# Cobalt complexes

## Introduction
Once the students have assimilated this problem, they will probably need further information – see Possible approaches.
Teachers who have not used the problems before should read the section Using the problems before starting.

## Prior knowledge
Transition metals and their complexes – which contain covalently bonded ligands. The problem is open-ended as far as properties are concerned and students are asked to write down what they know or what they can find in textbooks or other sources of information. If the students have not met the difference between chlorine bonded covalently in the complex and the ionic chloride outside the complex, and the fact that silver nitrate reacts with only the ionic chloride, you may wish to point this out or direct them toward an explanation in a textbook. A detailed knowledge of the concepts are unnecessary as students are encouraged to consult textbooks and data books during the exercise.

## Resources
Inorganic textbooks and perhaps data books should be available for reference.

## Group size
3–4.

## Possible strategies
Point out that a useful strategy is to start by examining the two extremes (compounds one and four) and fit in the intermediate compounds thereafter. In particular, you could feed in the following information about compounds one and four. Some explanation may be required but you can test whether the students understand the situation by letting them apply the information to compounds two and three.

$Co(NH_3)_3Cl_3$ was written $[Co(NH_3)_3Cl_3]$ in the textbook;
$Co(NH_3)_4Cl_3$ was written $[Co(NH_3)_4Cl_2]Cl$ in the textbook;
$Co(NH_3)_5Cl_3$ was written $[Co(NH_3)_5Cl]Cl_2$ in the textbook; and
$Co(NH_3)_6Cl_3$ was written $[Co(NH_3)_6]Cl_3$ in the textbook.

## Possible solutions
1. Recognise that the six ligands in the first compound are 3 x Cl and 3 x $NH_3$; second compound are 2 x Cl and 4 x $NH_3$; third compound, 1 x Cl and 5 x $NH_3$ and the fourth compound, 6 x $NH_3$.
2. Different properties
   The compounds:
   - have different formula masses;
   - have free chloride ions which can be detected using silver nitrate solution (except for compound 1);
   - will conduct electricity in solution (except compound 1 which has covalent neutral molecules). The conductivity increases as the number of ions increases;
   - should give chlorine at the anode on electrolysis (except for compound 1 which slowly releases oxygen);

- will react with zero, one, two and three equivalents of silver nitrate respectively; and
- will react with three, four, five and six equivalents of hydrochloric acid respectively.

3. Similar properties
   The compounds:

   - show cobalt in oxidation state 3 in each complex ($d^6$ complexes);
   - exhibit d–d splitting which means that each complex will probably be coloured;
   - the ammonia in each compound will neutralise acids; and
   - will evolve ammonia on warming.

## Suggested approach

During trialling the following instructions were given to students and proved to be extremely effective:

1. Working as a group, discuss the problem and how you are going to solve it. You can divide the work amongst you if you wish but keep each other informed of your progress.
2. Discussion can play a vital part in working out possible solutions to open-ended problems like this. Several minds working on a problem together can stimulate ideas that one on its own could not manage.
3. Write a brief account of your ideas.
4. Working as a group, prepare a short (ca 5-minute maximum) presentation to give to the rest of the class. If possible all group members should take part: any method of presentation (such as a blackboard, overhead projector, etc) can be used.

Outline the problem, describe what you did and explain your predictions. After the presentation, be prepared to accept and answer questions and to discuss what you did with the rest of the class.

## Cobalt complexes

I. Devise structures for the complexes given below.
II. Decide how to distinguish between the four complexes, ie in what ways are they different?
III. Identify some properties or characteristics that are the same for all four complexes.

This problem gives little information. Facts about transition metals and their complexes will have to be recalled or looked up in textbooks and applied to the problem.

The formulae for four different octahedral complexes formed between cobalt ions, ammonia molecules and chloride ions are:

1. $Co(NH_3)_3Cl_3$ ;
2. $Co(NH_3)_4Cl_3$ ;
3. $Co(NH_3)_5Cl_3$ ; and
4. $Co(NH_3)_6Cl_3$.

You should refer to any sources of information that you think might help such as your notebooks, textbooks and data books. Ask for assistance if you get stuck.