Teaching ideas for Chapter 6, *Rates of reaction*

Questions

Two worksheets of questions are provided:
- the first worksheet deals with the Standard Level part of the syllabus
- the second worksheet is for Higher Level only.

There are also a large number of questions available in the Coursebook and on the accompanying CD-ROM.

Teaching ideas

Much of this topic can be taught through practical work (see below).

- Students can research the application of catalysts in industry. The application of kinetics in industrial processes can be linked to discussions about industrial processes in the equilibrium topic (Chapter 7).
- The use of catalytic converters in reducing the environmental impact of burning fossil fuels for transport purposes could be discussed. This could lead to discussions about the environmental impact of transport in general.
- A discussion of catalytic converters could also lead to a discussion of leaded gasoline:
  – why leaded gasoline was used
  – the environmental impact of leaded gasoline and
  – alternatives that are used now.
  Alternatives to lead tetraethyl in gasoline include MTBE, which also has environmental problems associated with it:
  http://www.chm.bris.ac.uk/motm/leadtet/leadh.htm
- It could be discussed why different countries use different additives for gasoline and how and why environmental laws vary between different countries.
- The application of kinetics to atmospheric chemistry could be discussed.
- The idea of a reaction mechanism and rate-determining step can be discussed using an analogy such as fans entering a football stadium. Students can find the concept of a reaction mechanism difficult and several examples should be used to help in the explanation. Students will generally benefit from the use of some sort of analogy and lots of practice. This work can be linked to S_N1 and S_N2 reactions in organic chemistry.
- Students could research the life and work of Arrhenius.
  Svante Arrhenius (1859–1927) was a Swedish scientist who was awarded the Nobel Prize for Chemistry in 1903. Arrhenius was the first Swede to win a Nobel Prize and since Arrhenius three other Swedish scientists have won the prize for Chemistry.
- Students could research the nationalities of other scientists who have won for the Nobel Prize for Chemistry.
  – Is chemistry an international subject?
  – In the future, chemical research could be the domain of a few very rich countries. Are scientists valued more in some countries than in others?

Practical activities

Safety

Extreme care must be exercised when carrying out any practical activities in the classroom and a risk assessment should be conducted before carrying out the experiments.

Demonstrations

- There are various demonstrations that can be carried out to demonstrate the idea of rate of reaction:
  - a very slow reaction would be the rusting of iron
  - moderate speed reactions would be the reaction of magnesium metal or calcium carbonate with hydrochloric acid (add magnesium ribbon or marble chips to 1 mol dm^{-3} hydrochloric acid in a beaker)
  - a fast reaction could be a methane/oxygen or hydrogen/oxygen explosion: http://www.rsc.org/Education/EiC/issues/2010November/ExhibitionChemistry.asp
- The method of determining the rate of reaction by measuring the decrease in mass of a system in which a gas is produced can be illustrated by conducting the reaction between calcium carbonate and hydrochloric acid on an electronic balance. The experimental set-up is given in the Coursebook, page 243.
- The idea that two particles must collide with sufficient energy in order for a reaction to occur can be demonstrated by rolling two apples together gently (no reaction) or pushing them together very hard so that they break.
- The effect of surface area on the rate of a reaction can be illustrated by sprinkling dry custard powder/milk powder/lycopodium powder into a flame or using a syringe to push these through a flame:
  http://www.practicalchemistry.org/experiments/the-cornflour-bomb,224,EX.html
  http://www1.chem.leeds.ac.uk/delights/texts/expt_6.html
  http://dwb4.unl.edu/Chemistry/dochem/DoChem048.html
  http://www.angelo.edu/faculty/kboudrea/demos/lycopodium/lycopodium.htm

  Combustible dust explosions have killed many people over the years. Dusts have a very high surface area. An explosion can occur when flour dust, grain dust or coal dust is present in the air and is ignited. A great deal of care must therefore be exercised in industries which generate combustible dusts and regulations are in place to reduce the chance of dust explosions.

Various reactions can be carried out to illustrate catalysis.

- The decomposition of hydrogen peroxide (100 volume is spectacular) using MnO_2 as the catalyst (**Care!**).
- The decomposition of hydrogen peroxide mixed with washing-up liquid using KI as the catalyst. This is often called ‘elephant’s toothpaste’:
  http://www.using-hydrogen-peroxide.com/elephant-toothpaste.html
  http://portal.acs.org/portal/fileFetch/C/CNBP_024574/pdf/CNBP_024574.pdf
  http://www.stevespanglerscience.com/experiment/hydrogen-peroxide-eruption
- A solution of sodium potassium tartrate (Rochelle salt) is reacted with hydrogen peroxide using cobalt chloride as a catalyst. This demonstration illustrates the idea that a catalyst is reformed at the end of the reaction. Full details of how to carry out the reaction can be found at:
  http://www.practicalchemistry.org/experiments/involvement-of-catalysts-in-reactions,160,EX.html

- The reaction of liver with hydrogen peroxide solution can be used to introduce students to the idea of enzymes as catalysts. A piece of raw liver is put into a boiling tube containing 10 volume hydrogen peroxide. The liver could also be cooked beforehand to show how heating denatures the enzyme.

Student practicals

This topic lends itself to practical work and many experiments can be carried out by students.

Some of the typical experiments that could be carried out are the following.

- Determination of a rate of reaction.
  Students could measure the rate of reaction between magnesium and hydrochloric acid by recording the volume of gas given off every 30 s. The results could be plotted on a graph and the average rate and rate at any particular time determined from the graph.
  0.2 g of magnesium ribbon and 50 cm^3 of 0.5 mol dm^{-3} hydrochloric acid should produce decent results. A 250 cm^3 measuring cylinder could be used to collect the gas.
- Students could investigate the effect of surface area, concentration or temperature on the rate of reaction by using the reaction between calcium carbonate and hydrochloric acid.
  Suitable quantities are 1.0 g of small marble chips and 40 cm^3 of 0.5 mol dm^{-3} HCl.
- Students could investigate catalysts by using the decomposition of hydrogen peroxide.
  The concentration of hydrogen peroxide, amount of catalyst, surface area of catalyst and temperature could all be varied.
  Suitable quantities are 20 cm^3 of 10 volume hydrogen peroxide and 0.2 g of catalyst.
- The experiments above could be used for assessment of Design.
  The students could be asked to investigate a factor that affects the rate of reaction between either magnesium metal or calcium carbonate and hydrochloric acid. They should come up with the research question, the experimental set-up, a procedure and the amounts/concentrations themselves. They must not be told the amount of reactants to use or suitable concentrations.
- Students could investigate the effect of concentration on rate of reaction by carrying out the reaction between sodium thiosulfate solution and hydrochloric acid.
  Investigating the effect of the concentration of sodium thiosulfate is simpler than investigating the effect of the concentration of hydrochloric acid.
  This experiment cannot be used for assessment of Design as it is a well-known procedure and details can be found in any practical chemistry book.
  Practical 1 – Chapter 6: ***Designing an experiment to investigate the effect of concentration on reaction rate*** is provided to help with teaching of the Design process.

  The reaction between sodium thiosulfate and hydrochloric acid can, however, be used for DCP and CE. If used for assessment the students must not be told how to process the results or given a table to fill in.
  Practical sheets are supplied.
  Practical 2 – Chapter 6: ***Investigating the effect of concentration on reaction rate*** is a teaching exercise and must not be given to students if the practical is to be assessed.
  Practical 3 – Chapter 6: ***Investigating the effect of concentration on reaction rate – Assessed Practical*** can be given to students if assessing DCP and CE.
- The reaction between sodium thiosulfate and hydrochloric acid can also be used to investigate the effect of changing temperature on rate of reaction.
  Again, two practical sheets are provided.
  Practical 4 – Chapter 6: ***Investigating the effect of temperature on reaction rate*** is a teaching exercise.
  Practical 5 – Chapter 6: ***Investigating the effect of temperature on reaction rate – Assessed Practical*** can be given to students for assessment.

- Students could investigate the effect of changing the concentration of various reactants on the rate of this reaction:

  $H_2O_2 + 2KI + H_2SO_4 \rightarrow 2H_2O + I_2 + K_2SO_4$

  Two experimental sheets are provided.
  Practical 6 – Chapter 6: ***Effect of concentration on rate*** can be used as a teaching exercise.
  Practical 7 – Chapter 6: ***Effect of concentration on rate*** should be used if the experiment is to be assessed.

- Determination of an activation energy:
  http://www.uccs.edu/~chemistry/nsf/106%20Expt2V-KineticsII.pdf
  http://webs.wofford.edu/arringtonca/gchem/Activation_Energy_of_a_Chemical_Reaction.pdf

Common problems

- Students tend to find the use of the Arrhenius equation to determine activation energy difficult and extra help will need to be given with the maths involved. The key point is getting over the idea of the equation being essentially that of a straight line.

ICT

There are many opportunities for using IT in this topic.

- Many of the excellent websites are listed below contain simulations or video.
- Students can use spreadsheets to process data and draw graphs.
- The variation of the Maxwell–Boltzmann distribution with temperature may be studied using Application 1 on the Coursebook CD-ROM.
- Some demonstrations of reactions:
  http://boyles.sdsmt.edu/listbydemo.htm
  http://www.chem.leeds.ac.uk/delights/
- Videos of some reactions:
  http://www.neatorama.com/2009/11/04/top-10-mad-science-worthy-chemistry-experiments/
- Details of how to carry out demonstrations/practicals on kinetics and many other topics:
  http://outreach.chem.indiana.edu/demos.asp
- Animations and videos:
  http://www.kentchemistry.com/links/Kinetics/FactorsAffecting.htm
- Rates animations:
  http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm
- Rates simulation:
  http://www.chm.davidson.edu/vce/kinetics/ReactionRates.html
- Collision theory simulations:
  http://michele.usc.edu/105b/105bfall98/resources/resource.html
- Activation energy:
  http://matdl.org/virtuallabs/index.php/3.091_VirtualLab
- Catalysis:
  http://www.catalysis-ed.org.uk/

Theory of knowledge (TOK)

The idea that a theory can never be actually proved correct, only proved incorrect, can be discussed with regard to collision theory or reaction mechanisms.

The use of inductive reasoning in chemistry could be discussed with regard to the effect of temperature on a chemical reaction. Do **all** chemical reactions get faster as the temperature is increased?