Name of the project:	**Digitization of chemistry experiments to improve the quality and support chemistry teaching in secondary schools**
Acronym:	**ChemIQSoc**
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Tittle: Electrolysis and metal coating

Work instructions

Task:

1. Perform electrolysis of NaCl, observe the formation of gaseous hydrogen, prove the formation of gaseous chlorine and the formation of basic NaOH.
2. Perform electrolysis of $CuCl_2$, prove the formation of gaseous chlorine and observe the precipitation of copper on the cathode.

Theory

Electrolysis is the decomposition of chemical substances–electrolytes by the action of direct electric current. An electrolyte is a solution or melt that contains freely movable electrically charged particles–ions, which can conduct electric current.

Electrolysis takes place in an electrolyser, which consists of a container for the electrolyte, a negatively charged electrode–cathode, a positively charged electrode–anode and a source of direct electric current.

Electrolysis can be utilised to perform a metal coating, while a coated object is a cathode.

Electrolysis of sodium chloride

Reactions that take place on the electrodes:

Anode:

Oxidation: $\mathbf{2\ Cl^- + 2\ e^- \rightarrow Cl_2^0\ (g)}$ (1)

Cathode:

Reduction 1: $\mathbf{2\ H^I_2O + 2\ e^- \rightarrow 2\ OH^- + H_2^0\ (g)}$ (2)

At the same time, the following reaction takes place on the cathode:

Reduction 2: $\mathbf{2\ Na^+ + 2\ e^- \rightarrow 2\ Na^0}$ (3)

Sodium is very reactive and immediately reacts with the present water:

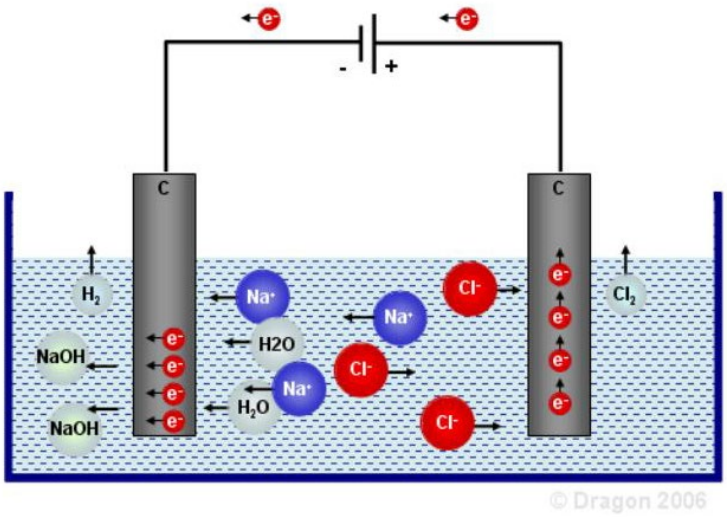
$\mathbf{2\ Na^0 + 2\ H^I_2O \rightarrow 2\ Na^IOH\ (aq) + H_2^0\ (g)}$ (4)

Summary reaction of electrolysis of NaCl solution

$\mathbf{2\ Na^ICl^{-I}\ (aq) + 2\ H^I_2O^{-II} \rightarrow 2\ Na^IO^{-II}H^I\ (aq) + H_2^0\ (g) + Cl_2^0\ (g)}$ (5)

We also write:

$$Na^{+} + 2\ Cl^{-I} + 2\ H^{+} + 2\ OH^{-} \rightarrow 2\ Na^{I}O^{-II}H^{I}\ (aq) + H_2^0\ (g) + Cl_2^0\ (g) \quad (6)$$



Proof of sodium hydroxide with phenolphthalein

Bubbles of chlorine are formed on the anode; hydrogen is formed on the cathode. Sodium hydroxide is also formed near the cathode, which causes a change in pH around the electrode, and therefore the basic solution around the cathode turns pink to purple in the presence of phenolphthalein.

Proof of chlorine with iodide-starch paper:

The resulting yellow-green gaseous chlorine can be proved by moistening iodide-starch paper (paper soaked in starch and potassium iodide). Chlorine reduces iodine from potassium iodide KI and then stains starch in paper blue (sometimes purple-blue and if there is more iodine, the colour remains dark brown from the present iodine).

Writing down the reaction to prove the presence of chlorine:

$$Cl_2^0 + 2\ K^{I}I^{-I} \rightarrow 2\ K^{I}Cl^{-I} + I_2^0 \quad (7)$$

Equipment: electrolytic bath, two carbon electrodes, source of direct electric current, laboratory lifting stool, stands, cables, clamps

Chemicals: sodium chloride, phenolphthalein, iodide-starch paper

Procedures:

1. Prepare a saturated solution of NaCl.
2. Pour the saturated solution of NaCl into the electrolytic bath.

3. Add a few drops of phenolphthalein, moisten the iodide-starch paper with distilled water and fold it over the anode.
4. Connect electrodes to a source of direct electric current (cathode to negative pole and anode to positive pole) and immerse them in the electrolyte.
5. Turn on the source of direct electric current and observe the process taking place in the electrolytic bath.

Electrolysis of copper chloride and copper plating

Reactions that take place on the electrodes:

Cathode(s):

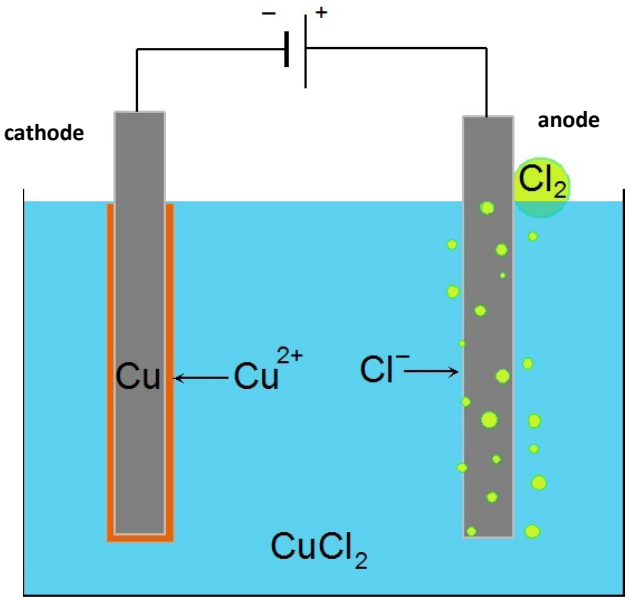
$$\mathbf{Cu^{2+} + 2e^- \rightarrow Cu^0\ (s)} \quad (1)$$

Anode:

$$\mathbf{2\ Cl^{-I} + 2\ e^- \rightarrow Cl_2^0\ (g)} \quad (2)$$

Summary reaction of electrolysis of $CuCl_2$ solution

$$\mathbf{Cu^{II}Cl_2^{-I}\ (aq) \rightarrow Cu^0\ (s) + Cl_2^0\ (g)} \quad (3)$$



Equipment: electrolytic apparatus (electrolytic bath, two carbon electrodes, DC current source), laboratory lifting table, stands, cables, clamps

Chemicals: copper chloride, iodide-starch paper

Procedures:

1. Prepare a saturated solution of $CuCl_2$.
2. Pour the saturated solution of $CuCl_2$ into the electrolytic bath.
3. Connect electrodes to a source of direct electric current (cathode to negative pole and anode to positive pole) and immerse them in the electrolyte.
4. Moisten the iodide-starch paper with distilled water and fold it over the anode.
5. Turn on the source of direct electric current and observe the process taking place in the electrolytic bath.
6. After finishing electrolysis, we can see a red brown layer of copper on the cathode.

Management of chemical substances

Chemicals	Form	H-statements	P-statements
NaCl	Solid	---	---
$CuCl_2$	Solid	H302, H319, H335, H315, H410	P261, P280, P305, P351, P338

Sources of risk and assessment of risk severity

When following all the principles for working with chemicals and using personal protective equipment (gloves, goggles, lab coat), there is no risk.

Waste management method

Chemicals should be disposed of in designated collection containers.

Risk reduction measures

Use of personal protective equipment (goggles, gloves, lab coat). When working with electrical equipment, increased caution is required, the device must be checked, turned on and off by the teacher.

References

1. Lišková, K.: *Chemické laboratórne cvičenia 1: Pre 1. ročník SPŠCH*. 2. vyd. Bratislava: PRÍRODA, 2001. ISBN 8007006877.

Worksheet

Calculations

1. Calculate the quantity of sodium chloride required to prepare 1 dm^3 of saturated solution at temperature 20 °C.
   s(NaCl, 20°C) = ... g compound/100 g solution

2. Calculate the amount of copper chloride required to prepare 1 dm^3 of saturated solution at temperature 20 °C.
   s($CuCl_2$, 20°C) = ... g compound/100 g solution

Observation

1. Describe the processes that take place at the cathode and anode during the electrolysis of a saturated copper chloride solution.

2. Describe the appearance and odour of the products of electrolysis of saturated copper chloride solution.

3. Search for the basic physicochemical properties of the products of electrolysis of saturated copper chloride solution.

Feature	Copper	Chlorine
Solubility in water		
Solubility in other solvents		
Melting point		

Questions

1. Write the equations of the reactions that take place in the electrolysis of a saturated copper chloride solution at the cathode and anode.
   Cathode:
   Anode:

2. Indicate at which electrode the same product is formed during the electrolysis of a saturated solution of cupric chloride and sodium chloride.

3. Indicate from what material the electrodes for the electrolysis of cupric chloride solution can be made.

4. Describe how you prove the sodium hydroxide and chlorine that are formed in the electrolysis of a copper chloride solution.

5. Suggest how to prepare iodide-starch paper.

6. Explain why the electrolysis of saturated sodium chloride solution does not produce sodium.

7. Suggest how sodium can be prepared by sodium chloride electrolysis.

8. Describe the use of electrolysis on an industrial scale.

9. Describe the uses of copper and chlorine.

Conclusion

Briefly summarize the objective of the experiment, the main results and compare them with the expected values.

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