UNIVERSITY of LIFE SCIENCES in Lublin

FACULTY OF VETERINARY MEDICINE

Department of Biochemistry

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Collegium Veterinarium in Lublin

Teaching aims

Knowledge about functions of macromolecules macroelements and microelements

Most common compounds

Most common elements in living things are carbon, hydrogen, nitrogen, and oxygen. These four elements constitute about 95% of your body weight. All compounds can be classified in two broad categories

-**organic compounds**

-**inorganic compounds**.

„Organic compound, any of a large class of chemical compounds in which one or more atoms of carbon are covalently linked to atoms of other elements, most commonly hydrogen, oxygen, or nitrogen. The few carbon-containing compounds not classified as organic include carbides, carbonates, and cyanides. ” *Encyclopædia Britannica*

Each small organic molecule can be a unit of a large organic molecule called a **macromolecule.** There are **few classes of macromolecules** i.e. (proteins, nucleic acids, lipids and carbohydrates)**.**

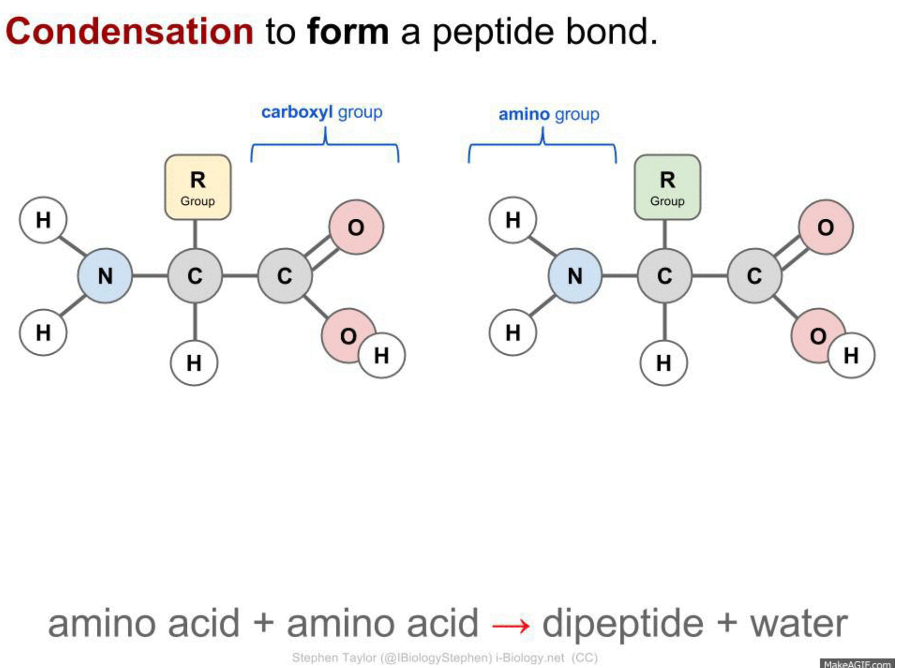
Proteins are made of carbon, hydrogen, oxygen, and nitrogen **(CHON, S , P).**

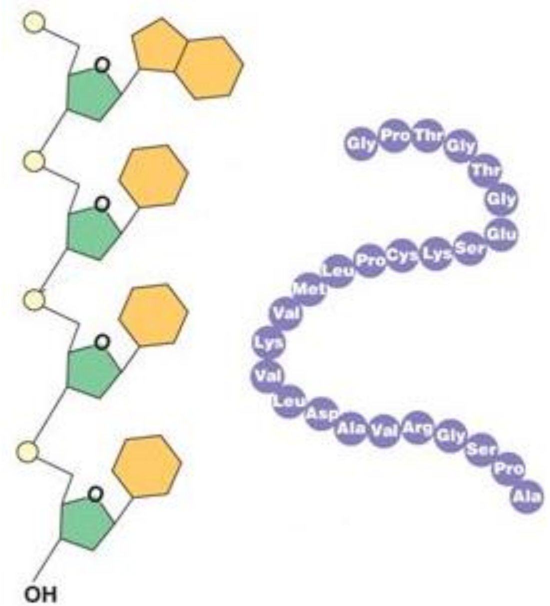
Nucleic acids such as DNA and RNA contain carbon, hydrogen, oxygen, nitrogen, and phosphorus **(CHON P).**

Carbohydrates and lipids are made of only carbon, hydrogen, and oxygen **(CHO**).

Nutrients
Essential Nutrients for organisms

Proteins, amino acids and nucleic acids

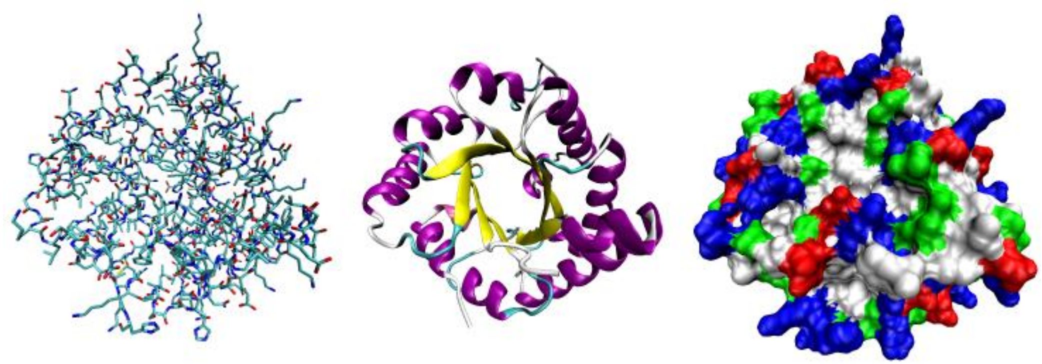




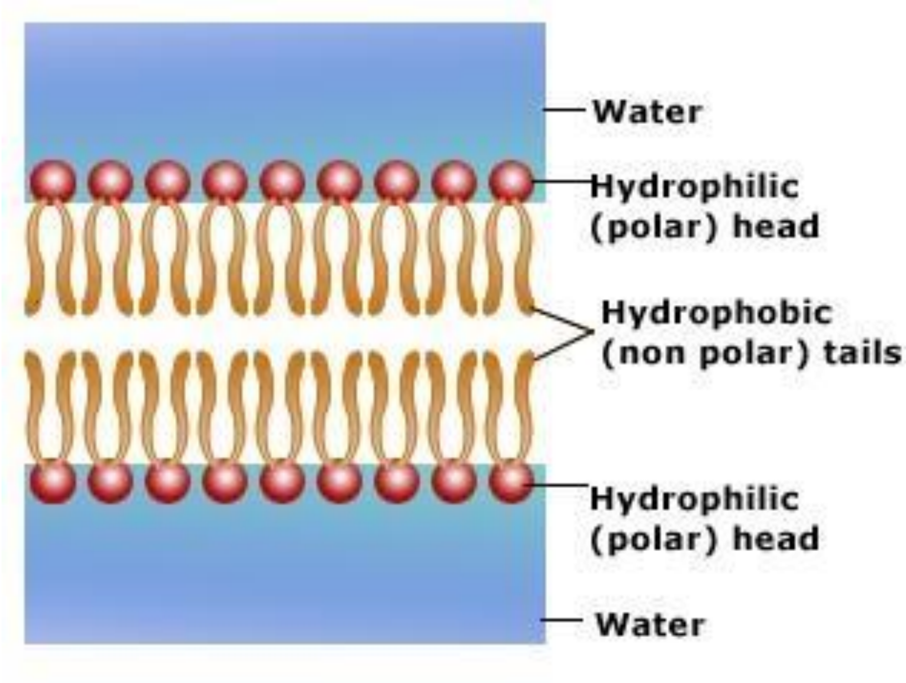
Proteins –general function

The function of proteins may be summarised as follows:

- To repair damaged or wasted tissue (tissue repair and maintenance) and to rebuild new tissue (as new protein and growth).
- Protein may be catabolized as a source of energy, or may serve as a substrate for the formation of tissue carbohydrates or lipids.
- Dietary protein are required within the animal body for the formation of hormones, enzymes and a wide variety of other biologically important substances such as antibodies or hemoglobin



Lipids

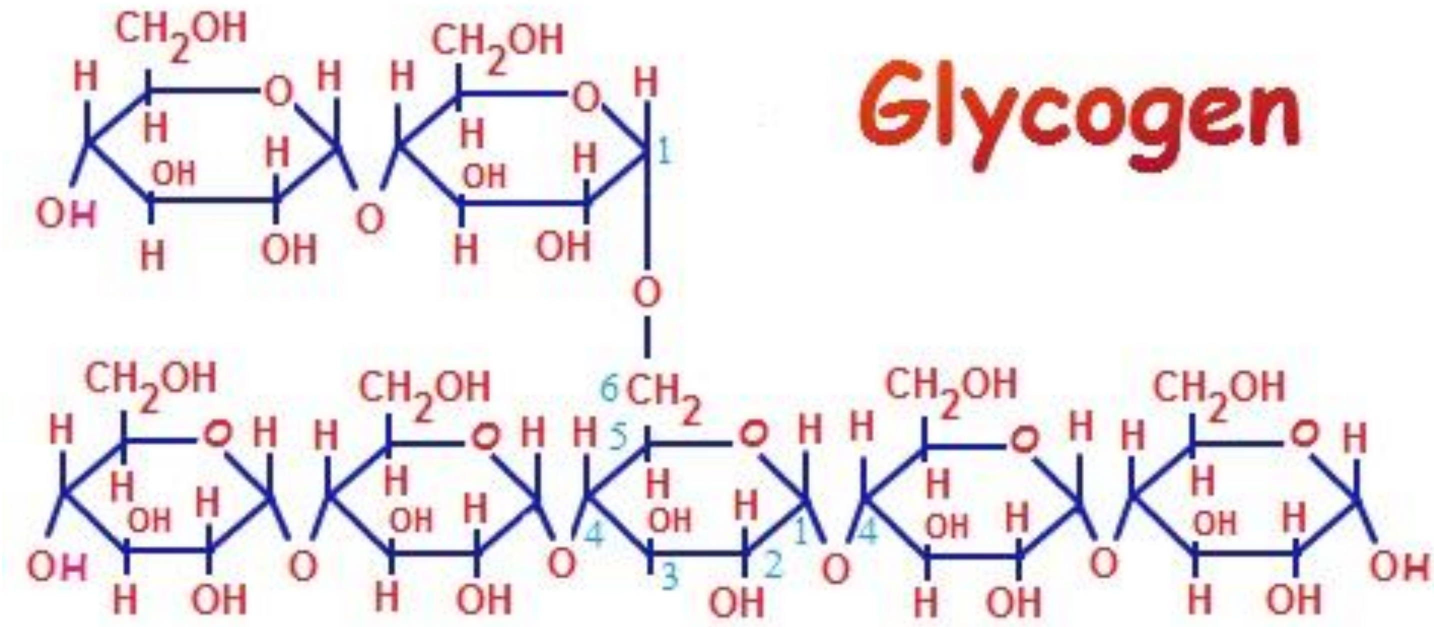

Water
Hydrophilic
(polar) head
Hydrophobic
(non polar) tails
Hydrophilic
(polar) head
Water

Lipids – general function

The function of lipids may be summarised as follows:

- Lipids are important sources of metabolic energy (ATP). In fact, the lipids are the most energy rich of all classes of nutrients: energy value of
  - Lipid 9.5 kcal/g
  - Protein 5.6 kcal/g
  - Carbohydrate4.1 kcal/g
- Lipids serve as biological carriers for the absorption of the fat soluble vitamins A, D, E and K
- Lipids are a source of essential fatty acids, which in turn are essential for the maintenance and integrity of cellular membranes
- Lipids are the source of essential steroids, which in turn are the substrates for a wide range of biologically important molecules

Carbohydrates



Carbohydrates – general function

The function of carbohydrates may be summarised as follows:

- Carbohydrates are the most important source of energy
- Participate in structure of DNA and RNA
- Bound to proteins may serve as biologically active molecules such as receptors, hormones or structural elements of connective tissue

Vitamins – general function

- Vitamins allow your body to grow and develop. They also play important roles in bodily functions such as metabolism, immunity and digestion.
- Fat-soluble vitamins (A, D, E, K) are stored in the body's cells and are not excreted as easily as water-soluble vitamins.

Minerals – general function

The function of minerals may be summarised as follows:

- Minerals are essential constituents of skeletal structures, bones
- Minerals play a key role in the maintenance of osmotic pressure, and regulate the exchange of water and solutes within the animal body.
- Minerals are essential for the transmission of nerve impulses and muscle contraction.
- Minerals play a vital role in the acid-base equilibrium of the body, and regulate the pH of the blood and other body fluids.
- Minerals serve as essential components of many enzymes, vitamins, hormones.

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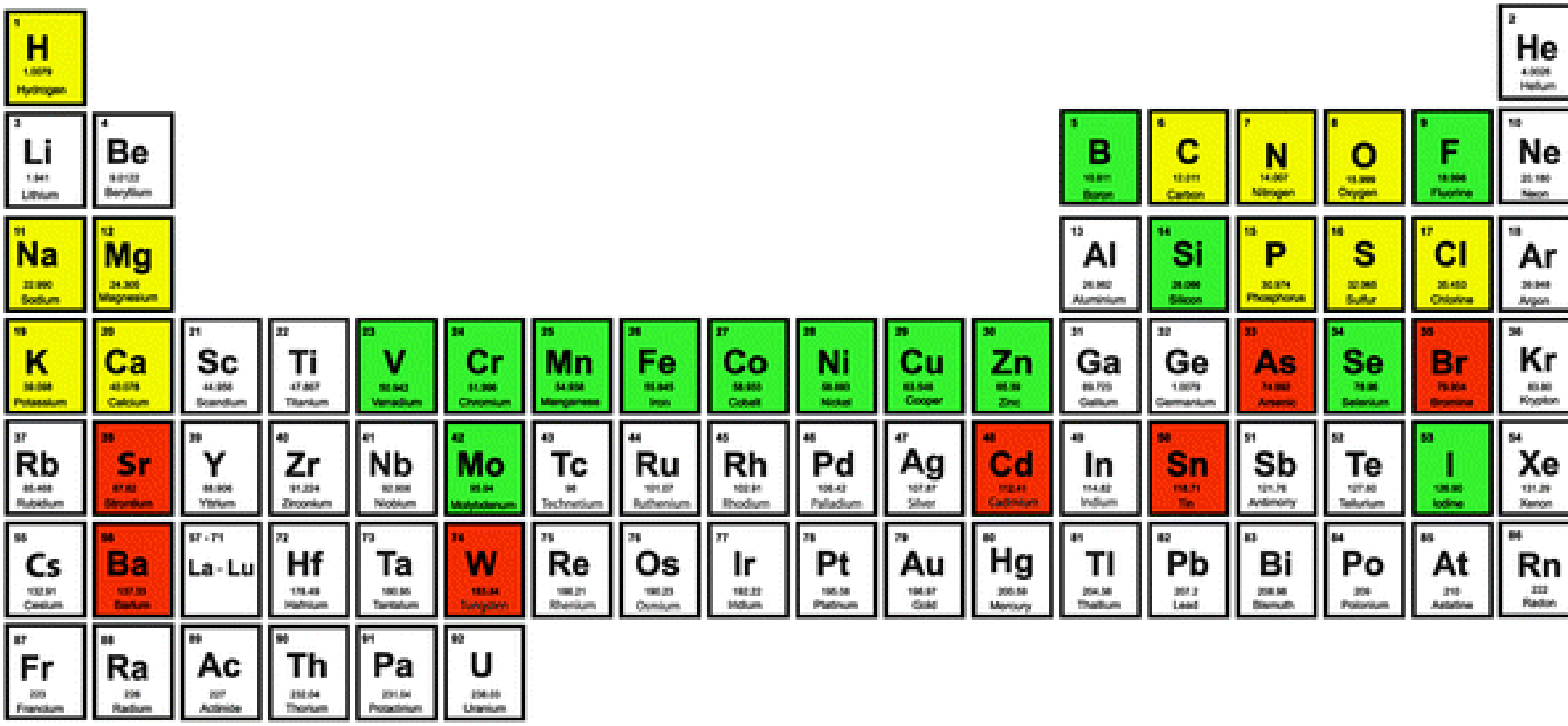


Bulk biological elements

Trace elements believed to be essential for bacteria, plants or animals

Possibly essential trace elements for some species

Because of the content of particular elements in a given material, we divide it into two groups:

-Macroelements - from 0.1% dry matter

-Microelements - occurring in smaller quantities than one part per thousand (10^{-3})

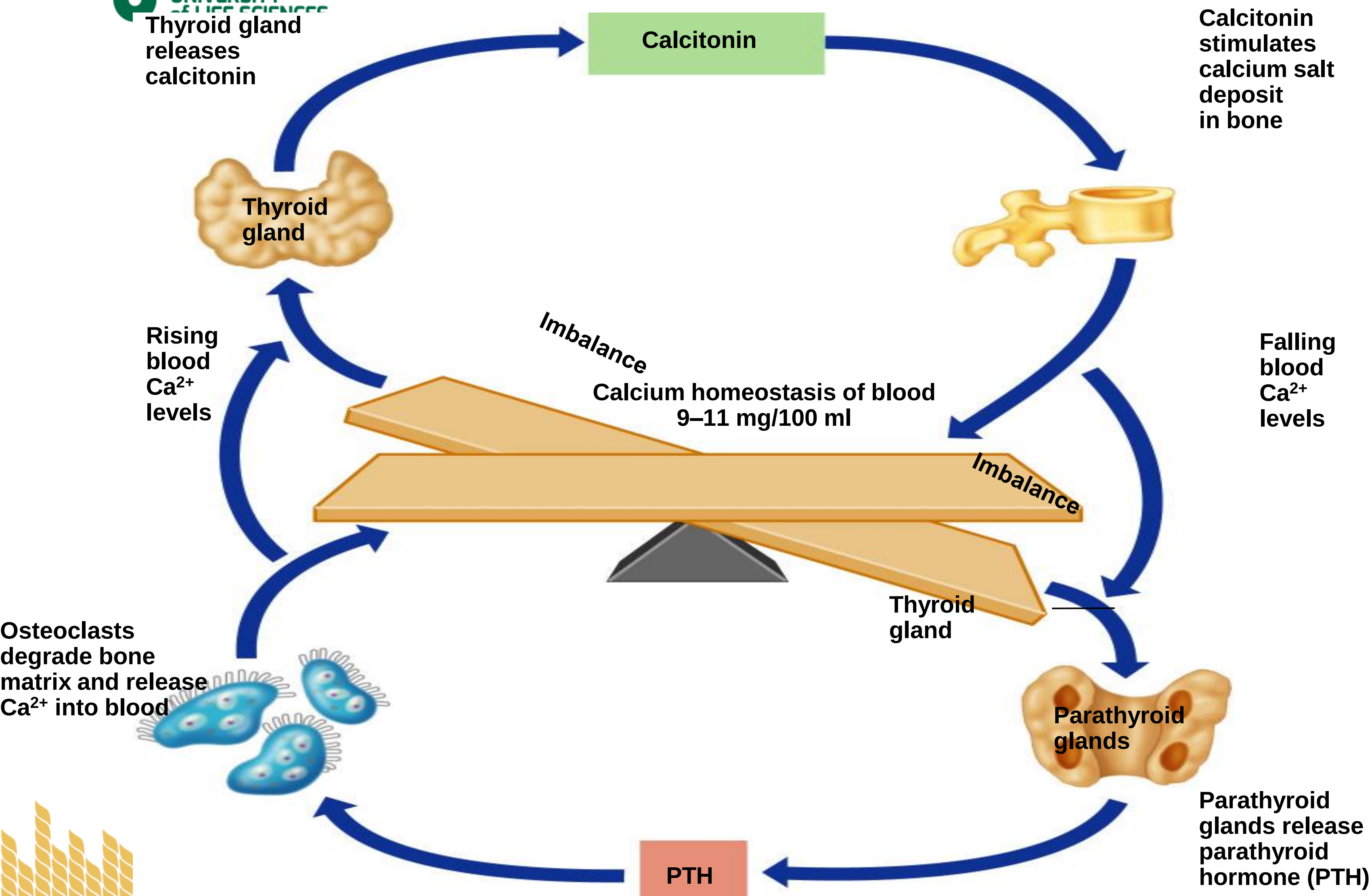
1,000 ppm

Macroelements		Microelements	
Cations	Anions		
Calcium (Ca) Magnesium (Mg) Sodium (Na) Potassium (K)	Phosphorus (P) Chlorine (Cl) Sulphur (S)	Iron (Fe) Zinc (Zn) Manganese (Mn) Copper (Cu) Iodine (I) Cobalt (Co) Nickel (Ni)	Fluorine (F) Vanadium (V) Chromium (Cr) Molybdenum (Mo) Selenium (Se) Tin (Sn) Silicon (Si)

Macroelements	
Cations	Anions
Calcium (Ca) Magnesium (Mg) Sodium (Na) Potassium (K)	Phosphorus (P) Chlorine (Cl) Sulphur (S)

Calcium (Ca)

- Calcium is an essential component of bone and cartilage
- Calcium is essential for the normal clotting of blood, by stimulating the release of thromboplastin from the blood platelets
- Calcium is an activator for several key enzymes, including pancreatic lipase, acid phosphatase, cholinesterase and succinic dehydrogenase
- Calcium stimulates muscle contraction (ie. promotes muscle tone and normal heart beat)
- Calcium, in conjunction with lipids, plays a key role in the regulation of the permeability of cell membranes
- Calcium occurs in the form of calcium phosphate carbonates in bones
- The ionic form Ca^{2+} is present in extracellular fluids

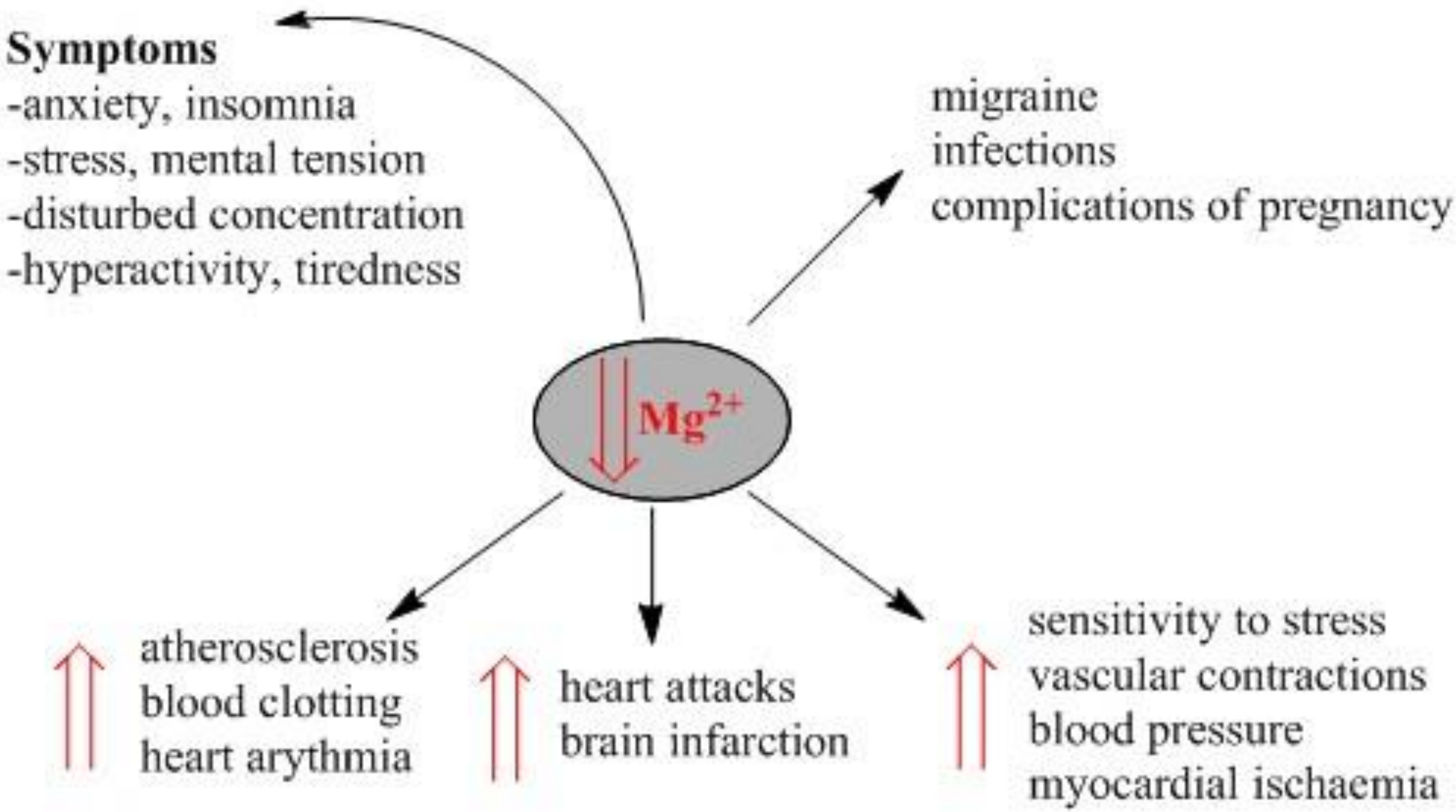


Thyroid gland releases calcitonin
Calcitonin
Calcitonin stimulates calcium salt deposit in bone
Thyroid gland
Rising blood Ca^{2+} levels
Imbalance
Calcium homeostasis of blood 9–11 mg/100 ml
Imbalance
Falling blood Ca^{2+} levels
Thyroid gland
Osteoclasts degrade bone matrix and release Ca^{2+} into blood
Parathyroid glands
Parathyroid glands release parathyroid hormone (PTH)
PTH

Magnesium (Mg)

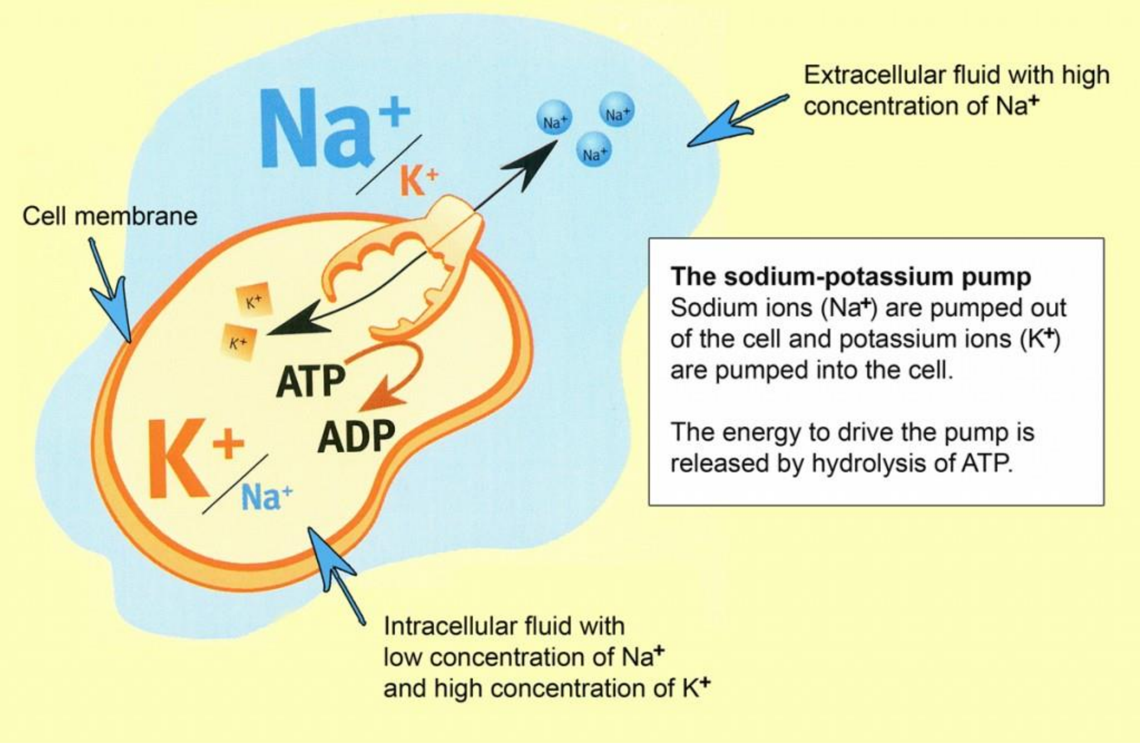
- Magnesium is an essential component of bone and cartilage
- Magnesium is an activator of several key enzyme systems
- Magnesium (like calcium) stimulates muscle and nerve irritability (contraction), is involved in the regulation of intracellular acid-base balance, and plays an important role in carbohydrate, protein and lipid metabolism.
- Magnesium occurs in the form of magnesium phosphate carbonates in bones
- The ionic form Mg^{2+} is present in intracellular fluids

Clinical magnesium deficiency

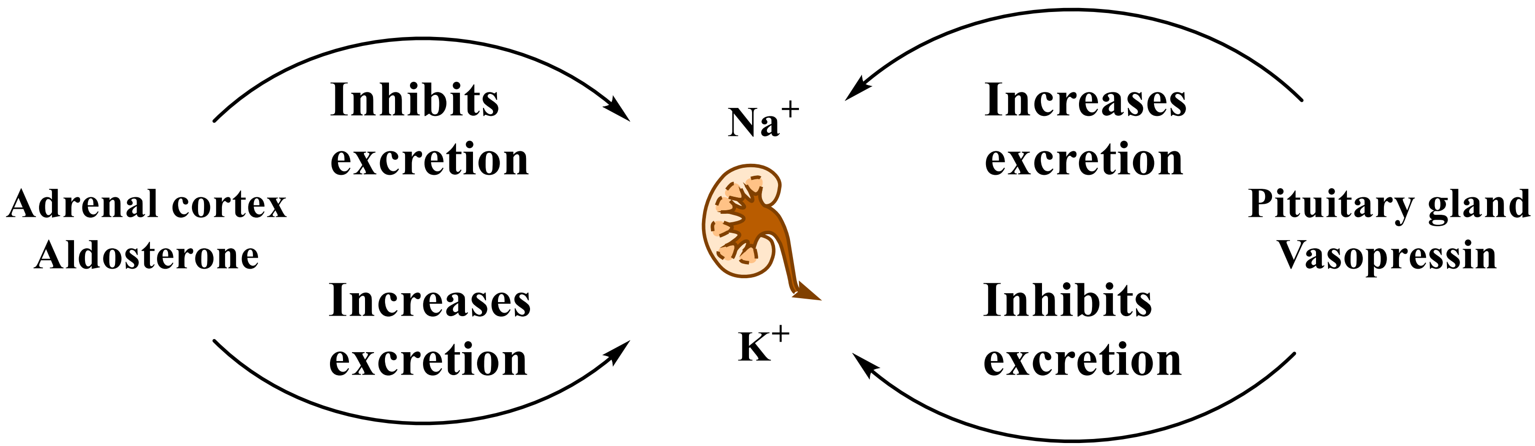


Sodium, Potasium and Chlorine

- Sodium, potassium, and chlorine occur almost entirely in the fluids and soft tissues of the body, sodium and chlorine being found mainly in the body fluids, and potassium occuring mainly in the cells. They serve a vital function in controlling osmotic pressures and acid-base equilibrium. They also play important roles in water metabolism.



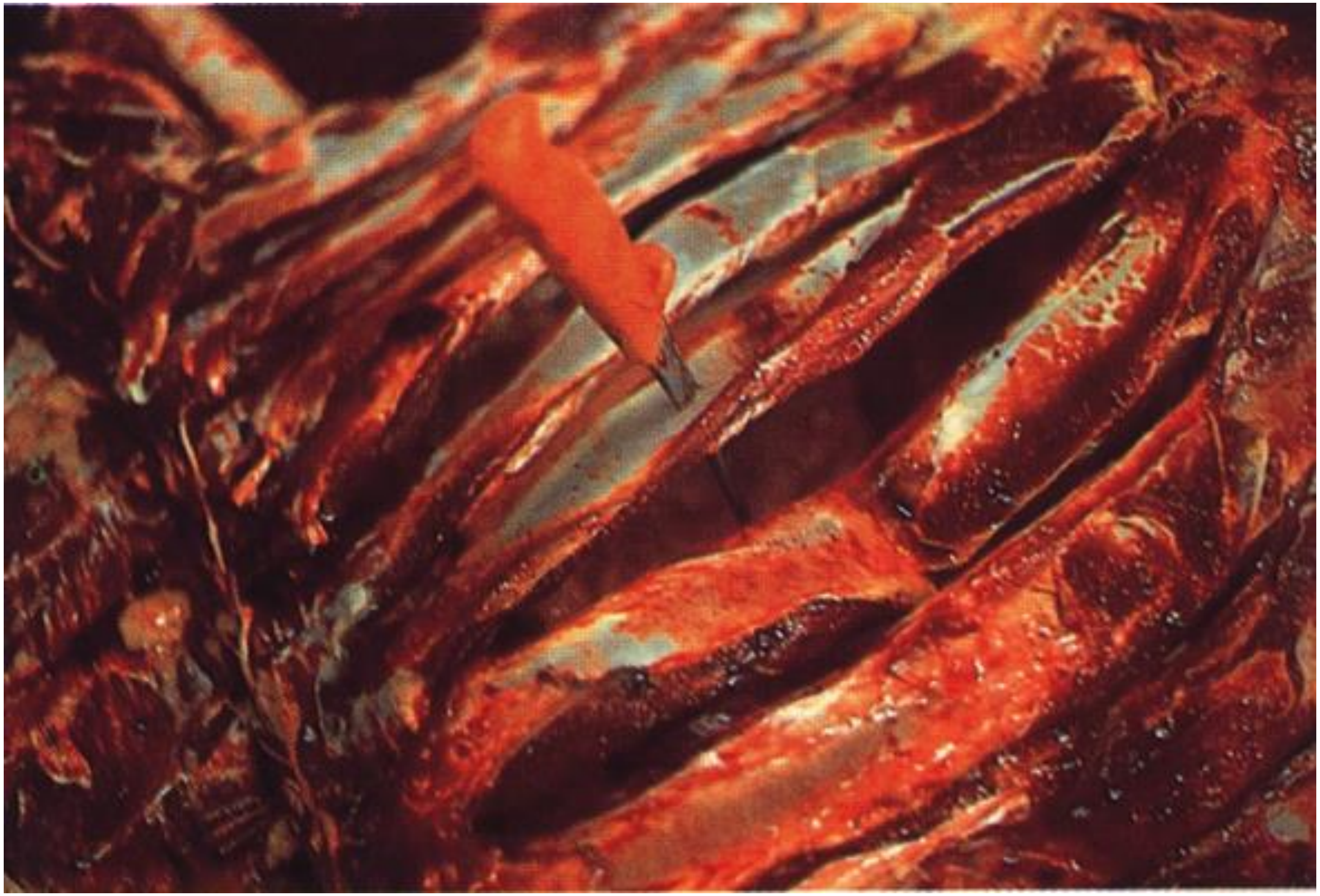
Hormonal regulation of Na^+, K^+



Phosphorus

- Phosphorus is an essential component of bone and teeth
- Phosphorus is an essential component of phospholipids, nucleic acids, phosphoproteins (casein), high energy phosphate esters (ATP), hexose phosphates, and several key enzymes.
- As a component of these important biological substances, phosphorus plays a central role in energy and cell metabolism.
- Inorganic phosphates serve as important buffers to regulate the normal acidbase balance (ie. pH) of animal body fluids.

Phosphorus



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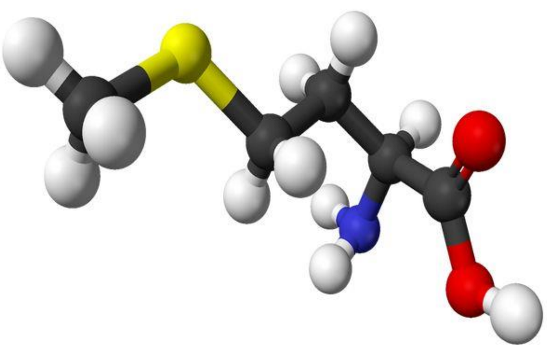
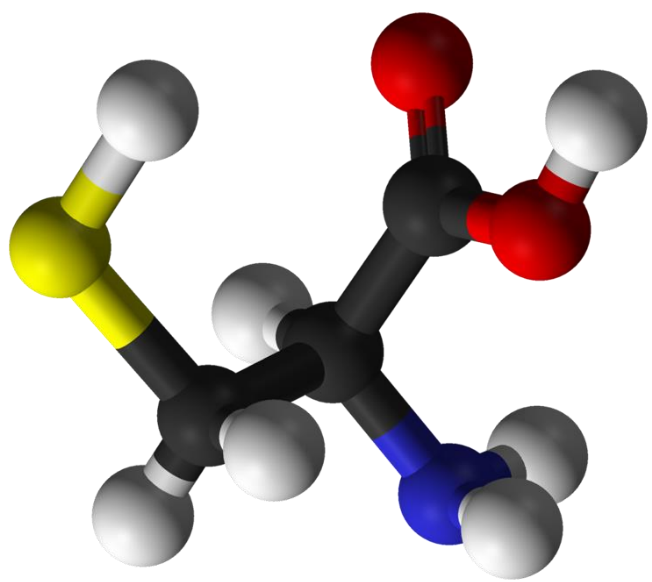
Sulphur

The principal biological functions of sulphur may be summarised as follows;

- Sulphur is an essential component of several key amino acids (methionine and cystine), vitamins (thiamine and biotin), the hormone insulin
- Several key enzyme systems such as coenzyme A and glutathione depend for their activity on free sulphydryl (SH) groups





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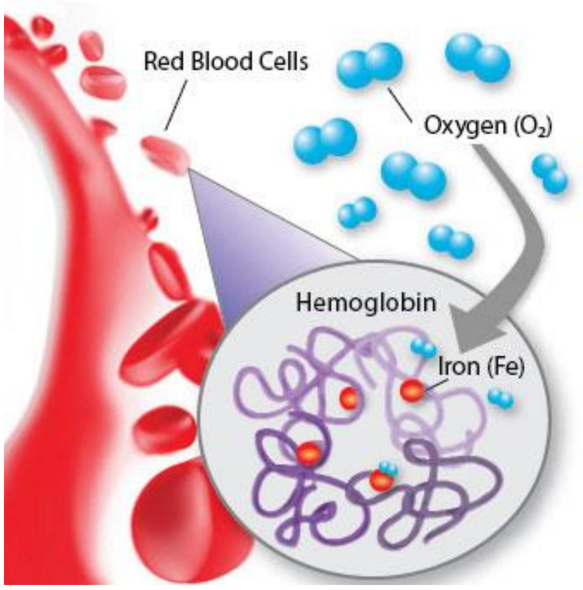
Microelements	
Iron (Fe) Zinc (Zn) Manganese (Mn) Copper (Cu) Iodine (I) Cobalt (Co) Nickel (Ni)	Fluorine (F) Vanadium (V) Chromium (Cr) Molybdenum (Mo) Selenium (Se) Tin (Sn) Silicon (Si)

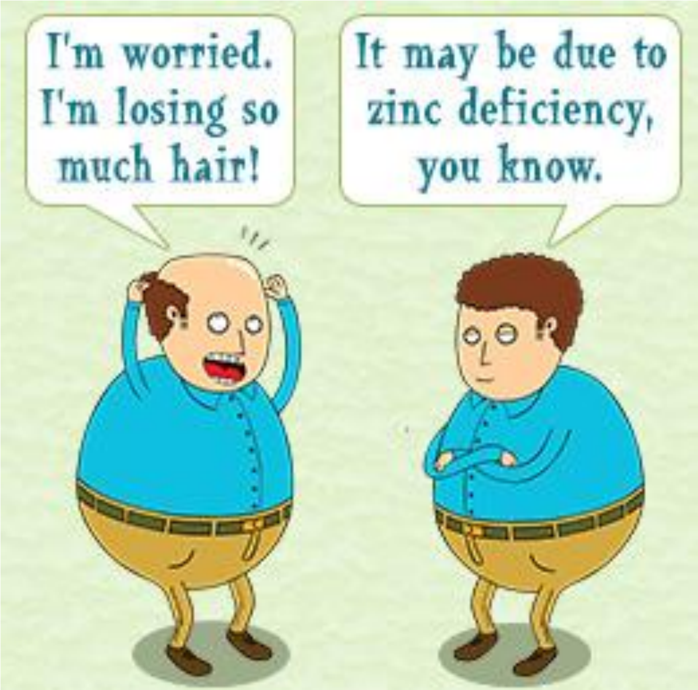
Iron

- Iron is an essential component of the respiratory pigments hemoglobin and myoglobin.
- Iron is an essential component of various enzyme systems
- As a component of the respiratory pigments and enzymes concerned in tissue oxidation, iron is essential for oxygen and electron transport within the body.
- More than half of this element is in hemoglobin
- Some iron is stored in the liver, spleen, kidney, serum or marrow in the form of ferritin (iron protein complex)



Zinc

- Zinc participates in the synthesis and degradation of carbohydrates, lipids, proteins and nucleic acids
- Boost immunity (especially against lower respiratory tract infection)
- It plays a role in cell division, cell growth, wound healing
- Zinc helps the cells in your body to communicate by functioning as a neurotransmiter
- Zinc is an essential component of more than 80 metalloenzymes
- Zinc is present inside the cell



Manganese

- component of the antioxidant enzyme superoxide dismutase (SOD), which helps scavage free radicals
- activator and a constituent of many enzymes

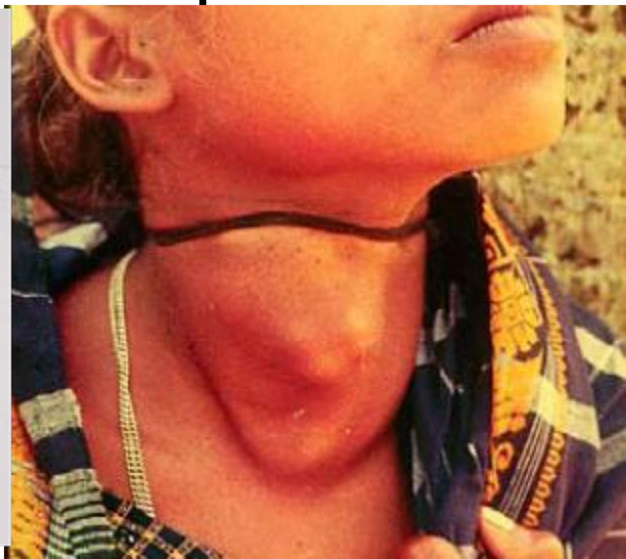
Copper

Copper has an important role in a number of functions, including the:

- production of red blood cells
- regulation of heart rate and blood pressure
- absorption of iron
- prevention of prostatitis, or inflammation of the prostate
- activation of the immune system

Iodine

- Iodine is an essential constituent of the thyroid hormones
- Iodine plays an important role in development of the central nervous system
- Alcohol solution of iodine have antiseptic properities



Cobalt

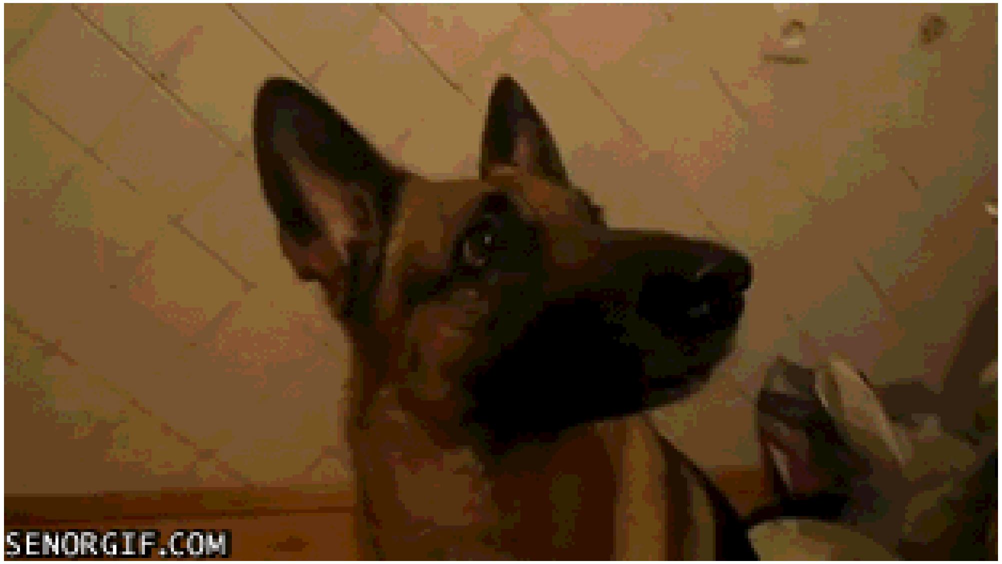
- Essential in the structure of vitamin B12.
- essential for red blood cell formation and the maintenance of nerve tissue

Nickel

- Nickel is component in specific metalloenzymes or metalloproteins
- It improves the absorption of iron by which to prevent anemia
- Improving bone health.

Fluorine

- fluoride strengthens the enamel thus increasing the resist of teeth to acids produced by bacteria decay



Vanadium

Vanadium complexes:

- cofactors for several enzymes
- they are involved in the regulation of glucose metabolism
- normalize blood pressure and play a key role in the metabolism of iron as well as in the regulation of total cholesterol

Selenium

- Selenium in combination with vitamin E acts as an antioxidant, which protects cells, cell membranes and DNA from damage by free radicals.
- Stimulates immunity and thyroid activity
- It also supports fertility

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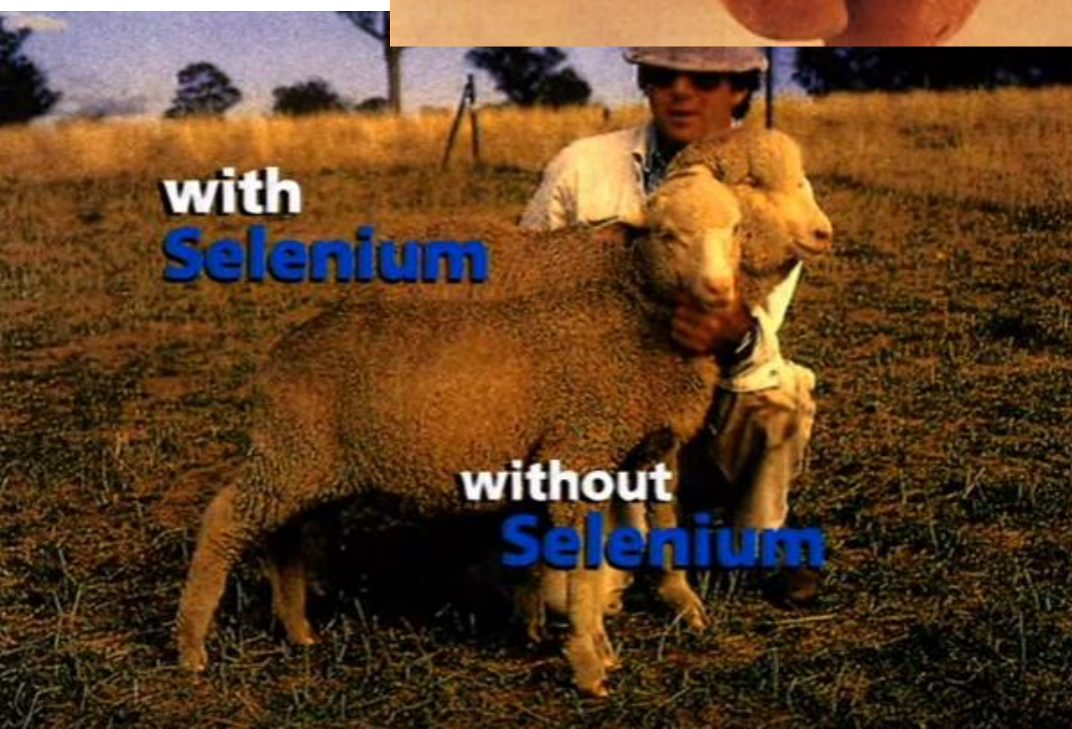
Selenium

in excess



Task 1

The aim of the task is to detect Ca^{2+} (calcium) ions

Execution

a. Test with $C_2O_4^{2-}$ (oxalate) ions

Add about 0.5 cm^3 of 0.2 mol/dm^3 ammonium oxalate ($NH_4C_2O_4$) to 0.5 cm^3 of Ca^{2+} solution.

Reaction:

$$Ca^{2+} + C_2O_4^{2-} \Rightarrow \downarrow CaC_2O_4$$

The resulting CaC_2O_4 precipitate is white, crystalline. If you add several drops of ammonia to a test tube, in which the reaction has occurred, the amount of precipitate is greater. Calcium oxalate is soluble in mineral (inorganic) acids, and insoluble in acetic acid.

b. Test with SO_4^{2-} (sulphate) ions

Add several drops of concentrated H_2SO_4 (sulphuric acid) to 0.5 cm^3 of Ca^{2+} solution.

Reaction:

$$Ca^{2+} + SO_4^{2-} \Rightarrow \downarrow CaSO_4$$

Reaction with sulphuric acid results in the precipitation of white $CaSO_4$ (copper sulphate).

Task 2

The aim of the task is to detect NH_4^+ (ammonium) ions

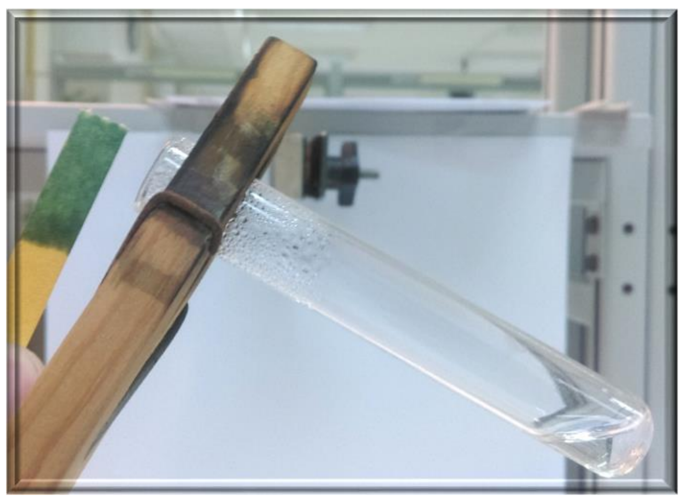
Execution

Add about 0.5 cm^3 of 2mol/dm^3NaOHto 0.5 cm^3 of NH_4^+ solution, and heat the contents of the test tube over a burner.

Reaction:

$$NH_4^+ + 2NaOH \Rightarrow \uparrow NH_3 + 2Na^+ + H_2O$$

Observe the change of litmus paper colour and the characteristic odour of escaping ammonia at the mouth of the test tube.



Task 3

The aim of the task is to detect Cu^{2+} (copper) ions

Execution

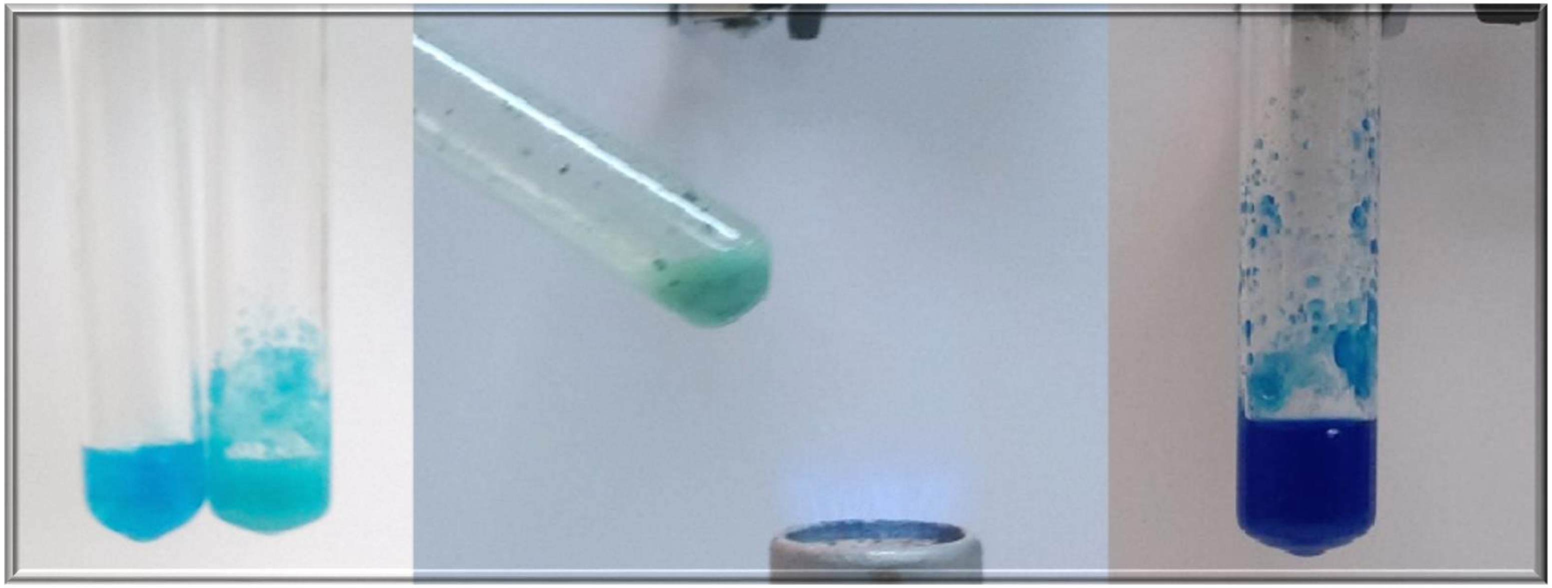
Take two test tubes, pour into each 0.5 cm^3 of Cu^{2+} solution, and then add 0.5 cm^3 of 2 mol/dm^3 NaOH. After the precipitation of $Cu(OH)_2$, heat one test tube over a burner, and add 0.5 cm^3 of concentrated $NH_3 \cdot H_2O$ to the other test tube.

Reactions:

$$Cu^{2+} + 2\ OH^- \Rightarrow \downarrow Cu(OH)_2$$

$$Cu(OH)_2 gel \Rightarrow \downarrow CuO + H_2O$$

$$Cu(OH)_2 + 4NH_3 \Rightarrow [Cu(NH_3)_4]^{2+} + 2OH^-$$



Task 4

The aim of the task is to detect Fe^{3+} (iron) ions

Execution

a. Test with potassium thiocyanate

Add 0.5 cm^3 of 1 mol/dm^3 KSCN (potassium thiocyanate) to 0.5 cm^3 of Fe^{3+} solution.

Reaction:

$$Fe^{3+} + 3\ SCN^{-} \Rightarrow Fe(SCN)_3$$

Observe the change of solution colour. Fe^{2+} ions do not give this reaction.

b. Test with sodium hydroxide

Add 0.5 cm^3 of 2mol/dm^3 NaOH to 0.5 cm^3 of Fe^{3+} solution.

Reaction:

$$Fe^{3+} + 3\ OH^{-} \Rightarrow \downarrow Fe(OH)_3$$

Observe the formation of red-brown $Fe(OH)_3$ precipitate, which is insoluble in an excess of the reagent.

Task 5

The aim of the task is to detect Ag^+ (silver) ions

Execution

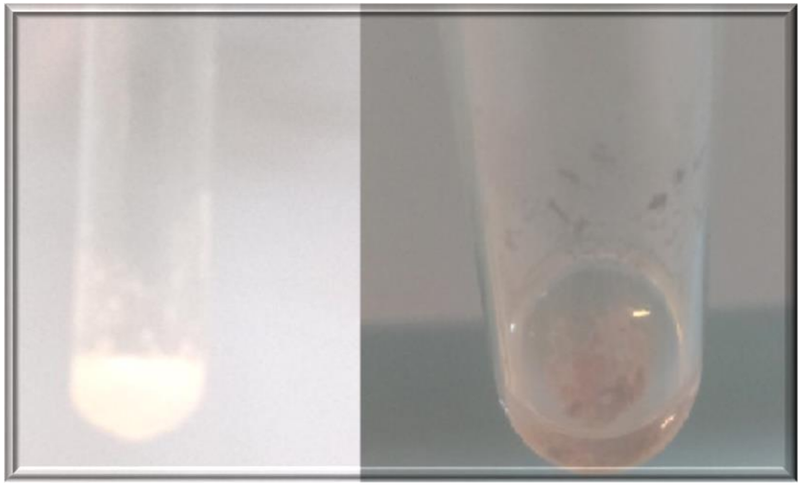
a. Test with Cl^- (chlorine) ions

Take two test tubes, pour into each 0.5 cm^3 of Ag^+ solution, and then several drops of concentrated HCl (hydrochloric acid). One test tube expose to sunlight and after some time observe photochemical reaction occurring in the test tube. Carefully heat the other test tube and observe the precipitate. Cool the test tube, then add drop by drop 2 mol/dm^3 $NH_3 \cdot H_2O$ until the formation of soluble silver diamine chloride ($[Ag(NH_3)_2]Cl$),and next add drop by drop concentrated HNO_3 until the reappearance of AgCl precipitate.

Ag^+ ions, occurring in neutral or acid solutions, react with Cl^- ions forming white, cheese-likeprecipitate of silver chloride (AgCl), which decomposes when exposed to light and darkens due to the precipitation of colloidal silver.

$$Ag^+ + Cl^- \Rightarrow \downarrow AgCl$$

$$2\downarrow AgCl \Rightarrow 2\downarrow Ag + \uparrow Cl_2$$

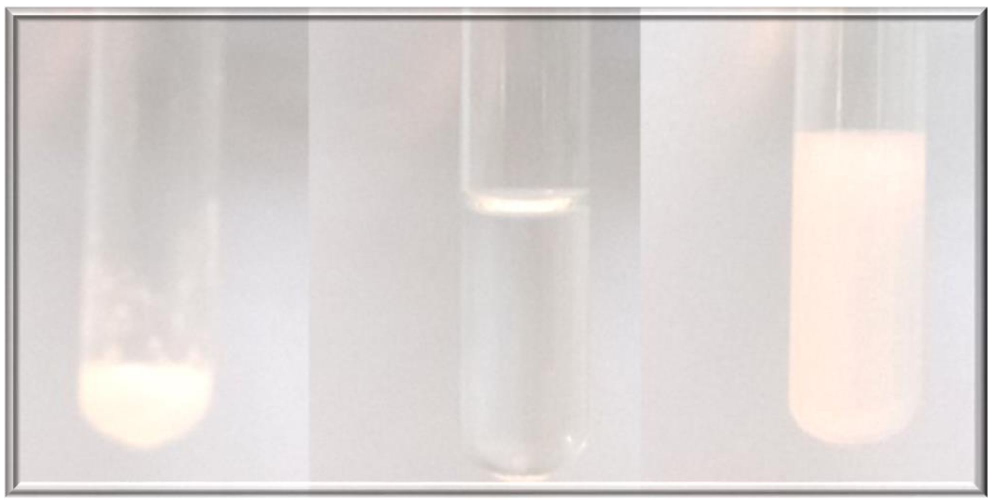


AgCl precipitate is insoluble in both cold and hot pure water but in the presence of ammonium ions it forms soluble, colourless, complex ion $[Ag(NH_3)_2]^+$.

$$2\downarrow AgCl \Rightarrow 2\downarrow Ag + \uparrow Cl_2$$

$$\downarrow AgCl + 2NH_3 \cdot H_2O \Rightarrow [Ag(NH_3)_2]Cl + 2H_2O$$

The addition of nitric acid causes the reprecipitation of AgCl.

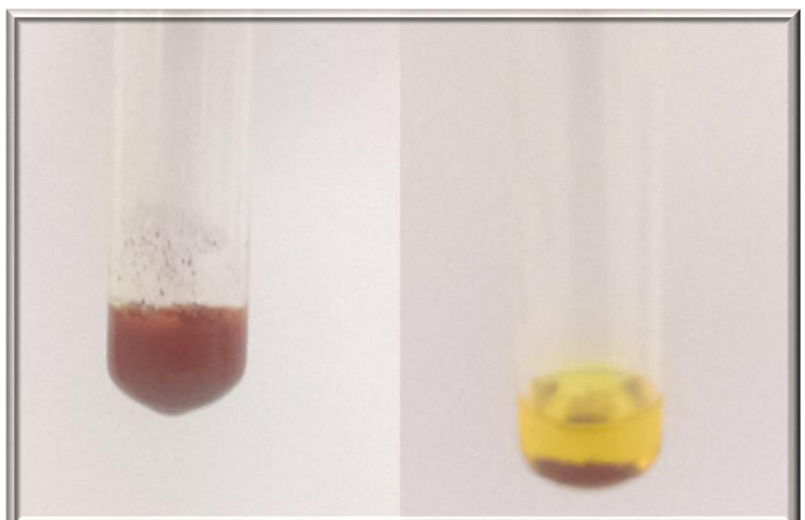


b. Test with CrO_4^{2-} (chromate) ions

Add 0.5 $cm^3$of 0.1 mol/dm^3 K_2CrO_4 to 0.5 cm^3 of Ag^+ solution.After the precipitation of Ag_2CrO_4,add several drops of concentrated nitric acid to the test tube. Observe the course of reaction.

$$2Ag^+ + CrO_4^{2-} \Rightarrow 2 \downarrow Ag_2CrO_4$$

Potassium chromate(K_2CrO_4)causes the precipitation ofred-brown silver chromate (Ag_2CrO_4)from the solutionscontaining Ag^+ ions. This reactionhas found practical application in the quantitative determination of silver in jewellery because the intensity of colour of formed Ag_2CrO_4depends on the amount of silver in the alloy, from which jewellery has been made.



Task 6

The aim of the task is to detect Pb^{2+} (lead) ions

Execution

a. Test with Cl^- (chlorine) ions

Add several drops of concentrated HCl to 0.5 cm^3 of Pb^{2+}solution.

Reaction:

$$Pb^{2+} + 2\ Cl^- \Rightarrow \downarrow PbCl_2$$

The precipitate of lead chloride (II) is formed. Add 2 cm^3 of distilled water to the test tube and heat until the precipitate is dissolved. After cooling, observe the formed crystals.

Cl^- ions, added to the solutions containing Pb^{2+} ions, cause the precipitation of white, crystalline lead chloride (II), which quickly settle on the test tube bottom.

This precipitate dissolves after heating in the test tube, and after cooling it reprecipitates in the form of needle-like crystals.

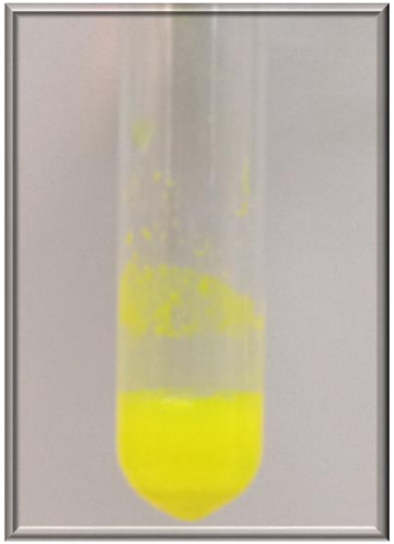
Test with heating silver and lead chlorides is important because it is used to easily distinguish AgCl from $PbCl_2$ (AgCl is insoluble in hot water).

b. Test with chromate

Add 0.5 $cm^3$of 0.1 mol/dm^3 K_2CrO_4 to 0.5 cm^3 of Pb^{2+} solution. After a few minutes, examine the formed precipitate.

$$Pb^{2+} + CrO_4^{2-} \Rightarrow \downarrow PbCrO_4$$

Potassium chromates($K_2CrO_4$and $K_2Cr_2O_7$), added to the solutions containingPb^{2+} ions, causes the precipitation of yellow lead chromates (II).



Task 7

The aim of the task is to detect Ba^{2+} (barium) ions

Execution

a. Test with SO_4^{2-} (sulphate) ions

Add 0.5 cm^3 of 0.1 mol/dm^3 H_2SO_4 to 0.5 cm^3 of Ba^{2+} solution. Reaction:

$$Ba^{2+} + SO_4^{2-} \Rightarrow \downarrow BaSO_4$$

Sulphuric acid (VI) causes the precipitation of white $BaSO_4$, which is insoluble in water.

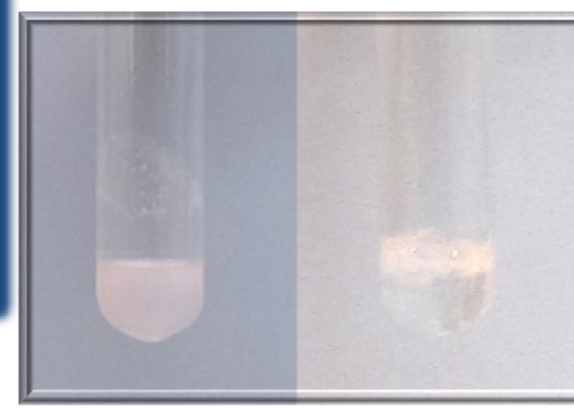
b. Test with CO_3^{2-} (carbonate) ions

Add 0.5 cm^3 of 0.2 mol/dm^3 Na_2CO_3 to0.5 cm^3 of Ba^{2+} solution. After the precipitation of $BaCO_3$, add 1 cm^3 of concentrated CH_3COOH.

Reactions:

$$Ba^{2+} + CO_3^{2-} \Rightarrow \downarrow BaCO_3$$

$$BaCO_3 + 2\ CH_3COOH \Rightarrow Ba(CH_3COO)_2 + CO_2 + H_2O$$



Carbonate ions, added to the solutions containing Ba^{2+} ions, cause the precipitation of white barium carbonate (II), which is easily soluble in acetic acid. If the precipitate is not dissolved, you can add 1 cm^3 of CH_3COOH more.

Task 8

The aim of the task is to detect Cl^- (chloride) ions

Execution

a. Test with Ag^+ (silver) ions

Add drop by drop about 0.5 cm^3 of 0.1 mol/dm^3 $AgNO_3$ to 0.5 cm^3 of Cl^- solution. Dissolve the resulting precipitate adding 2 mol/dm^3 $NH_3{\cdot}H_2O$ drop by drop. Then add several drops of concentrated HNO_3 in order to cause the reprecipitation of AgCl.

Reactions:

$$Ag^+ + Cl^- \Rightarrow \downarrow AgCl$$

$$AgCl + 2NH_3{\cdot}H_2O \Rightarrow [Ag(NH_3)_2]Cl + 2H_2O$$

$$[Ag(NH_3)_2]Cl + 2\ H_3O^+ + 2NO_3^- \Rightarrow \downarrow AgCl + 2NH_4NO_3$$

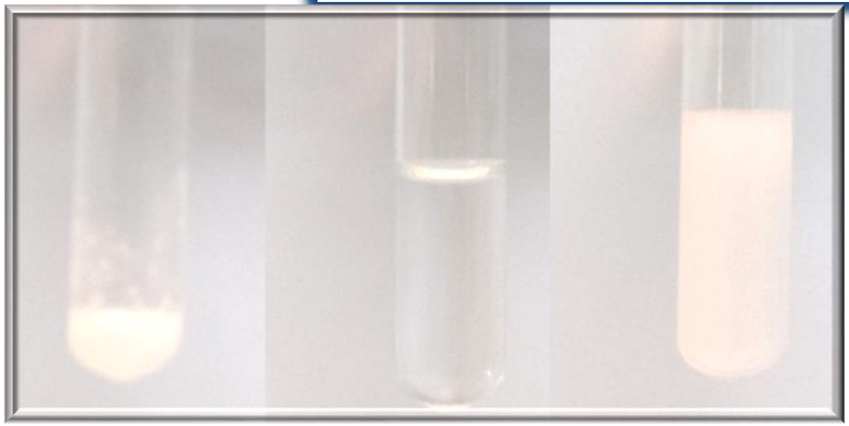
b. Test with potassium premanganate

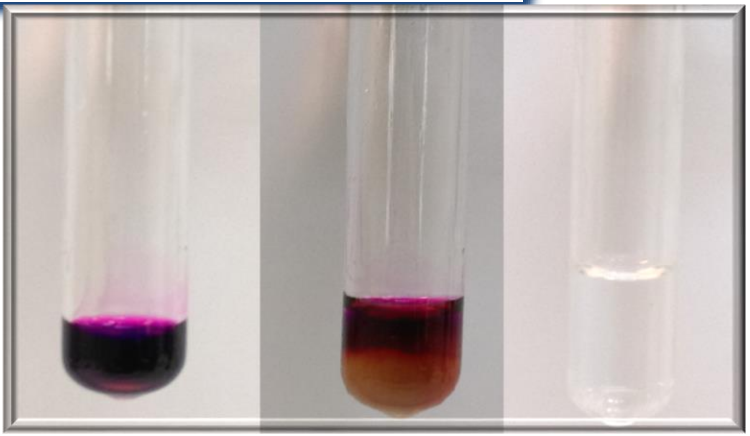
Add 0.5 cm^3 of 0.1 mol/dm^3 $KMnO_4$ and several drops of concentrated H_2SO_4 to 0.5 cm^3 of Cl^- solution.

Reaction:

$$10Cl^- + 2MnO_4^- + 16H^+ \Rightarrow 5Cl_2 + 2Mn^{2+}\ 8H_2O$$

Potassium permanganate, as strong oxidant, is reduced in acid environment (the solution becomes discoloured), while Cl^-, as weak reducer, escapes in the form of gas with a characteristic odour.





Task 9

The aim of the task is to detect CO_3^{2-} ions

Execution

a. Test with strong acid

Add drop by drop 2 mol/dm^3 H_2SO_4 to0.5 cm^3 of CO_3^{2-} solution. Observe the course of reaction.

$$CO_3^{2-} + 2\ H_3O^+ \Rightarrow H_2CO_3 + 2H_2O \Rightarrow 3H_2O + \uparrow CO_2$$

b. Test with Ba^{2+} ions

Add 0.5 cm^{3}of 0.1 mol/dm^3 $BaCl_2$ to 0.5 cm^3 of CO_3^{2-} solution. Reaction:

$$Ba^{2+} + CO_3^{2-} \Rightarrow \downarrow BaCO_3$$

White precipitate of barium carbonate is soluble in acetic, nitric and hydrochloric acids, and insoluble in sulphuric acid.

Task 10

The aim of the task is to detect PO_4^{3-} ions

Execution

Add 5 drops of concentrated $HNO_3$and 0.5 cm^3 of $(NH_4)_2MoO_4$ to0.5 cm^3 of PO_4^{3-} solution. Heat the test tube over a burner.

Reaction:

$$Na_2HPO_4 + 12(NH_4)_2MoO_4 + 23\ HNO_3 \Rightarrow (NH_4)_3P(Mo_3O_{10})_4 + 21\ NH_4NO_3 + 2\ NaNO_3 + 12\ H_2O$$

Task 11

The aim of the task is to detect SO_4^{2-} ions

Execution

a. Test with Pb^{2+} (lead) ions

Add 0.5 cm^3 of 2 mol/dm^3 $Pb(CH_3COO)_2$ to 0.5 cm^3 of SO_4^{2-} solution. Reaction:

$$SO_4^{2-} + Pb^{2+} \Rightarrow \downarrow PbSO_4$$

The resulting white precipitate of $PbSO_4$ is insoluble in inorganic acids, except concentrated sulphuric acid (VI), and it is also insoluble in concentrated NaOH and KOH.

b. Test with Ba^{2+} (barium) ions

Add 0.5 cm^3 of 1 mol/dm^3 barium chloride ($BaCl_2$) to 0.5 cm^3 of SO_4^{2-} solution. Reaction:

$$SO_4^{2-} + Ba^{2+} \Rightarrow \downarrow BaSO_4$$

The resulting white precipitate of $BaSO_4$ is insoluble in HCl and HNO_3 event after heating, while it is soluble in concentrated H_2SO_4.

Task 12

The aim of the task is to detect $C_2O_4^{2-}$ ions

Execution

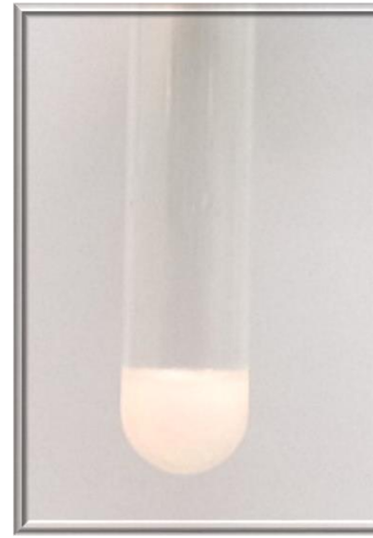
a. Test with $CaCl_2$

Add drop by drop 0.5 $cm^3$of 1 mol/dm^3 $CaCl_2$ to0.5 $cm^3$of $C_2O_4^{2-}$ solution.

Reaction:

$$Ca^{2+} + C_2O_4^{2-} \Rightarrow \downarrow CaC_2O_4$$

Calcium chloride causes the precipitation of white crystalline precipitate, which is soluble in mineral acids, and insoluble in acetic acid.



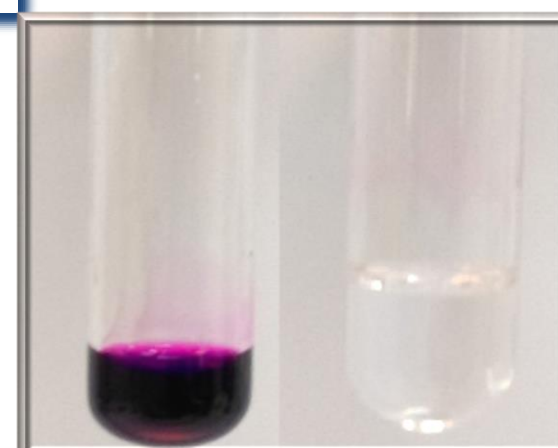
b. Test with potassium premanganate

Add 0.5 $cm^3$of 0.1 mol/dm^3 $KMnO_4$ and 0.5 $cm^3$of concentrated H_2SO_4 to 0.5 cm^3 of $C_2O_4^{2-}$ solution.

Reaction:

$$2MnO_4^{2-} + 5C_2O_4^{2-} + 16H^+ \Rightarrow 10CO_2 + 2Mn^{2+}\ 8H_2O$$

Potassium permanganate becomes discoloured in acid solution containing oxalate ions ($C_2O_4^{2-}$). Characteristic bubbles of CO_2 are formed during this reaction.



Learning effects

Knowledge about importance of macromolecules macroelements and microelements for biological functions of living cells

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