Teaching ideas for Chapter 4, *The periodic table*

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

In the Coursebook this chapter comes after the chapter on bonding, but in the IB Chemistry Guide they are the other way around. The ideas in one chapter rely on those in the other and they could be taught in either order.

- Students can be shown samples of various elements to demonstrate differences in appearance and other physical properties. Sets of elements are available from e.g. http://www.element-collection.com/
- Molecular models may be used to demonstrate the structures of sulfur, phosphorus and phosphorus oxides.
- Students can be shown samples of various transition metal salts to illustrate colours. Note that sodium dichromate(VI) and potassium manganate(VII) are both $3d^0$ and the colours are due to charge transfer and not the explanation given on the course.
- Students could research the history of the periodic table and the history of the discovery of the elements. They could also pick a particular element and research its history, properties and uses and present the data to the rest of the class. The significance of the names of some of the elements could be discussed and how this illustrates the international nature of Chemistry. Periodic tables in other languages could be discussed, highlighting the fact that they are all of the same form.
- Different forms of the periodic table could be investigated.
- A set of cards with element properties could be made (or the students could make them) and students asked to order them into a table. This is similar to the procedure adopted by Mendeleev – he used cards with the name of the element, atomic weight and chemical properties.
- Students could research the life of Mendeleev.
- Students could research countries where various elements are found, covering the uses of these elements and political and economic factors that influence the supply of these elements.
  http://www.instituteforenergyresearch.org/2010/02/17/rare-earth-elements-are-vulnerable-to-supply-disruptions-when-china-controls-97-of-the-world%E2%80%99s-production/
  http://www.ibcadvancedalloys.com/investors/about-beryllium/
  http://www.world-nuclear.org/education/mining.htm
- Students can research the environmental problems caused by the production of acidic non-metal oxides in industrial processes and in the internal combustion engine.
  - They could look at levels of sulfur dioxide and nitrogen oxides in their local areas.
  - They could look at regulations for the emission of these and how and why they vary between different countries.

  - Acid rain is an example of an environmental problem that can originate in one country but can affect other countries. The responsibilities we have towards our neighbouring countries could be discussed.

- The life and work of Linus Pauling could be researched by students. Pauling won not only a Nobel Prize for Chemistry but also one for Peace.
- Students could be encouraged to read ‘The Periodic Table’ by Primo Levi.
- White phosphorus can be used in incendiary weapons but its use in civilian areas has been banned by the Geneva Convention, although there is some evidence that it has been used in civilian areas in recent conflicts. The role of chemistry in warfare could be discussed as well as the moral responsibility of scientists – students could also be encouraged to read ‘Die Physiker’ by Dürrenmatt.
- Students could research more advanced theories of the bonding in transition metal complexes:
  - crystal field theory
  - ligand field theory
  - molecular orbital theory.

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 in this topic.

- The reaction of alkali metals with water

  Lithium, sodium and potassium are usually stored under oil. A small piece (maximum about 2–3 mm cube) is cut when the metal is still under the oil. The piece of metal is removed from the oil using tweezers (do not touch the metal with your fingers) and the oil removed with a paper towel. The metal is placed in a large trough of water to which some universal indicator solution has been previously added. Students should stand well back and they should either wear eye protection or there should be a safety shield between them and the trough.

  Extreme care must be exercised when handling potassium as this can be a lot more unpredictable than the other metals. The lab should also be well-ventilated as choking fumes are given off.

  The piece of sodium can be put on a piece of filter paper in the trough for a more spectacular reaction (**Care!**). It is held in the same position and the hydrogen should catch light.

  A very small piece of lithium can be added to water in a boiling tube and the gas collected to demonstrate that hydrogen is produced (**Care!**).
  http://www.suite101.com/content/experiment-with-sodium-in-water-a284413

- The reactions of alkali metals with chlorine and oxygen could be demonstrated (**Care!**):
  http://www.practicalchemistry.org/experiments/heating-group-1-metals-in-air-and-in-chlorine,127,EX.html
  http://www.angelo.edu/faculty/kboudrea/demos/sodium_chlorine/sodium_chlorine.htm

- The reactions of aluminium or iron with chlorine, bromine and iodine can be demonstrated:
  http://www.practicalchemistry.org/experiments/27-july-07-reactions-of-chlorine-bromine-and-iodine-with-aluminium,120,EX.html
  http://www.practicalchemistry.org/experiments/halogen-reactions-with-iron,44,EX.html

- The elements in period 3 may be reacted with oxygen and the acid–base behaviour of the resulting oxides investigated by adding universal indicator solution. Sodium, magnesium, phosphorus and sulfur all react well with oxygen.

  sodium + oxygen
  A small piece of sodium (2–3 mm cube) is removed from the oil and dabbed dry with a paper towel. This is placed on a deflagrating spoon and heated in a Bunsen flame until it ignites. It is then placed in a gas jar of oxygen and white fumes of sodium oxide should be seen. When all the sodium has reacted a small amount of water is added to the gas jar, followed by some universal indicator solution. Care must be exercised when adding water as there may be some unreacted pieces of hot sodium present.

  magnesium + oxygen
  A piece of magnesium ribbon about 15 cm long is folded in two and held, using tongs, in a Bunsen flame until it ignites. Quickly remove the lid from a gas jar of oxygen and then hold the burning magnesium in the gas jar. Try not to drop the burning magnesium ribbon as it can crack the gas jar. Students should be told to try to avoid looking directly at the bright white light. Once the reaction has finished some water and universal indicator solution are added to the gas jar. Note that magnesium oxide is not particularly soluble in water; the indicator may not turn blue if not enough dissolves.

  aluminium + oxygen
  http://www.practicalchemistry.org/experiments/the-real-reactivity-of-aluminium,212,EX.html

  phosphorus + oxygen
  Warning: do not carry out this demonstration if you are at all unsure about it!
  White phosphorus is spontaneously flammable in air.
  This reaction should be carried out in a fume hood.
  Put some sand in the bottom of a gas jar filled with oxygen, The phosphorus should be cut while under water and left under water until you are ready to use it. Take a small piece of phosphorus (2 mm cube) out of the container using tongs. Quickly dab it dry and drop it into the gas jar. Touch the piece of phosphorus with a heated piece of metal. Cover the gas jar with a lid. When the reaction has finished add a small amount of water and universal indicator solution by pouring it down the side of the gas jar.
  http://www.angelo.edu/faculty/kboudrea/demos/burning_phosphorus/burning_phosphorus.htm

  sulfur + oxygen
  This reaction must be carried out in a fume hood as sulfur dioxide is produced.
  A small piece of sulfur is placed on a deflagrating spoon and held in a Bunsen flame in a fume hood until it ignites. It is then placed in a gas jar of oxygen. Once the reaction has finished some water and universal indicator should be added to the gas jar.

- If a visible spectrometer is available then the idea that the complementary colour is absorbed by transition metal complex ions could be investigated.

Various demonstrations can be carried out to illustrate the properties of transition metal compounds. Here are some examples.

- Copper complexes:
  About 50 cm^3 of 0.5 mol dm^{-3} copper sulfate is placed in a conical flask. Concentrated ammonia (**Care**!) is added to the flask to produce the indigo colour of the ammonia complex. Concentrated hydrochloric acid (**Care!**) is added down the side of the conical flask to create a second (green) layer.

- Potassium thiocyanate solution is added to a solution of iron(III).

- Potassium iodide solution is added to copper sulfate solution. Iodine and a precipitate of CuI are formed.

- Different oxidation states can also be illustrated using vanadium:
  http://media.rsc.org/Classic%20Chem%20Demos/CCD-92.pdf

- A solution of Fe^{2+}(aq) can be heated with acidified potassium dichromate(VI) in a boiling tube to illustrate the oxidation of iron(II) and chromium(VI).
- Transition metal compounds as catalysts can be demonstrated by adding a small amount of MnO_2 powder to 10 cm^3 of hydrogen peroxide solution in a boiling tube. Spectacular results can be obtained by using 100 volume hydrogen peroxide but extreme care must be exercised as the reaction is extremely exothermic and the hydrogen peroxide can burn. Students should wear eye protection and stand well back.

Student practicals

- Students can investigate the displacement reaction of halogens by adding chlorine water, bromine water or iodine solution to separate solutions of potassium chloride, potassium bromide and potassium iodide. They need to observe the colour changes. The final solutions could also be shaken with hexane.
  http://www.creative-chemistry.org.uk/alevel/module2/documents/N-ch2-05.pdf
  http://www.practicalchemistry.org/experiments/reactions-of-aqueous-solutions-of-the-halogens,136,EX.html
- Students could investigate the reactions of period 3 chlorides with water, using NaCl, $MgCl_2$, $AlCl_3$ (anhydrous), $SiCl_4$, PCl_3 and PCl_5.
  See **Practical 1 – Chapter 4: *Reactions of period 3 chlorides***.
  A guidance sheet is available for this practical.
- Students could investigate the reactions of transition metal compounds.
  See **Practical 2 – Chapter 4: *Reactions of transition metal solutions***.
  For Test 1, 0.1 mol dm^{-3} solutions of Cu^{2+}, Fe^{2+} and Fe^{3+} will be suitable. Use dilute solutions of ammonia and sodium hydroxide.
  For Test 2 use 0.1 mol dm^{-3} potassium chromate (VI) and 0.02 mol dm^{-3} potassium manganate(VII).

Common problems

- Students can find this topic more difficult as it requires some memorising of equations for reactions.
- There can be some confusion about the colours of transition metals and it must be stressed that the colours are due to the frequencies of light that are **not** absorbed.

ICT

- Students could investigate the properties of elements using Application 1 on the Coursebook CD-ROM. They can use the data to produce graphs in Excel. This fulfils the ICT requirements stated on the course for use of a database and for using graph-drawing software.
- There are many excellent websites featuring interactive periodic tables:
  http://www.element-collection.com/
  http://www.webelements.com/
  http://www.ptable.com/
  http://www.touchspin.com/chem/DisplayTable.html
  http://www.chemicool.com/
  http://periodic.lanl.gov/index.shtml
  http://www.rsc.org/chemsoc/visualelements/pages/periodic_table.html
  http://www.periodictable.com/
  http://www.merck-chemicals.com/periodic-table/c_v.Gb.s1LjHEAAAEWTeYfVhTo
  (also available as app for iphone/ipad)

- This site allows you to plot data:
  http://acswebcontent.acs.org/games/pt.html
- This excellent site contains videos of the elements:
  http://www.periodicvideos.com/
- This site shows electrons in shells and emission spectra:
  http://www.colorado.edu/physics/2000/applets/a2.html
- Other applications which may be of use:
  http://genesismission.jpl.nasa.gov/educate/scimodule/cosmic/ptable.html
- Database including a quiz:
  http://www.elementsdatabase.com/
- Lots of activities on this site:
  http://www.nclark.net/PeriodicTable#Activities
- The following is a zipped file containing a database about the elements
  http://www.rsc.org/Education/Teachers/Resources/Databook/data/databases/elements.zip
- Tom Lehrer's *The Elements Song*:
  http://www.privatehand.com/flash/elements.html
- Transition metal salts reactions
  http://www.chem.ox.ac.uk/vrchemistry/LiveChem/transitionmetals_content.html

Theory of knowledge (TOK)

The idea of a scientist as a 'risk taker' can be discussed by reference to Mendeleev and the risks that he took by presenting a periodic table with gaps for missing elements.

Mendeleev claims to have seen the arrangement of the elements in the periodic table in a dream. The idea that the origins of a theory do not make it scientific or non-scientific could be discussed in the light of this.

The nature of colour could be discussed when looking at transition metal complexes. Is colour a property of matter or simply in the mind of the beholder? What about other properties of compounds?