Teaching ideas for Chapter 5, *Energetics*

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

- Cold packs used for sports injuries can be shown to illustrate endothermic reactions.
- A discussion of exothermic reactions could be extended to the ideas of fuels in general.
- The combustion of all fossil fuels involves exothermic reactions.
- Alternative forms of energy could be discussed, looking at the various energy interchanges that occur.
- The attitudes of different countries to the burning of fossil fuels and use of alternative forms of energy could be discussed.
- Ethanol (and other biofuels) and petrol (gasoline) as fuels could be discussed. Is it only the amount of energy that is given out that determines a good fuel or must other factors (products of the reaction, source of the fuel, etc.) be considered?
- The specific heat capacity of water could be compared to that of other substances; water has a high specific heat capacity. This means that quite a lot of energy is required to change its temperature by a significant amount. This is important to life on Earth. It means that the oceans maintain a fairly uniform temperature and as such are a suitable habitat for marine organisms. It also means that the water present within living cells helps to maintain a fairly constant temperature, which is suitable for the biochemical reactions needed for life.
- The idea of stability can be discussed, considering the difference between thermodynamic stability and kinetic stability. This topic can be brought up again when teaching about rates of reaction in Chapter 6.
- Energetics can be linked to work on kinetics, equilibrium and industrial processes in Chapter 7.
- Entropy could be introduced from a statistical point of view by, for example, throwing a pack of cards in the air and suggesting to students that they are going to land as a card house: http://www.rsc.org/Education/Teachers/Resources/QuantumCasinoSite.asp
- The idea of entropy as the ‘arrow of time’ could be discussed:
  http://hyperphysics.phy-astr.gsu.edu/hbase/therm/entrop.html
  http://www.bbc.co.uk/programmes/p00fflcs
- Students could research the life of Ludwig Boltzmann and the equation $S = k \log W$.
- The importance of a consideration of ΔG in industrial processes could be linked to the ideas of extracting metals from their ores. Ellingham diagrams could also be introduced.

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 both exothermic and endothermic reactions.

- The reaction between magnesium turnings and concentrated hydrochloric acid:
  A spatula load of magnesium turnings is added to 20 cm^3 of concentrated hydrochloric acid in a small beaker. Wear eye protection and make sure students are well back.
- The decomposition of hydrogen peroxide using manganese(IV) oxide as the catalyst:
  Add a spatula load of manganese(IV) oxide to 20 cm^3 of 100 volume hydrogen peroxide solution in a boiling tube. Wear eye protection and make sure students are well back.
- An endothermic reaction occurs when solid barium hydroxide is stirred rapidly with solid ammonium thiocyanate. The temperature can drop to about –30 °C! Care must be exercised as ammonia gas is produced in this demonstration.
  http://www.practicalchemistry.org/experiments/endothermic-solid-solid-reactions,277,EX.html
  http://jchemed.chem.wisc.edu/JCESoft/CCA/CCA3/MAIN/ENDO2/PAGE1.HTM
  http://www.chem.umn.edu/outreach/endoexo.html

Student practicals

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

Many experiments can be carried out using data-logging equipment, so fulfilling this section of the ICT requirements.

There is also plenty of opportunity to process the data using spreadsheets.

Here are some typical experiments that could be carried out.

- The determination of the enthalpy change of combustion of a liquid fuel such as an alcohol. The liquid fuel could be put into a spirit burner and used to heat up a known mass of water. A variation of this is to burn food such as nuts in order to determine the calorific value of food (with a link to Option B, *Human biochemistry*). Check whether any students have severe nut allergies; if so, popcorn is a safe alternative.
  http://www.practicalchemistry.org/experiments/measuring-heat-energy-of-fuels,21,EX.html
  http://www.creative-chemistry.org.uk/alevel/module2/documents/N-ch2-09.pdf

  This sort of practical can also be used for a 'Design' experiment, but in this case practical sheets should not be given out to students. The students could be given a list of alcohols and asked to investigate something to do with the combustion of alcohols.
- The determination of enthalpy change of neutralisation by mixing together an acid and an alkali. This experiment could also be linked to Chapter 8 by comparing the enthalpy change of neutralisation of strong and weak acids.
  See **Practical 1 – Chapter 5: *Enthalpy change of neutralisation***.
  http://www.cerlabs.com/experiments/10875409016.pdf

- The determination of the enthalpy change of solution.
  5 g of an ionic salt is dissolved in 25 cm^3 of water and the temperature change measured. Some salts dissolve in an endothermic process, others in an exothermic process. The influence of entropy can be discussed for an endothermic process.
  A variation is to investigate how changing the mass of the salt being dissolved affects the temperature change and the value of the enthalpy change of solution.
  This experiment can be used as a 'Design' experiment; if so, the minimum amount of information must be given. The students could be given a list of salts and asked to investigate a factor associated with dissolving and the amount of heat given out/taken in.
- The reaction between zinc and copper sulfate solution can be investigated. The temperature of 25 cm3 of 0.50 mol dm–3 copper sulfate can be measured every 20 s and then, at precisely 2 minutes, 3 g (excess) zinc is added and the mixture stirred rapidly. The temperature should be recorded for a further 8 minutes. The data should then be plotted and the cooling part of the curve extrapolated back to 2 minutes to give a better estimate of the actual temperature change. Note that this experiment has featured in at least two past examination papers.
  Practical 2 – Chapter 5: Displacement reactions: data-logging to find an enthalpy change is a version of this practical designed for dataloggers. Note that the practical sheet is designed as a teaching exercise and is not for assessment. However, this experiment can be used for assessment of DCP by omitting everything after point 8 on the practical sheet.

Hess's law can be illustrated in various ways.

- The determination of the enthalpy change of hydration.
  Suitable examples are either copper sulfate or sodium carbonate. This can be done by dissolving separate samples of the hydrated and anhydrous salts in water and measuring the temperature changes. The enthalpy changes may then be determined.
- The determination of the enthalpy change of formation of magnesium oxide.
  This can be done by adding magnesium and magnesium oxide to separate samples of hydrochloric acid and measuring the temperature changes. The students will also need to be given a value for the enthalpy change of formation of water.
  See **Practical 3 – Chapter 5:** ***Enthalpy change of formation of magnesium oxide***.
- The determination of the enthalpy change of decomposition.
  Suitable compounds to work with are sodium hydrogencarbonate (or potassium hydrogencarbonate) decomposing to sodium carbonate (or potassium carbonate). The temperature changes are measured when adding both the carbonate and the hydrogencarbonate to separate samples of hydrochloric acid.
  Details of how to carry out these experiments are given in the links below. However, if the practical is to be used to assess DCP, details of how to record the data or to process it must not be given to students.
  http://www.files.chem.vt.edu/RVGS/ACT/lab/Experiments/Exp_10-Hess_Law.html
  http://www.cdli.ca/courses/chem3202/unit03_org03_ilo05/c3lab06.pdf
  http://store.aqa.org.uk/qual/gce/pdf/AQA-2420-W-TRB-PSA04.PDF
  http://www.smc.edu/projects/28/Chemistry_11_Experiments/Calorimetry_Procedure.pdf
  http://www2.ucdsb.on.ca/tiss/stretton/chem2/enthlab3.htm

Common problems

- Students sometimes get confused about endothermic reactions and, if heat is taken in, why the temperature does not increase. It should be stressed that this energy is converted to a different form (chemical energy).
- This topic requires a great deal of practice on the various types of calculations that can be encountered. There are a large numbers of questions in the Coursebook and the accompanying CD-ROM. The most able students can be stretched with, for example, questions from Chemistry Olympiads, available from the Royal Society of Chemistry website:
  http://www.rsc.org/Education/SchoolStudents/Olympiad/index.asp

- When teaching the different methods of calculations for determining enthalpy changes, it should be stressed that it is the data that is given that determines the method used and not what has to be found.

ICT

There are many opportunities for using IT in this topic.

Many excellent websites, containing simulations or videos, are listed below.

Datalogging can be used for practical work and students can be shown how to process data and draw graphs using a spreadsheet program such as Excel.

- The ***Enthalpy of solution formulas*** spreadsheet can be used for processing data for an enthalpy change of solution experiment.
- Application 1 on the Coursebook CD-ROM is a spreadsheet that calculates the value of ΔG as the temperature changes.
- Bond energies and energy level diagrams:
  http://schools.matter.org.uk/Content/Reactions/BondActivation.html
- Hess's law – links in with the experiment to determine the enthalpy change of formation of magnesium oxide (see **Practical 3 – Chapter 5**):
  http://www.dartmouth.edu/~chemlab/info/resources/deltah/deltah.html
- Virtual laboratory, where experiments on thermochemistry and other topics can be carried out:
  http://www.chemcollective.org/applets/vlab.php
- Some experimental simulations on energetics and other topics:
  http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm
- Born–Haber cycle simulations are available from yteach, but they must be purchased:
  http://www.yteach.co.za/
- Interactive Born–Haber cycles
  http://www.rsc.org/Education/Teachers/Resources/Databook/int_born_haber.htm
- Experiments on specific heat capacity and other things:
  http://www.chm.davidson.edu/vce/
- Videos and instructions for demonstrations on thermochemistry and various other things:
  http://chemed.chem.purdue.edu/demos/index.html#Ch5
- Databases, as zipped files:
  http://www.rsc.org/Education/Teachers/Resources/Databook/data/databases/bondenergies.zip
  http://www.rsc.org/Education/Teachers/Resources/Databook/data/databases/compounds.zip
- The song 'The first and second law' by Flanders and Swann is available on YouTube or from the following website:
  http://www.uky.edu/~holler/CHE107/media/first_second_law.mp3

Theory of knowledge (TOK)

The variation between experimental and theoretical data can be discussed.

What criteria do we use to judge whether the difference between the two values is due to experimental errors or the limitations of the theoretical models?

The use of mathematical models to describe the real world can be discussed by reference to the lattice enthalpies obtained from a Born–Haber cycle and those obtained from using models of various levels of sophistication (the Born–Landé, Born–Mayer and Kapustinskii equations).

