

Colour, complexes and catalysis in the d-block

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

What colours do copper(II) complexes show when the ligands change, and how can a colorimeter turn colour into a concentration? You will make four complex ions, explain the colour changes, and use a calibration graph to find the concentration of an unknown ammonia complex solution.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.2.5

Aim

To make different copper(II) complex ions by ligand substitution, record their colours and use a colorimeter to find the concentration of an unknown solution of tetraamminecopper(II).

Equipment

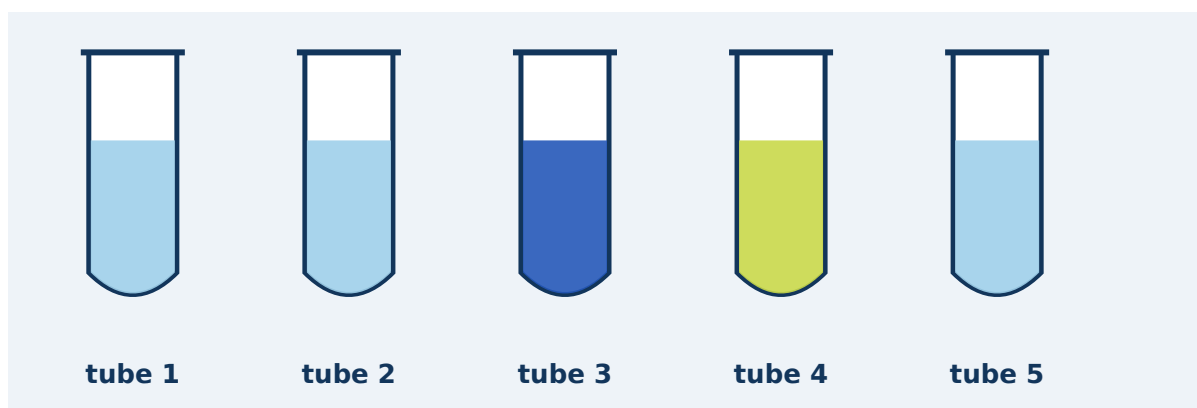
- 0.10 mol dm⁻³ copper(II) sulfate solution
- Dilute and 1 mol dm⁻³ ammonia solution, concentrated hydrochloric acid (teacher dispensed)
- Test tubes and rack, droppers, 10 cm³ measuring cylinder, volumetric flask or graduated pipettes
- Colorimeter or phone light sensor with orange filter and cuvettes

Safety

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Wear goggles. Concentrated hydrochloric acid and ammonia vapours irritate the lungs: use only in a ventilated area or fume cupboard. Copper(II) compounds are harmful, so wash hands and dispose of waste in the labelled container.

Method



Five tubes used to compare copper(II) complexes.

1. Put 2 cm depth of copper(II) sulfate in tubes 1 to 5. Tube 1 stays as the control.
2. To tube 2 add 5 drops of ammonia, record the colour; add excess ammonia to tube 3 and record.
3. To tube 4 add 2 cm of concentrated hydrochloric acid and record the colour; pour half of it into tube 5, add water drop by drop and record the colour.
4. Prepare standards of $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ by diluting a stock solution to 0.020, 0.040, 0.060 and 0.080 mol dm^{-3} and measure the absorbance of each at 600 nm. Measure the unknown, which was diluted 5.0 cm^3 to 25.0 cm^3 .

Results

Tube	Reagent added	Observation
1	none	pale blue solution
2	few drops ammonia	pale blue precipitate
3	excess ammonia	deep blue solution
4	conc. HCl	yellow-green solution
5	half of tube 4, then water	turns blue again

Concentration (mol dm^{-3})	0.020	0.040	0.060	0.080	unknown
Absorbance	0.15	0.31	0.44	0.60	0.36

Analysis questions

Question 1 Colour changes

Write the formula of the copper complex responsible for the colour in tubes 1, 3 and 4.

Question 2 Equations

Write ionic equations for the reactions in tubes 2 and 3.

Question 3 Explain the change in tube 4

Explain why the coordination number changes in tube 4 and why adding water in tube 5 reverses the colour.

Question 4 Calibration graph

Plot absorbance against concentration for the standards and describe the graph.

Question 5 Molar absorptivity

Calculate the slope of the line through the origin for these data and say what the slope tells you about the complex.

Question 6 Unknown solution

Use the graph to find the concentration of the diluted unknown and then of the original solution.

Question 7 Why a filter

Explain why an orange filter (about 600 nm) is chosen for the blue complex.

Question 8 Improvements

Suggest two improvements to make the concentration more precise.