The Catalytic Oxidation of Ammonia: An Interactive Web-Based Virtual Experiment and Teaching and Learning Resource

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Introduction

How often do you perform a chemistry demonstration in a fume cupboard? For science teachers, the response is 'almost every day'. Now answer this: How often are you sure that every student in the class can see the demonstration clearly? For most science teachers, the reply changes to 'almost never'. With many class sizes in secondary schools approaching the thirty mark, it is not surprising that demonstrating a chemical reaction effectively can be problematical, with many students not being able to get close enough to see what is occurring.

It is in this area that ICT can enhance lessons, particularly when it enables students to 'see' something that they would not be able to observe by just carrying out the practical. The animation that ICT can provide links the physical changes students observe with the chemistry theory and can give students a better understanding of what occurs during a reaction. ICT also ensures high-quality images and a far more dynamic presentation of the processes than has been previously possible. The user has total control over the images shown and is able to go back to the video clips or pictures to check their own understanding, or clarify a point, all at their own pace.

With the above in mind, we aimed to create a virtual experiment to show students a reaction that they would otherwise be unable to easily observe as a demonstration in the laboratory fume cupboard or complete themselves as a class practical due to the hazards and expense of the materials used.

Using ICT in the classroom

This lesson would come into a series of lessons for Key Stage 4 students based on Sc3 Materials and their properties, looking at Industrial Chemistry and Catalysts. As Information and Communications Technology (ICT) is a compulsory subject in the curriculum at Key Stage 4, and has also been identified as a Key Skill, teachers should try to encourage students to increasingly develop ICT skills through their work. Many students will, of course, wish to pursue ICT in more depth and to gain appropriate qualifications. This resource provides an excellent opportunity for teachers to link the subjects of science and ICT and can be used as a teaching and learning resource for students and teacher alike.

This resource can be utilised in two ways; either in the classroom in place of a demonstration or as a web-based exercise for students to complete in the computer suite. The demonstration is part of a website resource that contains information about catalysts, and an interactive quiz that can be used as a revision tool for GCSEs or end of topic tests. In the laboratory, the computer would be used to show a demonstration on the white board using a data projector or interactive white board. Even though in this instance the students may not be directly using ICT the use of it by the teacher can enhance and stimulate the learning experiences of the students and contribute to the achievement of subject objectives. If the lesson were to be held in the computer suite, students would access the website and use it to answer questions on a worksheet, as well as completing the quiz. The website has been set up so that students could access the resource at home as well as in school.

Prior to, or following, this exercise students could use an Internet search engine to find information about the use of catalysts in other industrial processes. Students would be provided with the Internet website, or the equivalent CD-ROM, and accompanying worksheets, with space for them to add their own notes. This is to ensure that if the resource is being used as part of a computer suite lesson, the activity is structured. They may also have a question sheet relating to the topic they have just observed.

This demonstration could be followed up by a discussion on variables and identifying the variables in the demonstration. Students may like to investigate what would happen if one or more of the variables were altered, for example the thickness or length of the wire, the material the wire is made of, number of turns in the spiral, oxygen flow rate etc. and could lead to a full Sc1 scientific investigation. Students would make predictions about what would happen and explain their reasoning, based on the research done during this activity. Alternatively, the teacher may like to follow this activity by looking more at catalysis, especially enzymes, or industrial processes. The students may be asked to identify the catalyst in the demonstration and explain how they know it is the catalyst.

Aims and Objectives

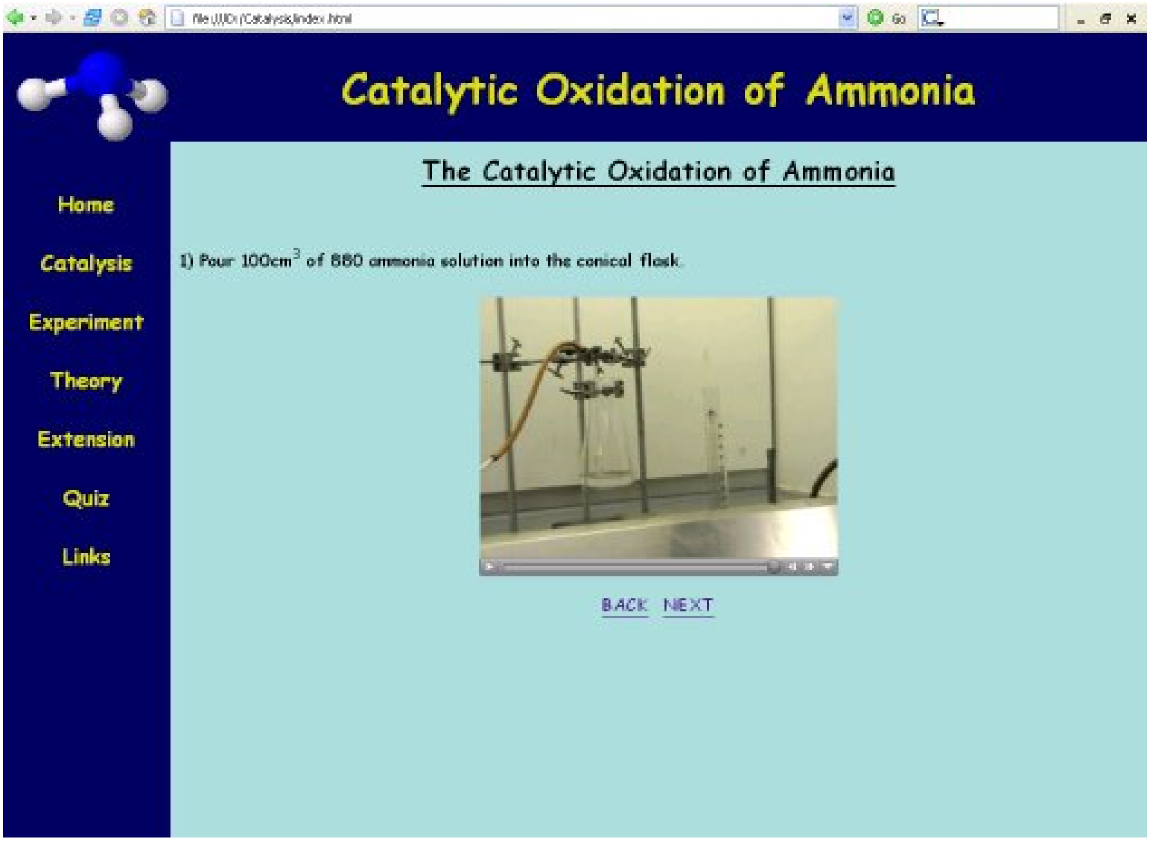
The aim of the ICT exercise was to produce an interactive teaching and learning resource for Key Stage 4 Science, extendable to other Key Stages. The learning objectives for this example resource are as follows:

- To introduce the students to the idea of catalysts, answering the questions:
    - What are catalysts and what do catalysts do?
    - How are catalysts used in industrial chemistry to increase the rate of chemical reactions to produce useful products?
- To introduce the Haber process and the Ostwald process as used in the manufacture of nitrogenous fertilisers, explosives and nylon.
- To allow students the opportunity to safely observe the effects of a catalysed reaction.
- To promote the use of ICT resources in the laboratory.

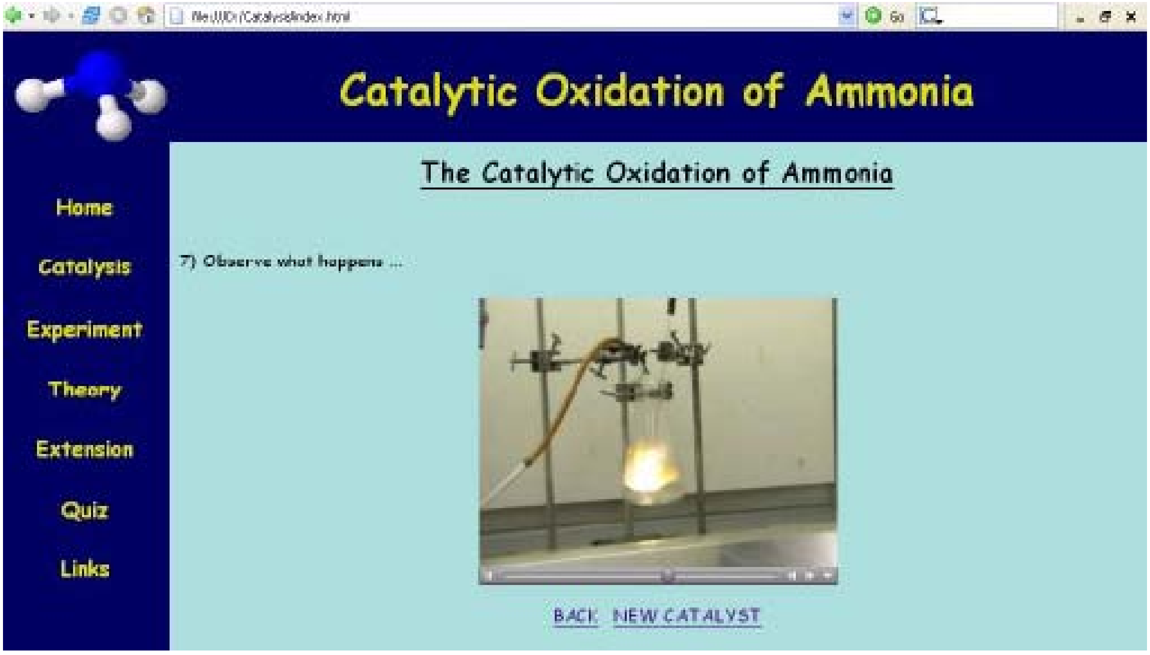
Prior to using this resource, students would be expected to have knowledge of how to access the Internet and navigate websites. In order to do their own searches of catalysts used in industrial manufacturing processes, they would need to be familiar with and know how to carry out a search on the Internet. Students may have previously studied enzyme-catalysed reactions in chemistry or biology lessons. They may also be familiar with the Haber process which uses a catalyst and have a basic knowledge of fertilisers and why they are important.

After using the resource, it is intended that all students should be able to describe the reaction between ammonia and oxygen and identify the reactants, products and equipment required. They should be able to define the term ‘catalyst’ and explain the catalyst’s function in this reaction, leading to an understanding the basic principles of how a catalyst works, in terms of increasing the probability of a successful collision between particles. Most higher tier students should also be able to write the word equations to represent the reactions occurring in the flask and relate the products and reactions to the commercial manufacture of nitric acid. Some students could extend this by writing balanced symbol equations for the reactions and using the links provided on the website to extend their knowledge of industrial chemistry and the use of catalysts.

The Experiment



The aim of the experiment was to show that when ammonia is oxidised in the presence of a platinum catalyst it is converted to oxides of nitrogen. A coil of platinum wire was gently heated and then lowered into a flask containing ammonia solution, until it was just above the surface. The platinum wire glowed red hot and the flask filled with fumes. The wire glowed because the ammonia reacted with oxygen on the metal surface. The reaction gave out heat – it was exothermic. To emphasise this point, when there was an excess of oxygen in the flask, the mixture ignited, causing a small explosion.



Once the reaction had started, the platinum continued to glow without further heating. Brown fumes of nitrogen dioxide appeared in the flask. In order to show that the platinum was the catalyst, two other metals were used; copper and constantan. The results showed that neither of these metals would catalyse the process.

Creating the resource

The resource was written in HyperText Mark-up Language (HTML) using a simple text editor. The website consists of a straightforward "frames page" which defines the layout of the site. All content is then loaded as and when required into each of the frames. All pages are relatively linked to two cascading style sheets (CSS) which control the format and graphical style of the site. This therefore allows the website to be visually integrated within a school's intranet by editing just two files. Further, the directory structure and file naming conventions used would allow the resource to become just one module of a whole series of teaching resources at a later date. All video footage on the site was encoded in a standard MPEG layer 1 format allowing playback with the use of a helper application (e.g. Apple QuickTime) on MacOS, Linux/Unix, and Windows based systems. This allows the universal application of this resource to any teaching and learning environment. Various screenshots of the resource can be found in the appendix. In addition, further information about the production of such web-based resources as this can be found in Kennedy, J. 2006.

Conclusion

ICT teaching tools provide opportunities to enhance topics and add value to the teaching and learning. For example, the use of video projection units connected to a computer can clearly demonstrate a process which students might otherwise not see due to the dangerous nature of the experiment or due to the fact that the school may not have the resources available to do the experiment. This particular experiment demonstrated on this website must be completed in a fume cupboard; something that is not always available in schools. There may not be any substitute for hands-on experience but this method is ideal for the ‘impractical demonstration’. The procedure is far too hazardous to allow a class of students to complete by themselves and may be difficult to observe in a fume cupboard with a large class. Rather than not see it at all, this is a good way of letting students observe the reaction in a safe environment. Additionally, the resource could be used to set homework or revision activities, as most students will have computer access, either in school or at home.

An improvement or an extension to this resource would be to have a video camera linked up to an interactive white board or a simple projector. The students could actually observe the experiment sitting at their desks while it is actually going on in the fume cupboard but at a safe distance. However, should an accident occur, the students may still be affected by the ammonia fumes or nitrogen dioxide gas. The ideas behind this resource pave the way for the long disputed ‘virtual laboratory’. Ultimately, it would be possible for the teacher to digitally record the experiment or demonstration before the lesson, upload it to the website and show it to the class at a later date. Again, the students may lose out on seeing the reaction happen in their laboratory but it would ensure that all students could observe the reaction easily, safely and as many times as was necessary, without using expensive materials (such as platinum) or vast quantities of solvents.

Summary

Advantages

- All of the students will be able to see the demonstration and it decreases the health and safety risks that are caused by the fumes produced by this reaction.

- The website allows students to work at their own pace and provides a useful revision resource for GCSE and end of topic tests.

- The students can access the website at home as well as in school.

- As the website has been produced using platform independent file formats, all that is required to use the website is a JavaScript enabled web browser and an MPEG file handler.

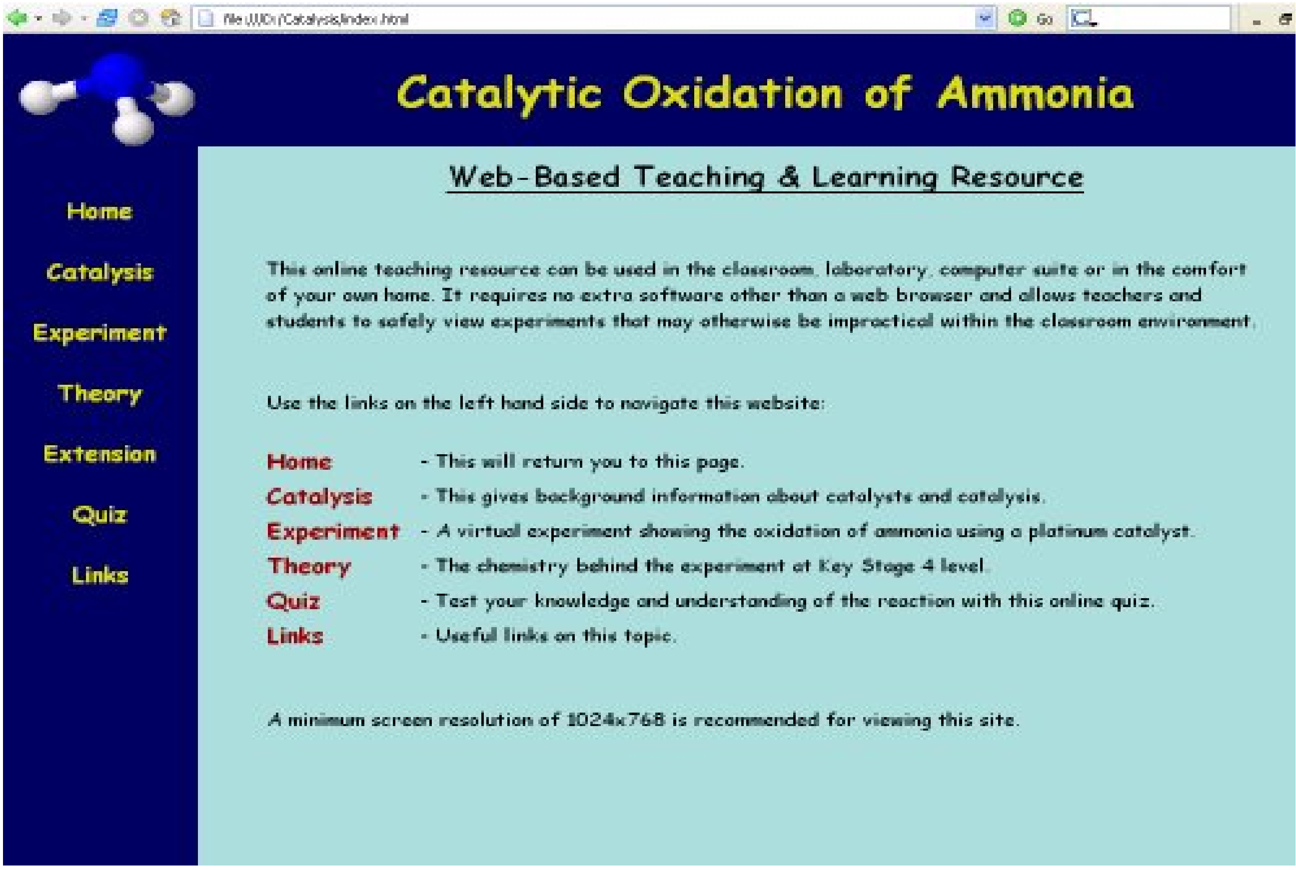
Disadvantages

- The demonstration may lose some effect because it is not really happening in front of the students.

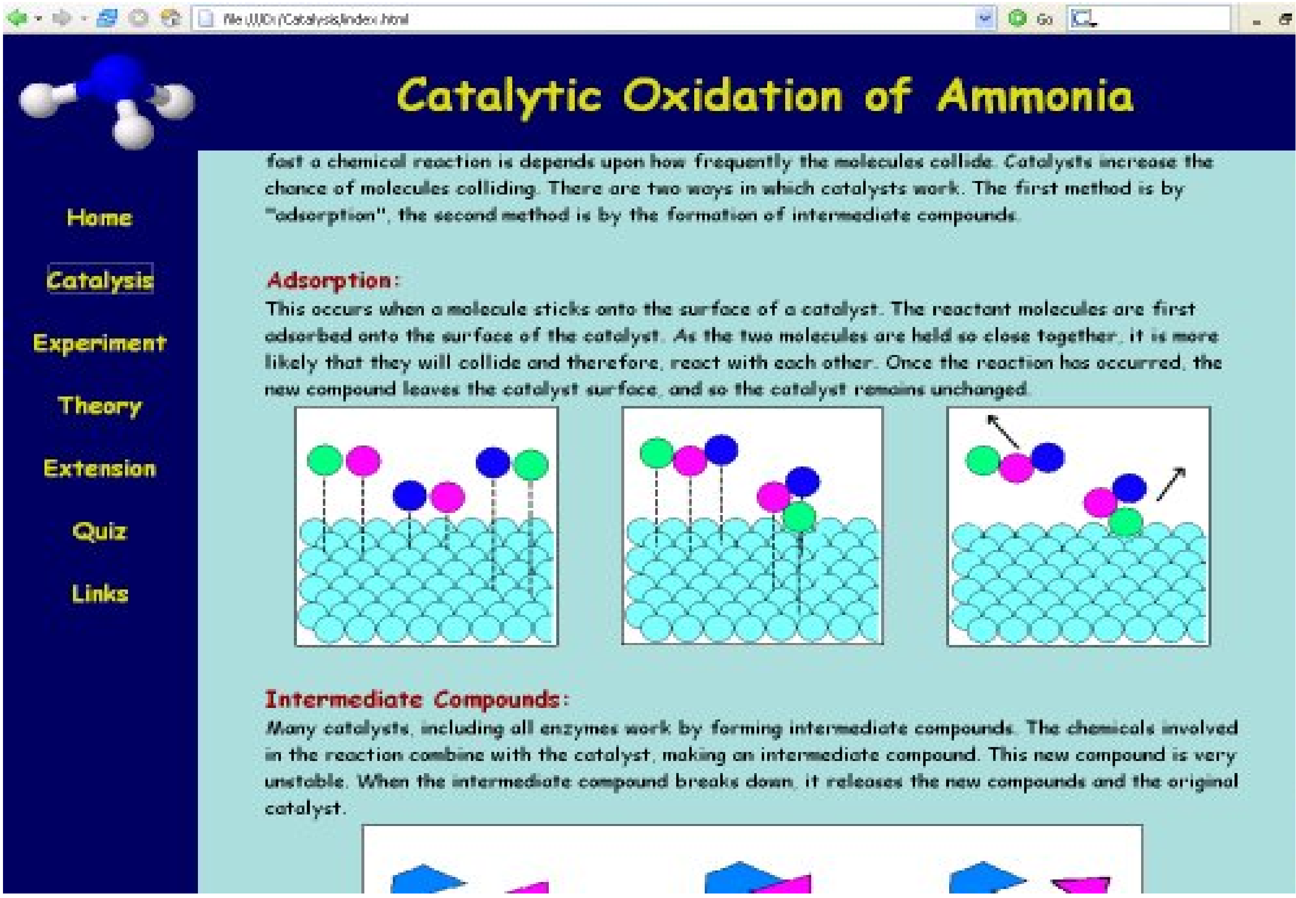
- If using the website as a computer suite activity, the teacher must ensure that students remain on-task and avoid browsing other inappropriate websites.

- The use of this website (or CD-ROM) requires a fully functioning network.

Appendix



file:///D:/Catalysis/index.html
Catalytic Oxidation of Ammonia
Home
Catalysis
Experiment
Theory
Extension
Quiz
Links
Web-Based Teaching & Learning Resource
This online teaching resource can be used in the classroom, laboratory, computer suite or in the comfort of your own home. It requires no extra software other than a web browser and allows teachers and students to safely view experiments that may otherwise be impractical within the classroom environment.
Use the links on the left hand side to navigate this website:
Home - This will return you to this page.
Catalysis - This gives background information about catalysts and catalysis.
Experiment - A virtual experiment showing the oxidation of ammonia using a platinum catalyst.
Theory - The chemistry behind the experiment at Key Stage 4 level.
Quiz - Test your knowledge and understanding of the reaction with this online quiz.
Links - Useful links on this topic.
A minimum screen resolution of 1024x768 is recommended for viewing this site.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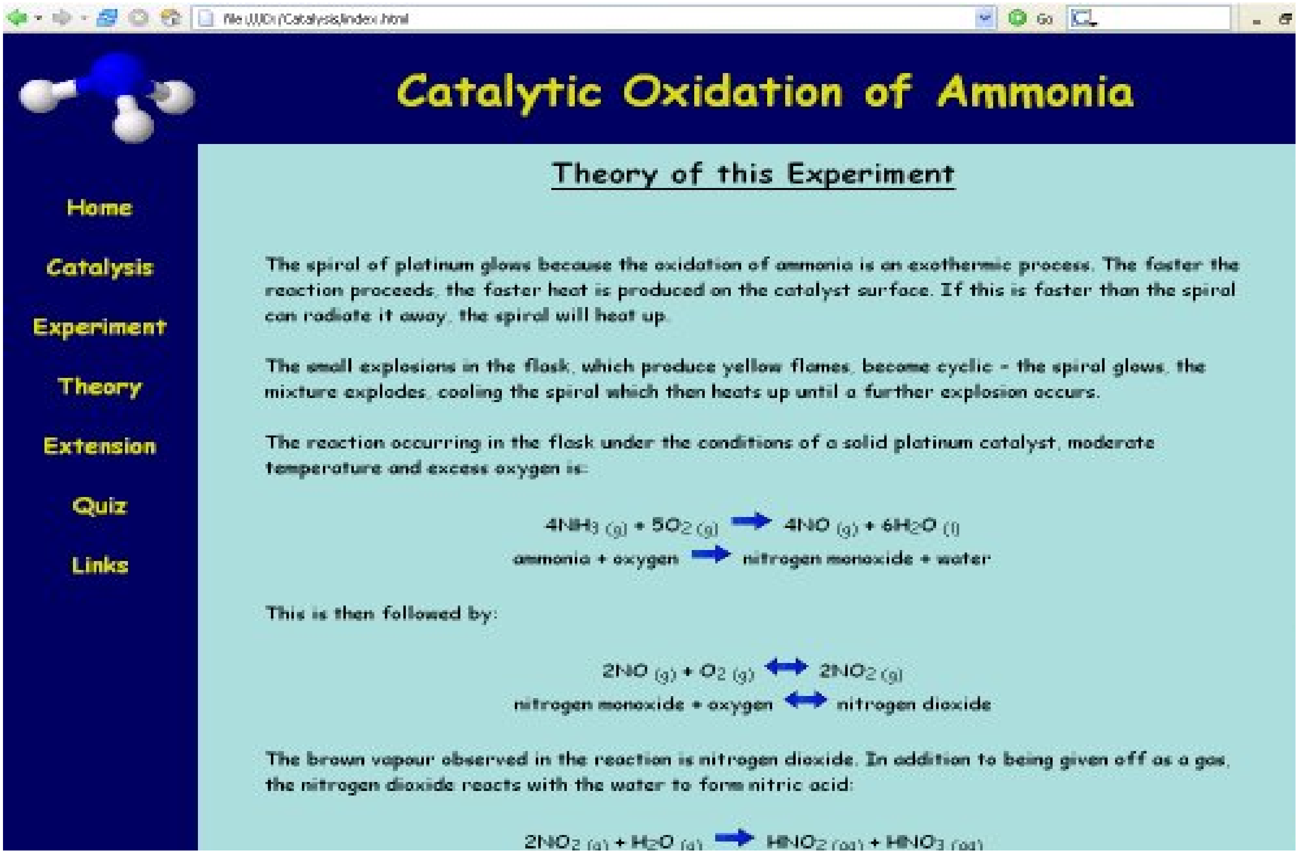
fast a chemical reaction is depends upon how frequently the molecules collide. Catalysts increase the chance of molecules colliding. There are two ways in which catalysts work. The first method is by "adsorption", the second method is by the formation of intermediate compounds.

Adsorption:

This occurs when a molecule sticks onto the surface of a catalyst. The reactant molecules are first adsorbed onto the surface of the catalyst. As the two molecules are held so close together, it is more likely that they will collide and therefore, react with each other. Once the reaction has occurred, the new compound leaves the catalyst surface, and so the catalyst remains unchanged.

Intermediate Compounds:

Many catalysts, including all enzymes work by forming intermediate compounds. The chemicals involved in the reaction combine with the catalyst, making an intermediate compound. This new compound is very unstable. When the intermediate compound breaks down, it releases the new compounds and the original catalyst.



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Theory of this Experiment

The spiral of platinum glows because the oxidation of ammonia is an exothermic process. The faster the reaction proceeds, the faster heat is produced on the catalyst surface. If this is faster than the spiral can radiate it away, the spiral will heat up.

The small explosions in the flask, which produce yellow flames, become cyclic - the spiral glows, the mixture explodes, cooling the spiral which then heats up until a further explosion occurs.

The reaction occurring in the flask under the conditions of a solid platinum catalyst, moderate temperature and excess oxygen is:

$$4NH_3\,(g) + 5O_2\,(g) \rightarrow 4NO\,(g) + 6H_2O\,(l)$$

ammonia + oxygen → nitrogen monoxide + water

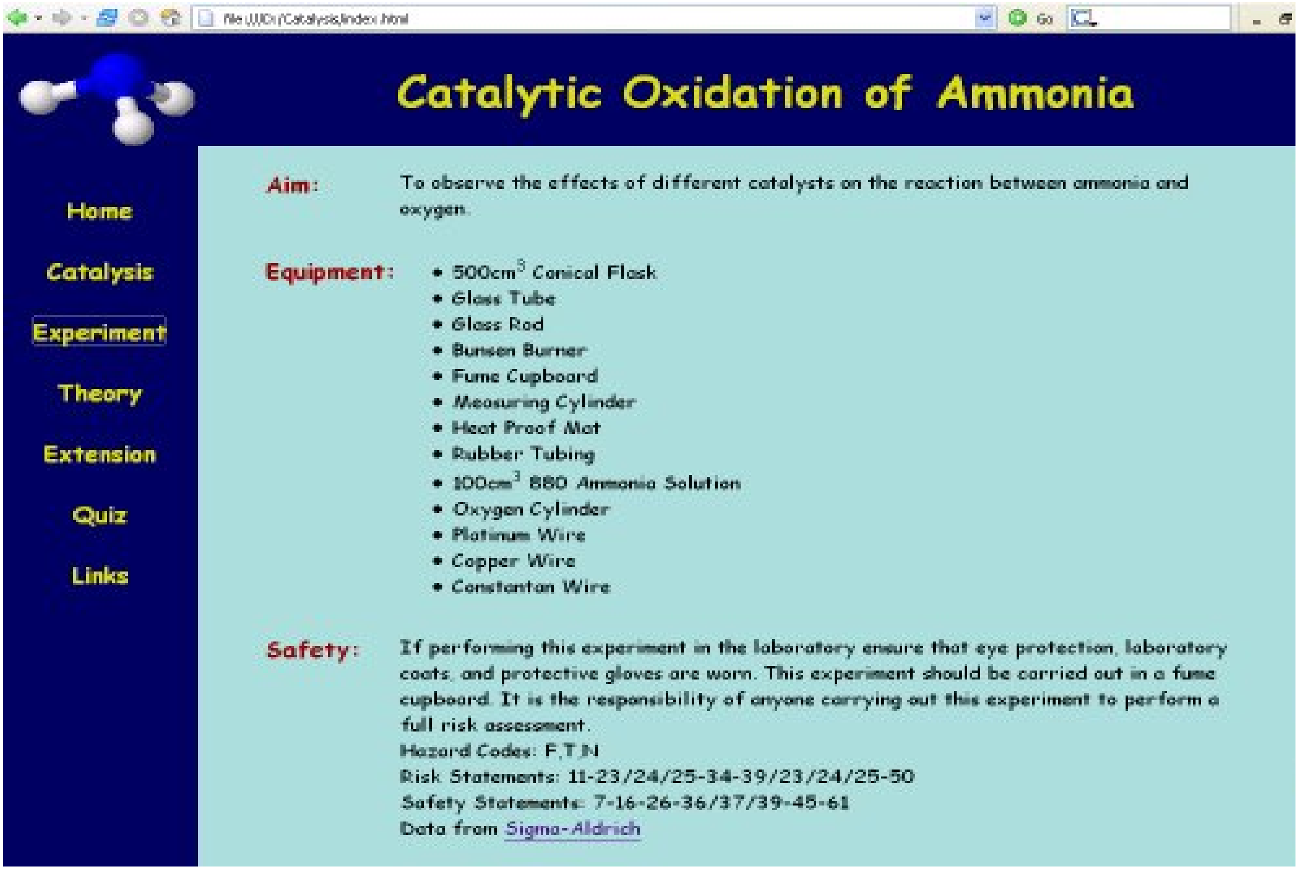
This is then followed by:

$$2NO\,(g) + O_2\,(g) \leftrightarrow 2NO_2\,(g)$$

nitrogen monoxide + oxygen ↔ nitrogen dioxide

The brown vapour observed in the reaction is nitrogen dioxide. In addition to being given off as a gas, the nitrogen dioxide reacts with the water to form nitric acid:

$$2NO_2\,(g) + H_2O\,(l) \rightarrow HNO_2\,(aq) + HNO_3\,(aq)$$



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Aim: To observe the effects of different catalysts on the reaction between ammonia and oxygen.

Equipment:

- 500cm^3 Conical Flask
- Glass Tube
- Glass Rod
- Bunsen Burner
- Fume Cupboard
- Measuring Cylinder
- Heat Proof Mat
- Rubber Tubing
- 100cm^3 880 Ammonia Solution
- Oxygen Cylinder
- Platinum Wire
- Copper Wire
- Constantan Wire

Safety: If performing this experiment in the laboratory ensure that eye protection, laboratory coats, and protective gloves are worn. This experiment should be carried out in a fume cupboard. It is the responsibility of anyone carrying out this experiment to perform a full risk assessment.

Hazard Codes: F,T,N

Risk Statements: 11-23/24/25-34-39/23/24/25-50

Safety Statements: 7-16-26-36/37/39-45-61

Data from Sigma-Aldrich