Activity 9: Judging models in science

This activity asks students to evaluate the usefulness of competing / complementary models in two different contexts by examining whether the models can explain data.

Overview of learning activity

This activity comprises of two related tasks. In both cases, the task concerns comparing two 'competing' models:

Task	'Competing' models of	Judged against
Choosing between models 1	**Particle theory (Model 1 vs Model 2)**	**Application to explaining common phenomena**
Choosing between models 2	**Ionic bonding (Model A vs Model B)**	**Application to explaining properties of NaCl**

In each case the students, working in groups, consider the merits of alternative models in providing explanations. The second task also includes some simple practical work, making observations. The groups are provided with sets of cards with features of the models, and the phenomena/properties to be explained, to sort during the tasks.

Rationale for the activity

This activity reinforces the central role of modelling in science, and the way that models are used in science to support explanations. In the two tasks students are asked to consider the merits of alternative models in explaining data. The tasks have been designed to generate discussion, and it is not intended that students will be able to simply select a 'better' model that fits all the data. This is especially the case in Task 1, 'Using the particle model', where they are briefed that for each phenomenon they may decide that:

- one of the models is more useful in explaining the phenomenon
- both of the models are useful in explaining the phenomenon

- neither of the models are useful in explaining the phenomenon

Using the particle model

Task 1 asks students to compare the very simple ‘hard billiard ball’ type model of particles often introduced early in secondary education (Model 1), with a more complex model of molecules are having internal structure, fuzzy edges, and the possibility of interacting with other molecules (Model 2).

Students are asked to consider a range of phenomena: an ice cube melting; starch being converted to glucose when mixed with saliva; steam produced from boiling water; salt dissolving in water; a copper bar being drawn out into a wire; a metal rod getting slightly longer when it is heated; methane and oxygen reacting in a Bunsen flame; putty adhering to a wall; the pressure of a gas increasing when the gas is heated; sugar dissolving faster in hot tea than cold tea; magnesium burning in the air to form magnesium oxide; current passing through a copper wire; iron on a bicycle rusting in a wet garden; chalk reacting quicker with acid solution when the lumps are turned into powder; a sample of radioactive material emitting alpha radiation; the pressure of a gas increasing when it is compressed; a spring returning to its original length when a load is removed; ozone in the atmosphere absorbing ultraviolet radiation; carbon dioxide and water reacting in photosynthesis; very hot metal glowing. (As with most of the ASCEND materials, individual teachers are free to modify the list).

> ***Model one***: everything is made up tiny particles, called molecules. These particles can be considered to be hard spheres, like tiny billiard balls, so that when they collide they bounce off each other. Unlike real billiard balls, they are ‘perfectly elastic’: this means that no kinetic energy is lost in the collision. In a solid the particles are packed together so that no more will fit – like a great many billiard balls arranged in a regular pattern. The particles move about, but they do not change.

> ***Model two***: everything is made up of tiny particles, called molecules. These molecules are themselves comprised of smaller particles: one or more positively charged core surrounded by a ‘cloud’ of negatively charged electrons. The electron cloud makes the atoms ‘soft’ so that they can overlap and ‘inter-penetrate’ one another. The positive and negative charges in one molecule will attract and repel the charged particles in another molecule. The particles inside molecules may be rearranged and exchanged when molecules interact.

Clearly, neither model is suitable for explaining *all* those phenomena that scientists use particles ideas to explain - and in school science different versions of particle theory are used at different stages, and in different topics. Part of the rationale of this activity is to help students appreciate that models are used in this way, and that often nature is too sophisticated to be represented by a single simple model. A scientifically useful model would need to incorporate features that enable it to explain all the relevant data without being internally inconsistent.

B1: 'Model 1 really doesn't have any . . . changes in molecules . . . it's purely physical . . . so any of these involving chemical change are going to be Model 2 . . . but the ones that involve physical changes like an ice cube melting seem to . . . (be) Model 1' . . .

G: 'but, can something be both . . . then?'

B2: 'when salt dissolves in nature, it doesn't interact with the water, does it?'

B1: 'not really . . . it would be a case of Model 1 . . . I think that's basically it , if it's chemical change Model 2, if it's physical change Model 1 . . . there's probably some in there that involve both . . .'

(Dialogue from the ASCEND session: the delegates relate the task to prior learning about chemical and physical change)

Explaining the properties of an ionic substance.

Task 2 is slightly different in that the two models being compared are not of similar status in terms of school science. These are models of ionic bonding.

Model A: Table salt is sodium chloride (NaCl) – a compound with ionic bonding. Sodium has an atom with one outer electron, and chlorine has an atom with seven outer electrons. The atoms need full outer shells. In ionic bonding the sodium atom donates an electron to the chlorine atom, so that both atoms can have full outer shells (octet) of electrons. *The ionic bond is the transfer of electrons* that leads to a sodium chloride molecule. Solid sodium chloride contains a very large number of NaCl molecules. The sodium and chlorine in a molecule are strongly held together by ionic bonding, and the sodium chloride molecules are also held together, by weak forces between molecules. Each ion can only be bonded to one other. This 'valency' of one is because sodium only needs to lose one electron, and chlorine only needs to gain one electron.

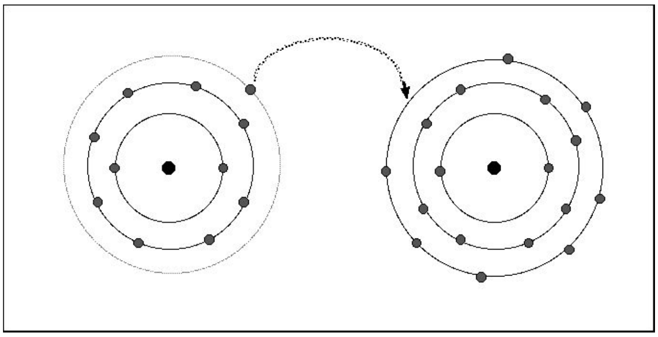

Figure 9.1: Diagram representing ionic bonding in Model A

Model B: Table salt is sodium chloride (NaCl) – a compound with ionic bonding. Sodium chloride contains sodium ions and chloride ions. Sodium ions have a positive charge, and chloride ions have a negative charge. In solid sodium chloride, each sodium ion is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions. The ions are attracted together by electrical forces. *The ionic bond is the electrical attraction* that holds the ions together in the lattice. Each ion is attracted strongly to the six oppositely charged ions that surround it – one above, one below, four in the same layer. This 'coordination number' of six occurs because of the way the two types of ion fit together into a tightly bound lattice structure.

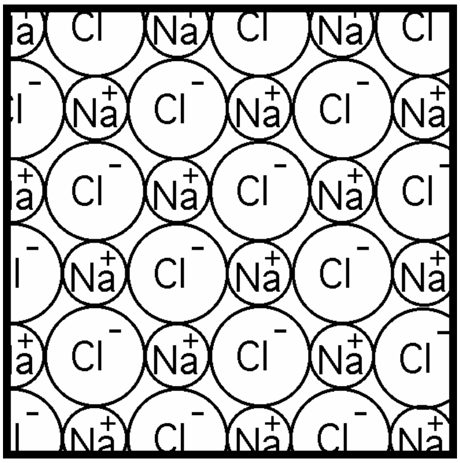

Figure 9.2: Diagram of ionic bonding according to Model B

Model B reflects a level of scientific understanding that is suitable for explaining properties of NaCl at a level appropriate for students of this age group. Model A does not reflect a scientific understanding, but is based on the type of thinking about ionic bonding that commonly develops in students by age 16 and which has limited value in explaining the properties of NaCl. Despite its clear inferiority, this type of model has been found to be readily adopted by students, perhaps even being intuitively attractive, and is encouraged by vague (or even inaccurate) descriptions of ionic bonding in many school level text books. Therefore, although the evidence *should* offer a clear preference for model B as having more value, it is likely that many students will initially find model A attractive, and the task is unlikely to be considered trivial by most groups of students. (Indeed the task would probably provide a very useful review of prior learning in an A level or similar course.) It is hoped this activity will either reinforce the model being taught in school science, or prepare the way for formal teaching later. Students who completed the ASCEND activity on Explaining Science (Activity 4) should also be alerted by the statement that "the atoms need full outer shells" with its anthropomorphic flavour.

The properties students are asked to explain are: Sodium chloride is a hard substance; sodium chloride cannot easily be compressed or stretched; solid sodium chloride does not conduct electricity; sodium chloride has a high melting temperature (1081K); molten sodium chloride conducts electricity; sodium chloride is colourless; sodium chloride dissolves in water; sodium chloride solution conducts electricity; sodium chloride forms crystals that are cubic; sodium chloride tastes salty; Sodium chloride is brittle (e.g. snaps rather than bends); a precipitate of silver chloride is produced when sodium chloride solution is mixed with a solution of silver nitrate; sodium chloride crystals decrepitate when heated strongly.

The second task includes two simple practical activities that can also provide data to be explained using the two models. Observing decrepitation is included because it is a very simple phenomena, requiring close observation, that fascinates many students: careful strong heating of a sample of NaCl leads to some of the grains suddenly appearing to 'jump' around. The effect can also be heard. If salt consisted of pure, perfect, crystals of NaCl, then this behaviour would not be expected: so decrepitation provides a challenge to both models, and encourages students to identify a feasible explanation. The effect is due to the heating of small air pockets trapped on crystallisation which lead to grain splitting violently as the internal pressure increases: "Decrepitation occurs when the internal pressure within the fluid inclusion exceeds the strength of the host mineral" (http://www.cas.gsu.edu/acres/sum2000/Fluid/page13.html, accessed August 2006).

> ***'bear in mind this is a theory . . . before, they're sort of quite cubical crystals because they're in lattice formation . . . so when you heat it, my theory is that you get to a point at which the bonds between the ion . . . the charged bonds in the lattice don't hold as much any more and the ions separate off as elect . . . as molecules so then you get . . . I'm not sure how good that is but . . . they go more rounded because they're no longer behaving as a lattice in general because now the strongest forces are between the . . . the molecules . . . the ions in the molecule rather than the same or throughout the lattice, so therefore they can form whatever shape they like . . . so they go round. . .'***
>
> *(An ASCEND delegate conjectures what is going on at the particle level during decreptiation)*

The second observation task is an example of a precipitation ('double decomposition') reaction. These reactions were commonly used in school science at one time (as tests for halides, sulphates etc.), but are not familiar to many students today. Explaining the precipitation requires thinking about the reaction at the level of particles, and appreciating the ionic nature of the reactants. The author knows from his own teaching that explaining precipitation is found to be quite challenging by some able students even after formal teaching about ionic bonding. This observation provides data that is therefore a test of the ability to apply model B.

Resources

The following resources are included on the CD:

Resource	Description	Filename
Model descriptions	Two pages. The first offers two models of particles (models 1, 2). The second offers two models of ionic bonding (models A, B), including a diagram for each.	Act 9 descriptions
Instructions	4 pages: instructions for Choosing between models 1: Using the particle model; Choosing between models 2: Explaining the properties of an ionic substance; Decrepitation; Precipitation.	Act 9 tasks
Particle model 1 cards	Key points of model 1. To print out as cards* on e.g. blue paper.	Act 9 blue
Particle model 2 cards	Key points of model 2. To print out as cards* on e.g. green paper.	Act 9 green
Ionic bonding model A	Key points of model A. To print out as cards* on e.g. red paper.	Act 9 red
Ionic bonding model B	Key points of model B. To print out as cards* on e.g. yellow paper.	Act 9 yellow
Phenomena cards	A set of pages with phenomena to be explained with particle theory, to be printed out as cards*	Act 9 phenomena
Property cards	A set of pages with properties of NaCl to be explained in terms of a model of ionic bonding - to be printed out as cards*	Act 9 properties

* Note: cards need to be printed, e.g. 4 per page.