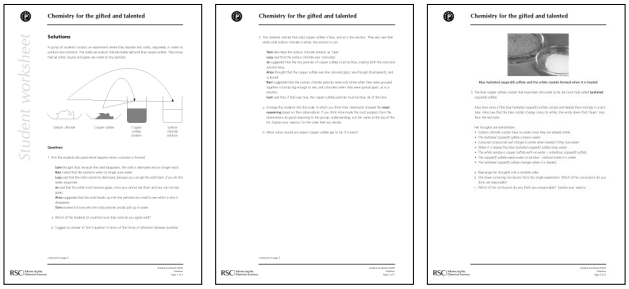
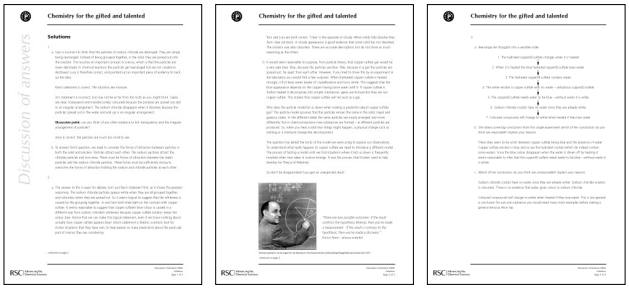
Solutions



Student worksheet: CDROM index 08SW



Discussion of answers: CDROM index 08DA

Topics

Dissolving, particles and hydrated crystals.

Level

Able students in the 11–13 age range.

Prior knowledge

The particulate nature of matter.

Rationale

This activity is designed to develop the students' higher order thinking – particularly critical thinking skills – in the context of solutions. The students have to apply some particle theory and logical reasoning to simple experimental observations.

Use

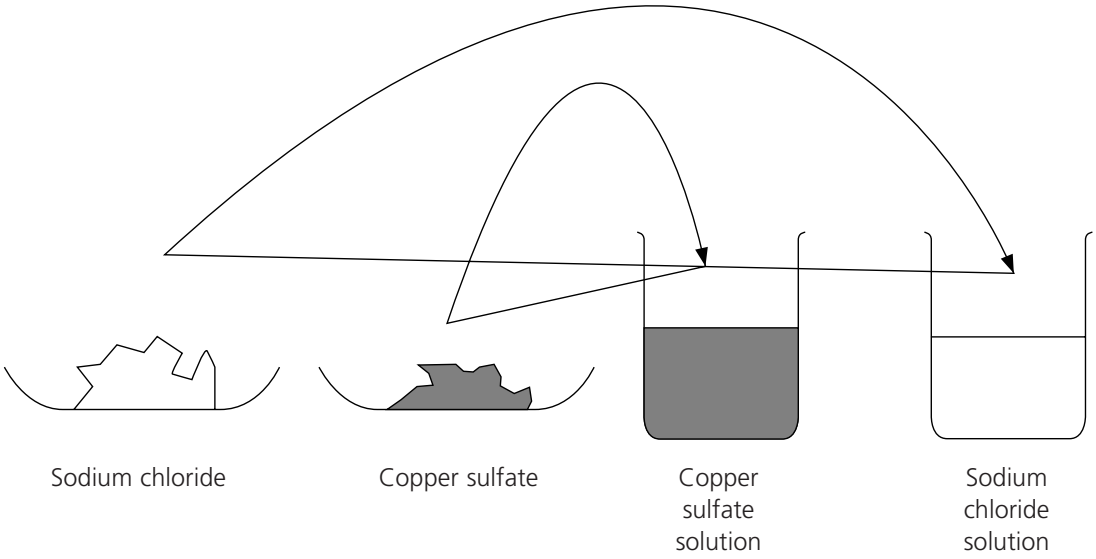
This could be given to a whole class or part of a class as part of more general work on dissolving and solutions. The students may need encouragement to think in terms of reasoning and logic rather than simply reciting facts.

When the students have completed the worksheet they should be given the *Discussion of answers* sheet. They could check their own work or conduct a peer review of the work of another student or group.

Student worksheet

Solutions

A group of students conduct an experiment where they dissolve two solids, separately, in water to produce two solutions. The solids are sodium chloride (table salt) and blue copper sulfate. They know that all solids, liquids and gases are made of tiny particles.



Questions

1. First the students discussed what happens when a solution is formed.

> **Sam** thought that, because the solid disappears, the solid is destroyed and no longer exists.
> **Ravi** noted that the solutions were no longer pure water.
> **Lucy** said that the solid cannot be destroyed, because you can get the solid back, if you let the water evaporate.
> **Jo** said that the solids must become gases, since you cannot see them and you can not see gases.
> **Alice** suggested that the solid breaks up into tiny particles too small to see which is why it disappears.
> **Tom** wanted to know why the solid particles would split up in water.

a. Which of the students (it could be more than one) do you agree with?

b. Suggest an answer to Tom's question in terms of the forces of attraction between particles.

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2. The students noticed that solid copper sulfate is blue, and so is the solution. They also saw that while solid sodium chloride is white, the solution is not.

   Tom described the sodium chloride solution as 'clear'
   Lucy said that the sodium chloride was 'colourless'
   Jo suggested that the tiny particles of copper sulfate must be blue, making both the solid and solution blue.
   Alice thought that the copper sulfate was like coloured glass, see-through (transparent), and coloured
   Ravi suggested that the sodium chloride particles were only white when they were grouped together in lumps big enough to see, and colourless when they were spread apart, as in a solution.
   Sam said that, if that was true, the copper sulfate particles must be blue, all of the time.

   a. Arrange the students into the order in which you think their statements showed the ***most reasoning*** based on their observations. If you think Alice made the most progress from the observations by good reasoning to the groups understanding, put her name at the top of the list. Explain your reasons, for the order that you decide.

   b. What colour would you expect copper sulfate gas to be, if it exists?

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Do we have a decent Hi-res of this photo?

Or shall I take a better one?

Blue hydrated copper(II) sulfate and the white crystals formed when it is heated

3. The blue copper sulfate crystals that have been discussed so far are more fully called ***hydrated*** copper(II) sulfate.

   Alice took some of the blue hydrated copper(II) sulfate crystals and heated them strongly in a test-tube. Alice saw that the blue crystals change colour to white, she wrote down that 'steam' rises from the test-tube.

   Her thoughts are listed below:

   - *Sodium chloride crystals have no water since they are already white.*
   - *The hydrated copper(II) sulfate contains water.*
   - *Coloured compounds will change to white when heated if they lose water.*
   - *When it is heated the blue hydrated copper(II) sulfate loses water.*
   - *The white residue is copper sulfate with no water – anhydrous copper(II) sulfate.*
   - *The copper(II) sulfate needs water to be blue – without water it is white.*
   - *The hydrated copper(II) sulfate changes when it is heated.*

   a. Rearrange her thoughts into a sensible order.
   b. She draws some big conclusions from this single experiment. Which of her conclusions do you think are reasonable?
   c. Which of her conclusions do you think are unreasonable? Explain your reasons.

Discussion of answers

Solutions

1.

a. Sam is incorrect to think that the particles of sodium chloride are destroyed. They are simply being rearranged. Instead of being grouped together, in the solid, they are spread out into the solution. This touches an important concept in science, which is that the particles are never destroyed. In chemical reactions the particles get rearranged but are not created or destroyed. Lucy is therefore correct, and pointed out an important piece of evidence to back up her idea.

   Ravi's statement is correct. The solutions are mixtures.

   Jo's statement is incorrect, but may not be as far from the truth as you might think. Gases are clear, transparent and invisible (unless coloured) because the particles are spread out and in an irregular arrangement. The sodium chloride disappears when it dissolves because the particles spread out in the water and end up in an irregular arrangement.

   Discussion point: can you think of any other evidence to link transparency and the irregular arrangement of particles?

   Alice is correct; the particles are much too small to see

b. To answer Tom's question, we need to consider the forces of attraction between particles in both the solid and solution. Particles attract each other. The sodium particles attract the chloride particles and vice versa. There must be forces of attraction between the water particles and the sodium chloride particles. These forces must be sufficiently strong to overcome the forces of attraction holding the sodium and chloride particles to each other.

2.

a. The answer to this is open for debate, but I put Ravi's statement first, as it shows the greatest reasoning. The sodium chloride particles appear white when they are all grouped together and colourless when they are spread out. So it seems logical to suggest that the whiteness is caused by the grouping together. Jo and Sam both shed light on the contrast with copper sulfate. It seems reasonable to suggest that copper sulfate's blue colour is caused in a different way from sodium chloride's whiteness because copper sulfate solution keeps the colour blue. Notice that we can make this logical statement, even if we know nothing about actually how copper sulfate appears blue! Alice's statement is helpful, scientists look for similar situations that they have met, to help explain or make predictions about the particular part of science they are considering.

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Tom and Lucy are both correct. 'Clear' is the opposite of cloudy. When solids fully dissolve they form clear solutions. A cloudy appearance is good evidence that some solid has not dissolved. The solution was also colourless. These are accurate descriptions but do not show as much reasoning as the others.

b. It would seem reasonable to suppose, from particle theory, that copper sulfate gas would be a very pale blue. Blue, because the particles are blue. Pale, because in a gas the particles are spread out, far apart from each other. However, if you tried to show this by an experiment in the laboratory you would find a few surprises. When (hydrated) copper sulfate is heated strongly, it first loses water (water of crystallisation) and turns white. This suggests that the blue appearance depends on the copper having some water with it. If copper sulfate is further heated it decomposes into simpler substances, gases are formed but they are not copper sulfate. This implies that copper sulfate will not exist as a gas.

Why does the particle model let us down when making a prediction about copper sulfate gas? The particle model assumes that the particles remain the same in the solid, liquid and gaseous states. In the different states the same particles are simply arranged and move differently. But in chemical reactions new substances are formed – ie different particles are produced. So, when you heat a solid two things might happen, a *physical change* such as melting or a *chemical change* like decomposition.

The question has tested the limits of the model we were using to explain our observations. To understand what really happens to copper sulfate we need to introduce a different model. The process of testing a model until we find situations where it lets us down is frequently involved when new ideas in science emerge. It was the process that Einstein used to help develop his Theory of Relativity.

So don't be disappointed if you get an unexpected result.

"There are two possible outcomes: If the result confirms the hypothesis (theory), then you've made a measurement. If the result is contrary to the hypothesis, then you've made a discovery."
Enrico Fermi - amous scientist

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3.

a. *Rearrange her thoughts into a sensible order.*

1. The hydrated copper(II) sulfate changes when it is heated
↓
2. When it is heated the blue hydrated copper(II) sulfate loses water
↓
3. The hydrated copper(II) sulfate contains water
↓
4. The white residue is copper sulfate with no water – anhydrous copper(II) sulfate
↓
5. The copper(II) sulfate needs water to be blue – without water it is white
↓
6. Sodium chloride crystals have no water since they are already white
↓
7. Coloured compounds will change to white when heated if they lose water

b. *She draws some big conclusions from this single experiment which of her conclusions do you think are reasonable? Explain your reasons.*

There does seem to be a link between copper sulfate being blue and the presence of water. Copper sulfate solution is blue and so are the hydrated crystals (which do indeed contain some water). Since the blue colour disappears when the water is driven off by heating it seems reasonable to infer that *the copper(II) sulfate needs water to be blue – without water it is white.*

c. *Which of her conclusions do you think are unreasonable? Explain your reasons.*

Sodium chloride crystals have no water since they are already white. Sodium chloride solution is colourless. There is no evidence that water gives colour to sodium chloride.

Coloured compounds will change to white when heated if they lose water. This is too general a conclusion for just one substance you would need many more examples before stating a general trend as Alice has.