Inorganic and Physical Chemistry Department
General and Inorganic Chemistry

Elements of IIIA group

In specialty 226 Pharmacy, industry pharmacy

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Plan

1. **Some properties of elements IIIA and IVA groups**
2. **Boron. The chemical properties of boron.**
3. **Biological role and application of compounds of boron in medicine.**
4. **Chemical properties of Aluminum and Aluminum Compounds.**
5. **Biological role of Aluminum compounds and application in medicine**
6. **Carbon. Carbonic acid. Silicon. Tin and Lead.**
7. **Biological role compounds of elements IIIA and IVA group and their application in medicine.**

Actuality of theme

Biologically active substances of elements of IIIA and IVA groups are of great importance in pharmacy and medicine.

Aim: Depending on the electronic structure of elements of IIIA and IVA groups , their properties and the place they occupy in medicine and pharmacy are determined.

Specific goals:

- Be able to write electronic formulas of elements of IIIA and IVA groups in various degree of oxidation.
- Know the ways to get and use them in medicine.

The Qualitative Reaction for Compounds Which Contain Boron, Carbon, Silicon, Tin, Lead, Nitrogen, Phosphorus and Arsenic

Bibliographical Guidance

General and inorganic chemistry: Textbook for students of higher schools Ye.Ya.Levitin, I.O.Vedernikova.– Kharkiv:Publishing House of NUPH :Golden Pages, 2009. – 360 p.

Laboratory Practicum in General and inorganic chemistry.I module/ Ye.Ya.Levitin, I.O.Vedernikova et al.– Kharkiv,2020. – 106 p.

General and inorganic chemistry:The lecture courses for the students of pharmaceutical universities. I Module / Ye.Ya.Levitin, I.O.Vedernikova et al.– Kharkiv: NUPH Publishers, 2020. – 123 p.

The collection of theoretical questions and tests in inorganic chemistry:for the students of higher school. / Ye.Ya.Levitin, I.O.Vedernikova.– Kharkiv: NUPH Publishers, 2007. – 76 p.

PERIODIC TABLE OF THE ELEMENTS

	I	II	III	IV	V	VI	VII	VIII	
1	(H)						H 1 $1s^1$ 1,0079 HYDROGEN	He 2 $1s^2$ 4,00260 HELIUM	Atomic number; Atomic symbol; 26 Fe; $3d^6 4s^2$; IRON 55,847; Electronic configuration; Atomic name; Atomic weight
2	Li 3 $2s^1$ 6,941 LITHIUM	Be 4 $2s^2$ 9,01218 BERYLLIUM	B 5 $2s^2 2p^1$ 10,81 BORON	C 6 $2s^2 2p^2$ 12,011 CARBON	N 7 $2s^2 2p^3$ 14,0067 NITROGEN	O 8 $2s^2 2p^4$ 15,999 OXYGEN	F 9 $2s^2 2p^5$ 18,9994 FLUORINE	Ne 10 $2s^2 2p^6$ 20,179 NEON	
3	Na 11 $3s^1$ 22,98977 SODIUM	Mg 12 $3s^2$ 24,305 MAGNESIUM	Al 13 $3s^2 3p^1$ 26,9815 ALUMINIUM	Si 14 $3s^2 3p^2$ 28,0855 SILICON	P 15 $3s^2 3p^3$ 30,973 PHOSPHORUS	S 16 $3s^2 3p^4$ 32,06 SULFUR	Cl 17 $3s^2 3p^5$ 35,453 CHLORINE	Ar 18 $3s^2 3p^6$ 39,948 ARGON	
4	K 19 $4s^1$ 39,0983 POTASSIUM	Ca 20 $4s^2$ 40,08 CALCIUM	21 Sc $3d^1 4s^2$ SCANDIUM 44,9559	22 Ti $3d^2 4s^2$ TITANIUM 47,90	23 V $3d^3 4s^2$ VANADIUM 50,9415	24 Cr $3d^5 4s^1$ CHROMIUM 51,996	25 Mn $3d^5 4s^2$ MANGANESE 54,938	26 Fe $3d^6 4s^2$ IRON 55,847	27 Co $3d^7 4s^2$ COBALT 58,9332; 28 Ni $3d^8 4s^2$ NICKEL 58,70
	29 Cu $3d^{10} 4s^1$ COPPER 63,546	30 Zn $3d^{10} 4s^2$ ZINC 65,38	31 Ga $4s^2 4p^1$ 69,72 GALLIUM	32 Ge $4s^2 4p^2$ 72,59 GERMANIUM	33 As $4s^2 4p^3$ 74,9216 ARSENIC	34 Se $4s^2 4p^4$ 78,96 SELENIUM	35 Br $4s^2 4p^5$ 79,904 BROMINE	36 Kr $4s^2 4p^6$ 83,80 KRYPTON	
5	Rb 37 $5s^1$ 85,4678 RUBIDIUM	Sr 38 $5s^2$ 87,62 STRONTIUM	39 Y $4d^1 5s^2$ YTTRIUM 88,9059	40 Zr $4d^2 5s^2$ ZIRCONIUM 91,22	41 Nb $4d^4 5s^1$ NIOBIUM 92,9064	42 Mo $4d^5 5s^1$ MOLYBDENUM 95,94	43 Tc $4d^5 5s^2$ TECHNETIUM [98]	44 Ru $4d^7 5s^1$ RUTHENIUM 101,07	45 Rh $4d^8 5s^1$ RHODIUM 102,9055; 46 Pd $4d^{10} 5s^0$ PALLADIUM 106,4
	47 Ag $4d^{10} 5s^1$ SILVER 107,868	48 Cd $4d^{10} 5s^2$ CADMIUM 112,41	49 In $5s^2 5p^1$ 114,82 INDIUM	50 Sn $5s^2 5p^2$ 118,69 TIN	51 Sb $5s^2 5p^3$ 121,75 ANTIMONY	52 Te $5s^2 5p^4$ 127,60 TELLURIUM	53 I $5s^2 5p^5$ 126,9045 IODINE	54 Xe $5s^2 5p^6$ 131,30 XENON	
6	Cs 55 $6s^1$ 132,9054 CESIUM	Ba 56 $6s^2$ 137,33 BARIUM	57 *La $5d^1 6s^2$ LANTHANUM 138,905	72 Hf $5d^2 6s^2$ HAFNIUM 178,49	73 Ta $5d^3 6s^2$ TANTALUM 180,9479	74 W $5d^4 6s^2$ TUNGSTEN 183,85	75 Re $5d^5 6s^2$ RHENIUM 186,207	76 Os $5d^6 6s^2$ OSMIUM 190,2	77 Ir $5d^7 6s^2$ IRIDIUM 192,22; 78 Pt $5d^9 6s^1$ PLATINUM 195,09
	79 Au $5d^{10} 6s^1$ GOLD 196,9665	80 Hg $5d^{10} 6s^2$ MERCURY 200,59	81 Tl $6s^2 6p^1$ 204,37 THALLIUM	82 Pb $6s^2 6p^2$ 207,2 LEAD	83 Bi $6s^2 6p^3$ 208,98 BISMUTH	84 Po $6s^2 6p^4$ [209] POLONIUM	85 At $6s^2 6p^5$ [210] ASTATINE	86 Rn $6s^2 6p^6$ [222] RADON	[ ] mass number of the longest-liveed isotope
7	Fr 87 $7s^1$ [223] FRANCIUM	Ra 88 $7s^2$ 226,0254 RADIUM	89 **Ac $6d^1 7s^2$ ACTINIUM 227,0278	104 Rf $6d^2 7s^2$ RUTHERFORDIUM [261]	105 Db $6d^3 7s^2$ DUBNIUM [262]	106 Sg $6d^4 7s^2$ SEABORGIUM [263]	107 Bh $6d^5 7s^2$ BOHRIUM [261]	108 Hs $6d^6 7s^2$ HASSIUM [265]	109 Mt $6d^7 7s^2$ MEITNERIUM [266]; 110 Uun $6d^8 7s^2$ UNUNNILIUM [269]

*Lanthanoid series

58 Ce $4f^1 5d^1 6s^2$ 140,12 CERIUM	59 Pr $4f^3 6s^2$ 140,9077 PRASEODYMIUM	60 Nd $4f^4 6s^2$ 144,24 NEODYMIUM	61 Pm $4f^5 6s^2$ [145] PROMETHIUM	62 Sm $4f^6 6s^2$ 150,4 SAMARIUM	63 Eu $4f^7 6s^2$ 151,96 EUROPIUM	64 Gd $4f^7 5d^1 6s^2$ 157,25 GADOLINIUM	65 Tb $4f^9 6s^2$ 158,9254 TERBIUM	66 Dy $4f^{10} 6s^2$ 162,50 DYSPROSIUM	67 Ho $4f^{11} 6s^2$ 164,9304 HOLMIUM	68 Er $4f^{12} 6s^2$ 167,26 ERBIUM	69 Tm $4f^{13} 6s^2$ 168,9342 THULIUM	70 Yb $4f^{14} 6s^2$ 173,04 YTTERBIUM	71 Lu $4f^{14} 5d^1 6s^2$ 174,967 LUTETIUM

**Actinoid series

90 Th $6d^2 7s^2$ 232,0381 THORIUM	91 Pa $5f^2 6d^1 7s^2$ 231,0359 PROTACTINIUM	92 U $5f^3 6d^1 7s^2$ 238,029 URANIUM	93 Np $5f^4 6d^1 7s^2$ 237,0482 NEPTUNIUM	94 Pu $5f^6 7s^2$ [244] PLUTONIUM	95 Am $5f^7 7s^2$ [243] AMERICIUM	96 Cm $5f^7 6d^1 7s^2$ [247] CURIUM	97 Bk $5f^9 6d^1 7s^2$ [247] BERCELIUM	98 Cf $5f^{10} 7s^2$ [251] CALIFORNIUM	99 Es $5f^{11} 7s^2$ [252] EINSTEINIUM	100 Fm $5f^{12} 7s^2$ [257] FERMIUM	101 Md $5f^{13} 7s^2$ [258] MENDELEVIUM	102 No $5f^{14} 7s^2$ [259] NOBELIUM	103 Lr $5f^{14} 6d^1 7s^2$ [260] LAWRENCIUM

In accordance with the position of the elements in the Periodic table, they are divided into *s*-, *p*- *d*- and *f*-electron families.

Elements of *p*-families

p-Elements are elements that use *s*- and *p*-electrons to form a chemical bond.

Elements of IIIA group

In the IIIA group are located 5 elements.
We are going to study only Boron and Aluminum, because compounds of these elements are used in medicine.
They have the following electron configuration:

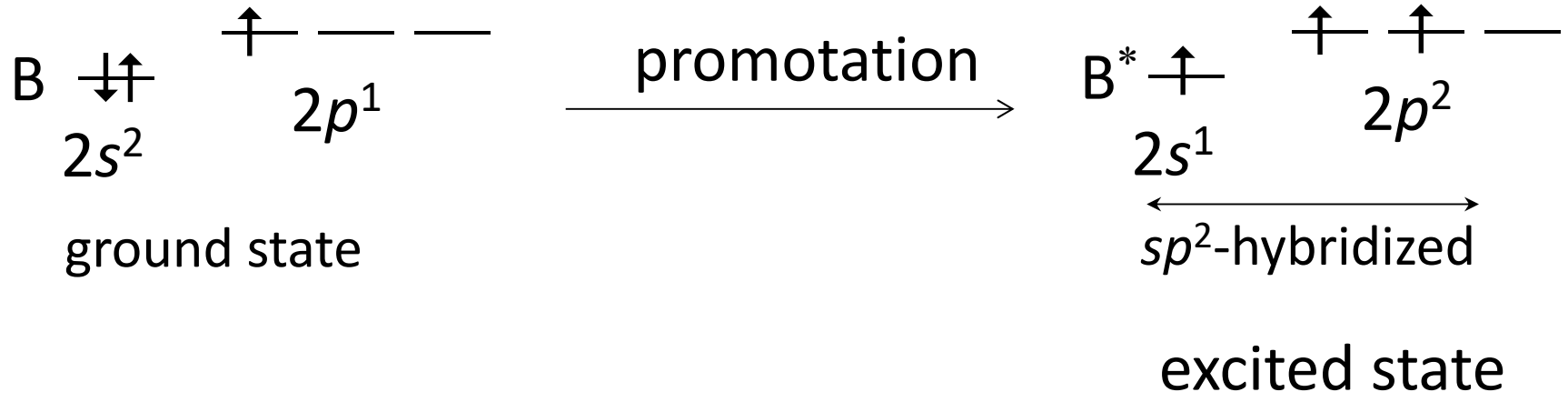
B [He] $2s^2 2p^1$

Al [Ne] $3s^2 3p^1$

Boron

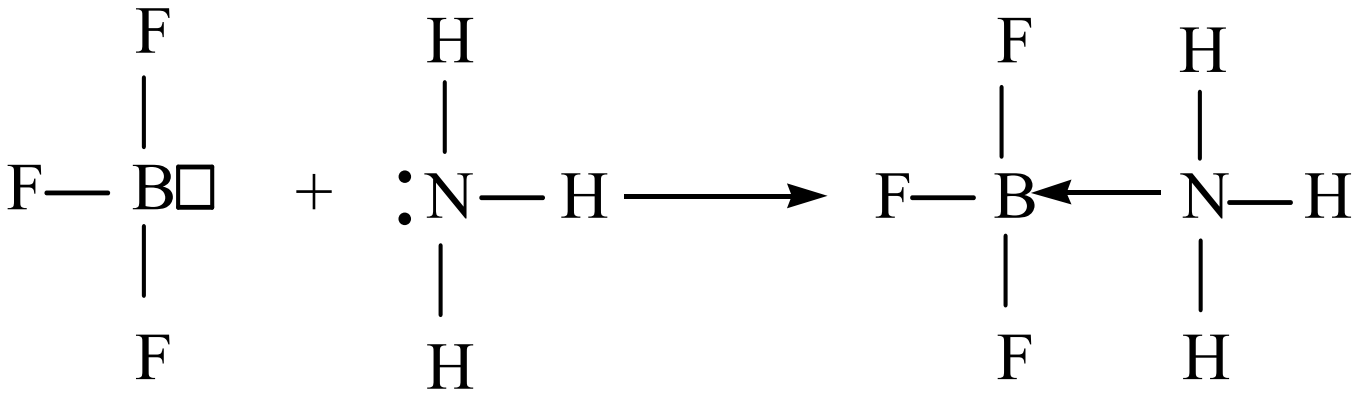
Boron is a chemical element with chemical symbol **B** and atomic number 5.

Boron atom has the following orbital box diagram of valence electrons:



In all compounds boron has oxidation state +3, because one of the 2*s* electrons is promoted to the 2*p* sublevel for the boron atom. Fore example in BF_3 boron has valency 3. The three sp^2 hybrid orbitales are directed in plane at angles of 120°. Thus, a molecule like BF_3 is trigonal planar.

The molecule of BF_3 is a acceptor of electrons pair. It produces the compound $H_3N{\cdot}BF_3$ with molecule NH_3 as a donor of electrons pairs



acceptor donor

In this compound Boron has valency 4 in the sp^3 hybridization.

In nature, it occurs in the form of boric acid H_3BO_3

and sodium tetraborate (borax) $Na_2B_4O_7 \cdot 10H_2O$.
- the **word comes** from the Arabic bawraq

Boron does not react with air at room temperature, but at higher temperatures it burns to form boron trioxide.

$$4B(s) + 3O_2(g) = 2B_2O_3(s)\ (700\ ^\circ C)$$

With the strong reducing agents it has oxidizing properties:

$$3Na + B = \overset{+}{Na}_3\overset{-3}{B}$$

sodium boride

$$Na_3B + 3H_2O = 3NaOH + B_2H_6$$

diborane

Interaction with acids:

Boron doesn't react with HCl, $H_2SO_{4(aq)}$, $HNO_{3(aq)}$, but can reacts with $H_2SO_{4(conc.)}$ and $HNO_{3(conc.)}$:

$$2B + 3H_2SO_{4(conc.)} = 2H_3BO_3 + 3SO_2$$

$$-3\bar{e} + B + 3H_2O \leftrightarrows H_3BO_3 + 3H^+ \quad | \quad 2$$

$$+2\bar{e} + SO_4^{2-} + 4H^+ \leftrightarrows SO_2 + 2H_2O \quad | \quad 3$$

$$2B + 6H_2O + 3SO_4^{2-} + 12H^+ = 2H_3BO_3 + 6H^+ + 3SO_2 + 6H_2O$$

Compounds of Boron

Boron oxide B_2O_3 is a transparent powder likes to glass. It dissolves in water with producing of boric acid H_3BO_3

$$B_2O_3(s)+ 3H_2O = 2H_3BO_3(aq)$$

Boric acid H_3BO_3 may be preparing from the decahydrate of sodium tetraborate with the sulphuric acid

$$Na_2B_4O_7 \cdot 10H_2O(aq) + H_2SO_4 = 4H_3BO_3(s) + Na_2SO_4(aq) + 5H_2O$$

The additional reguired in the equation are Na_2SO_4 and H_2O

Boric acid, H_3BO_3 is a weak monoprotic acid (produces H^+ rather than OH^- in aqueous solution)

$$H_3BO_3(s) + 2H_2O \leftrightarrows [B(OH)_4]^-(aq) + H_3O^+ \quad Ka = 7.3\times10^{-10}$$

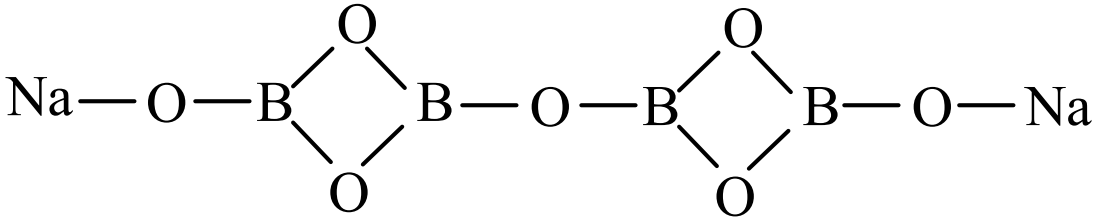
When H_3BO_3 reacts with one mol. of NaOH it forms metaboric acid's salt – sodium metaborate.

$$H_3BO_3(s) + NaOH(aq) = NaBO_2(aq) + H_2O$$

With the two molecules of sodium hydroxide H_3BO_3 produces **sodium tetraborate (borax)**

$$4H_3BO_3(s) + 2NaOH(aq) = Na_2B_4O_7(aq) + 7H_2O$$

The graphic formula of $Na_2B_4O_7$ is



The Qualitative Reaction for Compounds Which Contain Boron

If added concentrated H_2SO_4 and ethanol (methanol)to the compounds which contain boron (B_2O_3, H_3BO_3, $Na_2B_4O_7$), they are combined to form boroethyl ester:

$$B(OH)_3 + 3C_2H_5OH = B(OC_2H_5)_3 + 3H_2O$$

This ester is the product of the elimination of water molecules from an acid and an alcohol molecule. The ester blazes by green fire.

$$2B(OCH_3)_3 + 9O_2 = 2H_3BO_3 + 6CO_2 + 6H_2O$$

Biological role and application of compounds of boron in medicine

Boric acid (H_3BO_3) is used as antibacterial, antifungal and antiparasitic means.

Aqueous solution 2% of H_3BO_3 is applied externally in ophthalmology.

If you have irritated eyes, you may suffer from redness, discharge and dryness. A boric acid eyewash will ease your discomfort in a pinch. In a few short steps, you can easily make a safe and effective 1.5% boric acid solution at home.

Alcoholic solutions of H_3BO_3 (0.5%, 1%, 2% and 3%) are used in the form of drops or turundas (rolled cotton wool) wetted with a solution in acute or chronic otitis.

Sodium tetraborate $Na_2B_4O_7$ (borax) is used externally as an antimicrobial and anti-inflammatory agent in cosmetology.

Aluminum

Aluminium (or **aluminum**) is a chamical element in the boron group with symbol **Al** and atomic number 13. It is silvery white, and it is not soluble in water under normal condition.

Pure aluminum is a malleable, ductile, silvery-colored metal of low-density.

It has the following electron configuration:

Al [Ne] $3s^2 3p^1$

Chemical properties

The powdered metal is easily oxidized in air

$$4Al(s) + 3O_2(g) = 2Al_2O_3(s)$$

Aluminum is one of a small group of metals, which called amphoteric metals that dissolves in alkaline (basic) as well as acidic solution.

$$2Al(s)+ 6NaOH(aq) + 6H_2O = 2Na_3[Al(OH)_6](aq) + 3H_2(g)$$

$$2Al(s) + 6HCl(aq) = 2AlCl_3(aq) + 3H_2(g)$$

Aluminum doesn't react with concentrated HNO_3 and H_2SO_4 because it has on its surface stable film of Al_2O_3.

Aluminum Compounds

The mineral corundum, which is used as an abrasive, is Al_2O_3.

Pure Al_2O_3 obtained by heating $Al(OH)_3$

$$2Al(OH)_3(s) = Al_2O_3(s) + 3H_2O(g) \qquad t\ ^\circ C$$

Al_2O_3 has amphoteric properties. It dissolves in NaOH(aq) and in acidic solution

$$Al_2O_3(s) + 6NaOH(aq) + 3H_2O = 2Na_3[Al(OH)_6](aq)$$

$$Al_2O_3(s) + 3H_2SO_4(aq) = Al_2(SO_4)_3(aq) + 3H_2O$$

When we add to the water solution of aluminum salts an OH^- we obtain white precipitate of aluminum hydroxide.

$$Al^{3+}(aq) + 3OH^- \leftrightarrows Al(OH)_3(s)$$

It dissolves in $NaOH_{(aq)}$ and in acidic solution, because it is amphoteric to as aluminum and aluminum oxide.

$$Al(OH)_3(s) + 3NaOH(aq) = 2Na_3[Al(OH)_6](aq)$$

$$Al(OH)_3(s) + 3HCl(aq) = AlCl_3(aq) + 3H_2O$$

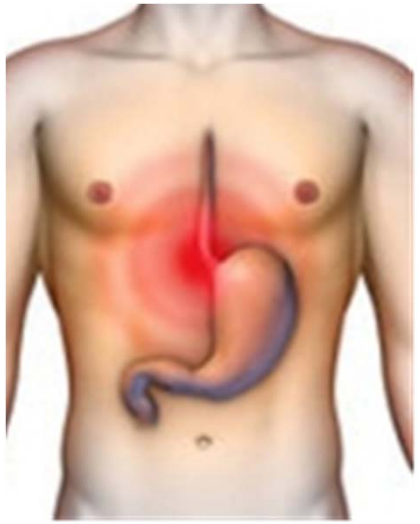
Biological role and application of compounds of aluminium in medicine

From metallic aluminium are make packaging for tablets – blisters.

Aluminum salts are used for water treatment as coagulants.

$$Al_2(SO_4)_3 + 6H_2O = 2Al(OH)_3 + 3H_2SO_4$$

Aluminum hydroxide, $Al(OH)_3$ is used externally in the form of powders, pastes, ointments as absorbent and enveloping tools in dermatology. It is part of the drug "Almagel" in the form of a suspension in a mixture with magnesium hydroxide for the treatment of gastritis and stomach ulcers as adsorbing and enveloping means.



Phosphalugel gel oral

- The main active substance is Aluminum Phosphate $AlPO_4$.
- The drug has an enveloping effect to the stomach and antacid.

Aluminum salts exhibit astringent, anti-inflammatory, hemostatic and antimicrobial action.

Aluminum potassium disulphate **$KAl(SO_4)_2 \cdot 12H_2O$** ***(potassium alum)*** is used in medical and cosmetic practice in the form of aqueous solutions as an astringent and styptic.

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Elements of IVA group

Some properties of elements IVA groups are resulted in

	C	Si	Ge	Sn	Pb
Atomic mass	12	28	72	118	207
Valence electrons	$2s^2 2p^2$	$3s^2 3p^2$	$4s^2 4p^2$	$5s^2 5p^2$	$6s^2 6p^2$

The principal oxidation states are +2, +4.

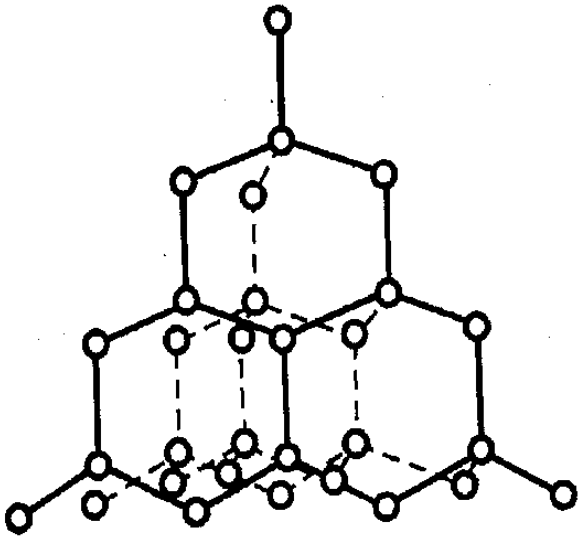
Carbon, the first member of group IV A, is a nonmetal. The next two members, Silicon and Germanium, are metalloids. Tin and Lead are mostly metallic in their behavior.

Carbon

Carbon is a chemical element with the symbol **C** and atomic number 6. It is a group IV, nonmetallic, tetravalent element, that presents several allotropic forms, of which the best known are diamond, graphite , graphene and fullerene.

Allotropy or allotropism (coined from Greek "other" + "form") is the property of some chemical elements to exist in two or more different forms, known as allotropes of these elements. The term allotropy is used for elements only, not for compounds.

The **diamond** structure has sp^3-hybridization.

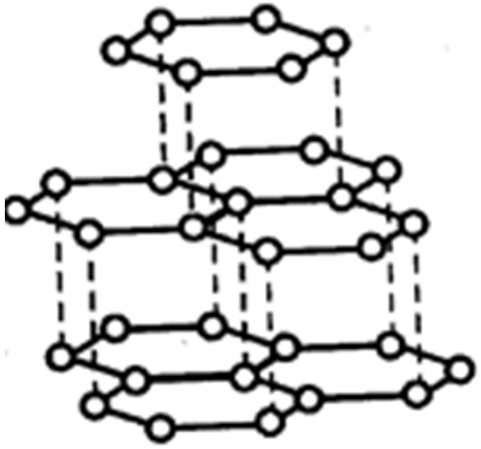


Each carbon atom is bounded to four others in a tetrahedral fashion. Diamond is extremely hard. It is used as abrasives, and diamond is the hardest substance knows. Diamond is not an electrical conductor because in its structure all of the valence electrons of the carbon are fixed permanently into singly covalent bonds.

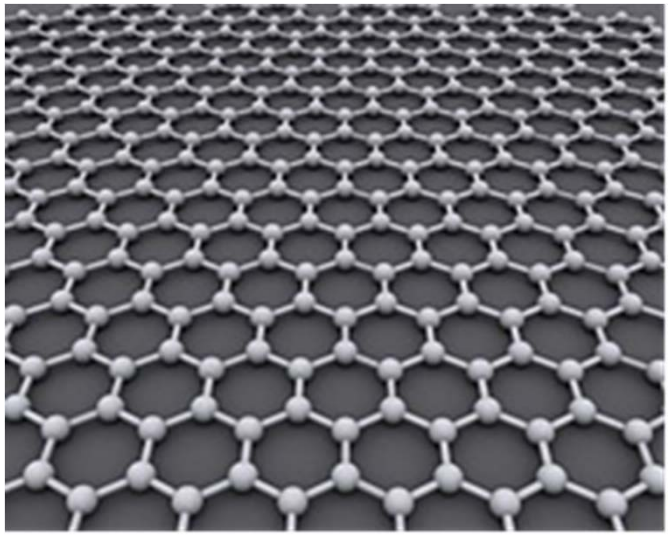
Graphite has sp^2-hybridization.

Graphite can conduct electricity.

The graphite structure.

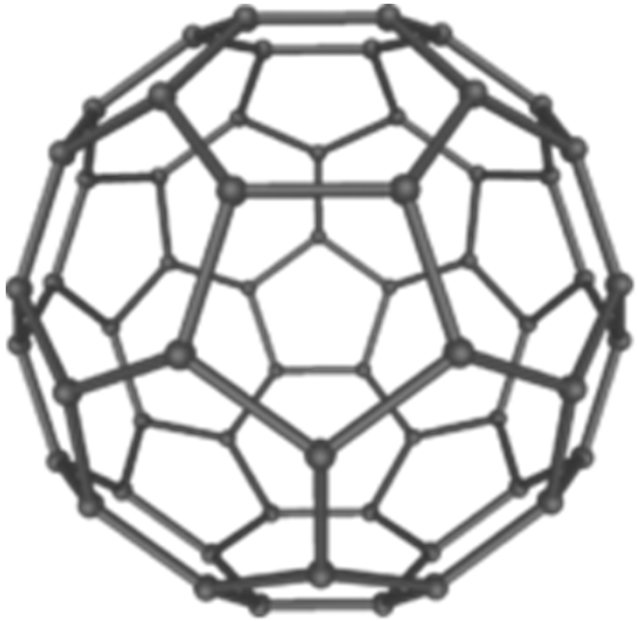


Graphene is a substance made of pure carbon, with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. It is very light, with a 1 square meter sheet weighing only 0.77 milligrams.



The Nobel Prize in Physics for 2010 was awarded to Andre Geim and Konstantin Novoselov at the University of Manchester "for groundbreaking experiments regarding the two-dimensional material graphene".

A **fullerene** is any molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid or tube. Spherical fullerenes are also called buckyballs, and they resemble the balls used in football.

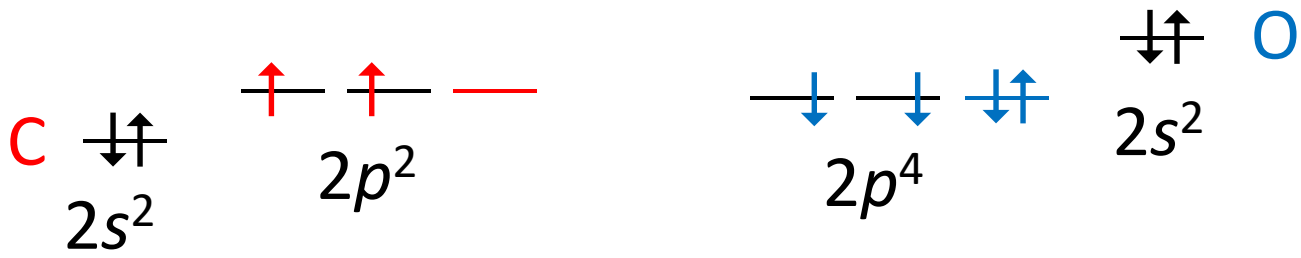


Oxides of Carbon

When carbon or any of a variety of organic compounds is burned in a limited quantity of air, the principal carbon-containing product is carbon monoxide

$$2C(s) + O_2(g) = 2CO(g)$$

An oxidation state of carbon is +2 and oxygen -2.



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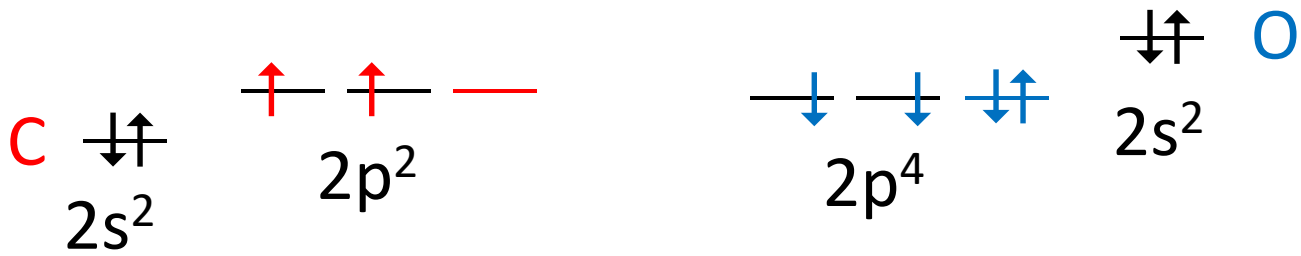


The number of covalent bonds between atoms carbon and oxygen is three. There are two bonds between atoms for exchange mechanism, and one of them for donor-acception mechanism.

Carbon monoxide is very toxic substance. In an excess of air, carbon dioxide is formed

$$2CO(g) + O_2(g) = 2CO_2(g)$$

Carbon dioxide in laboratory is prepared by treating sodium carbonate with HCl(aq)

$$Na_2CO_3(s) + 2HCl(aq) = 2NaCl(aq) + CO_2(g) + H_2O$$

A simple industry method of producing $CO_2(g)$ involves heating $CaCO_3$

$$CaCO_3(s) = CaO(s) + CO_2(g)$$

$CO_2(g)$ dissolves in water and comes into equilibrium with carbonic acid, a weak acid that ionizes in two stages

$$CO_2(g) + H_2O \leftrightarrows H_2CO_3(aq) \leftrightarrows H^+ + HCO_3^-(aq) \leftrightarrows 2H^+ + CO_3^{2-}(aq)$$

Carbonic acid has the formula H_2CO_3. It is also a name sometimes given to solutions of carbon dioxide in water, which contain small amounts of H_2CO_3. The salts of carbonic acids are called hydrogencarbonates and carbonates. It is a weak acid. Carbon dioxide dissolved in water is in equilibrium with carbonic acid:

$$CO_2 + H_2O \leftrightarrows H_2CO_3$$

Carbonic acid is diprotic, that is it has two hydrogens which dissociate from the parent molecule, and thus there are two dissociation constants:

$$H_2CO_3 \leftrightarrows H^+ + HCO_3^- \qquad K_{a1} = 2.5\times10^{-4};$$

$$HCO_3^- \leftrightarrows H^+ + CO_3^{2-} \qquad K_{a2} = 5.61\times10^{-11}$$

Neutralization of the carbonic acid by NaOH through the first stage produced a salt called a sodium hydrogen carbonate

$$H_2CO_3(aq) + NaOH(aq) = NaHCO_3(aq) + H_2O$$

Neutralization through the second stage yields a carbonate

$$H_2CO_3(aq) + 2NaOH(aq) = Na_2CO_3(aq) + 2H_2O$$

Carbon combines with metal to form carbides. Calcium carbide is formed by the high-temperature reaction of quicklime and coke

$$CaO(s) + 3C(s) = CaC_2(s) + CO(g) \qquad 2000\ ^\circ C$$

Calcium carbide is an impotent product because its reaction with water produces acetylene, a gas widely used in the synthesis of organic compounds.

$$CaC_2(s) + 2H_2O = Ca(OH)_2(aq) + C_2H_2(g)$$

Qualitative Identification of Carbonate Ions

$$Na_2CO_3(s) + 2HCl(aq) = 2NaCl(aq) + CO_2(g) + H_2O$$

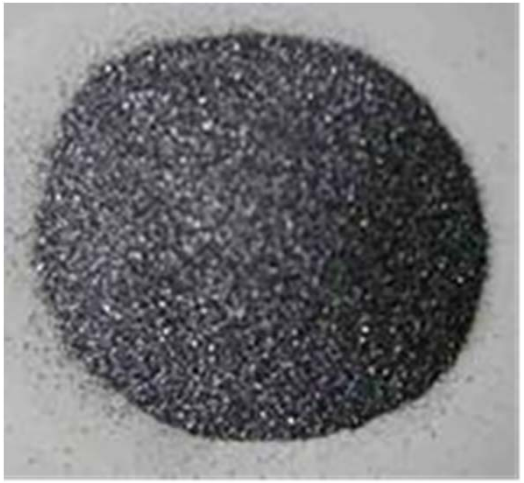
$$CO_2 + Ca(OH)_2(aq) \leftrightarrows CaCO_3(s) + 2H_2O$$

$$CaCO_3(s) + CO_2 + H_2O = Ca(HCO_3)_2(aq)$$

Silicon

Silicon is the chemical element that has the symbol **Si** and atomic number 14.

Silicon is a solid at room temperature, with relatively high melting and boiling points. Silicon is a semiconductor.



A silicon atom, like a carbon atom, can form four bonds in a tetrahedral fashion.

Silicon dissolves in NaOH to produce sodium metasilicate and hydrogen

$$Si(s) + 2NaOH(aq) + H_2O = Na_2SiO_3(aq) + 2H_2(g)$$

$$-4\bar{e} + Si + 6OH^- \leftrightarrows SiO_3^{2-} + 3H_2O \quad | \quad 1$$

$$+2\bar{e} + 2H_2O \leftrightarrows H_2 + 2OH^- \quad | \quad 2$$

$$Si + \cancel{6OH^-} + \cancel{4H_2O} = SiO_3^{2-} + \cancel{3H_2O} + 2H_2 + \cancel{4OH^-}$$

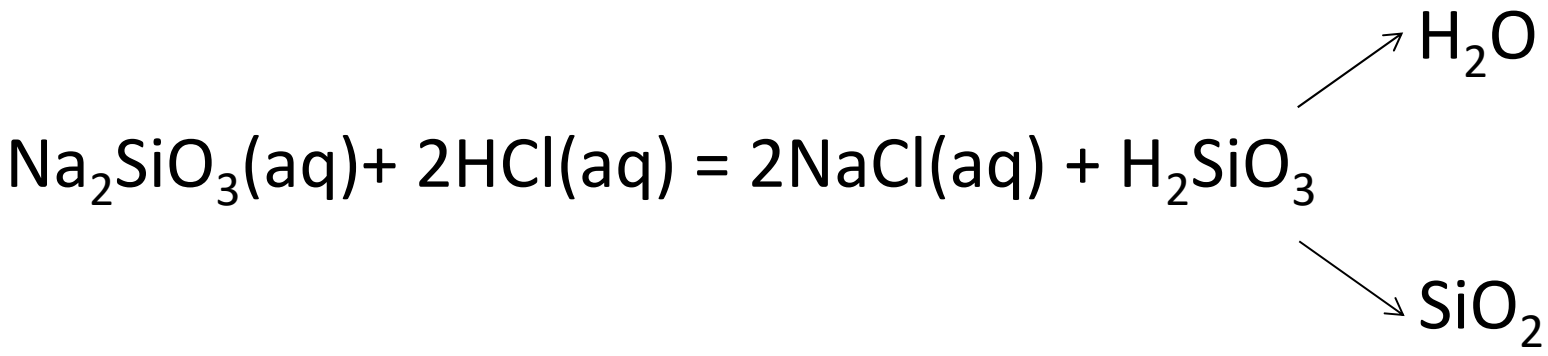
$$2OH^-$$

SiO_2 dissolves slowly in strong bases with formation silicates

$$SiO_2(s) + 2NaOH(aq) = Na_2SiO_3(aq) + H_2O$$

Qualitative Identification of Silicate Ions

The silicic acid resulting from the acidification of silicate solutions is also unstable; it decomposes to silica (SiO_2)



Depending on the acidity of the solution, the silica may be obtained as colloidal dispersion, a gelatinous precipitate, or a solid like gel.

Silica gel is a granular, vitreous, porous form of silicon dioxide. Silica gel's high surface area (around 800 m^2/g).

Silica gel is most commonly encountered in everyday life as beads in a small paper packets. In this form, it is used as a desiccant to avoid spoilage or degradation of some goods. Because of poisonous dopants and their very high absorption, silica gel packets usually bear warnings for the user not to eat the contents.

Hydrolysis of Sodium Silicate

The hydrolysis of sodium silicate, unlike other similar salts, is occured with formation of dimetasilicate-ion:

$$Na_2SiO_3 \rightarrow 2Na^+ + SiO_3^{2-}$$

$$SiO_3^{2-} + HOH \leftrightarrows HSiO_3^- + OH^-$$

$$2HSiO_3^- \leftrightarrows Si_2O_5^{2-} + H_2O$$

Total reaction equation of hydrolysis is:

$$2Na_2SiO_3 + HOH \leftrightarrows Na_2Si_2O_5 + 2NaOH$$

Reactions of Tin and Lead

Tin dissolves in HCl(aq)

$$Sn(s) + 2HCl(aq) = SnCl_2(aq) + H_2(g)$$

In concentrated $HNO_3(aq)$, tin is oxidized to $SnO_2(s)$ (nonmetal properties)

$$Sn(s) + 4HNO_3(aq) = H_2SnO_3(s) + 4NO_2(g) + H_2O$$

$(SnO_2 \cdot H_2O)$

In dilute $HNO_3(aq)$, tin is oxidized to Sn^{2+} ion (metalic properties)

$$3Sn(s) + 8HNO_3(aq) = 3Sn(NO_3)_2(aq) + 2NO(g) + 4H_2O$$

The reaction of lead with dilute HCl and H_2SO_4 stop after an initial brief reaction because the products, $PbCl_2$ and $PbSO_4$ protect the metal from further attack. The products of reaction lead with HNO_3 are $Pb(NO_3)_2$ and various oxides of nitrogen.

$$3Pb(s) + 8HNO_3(aq) = 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O$$

$$-2\bar{e} + Pb \leftrightarrows Pb^{2+} \quad | \quad 3$$

$$+3\bar{e} + NO_3^- + 4H^+ \leftrightarrows NO + 2H_2O \quad | \quad 2$$

$$3Pb + 2NO_3^- + 8H^+ = 3Pb^{2+} + 2NO + 4H_2O$$

PbO_2 is a strong oxidizing agent

$$4HCl(aq) + PbO_2(s) = PbCl_2(aq) + Cl_2(g) + 2H_2O$$

$[Sn(OH)_4]^{2-}$ ion is a reducing agent. This reaction can be used for **qualitative identification of tin compounds**

$$3Na_2[Sn(OH)_4]\,(aq) + 2Bi(OH)_3(s) = 3Na_2[Sn(OH)_6](aq) + 2Bi(s)$$

$$-2\bar{e} + [Sn(OH)_4]^{2-} + 2OH^- \leftrightarrows [Sn(OH)_6]^{2-} \quad | \quad 3$$

$$+3\bar{e} + Bi(OH)_3 \leftrightarrows Bi + 3OH^- \quad | \quad 2$$

$$3[Sn(OH)_4]^{2-} + \cancel{6OH^-} + 2Bi(OH)_3 \rightarrow 3[Sn(OH)_6]^{2-} + 2Bi^0 + \cancel{6OH^-}$$

black sediment

Tin (II) chloride is a good reducing agent too.

$$3SnCl_2(aq) + K_2Cr_2O_7(aq) + 20HCl(aq) = 3H_2[SnCl_6](aq) + 2CrCl_3(aq) + 2KCl(aq) + 7H_2O$$

$-2\bar{e} + Sn^{2+} + 6Cl^- \leftrightarrows [SnCl_6]^{2-}$	3
$+6\bar{e} + Cr_2O_7^{2-} + 14H^+ \leftrightarrows 2Cr^{3+} + 7H_2O$	1

$$3Sn^{2+} + 18Cl^- + Cr_2O_7^{2-} + 14H^+ \rightarrow 3[SnCl_6]^{2-} + 2Cr^{3+} + 7H_2O$$

Qualitative Identification of Lead compounds

$$Pb^{2+}(aq) + S^{2-}(aq) \leftrightarrows PbS(s)$$

black sediment

$$Pb^{2+}(aq) + 2I^{-}(aq) \leftrightarrows PbI_2(s)$$

yellow sediment

Biological role compounds of Carbon, Silicon and Lead and their application in medicine

The **activated carbon** is used in chemical, pharmaceutical and medical practice as adsorbent. One gram of activated carbon has a surface area of approximately 500 m^2 .It is used to treat poisonings and mild diarrhea.

A metallic lead and lead compounds are toxic. Maximum concentration of lead salts makes 10^{-5} mg/L. During poisoning compounds of lead hold out the albumens of red corpuscles, then concentrated in blood plasma and entered in kidneys and liver.

White Coal

White Coal is one of the most modern enterosorbents.

Actives of sorbent - microcrystalline cellulose and fumed silica (SiO_2). Excipients - potato starch, powdered sugar.

Inorganic and Physical Chemistry Department
General and Inorganic Chemistry

Elements of VA group

In specialty 226 Pharmacy, industry pharmacy

Ye.Ya.Levitin,
Doctor of Pharmaceutical Sciences, Professor

The group VA elements consists of some elements:

nitrogen N, phosphorus P,
arsenic As, antimony Sb, bismuth Bi

Their outer shell electron configurations are ns^2np^3.

For group VA the usual decrease of ionization energy with increasing atomic number is noted.

This establishes the order of metallic character within the group.

Nitrogen is least metallic and bismuth is most metallic.

Some properties of elements VA

	N	P	As	Sb	Bi
Atomic mass	14.01	30.97	74.92	121.75	208.98
Valence electrons	$2s^2 2p^3$	$3s^2 3p^3$	$4s^2 4p^3$	$5s^2 5p^3$	$6s^2 6p^3$

Nitrogen

Nitrogen has the electron configuration $1s^2 2s^2 2p^3$ the oxidation state of N in its compounds can range from –3 to +5.

The maximum oxidation state corresponds to its periodic group number VA.

The maximum valence is 4.

–3	–2	–1	0	+1	+2	+3	+4	+5
NH_3 NH_4^+	$NH_2\,NH_2$	NH_2OH	N_2	N_2O	NO	N_2O_3 HNO_2	NO_2 N_2O_4	N_2O_5 HNO_3

Physical and Chemical Properties of Nitrogen

Nitrogen is colorless gas, tasteless and odorless.

It badly dissolves in water and in organic solvents.

$N_{2(g)}$ is the primary component of air (78%, by volume).

Elemental nitrogen, N_2, is rather inert.

Nitrogen is react only with lithium without heating

$$6Li_{(s)} + N_{2(g)} = 2Li_3N_{(s)}$$

Ammonia and Ammonium Compounds

Nitrogen gas and hydrogen gas will combine to produce gaseous ammonia in industry

$$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$$

Ammonia in laboratory is prepared by treating ammonium chloride with calcium hydroxide

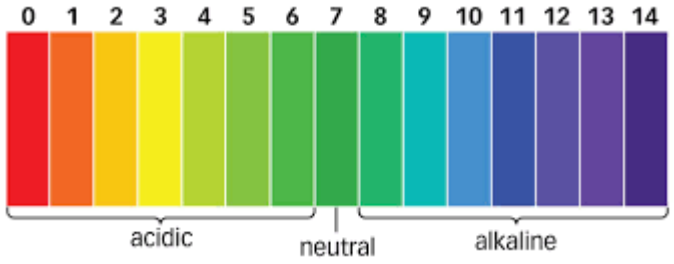
$$2NH_4Cl_{(s)} + Ca(OH)_{2(s)} = CaCl_{2(s)} + 2NH_{3(g)} + 2H_2O$$

This reaction is used for the **qualitative identification of ammonium salts**.

The hydroxide ion removes a proton from the ammonium ion to release the ammonia.

$$NH_4^+{}_{(aq)} + OH^-{}_{(aq)} = NH_{3(g)} + H_2O_{(l)}$$

Smelly ammonia released and a wet strip of a red litmus paper turns blue.



The most impotent use of NH_3, is in synthesizing a host of other nitrogen compounds.

The reaction of ammonia (a base) with acids produces ammonium salts, such as

$$NH_{3(aq)} + HCl_{(aq)} = NH_4Cl_{(s)}$$

ammonium chloride

NITROGEN OXIDES

Nitrogen forms a series of oxides in which the oxidation state can have every value from +1 (N_2O) to +5 (N_2O_5).

Nitrogen (I) oxide N_2O (nitrogen monoxide).

It can be prepared by next reaction:

$$NH_4NO_{3(s)} = N_2O_{(g)} + 2H_2O$$

Its main use is as an anesthetic (“laughing gas”).

Nitrogen (II) oxide NO (nitrogen oxide, nitric oxide**)**

Laboratory methods for preparation NO include the reaction of Cu with cold dilute $HNO_{3(aq)}$:

$$3Cu + 8HNO_{3(dilute)} = 3Cu(NO_3)_2 + 2NO_{(g)} + 4H_2O$$

Commercially, NO is produced by the catalytic oxidation of NH_3:

$$4NH_{3(g)} + 5O_2 = 4NO_{(g)} + 6H_2O_{(g)}$$

Nitrogen (III) oxide N_2O_3 (dinitrogen trioxide)

It forms upon mixing equal parts of nitrogen oxide and nitrogen dioxide and cooling the mixture below −21°C

$$NO_{(g)} + NO_{2(g)} \leftrightarrows N_2O_{3(g)}$$

It is the anhydride of the unstable **nitrous acid (HNO_2)**, and produces it when mixed into water.

$$N_2O_{3(g)} + H_2O = 2HNO_{2(aq)}$$

Nitrous acid and its salts nitrites have red-ox duality

$$\overset{-1}{2KI} + \overset{+3}{2KNO_2} + 2H_2SO_4 = \overset{+0}{I_2} + \overset{+2}{2NO} + 2K_2SO_4 + 2H_2O$$

oxidizing agent

$$-2\bar{e} + 2I^- \leftrightarrows I_2 \quad | \; 1$$

$$+1\bar{e} + NO_2^- + 2H^+ \leftrightarrows NO + H_2O \quad | \; 2$$

$$2I^- + 2NO_2^- + 4H^+ = I_2 + 2NO + 2H_2O$$

$$\overset{+3}{5NaNO_2} + \overset{+7}{2KMnO_4} + 3H_2SO_4 = \overset{+5}{5NaNO_3} + \overset{+2}{2MnSO_4} + K_2SO_4 + 3H_2O$$

reducing agent

$$-2\bar{e} + NO_2^- + H_2O \leftrightarrows NO_3^- + 2H^+ \quad | \; 5$$

$$+5\bar{e} + MnO_4^- + 8H^+ \leftrightarrows Mn^{2+} + 4H_2O \quad | \; 2$$

$$5NO_2^- + \cancel{5H_2O} + 2MnO_4^- + \cancel{16H^+} = 5NO_3^- + \cancel{10H^+} + 2Mn^{2+} + \cancel{8H_2O}$$

$$6 \qquad\qquad 3$$

Nitrogen (IV) oxide NO_2(nitrogen dioxide)

NO_2 produces both HNO_2 and HNO_3 when it reacts with water

$$2NO_{2(g)} + H_2O = HNO_{3(aq)} + HNO_{2(aq)}$$

The reaction of NO_2 with water and oxygen describes the commercial preparation of nitric acid

$$4NO_{2(g)} + 2H_2O + O_2 = 4HNO_{3(aq)}$$

Nitrogen (V) oxide N_2O_5 (dinitrogen pentaoxide)

Dehydration is a method of preparation N_2O_5

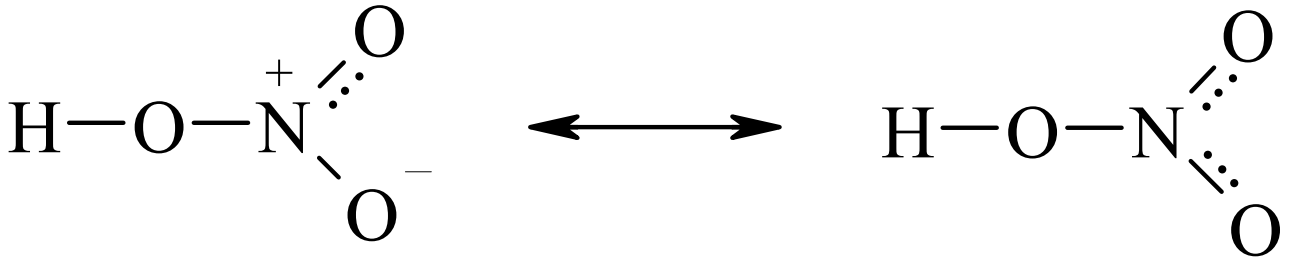
$$4HNO_3 + P_4O_{10} = 4HPO_3 + 2N_2O_5$$

The reaction of N_2O_5 with water produces the nitric acid

$$N_2O_{5(g)} + H_2O = 2HNO_{3(aq)}$$

Nitric Acid HNO_3

has the next structure



Pure nitric acid is a colorless liquid (d = 1.50 g/cm^3).

Nitrate salts are produced by neutralizing nitric acid

$$2HNO_3 + Ca(OH)_2 = Ca(NO_3)_2 + 2H_2O$$

HNO_3 is a good oxidizing agent.

With **dilute HNO_3** and an active metal (Zn, Mg, Sn, Fe) the reduction product is N_2O (or even NH_4^+ in some cases)

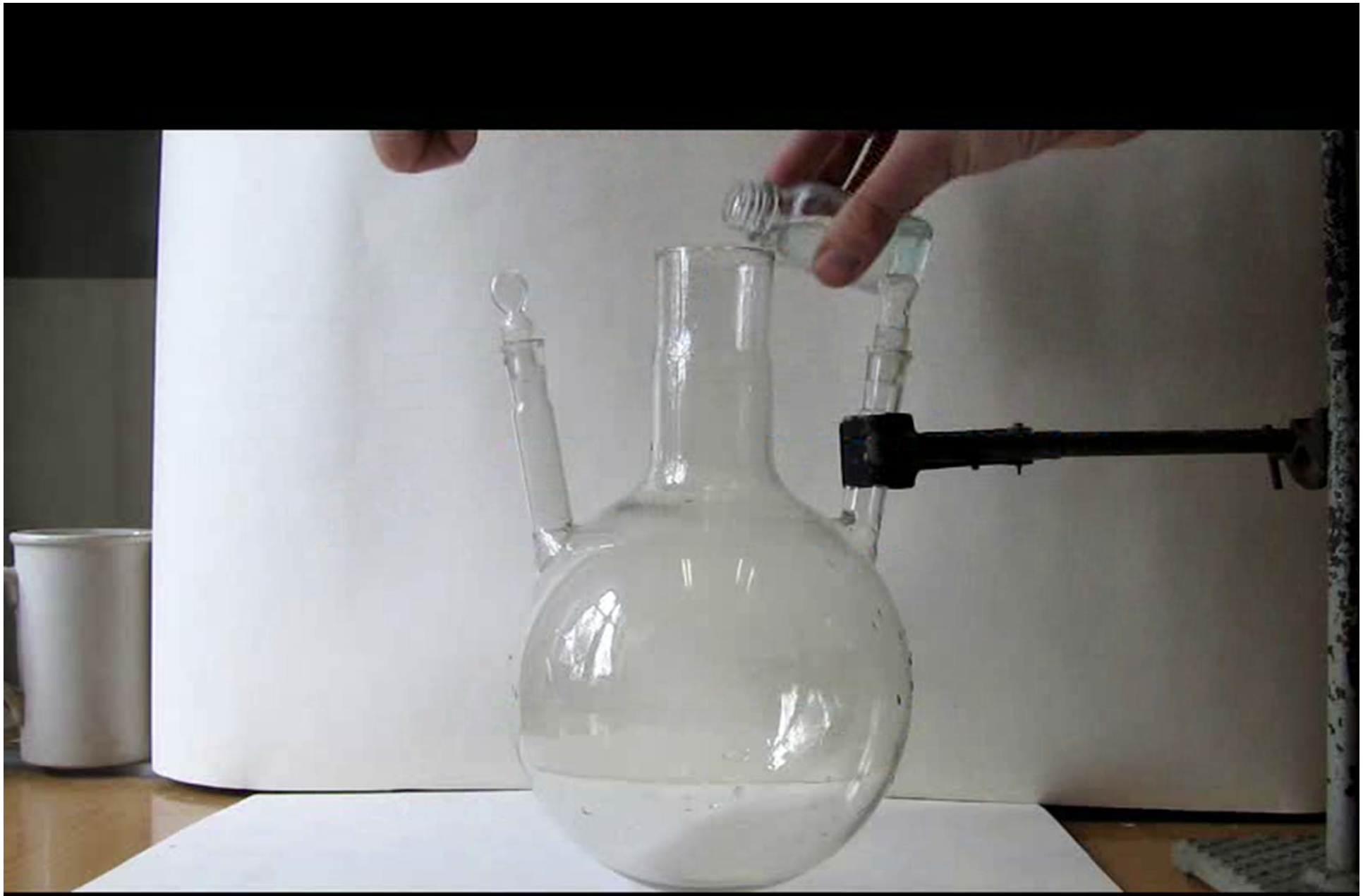
$$4Zn + 10HNO_{3(dilute)} = 4Zn(NO_3)_2 + N_2O_{(g)} + 5H_2O$$

$$4Fe + 10HNO_{3(very\ dilute)} = 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$$

With a less active metal, the reduction product is NO

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 2NO_{(g)} + 4H_2O$$

$$NO_{(g)} + O_2 = 2NO_{2(g)}$$ colour – “Fox's tail”



With **concentrated HNO_3**, the product is $NO_{2(g)}$

$$Ag + 2HNO_{3(conc.)} = AgNO_3 + NO_{2(g)} + H_2O$$

Nitric acid also reacts with nonmetallic elements, generally with the formation of an oxoacid and $NO_{(g)}$

$$S + 2HNO_3 = H_2SO_4 + 2NO_{(g)}$$

PHOSPHORUS

Configuration of valence electrons $_{15}\mathbf{P}\ 3s^2 3p^3$

–3	0	+1	+3	+5
PH_3 phosphine PH_4^+ phospho-nium ion	P_4 phos-phorus	$H[PO_2H_2]$ hypophos-phorous acid	$H_2[PO_3H]$ phos-phorous acid P_4O_6	H_3PO_4 phosphoric acid P_4O_{10}

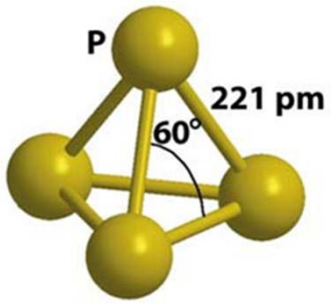
Due to its high reactivity, phosphorus is never found as a free element on Earth.

Phosphorus produced by sintering of phosphate, sand and coke (1500 °C):

$$3Ca_3(PO_4)_2 + 10C + 6SiO_2 = 6CaSiO_3 + 10CO + P_{4(white)}$$

Phosphorus forms a few allotropic modifications, major from them the phosphorus white, red and black.

The basic structural units of white phosphorus are P_4 molecules (tetrahedron)



Oxides and Oxoacids of Phosphorus

The two most important oxides of phosphorus are oxides having P in the oxidation states of +3 and +5.

The simplest formulas that can be written for these are P_2O_3 and P_2O_5, with the corresponding names, **phosphorus (III) oxide** and **phosphorus (V) oxide**.

However, more appropriate molecular formulas are P_4O_6 and P_4O_{10}.

P_4O_6 is produced when the available quantity of O_2 is limited

$$P_4 + 3O_2 = P_4O_6$$

In an excess of O_2, P_4O_{10} is formed

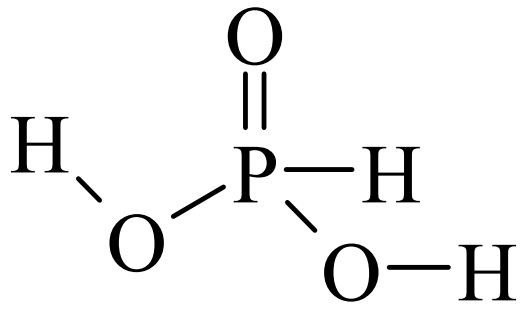
$$P_4 + 5O_2 = P_4O_{10}$$

P_4O_6 and P_4O_{10} each react with water to produce an oxoacid

$$P_4O_6 + 6H_2O = 4H_2[PO_3H]$$

phosphorous acid

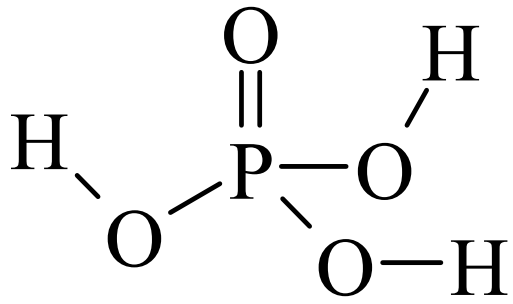
Phosphorous acid is diprotic acid. The graphic formula of $H_2[PO_3H]$ is



One atom of hydrogen is connected with the atom of phosphorus directly. It is the diprotic acid of middle force.

Orthophosphoric acid forms when P_4O_{10} reacts with an excess of H_2O

$$P_4O_{10} + 6H_2O = 4H_3PO_4$$



Ortophosphoric acid waterless is colorless crystals.

Acid with a mass percent 83-98% is liquid as syrup.

Ionization occurs in three steps

$$H_3PO_4 \leftrightarrows H^+ + H_2PO_4^-$$

$$H_2PO_4^- \leftrightarrows H^+ + HPO_4^{2-}$$

$$HPO_4^{2-} \leftrightarrows H^+ + PO_4^{3-}$$

When orthophosphoric acid is heated to temperatures in excess of 215 °C, **diphosphoric acid** is formed

$$2H_3PO_4 = H_4P_2O_7 + H_2O$$

When either the ortho- or di- acid is heated to temperatures in excess of about 300 °C, a glassy product is formed.

$$H_3PO_4 = HPO_3 + H_2O$$

This is probably a polymerized form of **metaphosphoric acid**, HPO_3, $(HPO_3)_n$, where n = 2, 3, 4, 6.

Order Compounds of Phosphorus

Nitric acid oxidizes phosphorus to ortophosphoric acid:

$$3P_4 + 20\ HNO_3 + 8H_2O = 12H_3PO_4 + 20NO$$

Phosphorus with a hot solution of NaOH forms a salt of hypophosphorous acid:

$$P_4 + 3NaOH + 3H_2O = 3Na[H_2PO_2] + PH_3$$

The free **hypophosphorous** acid may be prepared by the action of a strong acid on these hypophosphorous salts:

$$[H_2PO_2]^- + H^+ = H[H_2PO_2]$$

This acid is monoprotic strong acid.

The Qualitative Reaction for compounds which contain phosphate ions

If added $MgCl_2$, NH_4Cl, $NH_3 \cdot H_2O$ to the solution which contain PO_4^{3-} ion, white sediment of magnesium ammonium phosphate is formed:

$$Na_2HPO_4 + MgCl_2 + NH_3 \cdot H_2O = MgNH_4PO_{4(s)} + 2NaCl + H_2O$$

Compound of Arsenic, Antimony and Bismuth

With hydrogen these elements do not react, although they are formed the hydrides of general formula EH_3.

Arsine AsH_3 is possible to get by reduction of arsenic compounds by zinc in the solution of hydrochloric acid.

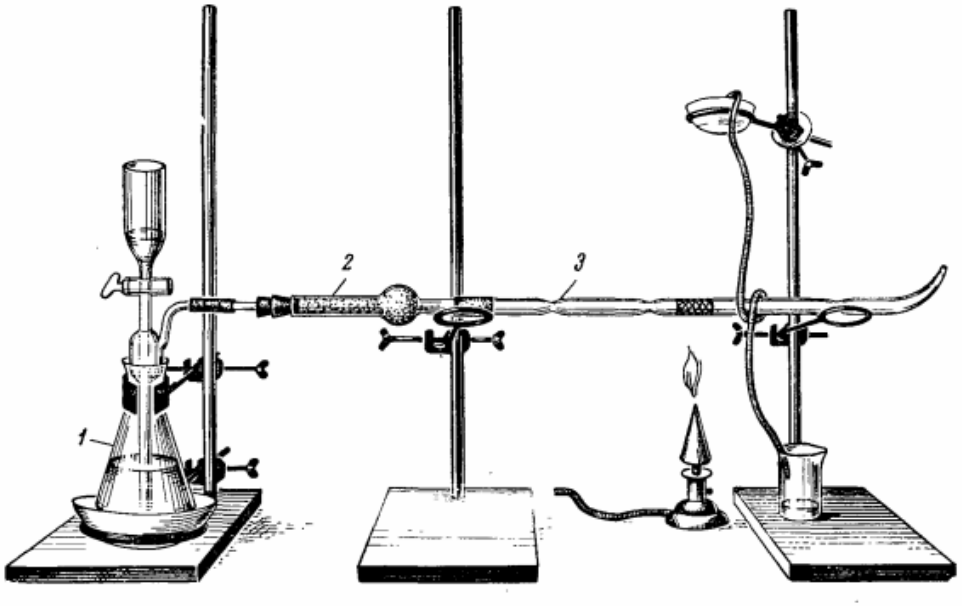
$$As_2O_3 + 6Zn + 12HCl = 2AsH_3 + 6ZnCl_2 + 6H_2O$$

In toxicological practice the **test of Marsh** is applied.

It is based on thermal instability of arsine, which decomposes at heating.

$$2AsH_3 = 2As + 3H_2$$

On the surface of the tube is formed like a silver mirror.



Arsenic (III) oxide (white arsenic)

As_2O_3 is the white crystalline matter a water-soluble.

It is amphoteric oxide:

$$As_2O_{3(s)} + 3H_2O = 2H_3AsO_{3(aq)}$$

orthoarsenous acid

$$As_2O_{3(s)} + 2NaOH_{(s)} = 2NaAsO_{2(s)} + H_2O\ (t, {}^0C)$$

sodium metarsinite

$$As_2O_{3(s)} + 2KOH_{(aq)} + 3H_2O = 2K[As(OH)_4]_{(aq)}$$

$$As_2O_{3(s)} + 8HCl = 2H[AsCl_4]_{(aq)} + 3H_2O$$

In the atmosphere of oxygen arsenic burns with formation of higher oxide:

$$4As + 5O_2 = 2As_2O_5$$

Arsenic (V) oxide As_2O_5 dissolves in water well, forming ortoarsenic acid:

$$As_2O_5 + 3H_2O = 2H_3AsO_4$$

Orthoarsenic acid H_3AsO_4 is the triprotic acid of middle force.

With alkalis it reacts with formation of the proper salts.

$$H_3AsO_4 + 3NaOH = Na_3AsO_4 + 3H_2O$$

sodium orthoarsenate

Orthoarsenic acid and its salts have oxidizing properties only in an acidic solution:

$$2KI + Na_3AsO_4 + H_2SO_4 = I_2 + Na_3AsO_3 + K_2SO_4 + H_2O$$

In water solution antimony (III) and bismuth (III) salts the hydrolysis reaction proceeds up to the end is easy not only on the first, but also on the second step:

$$BiCl_3 = Bi^{3+} + 3Cl^-$$

$$Bi^{3+} + H_2O \leftrightarrows BiOH^{2+} + H^+$$

$$BiOHCl_2 + H_2O \leftrightarrows Bi(OH)_2Cl + HCl$$

$$Bi(OH)_2Cl \leftrightarrows BiOCl_{(s)} + H_2O$$

At acidifying sediment dissolves:

$$BiOCl_{(s)} + 2HCl \leftrightarrows BiCl_{3(aq)} + H_2O$$

Biological role compounds of elements VA group and their application in medicine

Liquid nitrogen is an efficient remedy for skin diseases (warts, papillomas, ets.).

Nitrogen (I) oxide N_2O is also known as “laughing gas”. It is used in medicine for narcosis when mixed with oxygen.

Ammonia solution 10% $NH_3 \cdot H_2O$ is used for breathing stimulation.

Arsenic (III) oxide As_2O_3 – (white arsenic) is used in stomatology.

Salts of bismuth are used for treatment of stomach ulcer and certain external for skin diseases