PUPIL
RESEARCHER
INITIATIVE

# Catalytic Traps

## Setting the Scene

*You will be working as a member of a team of research students in a university chemistry department. The Research Council has issued a press release announcing that funding is available for new research projects in catalysis. You have been asked to try out some new ideas before the department writes its bid for funding.*

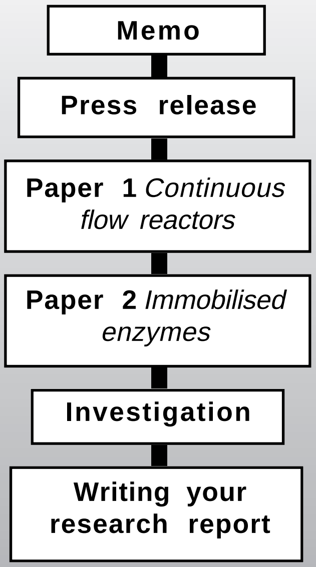
# Pupil Research Brief

## Study Guide

### Syllabus Targets *Science you will learn about in this Brief*

- ❑ 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




### Outcome Checklist

You will produce a research report for the Head of the School of Chemistry. A memo guides you through the Brief. You should make sure you produce the following items as you work through the Brief.

**Paper 1**

- ❑ notes based on reading the paper and ideas for the investigation

**Paper 2**

- ❑ report on investigation(s) on immobilised catalysts
- ❑ suggestions about which industrial chemical reactions the continuous flow reactor could be used for

Carlston University
*Science Faculty*

Institute of Catalyst Research

# Memorandum

**From:** Professor Mackenzie

**To:** Research Teams

**Subject:** Research Council press release on catalyst research

I have recently received a copy of the latest Research Council press release. A copy is attached to this memo. They are looking for proposals for projects aimed at research into catalysts and their applications in the chemical industry.

At a recent seminar, a group of staff in the Institute came up with a number of ideas for research in this area. The outcomes of this meeting were written up as a short paper (*Continuous flow reactors*), which you may have read. I think that this paper gives a good basis for developing a research bid to the Research Council. We need to do some work firming up the ideas - which is where your team could help. Before we start writing the bid, one or two investigations need to be carried out to see if the seminar ideas actually work.

This is what I suggest you should do.

1. Read the press release and Paper 1 (*Continuous flow reactors*). I have written some notes on the paper which should guide you through the task.

2. Read Paper 2 (*Immobilising Enzymes*) - this sets out the experimental details you will need to try out some of the ideas suggested during the seminar.

Your report should:

- outline the investigation(s) you carry out - set this out as a standard scientific report

- offer suggestions about which industrial chemical reactions the continuous flow reactor idea could be used for.

I look forward to reading your report.

# Press Release

## *Research Council calls for research proposals in catalysis and catalytic processes*

The Research Council invites outline proposals, from universities and other academic institutions, for research projects aimed at making fundamental advances in catalysts and their applications in chemical processing.

Catalysis is an excellent example of an area where science can play a part in creating wealth for the country. This was one of the principal conclusions arising from the government's Technology Foresight programme, which identified catalysis as a priority area.

Proposals are sought for all areas of research in catalysis and catalytic processes. The research can be carried out by individuals or groups. The work should be an investigation seeking new approaches which offer advantages over present practice. It should attempt to provide new and potentially cost-effective ways of solving the underlying problems currently faced by industry. Research into product development will not be supported.

Priority will be given to proposals which contain ideas which could have beneficial industrial applications. The Research Council would prefer ideas which have a wide range of uses, rather than ones which focus on the needs of one industry or on one particular catalytic process or reaction.

Collaboration with researchers in industry or different academic departments is not essential but is strongly encouraged.

# Continuous flow reactors

*A short paper (for internal circulation only) outlining a number of ideas for future research into catalysts and catalytic processes, produced by the Institute following a joint seminar with staff from the School of Engineering. The seminar was held to respond to the Research Council's call for research proposals in catalysis.*

The seminar heard presentations by Dr A. Khan (the Institute) - *Problems with catalysts*, and Professor J. Atkins (School of Engineering) - *Learning from biotechnology: continuous flow fermenters and immobilised enzymes.*

Following the presentations there was an open discussion which produced a number of suggestions for future research.

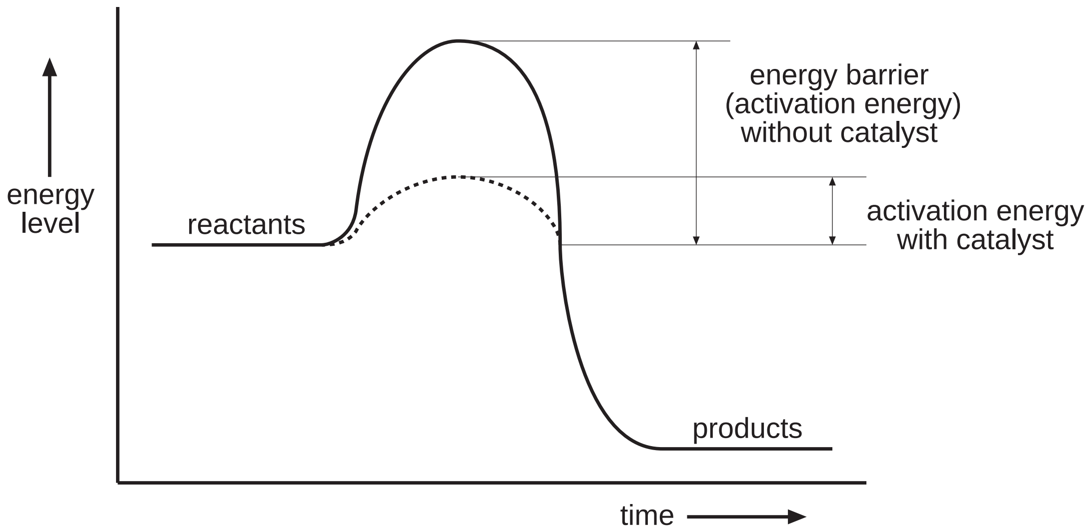
## Problems with catalysts (Dr A. Khan)

this was included for the non-chemists in the seminar

### What are catalysts?

A catalyst is a substance which speeds up the rate of a chemical reaction, without itself being used up in the process. Catalysts work by reducing the activation energy for a particular reaction. Activation energy is the energy which needs to be supplied before a reaction can occur.

*Figure 1 Catalysts reduce energy barriers to reactions*




Catalysts are usually specific to one reaction, that is, different reactions need different catalysts. Since a catalyst is not used up during a chemical reaction, it can be used over and over again to convert reactants to products.

Examples of catalysts are:

- manganese dioxide (in the conversion of hydrogen peroxide converted to water and oxygen)
- iron (for the production of ammonia in the Haber Process)
- platinum and palladium (in car catalytic converters)
- enzymes (in living organisms)
- zeolites (in producing petrol from oil).

## The importance of catalysis in the economy

Paper 1 ctd.

Stevenson (1995) states that:

*Practically all of the UK chemical industry's annual sales of £35 billion rely directly or indirectly on catalysis.*

Since catalysts speed up chemical reactions, they obviously are important to the chemical industry, where speed means money. Developing new catalysts and catalytic processes allows us to make new chemicals. It is increasingly important that chemical processes become cleaner, and more environmentally friendly. Catalysts can help us to develop clean technology, such as the catalytic converters in cars which reduce pollutant emissions.

## Problems and possible solutions

If catalysts are used over and over again in a chemical reaction, then one of the main challenges facing scientists and engineers working in this field of research is to design processes which allow catalysts to be collected and re-used following the reaction. This is particularly difficult when the reactants and the catalyst are both liquids, or where the catalyst is a powder mixed with liquid reactants. Our two departments should collaborate on future research into this issue.

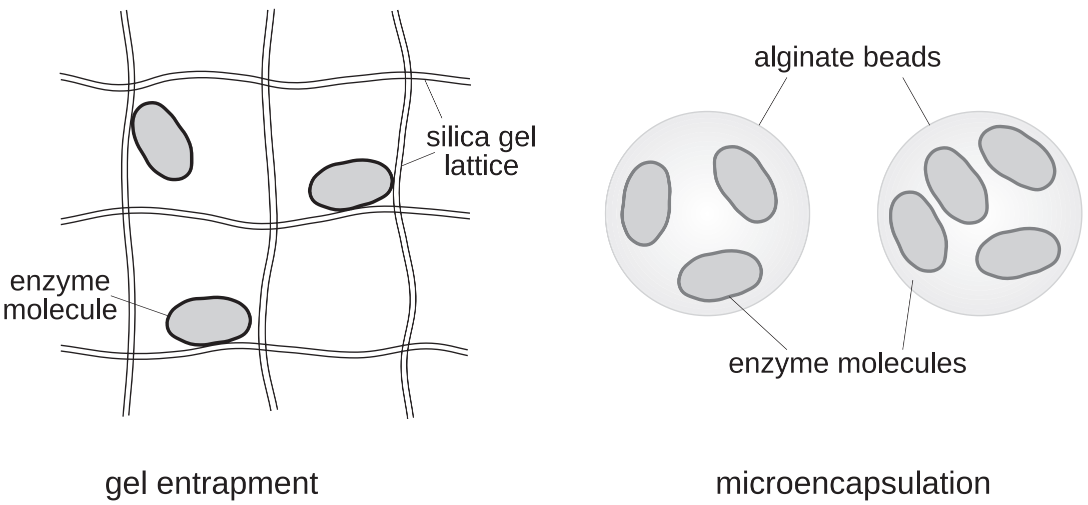
# Learning from biotechnology: continuous flow fermenters and immobilised enzymes. (Professor J. Atkins)

## Production processes used in biotechnology

make sure you know what these are

Biotechnology involves using microorganisms or enzymes to produce useful substances. Recent advances in production processes have overcome the problems of contamination of the product with the enzyme or microorganism, and the recovery of the enzyme for later use. The solution depends on the process of *enzyme (or microorganism) immobilisation.* Enzymes, or microorganisms are attached to, or entrapped in, an insoluble material, such as silica gel or alginate beads.

*Figure 2 Immobilising enzymes*



Alginate beads containing an enzyme can be held in a reaction vessel. Reactants are then poured through the beads, which remain in place. As they pass over the beads the reactants are converted into the products by the action of the enzyme. The product can then be drained from the bottom of the vessel as more reactant is poured in at the top. The process can be used for a variety of chemical reactions involving enzymes as catalysts, including certain types of fermentation.

This gives you an idea about the process you will be investigating. Paper 2 has a diagram to show a continuous flow fermenter

## Discussion - summary of key points

Discussion centred on the possibilities of using some of the recent advances in biotechnology to design systems for non-biological catalysts. For example, it may be possible to use alginate beads to immobilise a powdered catalyst such as manganese dioxide, which catalyses the reaction:

$$\underset{2H_2O_2}{\text{hydrogen peroxide}} \xrightarrow[\text{(catalyst)}]{\text{manganese dioxide}} \underset{2H_2O}{\text{water}} + \underset{O_2}{\text{oxygen}}$$

There was discussion about the possible development of a **continuous flow reactor**, for chemical reactions where the recovery of the catalyst was a problem. It could also be used where the reaction product could be contaminated by the catalyst, due to the difficulties of separating the catalyst from the products.

It was suggested that one of the research teams within the Institute could investigate this to see whether catalyst immobilisation with alginate beads actually worked.

A number of other related factors could also be investigated by the team:

- the effect of temperature on the performance of the alginate beads
- the effect of bead size on the rate of reaction
- the ratio of catalyst to alginate used in the reaction

It was agreed that Professor Mackenzie (Institute of Catalyst Research) would approach some of her researchers to carry out the feasibility study, before more work was carried out on producing a research proposal for the Research Council.

### References

Stephenson, R. A catalyst for the future, *Chemistry in Britain*, 1995, 31, 927-9.

Look at the paper 'Immobilising enzymes', by Ann Baker. This shows you how to produce alginate beads. Have a go at the technique using manganese dioxide instead of enzyme. Then follow up some of the above investigation ideas set out in this paper. I have also come across an interesting paper in the School Science Review vol 77 Number 280 (March 1996 - page 65) Simple studies on an immobilised enzyme, by Hawcroft.

Journal of Biotechnology December 1992

Paper 2

# IMMOBILISING ENZYMES

**Ann Baker**

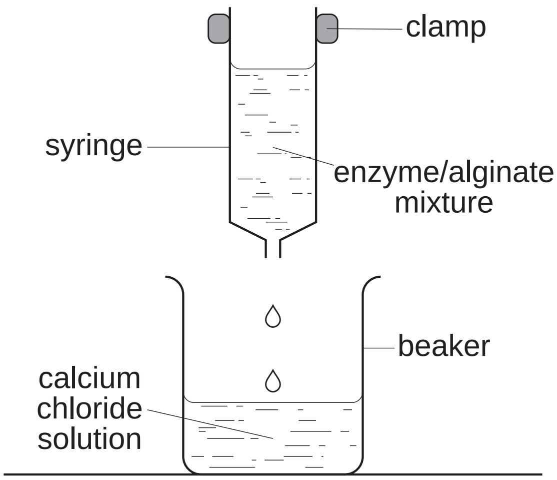
*This short article is intended to provide information for researchers on how to immobilise enzymes using alginate beads.*

Immobilised enzymes are increasingly being used in continuous flow fermenters to ensure that products of fermentation and other biochemical reactions can be produced that are free from contamination by the enzyme. This also provides an efficient means of recovering enzymes from reaction mixtures for later use.

## Making alginate beads

An aqueous solution of sodium alginate should be mixed with a known quantity of the required enzyme. A syringe should be filled with the mixture and placed in a clamp with the nozzle pointing vertically down. A beaker placed under the nozzle collects drips as they fall (see figure 1). The collecting beaker should contain a solution of calcium chloride. Beads form as the alginate/enzyme mixture drips enter the calcium chloride solution.

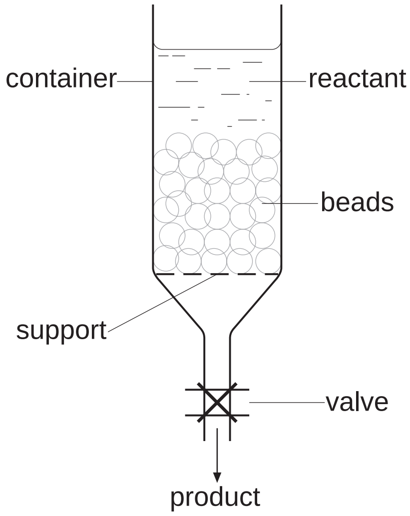
*Figure 1 Producing alginate beads*




Different nozzle sizes produce beads of different sizes.

A continuous flow fermenter can be made using apparatus as shown in figure 2.

*Figure 2 A continuous flow fermenter*




Once the fermenter is set up , then the reactant(s) should be poured onto the beads. The level should be kept as constant as possible, to ensure that a constant pressure is acting on the system, and so keeping flow rates of reactant(s) over the alginate beads constant.

The product emerging from the lower end of the apparatus should be tested to check that the required chemical reaction has taken place, and to measure the concentrations of remaining reactant(s) in the outflow. Various factors can be adjusted, such as the amount of enzyme in the beads, size of beads, flow rates or the height of the column, to ensure that all reactants have been converted into the product as it passes through the fermenter.