PUPIL RESEARCHER INITIATIVE

Catalytic Traps

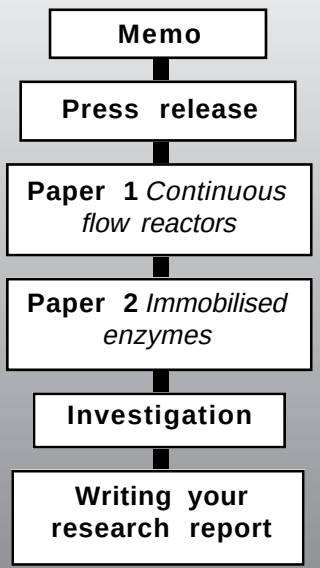
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ the speed of a chemical reaction increases if a catalyst is used
- ❑ a catalyst is not used up during a chemical reaction
- ❑ a catalyst is used over and over again to speed up the conversion of reactants to products
- ❑ different reactions need different catalysts
- ❑ increasing the rate of chemical reactions is important to industry because it helps to reduce costs
- ❑ enzymes are biological catalysts

Route through the Brief



Introduction

In this Brief teacher and pupils take on the roles of members of a university chemistry department research team. They are required to try out some ideas about using entrapped catalysts before submitting a bid for funds to a research council. The work involves investigating the various factors that might affect the efficiency of a catalyst trapped inside alginate beads.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Before attempting this unit pupils should have covered the basic work on the use of catalysts to speed up chemical reactions.

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Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are:

Initial briefing	-	whole class; teacher introduces the topic
Memo and press release	-	whole class; teacher leads pupils through these sheets setting the scene
Paper 1	-	pairs or small groups; pupils make notes and come up with ideas for the investigation
Paper 2	-	pairs or small groups; information is given on how to prepare alginate beads
Investigations	-	pairs or small groups; possibly each pair or group doing one of three investigations and reporting back
Communication	-	individual if written reports assessed, otherwise pairs or groups

Timing

Depending on how investigations are allocated within the class, the Brief could take between 4 and 6 hours of classroom time.

Activities

The teacher should issue the pupils with the **Study Guide** which provides them with a summary of what they should produce as they work through the Brief. It can also act as a checklist for pupils to monitor their own progress. The leader of the research team (the teacher) should hand out and go through the **memo** from Professor Mackenzie, and the **press release** from the Research Council, inviting bids from academic institutions for funds for research projects on catalysis. These set the scene for the investigations which follow.

Paper 1 *Continuous flow reactors* provides background information on the use of catalysts to speed up chemical reactions, the problems involved in recovering catalysts and the possibility of using an immobilisation technique already used in biotechnology. The paper contains a graph of energy against time for a chemical reaction with and without a catalyst present. The graph shows the reduction in activation energy achieved when the catalyst is present. The teacher may wish to provide some additional information about activation energy at this point. Paper 1 also provides suggestions for the 3 strands of investigations the research team should carry out.

Paper 2 *Immobilising enzymes* is provided to give pupils instructions on how to make alginate beads containing enzymes - and hence how to make them containing catalysts.

The teams need to make beads containing manganese dioxide, and use them to catalyse the breakdown of hydrogen peroxide into water and oxygen. This reaction is used to test the effectiveness of the beads.

Once the practical work is completed, a plenary session should be held in which the results of all the investigations are presented. Pupils then write a report on the work undertaken.

Investigation details

The practical work in this Brief is based around the reaction:

$$\text{hydrogen peroxide} \xrightarrow[\text{(catalyst)}]{\text{manganese dioxide}} \text{water + oxygen}$$

The suggested investigations are intended to cover a wide range of investigative skills and they offer good opportunities to stretch higher achieving pupils. They could learn the technique of producing alginate beads containing manganese dioxide, although this could be carried out by the teacher or technician prior to the lesson. There are four suggested investigations. These are:

1. does immobilising manganese dioxide in alginate beads allow it to catalyse the hydrogen peroxide reaction?
2. varying the temperature of the beads to see if this alters their effectiveness in catalysing the reaction;
3. varying the size of the beads in contact with the hydrogen peroxide to see if this makes the catalyst more or less effective;
4. varying the ratio of catalyst to alginate in the beads to determine if this has a measurable effect on the rate of reaction.

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It is suggested that all pupils carry out investigation 1. If time allows each pupil group could do all three follow-up investigations (2-4). However, it is probably more realistic to have different groups tackle different investigations and report back their findings. Pupils may suggest other factors which could be investigated.

Investigation 2 could be carried out by incubating sets of alginate beads (containing catalyst) for periods of time at different temperatures prior to their use in the reactor.

It is important that pupils ensure that the flow of hydrogen peroxide through the beads is kept constant. In all cases pupils need to decide on a standard procedure in order to ensure that results obtained can be compared fairly.

Technical details

Producing alginate beads with entrapped manganese dioxide

- Gently warm 50cm^3 of distilled water in a small beaker on a stirrer hotplate.
- Weigh out 2g of sodium alginate, add to the warm water and allow to dissolve with constant stirring.
- Dissolve 1.4g of calcium chloride in 100cm^3 of distilled water and place the solution in a 250cm^3 beaker.
- Add manganese dioxide to the alginate solution with constant stirring.
- Clamp a 50cm^3 plastic syringe body approximately 10cm above the surface of the calcium chloride solution in the beaker.
- Add 25cm^3 of the manganese dioxide/alginate mixture to the syringe and allow it to drop into the calcium chloride solution drop by drop.
- When most of the mixture has left the syringe, top up the syringe with the remaining 25cm^3 of mixture and allow it to drop into the calcium chloride solution.
- Allow the beads to stand in the calcium chloride solution for 20 minutes.
- The beads can be removed from the calcium chloride solution by straining through a sieve or tea strainer. They are now ready for use.

Note: For further details of the absorption of H_2O_2 solution using MnO_2 entrapped in sodium alginate beads - refer to the 'Clear solutions' Brief Teachers' notes where yeast is substituted for MnO_2 and methylene blue for H_2O_2.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

Hydrogen Peroxide 20vol: irritant - dangerous if swallowed.

If concentration greater than 5.9M (71 vol): corrosive. Dangerous with organic compounds.

at 20-120 ppm: minimal hazard.

If swallowed: wash mouth and give water to drink. Seek medical attention as soon as possible.
If in eyes: flood eye with flowing tap water for at least 10 minutes. Seek medical attention.
If on skin: flood area with water. Remove contaminated clothing. Seek medical attention if skin blistered or large area affected.

Wear eye protection.

Check amounts of catalyst proposed in pupil investigations.

Manganese dioxide: harmful.

Dangerous with powerful oxidants, aluminium and other metal powders.

If swallowed: wash mouth and give water to drink. Seek medical attention.
If in eyes: flood eye with flowing tap water for at least 10 minutes. Seek medical attention.

Wear eye protection.

Oxygen: oxidising agent.

Wear eye protection.

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Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales, Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

Investigations 1-4 allow access to all marks across **Skill Areas P, O, A and E.** Investigation 1 is based upon a procedure set out in the paper Immobilising enzymes, and this must be taken into account when looking at pupil achievement in **Skill Area P**. Obviously Investigations 2-4 are based around the same procedure as in Investigation 1, but in these investigations the method provided in is merely a starting point for further planning.

Scottish syllabus coverage

Standard Grade Biology - *Biotechnology*
Standard Grade Chemistry - *Speed of Reactions*

Further pupil research opportunities

Pupils could determine the effectiveness of the process by testing the water sample coming out of the catalytic column for the presence of hydrogen peroxide using the luminol/ H_2O_2 reaction described in the Brief *Seeing the light*.