EUROPEAN UNION
MINISTRY OF EDUCATION, YOUTH AND SPORTS
OP Education for Competitivness
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

METALS

Structure and physical properties

1. *Draw the model of the metallic structure and describe it.*

2. *Explain the term* ***„delocalised electrons“****. Explain how the delocalised electrons affect the bonding in metals*.

3. *How do the density, boiling and melting point vary in the series: Na→Mg→Al? And why?*

4. *Why, unlike sodium, cannot aluminium be cut with a knife?*

5. *What other properties are caused by delocalised electrons?*

6. *What does it mean that metals are* ***malleable*** *and* ***ductile****? Draw a picture to explain it.*

7. *Give two ways how metals can be hardened.*

Chemical properties

Metals have *high/low* ionization energies and *high/low* electron affinities which means that they easily *lose/gain* electrons and that they are good ***oxidising/reducing*** **agents**.

Metal reactivity series

K^{I} Na Ca Mg Al Zn Fe Pb **H_2** Cu Hg Ag Au

8. *Write down the most common oxidation numbers of its ion to each metal in the metal reactivity series.*

Reaction with <u>oxygen</u>

Metals on the left side of mercury react with oxygen to form stable oxides.

9. *Write a balanced equation for the reaction of the following when heated with air:*

iron	copper	gold
calcium	platinum	zinc
sodium	magnesium	

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Reaction with <u>water and steam</u>

Electrons from metal atoms are taken by water molecules which form oxide ions and hydrogen.

$M + H_2O \rightarrow MO + H_2$

The oxides of very reactive metals (Na_2O, CaO) react with more water to form solutions of their hydroxides.

$Ca + 2\ H_2O \rightarrow Ca(OH)_2 + H_2$

10. Finish the following equations

a. $Na + H_2O \rightarrow$	c. $Ca + H_2O \rightarrow$	e. $K + H_2O \rightarrow$
b. $Zn + H_2O \rightarrow$	d. $Al + H_2O \rightarrow$	f. $Ag + H_2O \rightarrow$

Reaction with <u>dilute acids</u>

Metals on the left side of hydrogen in the reactivity series react with dilute acids to form a salt and hydrogen.

11. Finish the following equations, all acids are dilute:

a. $HCl + Mg \rightarrow$	e. $HCl + Au \rightarrow$	i. $H_2SO_4 + Cu \rightarrow$
b. $HCl + Al \rightarrow$	f. $HCl + Cu \rightarrow$	j. $H_2SO_4 + Ca \rightarrow$
c. $HCl + Zn \rightarrow$	g. $H_2SO_4 + Pb \rightarrow$	k. $H_2SO_4 + Hg \rightarrow$
d. $HCl + Na \rightarrow$	h. $H_2SO_4 + Al \rightarrow$	l. $H_2SO_4 + K \rightarrow$

<u>Displacement</u> reactions

The more reactive metal displaces the less reactive metal from its compound.

12. Finish the following equations:

a. $AgNO_3 + Zn \rightarrow$	e. $CuSO_4 + Fe \rightarrow$	i. $Al_2(SO_4)_3 + Mg \rightarrow$
b. $FeSO_4 + Cu \rightarrow$	f. $MgSO_4 + Hg \rightarrow$	j. $Na_2SO_4 + Fe \rightarrow$
c. $NaCl + Pb \rightarrow$	g. $AgNO_3 + Al \rightarrow$	k. $CuSO_4 + Ag \rightarrow$
d. $Pb(NO_3)_2 + Al \rightarrow$	h. $CuSO_4 + Al \rightarrow$	l. $Hg(NO_3)_2 + Zn \rightarrow$

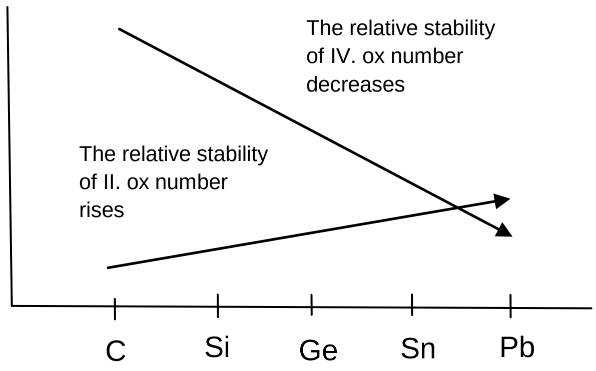
<u>TIN AND LEAD</u>

1. *Use the noble gases to show the electronic configuration of tin and lead.*

Oxidation numbers:	Sn	Pb
In ionic compounds	II	II
In covalent compounds	IV	IV

2. *Why do Sn^{IV} and Pb^{IV} compounds have a covalent and not ionic character?*

3. *Use the following graph to determine the more stable ox. number of Sn and Pb.*



Occurrence: SnO_2 tinstone (cínovec), PbS galena

Obtaining:

4. *Write down the equations:*

Sn: reduction of its ore by coke:

Pb: 1. step: roasting (pražení): galena is heated in the presence of air forming two oxides:

2. step: reduction of PbO by coke:

*5 . What properties of Sn and Pb make them suitable for the following **uses?***

Sn is used for making tin plated steel (e.g. canning meat)

Pb is suitable for X-Ray shields and antiradioactivity screens.

6. Can you remember one use of H_2SO_4 where Pb is also used?

ALUMINIUM

1. *Write down **the electronic configuration** of aluminium and determine its most common **oxidation number**.*
2. *Boron and aluminium are in the same group of the periodic table, they have the same oxidation number in its compounds. Explain why boron forms covalent compounds only while aluminium forms also ionic compounds.*

Occurrence of Al

Aluminium is the ……………… abundant element in the Earth´s crust (8%) just after ……………… (50%) and ………………..(23%). It is the ……………… abundant metal. Because of its high reactivity it *always/never* occurs freely in nature.

Al minerals: bauxite $Al_2O_3 \cdot 2\ H_2O$ (ore of Al) chemical name: ……………....…………………… …………………………

corundum Al_2O_3 with coloured sorts: sapphire (…………..) and ruby (…………..)

cryolite ……………………….*

clays, mica (aluminosilicates)

3. *Cryolite consists of 33% (by mass) of Na, 13 % of Al and 54 % of F. Calculate its empirical formula.*

Physical properties: Aluminium is *silver/yellow*, *heavy/ light metal/non-metal*. It is a *good/bad* electric and thermal conductor and it has a *higher/lower* melting point than steel.

Chemical reactions

4. *Finish the equations and name the products of the following reactions:*

a. With non-metals:

$Al + O_2 \rightarrow$ forms a layer on the surface of Al, protects it from further oxidation.

$Al + S \rightarrow$

$Al + Cl_2 \rightarrow$

$Al + N_2 \rightarrow$

$Al + C \rightarrow$

b. With acids: (after heating due to the compact layer of aluminium oxide)

$Al + HCl \rightarrow$

$Al + H_2SO_4 \rightarrow$

c. With hydroxides

$Al + NaOH + H_2O \rightarrow 3/2\ H_2 + Na[Al(OH)_4]$ sodium tetrahydroxoaluminate

d. With metal oxides = ALUMINOTHERMIC reactions (a lot of heat is ……………………….)

	Uses
$Al + Fe_2O_3 \rightarrow$	welding railway lines
$Al + V_2O_5 \rightarrow$	manufacture of metals which are difficult to melt
$Al + Cr_2O_3 \rightarrow$	

Manufacture of Al

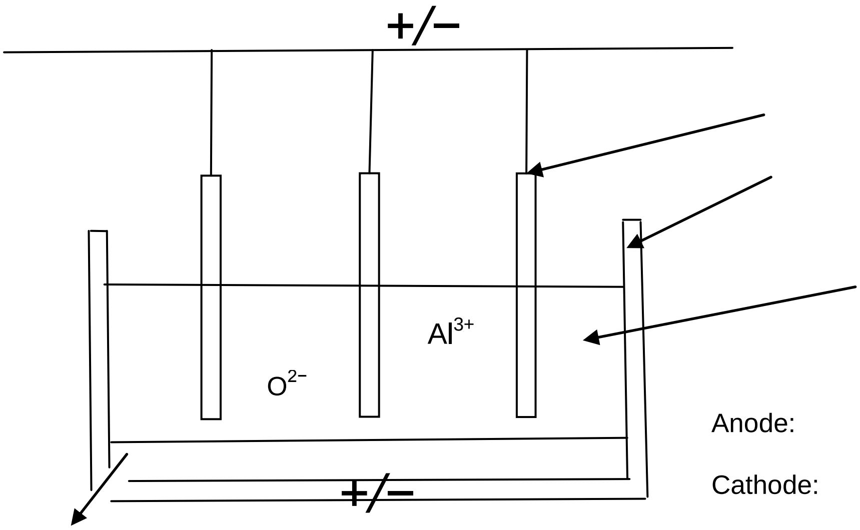
Aluminium is produced by electrolysis of molten aluminium oxide.

5. *Why cannot aluminium be produced by reduction by coke (the same way as tin or lead)?*

6. *Why should Al_2O_3 be molten in order to be electrolysed?*

Bauxite (Al_2O_3 · ....) is at first purified to get rid of impurities mainly .... and .... oxides. Then it is dissolved in molten .... This saves a lot of energy because the melting point of bauxite is about .... while that of cryolite is ....

7. *Describe the diagram of the electrolysis of aluminium oxide, write down the half equations for the reactions taking place at the electrodes.*



8. *Why cannot the anodes be made of steel?*
9. *Why must the anodes be replaced from time to time?*

Uses of Al:

- building
- airplanes
- power lines
- packaging and cans
- coolers (in cars, computer chips)

10. *State what properties of aluminium make it suitable for the above uses.*
11. *Find the meaning of the term* **“anodising aluminium”**

Aluminium compounds

Aluminium halides:

12. *The melting points of aluminium halides are as follows: AlF_3 1291°C, $AlCl_3$ 190°C, $AlBr_3$ 97.5°C, AlI_3 191°C. Explain the big difference between the melting point of AlF_3 and the melting points of the other aluminium halides.*

13. *1 gram of aluminium bromide vapour at the temperature of 200°C and the atmospheric pressure (101 325 Pa) has a volume of 0.145 dm^3. Use the ideal gas equation ($pV = nRT$) and the gas constant ($R = 8.31$ J/mol/K) to calculate the number of moles and the molar mass of aluminium bromide. Suggest the possible molecular formula of aluminium bromide.*

Aluminium oxide is a white solid insoluble in water. It has an **amphoteric** character.

14. *Suggest two reactions which would confirm this statement and write down their equations:*
    a.
    b.

Uses of Al_2O_3:

Aluminium hydroxide has the same properties as Al_2O_3

15. *Finish equations:*
    a. $Al(OH)_3 + H_2SO_4 \rightarrow$
    b. $Al(OH)_3 + NaOH \rightarrow$
    c. $Al_2(SO_4)_3 + NaOH \rightarrow$
    d. $Al(OH)_3 \rightarrow$ thermal decomposition

    Uses of $Al(OH)_3$:

Alums = binary salts with a general formula $M^IAl(SO_4)_2$

16. *Write down the formula of potassium aluminium sulphate.*

s-BLOCK ELEMENTS

ALKALI METALS		I_1	I_2	ALKALINE EARTH METALS		I_1	I_2	I_3
Li		520	7300	Be		900	1800	14800
Na		500	4600	Mg		740	1450	7700
K		420	3100	Ca		590	1150	4900
Rb		400	2700	Sr		550	1060	4200
Cs		380	2400	Ba		500	970	

1. *Write down the names of alkali metals and alkaline earth metals into the table above.*

2. *What is the general* **electronic configuration** *of:*
   a. *alkali metals*
   b. *alkaline earth metals*

3. *See the table with ionization energies and answer the following questions:*
   a. *Why do the ionization energies decrease going down the groups?*

   b. *Why are the second ionization energies of alkaline earth metals higher than the first ionization energies?*

   c. *Why is there such a big difference between I_1 and I_2 of alkali metals and between I_2 and I_3 of alkaline earth metals?*

Occurrence: s- elements are *not/very* reactive so they ***never/always*** occur **freely** in nature.
Ca, Na, K, Mg are the 5.- 8. most abundant elements in the earth's crust.

4. *Fill the table with minerals:*

Rock salt		
	KCl	
Limestone		
		magnesium carbonate
	$CaCO_3 \cdot MgCO_3$	
Gypsum		

Na^+, K^+, Ca^{2+} and Mg^{2+} ions are also important for living things, e.g. calcium is present in .... and ...., magnesium in .... and ....

Chemical properties:

s- elements have *high/low* electronegativities, they are good *reducing/oxidising* agents. Alkali metals form .... ions, alkaline earth metals form .... ions.

Reactions with: + $O_2 \rightarrow$ oxides, peroxides (in the excess of air)

Na_2O_2 =

KO_2 =

$KO_2 + CO_2 \rightarrow$

+ $X_2 \rightarrow$ ....,

+ $H_2 \rightarrow$ .... $H^{....}$,

+ S $\rightarrow$ ....,

+ acids $\rightarrow$

+ water $\rightarrow$

Because of their reactivity they tarnish in air so they must be kept under *oil/water*.

5. *Finish equations:*

$Mg + O_2 \rightarrow$

$K + Cl_2 \rightarrow$

$Mg + Br_2 \rightarrow$

$Na + O_2 \rightarrow$

$Ca + H_2 \rightarrow$

$Ca + H_2O \rightarrow$

$Na + H_2O \rightarrow$

$K + H_2O \rightarrow$

$Mg + HCl \rightarrow$

$Na + H_2 \rightarrow$

$Ca + H_2SO_4 \rightarrow$

$Mg + CH_3COOH \rightarrow$

Manufacture

The manufacture of all s^1 and s^2 elements is based on their *oxidation/reduction* using electrolysis of their *molten compounds/solutions*, usually *halides/sulphides*. (*MX/M_2S*)

A:

C:

Sodium is made by the electrolysis of *molten/dissolved* ....

6. *Write equations for the process at each electrode during the manufacture of sodium.*

7. *In Down's cell, the cathode is made of steel, but the anode is made of graphite. Why?*

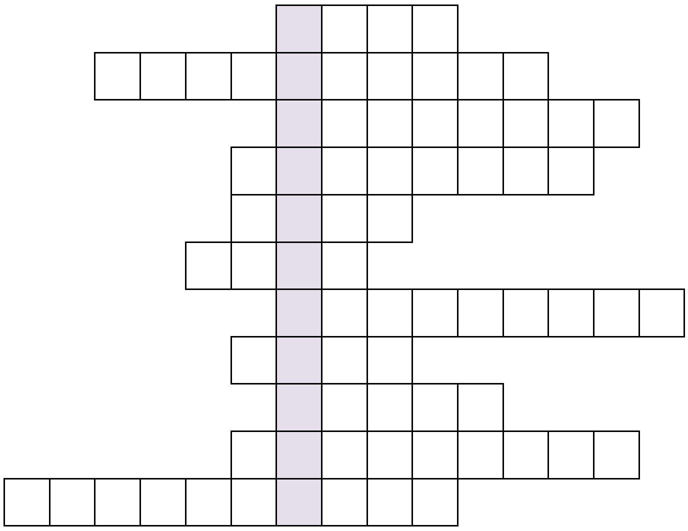
8. *Why is necessary to prevent the product at the anode from mixing with the product at the cathode?*

Compounds of alkali metals

General physical properties: All compounds of alkali metals are *ionic/covalent* substances and they are *not/well* soluble in water. Ions of alkali metals *are/are not* coloured and so most alkali metals compounds are *white/brightly coloured*.

NaOH

9. *Solve this crossword and use the terms 1-11 and the secret word (one property of NaOH) to fill the following text about sodium hydroxide.*



1	Structural proteins form e.g. skin, or **1**
2	Fats are esters of **2** and **3**
3	Macromolecular substances made of aminoacids = **4**
4	
5	A tree is made of **5**
6	NaOH is a strong **6**
7	A polysaccharide, a component of cell walls
8	A detergent
9	A product made from wood.
10	A method of analytical chem using a burette
11	Carboxylic acids with NH_2 (amino) group

Properties and uses of NaOH

NaOH is a ....(colour) ....(state) .... in water. It is a ....(6) It is able to hydrolyse ....(4) to ....(11). That is why it is used as a drain .... as it dissolves ....(1) in blocked drains. NaOH is also used in the production of ....(8) which is in fact a mixture of sodium salts of ....(2). Fats are boiled with .... to produce ....(8) and ....(3). NaOH is also able to separate ....(7) from ....(5). That is used in the manufacture of ....(9). NaOH absorbs *acidic/basic* gases like *CO_2, CH_4, CO, SO_2 (Choose the correct gases.)* from the air. This may be used e.g. in submarines or space shuttles to decrease the concentration of .... NaOH absorbs also water from the air – it is ....(secret word). It means that it must be stored in a .... container. NaOH is also used in analytical chemistry for acid -base ....(10)

10. *Calculate the concentration of sulphuric acid if 20 cm^3 of it requires 15 cm^3 of 0.1 M NaOH for neutralization.*

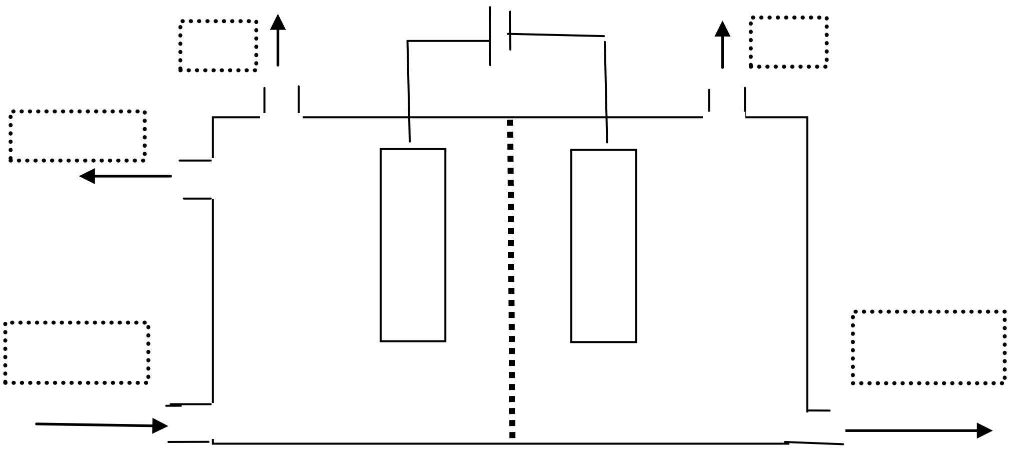
11. *NaOH reacts with glass and it „pastes" glass components of equipment together. What precautions should you take to prevent this when titrating NaOH against H_2SO_4?*

12. *What is the pH of*
    a. *NaOH*
    b. *H_2SO_4 from the question 10?*

13. *What volume of water must be added to 200 g of 40% solution of NaOH in order to get 25% solution?*

14. *How would you detect sodium chloride and sodium carbonate impurities in a sample of sodium hydroxide?*

Manufacture of NaOH



15. *Match the labels:* NaOH, brine, used brine, Cl_2, H_2, +, -.
16. *Complete the table:*

Electrode	charge	Primary reaction	Secondary reaction
Anode			
Cathode			

17. Why is it more convenient to use **LiOH** rather than NaOH in space shuttles to get rid of CO_2? Write down both equations:

$LiOH + CO_2 \rightarrow$

$NaOH + CO_2 \rightarrow$

KOH has similar properties to NaOH and it is manufactured in the same way.

18. *Suggest what may be the raw material for the manufacture of KOH and write down the equations.*

Na_2CO_3, soda ash

19. *Give the chemical name for soda ash:*
20. *What is the pH of its solution and why?*

Soda is used for the production of .... together with SiO_2 and ....

21. *Write down the two equations for the manufacture of soda by the Solvay process:*
    1. Brine reacts with ammonia and carbon dioxide to produce ammonium chloride and sodium hydrogen carbonate.

    2. Sodium hydrogen carbonate is thermally decomposed.

$NaHCO_3$, baking soda

It is used in .... powders, in .... tablets or to neutralise the .... juice.

General equation: $NaHCO_3 + H^+ \rightarrow$

$NaNO_3$ and KNO_3 are used as .... (e.g. in gunpowder) or as artificial ....

KH, NaH

22. *Name these two substances.*
23. *Finish equations*: $KH + H_2O \rightarrow$

    $NaH + H_2O \rightarrow$

<u>**Compounds of alkaline earth metals**</u>

Mg^{2+}, Ca^{2+} compounds are white ionic solids

CaO = quick or burnt .... (..................... vápno) is made by .... decomposition of .... Equation:

It is *an acid/a base* forming oxide, which means that not only does it react with *acids/bases* but it also reacts with .... to produce *an acid/a hydroxide*.

24. *Finish equations:*

    $CaO + H_2O \rightarrow$

    $CaO + HCl \rightarrow$

    $CaO + CO_2 \rightarrow$

Uses of CaO: in .... to *decrease/increase* the pH of soil and as a .... to produce .... lime (....................... vápno) which is used in the .... industry.

$Ca(OH)_2$ = ... lime is produced from quick lime: ....(eq). It is *very/slightly* soluble in water, its solution is called ...., it is used for the detection of *CO/CO_2* ....(eq) because a visible change is the formation of a *precipitate/ brightly coloured solution* . This reaction is also used in the.......................... industry. The mixture of $Ca(OH)_2$, ... and water is called .... and it is used as a building ....The suspension of $Ca(OH)_2$ is called .... and it is used in the production of .... from sugar .... or .... It removes impurities and other non-sugar substances from the beet juice.

$Mg(OH)_2$, its suspension = milk of magnesia, used as an .... = a substance which *decreases/increases* the pH of .... juice.

$CaCO_3$

25. *What is its state, colour and solubility in water?*

$CaCO_3$ is used in the production of .... and together with sand ....and soda ash............ it makes .... It is also used in the manufacture of .... because it removes the impurities (mainly ....) from its ores.

$CaCO_3$ + ... → CO_2 + ... = ... and it is used in .... building.

CaC_2 = ...

26. *What is its* a. *structure*
    b. *state*

27. *What are the products of its reaction with water and what is (was) this reaction used for?*

28. *1 kg of impure calcium dicarbide produces 280 dm^3 (at s.t.p.) of C_2H_2 when reacted with water. What is the purity (mass of pure/mass of impure) of CaC_2?*

$Ca(HCO_3)_2$, $Mg(HCO_3)_2$ & hardness of water

Liquid water has a high surface tension because of strong interactions between its molecules. Because of this high surface tension some insects like water striders can walk on the surface of water. Another consequence of high surface tension is that water penetrates the fibres of some cloths with difficulties and this fact limits the washing abilities of water. The surface tension of water may be decreased by adding a detergent, e.g. soap. Common soap is a mixture of sodium salts of fatty acids, like e.g. sodium palmitate $C_{15}H_{31}COONa$. Palmitate ion has two parts: non-polar hydrocarbon part $C_{15}H_{31}$ (vvvvvvv) and a negatively charged COO^- (ϴ). vvvvvvvϴ. The COO^- part is hydrophilic, it means that it interacts with water molecules. However the non-polar (hydrophobic) hydrocarbon part of the palmitate ion does not interact with water molecules. (It makes a barrier between water molecules.) In this way the strong interactions between water molecules are weakened and the surface tension is decreased. Soaps also enable fats to be dissolved in water as their non-polar parts interact with the fat and in this way make them disperse in water. When Ca^{2+} or Mg^{2+} ions are present in water they precipitate out palmitate ions: $Ca^{2+} + C_{15}H_{31}COO^- \rightarrow (C_{15}H_{31}COO)_2Ca$ → the soap cannot work.

29. *What is the name of the interactions between water molecules?*

30. *Suggest one way how Ca^{2+} may get into the water.*

Hardness of water	Caused by	May be removed
Temporary		
Permanent		

d-BLOCK ELEMENTS

= elements with general configuration of valence electrons: $(n\text{-}1)d^{1\text{-}10}\ ns^2$

4^{th} period d-elements: Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn

TRANSITION METALS

= d-block elements with at least one ion with partially filled d-orbitals

4^{th} period transition metals: Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu

1. *Why is zinc not considered a transition metal?*

Electronic configuration: $3d^{1\text{-}10}4s^2$, exceptions:

Cr[Ar] $4s^2\ 3d^4$ □ □□□□□ □ □□□□□ $4s^1\ 3d^5$

Cu[Ar] $4s^2\ 3d^9$ □ □□□□□ □ □□□□□ $4s^1\ 3d^{10}$

$4s^1\ 3d^5$ is a *more/less* stable arrangement than $4s^2\ 3d^4$ as there is equal distribution of d - electrons around the atom.

General properties of transition metals

1. metallic character

The metallic bond of transition metals is very *weak/strong* because both .... and .... electrons take part in it. That's why transition metals have a *high/low* melting point, a *high/low* density, they are *good/bad* thermal and electric conductors.

2. variable oxidation numbers

Transition metals usually show more than one oxidation number in their compounds.

2. *What are the most common oxidation numbers of:*
   - *a. Fe* *c. Mn*
   - *b. Cu* *d. Cr?*

When transition metals form ions at first *s*-electrons are lost and then *d*-electrons.

3. *Write down the box diagrams for the valence electrons of:*

a. Fe □ □□□□□ Fe^{2+} □ □□□□□ Fe^{3+} □ □□□□□

b. Co □ □□□□□ Co^{2+} □ □□□□□ Co^{3+} □ □□□□□

For forming bonds both *d* and *s* electrons may be used as they have similar energy. The common oxidation states for each element are II or III. The highest oxidation numbers are reached in compounds with fluorine and oxygen. With increasing oxidation number the covalent character of the bonds and acidity of the compound increase.

4. *Match the oxides of manganese with their acid-base properties.*

MnO	acidic
MnO_2	slightly basic
Mn_2O_7	amphoteric

3. catalytic properties

5. *What is a catalyst?*
6. *What are the catalysts of the following industrially used reactions?*
   a. Haber process: $N_2 + 3\,H_2 \rightarrow 2\,NH_3$
   b. Contact process – manufacture of H_2SO_4: $SO_2 + ½\,O_2 \rightarrow SO_3$
   c. hardening fats – making margarine: $– CH=CH – + H_2 \rightarrow – CH_2 – CH_2 –$
   d. car catalysts: $2\,CO + 2\,NO \rightarrow 2\,CO_2 + N_2$

4. coordination (complex) compounds

= compounds containing ligands bonded to a central atom by a dative (coordination covalent) bond.

Dative bond: one atom donates .... = donor, the second atom has .... = acceptor

Central atom (ion) – contains empty valence orbitals = electron pair ...., often ions of transition metals

Ligands – negative ions or neutral molecules attached to a central atom, contain lone pairs of electrons = electron pair ...., e.g. F^-, Cl^-, Br^-, I^-, CN^-, OH^-, H_2O, NH_3, CO,…

Cu^{2+} [ ] [↑↓|↑↓|↑↓|↑↓|↑] [| |]
NH_3 NH_3 NH_3 NH_3

Formula:
EN name:
CZ název:

In the case that the ligands are neutral molecules the overall charge of the complex ion is .... → complex *anion/cation*.

In the case that the ligands are negative ions the overall charge of the complex ion is often .... → complex *anion/cation*.

Pt^{2+} [ ] [↑↓|↑↓|↑↓|↑|↑] [| |]
Cl^- Cl^- Cl^- Cl^-

Formula:
EN name:
CZ název:

Naming complex compounds:

Ligands:

Formula	Cl^-	OH^-	CN^-	SCN^-	H_2O	NH_3	CO
EN name	chloro	hydroxo	Cyano	thiocyano	aqua	ammine	carbonyl
CZ název	chloro	hydroxo	Kyano	rhodano	aqua	ammin	karbonyl

Compounds containing a complex cation

Formula: formula of the complex cation = [metal ion + ligands (name and number)] + formula of the anion, applied cross rule

English name: name of the complex cation (= number and name of the ligands + name and the charge of the metal ion) + name of the anion

Český název: název aniontu + název komplexního kationtu (= počet a název ligandu + název kationtu kovu s koncovkou příslušného oxidačního čísla)

7. *Fill the table:*

	hexaamminechromium(III) chloride	
$[Cu(NH_3)_2]_2SO_4$		
		síran hexaaquakobaltitý

Compounds containing a complex anion

Formula: formula of cation + formula of the complex anion [metal ion + ligands (name + number)], applied cross rule

English name: name of the cation + name of the complex anion (= number and name of the ligands + Latin name of the metal ion with the suffix –ate and with the oxidation number)

Český název: název komplexního aniontu (= počet a název ligandu + název kovu s koncovkou oxidačního čísla + -an) + název kationtu

8. *Complete the table:*

	sodium hexachloroplatinate(IV)	
$K_4[Fe(CN)_6]$		
		dikyanozlatnan sodný

9. Mark the compounds with a complex cation with + and the compounds with a complex anion with – and write down their names or formulae.

+/−			chlorid diamminměďný
		hexaaquanickel(II) sulphate	
			hexabromothalitan sodný
	$Rb[SnCl_6]$		
			chlorid diamminstříbrný
			hexarhodanortuťnatan zinečnatý
	$K_2[PtCl_4]$		
			hexahydroxohlinitan draselný
		potassium tetrachlorocobaltate(II)	
	$[Fe(NH_3)_6](NO_3)_3$		
			tetrachlorozlatitan sodný
		calcium hexacyanomanganate(II)	
	$K_3[Fe(CN)_6]$		

Stereochemistry (shapes) of complex ions

The most common coordination numbers (number of lone electron pairs attached to the central atom):

2: .... shape, e.g. $[Ag(NH_3)_2]^+$

4: .... (e.g. $[NiCl_4]^{2-}$) or square (e.g. $[Ni(CN)_4]^{2-}$)

6: .... (e.g. $[Fe(CN)_6]^{3-}$)

10. Draw the shapes of the above mentioned ions.

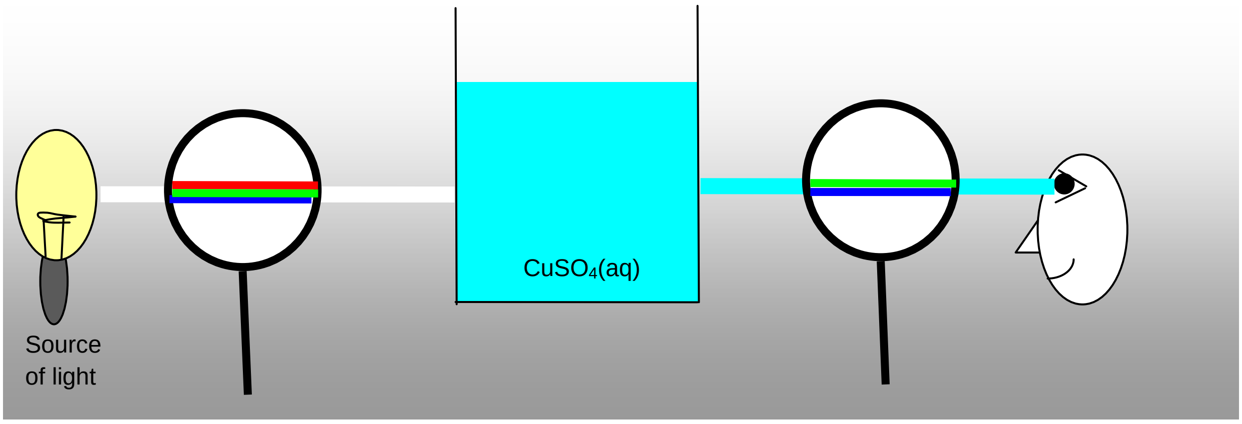
Uses: analytical chemistry ($K_3[Fe(CN)_6]$, $K_4[Fe(CN)_6]$)
catalysts

Important for life – haemoglobin (........), chlorophyl (.........), vitamin B_{12} (Co)

5. coloured compounds

The compounds of transition metals are usually coloured.

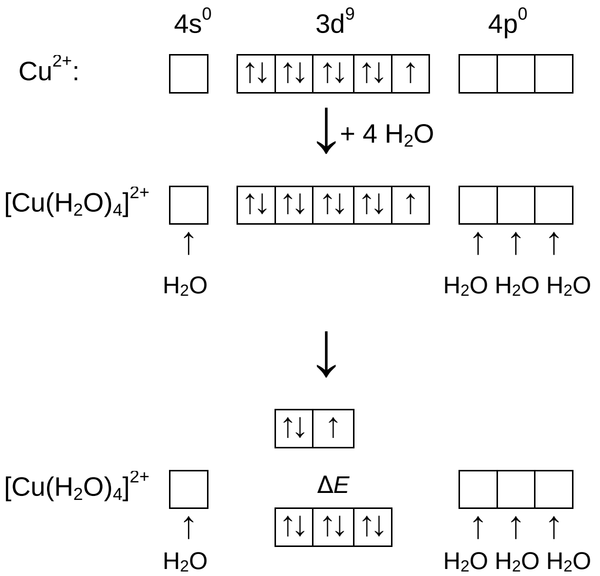
Why?



They absorb a part of visible light (a kind of ....).

Why?

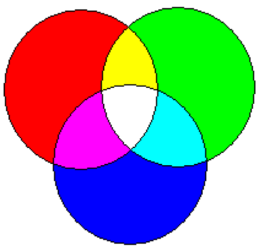
$CuSO_4$(s) (anhydrous) is white, contains Cu^{2+}



$[Cu(H_2O)_4]^{2+}$ in $CuSO_4$(aq) or in $CuSO_4 \cdot 5\ H_2O$ are blue

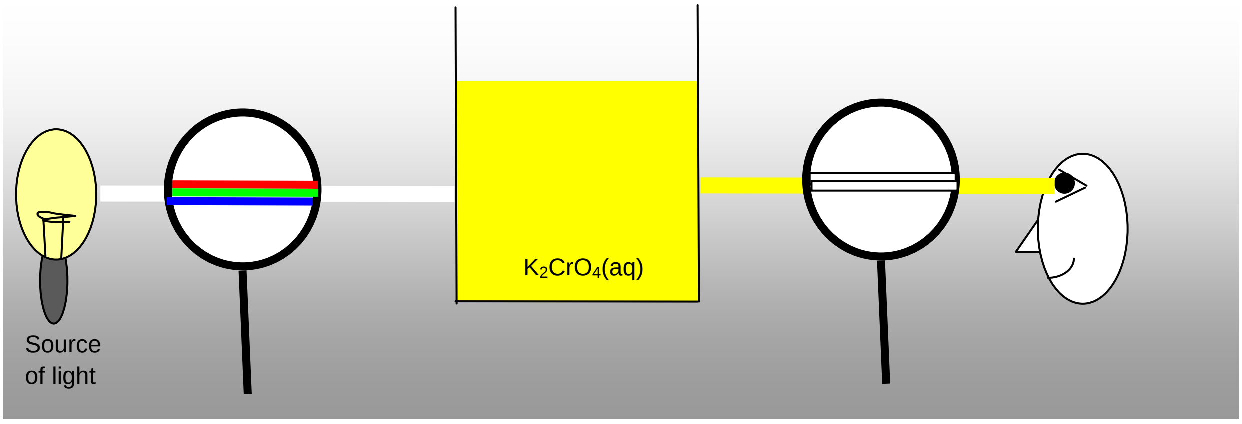
The water molecules bonded to the central atom influence the energies of the *d*-orbitals (because of repulsion between *d*-electrons and lone electron pairs of the water molecules). They then have different energies.

An electron from an energy *lower/higher* *d*-orbital absorbs energy (light) to jump to a *lower/higher* *d*-orbital.

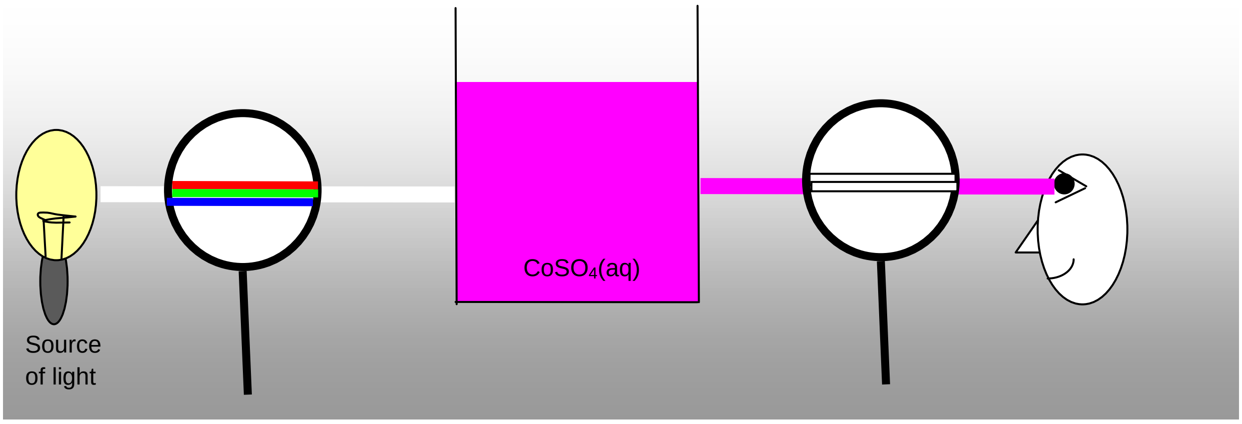


11. *Use the coloured discs above to say lights of what colours are absorbed by the following solutions:*

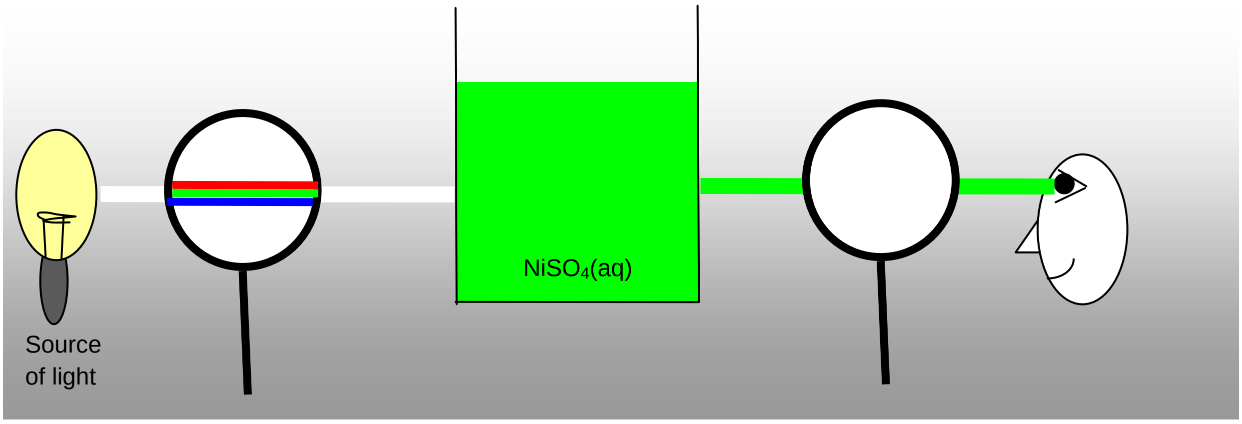
a.



b.



c.



12. *What is the colour of a christmas tree seen when it is lit by red lights only?*

13. *Make the el. configurations for Sc^{3+}, Cu^{+} and Zn^{2+} and explain why the compounds containing these ions are colourless.*

Some of the coloured ions of the 4th period of transition metals:

Cr^{3+} green	Mn^{2+} pink	Fe^{2+} pale	Co^{2+} (aq) pink
CrO_4^{2-} yellow	MnO_4^{2-} green	Fe^{3+}	Cu^{2+}(aq) ....
$Cr_2O_7^{2-}$ orange	MnO_4^{-}		Ni^{2+}(aq) green

Occurrence and manufacture of transition metals

Occurrence: mainly as oxides – TiO_2 rutile, MnO_2 pyrolusite, $FeCr_2O_4 = FeO \cdot Cr_2O_3$ chromite…

sulphides – $CuFeS_2$ copper pyrite, ZnS zinc blende, HgS cinnabar…

Pt metals (Ni, Pd, Pt), Au, Ag occur freely

Manufacture: is based on the reduction of their oxides: $M^{n+} + n\,e^{-} \rightarrow M$, using

- reducing agents: C, CO, Mg, Al, H_2,…
- electrolysis of molten compounds or solutions

14. *Chromium and manganese are manufactured from their oxides using aluminium as a reducing agent.*
    a. *Give the equations for these reactions.*
    b. *What type of reaction is this?*

IRON

Electronic structure

1. *Write down the electronic configuration of iron.*
2. *Draw the box diagrams for the valence electrons of:*

Fe	☐		☐	☐	☐	☐	☐
Fe^{2+}	☐		☐	☐	☐	☐	☐
Fe^{3+}	☐		☐	☐	☐	☐	☐

Physical properties: pure iron is *lustrous/dull, hard/soft* and it is strongly attracted to ....

Chemical properties: Iron reacts with:

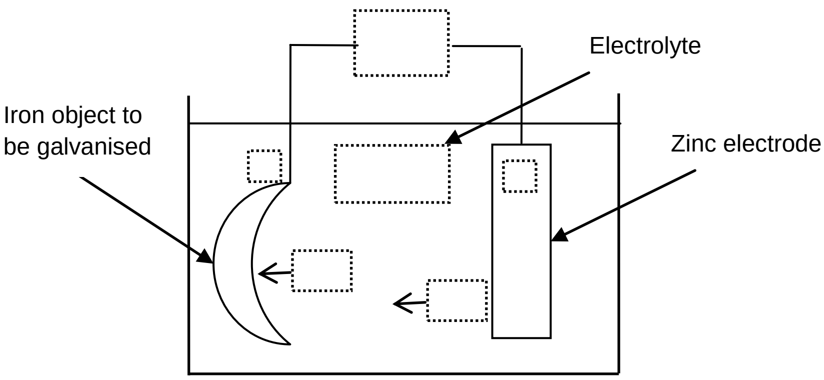
nonmetals:	$Fe + O_2 \rightarrow$	acids:	$Fe + HCl \rightarrow$
	$Fe + Cl_2 \rightarrow$		$Fe + H_2SO_4 \rightarrow$
	$Fe + S \rightarrow$		$Fe + H_2SO_4 \rightarrow$
			$Fe + HNO_3 \rightarrow$

3. *Explain why the oxidation number of iron in the first two equations (with O_2, Cl_2) is III while that in the third equation (with S) is II.*

Iron corrodes: Fe + ... + ... → mixture of hydrated iron oxides and hydroxides = ...

4. *Why is the corrosion of iron so unpleasant? How can be iron prevented from corroding?*

5. *Fill the missing labels in the picture of the galvanisation of iron and write down the equations of the reactions taking place at each electrode.*



Iron compounds

Fe^{2+} salts have .... colour, e.g. .... vitrol ($FeSO_4 \cdot$ .... H_2O)

Fe^{2+} + ... OH^- → ....↓ → H_2O + ... *acidic/basic*

Fe^{3+} salts have .... colour, e.g. iron(III) sulphate (....................)

Fe^{3+} + ... OH^- → ....↓ → H_2O + ... *acidic/basic*

Iron (III) sulphate is used for the removal of phosphate ions from sewage water.

6. *Write down the equation for the reaction between iron (III) sulphate and phosphate ions.*

7. *How can phosphate ions get into the sewage water and why is it necessary to remove them?*

Occurrence of iron

Iron is the .... most abundant element in the Earth´s crust. It occurs there in minerals mainly.

8. *Fill the table of iron ores:*

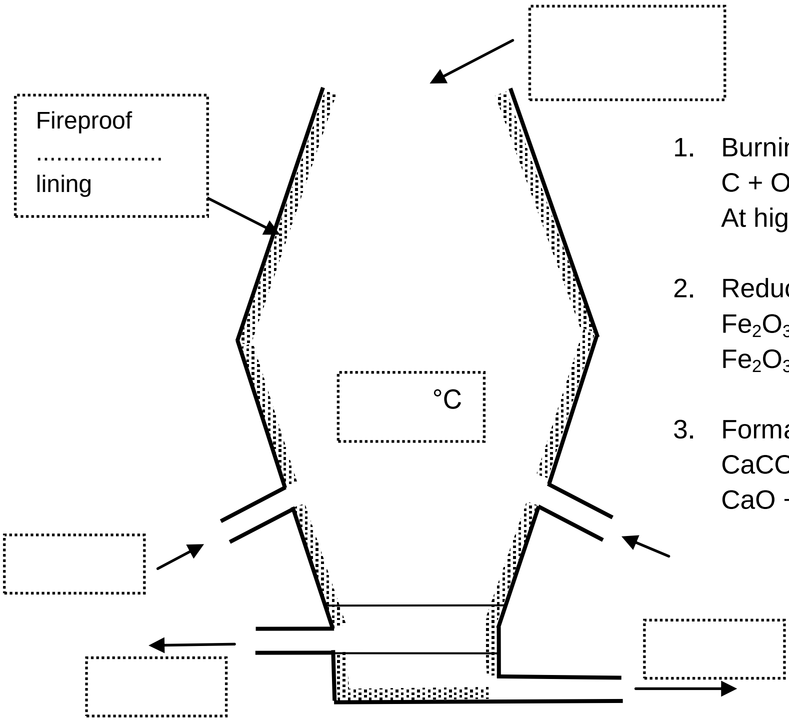
Fe_2O_3	Haematite		
	Limonite	Hnědel	Hydrated iron (III) oxide
	Magnetite		Iron (II,III) oxide
$FeCO_3$	Siderite	Ocelek	
	Pyrite		Iron disulphide

9. *Estimate which of the iron ores contains the highest percentage of iron. Calculate its value.*

10. *What mass of iron can be theoretically produced from 20 tonnes of haematite containing 10% of impurities. What is the principal impurity in haematite?*

Elemental iron forms 80% of the Earth's ....

Manufacture of iron



1. Burning of coke:
   $C + O_2 \rightarrow$
   At high t: $CO_2 + C \rightarrow$
2. Reduction of iron oxides by C or CO:
   $Fe_2O_3 + C \rightarrow$
   $Fe_2O_3 + CO \rightarrow$
3. Formation of slag:
   $CaCO_3 \rightarrow$
   $CaO + SiO_2 \rightarrow$

11. *Why is limestone added to the blast furnace?*
12. *What is the main impurity in iron ores?*
13. *What is the role of slag in the manufacture of iron?*
14. *What is the slag used for?*

Iron made in the blast furnace is called .... iron. It is .... because it contains a lot of impurities, mainly ....

It cannot be hammered and that's why it is either poured into moulds forming .... iron (..................) or it is used for making ....

Making steel

Making steel is based on removing .... from .... iron. There are two main ways of doing it.

Basic oxygen process: oxygen is blown into the molten pig iron, carbon amount is decreased due to the reaction: $C + O_2 \rightarrow$

Electric arc furnace: pig iron is mixed with .... iron (železný ....) and the following reaction takes place: C (from the .... iron) + Fe_2O_3 (from the .... iron) →
Other impurities (Si, S, P) are oxidised as well as carbon, they escape in the form of .... or they react with the slag forming materials like CaO or MgO.

15. *How would you classify CaO and MgO according to their acid-base properties?*
16. *Finish these equations:*

    $MgO + SiO_2 \rightarrow$

    $CaO + P_2O_5 \rightarrow$ (used in agriculture as a .... - source of Ca and P)

Types of steel	% of carbon	Properties	Uses
Mild steel	0.05 – 0.30 %	Not brittle, malleable	
Medium carbon steel	0.3 – 0.6 %	Ductility and strength balanced	
High carbon steel	0.6 – 2.0 %	Brittle, hard	

17. *Estimate what type of steel may be used for: knives, chains, cutting tools, cars, ships, scissors, gears.*

Alternating the properties of steel:

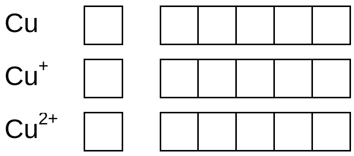
- Quenching – red hot steel is cooled down rapidly, this rapid crystalization causes the formation of *big/small* crystals of iron. Quenched steel is *hard/soft*, *malleable/brittle*.
- Tempering –
- Alloying –

	Composition	properties	uses
Manganese steel			
Stainless steel			
Titanium steel			

IB group: Cu, Ag, Au

COPPER, Cu

1. *Fill in the box diagrams for the valence electrons of:*



Physical properties:

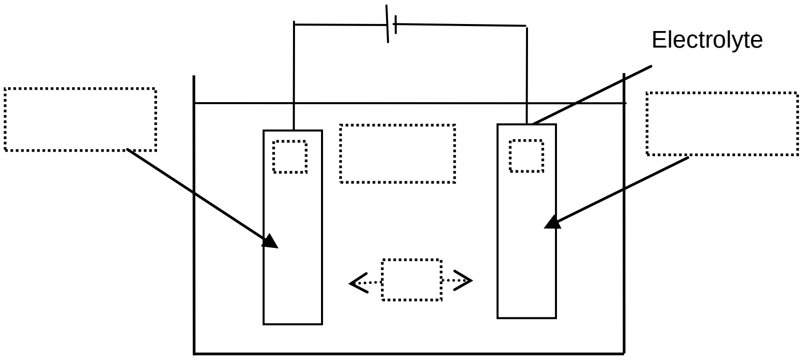
Occurrence and manufacture

Copper is extracted from ....($CuFeS_2$) by heating with a controlled amount of air:

$CuFeS_2$ = CuS · ....

$CuS + O_2 \rightarrow$

Pure copper may be obtained by electrolysis:



2. *Label the diagram above with the following: pure Cu, impure Cu, +, - , $CuSO_4$, Cu^{2+} and choose the correct direction of the arrow.*

Uses of Cu:

Copper alloys: Cu + Sn = ..., Cu + Zn = ..., Cu + Au = ...

3. *What are the uses of the above alloys?*

Cu compounds and reactions

4. *What two copper oxides exist and what are their colours?*

Aqueous solutions of copper(II) salts have usually .... colour.

Reactions of Cu

$Cu + O_2 \rightarrow$

$Cu + HCl \rightarrow$

$Cu + HNO_3 \rightarrow$

The product of the corrosion of copper is a mixture of hydrated carbonates, it has .... colour and it is called .... (........................)

SILVER, Ag

Ag						
Ag^+						

Physical properties:

Uses :

Compounds:

AgBr is photosensitive, it means that it decomposes in the presence of .... This is used in black and white ....

Ag^+ ions are used in analytical chemistry to identify .... ions:

Ag^+ + ... → .... white precipitate

Ag^+ + ... → .... precipitate

Ag^+ + ... → .... yellow precipitate

Darkening of silver is caused by trace amounts of .... in the air: Ag + ... → Ag_2S +

II. B GROUP: Zn, Cd, Hg

5. *Write down the **electronic configurations** of:*

Zn						
Cd						
Hg						

6. *Use the electronic structures of these elements to explain the following:*
   a. *II. B group elements have a relatively low melting point*
   b. *These elements have white compounds.*

Occurrence and manufacture:

Zinc is manfactured from ZnS = zinc blende (sfalerit) by the same method as .... from ....

- Roasting: ZnS + ... → .... + ...
- Reduction by coke:

Mercury is manufactured from HgS = cinnabar (....................) by heating with a controlled amount of air: HgS + ... → Hg + ...

Cadmium is found in minerals together with Zn, it is manufactured the same way and then separated from Zn.

Chemical properties and compounds

Zinc:

7. *Finish the equations*
   a. $Zn + I_2 \rightarrow$
   b. $Zn + O_2 \rightarrow$
   c. $Zn + H_2SO_4 \rightarrow$
   d. $Zn + NaOH + H_2O \rightarrow Na_2[Zn(OH)_4] + H_2$
8. *What kind of property of Zn enables the reactions c. and d.?*

$ZnCl_2$, $ZnSO_4$ and $Zn(NO_3)_2$ are soluble in water, $Zn(OH)_2$ is insoluble in water.

9. *Name all these four substances and suggest a way of preparing them.*

$Zn(OH)_2 + HCl \rightarrow$

$Zn(OH)_2 + NaOH \rightarrow$

Testing for the presence of Zn^{2+}: $Zn^{2+} + S^{2-} \rightarrow$ .... white

Cadmium:

$Cd + HCl \rightarrow$

Testing for the presence of $Cd^{2+} + S^{2-} \rightarrow$ .... yellow, used as a ....

Mercury:

$Hg + HCl \rightarrow$

$Hg + I_2 \rightarrow$

$Hg + S \rightarrow$

Uses

Zn:

zinc plated steel – prevention from ....

alloy of Zn and Cu = ... (...................)

ZnO = ...(colour) pigment used in paints and as a sunscreen

Cd: nickel-cadmium batteries

Hg: thermometers, alloys with Ag = ..., used as .... fillings

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