ZINC LAYERS

ALEXANDRA MARIA CUREA

TEAM NITRO

12. ZINC LAYERS

IF A COPPER COIN AND SMALL GRANULES OF ZINC ARE IMMERSED INTO A SOLUTION OF ZINC SULPHATE AND THEN HEATED, A LAYER OF ZINC APPEARS ON THE COIN. WHAT IS THE THICKNESS OF THE ZINC LAYER? WHAT OTHER METALS CAN BE COVERED WITH ZINC IN SUCH AN EXPERIMENT? INVESTIGATE AND EXPLAIN THE EFFECT.

Summary

Theoretical Part

- ✓ Introduction
- ✓ Theory
- ✓ Hypothesis

Experimental Part

- ✓ Material and Methods
- ✓ Results and Discussion

Final Part

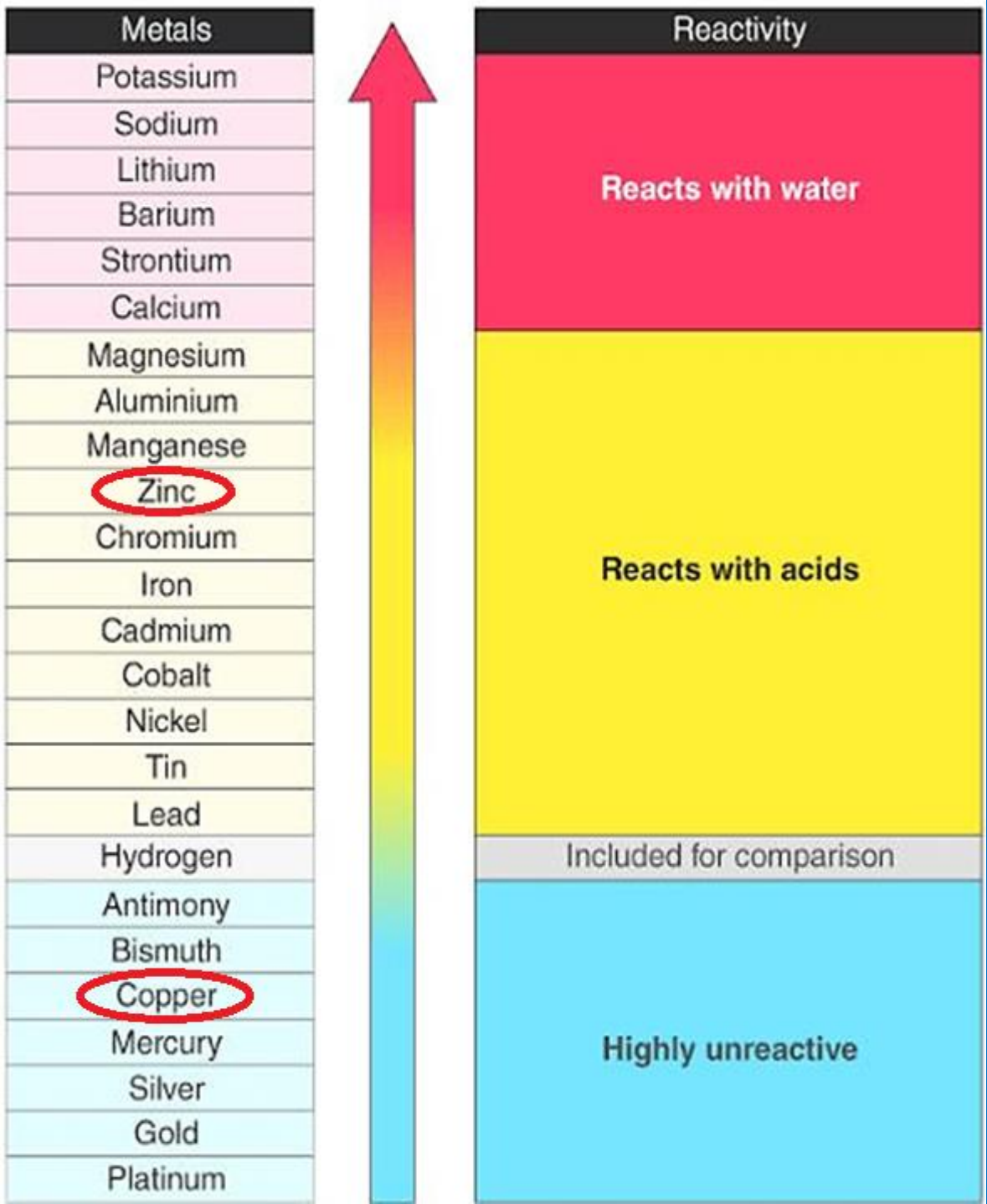
- ✓ Conclusions
- ✓ References
- ✓ Appendices

Theoretical Part

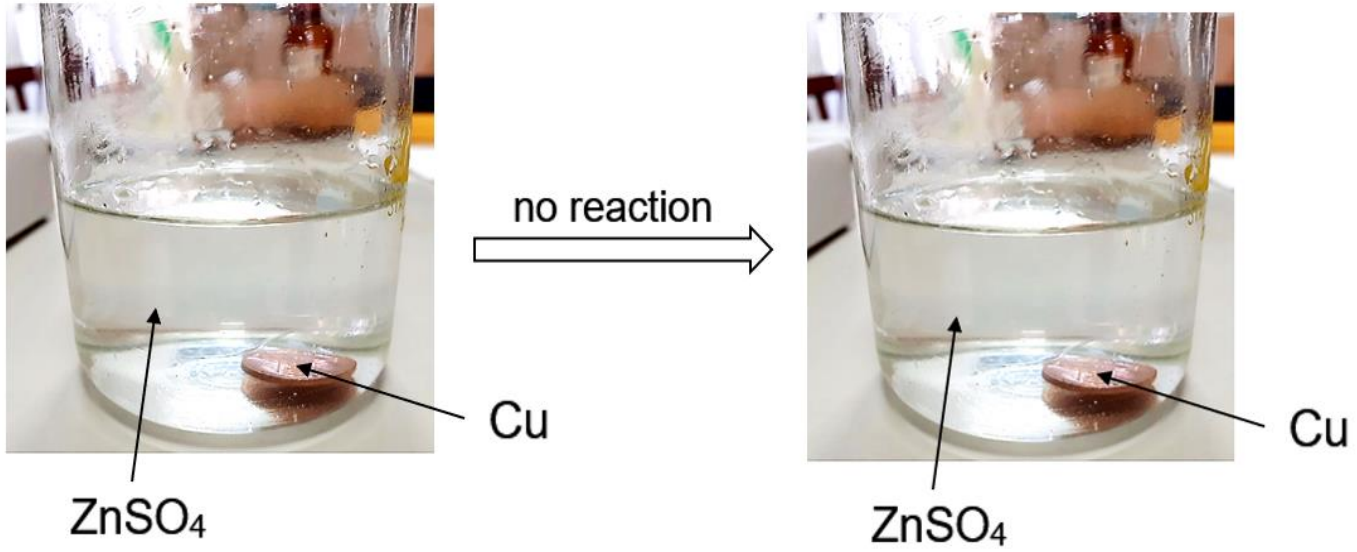
slides 4 - 13

1.1 Theory

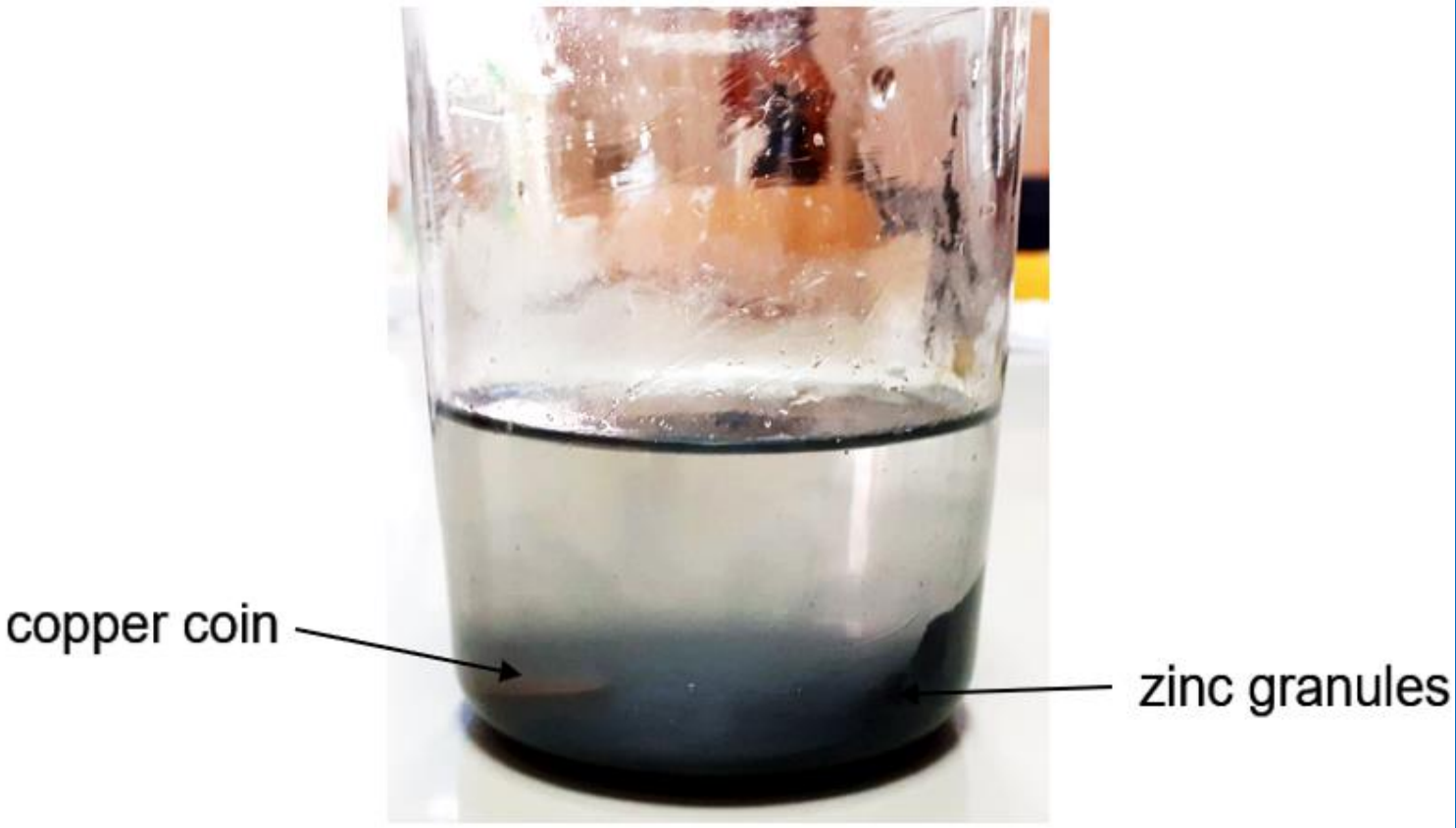
Is it possible for the copper (from the coin) to react with zinc sulfate?



Without zinc granules no plating takes place



Plating can only take place under the following conditions:



The mechanism of zinc coating

When zinc and copper are in contact in an electrolyte, differences in electrical potential develop and an electrolytic (galvanic) cell is formed.

We know the reduction potentials:

$$V_{Zn} = -0{,}76 \text{ V}$$

$$V_{Cu} = +0{,}34 \text{ V}$$

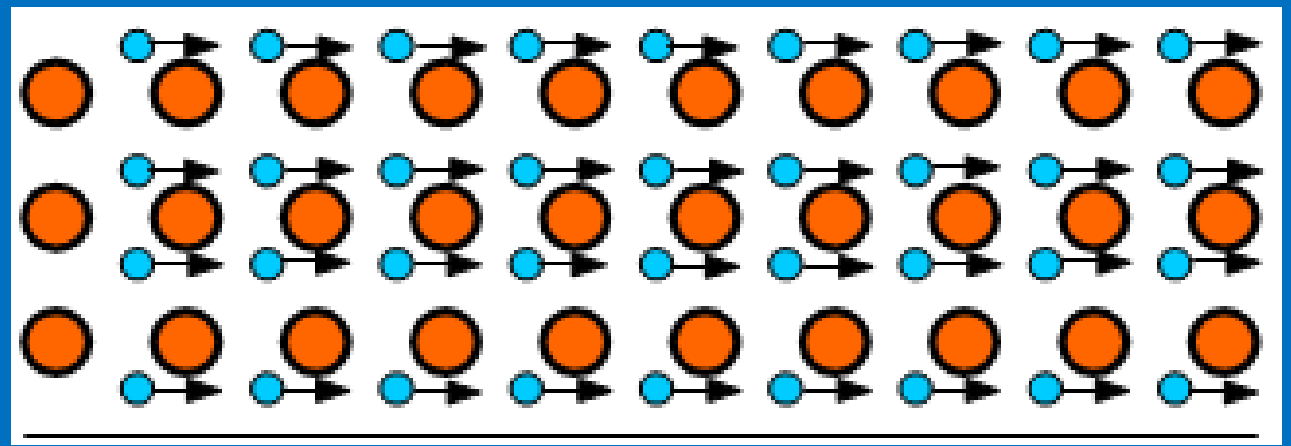
But at the cathode we have no reaction (no reduction, no oxidation). In our case the cathode potential is 0.

In conclusion, only the potential at the anode (zinc) will manifest

$\Delta V_{Cu\text{-}Zn} = 0 - (-0{,}76) = +0{,}76$ V

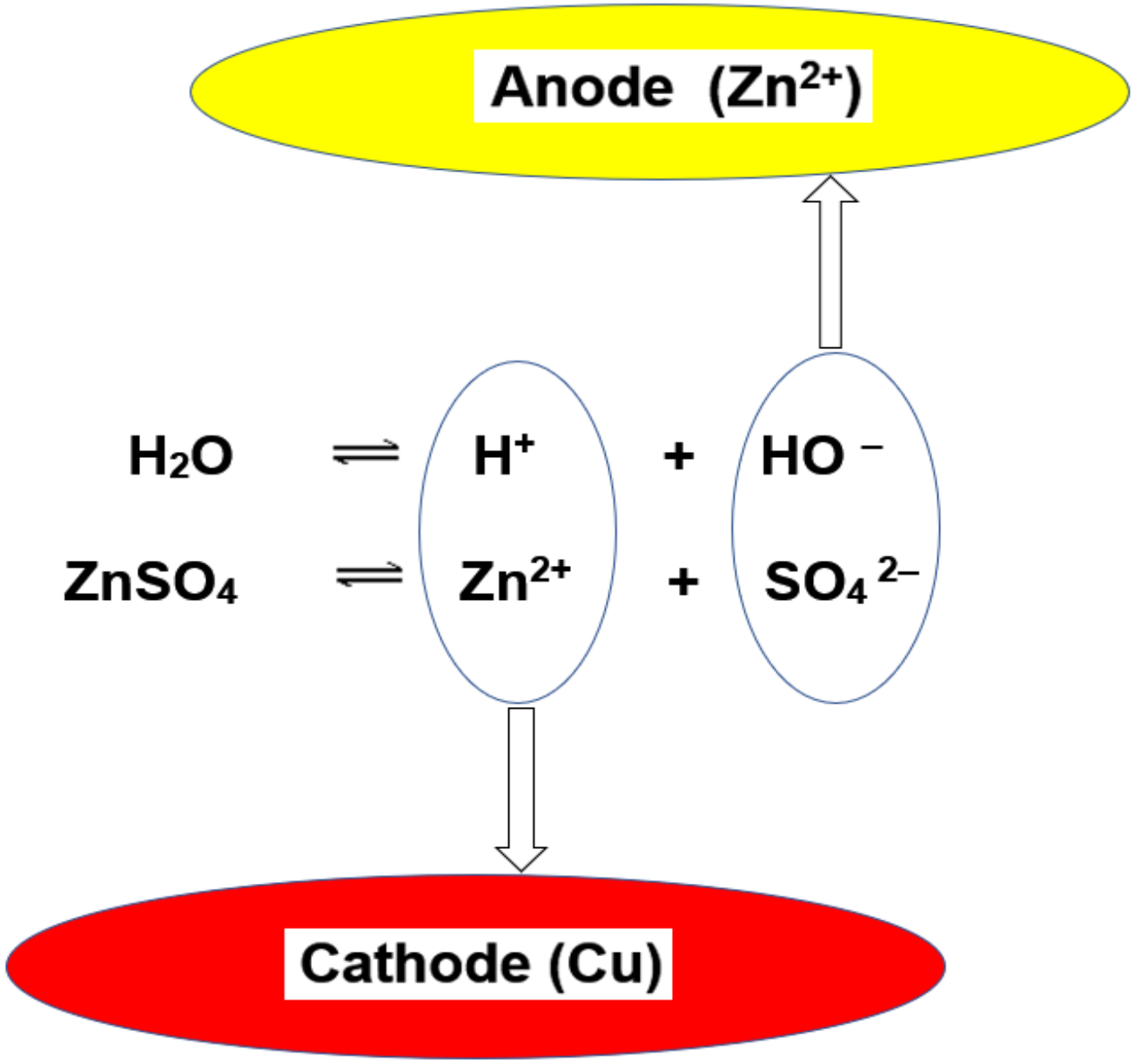
Metal in an electric field

Anode Zn

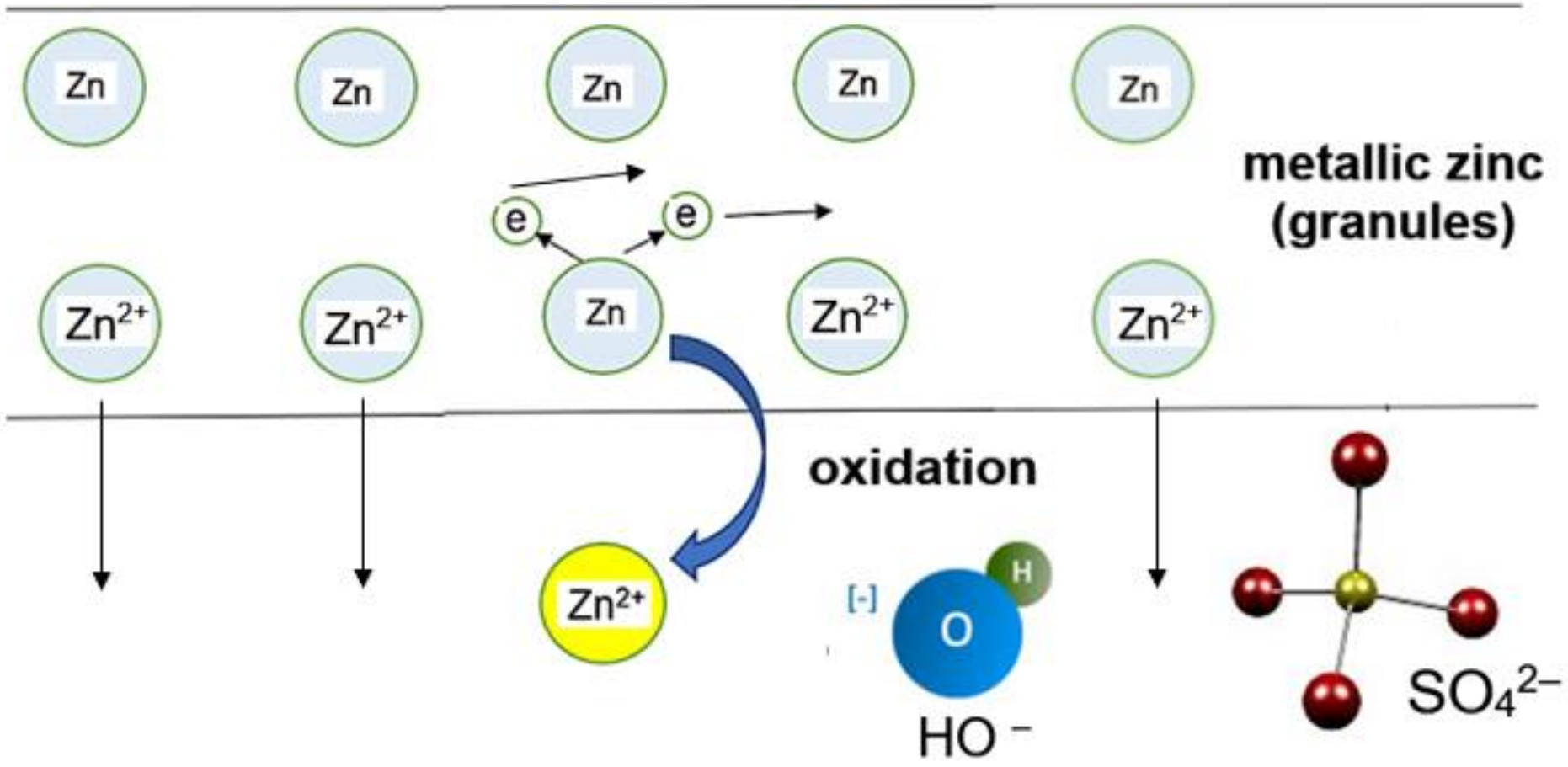


Cathode Cu

H_2O and $ZnSO_4$ dissociation



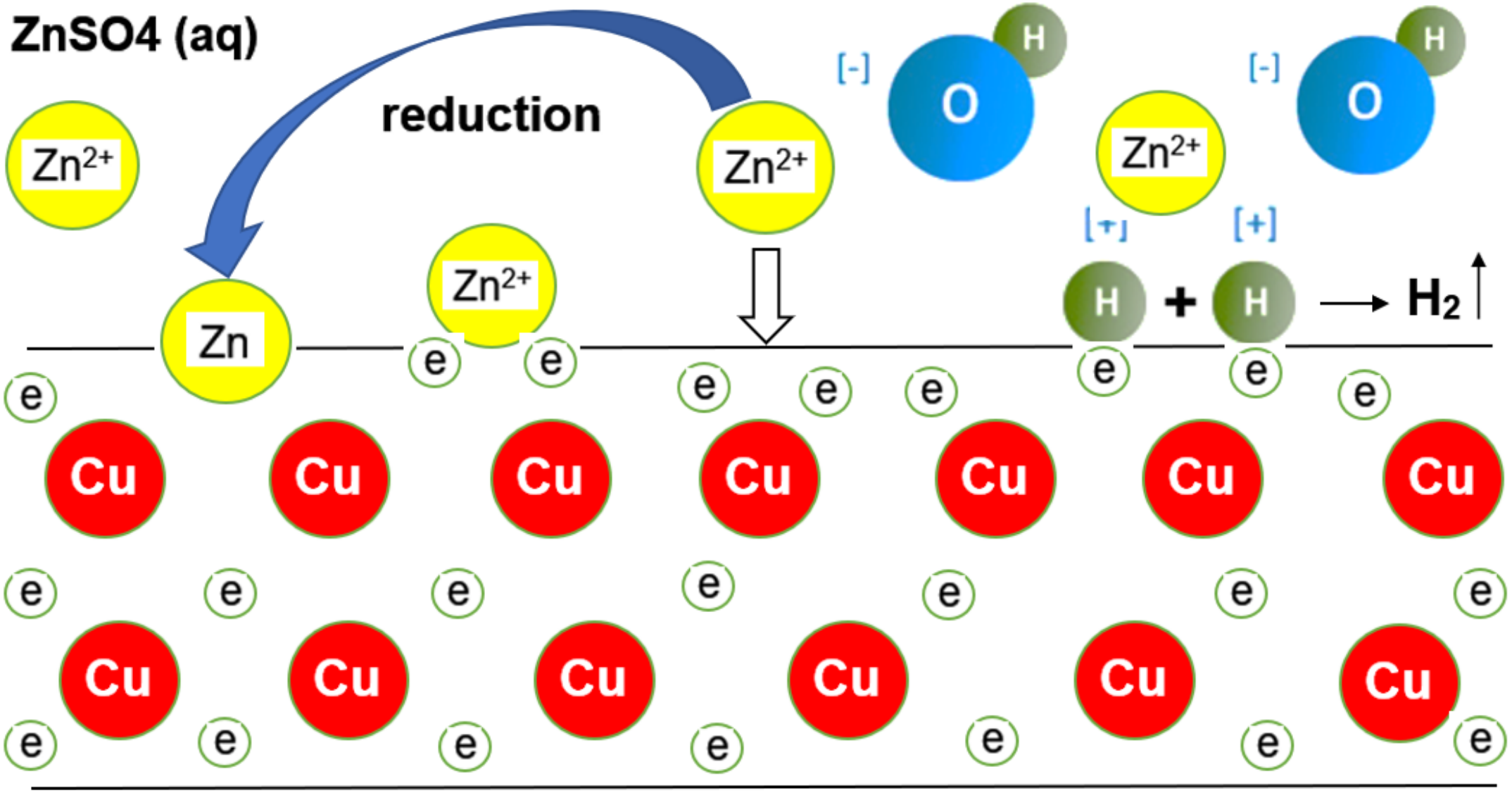
Anode



The solubility of zinc depends on:

- ✓ temperature
- ✓ ph of the solvent

Reaction at cathode



There is no chemical reaction between the copper (cathode) and the electrolyte!

Zinc oxidation – reduction reaction

Anode: $\mathbf{Zn_{Zn} \rightarrow Zn^{2+}\,(aq) + 2e^{-}}$

Zn_{Zn} = zinc that deposits on the granular zinc
Zn^{2+} (aq) = zinc ions from the aqueous solution

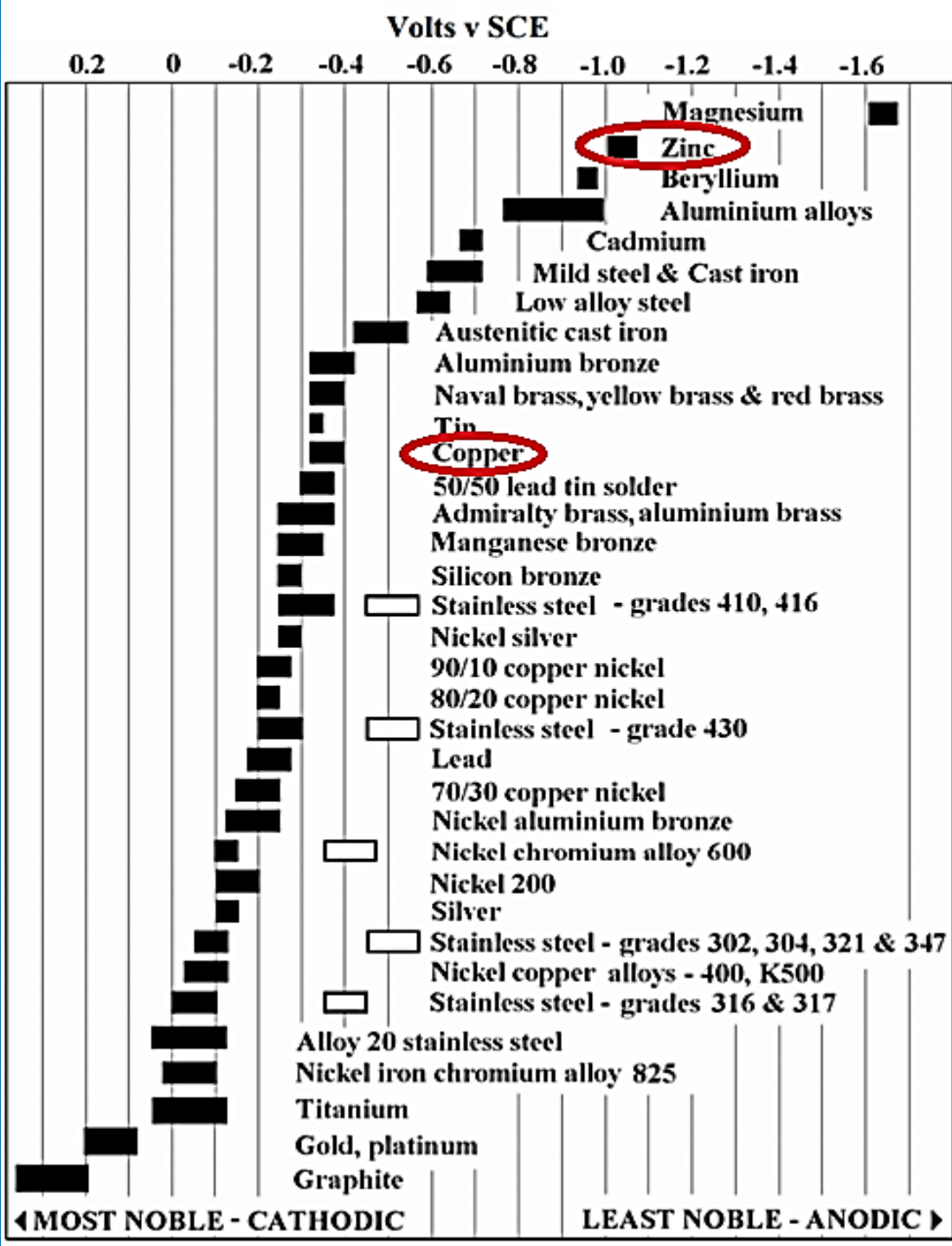
Cathode: $\mathbf{Zn^{2+}\,(aq) + 2e^{-} \rightarrow Zn_{Cu}}$

Zn^{2+} (aq) = zinc ions from the aqueous solution
Zn_{Cu} = zinc that deposits on the copper

What metals can be plated with zinc?

For the galvanization to occur, three conditions must all be present:

- ✓ sufficient potential difference between the metals (for harsh environments: minimum 0.20 V)
- ✓ electrical contact between the metals
- ✓ an electrolyte linking the two metals



1.2 Hypotheses

1. Zinc in the granules will disolve and deposit on the copper coin, a process known as galvanization or zinc plating.

2. Galvanization in the zinc sulphate solution can occur both with copper and other metals (such as iron, nickel) provided that they are less reactive than zinc in the series of chemical reactivity and the electric potential difference is minimum 0.20 V.

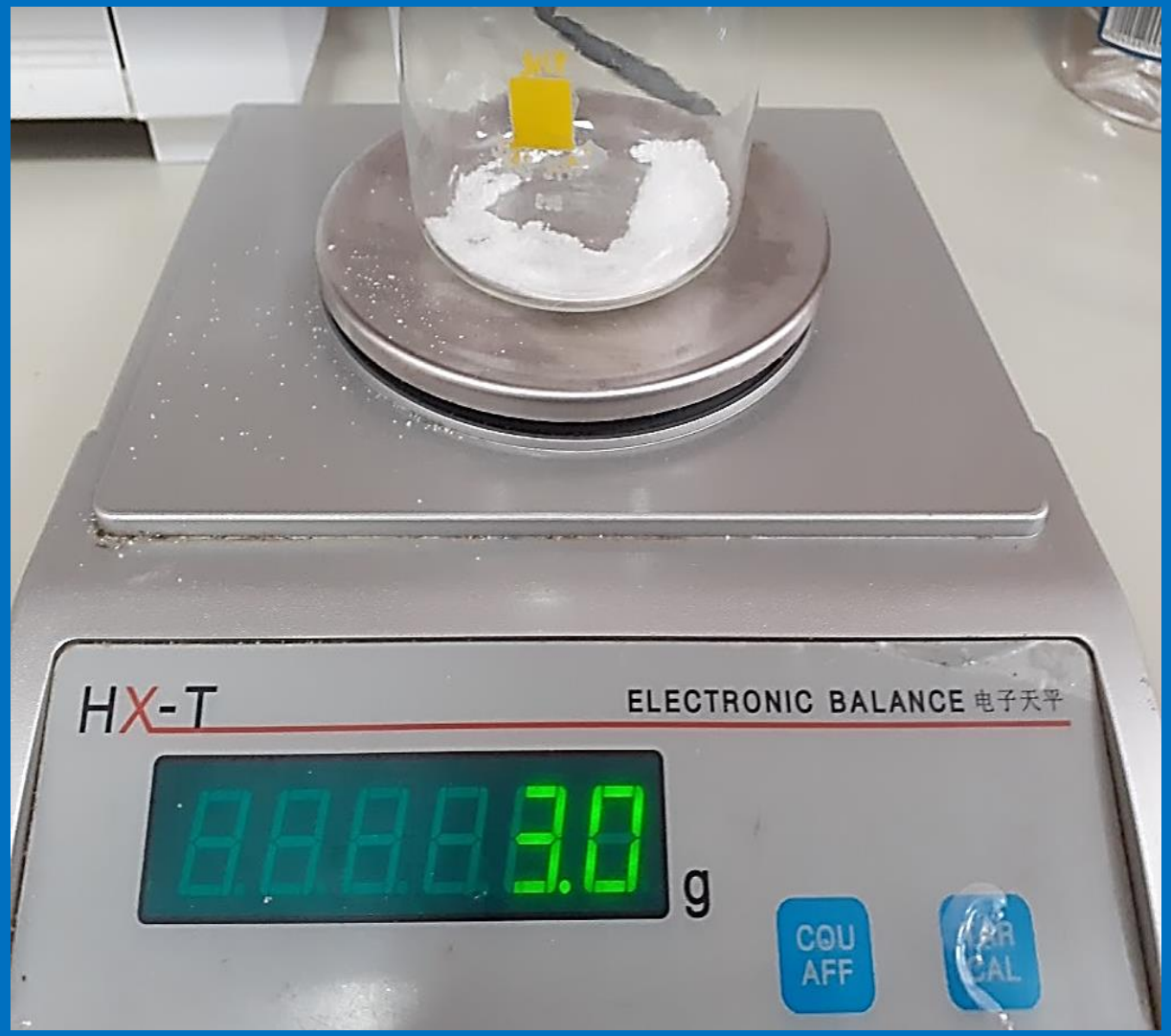
Experimental Part

slides 14 - 29

Necessary materials

- ✓ Two Berzelius beakers: 200 ml and 500 ml
- ✓ Bunsen burner
- ✓ Crucible tongs
- ✓ 40 g zinc sulfate
- ✓ 23 g metallic zinc granules
- ✓ Glass rod
- ✓ Distilled water
- ✓ Well cleaned copper coin
- ✓ Electronic scale
- ✓ PH meter
- ✓ Micrometer
- ✓ Calliper

Cleaning of the copper coin

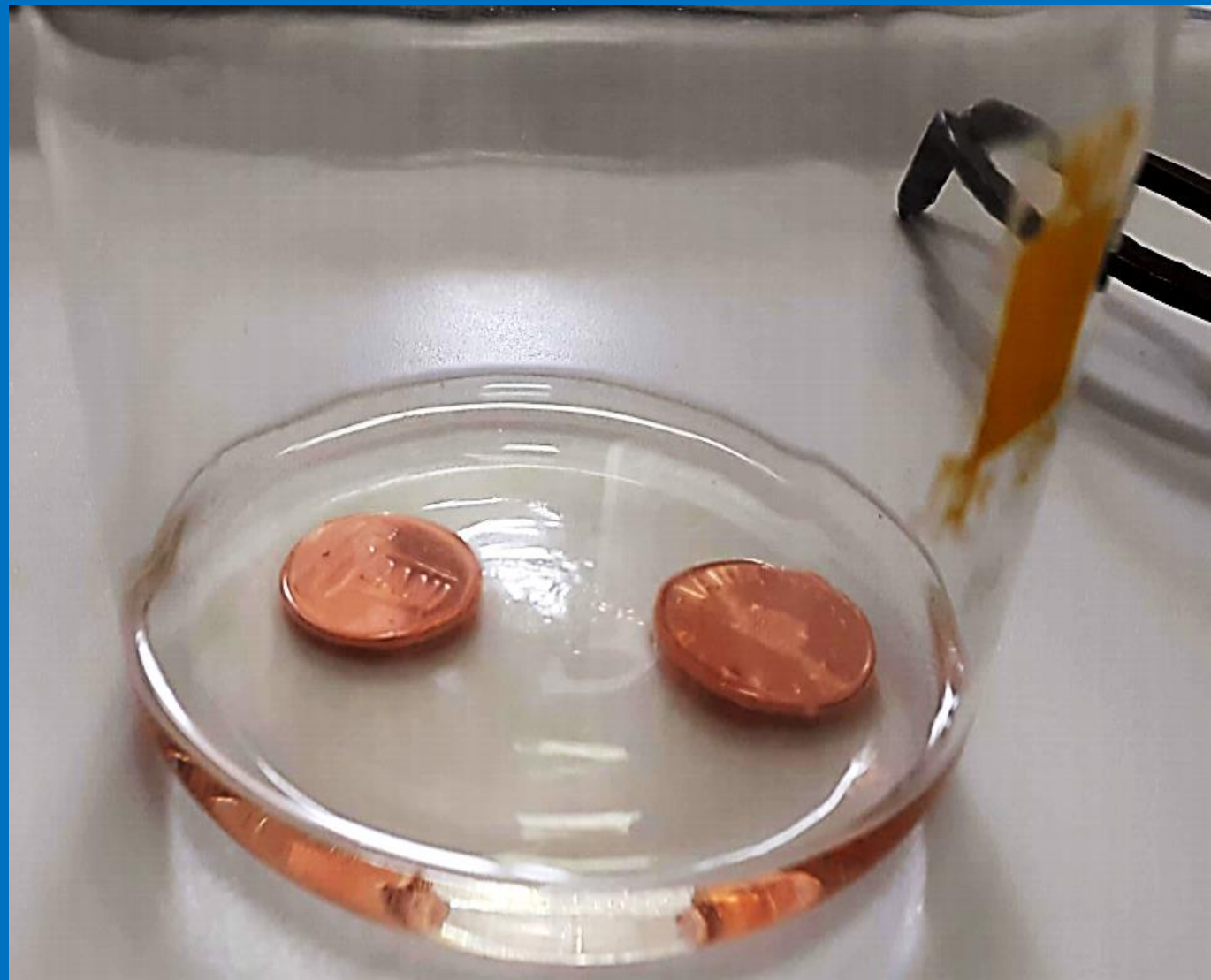


3 g NaCl

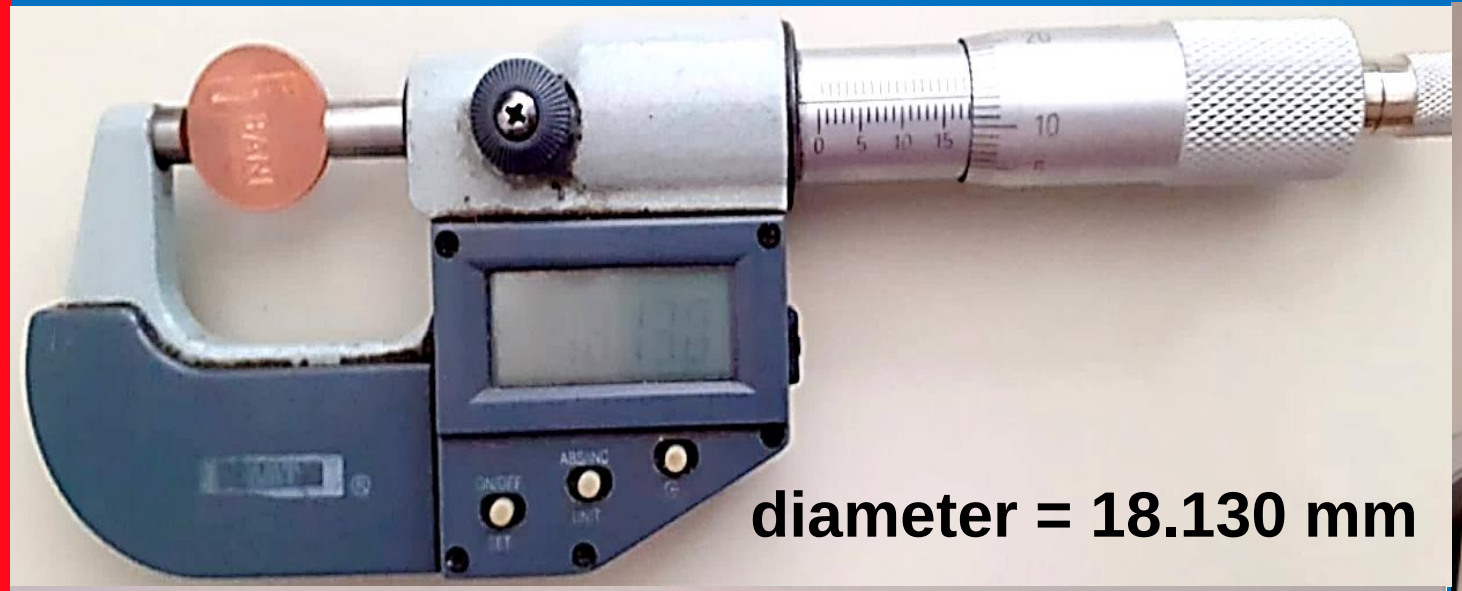
15 ml kitchen vinegar 9%

The cleaning solution

- ✓ Mix in a 100 ml glass 3 g of sodium chloride (table salt) and 15 ml of acetic acid soil. 9% (kitchen vinegar).



Measuring the initial parameters of the coin:

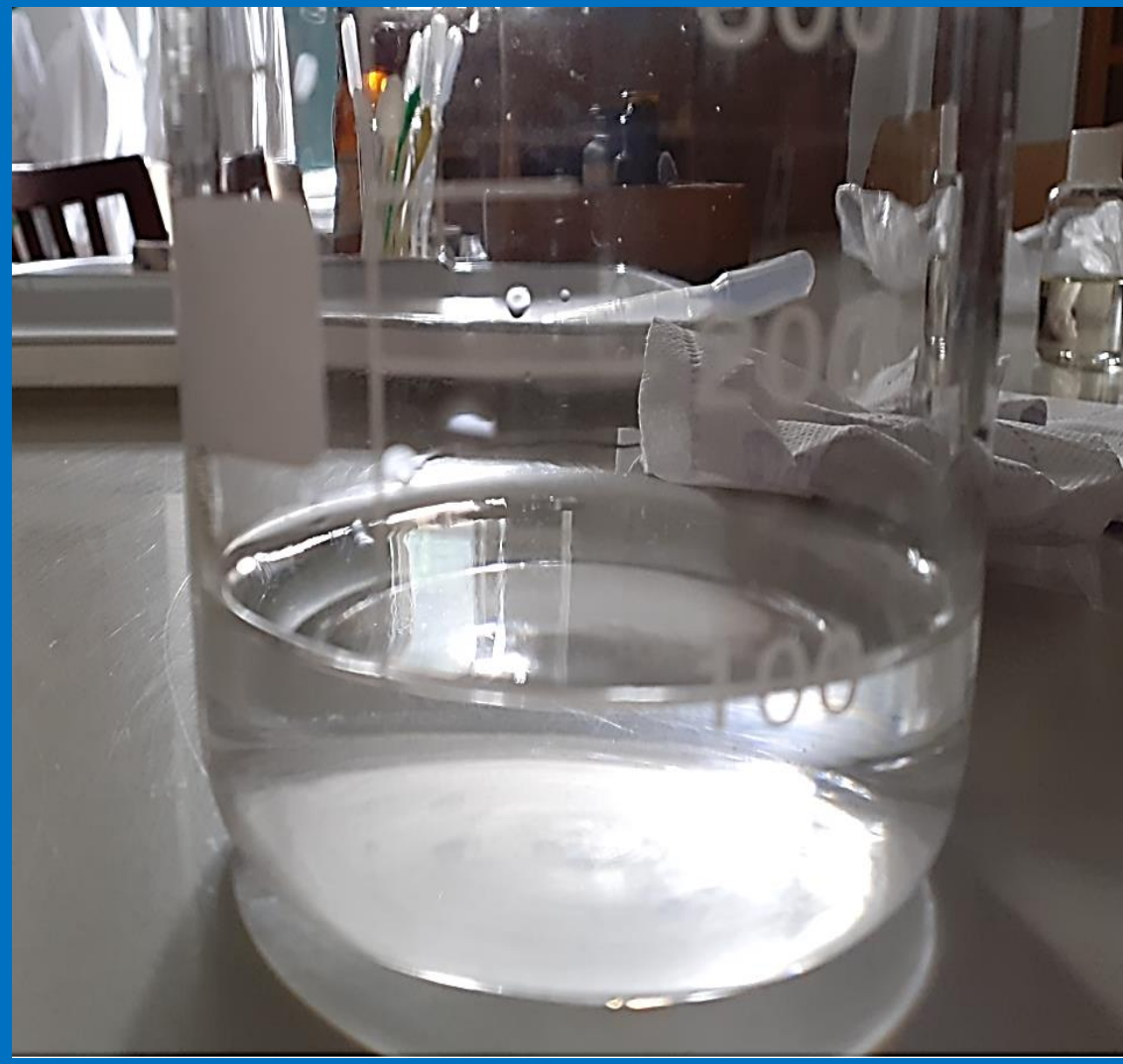


diameter = 18.130 mm

thickness = 1.416 mm

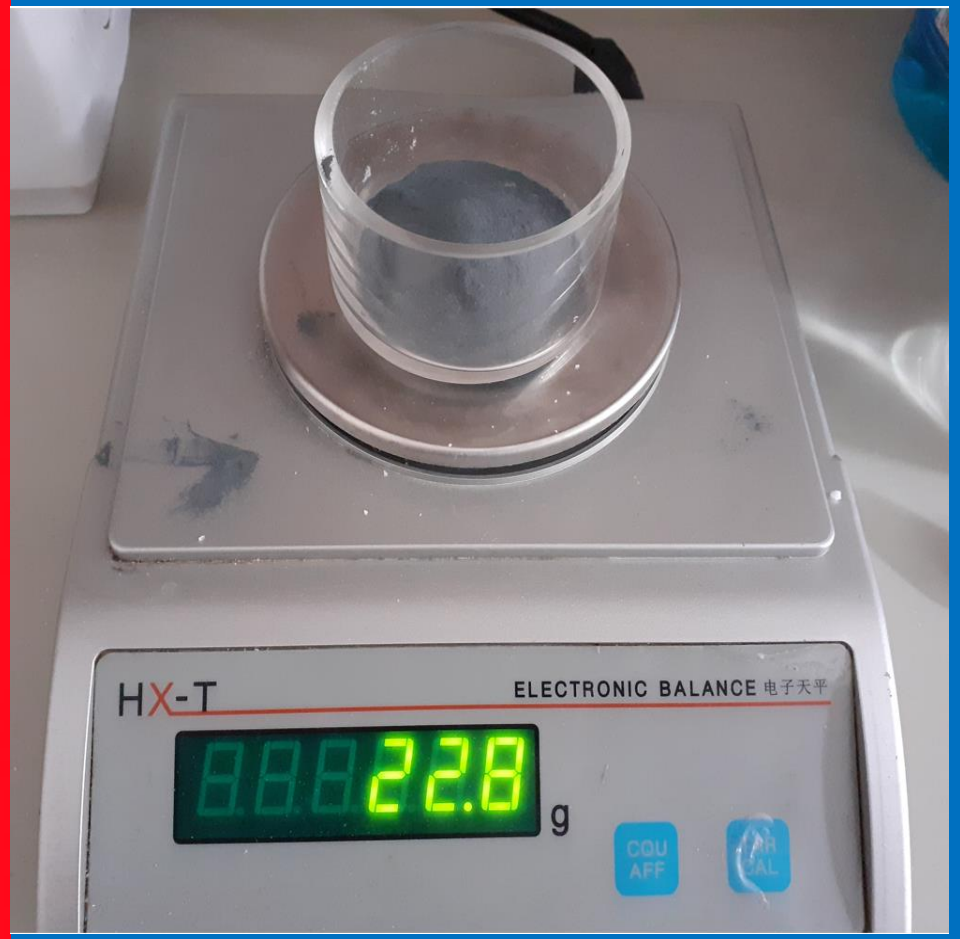
mass = 2.76 g

Conducting the experiment

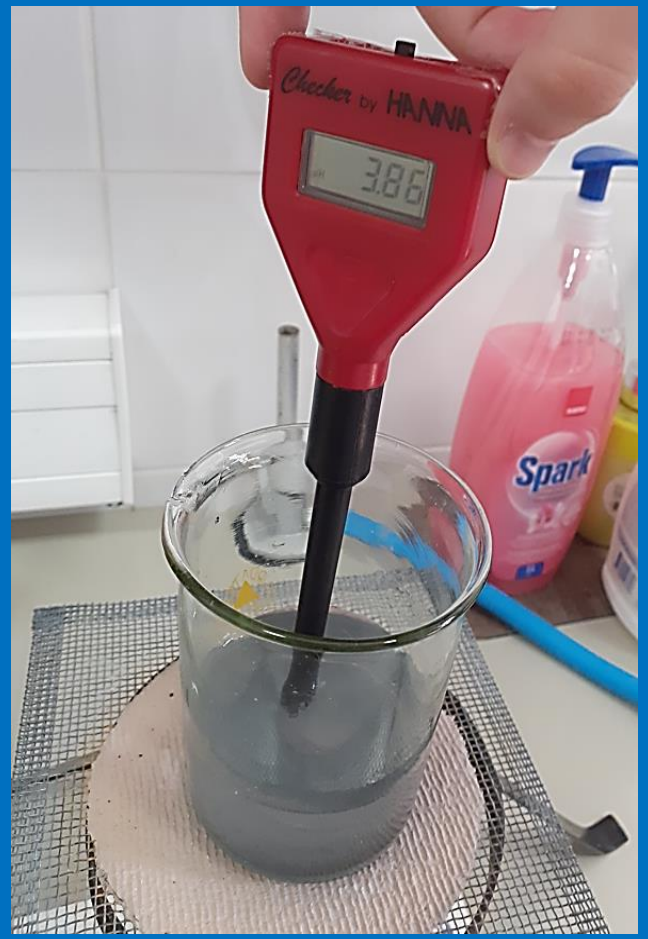


40 g zinc sulfate

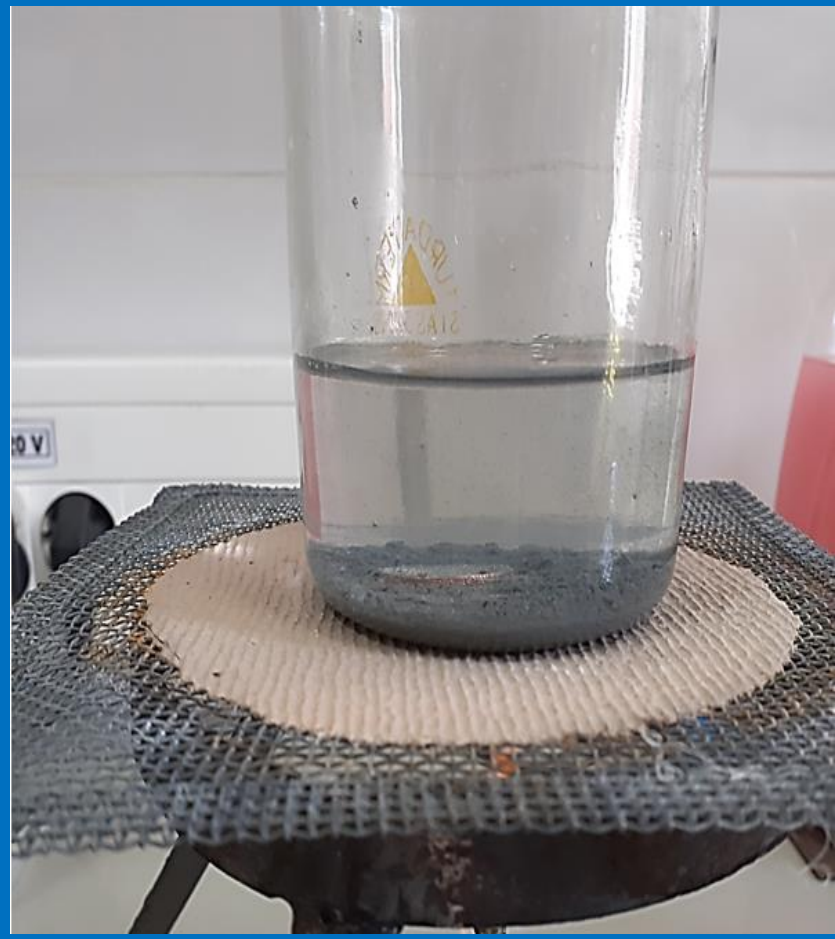
100 ml of distilled water



23 g metallic zinc granules

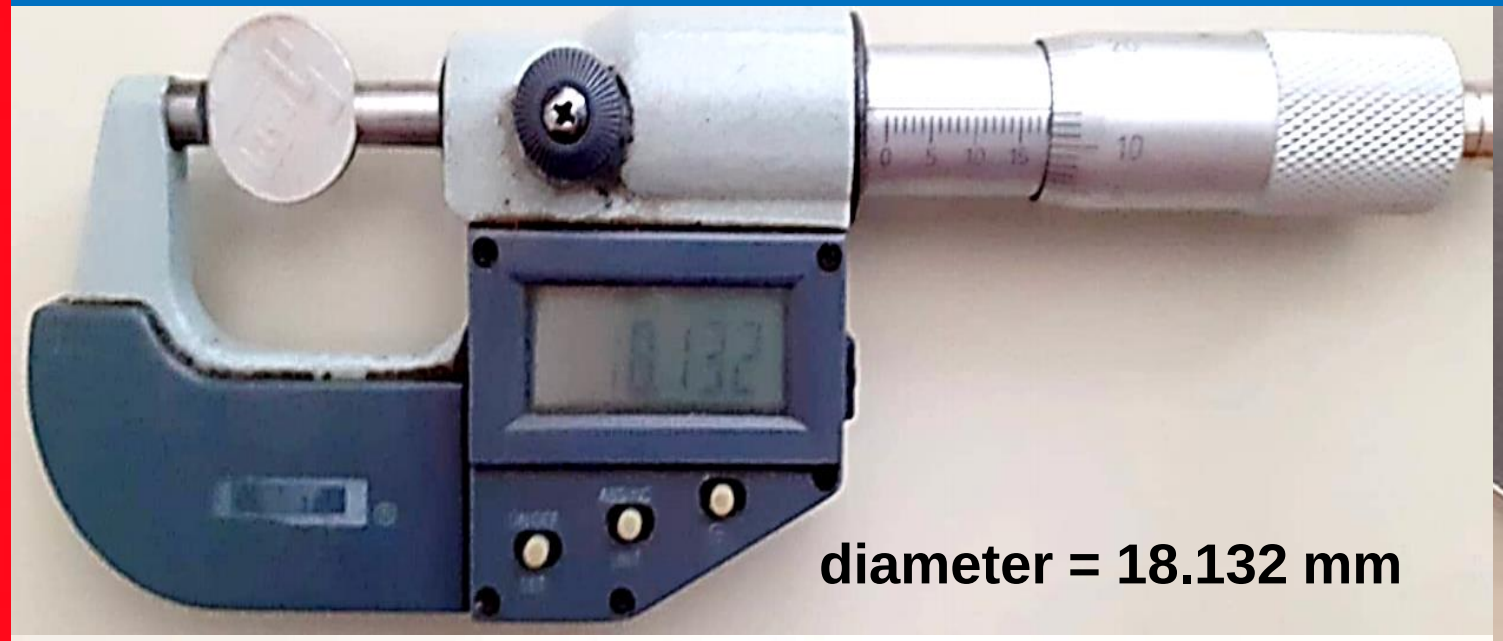


pH = 3.86



heating

Measuring the final parameters of the coin (după placare)



diameter = 18.132 mm

thickness = 1.424 mm

mass = 2,78 g

The modification of the coin's parameters

Values obtained by direct measurement

- ✓ Mass of the zinc deposited on the coin:

  $\Delta m = m_f - m_i$

  $\Delta m = 2.78 - 2.76 = 0.02\ g = 20\ mg$

- ✓ Thickness of the zinc layer on a face: $\Delta l = (l_f - l_i)/2$

  $\Delta l = (1.424 - 1.416)/2 = 0.004\ mm = 4\ \mu m$

Values obtained by calculation

$$\Delta V = \frac{\Delta m}{\rho_{Zn}}$$

$$\Delta V = \frac{0.02\ g}{7.14\ g/cm^3} = 0.0028\ cm^3$$

ρ_{Zn} = zinc density (7.14 g/cm^3)
$\Delta m = m_f - m_i$ = mass of the zinc deposited
ΔV = volume of the zinc layer

We consider the coin as a cylinder and zinc is uniformly placed on the coin.
The increase in volume of the coin (cylinder) is:

$$\Delta V = S_{total} \times \Delta h \Longrightarrow \Delta h = \frac{\Delta V}{S_{total}} = \frac{\Delta V}{2\pi R^2 + 2\pi R h}$$

S_{total} = total area of the surface of the coin
Δh = increase in the coin's thickness

$$\Delta h = \frac{0.0028\ cm^3}{(2*3.14*9.065^2 + 2*3.14*9.065*1.416)mm^2} \cong 0.0047\ mm = 4.7\ \mu m$$

Good job

Waste management

- ✓ The cleaning solution is thrown in the sink.
- ✓ The zinc sulphate solution and the unconsumed zinc granules are recovered
- ✓ **Zinc sulphate is not thrown into the sink (sewer) because it is toxic to the aquatic environment with long-term effects!**

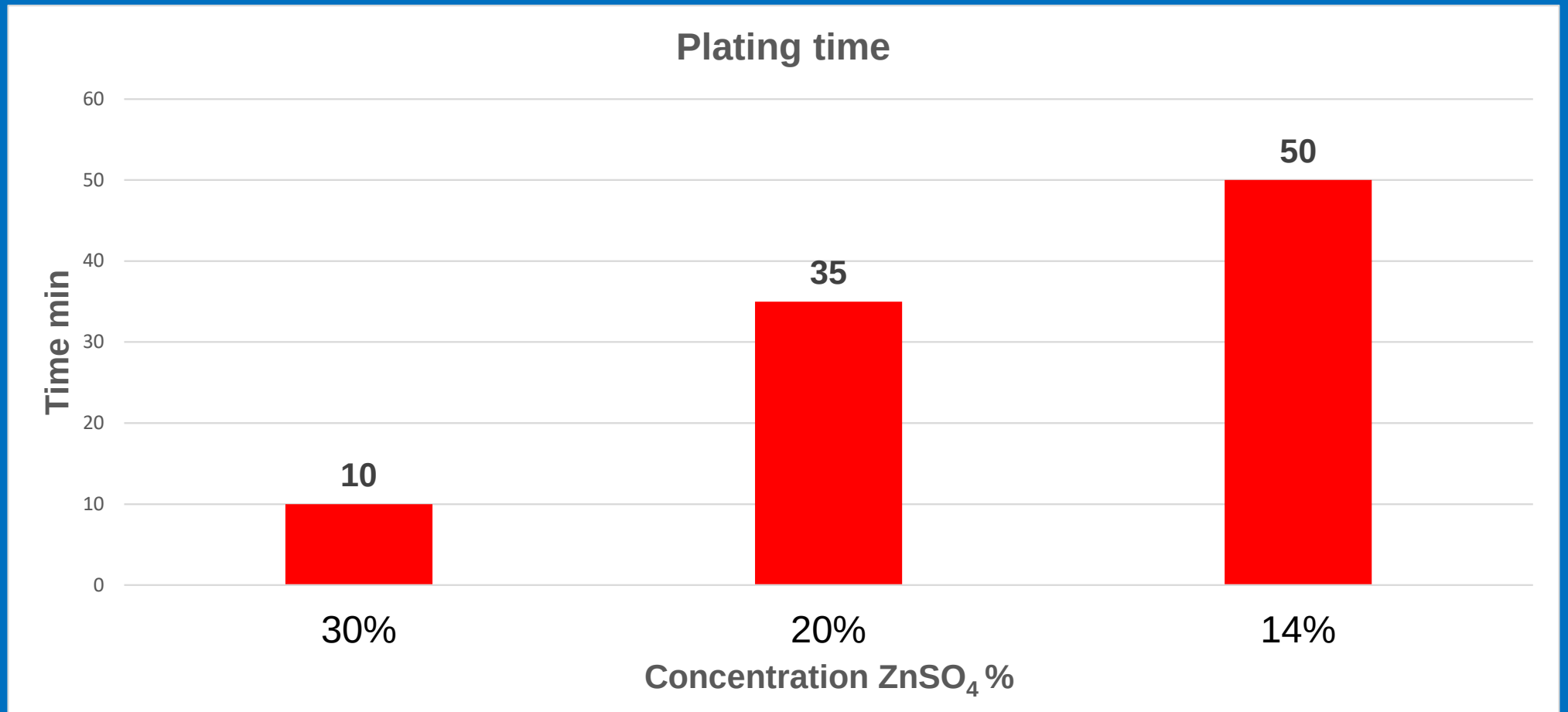
Results and discussions

We have obtained the following results for the zinc plating:

- Copper coin
  - Thickness of the layer on a face
    - ✓ 4 μm (direct measurement)
    - ✓ 4.7 μm (theoretical calculation)
  - Deposited mass: 20 mg
- Nickel coin
  - Thickness of the layer on a face:
    - ✓ 2 μm (direct measurement)
    - ✓ 3.1 μm (theoretical calculation)
  - Deposited mass: 100 mg
- Aluminium coin
  - No plating takes place

The thickness of the zinc layer was influenced by the following parameters:

1. **Boiling period**
2. **Temperature**
3. **The concentration of the zinc sulfate solution.**



4. The pH of the aqueous solution.

5. Zinc granulation

6. Placing copper coins on the zinc granules

7. Cleaning of the copper coin.

Final Part

slides 30 - 33

Conclusions

- ✓ The copper coin is covered with a layer of zinc only if the zinc granules are in contact with the copper coin and both metals are immersed in an electrolyte (zinc sulphate).
- ✓ The thickness of the deposited zinc layer depends on several parameters, the most important of which are: reaction time, temperature, zinc granulation, electrolyte concentration, contact between metals.
- ✓ In addition to copper, other metals that can be visibly plated with zinc have to satisfy two conditions: the potential difference between the metals is greater than 0.20 V and they are located under zinc in the series of chemical reactivity (examples: nickel, iron)

Errors and limitations

It is the kind of experiment in which we have both measurement errors and measurement limits of the instruments used.

1. Instrument measurement limit:

- ✓ Digital micrometer +/- 0.001 mm = +/- 1 µm
- ✓ Electronic scale: +/- 0,01 g = +/- 10 mg

2. Measurement errors due to the experimenter:

- ✓ the screwing force of the micrometer must be between 5 - 10 N, but it is unlikely to apply the same force at two different measurements

3. Errors related to the particularities of the coin: any coin does not have a perfect flatness, it is engraved (otherwise it could not be a coin). These inlays deform the surface of the coin, making it difficult to determine the exact thickness of the coin.

References

https://sites.google.com/a/gapps.smc.edu/timdong/blog/turningcopperpenniesintosilverandgoldpennies

https://www.sciencecompany.com/Turn-Copper-Pennies-Into-Silver-and-Gold-Pennies.aspx

https://www.flinnsci.com/api/library/Download/674479ccda964683ac6201381ffbdb89

https://www.rsc.org/globalassets/03-membership-community/connect-with-others/through-interests/interest-groups/speciality-chemicals/zinc-projectforprimary-schools_tcm18-247271.pdf

https://melscience.com/AU-en/chemistry/experiments/transmutation/

https://translate.google.com/translate?hl=ro&sl=en&u=https://melscience.com/AU-en/chemistry/experiments/transmutation/&prev=search&pto=aue

https://translate.google.com/translate?hl=ro&sl=ru&u=https://melscience.com/RU-ru/articles/eksperiment-zoloto-alhimika/&prev=search&pto=aue

https://www.ncfu.ru/export/uploads/imported-from-dle/op/doclinks2015/Metod_Obsch.i-neorg.him.3_18.03.01.pdf

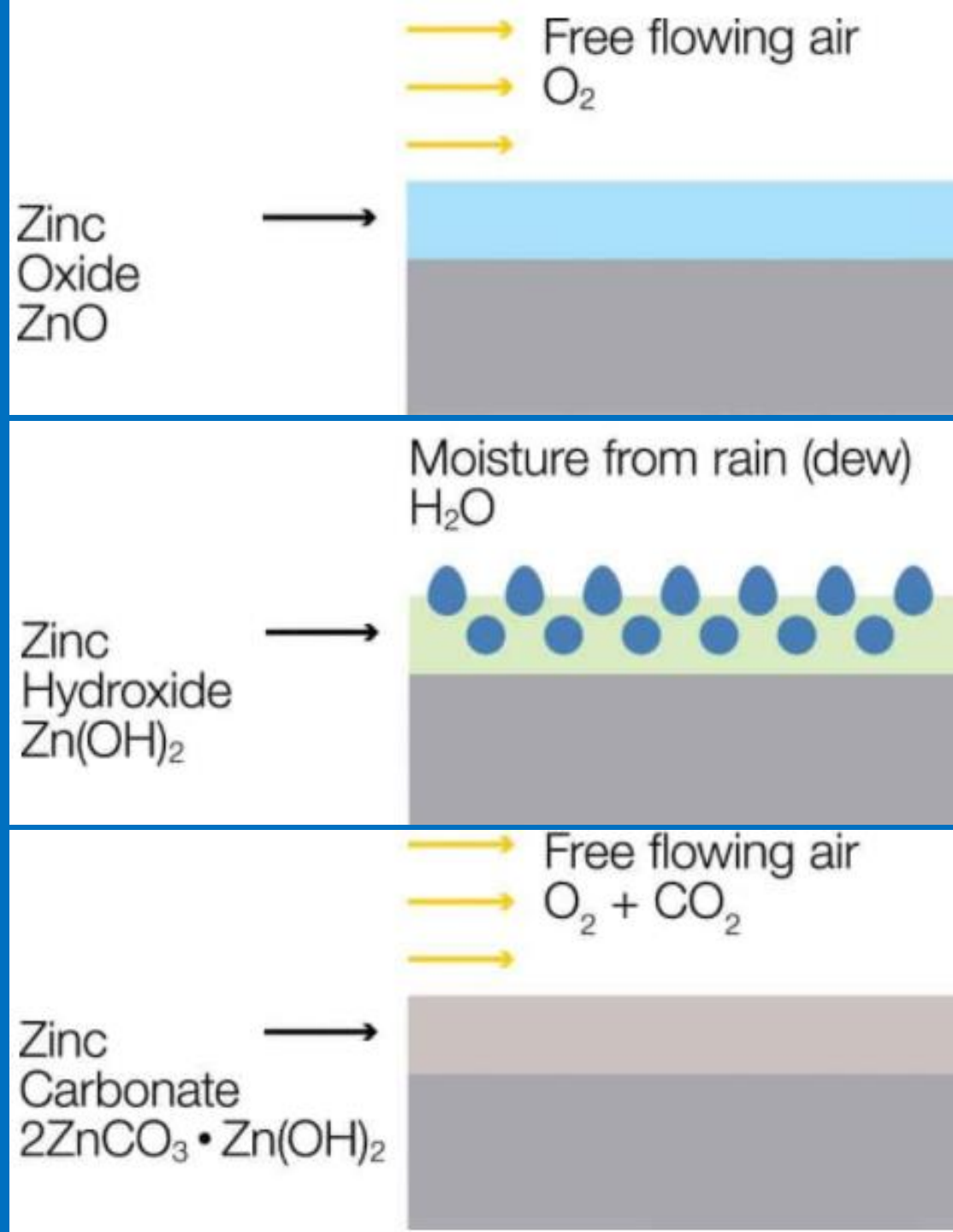
https://translate.google.com/translate?hl=ro&sl=en&u=https://archives.library.illinois.edu/erec/University%2520Archives/1505050/Rogers/Text14/Tx145/tx145.html&prev=search&pto=aue

Appendices

slides 32 - 35

The practical importance of galvanizing

A protective patina is generally made up of insoluble zinc oxides, hydroxides and carbonates, but can contain other basic zinc salts depending on the environment.



Measuring the initial parameters of the nickel coin:

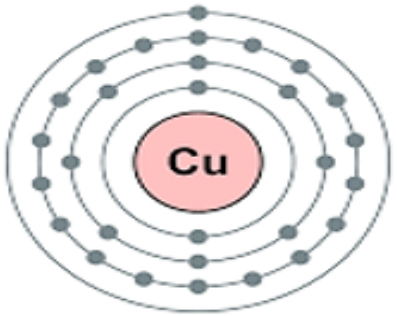
Measuring the final parameters of the nickel coin:

Electronegativity scale of chemical elements (Pauling scale)

K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
0.82	1.00	1.36	1.54	1.63	1.66	1.55	1.83	1.88	1.91	1.90	1.65	1.81	2.01	2.18	2.55	2.96	3.00

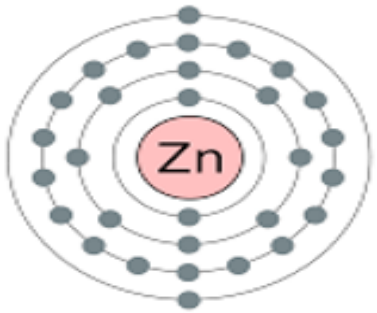
Copper has an electronegativity of 1.9, while zinc has a 1.65 electronegativy on the Pauling scale. This means that more energy is needed to remove the 2 valence electrons from copper than from zinc. In order to In order to remove the second electron, the second ionizing energy of zinc is 1733,3 KJ / mol, iar pentru Cu de 1957,9 KJ / mol. Copper yields the second electron harder compared to zinc.

29: Copper 2,8,18,1



Cupru: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

30: Zinc 2,8,18,2



Zinc: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

Zinc second electron is on 4s layer, while copper second electron is on 3d layer. As the electrons on the 3d layer (layer closer to the nucleus) are more stable than those on the 4s layer, removing the second electron from the copper will require a greater amount of energy than in the case of zinc.