Name of the project:	**Digitization of chemistry experiments to improve the quality and support chemistry teaching in secondary schools**
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Tittle: Preparation of copper by cementation

Work instructions

Task: Prepare 3 g of Cu by cementation.

Theory

Use of the Becketov's series

Already in the work Dissolution of metals in acids, you have been introduced to the Beketov's metal displacement series (Scheme 1). One of the main pieces of information that can be gleaned from this series is the possibility of displacing one metal from a compound by another. This information can be very useful for the preparation of basic inorganic compounds.

Li, Cs, K, Ca, Na, Mg, Sc, Al, Ti, Zn, Cr, Ga, Fe, Cd, Co, Ni, Sn, Pb, H, Cu, Ag, Hg, Pt, Au

Diagram 1 – Beketov's metal displacement series. In orange (to the left of H) are the non-noble metals. The noble metals are on the right of hydrogen and are shown in green. Underlined are then iron and copper, which we use in this work.

If we have a metal in a soluble compound in a suitable oxidation state, it is possible to reduce this metal from solution by using the metal to the left of it. For example, copper from blue vitriol can then be recovered by, for example, placing aluminium foil or an iron nail in the blue vitriol solution. It is quite common to use aluminium and iron, which are the cheapest metals for this type of reaction.

$$\mathbf{CuSO_4 + Fe \rightarrow FeSO_4 + Cu} \quad (1)$$

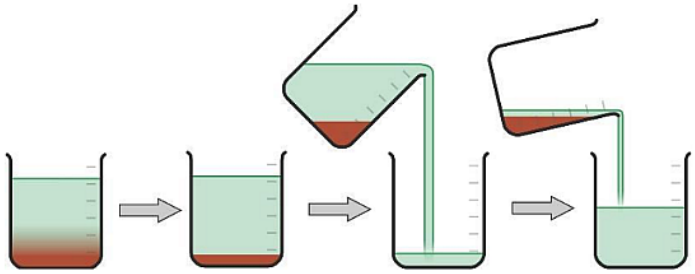
$$\mathbf{3\ CuSO_4 + 2\ Al \rightarrow Al_2(SO_4)_3 + 3\ Cu} \quad (2)$$

We can say that the metals on the right side of the Beketov's series prefer to occur in elemental form (for example, copper in wire or crystal form), while the left side of the series prefers to occur in a compound (sodium in sodium chloride, elemental sodium does not occur in nature).

Decanting

It is the process of separating solid and solution from a suspension without using a filter baffle. As a rule, it is resorted to if the solid in suspension has a sufficiently high density (metals are almost ideal, otherwise filtration is preferable). The suspension is stirred and then left to rest to allow the solids to sink to the bottom. Then carefully pour off the solution (the solid portion

should not go into it–stop pouring as soon as the precipitate approaches the beaker beak or the rim of the container). If clean water is subsequently added to the liquid-depleted suspension and the process repeated, it is possible to wash the impurities out of the precipitate in this way.



Copper

It is one of the so-called non-ferrous metals. These metals are not silvery or grey, but in the case of copper, for example, they can be reddish brown. Copper is the first metal that humanity learned to modify. The low melting point and the ease of reduction, thanks to its nobility, helped to make it so. When mixed with tin, it forms bronze, which was the first alloy used by humankind on a mass scale. Also significant are its thermal and electrical conductivity, softness, malleability, and ductility, which make it an ideal material for power line wires and wiring.

Equipment: beakers (400, 1000 ml), graduated cylinder, glass rod, burner, wire gauze, tripod, scales, crystallisation dish, watch glass, Büchner funnel, suction flask, water jet pump, filter paper

Chemicals: copper sulfate pentahydrate, ferrous sulfate heptahydrate, copper, iron

Procedures:

1. Prepare a 10% $CuSO_4$ solution in a 1000 ml beaker. First measure 63 ml of water into it and then add 11.8 g of $CuSO_4 \cdot 5H_2O$.
2. Prepare a 10% solution of $FeSO_4$ in a 400 ml beaker. Again, first measure 59 ml of water into it and then add 13.1 g of $FeSO_4 \cdot 7H_2O$.
3. Add the $FeSO_4$ solution to the $CuSO_4$ solution in a 1000ml beaker and heat to boiling.
4. Weigh out the 2.9 g of iron nails needed to prepare the specified amount of Cu and add them into a hot solution of $CuSO_4$ and $FeSO_4$.
5. During the reaction, peel off the excluded copper from the Fe nails with a glass rod, stir the reaction mixture and maintain at boiling point.
6. The end of the reaction is indicated by the change in colour of the solution from blue to light green. On the nails, the copper stops being excluded or the nails dissolve completely.

7. Pour the solution over the copper into a crystallisation dish and leave until the next laboratory exercise.
8. Allow $FeSO_4 \cdot 7H_2O$ to crystallise by free evaporation of the solvent (to prevent oxidation of Fe^{2+} to Fe^{3+}, add 1 iron nail and a drop of concentrated H_2SO_4 to the solution in the crystallisation dish).
9. Decant the green $FeSO_4$ solution from copper into a separate beaker and then wash the copper with 100 ml of water.
10. Decant this water (into the waste beaker) and repeat the whole procedure twice more.
11. Next lab exercise $FeSO_4 \cdot 7H_2O$ crystals obtained by free evaporation of the solvent by crystallisation are also aspirated on a Büchner funnel, dried and weighed.

Management of chemical substances

Chemicals	Form	H-statements	P-statements
$CuSO_4 \cdot 5H_2O$	Solid	H302, H319, H315, H410	P273, P302 + P352, P305 + P351 + P338
$FeSO_4 \cdot 7H_2O$	Solid	H302, H319, H315	P305 + P351 + P338, P302 + P352, P280
Cu	Solid, powdered	H228, H410	P210, P273
Fe	Solid, nails	---	---

Sources of risk and assessment of risk severity

Copper sulfate is harmful if ingested, irritates the skin, and penetrates the skin. Causes serious eye irritation. It is highly toxic to aquatic organisms, with long-term effects. Powdered copper is toxic to aquatic organisms and can be an irritant. Green vitriol has irritating effects on eyes and mucous membranes. Students use protective equipment when working with these substances. Weighing and handling of these substances is done under the supervision of the teacher. Acceptable risk.

Waste management method

Residues of copper sulfate pentahydrate, powdered copper and green vitriol shall not be disposed of with municipal waste and shall not be discharged to sewers. In the event of spillage, sweep up the substance and place it in a carefully labelled closed container provided for this purpose.

Risk reduction measures

Wear a face shield or safety glasses. Wear protective gloves. Gloves must be inspected before use. Use proper glove removal technique without touching the outer surface of the gloves to prevent skin contact with this product. Do not eat, drink, or smoke while working. Wash hands with soap and water after work or when work is interrupted or treat with a protective cream. In case of an accident or if you feel unwell, inform the teacher immediately. Prevent further leakage or spillage unless there is a risk involved. Do not allow to enter drains. Prevent discharge into the surrounding environment.

Worksheet

Chemical calculations and evaluation

Calculate the relative yields of Cu and $FeSO_4 \cdot 7H_2O$.

$CuSO_4 \cdot 5H_2O + 2\ H_2O + Fe \rightarrow FeSO_4 \cdot 7H_2O + Cu$

1. Calculate the amount of $CuSO_4 \cdot 5H_2O$ needed to prepare the specified amount of Cu.

2. Calculate the amount of water required to prepare a 10% $CuSO_4$ solution.

3. Calculation of the amount of Fe needed to prepare the specified amount of Cu (+10% extra).

4. Calculating the equimolar amount of $FeSO_4 \cdot 7H_2O$. Equimolar amount means the same number of moles. So, we must first determine how many moles of $CuSO_4 \cdot 5H_2O$ we have in the reaction mixture. We add the same number of moles of $FeSO_4 \cdot 7H_2O$.

5. Add the same number of moles of $FeSO_4 \cdot 7H_2O$. As with $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$ can be viewed as an aqueous solution. First calculate its concentration and then use the cross rule to calculate the amount of water needed to dilute it to a 10% solution.

6. Calculation of the relative yield of Cu

Yield	**Value**
Theoretical yield	
Practical yield	

$$RV = \frac{PV}{TV} \cdot 100$$

7. Calculation of the relative yield of $FeSO_4 \cdot 7H_2O$

Yield	**Value**
Theoretical yield	
Practical yield	

$$\boldsymbol{RV = \frac{PV}{TV} \cdot 100}$$

Conclusion

Evaluate your work.