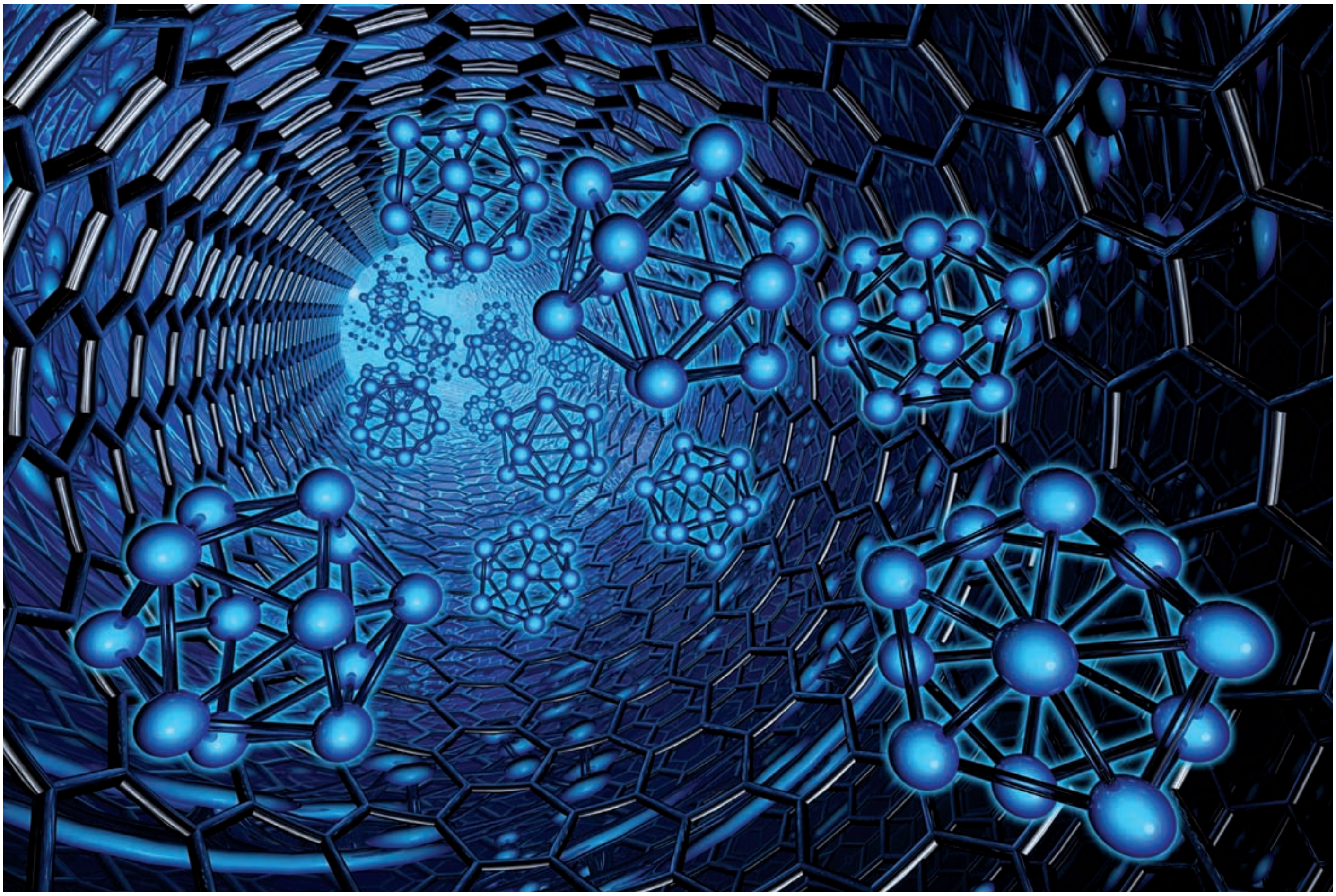
Structure and Bonding

Teacher Notes



Structure and Bonding is funded as part of the Reach and Teach educational programme supported by the Wolfson Foundation

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Structure and Bonding

Why focus on G&T and higher achievers?

Within the education system every child has the right to develop their learning so as to maximise their potential.

These exercises are designed to enthuse students and provide enrichment activities that although related to the curriculum are in fact taking the learning experience to the next level whilst also showing chemistry in a familiar context. This has been found to be a successful model for not only improving learning but also for raising levels of motivation. Higher achieving students can find the restraints of the standard curriculum to be demotivating leading to underachievement.

The different activities are designed to improve a number of skills including practical work/dexterity, thinking/analysis skills, literacy, research activities, use of models and teamwork. Students should also gain confidence through achievements in conceptually advanced activities and improve their ability to express themselves.

Some of the activities may appear to be complex for KS3 (year 9), however at this stage in their learning high achieving students are open to new concepts and are ready to explore issues without pre-conceptions. They are keen to link ideas and develop concepts and understanding. It can prove to be an uplifting experience.

Introduction

Knowledge of structure and bonding can help explain the properties of materials. All the properties of a particular substance depend upon the elements present and how they are bonded to each other.

This programme is designed to develop students understanding of structure and bonding as well as developing thinking and research skills.

Topic	Type of activity	Summary	Timing (mins)	KS3	KS4	KS5	Page
Lewis cubes	Thinking skills	Learning about the formation of double bonds Understanding the limitations of models	60	√	√		5
Limonene	Practical	Steam distillation of essential oils Analysis of alkenes How science works	60-80	√	√	√	11
Chirality	Research activity	Research into thalidomide – a chiral molecule where one enantiomer can cause severe health implications	Student Centred	√	√		21
Chirality	Practical	Measuring optical rotation in naturally occurring	30	√	√	√	23

		substances using polarimetry					
Chirality	Questions/ Research activity	Questions based upon chirality to stretch the level of understanding and develop research skills	20-30			√	25

The first activity looks at the use and limitation of models. Many students accuse teachers of telling ‘lies’ as their learning develops, particularly when teaching structure and bonding. Lewis developed a model for covalent bonding based upon cubes. This is a model that works well for single and double bonds but fails with triple bonds. It is good for the students to explore the limitations by making the models. They should appreciate that models work for the information and understanding available at the time. It is also a good learning or revision tool for covalent bonding and the idea of sharing electrons between two atoms.

Having explored the basic idea of bonding related to structure with Lewis cubes the following work on limonene starts to apply that knowledge to a real situation. The limonene experiment provides many opportunities for extension activities as well as gaining an understanding of structure and particularly isomerism. This can then be related to properties exhibited by the covalent molecule. Opportunities linked to this experiment include optical isomerism and their detection, unsaturation and its detection, and the principles of steam distillation related to extraction of plant oils. A useful website is that of Norfolk Lavender http://www.norfolk-lavender.co.uk/pages/lavender-oil-distillery.php a company who use this process to extract oil from lavender flowers. The link gives a photograph and some information of their distillation process. This puts the knowledge gained into a context and clearly links to How Science Works. It also provides for higher level practical skills as well as developing interpretive skills and understanding.

Having gained a basic understanding of structure and bonding and how it can affect the properties of molecules, the next activity takes that knowledge and understanding to the next level by investigating the role of isomers and specifically optical isomers (chiral molecules) and the effect seen with these mirror image molecules. Using polarimetry links through to the properties of light, introducing the concept of plane polarised light, and provides a practical experience of the identification and measurement of optical rotation using a naturally occurring molecule such as glucose.

The work on chiral molecules provides for a research topic based around thalidomide, an independent learning exercise, thereby allowing for the development of research skills including searching for information and presenting data/reports and promoting literacy skills.

For key stage 5 students the higher level question on chirality act as a further extension activity for key stage 5 that is best treated as a research exercise.

Aims and objectives

The aims and objectives of these activities are:

- Developing questioning skills through problem solving.
- Exploring the use of models to expand understanding

- To appreciate that all models have limitations dependent upon the knowledge available and the application.
- Develop practical skills and dexterity.
- Promote independent learning and research skills.

Chemistry topics:

- Covalent bonding.
- Steam distillation.
- Organic structures.
- Tests for alkenes.
- Chirality.
- Polarimetry.

These exercises can be used with key stages 4, 5 and higher achieving key stage 3 as indicated on the *Possible Routes*.

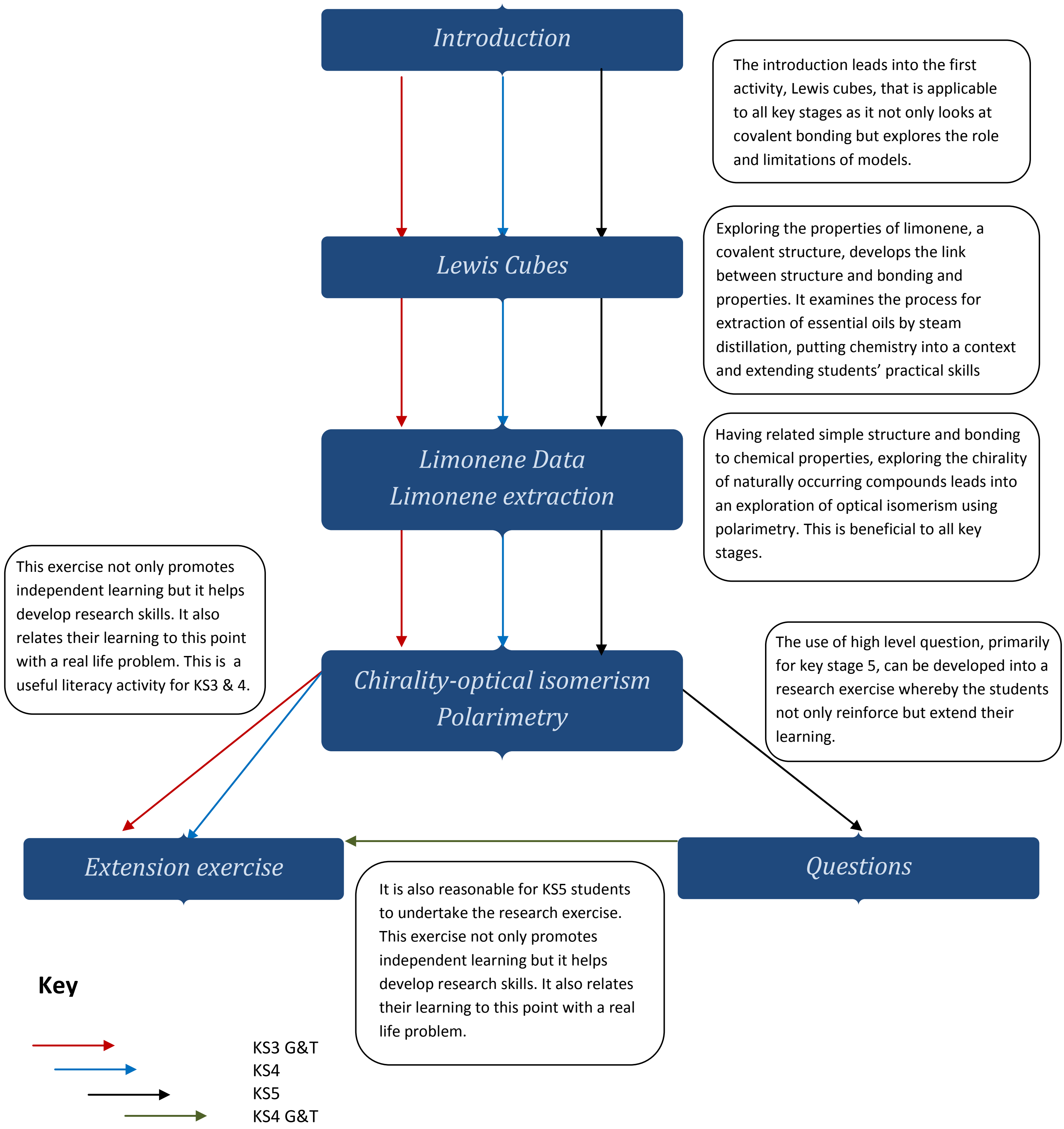
These activities have proved very successful with G&T Year 9 students who have followed the prescribed pathway and have been stimulated into further independent learning. They have even successfully identified chiral centres in complex organic molecules.

At key stage 4 it has enhanced understanding of extraction of essential oils, biofuel development and food additives, as well as reinforcing organic structures and tests.

This exercise provides a reinforcement and revision tool for a number of topics from the A level syllabus.

At all levels there is promotion of questioning skills, independent learning and research skills.

Possible routes



Activity 1: Lewis cubes

Student worksheet

This exercise has two key aspects:

1. It can be used to explain covalency bonding by representing the 2,8,8 model of electron structure by the corners of a cube. In order to gain a *Full outer electron shell* two adjacent, bonded, squares can share an edge or a face, exemplifying the idea of sharing electrons.
2. At a higher level it can be used to show the limitations of models in that it only works for single and double covalent bonds. It is not possible to share a side and a face to form a triple bond! It is good for students to realise that all models are limited by the knowledge available at that particular time, as with their learning pathway.

Bonding models

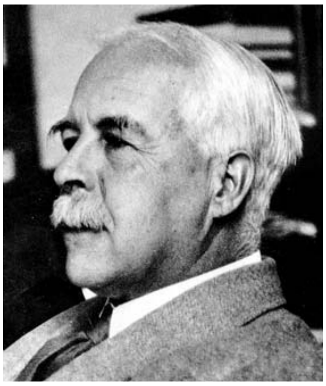
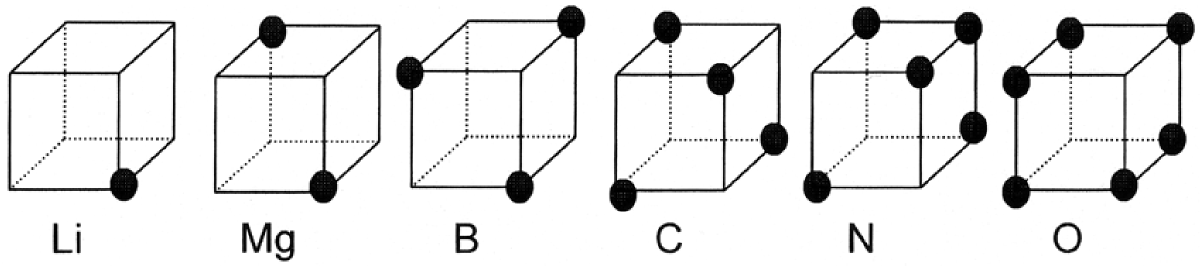


photo from http://dewey.library.upenn.edu/sceti/smith/scientist.cfm?PictureID=263&ScientistID=184 Used with permission of Edgar Fahs Smith Collection, University of Pennsylvania Library

The person who is largely credited with developing the 'dot and cross' model of bonding was an American called Gilbert Newton Lewis (1875–1946). Dot and cross representations are also called Lewis structures, particularly in America.

Lewis' ideas developed over a long period of time, based on the observation that the periodicity of the properties of the elements seemed linked to the number eight. If you arrange the elements in order of increasing atomic number, the properties of the elements fall into a repeating pattern every eight elements (with some exceptions!). It follows from the work of Mendeleev on the Periodic Table.

He initially represented the 'electron shells' as cubes rather than the circles we use in the modern dot and cross model.



How Lewis represented the structure of atoms in 1916

His ideas can be expressed as follows:

- The electrons in an atom are arranged in concentric *cubes*.
- A neutral atom of each element contains one more electron than a neutral atom of the next smallest element in the period.
- The cube of eight electrons is reached in the atoms of the noble gases, and this cube becomes, in some sense, the core about which the larger cube of electrons of the next period is built. *(Lewis believed that helium had eight electrons).*
- The electrons of an outer, incomplete cube may be given to another atom, as in Mg^{2+} or enough electrons may be taken from other atoms to complete the cube, as in Cl^-, thus accounting for positive and negative ions.

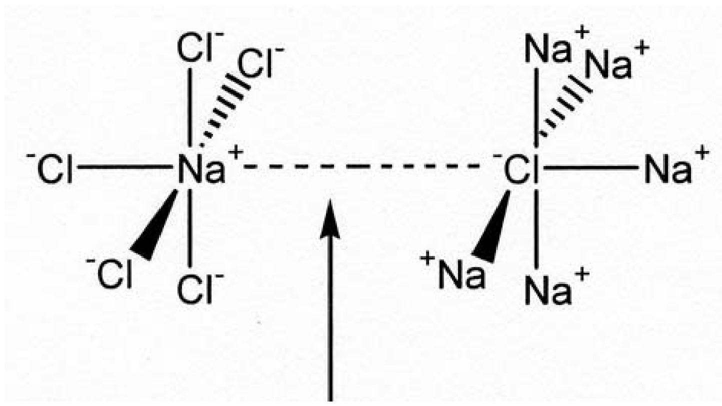
Questions

1. Can you suggest reasons why Lewis was attracted by the idea of the electrons occupying the corners of a cube?

2. Draw the electronic structure of neon using Lewis' ideas.

3. Draw the electronic structure of a sodium ion and a chloride ion.

4. Oppositely charged ions attract each other. This attraction gives rise to ionic bonding. The ions group together in a vast three dimensional array called a giant lattice. In the lattice of sodium chloride each ion has six nearest neighbours of the oppositely charged ion. Sodium chloride is said to have a coordination number of six.



This distance is exaggerated for clarity in the diagram

NaCl coordination number six. Note: the lines do *not* represent discreet bonds.

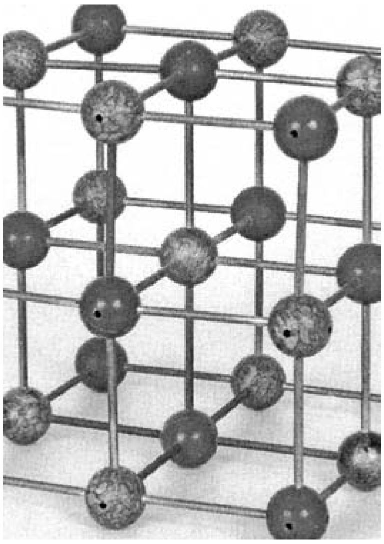


Photo of a NaCl model that is commonly used in schools

Explain how Lewis' cubic model would account for the coordination number of the sodium chloride.
Hint: can you find some connection between the shape of cubes and a coordination number of six?

5. Lewis could account for covalent bonds as the sharing of electrons. The diagram below shows the structure of Cl_2. Draw similar diagrams for F_2 and O_2.

6. Is it possible to draw a structure similar to the one in Question 5 above showing a triple bond as in the molecule N_2?

Activity

1. Using two colours of Plasticine® and cocktail sticks, build models of O2 and CCl_4. There are two ways of arranging CCl_4 – which do you think is best?

2. In a group, discuss the advantages and disadvantages of the cubic model compared with the circular dot and cross model.

3. Why do you think Lewis abandoned cubes for representing atoms?

Further research

Find out:

- What model of the atom was used before Lewis.
- What model Lewis introduced for acids and bases and which model it supplanted/refined.
- What role Lewis took in the famous Manhattan project to produce the first nuclear bomb.

For an introduction to bonding, visit:
www.chm.bris.ac.uk/pt/harvey/gcse/struc_bond_welcome.html

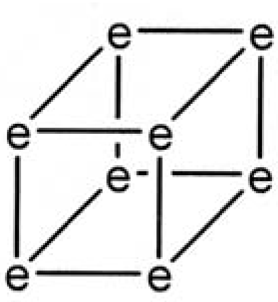
Bonding models Teacher notes

Questions

1. Can you suggest reasons why Lewis was attracted by the idea of the electrons occupying the corners of a cube?

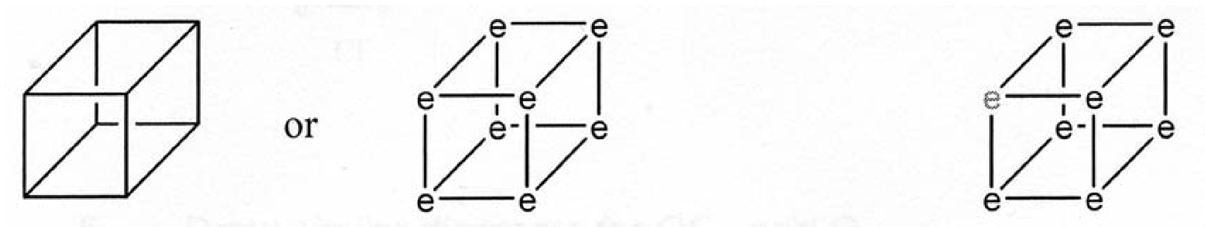
Cubes have eight corners which fitted nicely with the idea of having eight electrons in a ‘shell’. Cubes could stack easily together like crates in a warehouse. Perhaps he was influenced by the visible shape of crystals and imagined the atoms as tiny versions of these.

2. Draw the electronic structure of neon using Lewis’ ideas.



Ne

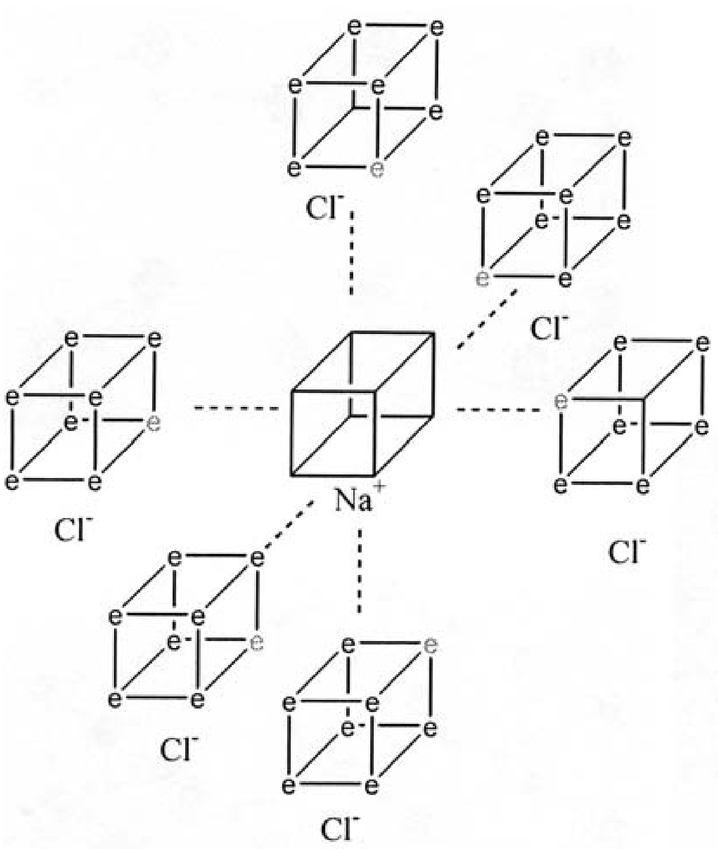
3. Draw the electronic structure of sodium and chloride ions.



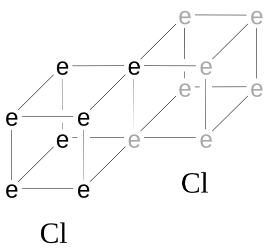
Na^+ Cl^-

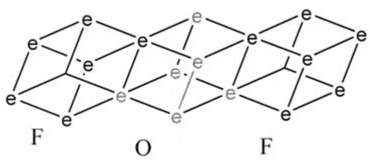
4. Explain how Lewis’ cubic model would account for the coordination number of the sodium chloride.

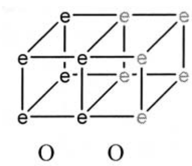
Each cube has six faces so could have six oppositely charged ions all equidistant alongside each face.



5. ....Draw similar diagrams for Cl_2, OF_2 and O_2.





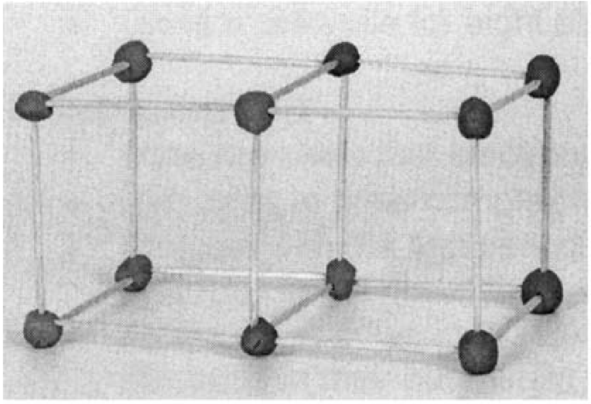


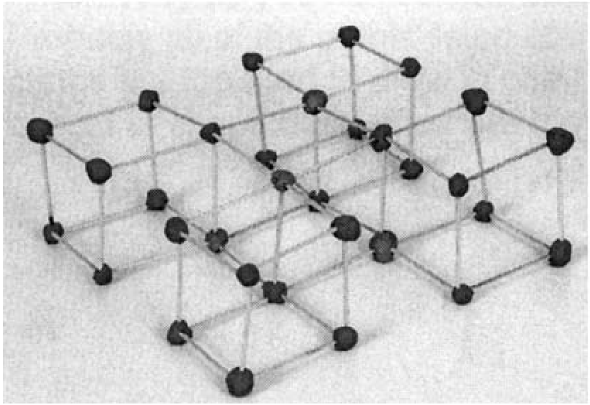
NB- you can also use these structures to explain why the Cl-Cl bond is longer than the O=O bond.

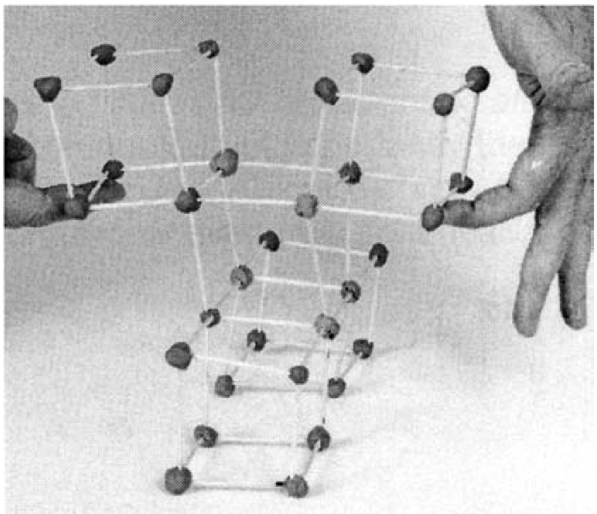
6. Is it possible to draw a structure similar to the one above showing a triple bond as in the molecule N_2?

No, the most electrons that two atoms could share would be two each as the cubes touch faces.

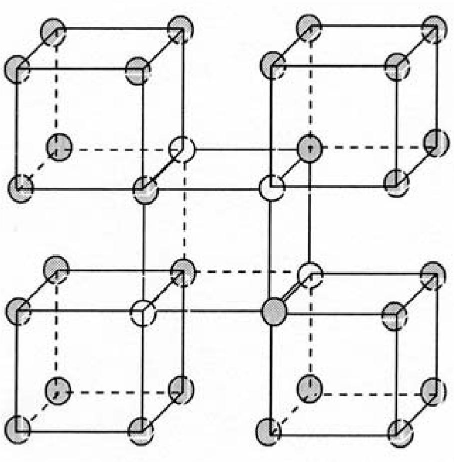
Activity

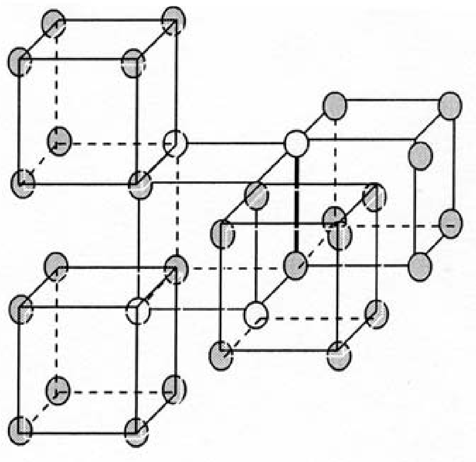






Photos of models of O_2 and CCl_4





Two alternative structures for CCl_4

1. The preferred arrangement for CCl_4 is the one where the atoms are not all in the same plane as this allows the chlorine atoms more space. The CCl_4 molecule is really three dimensional not flat.

2. Compare the advantages and disadvantages of the cubic model with the circular dot and cross model.

Advantages

• Highlights that atoms and molecules are three dimensional not two dimensional.
• Easy to show a double bond.
• Gives a rationale for eight electrons in the outer shell.

Disadvantages

• Does not show that electrons go in pairs.
• Very hard to draw complex molecules.
• Problem with the first period, hydrogen and helium. Only two electrons in the outer shell.
• Atoms lower down in the Periodic Table can have more than eight electrons in their outer shell – so you need to abandon the cube for a polyhedron with more corners.

3. Why do you think Lewis abandoned cubes for representing atoms?

Probably all of the points listed above contributed but importantly the cubes are too hard to draw in complex molecules. Atoms are certainly not cuboid in shape, but neither are they circular, or even truly spherical.

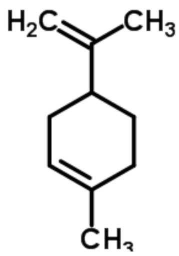
Activity 2: Limonene extraction

Teacher notes

This practical is suitable for key stages 3 – 5. It is included in order to further illustrate how structure and bonding can affect the properties of a molecule, but at a higher level. Limonene is a relatively simple organic covalently bonded molecule, but is more complex than those considered up to this point. It brings in concepts such as double bonding, 3D shapes, and ring structures.

It also provides an opportunity for many of the students to handle more complex procedures and apparatus.

Limonene is the oil in the outer skin of oranges and lemons that gives the recognised citrus smell. It is an organic molecule based upon a ring structure and has a boiling point of around 176^{o}C.

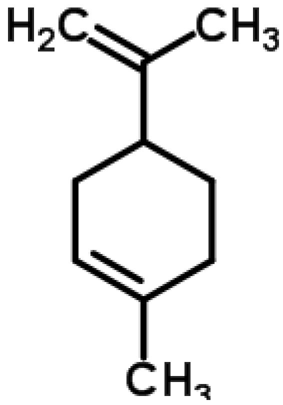


However, it can be extracted by distillation with steam at the normal boiling point of water (steam distillation). This is a process used for extracting many essential oils. Having a lower density than water it will appear 'floating' on the water that is also distilled. See the data sheet below for further information.

As the molecule contains double bonds, it is unsaturated, and it is possible to test for the presence of these bonds using bromine water or purple potassium manganate VII solution. In both cases the presence of a C=C bond will decolourise the testing solution.

Limonene - data

Limonene is an organic (carbon based) molecule classed as a terpene. Its name is based on the fact that that it exists as a colourless oil at room temperature that can be extracted from the rind of lemons, and oranges.



Limonene exists as two isomers with one form more common than the other. This is common with naturally occurring molecules that exhibit 'chiral' behaviour. The isomers of these molecules are referred to as enantiomers. The common enantiomer is the (+) enantiomer, sometimes referred to as the *D* or *R* form. These symbol reference the fact that these isomers are optical isomers and can rotate plane polarised light in either a clockwise (+) or anticlockwise (-) direction.

Uses of limonene include food flavouring, cosmetics, as a perfume in cleaning fluids and as a degreasing solvent. As a renewable product there have even been experiments for its use as a biofuel. The effect of the isomerism is apparent in the properties of the molecule as the (+) enantiomer has a distinctive lemon/orange odour whereas the (-) enantiomer smells of turpentine.

Data

IUPAC name	1-methyl-4-prop-1-en-2-yl-cyclohexene
Molecular formula	$C_{10}H_{16}$
Molecular mass	136.24
Boiling point	176 °C
Density	0.8411 g/cm^3
Flash point	50°C

Figures quoted at 25°C and 100 kPa

For comprehensive data visit:

http://www.chemspider.com/Chemical-Structure.20939.html

Extracting limonene from oranges by steam distillation

This experiment demonstrates the extraction of plant oils.

The peel of oranges is boiled in water and the oil produced (limonene) distilled in steam at a temperature just below 100°C, well below its normal boiling point. The immiscible oil can then be separated. Direct extraction by heating would result in decomposition whereas steam distillation does not destroy the chemicals involved.

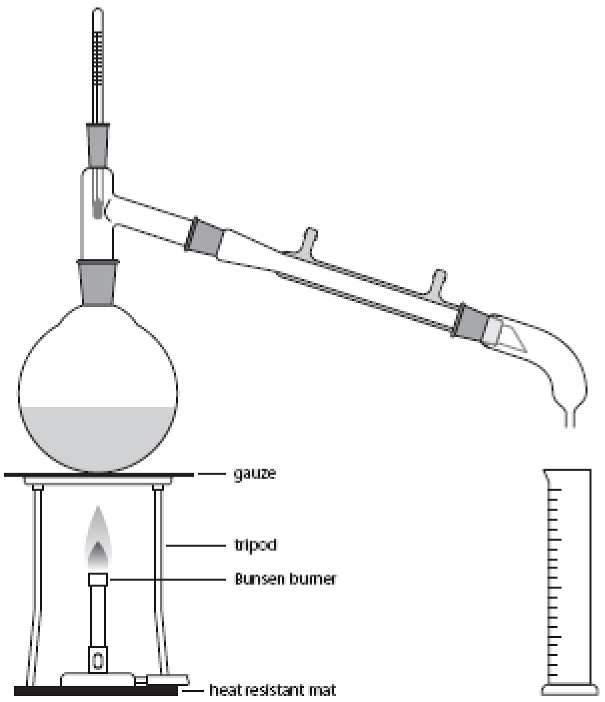
The experiment also links to tests for unsaturation, and at a higher level, chirality.

Apparatus and chemicals

Eye protection
Grater
Bunsen burner
Heat resistant mat
Tripod and gauze
Oranges, 2
110°C thermometer
Measuring cylinder (100 cm^3)
Measuring cylinder (50 cm^3)
Distillation apparatus
250 cm^3 round bottomed flask
Still head
Thermometer pocket
Condenser
Receiver adapter
Test tubes and bungs, 3
Dropping pipette
Anti-bumping granules
Bromine water, no more than 0.2% v/v (**Harmful**) CLEAPSS Hazcard 15B & CLEAPSS Recipe Book sheet 17
Potassium manganate(VII). 0.001 M, (solid – **Oxidising** & **Harmful;** solution – **low hazard**) See CLEAPSS Hazcard 81
Cyclohexene (**Highly Flammable & Harmful**) See CLEAPSS 45C
Cyclohexane (**Highly Flammable & Harmful**) See CLEAPSS 45B
Distilled water, 100 cm^3.

The apparatus should be assembled as shown in the diagram.

Apparatus



Procedure

HEALTH & SAFETY: Wear eye protection

Stage 1

a) Grate the outer orange coloured rind of two oranges and add to 100 cm^3 of distilled water in the 250 cm^3 round bottomed flask. Add anti-bumping granules to the round bottomed flask.
b) Set up the distillation apparatus as shown in the apparatus section.
c) Heat the flask so that distillation proceeds at a steady rate, approximately one drop per second of distillate. (Note: Take care not to let the liquid in the round bottomed flask boil too strongly).
d) Collect approximately 50 cm^3 of distillate in the measuring cylinder. The oil layer will be on the surface.
e) Using a dropping pipette carefully remove the oil layer into a test tube for the next stage.

Stage 2

Odour

f) Cautiously smell the extracted oil by wafting the fumes towards the nose. Do not breathe in directly from the test tube.

Action of bromine water

g) Measure out approximately 1 cm^3 of bromine water into each of three test tubes.
h) Add a few drops of the limonene oil to one test tube, a few drops of cyclohexane to another, and a few drops of cyclohexene to the third. Place in the bungs and agitate. If the bromine water is decolourised the molecule contains double bonds.
i) 0.001M potassium manganate(VII) can be substituted for the bromine water if required.

Extracting limonene from oranges by steam distillation

Teacher notes

Lesson organisation

This experiment can be conducted as a demonstration at secondary level as an introduction to some of the ideas about the extraction of plant oils and also as a discussion point for exploring structure and bonding. It can be used to stimulate discussion about the commercial extraction of plant oils – how science works.

As described this practical will take a full lesson of approximately 50 minutes (80 if apparatus to be set up). If possible the students will gain much more from this practical if they conduct it themselves. It can be conducted as a class practical at key stages 3, 4 and 5. For key stage 3 it would be most applicable with higher achieving students (Year 9).

It can stimulate further discussions as to the process of steam distillation where oil with a boiling point of 176 °C is “distilled” at just under 100 °C.

Additional notes

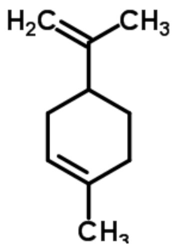
The amount of oil extracted varies considerably with the variety, season and storage of the oranges. However, it is always possible to extract sufficient.

Do not distill more than 50% of the initial volume of water or solid “jam” will form in the flask which is difficult to remove.

Always use a gauze on the tripod or the orange will burn.

Teaching notes

Limonene (1-methyl-4-prop-1-en-2-yl-cyclohexene) is classed as a terpene. Its molecular formula is $C_{10}H_{16}$.

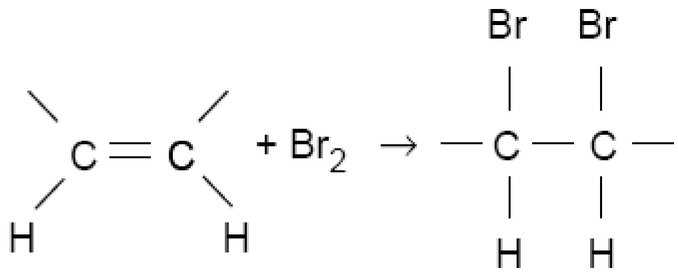


Limonene is a chiral molecule with two optical isomers (enantiomers). The major biological form *d*-limonene, the (*R*)-enantiomer, is used in food manufacture and medicines. It is also used as a fragrance in cleaning products, a botanical insecticide, and due to its flammability, a potential biofuel.

The (*S*)-enantiomer, *l*-limonene, is also used as a fragrance but has a piney, turpentine odour. It is possible to allow students to observe the optical activity of chiral molecules by comparing saturated glucose solution with distilled water in a polarimeter.

Testing for unsaturated bonds

Bromine adds on across the carbon-carbon double bonds of an unsaturated molecule:



The unsaturated aldehyde propenal, CH_2=CHCHO, is reported to be one of a number of chemicals responsible for the odour of frying bacon, but unsaturated fats will contribute as well.

Testing for rotation of plane polarised light

It is possible to measure the degree and direction of rotation of plane polarised light for a saturated solution of glucose. A simple polarimeter can be made using a piece of drainpipe, a lamp, the two parts of a plastic film canister (each with a piece of Polaroid film) and a protractor. Below is a photograph of such a homemade polarimiter.

Extracting limonene from oranges by steam distillation

Technician notes

Technical notes

1. Cyclohexene and cyclohexane are highly flammable and harmful.
2. Bromine water is toxic and irritant at high conc. The concentration should not exceed 0.3% v/v.

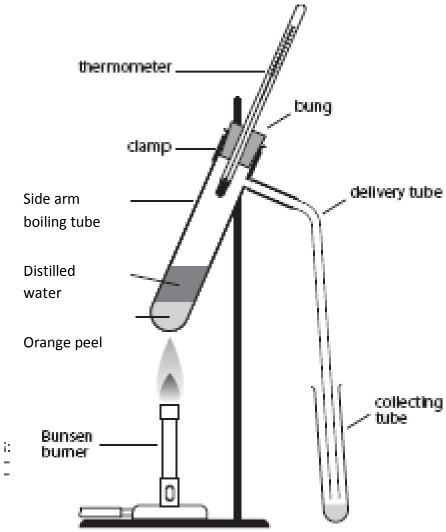
Apparatus and chemicals

Eye protection
Grater
Bunsen burner
Heat resistant mat
Tripod and gauze
Oranges, 2
110 °C thermometer
Measuring cylinder (100 cm^3)
Measuring cylinder (50 cm^3)
Distillation apparatus
250 cm^3 round bottomed flask
Still head
Thermometer pocket
Condenser
Receiver adapter
Test tubes and bungs, 3
Dropping pipette
Anti-bumping granules
Bromine water, no more than 0.2% v/v (**Harmful**) – 0.1% v/v would work and is even safer. See CLEAPSS Hazcard 15B
Potassium manganate(VII). 0.001 M, (solid - **Oxidising, Harmful;** solution – **Low Hazard**) See CLEAPSS Hazcard 81
Cyclohexene 0.5 cm^3 per group (**Highly Flammable & Harmful**) See CLEAPSS 45C
Cyclohexane 0.5 cm^3 per group (**Highly Flammable & Harmful**) See CLEAPSS 45B
Distilled water, 100 cm^3.

The apparatus should be assembled as shown in the diagram on the student worksheet.

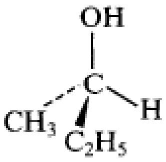
Alternative apparatus

Providing apparatus for a class practical can be difficult. However, it is possible to use the apparatus below. It may be an advantage to place the collecting test tube into a beaker of cold water. The quantities would have to be adjusted according to the tube used. There will be less product, but there should be sufficient for the basic tests.



Activity 3: Chirality

Chirality, also referred to as optical isomerism due to the ability of the two enantiomers to rotate plane polarised light in different directions, describes the fact that a number of naturally occurring chemicals can exist as mirror images of each other, they are 'left or right handed'. A common example would be glucose. For this to happen it is necessary to have a carbon with four different groups attached.

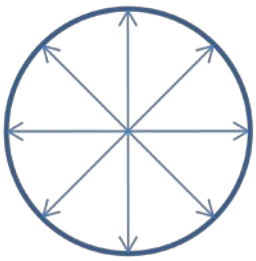


This can be easily illustrated using *Molymods*. The two forms are referred to as enantiomers. They are preceded by + and -, *D* and *L*, or *R* and *S*. It is a little confusing as there are several ways of expressing the same thing! The two different forms are chemically similar but biologically very different.

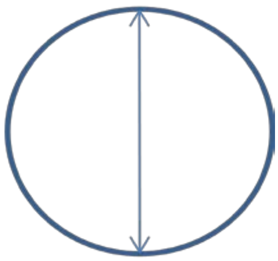
Asymmetric optically active molecules are often called chiral molecules, from the Greek word which means 'a hand'.

Chiral molecules and optical isomerism brings another higher level concept around structure and bonding that builds on the learning achieved to this point. It involves complex concepts such as mirror image molecules which are chemically similar but biologically very different, sometimes with disastrous results, hence the research exercise into thalidomide.

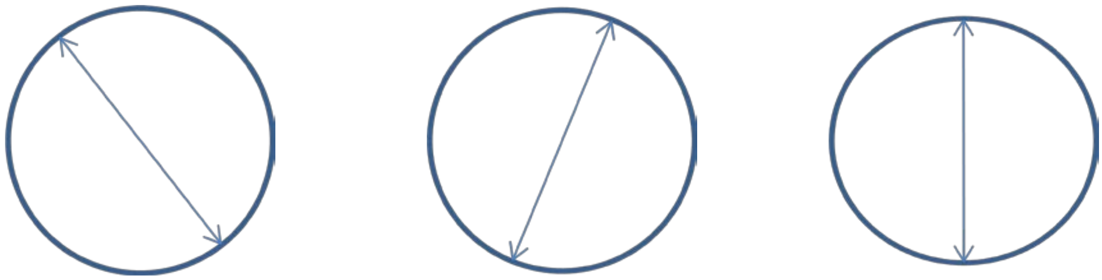
Optical isomerism occurs when there are four different atoms or groups of atoms joined to a central carbon atom. There are two possible arrangements, and each will be a mirror image of the other. The isomer structures will not be superimposable upon eachother, and each will interact with plane polarised light, twisting the light in either a clockwise or anticlockwise direction.



Normal light travelling in all directions



Plane polarised light travels in a single



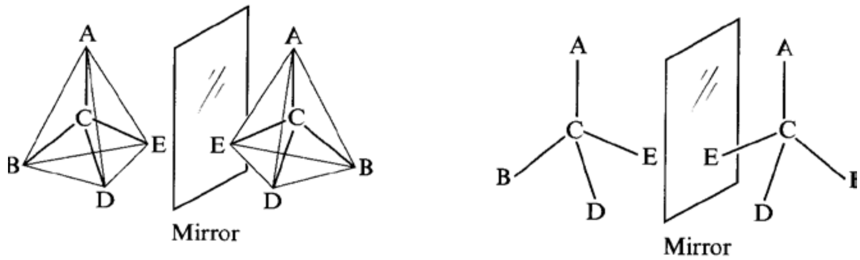
(-) enantiomer — Anticlockwise rotation

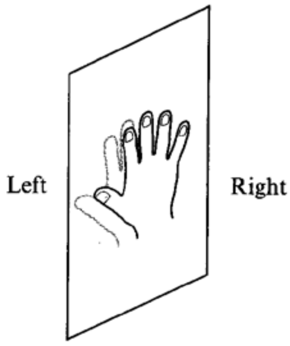
(+) enantiomer — Clockwise rotation

(±) racimate — No overall effect as each enantiomer cancels out

We say that molecular structures like that of glucose are asymmetrical, and it is the asymmetry around the carbon atoms which enables the formation of a pair of optically active isomers (enantiomers). The isomers are mirror images of each other.

Optical isomerism



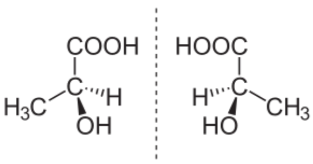


Isomers are mirror images of each other

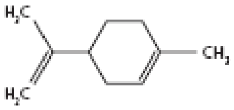
The two isomers are different, and a bit like your hands; if you put your hands flat together they are mirror images of each other. You cannot put your hands one on top of the other so that they match thumb on top of thumb. Neither can you place optical isomers one on top of the other. They are non-superimposable.

Try it with Molymods.

e.g. Lactic acid



Now attempt limonene



Polarimetry

Polarimetry is a technique used to measure optical isomerism. It allows for the measurement of the degree and direction of rotation of plane polarised light passing through different enantiomers such as limonene. Plane polarised light is unidirectional light waves. With saturated glucose, using the apparatus illustrated on page 18 will result in a rotation of approximately 15^{o}.

The process illustrates another practical technique, identification and measurement and links well to studies on waves and light.

Activity 4: Research activities and questions

The research activity is designed for KS3 students, probably year 9, and for KS4 students.

The development of independent learning is a key aspect of learning. Student need to be taught how to search for information for a topic and present the information in written format. It will help to develop literacy skills, a growing need with the new assessment system, illustrating skills in depth of research, reading, critical thinking and writing.

Finding the information is the first part of the process. Students need to appreciate that they have to critically extract suitable information that supports their answers, not just 'cut and paste'. They need to develop a balanced approach to information looking at different sources. Most will immediately turn to the internet but should appreciate the often lack of peer review of such information – it may be biased or even totally inaccurate! It is a worthwhile activity to suggest that students speak with the school librarian who may have many varied sources of information. Any information collected should be referenced properly, teaching students the importance of acknowledging their sources and a set of skills used every day by research academics .

The next step is that the students will often need to be guided in how to express this data in a logical and coherent manner.

The question on chiral chemicals is for use with KS5 students. This is a very demanding question that will need a high level of understanding in order to gain a good mark. One approach to this is to set it as a research task whereby the students seek information to be able to answer the question. In order to be successful they will need to look at a range of resources such as textbooks, jouranals and the internet.

As above, this is an opportunity for students to appreciate that they have to critically extract suitable information that supports their answers and understand how to use it.

Research Activities (extension)

During the 1950s a new drug, thalidomide, was launched. Thalidomide was a sedative drug, often prescribed for morning sickness. It was widely sold between 1957 and 1961 before being withdrawn from the market.

1. Research the background of the development of thalidomide.
2. Draw the structure and identify any isomers.
3. Why was the drug withdrawn and what were the side effects?
4. Is the drug on sale again?
5. What processes are involved in the new method of production that ensure that the side effects are removed?

Guidance

Below are several websites that would form the starting point for any research. There are plenty of references in periodicals and texts.

Thalidomide is a chiral drug which caused severe birth defects when prescribed to pregnant women. At the time of development the identification of chiral enantiomers was difficult. It is now possible to isolate the two enantiomers using chromatography and the drug has been relaunched.

General information

http://en.wikipedia.org/wiki/Thalidomide

BBC report

http://news.bbc.co.uk/1/hi/uk/2031459.stm

Chiral drugs

http://www.chem.yale.edu/~chem125/125/thalidomide/thalidomide.html

General information

http://www.britannica.com/EBchecked/topic/589836/thalidomide

Activity 5: Question on chiral molecules

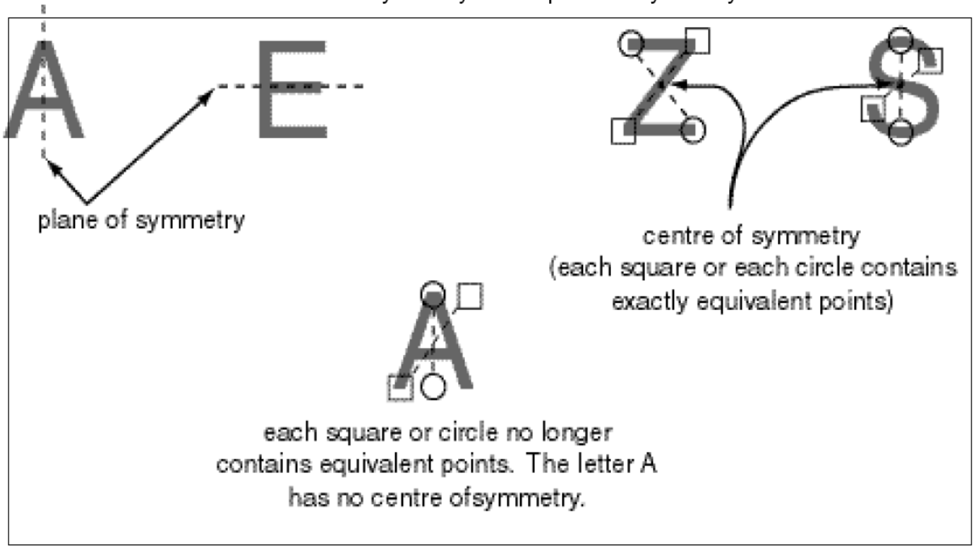
A carbon atom bonded to four different groups is called a chiral centre (asymmetric carbon, *C). For example, hexan-3-ol has a chiral centre:

$CH_3CH_2{}^*CH(OH)CH_2CH_2CH_3$

and can exist as two different optical isomers (enantiomers), which are nonsuperimposable mirror images. A molecule which contains just one chiral centre will always exist in two enantiomeric forms. However, some molecules with two or more chiral centres can be achiral, i.e. they *can* be superimposed on their mirror images. Such achiral molecules will have either a **plane** or **centre of symmetry**.

A **plane of symmetry** ('mirror plane') is one which cuts an object into two parts so that each part is the mirror image of the other. For example, the letters A and E both contain a plane of symmetry.

A **centre of symmetry** is a point from which lines, when drawn on one side and continued in the same direction an equal distance on the other side, will meet exactly similar points in the object. For example, the letters Z and S both have a centre of symmetry but no plane of symmetry.

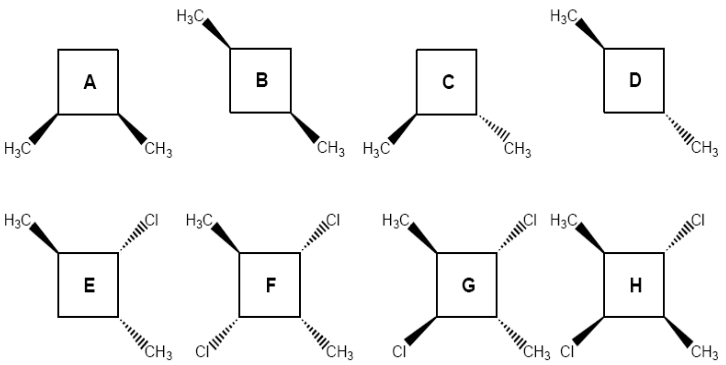


Compounds possessing a plane or centre of symmetry are always **achiral.**

a) Which of the molecules given below have a plane of symmetry?

b) Which molecules have a centre of symmetry?

c) Which molecules are chiral and therefore have nonsuperimposable mirror images?



(7)

Mark Scheme for question on chirality

a)	A B D F H	*(3 marks – 3 marks for all 5 correct, 2 marks for 4 correct, 1 mark for 3 correct)*
b)	D G	*(2 marks – 1 mark each)*
c)	C E	*(2 marks - 1 mark each)*

Throughout question –1 mark for every 'extra' incorrect answers given, down to zero.

Total **7**

Glossary

Below are some of the terms used within this document:

Term	Definition
alkene	An unsaturated compound containing at least one C=C bond.
asymmetrical carbon	A carbon atom attached to four different atoms or groups of atoms.
centre of symmetry	An atom attached to four different atoms or groups of atoms.
chiral	A molecule that does not have a plane of symmetry forming two mirror images.
covalent bond	A bond formed by the sharing pairs of electrons between two atoms.
enantiomer	Stereoisomers of molecules that are mirror images of each other.
hydrocarbon	A hydrocarbon is an organic compound consisting of hydrogen and carbon.
isomer	Compounds with the same molecular formula but different structural formula.
optically active	A chiral molecule that causes the rotation of plane polarised light.
plane polarised	Light waves restricted to a single plane.
polarimeter	An instrument used to measure the degree of rotation of plane polarised light through a chiral molecule.
racemic mixture	A mixture, in equal proportions, of the left and right handed enantiomers.
stereoisomer	Isomers that have the same molecular formula and bonded atoms but differ in the three-dimensional orientations of their atoms.
unsaturated	Unsaturated compounds are hydrocarbons containing double bonds.

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