

Introduction to pharmaceutical
analysis;
Biological roles of inorganic
compounds

Lectures 14 - 15

The plan of the lecture

- Theoretical basis of pharmaceutical analysis
- Analysis of the most important inorganic compounds
- Compatibility of substances
- Biological roles of the most important inorganic compounds

Pharmacy

is a complex of disciplines on design, safety, investigations, storage, marketing and natural sources of medicines.

State pharmacopeia

Each country has its own official pharmacopeia, that is a book containing all the essential information on current methods of qualitative and quantitative analysis of medicines.

Pharmaceutical analysis

includes chemical, physical and chemical, biological methods for checking the quality of medicines during their production, distribution and storage.

Pharmacopeia analysis

is a part of pharmaceutical analysis that includes only official methods for checking:

- a) the qualitative content of a medicine,
- b) the presence and amounts of impurities,
- c) the quantitative analysis of main acting substances and additional ingredients of a medicine.

Authenticity of a medicine

Authenticity of a medicine means the qualitative analysis with the aim to confirm that a medicine really contains all ingredients listed

For inorganic substances one has to confirm the presence of both cations and anions: these procedures are performed separately.

Lithium salts

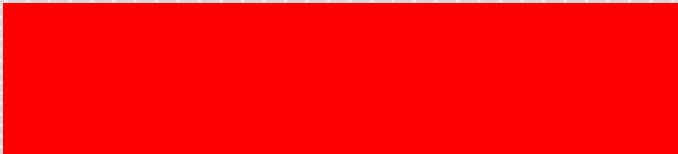
- Li_2CO_3 – antipsychotic
- Carmine-red color of the flame.
- $\text{Li}_2\text{CO}_3 \downarrow + 2\text{HCl} = 2\text{LiCl} + \text{CO}_2 \uparrow + \text{H}_2\text{O}$
- $3\text{Li}^+ + \text{HPO}_4^{2-} + \text{OH}^- = \text{Li}_3\text{PO}_4 \downarrow + \text{H}_2\text{O}$

white

Shades of red



carmine



red

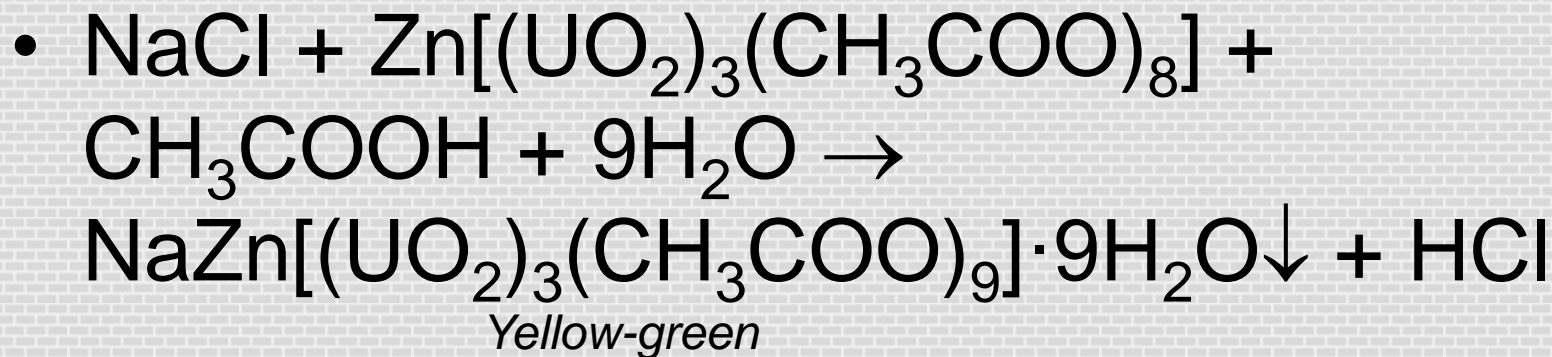


carmine-red

Sodium salts

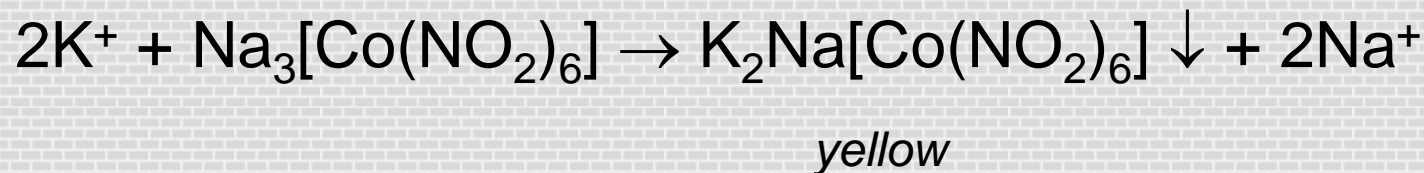
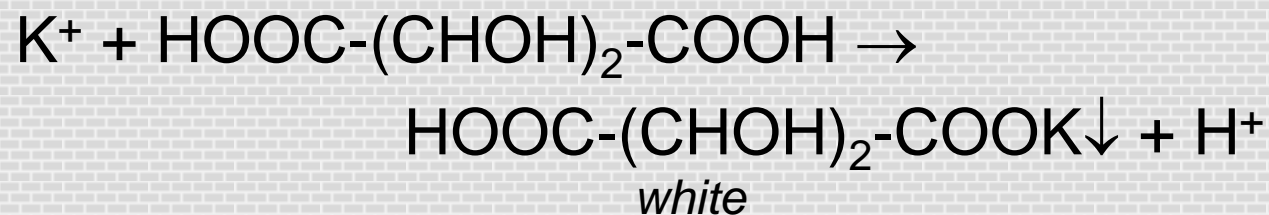
- Yellow color of the flame

Zinc uranylacetate



Potassium salts

Tartaric acid



Potassium salts

- The color of the flame is violet, while if you look through the blue glass it is purple-red



violet



purple-red

Magnesium salts

- Shiny-white color of the flame
- $\text{MgSO}_4 + \text{Na}_2\text{HPO}_4 + \text{NH}_3 \rightarrow \text{MgNH}_4\text{PO}_4 \downarrow$
+ Na_2SO_4
white,
soluble in CH_3COOH

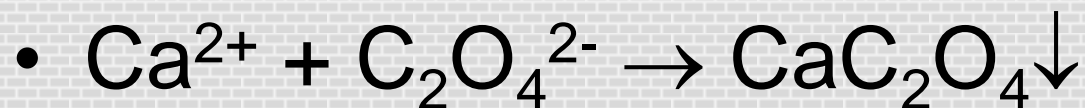
Calcium salts

- Red-brick color of the flame



Brick-red

Calcium salts



*White precipitate that is soluble in mineral acids,
and not in acetic acid*



yellow

Calcium salts

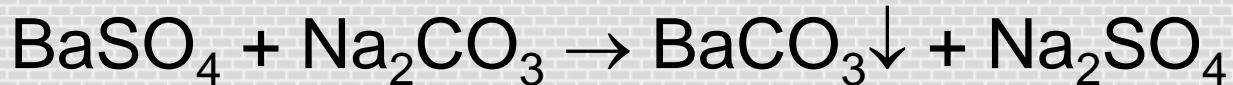
- Citrate + $\text{CaCl}_2 \rightarrow$ white precipitate that is formed at high temperature

Barium salts

- Yellow-green color of the flame



- At boiling:



After that sulfates are determined in the solution, while precipitate is separated and treated by hydrochloric acid.

Then the presence of barium cations is checked in the solution.

Boric acid and borax

- Boric acid forms ethers with alcohols
- $\text{B(OH)}_3 + 3\text{C}_2\text{H}_5\text{OH} \rightarrow \text{B(OC}_2\text{H}_5)_3 + 3\text{H}_2\text{O}$
- $\text{B(OC}_2\text{H}_5)_3$ burns with green cold flames

Aluminum hydroxide

- $\text{Al(OH)}_3 + \text{NaOH} \rightarrow \text{Na[Al(OH)}_4]$
- $\text{Na[Al(OH)}_4] + \text{NH}_4\text{Cl} \rightarrow \text{Al(OH)}_3\downarrow + \text{NaCl} + \text{NH}_4\text{OH}$

In the melt
- $4\text{Al(OH)}_3 + 2\text{Co(NO}_3)_2 \rightarrow 2\text{Co(AlO}_2)_2 + 4\text{NO}_2 + \text{O}_2 + 6\text{H}_2\text{O}$

Thinner's blue

Compounds of arsenic

- $\text{AsO}_3^{3-} + 3\text{Ag}^+ \rightarrow \text{Ag}_3\text{AsO}_3 \downarrow$ (yellow)
- $\text{AsO}_4^{3-} + 3\text{Ag}^+ \rightarrow \text{Ag}_3\text{AsO}_4 \downarrow$ (brown)

Compounds of arsenic

- Morphine + K_3AsO_4 = dark-green color
- Codeine + K_3AsO_4 = blue color
- Papaverine + K_3AsO_4 = red color

Compounds of antimony

- $\text{VitA} + \text{SbCl}_3 \rightarrow \text{blue color}$
- $\text{VitD2} + \text{SbCl}_3 \rightarrow \text{orange-yellow color}$

Copper salts

- Green color of the flame
- $\text{Cu}^{2+} + \text{OH}^- \rightarrow \text{Cu}(\text{OH})_2 \downarrow$ (*blue*)
- $\text{Cu}(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} + 2\text{OH}^-$
- $2\text{Cu}^{2+} + [\text{Fe}(\text{CN})_6]^{4-} \rightarrow \text{Cu}_2[\text{Fe}(\text{CN})_6] \downarrow$
Red-brown

Copper compounds

- Fresh $\text{Cu}(\text{OH})_2$ + glycerine = blue color
- Methionine + $\text{Cu}(\text{CH}_3\text{COO})_2$ = violet-blue precipitate

Silver compounds

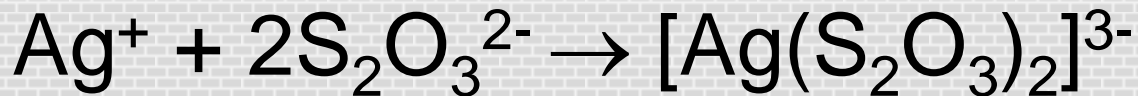
- $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl} \downarrow$ (white)
- $\text{AgCl} + 2\text{NH}_3 \cdot \text{H}_2\text{O} \rightarrow [\text{Ag}(\text{NH}_3)]\text{Cl} + 2\text{H}_2\text{O}$
- $\text{AgNO}_3 + \text{KI} \rightarrow \text{KNO}_3 + \text{AgI} \downarrow$ (yellow)
- $\text{NO}_3^- + \text{diphenylamine} \rightarrow \text{blue color}$
- Silver in colloid solutions cannot be detected by these tests. First one needs to treat a sample by nitric acid that converts colloid silver to silver nitrate.

Compounds of silver

- Colors of insoluble salts:

Cl^- , Br^- , I^- ,
white *light-yellow* *yellow*

S^{2-} , SO_4^{2-} , CrO_4^{2-} , PO_4^{3-} ,
black *white* *brick-red* *yellow*



Compounds of silver

- $[\text{Ag}(\text{NH}_3)_2]\text{NO}_3$ – Tollens' reactant that produces silver mirror in reactions with glucose, ascorbate, and formaldehyde

Compounds of mercury

- HgCl_2 – is used for Fe^{3+} detection



Red color



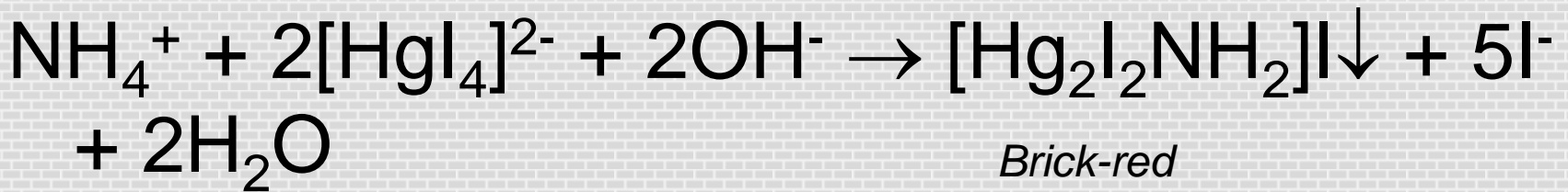
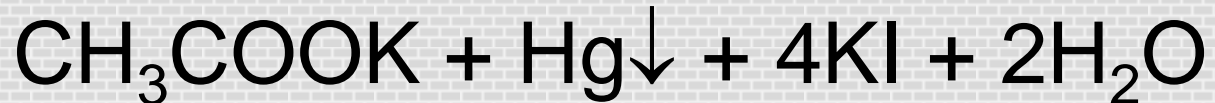
Red color disappears

Compounds of mercury

- $\text{Hg}(\text{NO}_3)_2$ – is used for iodide anions detection:
- $\text{Hg}^{2+} + 2\text{I}^- \rightarrow \text{HgI}_2 \downarrow$
orange
- $\text{HgI}_2 + 2\text{KI} \rightarrow \text{K}_2[\text{HgI}_4]$
colorless
- Excessive drop of $\text{Hg}(\text{NO}_3)_2$ leads to the formation of orange precipitate again:
- $\text{K}_2[\text{HgI}_4] + \text{Hg}(\text{NO}_3)_2 \rightarrow 2\text{HgI}_2 \downarrow + 2\text{KNO}_3$
orange

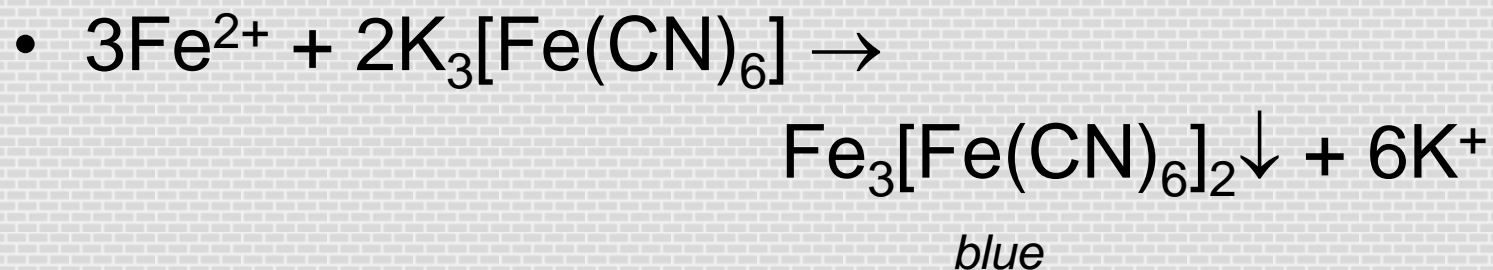
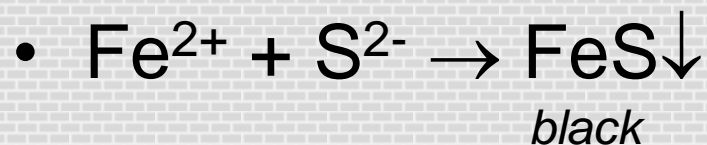
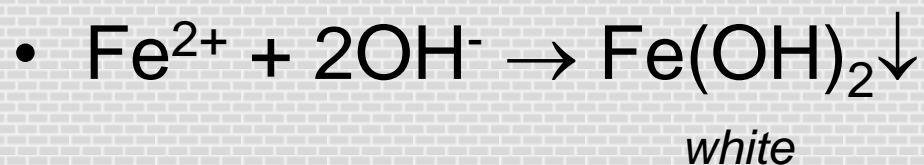
Compounds of mercury

- Nessler's reactant: alkaline solution of $K_2[HgI_4]$ – is used for the detection of traces of aldehydes and ammonium salts in other medicines:



Brick-red

Compounds of iron



Cerium (IV) sulfate

- $\text{Ce}^{4+} + e \rightarrow \text{Ce}^{3+}$
- $2\text{FeSO}_4 + 2\text{Ce}(\text{SO}_4)_2 \rightarrow \text{Fe}_2(\text{SO}_4)_3 + \text{Ce}_2(\text{SO}_4)_3$
- $\text{Fe}^{2+} + \text{dipyridyl} = \text{red color}$
- $\text{HCHO} + 2\text{Ce}(\text{SO}_4)_2 + \text{H}_2\text{O} \rightarrow$
 $\text{HCOOH} + \text{Ce}_2(\text{SO}_4)_3 + \text{H}_2\text{SO}_4$
Aspirin, phenol, paracetamol, vitamins
E and K

Cobalt compounds

- $\text{Na}_3[\text{Co}(\text{NO}_2)_6]$ – detection of K^+
- $\text{Co}(\text{OH})_2$ – detection of sucrose (violet color)
barbiturates (violet-blue color)
- $\text{Co}(\text{NO}_3)_2$ – detection of Zn^{2+} and Al^{3+}
- $\text{ZnO} + \text{Co}(\text{NO}_3)_2 \rightarrow \text{CoZnO}_2 + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$
Rhinmann's green
- $4\text{Al}(\text{OH})_3 + 2\text{Co}(\text{NO}_3)_2 \rightarrow 2\text{Co}(\text{AlO}_2)_2 + 4\text{NO}_2 + \text{O}_2 + 6\text{H}_2\text{O}$
Thenar's blue

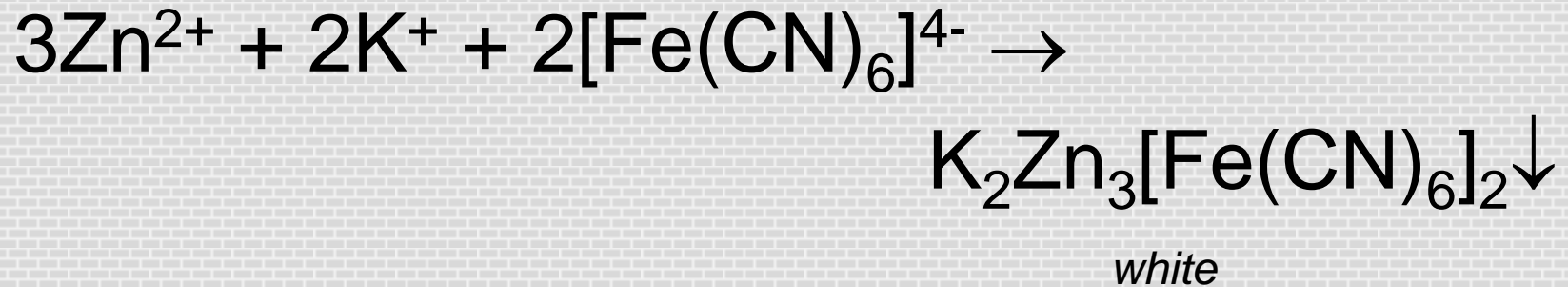
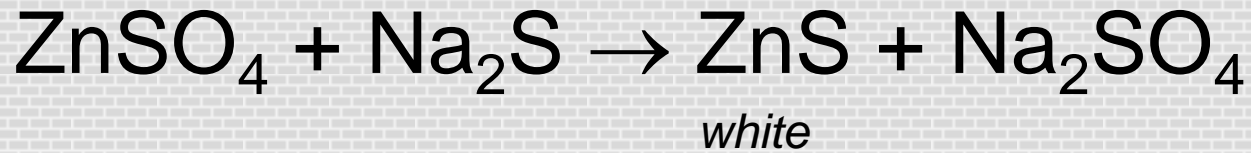
Compounds of chrome

- K_2CrO_4 – detection of Pb^{2+}
- $\text{Pb}^{2+} + \text{CrO}_4^{2-} \rightarrow \text{PbCrO}_4 \downarrow$
yellow
- H_2CrO_4 – detection of cocaine
- $\text{K}_2\text{Cr}_2\text{O}_7$ – detection of reducers like ethanol and iron (II) cations
- $3\text{C}_2\text{H}_5\text{OH} + \text{K}_2\text{Cr}_2\text{O}_7 + 4\text{H}_2\text{SO}_4 \rightarrow 3\text{CH}_3\text{COH} + \text{K}_2\text{SO}_4 + \text{Cr}_2(\text{SO}_4)_3 + 7\text{H}_2\text{O}$
- $6\text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \rightarrow 6\text{Fe}^{3+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$

Compounds of molybdenum

- $(\text{NH}_4)_2\text{MoO}_4$ – detection of PO_4^{3-} , scopolamine
- $\text{H}_3\text{PO}_4 + 12(\text{NH}_4)_2\text{MoO}_4 + 21\text{HNO}_3 \rightarrow$
 $(\text{NH}_4)_3\text{PO}_4 \cdot 12\text{MoO}_3 \downarrow + 21\text{NH}_4\text{NO}_3 + 12\text{H}_2\text{O}$
yellow
- $\text{H}_3\text{PO}_4 \cdot 12\text{MoO}_3$ – detection of alkaloids
- $((\text{NH}_4)_2\text{MoO}_4 + \text{NH}_4\text{VO}_3)$ – molybdenum vanadium reactant

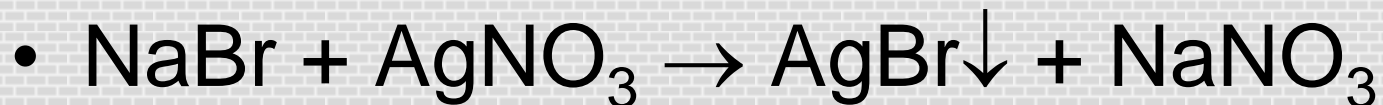
Compounds of zinc



Chlorides

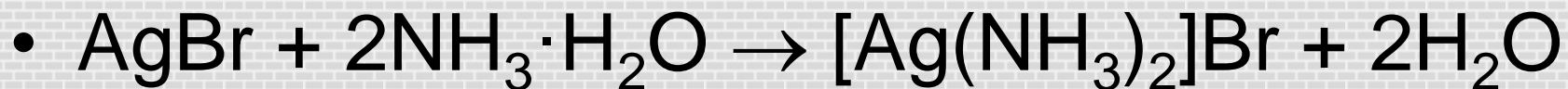
- $\text{NaCl} + \text{AgNO}_3 \rightarrow \text{AgCl}\downarrow + \text{NaNO}_3$
white
- Precipitate is soluble in $\text{NH}_3 \cdot \text{H}_2\text{O}$
- $\text{AgCl} + 2\text{NH}_3 \cdot \text{H}_2\text{O} \rightarrow [\text{Ag}(\text{NH}_3)_2]\text{Cl} + 2\text{H}_2\text{O}$

Bromides

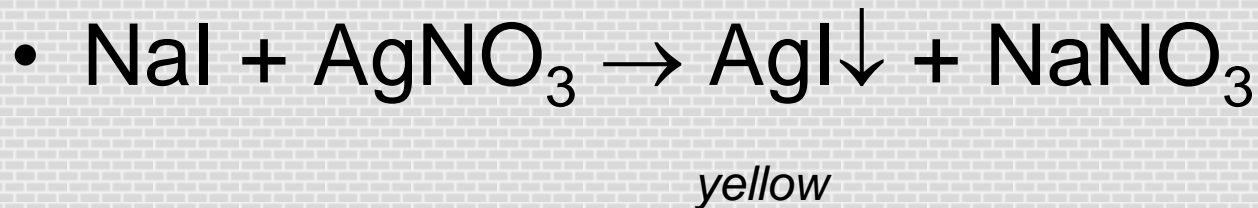


Light-blue

- Precipitate is hardly soluble in $\text{NH}_3 \cdot \text{H}_2\text{O}$



Iodides



- Precipitate is insoluble in $\text{NH}_3 \cdot \text{H}_2\text{O}$



yellow



light-yellow



white

Fluorides

- AgF is soluble in water, unlike CaF₂
- $2\text{NaF} + \text{CaCl}_2 \rightarrow \underset{\text{white}}{\text{CaF}_2} \downarrow + 2\text{NaCl}$
- Fluorides remove the red color of iron
thiocyanate solution:
$$[\text{Fe}(\text{CNS})_6]^{3-} + 6\text{F}^- \rightarrow [\text{FeF}_6]^{3-} + 6\text{CNS}^-$$

Chemical compatibility and incompatibility of medicines

- Medicines are able to interact with each other on different steps of their usage. That is why their chemical properties must be known for drug designers and pharmacists.
- One should not include two substances which decrease the effect of each other in the same tablet.

Types of interactions between medicines

- Pharmaceutical interactions – are chemical reactions during the storage (folic acid and zinc ions)
- Pharmacokinetic interactions – appear during the absorption in the digestive tract (VitD3 and Ca^{2+} ; ascorbate and Fe^{2+} ; antacides ($\text{Al}(\text{OH})_3$ or AlPO_4) and Fe^{2+})
- Pharmacodynamic interactions – appear when there is an influence of one medicine on the effect of another medicine (after their absorption in digestive tract)

Types of pharmaceutical incompatibility

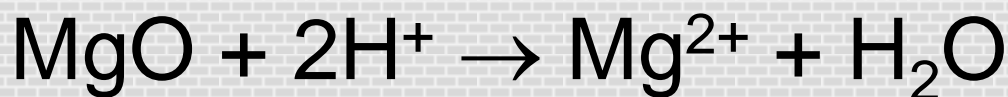
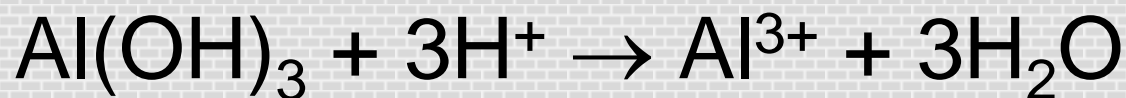
- Physical and physical and chemical incompatibility: hydration of powders because of their hygroscopic properties or because of the water production in the reaction between their ingredients.

Types of pharmaceutical incompatibility

- Chemical incompatibility:
 - precipitation (CaCl_2 cannot exist together with carbonates, sulfates and phosphates)
 - production of a gas (CaCO_3 and NaHCO_3 cannot exist together with acids that are stronger than carbonic acid)
 - redox reaction (KMnO_4 cannot exist together with the most of organic substances, with NaNO_2 , HCl and its salts, with iodides, bromides, H_2O_2 , ethanol)

The role of ionic (including acid-base) interactions in the metabolism of medicines (and mixtures of medicines) and their pharmaceutical analysis

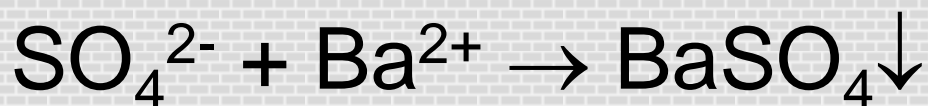
- In the metabolism of medicines (when antacids get to stomach):



- In the quality control (MgSO_4):



white



white

- In the design of medicines which include several substances (Antigrippine)

Antigrippine contains both dimedrol and ascorbic acid which interact with each other and release water.

To prevent the interaction between these substances they are stored in different granules.

Biological roles of nitrogen and phosphorus

- N – is a key atom in nucleic acids and proteins
- P – is a part of phosphates making phosphodiester bonds in proteins and those used for phosphorylation of proteins
- $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$ and $\text{Ca}_5(\text{PO}_4)_3\text{F}$ – make the matrix of bone and tooth tissues
- ATP, ADP, AMP, cycloAMP, cycloGMP, etc.

The usage of O_2 , O_3 and H_2O_2 in medicine and pharmacy

- The mixture of gases with 40 – 60% of O_2 is used for artificial breathing in case of hypoxia caused by intoxication by CO , HCN , Cl_2 and $COCl_2$.
- Carbogen contains 95% of O_2 and 5% of CO_2 .
- O_2 – is an obligatory component of mixtures for narcosis
- O_2 – is used in oxygen cocktails
- O_2 – is used in barotherapy

The usage of H_2O_2 in medicine and pharmacy

- H_2O_2 – is a disinfectant
- H_2O_2 – is used for depigmentation of skin
- H_2O_2 – is used for mineralization of organic samples

Biological roles of sulfur: disulfide bonds in proteins

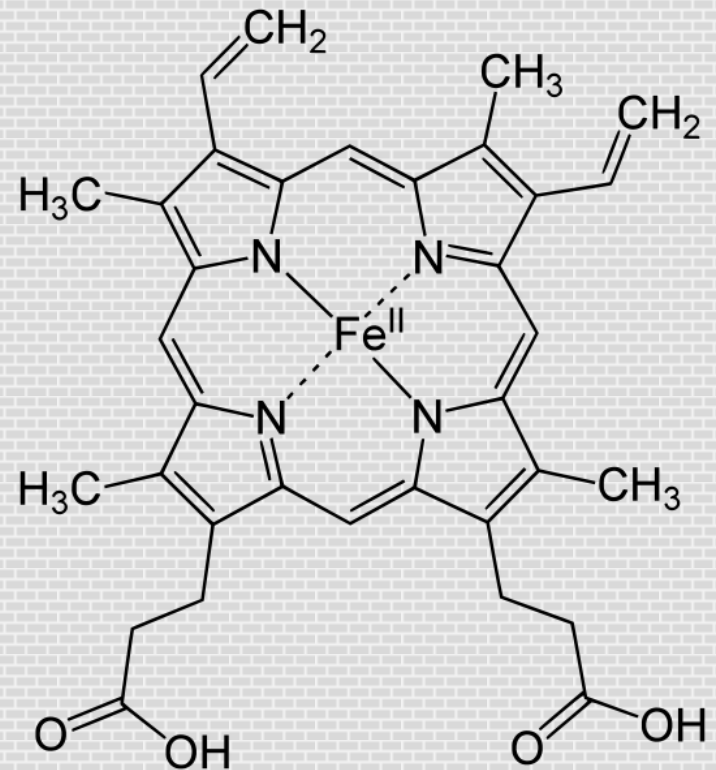
- Sulfur in proteins can be found in:
 - 1) sulfhydryl (-SH) groups can be found in side chains of cysteine residues, they are often involved in catalytic activity
 - 2) disulfide bonds (-S-S-) between two cysteine residues play important roles in the formation of tertiary and quaternary structure of proteins
 - 3) thioether (-S-CH₃) groups can be found in side chains of methionine, they make hydrophobic contacts, as well as sulfur-aromatic interactions

Biological roles of selenium

- Selenium is an atom from the 21st amino acid – selenocysteine
- Posttranslational modification introduces selenium into: glutathione peroxidase; peroxidase; enzymes for deiodination of thyroid hormones
- In general, selenium is an antioxidant
- Selenium deficiency increases the risk of heart diseases development and oncological pathology
- Compounds of selenium can play a role of antidotes in mercury and cadmium poisoning (because of the concurrence for protein binding)
- Selenium and VitE enhance antioxidative activities of each other

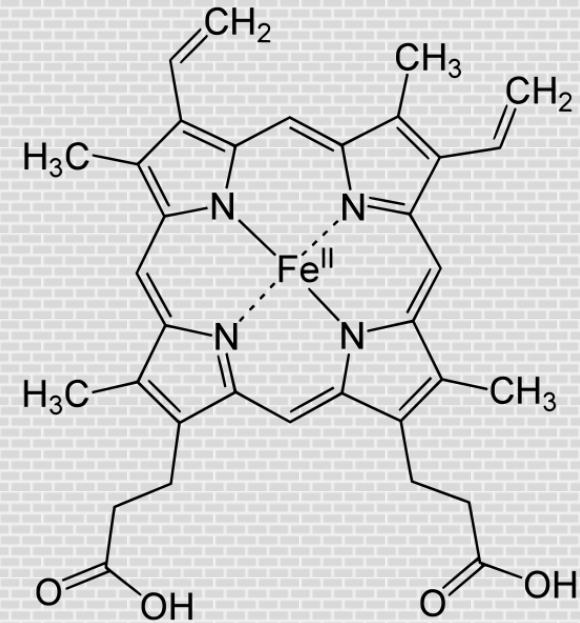
Hemoglobin

- Porphyrin ring is a derivative of tetrapyrrole compound called porphine.
- The classification of porphyrins is based on the nature of side chains.
- Protoporphyrins contain 4 methyl groups, 2 vinyl groups, and 2 residues of propionic acid.
- Protoporphyrin is a part of hemoglobin, myoglobin and the most of cytochromes.



Hemoglobin

- Chelate complex of porphyrin and Fe^{2+} is called heme. A complex with Fe^{3+} is called hemine. If oxygen is bound or removed from hemoglobin, the oxidation state of iron cation stays the same (+2). Different oxidizers can turn Fe^{2+} to Fe^{3+} (methemoglobin that cannot bind oxygen will be formed).



Iron containing enzymes

- Catalase
- Cytochromes
- Lipoxigenases

Toxic effect of cyanides

- Cytochromes are iron containing proteins taking part in the transfer of electrons in mitochondria: from flavoproteins to molecular oxygen. All cytochromes contain porphyrin groups with iron (II) cations. The last cytochrome in a chain that reacts with oxygen is called cytochrome oxidase. Cyanides block the transfer of electrons from cytochrome b to cytochrome c, as well as the last step of the electron transfer. Resulting condition is hypoxia on the level of tissues, heart failure and the stop of breathing.

The usage of redox reactions in medicine and pharmacy (sample)

- Solution of H_2O_2 is used as antiseptic and deodorant
- $2\text{H}_2\text{O}_2 \rightarrow (\text{catalase, peroxidase}) 2\text{H}_2\text{O} + \text{O}_2\uparrow$
- Quality control of H_2O_2 :
- $2\text{I}^- + \text{H}_2\text{O}_2 + 2\text{H}^+ \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$
- Titration of H_2O_2 :
- $2\text{KMnO}_4 + 5\text{H}_2\text{O}_2 + 3\text{H}_2\text{SO}_4 \rightarrow$
 $\rightarrow 2\text{MnSO}_4 + \text{K}_2\text{SO}_4 + 8\text{H}_2\text{O} + 5\text{O}_2\uparrow$

The usage of complexes in medicine and pharmacy (samples)

- Vit B12 – cyanocobalamine – is a complex compound
- Cisplatin and Oxaliplatin – are antitumor drugs
- Complexes are used in quality control:
- $\text{Na}^+ + \text{Zn}^{2+} + [(\text{UO}_2)_3(\text{CH}_3\text{COO})_8]^{2-} + \text{CH}_3\text{COOH} + 9\text{H}_2\text{O} \rightarrow \text{NaZn}[(\text{UO}_2)_3(\text{CH}_3\text{COO})_9] \cdot 9\text{H}_2\text{O} \downarrow + \text{H}^+$
- $2\text{K}^+ + \text{Na}^+ [\text{Co}(\text{NO}_2)_6]^{3-} \rightarrow \text{K}_2\text{Na}[\text{Co}(\text{NO}_2)_6] \downarrow$

The usage of hydrochloric acid, fluorides, bromides, chlorides and iodides in medicine and pharmacy

- Two solutions of hydrochloric acid are used:
- 1 – hydrochloric acid with the mass percentage of 24.8 – 25.2%
- 2 – dilute hydrochloric acid 8.2 – 8.4 %
- Dilute hydrochloric acid is used in case of decreased acidity of gastric juice

The usage of hydrochloric acid, fluorides, bromides, chlorides and iodides in medicine and pharmacy

- NaCl – is as a part of physiological solution (0.85% by mass) for the compensation of blood loss. Its osmolarity is 0.3 mol/L.
- KCl – is an antiarrhythmic drug (it decreases the heart beat rate).

The usage of hydrochloric acid, fluorides, bromides, chlorides and iodides in medicine and pharmacy

- NaBr, KBr – are used for sedation
- NaI, KI – are used for the compensation of iodine deficiency
- NaF – is used in dentistry to prevent caries

Complex nature of metalloenzymes

- Metalloenzymes have at least one metal cation coordinated in their active center
- Cation itself performs certain steps in the mechanism of catalysis
- Cation is coordinated by oxygen, nitrogen and, sometimes, sulfur atoms from side chains of amino acid residues, and, sometimes, also by oxygen and nitrogen from the main chain of proteins

Toxicity of cadmium and mercury

- The mechanism of toxicity of cadmium is associated with the binding of carboxyl, amino, and, especially, sulfhydryl (-SH) groups of proteins. As a result, the activity of enzymes becomes altered.
- Cadmium is deposited in frequently dividing cells like tumor or gonad cells.

Toxicity of mercury

- The mechanism of the toxic effect of mercury includes the binding of carboxylic and amino groups, the binding of sulfhydryl groups, and the replacement of selenium, for example, in thyreoredoxine reductase.

Chlorine water, bleaching powder,
and substances producing active
chlorine

- Inorganic substances and mixtures containing halogen atoms are divided into:
 - Substances and mixtures containing or producing molecular halogens
 - Iodine and its ethanol solutions. 5% iodine solution in ethanol is used in medicine as an antiseptic (in surgery)
 - Such substances as bleaching powder, chloramine and pantocid are slowly releasing molecular chlorine in the presence of HCl.
 - Substances and mixtures containing halide ions (F^- ; Cl^- ; Br^- ; I^-)

- Antiseptic properties of chloramine B and pantocid are based on the formation of hypochloric acid.
- These substances are used for disinfection of hands, instruments and for the treatment of infected wounds.
- Pantocid is used for disinfection of water.

- Bleaching powder is also used for disinfection of cesspools, corpses of infected animals.
- Bleaching powder is used as an oxidizer for the qualitative analysis of phenols

Bactericide activity of chlorine and iodine

- Chlorine forms hypochlorous acid in its reaction with water:
- $\text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HClO} + \text{HCl}$
- In the presence of hydrochloric acid the equilibrium is shifted to the left. Because of this the amount of hypochlorous acid in chlorine water is not very high.

- In the acidic medium hypochlorous acid slowly decomposes:
- $4\text{HClO} \rightarrow 2\text{Cl}_2 + \text{O}_2 + 2\text{H}_2\text{O}$
- In slightly acidic medium under the influence of visible light hypochlorous acid decomposes in a different way:
- $2\text{HClO} \rightarrow \text{O}_2 + 2\text{HCl}$
- In slightly basic medium, especially, at high temperature, hypochlorous acid disproportionates into chlorates and chlorides:
- $2\text{HClO} + \text{ClO}^- \rightarrow \text{ClO}_3^- + 2\text{H}^+ + 2\text{Cl}^-$

Active chlorine

- Active chlorine – is a chlorine that is releasing in the reaction of a given substance with hydrochloric acid. This process is nothing but redox reaction of conproportioning in which chlorine atoms in positive oxidation states (+1; +3; or +5) form molecular chlorine with chloride anions.
- $\text{NaClO} + 2\text{HCl} \rightarrow \text{Cl}_2 + \text{NaCl} + \text{H}_2\text{O}$

- Chlorine water is a disinfectant. That is why it is used for water decontamination.
- Free HClO is about 300 times more active, than hypochloride ions ClO⁻.
- HClO molecule is able to get through membranes of bacteria.

- Iodine is able to kill gram-positive and gram-negative bacteria, fungi, viruses and protozoa. Iodine is an oxidizer. It interacts with amino acids and disturbs the structure of a protein. Iodine oxidizes mostly extracellular enzymes of bacteria and transmembrane proteins, as well as pili (protein complexes used for the attachment to a surface).

The usage of noble gases in medicine

- All noble gases (He, Ne, Ar, Kr, Xe, Rn) demonstrate narcotic effect at high pressure.
- Narcosis can be caused only in case of argon inhalation at high pressure (higher than 0.2 MPa).
- In 1999 xenon was allowed for the usage as a component of gas mixtures for narcosis.
- One of the best mixtures for narcosis includes 80% of xenon and 20% of oxygen.
- At high concentration noble gases cause asphyxia.

The usage of noble gases in medicine

- An artificial air (a mixture of oxygen with noble gases like helium and neon) is used by divers working at high pressure with the aim to avoid nitrogen narcosis.

The usage of noble gases in medicine

- An artificial air with neon and helium helps the patients with bronchial asthma.
- Radioactive isotopes (^{127}Xe , ^{133}Xe , ^{137}Xe , and others) are used as sources of radiation in radiography for diagnostics in medicine.

The usage of radon in medicine

- Radon waters (both natural and artificial) may be used for drinking;
- Radon shower is also used;
- During that procedure patients breathe in aerosol with radon.

The usage of radon in medicine

- On one hand, radon shower was shown to have relaxing and anesthetic effects.
- On the other hand, the effectiveness of radon showers has not been completely approved yet.
- Radon inhalation is one of the factors that may lead to the development of lung cancer.

Thank you for listening!