Investigating the formulae of complex ions

Background

Complex ions consist of a central metal ion surrounded by a specific number of molecules and ions. For example the ion hexaaquacopper (II) ion, $[Cu(H_2O)_6]^{2+}_{(aq)}$ has six water molecules attached or bonded to the central copper ion. These surrounding molecules or ions are called ligands.

Practical Techniques

You will need to find out about the technique of colorimetry and how to make up accurate solutions.

Where to start

Ethylenediaminetetraacetic acid (EDTA) can act as a ligand. EDTA can complex with nickel (II), Ni^{2+}. When the complex forms a blue colour is observed. The idea is to find the number of moles of EDTA and the number of moles of nickel (the mole ratio) that combine to give the blue colour is at its maximum intensity. Plan an experiment to find the number of EDTA ions that form a complex with one nickel (II) ion.

Possible Investigations

- Investigate the formulae of other nickel complexes. You could try ligands such as chloride ions, ammonia, phenylamine, salicylate ions (from sodium salicylate), 1,2-diamminoethane, 1,2 dihydroxybenzene, hydroxylamine, thiocyanate ions.

- Investigate the formulae of complex ions of other transition metals such as copper and iron.

- Are there changes conductivity, pH or temperature when complex ions form? Can these changes be used to determine the optimum mole ratio needed to produce the maximum yield of the complex ion?

Sources of information

- Thorpe A., Colorimetry, *Chemistry Review*, February 2003

- Thorpe A., Making a standard solution, *Chemistry Review,* November 2002

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- Lindsey D., Measuring pH. *Chemistry Review*, September 1998

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- Thorpe A., Experimental error and error analysis: just how good are those results, *Chemistry Review*, November 2001

Teachers' Notes

General

This is investigation is based on standard experiments that can be found in many practical chemistry books. The experimental techniques are fairly straightforward and most students should be able to obtain good sets of results.
The nickel (II) salt will give maximum absorbance with a red filter. However as the complex formed is blue an orange filter would probably give better results.
The stoichiometry of the nickel – edta complex should be 1:1.
Each run of the experiment will probably be take about 30 - 45 minutes and data can be obtained quickly.

Chemical Principles

Transition metals, complex ions, colour chemistry

Essential Equipment

Colorimeter

Essential Chemicals

Disodium salt of EDTA, nickel (II) sulphate/chloride/nitrate

Safety

No risk assessment has been given. It is essential that students prepare a detailed risk assessment before they start. Teachers should check all plans and must be satisfied that this is suitable for the proposed investigation.

Starter Experiment Sheet -Investigating the formulae of Complex Ions

Ethylenediaminetetraacetic acid (EDTA) can act as a ligand. EDTA can complex with nickel (II), Ni^{2+}, ions. The purpose of this experiment is to find the number of EDTA molecules that combine with one nickel (II) ion and hence determine the formula of the complex formed between the Ni^{2+} and the EDTA.

In this experiment EDTA is used in the form of its disodium salt.

You should prepare the following solutions

- 0.05 mol dm^{-3} disodium salt of EDTA
- 0.05 mol dm^{-3} Nickel (II) salt

You will need to think about how much of each solution to prepare. This will depend on how much of each solution is used in each experiment and how many experiments you do (including any repeats).

Prepare the following mixtures

Mixture	0.05 mol dm^{-3} Ni^{2+} cm^3	0.05 mol dm^{-3} EDTA cm^3
1	10	0
2	9	1
3	8	2
4	7	3
5	6	4
6	5	5
7	4	6
8	3	7
9	2	8
10	1	9
11	0	10

Use a suitable filter, place each solution in a colorimeter and measure the absorbance of each mixture.

When the two substances react there will be an optimum mole ratio needed to produce the maximum yield of the complex ion. By varying the mole ratios of the reactants the maximum product can be determined when the colour of the complex ion is at its most intense.

A suitable graph of absorbance against mole ratio can be plotted to determine the maximum yield of complex ion. The graph can then be used to determine the formula of the complex ion formed.