

Topic4.4. The structure and properties of the nitrogen and ammonia molecules. Industrial production of nitrogen fertilizers.

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Outline

- ❖ **Introduction**
- ❖ **Main part**
 - ❖ 1. Nitrogen
 - ❖ 2. Ammonia
 - ❖ 3. Nitrogen oxides
 - ❖ 4. Nitric acid
 - ❖ 5. Ammonium salts. Nitrates
- ❖ **Conclusion**
- ❖ **Literature**



1. Nitrogen

Chemical element

Nitrogen is a chemical element number **7**. It is located in the VA group of the Periodic Table of Chemical Elements.

N7 + 7) 2e) 5e

The outer layer of the nitrogen atom contains five valence electrons, three electrons are missing to it is completed. Therefore, in compounds with metals and hydrogen, nitrogen is characterized by an oxidation state of **-3**, and when interacting with more electronegative oxygen and fluorine, it exhibits positive oxidation states from **+1** to **+5**.



Группа ↓ Период	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
Лантаноиды			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
Актиноиды			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	



1. Nitrogen

Chemical element

Nitrogen is found in the **air** as a simple substance. Its volume fraction is **78%**. Nitrogen compounds are rare in the earth's crust. There is a known deposit of sodium nitrate **NaNO_3** (Chilean nitrate).

Nitrogen is a vital element, as it is part of the molecules of proteins and nucleic acids.



1. Nitrogen

Simple substance

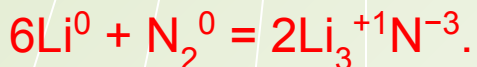
Molecules of a simple substance consist of two atoms linked by a strong **triple bond**:



Under normal conditions, nitrogen **is a colorless**, odorless and tasteless gas, slightly soluble in water. Not poisonous.

Nitrogen is chemically **inactive** due to a strong triple bond and enters into chemical reactions only at high temperatures.

At room temperature, it only reacts with lithium to form **lithium nitride**:

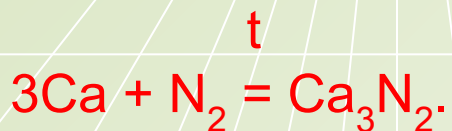




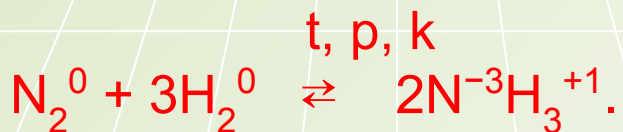
1. Nitrogen

Simple substance

When heated, it forms **nitrides** with some other metals:



Nitrogen reacts with hydrogen only at high pressure, elevated temperature and in the presence of a catalyst. **Ammonia** is formed in the reaction:



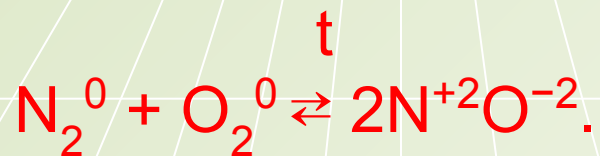
In reactions with metals and hydrogen, nitrogen exhibits **oxidizing properties**.



1. Nitrogen

Simple substance

The **reducing properties** of nitrogen are manifested in reaction with oxygen:



The reaction is possible only at very high temperatures (3000°C) and partially takes place in the atmosphere during a thunderstorm. **Nitric oxide (II)** is formed.



1. Nitrogen

Application and obtaining

A large amount of nitrogen is used to obtain **ammonia and nitrogen fertilizers**.

It is used to create an **inert environment** during chemical reactions. **Liquid nitrogen** is used in medicine, it is used for cooling in chemical and physical research.

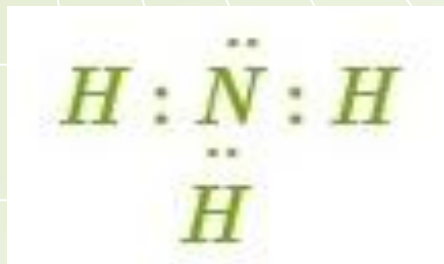
Pure nitrogen is obtained from **air**.



2. Ammonia

Molecule structure

The ammonia formula is NH_3 . The oxidation state of nitrogen is -3 . The molecule has three covalent polar bonds. At the nitrogen atom, **one electron pair** remains **lonely** and plays an important role in the ability of ammonia to enter into chemical reactions.



The ammonia molecule has the shape of a **pyramid** with a nitrogen atom at the top and three hydrogen atoms at the base.



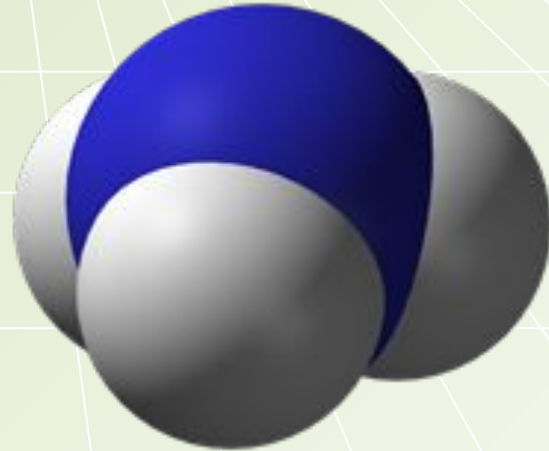
2. Ammonia

Molecule structure

The common electron pairs in the molecule are shifted towards the more electronegative nitrogen atom. It is negatively charged and the hydrogen atoms are positively charged. Therefore, the molecule is polar and is a **dipole**. Due to the high polarity, ammonia molecules are able to form hydrogen bonds with each other and with water molecules. The formation of hydrogen bonds affects the physical properties of a substance.

2. Ammonia

Molecule structure





2. Ammonia

Physical properties

Under normal conditions, ammonia is a **colorless** gas with a pungent, **unpleasant** odor. It is lighter than air. Poisonous.

Ammonia **dissolves** very well in water - at **20°C**, up to **700** volumes of ammonia can dissolve in one volume of water. A solution with a gas content of **25%** is called ammonia water, and a **10%** solution is used in medicine as ammonia.

Ammonia liquefies easily at low temperature or high pressure. When liquid ammonia evaporates, a lot of heat is absorbed, which allows it to be used in refrigeration plants.



2. Ammonia

Physical properties





2. Ammonia

Chemical properties

1. Reducing properties.

The oxidation state of nitrogen in ammonia is -3 , therefore, in redox reactions, it acts as a **strong reducing agent**.

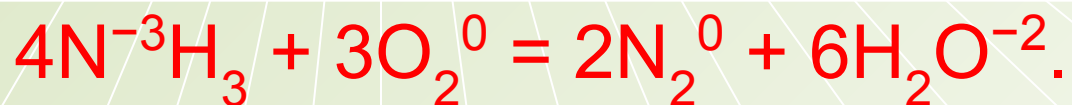
Ammonia is oxidized by **oxygen** to form nitrogen or nitric oxide (II). The result of the reaction depends on the conditions of its course.



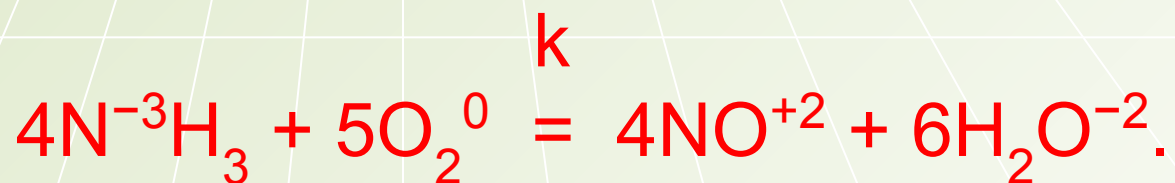
2. Ammonia

Chemical properties

1. Reducing properties.



If the reaction is carried out with a catalyst, then nitrogen oxide (II) is formed:

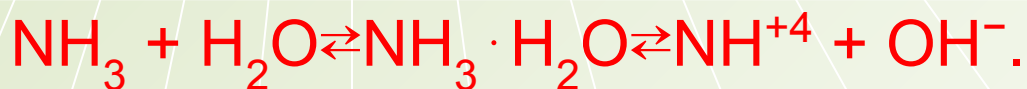




2. Ammonia

2. *Basic properties.*

If you add a few drops of phenolphthalein to an aqueous solution of ammonia, then its color will turn crimson. This means that the solution contains hydroxide ions. The formation of these ions occurs as a result of the reaction between water and ammonia molecules:



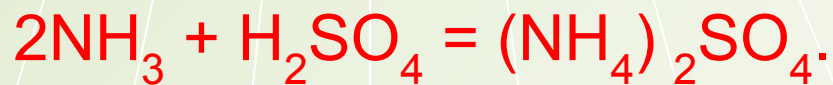
The unstable **ammonium hydrate** formed in the reaction partially dissociates into **ammonium ions** and **hydroxide ions**.



2. Ammonia

2. *Basic properties.*

Ammonia reacts with **acids**. In this case, **ammonium salts** are formed. So, with hydrochloric acid, **ammonium chloride** is formed, and with sulfuric acid, **ammonium sulfate**:

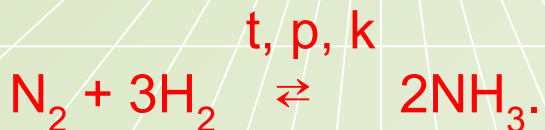




2. Ammonia

Receiving and using

In industry, ammonia is synthesized from nitrogen and hydrogen:



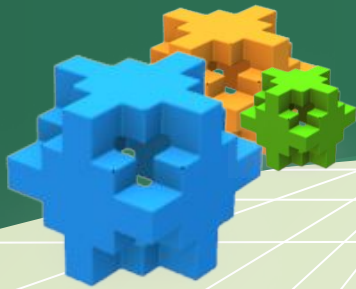
Laboratory method of obtaining - the reaction between ammonium salt and calcium hydroxide:



Ammonia is used in large quantities for the **production of nitric acid and mineral fertilizers**, as well as **dyes and explosives**. Used in **refrigeration units**. Ammonia is used in medicine and in everyday life.



APEC PetroTechnic
HIGHER COLLEGE



Ammonia production



3. Nitrogen oxides

Nitrogen exhibits positive oxidation states from **+1** to **+5** and forms compounds with oxygen:

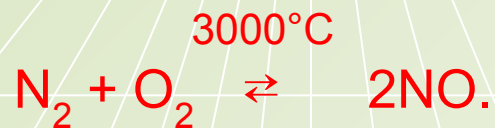
N_2O - nitrogen(I)oxide, NO - nitrogen (II) oxide,
 N_2O_3 - nitrogen (III) oxide, NO_2 - nitrogen (IV)
oxide, N_2O_5 - nitric (V) oxide.

The first four substances under normal conditions are **gases**, and N_2O_5 is a **solid**. All nitrogen oxides are poisonous.

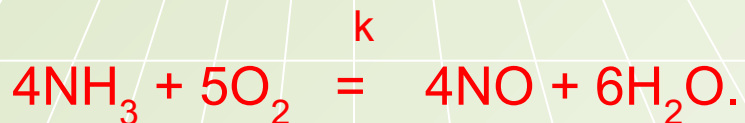


3. Nitrogen oxides

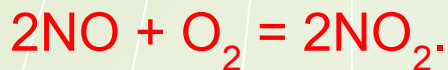
Colorless nitric (II) oxide is formed in the reaction of nitrogen with oxygen at high temperatures:



This oxide is also a product of the catalytic oxidation of ammonia:



Nitrogen (II) oxide oxidizes easily at room temperature. This produces a brown gas with an unpleasant odor - nitrogen (IV) oxide :





3. Nitrogen oxides

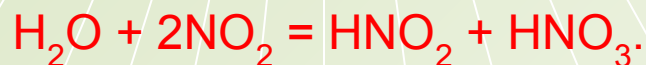
Pay attention!

Nitric (I) oxide and nitrogen (II) oxide are **non-salt-forming** oxides. They do not react with water, acids and bases.



3. Nitrogen oxides

Other oxides are **salt-forming (acidic)**. Nitric (III) oxide corresponds to a weak nitrous acid HNO_2 , to nitrogen (V) oxide - a strong nitric acid HNO_3 . Nitrogen (IV) oxide, when dissolved in water, forms two acids at the same time - nitric and nitrogenous:



In the presence of oxygen, the reaction between nitric (IV) oxide and water proceeds differently, and only nitric acid is formed:



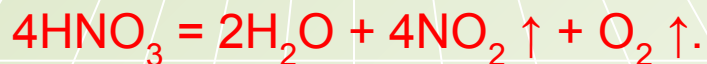
Nitric (II) oxide and nitrogen (IV) oxide are intermediates in the production of nitric acid.



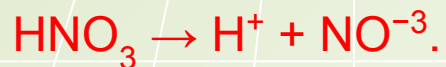
4. Nitric acid

Physical properties

Nitric acid HNO_3 is a colorless liquid fuming in air with an unpleasant odor. When stored in the light, it decomposes and can turn yellow due to the formation of brown nitric (IV) oxide :



Nitric acid is miscible with water in any ratio and in an aqueous solution completely decomposes into ions:



4. Nitric acid

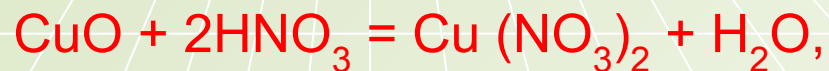




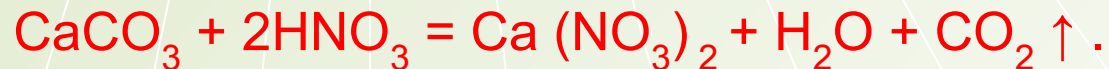
4. Nitric acid

General properties of acids

Nitric acid reacts with basic and amphoteric oxides and hydroxides to form nitrates:



Nitric acid enters into exchange reactions with salts of other acids if a gas or precipitate is formed:





4. Nitric acid

Special properties

Unlike other acids, nitric acid reacts with most metals except noble ones.

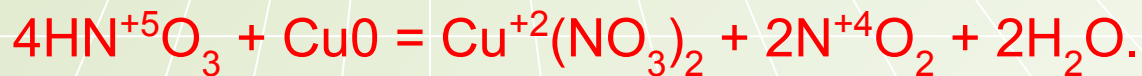
Pay attention!

Hydrogen is never formed in the reactions of nitric acid with metals.

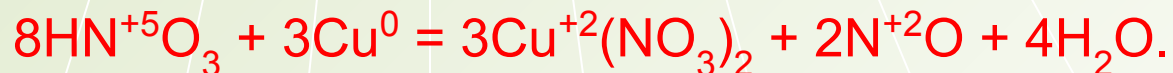


4. Nitric acid

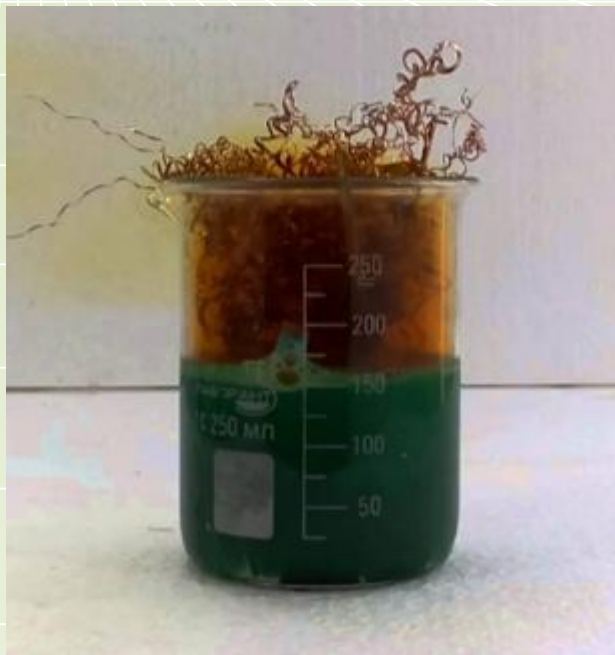
The **oxidizing agent** in these reactions is the **nitrogen atom** of the acid residue, therefore, the reaction products are nitrogen compounds in different oxidation states. The composition of the compounds depends on the activity of the metal and the concentration of nitric acid. So, when **concentrated** nitric acid interacts with copper, brown nitric (IV) oxide is formed:



When **diluted** nitric acid interacts with copper, the reaction product is colorless nitric (II) oxide :



4. Nitric acid



Copper with concentrated nitric acid



4. Nitric acid

Pay attention!

Concentrated nitric acid passivates iron and aluminum.

A strong film forms on their surface under the action of concentrated acid, which protects the metal from further reaction. Therefore, concentrated nitric acid can be transported in steel or aluminum tanks.

Nitric acid is capable of oxidizing other inorganic and organic substances. Organic substances can ignite on contact with nitric acid, and handling it requires care and attention.



4. Nitric acid

Application

Nitric acid is used in industry to obtain:

- mineral fertilizers,
- medicines,
- explosives,
- plastics,
- dyes,
- varnishes.

5. Ammonium salts. Nitrates

Ammonium salts

Ammonium salts are complex substances formed by the ammonium cation NH_4^+ and an acidic residue.

NH_4Cl - ammonium chloride, $(\text{NH}_4)_2\text{SO}_4$ - ammonium sulfate, NH_4NO_3 - ammonium nitrate.

Ammonium salts are similar in properties to sodium or potassium salts. They have an ionic structure and are solid white substances that dissolve well in water.

5. Ammonium salts. Nitrates

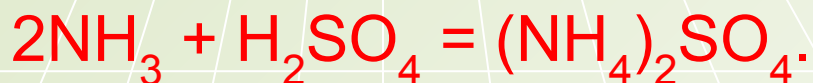


Ammonium nitrate

5. Ammonium salts. Nitrates

Ammonium salts

Ammonium salts are formed when ammonia interacts with acids:



Ammonium salts are characterized by both properties common to all salts and special ones.

5. Ammonium salts. Nitrates

Ammonium salts

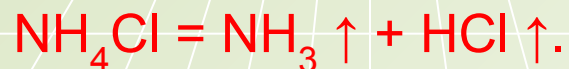
The **general properties** of salts include the ability to enter into replacement reactions with acids and other salts if a gas or precipitate is formed:





The **special properties** of salts are due to the instability of the ammonium ion and its ability to decompose to form ammonia:

1. Ammonium salts **decompose** when heated:



2. Ammonium salts when heated react with **alkalis** with the release of ammonia:



Ammonium salts are used as fertilizers. Ammonium carbonate is used by pastry chefs as a baking powder. Ammonium chloride is used in brazing for cleaning metal surfaces.



Nitrates

Nitrates are salts of nitric acid.

NaNO_3 - sodium nitrate, $\text{Cu}(\text{NO}_3)_2$ - copper (II) nitrate, NH_4NO_3 - ammonium nitrate. Nitrates of alkali metals, calcium and ammonium are also called nitrate: $\text{Ca}(\text{NO}_3)_2$ - calcium nitrate, NH_4NO_3 - ammonium nitrate.

All nitric acid salts are **highly soluble** in water. When heated, they decompose with **the evolution of oxygen**, therefore they are explosive.



Nitrates are used as **fertilizers**, as well as for the manufacture of **explosive mixtures**. **Silver nitrate** is used medicinally as a **cauterizing agent**.



Questions for self control



1. Indicate the formula for saltpeter:

- A) NH_4HCO_3
- B) Na_3PO_4
- C) NaNO_3

2. Choose the name of the substance whose formula is NO:

- A) nitrogen (I) oxide
- B) nitrogen (II) oxide
- C) nitrogen (IV) oxide

3. Nitric acid is used:

- A) for plant nutrition
- B) in the manufacture of confectionery
- C) to obtain saltpeter



4. Specify the characteristic of nitrogen:

- A) easily liquefies when cooled
- B) reacts with oxygen at high temperature
- C) oxidizes most complex substances
- D) brown gas

5. Is it a chemical element or a simple substance in the sentence?

The air contains 78% nitrogen.

- A) Chemical element
- B) Simple substance

6. Choose the structural features of the nitrogen molecule:

- A) there are positive and negative poles in the molecule
- B) the electron density of the chemical bond is shifted from the nitrogen atom
- C) atoms are linked by a covalent polar bond
- D) consists of two identical atoms
- E) atoms are linked by a triple bond



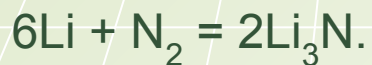
7. Choose the properties of ammonium salts:

- A) resistant to heat
- B) formed in the reaction of ammonia with acids
- C) have an ionic structure
- D) release oxygen when heated

8. Choose rows, in each of which all substances react with nitric acid.

- A) Ag_2O , CuO , Na_2CO_3
- B) Cu , Na_2O , Na_2SiO_3
- C) $\text{Cu}(\text{NO}_3)_2$, CO , Au
- D) MgCO_3 , Fe , BaCl_2

9. Determine what nitrogen is in the reaction - an oxidizing agent or a reducing agent:



- A) Oxidizing agent
- B) Reducing agent



10. Establish an accordance between the formula of a substance and its characteristics.

1 - N_2 , 2 - NH_3 , 3 - HNO_3 , 4 - NO_2 ;

a - does not react with water;

b - yellow-green gas;

c - dissolves indefinitely in water;

d - formed by oxidation of nitrogen oxide (II);

e - the process of dissolution in water is accompanied by a reaction.



Literature

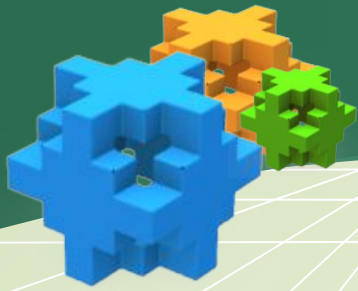
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8. Электронные ресурсы с www.bilimland.kz



Do you have any questions?

