Helping an industrial chemist

Introduction
Teachers who have not used the problems before should read the section Using the problems before starting.

Prior knowledge
Interconversion of salts, reduction of oxides and the effect of heat on nitrates. A detailed knowledge is unnecessary as students are encouraged to consult textbooks and data books during the exercise.

Resources
Databooks and inorganic textbooks should be available for reference. Copper(II) nitrate powder and aluminium nitrate powder should be provided at the start of the exercise.

Students can request apparatus and chemicals during the practical session: these should be issued provided that it is safe to use them. In particular, sodium carbonate decahydrate (washing soda) and a set-up for reducing metal oxides with natural gas will probably be needed but keep these out of view until requested.

Group size
2–3.

Risk assessment
A risk assessment must be carried out for this problem.

Special safety precautions
If the nitrate is heated you should note that poisonous nitrogen dioxide is produced; also water released from the hydrated salt could run down and crack the hot glass.

There is a danger of explosion with any gas reduction apparatus.

Possible methods
Industrially, solutions of the two starting materials are mixed and processed together. Reduction of the oxide mixture gives the catalyst. Do not tell students this – within the limits of safety, they should be allowed to proceed by whatever method they choose.

1. Mix the nitrates thoroughly, heat in air to form oxides, and then heat these with hydrogen or natural gas to reduce the CuO, leaving the Al_2O_3 unchanged.

2. As for **1**, but mix the two nitrates in the presence of sufficient water to dissolve them.

3. As for **1**, but process the two nitrates separately, and mix aluminium oxide and copper at the end.

4. Dissolve both nitrates in a little water, add sodium carbonate solution, and filter off the ensuing solid. Heat the filtrate to drive off carbon dioxide and water, and finally, react with hydrogen or natural gas to reduce the CuO. This is the basis of the method used in industry.

NB It is likely that the solid produced by adding the sodium carbonate solution is a mixture of basic copper(II) carbonate and aluminium hydroxide

5. As for **4**, but process the two nitrates separately, mixing at the end.

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 list as many different methods as you can. You should be able to think of at least three different methods – ask for advice if you can't.

2. Discuss the advantages and disadvantages of each method. Such discussion plays an important part in deciding on suitable experimental methods. Several minds focusing on a problem together can achieve much more than the same minds working independently. About 10 minutes should be spent on this initially with further discussion as required.

3. Each person in the group should choose one method to try. Describe your chosen method in note form, including the quantities of chemicals that you intend to use.

4. Get your method checked for safety and then carry out the practical work to find out how well it works.

5. Write a brief account of what you did, including any problems you found.

6. As a group, discuss all the results and decide on the best procedure – this could be one of the methods tested or a procedure using the 'best bits' from several methods.

7. 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 how you decided on the best method. After the presentation, be prepared to accept and answer questions and to discuss what you did with the rest of the class.

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Starting with solid copper(II) nitrate $Cu(NO_3)_2.6H_2O$ and solid aluminium nitrate $Al(NO_3)_3.9H_2O$, devise a method for making a copper catalyst dispersed on an aluminium oxide support.

An industrial chemist requires a sample of copper to use as a catalyst. It is used to catalyse the reaction between carbon monoxide and hydrogen to make methanol. To be effective, the copper has to be extremely finely divided, as atoms or groups of atoms spread on an unreactive support such as aluminium oxide.

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.

Safety

Normal safety procedures when handling chemicals should be adhered to and eye protection worn. There are particular hazards that could arise depending on how you tackle the problem.

You must get your method checked for safety before starting on the practical work.

	Mp °C	Decomposes °C
$Cu(NO_3)_2.6H_2O$	115	170
$Al(NO_3)_3.9H_2O$	73	140