catalysts and converts harmful exhaust gases into less harmful gases like $CO_2$, $N_2$, and $H_2O$, thus reducing air pollution effectively.

**Example:**

Modern cars use catalytic converters so that harmful gases from fuel combustion do not directly pollute the air in cities.

### 🌟 Q.6 Describe the nitrogen cycle focusing on nitrification and denitrification processes.

**Answer:**

The nitrogen cycle is a natural biological process in which nitrogen is continuously circulated between the atmosphere, soil, plants, animals, and microorganisms. Nitrogen is an essential element for the formation of proteins and nucleic acids, but atmospheric nitrogen ($N_2$) cannot be directly used by plants. Therefore, it must be converted into usable forms through different biological processes.

Two important stages of the nitrogen cycle are nitrification and denitrification.

**1. Nitrification:** Nitrification is the process in which ammonium ions ($NH_4^+$) are converted into nitrites ($NO_2^-$) and then into nitrates ($NO_3^-$) by the action of soil bacteria.

## Steps of nitrification:

**Step 1: Ammonium → Nitrite**

$NH_4^+ \longrightarrow NO_2^-$

👉 This step is carried out by bacteria such as Nitrosomonas.

**Step 2: Nitrite → Nitrate**

$NO_2^- \longrightarrow NO_3^-$

👉 This step is carried out by bacteria such as Nitrobacter.

**Importance of Nitrification:**

- Converts nitrogen into a form usable by plants
- Nitrates are absorbed by plants to make proteins
- Helps maintain soil fertility

## 2. Denitrification:

Denitrification is the process in which nitrates ($NO_3^-$) are converted back into nitrogen gas ($N_2$) and released into the atmosphere.

**Reaction:**

$NO_3^- \longrightarrow NO_2^- \longrightarrow N_2$ (gas)

👉 This process is carried out by denitrifying bacteria such as Pseudomonas.

**Importance of Denitrification:**

- Returns nitrogen back to the atmosphere
- Maintains balance of nitrogen in nature
- Prevents excessive accumulation of nitrates in soil

### 3. Overall Nitrogen Cycle Concept:

- Atmospheric nitrogen ($N_2$) is fixed into ammonia and ammonium compounds
- Ammonium is converted into nitrites and nitrates (nitrification)
- Plants absorb nitrates to make proteins
- Animals get nitrogen by eating plants
- Waste and dead organisms return nitrogen to soil
- Nitrates are converted back to nitrogen gas (denitrification)

**Summary:**

The nitrogen cycle is a continuous natural process that maintains the balance of nitrogen in the environment. Nitrification converts ammonium into nitrates for plant use, while denitrification returns nitrates back to atmospheric nitrogen, completing the cycle.

**Example:**

When plants absorb nitrates from soil, they use it to make proteins. After plant and animal decay, bacteria convert nitrates back into nitrogen gas, completing the cycle.

## 🌟 Q.8 Describe the uses and importance of sulfur and sulfuric acid in industry and daily life.

**Answer:**

Sulfur and sulfuric acid are among the most important substances in chemistry. They are widely used in industry, agriculture, medicine, and daily life products. Sulfur is a raw material for many compounds, while sulfuric acid is called the “King of Chemicals” because it is involved in almost every industrial process.

## 1. Uses and Importance of Sulfur

Sulfur is a yellow, non-metal element that occurs naturally and is also obtained from industrial processes. It is very reactive and forms many useful compounds, making it important in different fields.

### (i) Vulcanization of Rubber

Sulfur is mainly used to improve the physical properties of natural rubber.

👉 In vulcanization, sulfur forms cross-links (S–S bonds) between long rubber polymer chains.

This changes soft rubber into a more useful material.

**Importance:**

- Increases strength and durability
- Improves elasticity (rubber returns to original shape)
- Makes rubber resistant to heat and wear

**Example:** Car tyres, conveyor belts, and shoe soles.

### (ii) Fertilizers in Agriculture

Sulfur is an essential nutrient required for plant growth along with nitrogen, phosphorus, and potassium.

👉 It is used in fertilizers such as:

- Ammonium sulfate $(NH_4)_2SO_4$
- Sulfur-coated fertilizers
- Gypsum ($CaSO_4 \cdot 2H_2O$)

**Importance:**

- Helps in protein formation in plants
- Improves soil fertility
- Increases crop yield

**Example:** Wheat, rice, and vegetable crops grow better with sulfur-rich fertilizers.

### (iii) Gunpowder and Explosives

Sulfur is an important component of black gunpowder along with potassium nitrate and carbon.

👉 **It helps in:**

- lowering ignition temperature
- increasing burning speed
- smooth combustion reaction

**Importance:**

- It makes explosive materials ignite quickly and efficiently.
- **Example:** Fireworks and blasting in mining.

**(iv) Industrial Chemical Production**

Sulfur is a starting material for many important chemicals.

👉 **It is used to produce:**

- sulfur dioxide ($SO_2$)
- sulfur trioxide ($SO_3$)
- sulfuric acid ($H_2SO_4$)

**Importance:**

These compounds are further used in fertilizers, acids, and industrial reactions.

**(v) Organic and Biological Compounds**

Sulfur is present in many organic compounds and biological molecules.

👉 **It is used in:**

- medicines (sulfa drugs)
- dyes
- fragrances (thiols and mercaptans)

**Importance:**

It helps in producing pharmaceuticals and aromatic compounds used in daily life.

## 2. Uses and Importance of Sulfuric Acid ($H_2SO_4$)

Sulfuric acid is one of the most widely used industrial chemicals in the world. It is very corrosive and reactive, which makes it extremely useful in chemical reactions.

### (i) Fertilizer Industry (Most Important Use)

The largest use of sulfuric acid is in fertilizer production.

👉 It is used to manufacture:

- ammonium sulfate
- superphosphate fertilizers

**Importance:**

- Increases soil fertility
- Improves plant growth
- Supports food production for growing population

**Example:** Used in wheat, rice, and maize farming.

### (ii) Lead-Acid Batteries

- Sulfuric acid acts as an electrolyte in car batteries.

**Importance:**

- Helps in flow of electric current

- Stores and releases energy
- **Example:** Used in cars, UPS systems, and backup batteries.

**(iii) Petroleum and Oil Refining**

- Sulfuric acid is used in refining crude oil.

**Importance:**

- Removes impurities from petroleum products
- Improves quality of fuels
- **Example:** Petrol and diesel purification.

**(iv) Chemical Manufacturing Industry**

- It is used as a raw material in many chemical processes.

👉 Used in production of:

- detergents
- dyes
- plastics
- paints
- pharmaceuticals

**Importance:**

- It acts as a strong acid and catalyst in many reactions.

**(v) Dehydrating Agent**

- Sulfuric acid has a strong ability to remove water from substances.

**Importance:**

- Used in chemical reactions requiring removal of water
- Helps in formation of new compounds

**Example:** It converts ethanol into ethene.

**(vi) Metal Processing and Extraction**

- Sulfuric acid is used to extract and purify metals like copper, zinc, and nickel.

**Importance:**

- Helps in separating metals from ores
- Used in electroplating industries

**(vii) Laboratory and Industrial Uses**

In laboratories, sulfuric acid is used as:

- strong acid reagent
- drying agent for gases

**Importance:**

- It is essential for experiments and chemical analysis.

**Summary:**

Sulfur is important for vulcanization, fertilizers, explosives, and chemical production, while sulfuric acid is essential for fertilizers, batteries, petroleum refining, and many industries. Both substances are fundamental for modern industry, agriculture, and daily life applications.

**Example:**

- Car tyres are strong due to sulfur vulcanization
- Car batteries work using sulfuric acid
- Fertilizers made from sulfuric acid increase crop production

# 📘 Exercise

## Q.1 Four choices are given for each questions. Select the correct choice.

**I. Despite being the most abundant gas in the Earth's atmosphere, nitrogen does not readily participate in combustion reactions because:**

(a) It is denser than oxygen.

(b) It has a high specific heat capacity.

(c) Breaking the N≡N bond requires a large amount of energy. ✅

(d) It is a noble gas.

**II. A student heats a solid ammonium salt with a solution of a strong alkali. The gas produced turns damp red litmus paper blue and has a characteristic pungent smell. The gas is:**

(a) Hydrogen ($H_2$)

(b) Carbon dioxide ($CO_2$)

(c) Ammonia ($NH_3$) ✅

(d) Sulfur dioxide ($SO_2$)

**III. The shape of ammonium is:**

(a) Pyramidal

(b) Triangular planar

(c) Tetrahedral ✅

(d) Linear

**IV. In a catalytic converter, the conversion of nitrogen oxides (NO) into nitrogen gas ($N_2$) and oxygen gas ($O_2$) is a process of:**

(a) Oxidation

(b) Reduction ✅

(c) Combustion

(d) Neutralization

**V. PAN formation starts when _____ reacts with the hydrocarbon:**

(a) NO

(b) $NO_2$ ✅

(c) $O_3$

(d) HO

**VI. Nitrification is the process by which:**

(a) Atmospheric nitrogen is converted into ammonia.

(b) Nitrate is converted into nitrogen gas.

(c) Ammonia is converted into nitrite and then nitrate. ✅

(d) Organic nitrogen is converted into ammonia.

**VII. The most stable species in an acidic environment is:**

(a) $SO_4^{2-}$

(b) $SO_2$

(c) $H_2S$ ✅

(d) S

**VIII. Which gas is used in separating hard water from normal water?**

(a) $SO_2$

(b) $H_2S$

(c) $NH_3$ ✅

(d) $NO_2$

**IX. The oxidation state of sulfur in $H_2SO_4$ is:**

(a) +1

(b) +2

(c) +4

(d) +6 ✅

**X. The drug omeprazole contains ------- group:**

(a) Thiol

(b) Sulfoxide ✅

(c) Bisulfide

(d) Sulfone

**XI. Sulfur dioxide ($SO_2$) produced from the combustion of sulfur can be further oxidized to sulfur trioxide ($SO_3$) under specific conditions, such as in the presence of a:**

(a) Catalyst (e.g., vanadium(V) oxide) and high temperature ✅

(b) Catalyst (e.g., iron) and low temperature

(c) Strong reducing agent and high pressure

(d) Dilute acid and room temperature

**XII. Sulfur trioxide ($SO_3$) is not directly dissolved in water to produce sulfuric acid in the Contact Process because this reaction is:**

(a) Too slow

(b) Reversible and would result in a low yield

(c) Highly exothermic and produces a mist of sulfuric acid ✅

(d) Requires very high pressures

## Q.2 Attempt the following short-answer questions:

**(a) List two reasons for the inertness of $N_2$**

Nitrogen gas is chemically inert due to:

- **Strong triple bond (N≡N):** It has very high bond enthalpy (+944 kJ $mol^{-1}$), so a large amount of energy is required to break it.
- **Non-polar nature:** Both nitrogen atoms share electrons equally, so no partial charges are formed, making it less reactive.

**Example:** Nitrogen does not burn easily under normal conditions.

**(b) How is nitrogen isolated from air?**

Nitrogen is obtained from air by fractional distillation of liquid air.

👉 **Steps:**

- Air is cooled and compressed to convert it into liquid
- Liquid air is slowly warmed
- Oxygen (lower boiling point) evaporates first
- Nitrogen is collected separately

**Example:** Industrial production of nitrogen for fertilizers.

**(c) Why ammonia ($NH_3$) is a weak base?**

Ammonia is a weak base because:

- It only partially ionizes in water
- It has a low basicity constant (Kb)
- Equilibrium lies mostly on the left side

**Reaction:**

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

**Example:** Ammonia solution shows weak alkaline nature.

**(d) Write down the reactions of photochemical smog formation**

Photochemical smog forms due to reactions of NOx and sunlight:

$NO_2 \longrightarrow NO + O$ (in sunlight)

$O + O_2 \longrightarrow O_3$ (ozone)

$O_3$ + hydrocarbons $\longrightarrow$ aldehydes + PAN

👉 These reactions produce harmful oxidizing agents.

**Example:** Smog in big cities like Los Angeles.

**(e) What is the construction and function of a catalytic converter?**

**Construction:**

- Honeycomb structure made of ceramic/metal
- Coated with $Al_2O_3$ (alumina)
- Contains catalysts: Pt, Pd, Rh

**Function:**

It converts harmful gases into less harmful ones:

- $CO \longrightarrow CO_2$
- $NO \longrightarrow N_2$
- Hydrocarbons $\longrightarrow CO_2 + H_2O$

**Example:** Used in vehicles to reduce air pollution.

**(f) Why sulfur is quite unreactive at room temperature?**

Sulfur is relatively unreactive at room temperature because:

- It exists as stable $S_8$ ring molecules
- Strong S–S bonds require energy to break
- It needs higher temperature to react

**Example:** Sulfur does not react with water or air at room temperature.

**(g) Which are the most stable oxidation states of sulfur in water at pH = 0 and pH = 14?**

- At pH = 0 (acidic medium): –2 oxidation state ($H_2S$) is most stable
- At pH = 14 (basic medium): +6 oxidation state ($SO_4^{2-}$) is most stable

**Example:**

- Acidic $\longrightarrow H_2S$ gas
- Basic $\longrightarrow$ sulfate ions in solution

**(h) How does sulfur react with halogens?**

Sulfur reacts with halogens to form sulfur halides:

**With fluorine:**

$S + F_2 \longrightarrow SF_6$ (very stable gas)

**With chlorine:**

$S + Cl_2 \longrightarrow S_2Cl_2$ (yellow liquid)

**Explanation:** Sulfur acts as a reducing agent and forms covalent compounds.

**(i) Draw the structures of cyclo-octasulfur ($S_8$) and sulfuric acid**

**$S_8$ Structure:**

- Crown-shaped ring of 8 sulfur atoms
- Each sulfur atom bonded to two others

**$H_2SO_4$ Structure:**

- Tetrahedral shape
- Two S=O double bonds
- Two S–OH single bonds

**Diagram:**

**$S_8$ (Ring Structure):**

S—S—S—S

|  |

S  S

|  |

S—S—S—S  (Crown shape)

**$H_2SO_4$ Structure:**

O

||

H—O—S—O—H

||

O

**(j) What is the role of sulfur in the vulcanization of rubber?**

Sulfur is used to form cross-links (S–S bonds) between rubber chains.

**Role:**

- Increases strength
- Improves elasticity
- Makes rubber heat resistant

**Example:** Car tyres become stronger after vulcanization.

**(k) What is the composition and the chemical reaction of gunpowder combustion?**

**Composition:**

- 75% Potassium nitrate ($KNO_3$)
- 15% Carbon (C)
- 10% Sulfur (S)

**Reaction:**

$10KNO_3 + 3S + 8C \longrightarrow 2K_2CO_3 + 3K_2SO_4 + 6CO_2 + 5N_2$

**Explanation:**

- $KNO_3 \longrightarrow$ oxidizing agent
- Carbon & sulfur $\longrightarrow$ fuels

**Example:** Used in fireworks and explosives.

**(l) What is the importance of disulfide bridges?**

- Disulfide bridges (–S–S–) link polymer chains
- Increase strength and durability of materials

- Improve elasticity of rubber
- Provide stability to protein structure

**Example:** Vulcanized rubber (tyres)

**(m) Write down self-ionization equation of sulfuric acid and its ionization in water.**

**Self-ionization:**

$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$

**Further ionization:**

$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$

Produces $H^+$ ions in water (strong acid)

**Example:** Used in battery acid

**(n) Give two examples where sulfuric acid acts as a dehydrating agent.**

Converts ethanol into ethene:

$C_2H_5OH \longrightarrow C_2H_4 + H_2O$

Removes water from sugar (forms carbon)

**Example:** Black carbon formation from sugar

**(o) How does $V_2O_5$ catalyze the formation of $SO_3$?**

- Acts as catalyst in Contact Process

- Provides surface for reaction
- Increases rate of reaction
- Lowers activation energy

**Reaction:**

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

**(p) What is purpose of formation of oleum?**

- Prevents direct reaction of $SO_3$ with water
- Avoids formation of acid mist
- Allows safe production of $H_2SO_4$
- Helps control concentration of acid

**Example:** Oleum is diluted to form sulfuric acid

## ❖ DESCRIPTIVE QUESTIONS

### 🌟 Q.3 Explain the preparation and basicity of ammonia.

### (A) Preparation of Ammonia ($NH_3$)

### 1. Industrial Preparation (Haber Process)

Ammonia is prepared on a large scale by combining nitrogen and hydrogen gases in the presence of suitable conditions.

**Reaction:**

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

**Conditions:**

Nitrogen is obtained from air, while hydrogen is obtained mainly from natural gas (methane). The reaction is carried out at high pressure and moderate temperature to increase yield. Iron is used as a catalyst, and promoters are added to increase efficiency.

**Explanation:**

High pressure shifts equilibrium towards ammonia formation because fewer gas molecules are produced. Moderate temperature is used because very high temperature reduces yield while very low temperature slows the reaction.

**Importance:**

Ammonia produced by this method is widely used in fertilizers such as urea and ammonium sulfate, and also in the production of nitric acid.

## 2. Laboratory Preparation of Ammonia

In the laboratory, ammonia gas is prepared by heating an ammonium salt with a strong base.

**Reaction:**

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

**Explanation:**

When ammonium chloride is heated with calcium hydroxide, ammonia gas is released. The gas is collected by downward displacement of air because it is lighter than air.

**Identification:**

Ammonia has a pungent smell and turns moist red litmus paper blue, confirming its basic nature.

## (B) Basicity of Ammonia ($NH_3$)

Ammonia behaves as a weak base in aqueous solution due to the presence of a lone pair of electrons on nitrogen.

**Reason:**

The nitrogen atom in ammonia has a lone pair which it can donate to accept a proton ($H^+$), forming ammonium ion.

**Reaction:**

$NH_3 + H^+ \longrightarrow NH_4^+$

In water, ammonia partially reacts to form ammonium and hydroxide ions:

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

**Why weak base:**

Ammonia does not fully ionize in water and establishes equilibrium where most ammonia remains in molecular form. Therefore, only a small number of $OH^-$ ions are produced.

**Nature:**

Ammonia is classified as a weak Brønsted-Lowry base because it accepts protons.

**Summary:**

Ammonia is prepared industrially by the Haber process and in the laboratory by heating ammonium salts with a base. It acts as a weak base due to partial ionization in water and its ability to accept protons using a lone pair of electrons.

## 🌟 Q.4 How oxides of nitrogen ($NO_x$) cause the formation of photochemical smog and PAN? Give its mechanism.

**Introduction**

Oxides of nitrogen (NO and $NO_2$), collectively called $NO_x$, are important air pollutants produced mainly from vehicle exhausts and industrial processes. In the presence of sunlight and volatile organic compounds (VOCs), $NO_x$ plays a key role in the formation of photochemical smog and peroxyacyl nitrates (PANs).

### 1. Formation of Photochemical Smog

Photochemical smog is a type of air pollution formed in sunlight. It is mainly found in urban areas with high vehicle emissions.

**Basic Components:**

- $NO_x$ gases (NO, $NO_2$)
- VOCs (hydrocarbons from fuels)

- Sunlight (UV radiation)

**Mechanism of Smog Formation:**

When nitrogen dioxide is exposed to sunlight, it breaks down:

$NO_2 \longrightarrow NO + O$

The oxygen atom reacts with oxygen gas:

$O + O_2 \longrightarrow O_3$ (ozone)

Ozone is a strong oxidizing agent and reacts with hydrocarbons present in the air. This produces harmful compounds such as aldehydes, ketones, and other oxidants.

These reactions result in a mixture of pollutants known as photochemical smog, which contains:

- Ozone ($O_3$)
- Nitrogen dioxide ($NO_2$)
- Organic oxidants

**Effects of Photochemical Smog:**

- Eye and lung irritation
- Damage to plants
- Reduced visibility
- Respiratory problems

## 2. Formation of PAN (Peroxyacyl Nitrates)

PAN is an important component of photochemical smog and is formed through a series of reactions involving $NO_x$ and VOCs.

**Mechanism of PAN Formation:**

Hydrocarbons ($R–CH_3$) present in air are first oxidized in sunlight:

Hydrocarbon + O ⟶ Aldehyde

The aldehyde reacts with hydroxyl radicals (•OH) to form acyl radicals:

Aldehyde ⟶ Acyl radical (RCO•)

The acyl radical reacts with oxygen to form peroxyacyl radical:

$RCO• + O_2 \longrightarrow RCO_3•$

Finally, this reacts with nitrogen dioxide:

$RCO_3• + NO_2 \longrightarrow PAN\ (RCO_3NO_2)$

**Importance of PAN:**

- Strong eye irritant
- Damages plant tissues
- Major toxic component of smog

## 3. Role of $NO_x$ in Smog Formation

$NO_x$ gases act as initiators of photochemical reactions:

- $NO_2$ absorbs sunlight and produces reactive oxygen
- NO participates in ozone cycle

- $NO_x$ helps in continuous formation of oxidants
- Thus, $NO_x$ acts as a key driver of both smog and PAN formation.

**Summary:**

Oxides of nitrogen ($NO_x$) play a central role in air pollution. Under sunlight, $NO_2$ decomposes to form ozone, which reacts with hydrocarbons to produce photochemical smog. Further reactions of oxidized hydrocarbons lead to the formation of PAN, making $NO_x$ one of the most harmful atmospheric pollutants.

**Mechanism Summary (Exam Diagram Concept):**

$NO_2 \longrightarrow NO + O$

$O + O_2 \longrightarrow O_3$

$O_3$ + VOCs ⟶ oxidized compounds

⟶ aldehydes ⟶ acyl radicals

⟶ + $O_2$ ⟶ peroxyacyl radicals

⟶ + $NO_2$ ⟶ PAN

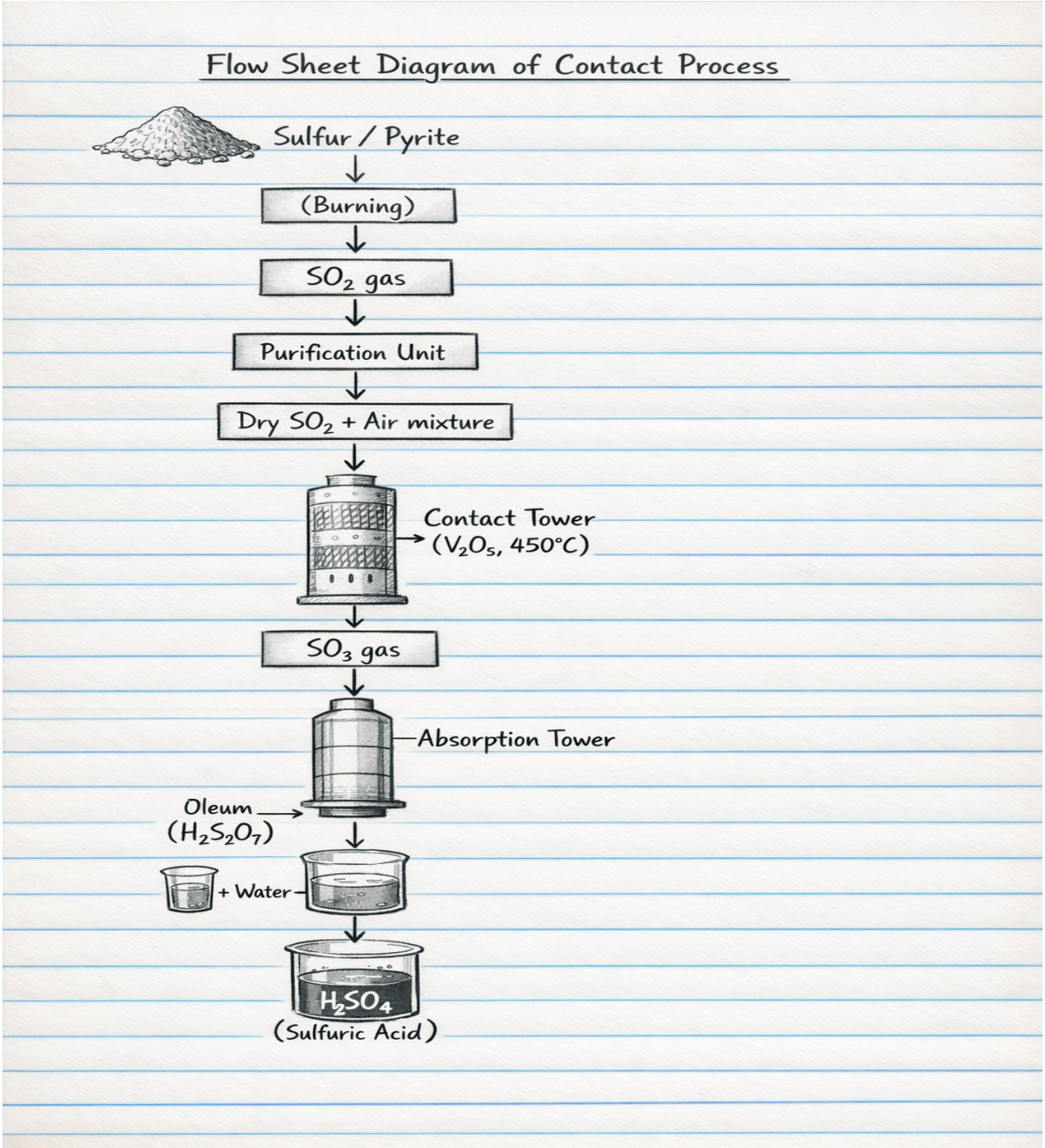
**🌟 Q.5 Give flowsheet diagram and equations involved in the Contact Process.**

**Introduction**

The Contact Process is an industrial method used for the manufacture of sulfuric acid ($H_2SO_4$). It is called “contact process” because sulfur

dioxide and oxygen come in contact with a catalyst ($V_2O_5$) to form sulfur trioxide.

## 1. Flow Sheet Diagram of Contact Process



## 2. Main Steps with Equations

### (i) Formation of Sulfur Dioxide ($SO_2$)

Sulfur or iron pyrite is burnt in excess oxygen.

**Equations:**

$S + O_2 \longrightarrow SO_2$

$4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

### (ii) Purification of $SO_2$ Gas

$SO_2$ gas contains dust, moisture, and arsenic compounds which are removed in purification units to protect the catalyst.

### (iii) Catalytic Oxidation (Contact Tower)

Sulfur dioxide reacts with oxygen to form sulfur trioxide.

**Equation:**

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

**Conditions:**

**Catalyst:** Vanadium pentoxide ($V_2O_5$)

**Temperature:** 420–450°C

Pressure: 1–2 atm

### (iv) Formation of Oleum (Absorption Step)

$SO_3$ is not directly dissolved in water because it forms acid mist. Instead, it is absorbed in concentrated sulfuric acid.

**Equation:**

$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$ (Oleum)

**(v) Formation of Sulfuric Acid**

Oleum is diluted with water to produce sulfuric acid.

**Equation:**

$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$

## 3. Important Conditions

- Catalyst: $V_2O_5$
- Temperature: 420–450°C
- Pressure: Low pressure (1–2 atm)
- Purified gases are necessary for high efficiency

**Summary:**

The Contact Process is a highly efficient industrial method for producing sulfuric acid. It involves five main stages: formation of $SO_2$, purification, catalytic oxidation to $SO_3$, absorption to form oleum, and final dilution to $H_2SO_4$.

### 🌟 Q.6 Discuss sulfuric acid as an oxidizing agent and a dehydrating agent with three reactions for each.

## Introduction

Sulfuric acid ($H_2SO_4$) is a very strong and important industrial acid. It shows two important chemical properties:

- It acts as an oxidizing agent (especially in hot concentrated form)
- It acts as a dehydrating agent (removes water from substances)

## 1. Sulfuric Acid as an Oxidizing Agent

Hot concentrated sulfuric acid can oxidize many metals and non-metals because it gets reduced to $SO_2$.

### (a) Reaction with Copper

$Cu + 2H_2SO_4$ (conc, hot) $\longrightarrow CuSO_4 + SO_2 + 2H_2O$

Copper is oxidized to $Cu^{2+}$ and sulfuric acid is reduced to $SO_2$.

### (b) Reaction with Carbon

$C + 2H_2SO_4$ (conc) $\longrightarrow CO_2 + 2SO_2 + 2H_2O$

Carbon is oxidized to $CO_2$.

### (c) Reaction with Sulfur

$S + 2H_2SO_4$ (conc) $\longrightarrow 3SO_2 + 2H_2O$

Sulfur is oxidized to $SO_2$.

## 2. Sulfuric Acid as a Dehydrating Agent

Concentrated sulfuric acid has a strong affinity for water and removes it from compounds.

**(a) Dehydration of Ethanol**

$C_2H_5OH \longrightarrow C_2H_4 + H_2O$

Sulfuric acid removes water from ethanol to form ethene.

**(b) Dehydration of Sugar**

$C_{12}H_{22}O_{11} \longrightarrow 12C + 11H_2O$

Sugar is converted into black carbon due to removal of water.

**(c) Dehydration of Hydrated Copper Sulfate**

$CuSO_4 \cdot 5H_2O \longrightarrow CuSO_4 + 5H_2O$

Blue crystals become white anhydrous $CuSO_4$.

**Summary:**

Sulfuric acid is a versatile chemical. As an oxidizing agent, it oxidizes metals like Cu, non-metals like C, and sulfur itself. As a dehydrating agent, it removes water from organic compounds, sugars, and hydrated salts, making it extremely important in industrial and laboratory chemistry.

## Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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**Purpose:** To contribute to education by offering insightful, valuable content that enhances learning and understanding.