

Identifying Physical and Chemical Changes

Critical teaching ideas - Science Continuum F to 10

Level: Moving towards level 8

Student everyday experiences

Students have difficulty distinguishing between physical and chemical change despite formal teaching and the distinction is somewhat arbitrary. However an understanding of the differences between purely physical processes such as melting, evaporation and boiling and the changes that take place in chemical reactions, particularly the point that new substances are formed, is important to an understanding of chemistry and students very frequently confuse the two. The following conversations are typical: (See Loughran Mulhall & Berry, 2002).

Pat (recording the group's notes about a prac): What happened?

Kim: It went fizzy.

Pat: Did you see any new substances?

Kim: Nope

Sam: What shall I write down was formed? Chris: A blue colour

Research shows that students frequently use the term chemical change to describe changes in physical state. Freezing and boiling are considered to be examples of chemical reactions. This depends on their conception of substance. If they regard ice as a different substance from liquid water they are likely to classify the melting of ice as a chemical change. Driver (Driver, 1994) found that 80% of students considered a difference in colour between the reactant and product evidence of chemical change. Students can consider Condy's crystals dissolving in water to be a chemical change because of the intense difference in colour. Melting and expansion on heating were also considered to be evidence of chemical change by some students.

Many students did not appreciate that a chemical change is characterized by the formation of a substance having different properties from the original substance and a considerable proportion of students who did were unable to offer suitable reasons for distinguishing a "new" substance (Driver 1994).



Students may believe that beer frothing is an example of a chemical change or an apple ripening is a physical change (Tsapalis, G. (2003) Chemical Phenomena versus Chemical Reactions: Do Students make the Connection? Chemistry Education: Research and Practice 4(1) p 31 - 43)

Students commonly believe that physical changes are reversible while chemical changes are not. Students also frequently believe that the original substance in a chemical reaction vanishes completely and forever. A common everyday application of a reversible chemical reaction is the charging and discharging of rechargeable batteries – including car batteries;

however students may believe that batteries are a container of stored electricity, rather than of chemicals that react in ways that convert chemical energy into electrical energy.

Other commonly held views are that chemical changes are caused by the mixing of substances/reactants or that heat (which is considered to be some form of material) has to be added.

The scientific view

- In a physical change the appearance or form of the matter changes but the kind of matter in the substance does not.
- In a chemical change, the kind of matter changes and at least one new substance with new properties is formed.
- The distinction between physical and chemical change is not clear cut. Frequently students are led to believe that a change is either physical or chemical. In fact this should be considered more of a continuum. (Fensham, P., 1994). For example salt dissolving in water is usually considered to be a physical change, however the chemical species in salt solution (hydrated sodium and chlorine ions) are different from the species in solid salt). Dissolving of instant coffee in water seems to be a physical change but in most cases dissolving is accompanied by an energy change and is probably better considered to be a chemical process even though it is possible to recover the original components by physical means.
- Many examples of materials dissolving e.g. an Alka Seltzer in water, metal in acid, the effect of acid rain on marble and concrete involve both chemical and physical processes.
- All chemical reactions are reversible although it can be difficult in practice. Many Junior School Science texts state that chemical changes are irreversible while physical changes can be reversed. Cutting paper into tiny pieces or crushing a rock are obvious physical changes but to restore the original piece of paper or rock is difficult. Rechargeable batteries use one chemical reaction when discharging, recharging involves driving that reaction backwards, turning the products back into the original reactants. The electrical generator (alternator) on a car recharges the car battery constantly while the car engine is running.

Critical teaching ideas

- In a physical change the nature of the substance, the particles of which it is composed and the numbers of particles remain unchanged.
- In a chemical change the properties of the new substances are different from the original, the particles are different and the number of particles can change
- While the distinction between physical and chemical change is a useful one it should be seen as more of a continuum
- Chemical reactions can be reversed but this can be difficult in practice

When teaching about physical and chemical changes it is important to allow students to see the classification as a continuum. They should be able to observe a number of changes and formulate their views on the kind of change and problems with the classification process. Students should come to see that chemical reactions produce new chemicals distinct from the starting materials but that chemical processes can be reversed. Examining examples of

reversible chemical reactions and considering why it is difficult to reverse many chemical changes can be very useful.

Teaching activities

Promote reflection on and clarification of existing ideas.

What follows is intended to get students identifying and then refining their ideas about physical and chemical change. It is important for students to observe a number of changes and to record their opinions on what is happening. They could record this in a booklet where they write about and draw results and observations. They should be encouraged to formulate and record hypotheses about what is happening with the knowledge that their opinions will not be assessed at this stage. (for an example of this technique see Using Logbooks in Year 10 Electricity, PEEL in Practice 2007). This can help bring out their existing ideas and help them challenge and extend their existing beliefs.

Examples could include:

- Heating steel wool in air and collecting the black powder that results. Weighing the reactant and product (there should be an increase). This could be done as a POE (Predict Observe, Explain - students are asked to predict what will happen to the weight of the steel wool when it burns). What has been added to the steel wool during combustion?
- Dissolving sugar and salt in water and comparing what happens to the electrical conductivity of the two solutions as the dissolving takes place. Recovering the salt by evaporation shows the salt is still there but the conductivity is indicating something new is forming.
- Comparing boiling water with mixing vinegar and baking soda - both produce bubbles but what's the difference. The baking soda and vinegar can be mixed in a Ziploc sandwich bag to show the production of a new substance which blows the bag up.
- Precipitation reactions particularly ones that produce an obvious colour change. E.g. Epsom salts and ammonia solution produce an obvious change. This can be compared with adding potassium permanganate to water. What are the differences?
- Acid - base reactions can be illustrated through the use of indicators both natural (cabbage juice) and synthetic. The colour changes help illustrate that new materials could be forming.

Practice using and build the perceived usefulness of a scientific model or idea.

It is important that examples of changes are not confined to materials and chemicals students are only exposed to in the classroom. As a homework activity students could be asked to collect examples of changes they see around them and classify these on their scale of physical and chemical changes - combustion of fuels, cooking, processes such as digestion, respiration and photosynthesis which they may be aware of can be included.

Clarify and consolidate ideas for/by communication to and with others.

To consolidate their views students in groups could be asked to choose two changes, one which is on the physical end of the continuum and one on the chemical end and explain to the class what the differences are. Communicating their ideas to others can help students clarify and consolidate new and existing ideas about changes.

Practice using and build the perceived usefulness of a scientific model or idea.

Chemistry is an area where fruitfulness for a number of key ideas is built gradually by using them in a range of situations and stressing how the same idea helps make a sense of many situations. Both elements and compounds – a key idea at the macro level – and atoms and molecules – which involves the same thinking at the micro level, can help make sense of physical versus chemical changes. These ideas may be introduced here, or referred back to if they have been introduced earlier. Writing chemical equations in word and symbolic form can be introduced as a useful way of describing some of the changes they have seen and also to show the advantages of chemical symbols in keeping track of the elements (or atoms) in ways that words do not. If the exact chemical formulae cannot be written (as is the case with most biochemicals) a drastic simplification can still be useful. For example wood is mostly cellulose, a polymer of glucose and a representation such as $(C_6H_{10}O_5)_n$ can be used to track changes in say combustion.

Models and diagrams can help here. For example, most schools have Chemistry model kits which can be adapted to show how molecules have altered and atoms have rearranged as a result of changes. Poster size diagrams can also be drawn by students to assist with their explanations.

Challenge some existing ideas.

Although it is difficult to demonstrate the reversibility of chemical changes, students are very familiar with the need to recharge their mobile phones, cameras and other rechargeable devices. This could be just discussed, although investigating the chemical reactions that power these devices could be a useful research project. A caveat here is that much of the available information can be very technical.

Promote reflection on how students' ideas have changed.

Re-examining their original journal entries can promote reflection on how students' views have changed. Students can then apply their new ideas to more examples of change. Activities such as the following can be used to promote discussion of the kinds of change taking place and of the difficulties of classifying some changes as physical or chemical:

- Dissolving metals in acid (magnesium and zinc) and testing the resultant gas.
- Investigating limestone and acid reactions (the production of limestone caves - what sort of change is this?)
- Adding zinc to copper sulfate solution and observing the colour changes that take place.
- Comparing the setting of paper glues such as Clag with two pack adhesives such as Araldite. The former works by evaporation of the solvent (water) and is reversible; the latter involves a chemical reaction (a thermosetting polymerisation reaction) between the two components and is not reversible.