Mixing drinks

PowerPoint® presentation (Student worksheet): CDROM index 26SW – see Use *below.*

Discussion of answers: CDROM index 26DA

Topics

Metacognition, thinking styles, investigations, trends and entropy changes in solution.

Level

Able post-16 students.

Prior knowledge

Intermolecular forces, hydrogen bonding and the structure of ice.

Rationale

This activity is designed to develop the students' metacognition (thinking about thinking). As they develop these skills they should have more thinking strategies with which to approach problems in chemistry and other subjects.

The activity uses two methods to develop metacognition. First, the students are asked to solve a problem and then reflect on the thinking styles that they used. In the other method students attempt to answer some questions and then discuss four modelled thinking styles of fictional students.

Use

This can be used as a differentiated activity for the most able in a mixed ability group, although there are benefits to using it as a whole class activity with teacher support.

You need a photocopy of the four students' (A-D) thinking styles for each group. It is best to show the early slides, up to and including the instructions for task 4, using a projector.

The students work in groups of four. The students should only see one slide at a time, so if this is used in paper form, the teacher can give out the sheets for tasks 1–3 as they are required. For task 4 the modelled thinking styles of students A–D should be printed out (on coloured paper if you want to reuse them) and each group of students given one set of the modelled thinking styles (one copy of each student A-D). The students in the group then each take one thinking style for task 4.

Student D uses entropy in their thinking, but their thinking **style** can still be described even if the topic of entropy has not been covered.

The aim is to get the students thinking about and discussing thinking styles, so it is important to allow plenty of time for discussion.

Mixing drinks

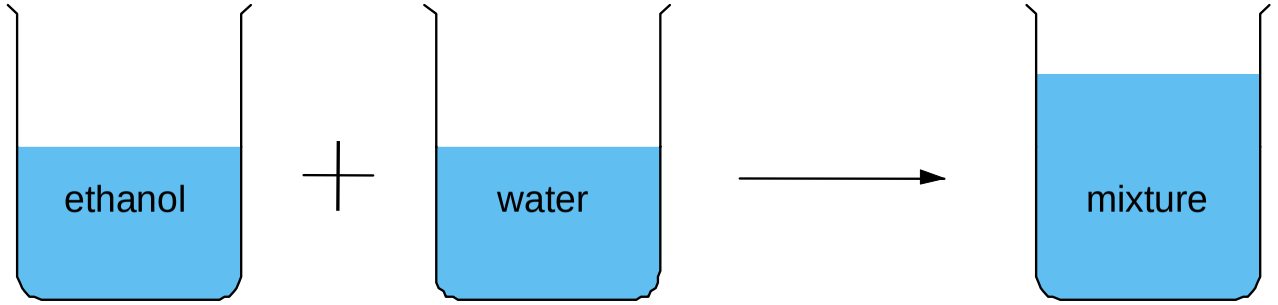
A metacognitive activity

Task 1

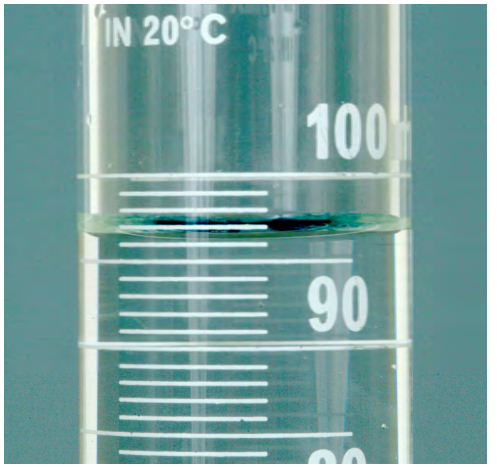
Mixing drinks

List four (and only four) different investigations that can be done relating to this phenomenon.

For example: how does the volume contraction vary with temperature?



50 cm^3 50 cm^3 96 cm^3



Task 2 Thinking about thinking

In your group discuss any thought process that you went through to arrive at the investigations. For example did you...

- Visualise the molecules and how they might behave?
- Identify and list all the variables?
- Systematically consider the variables in turn?
- Consider the practical difficulties with some investigations?
- Think of more than four investigations. If so, by what criteria did you choose between them?
- Something else...?

Task 3

Now *speculate* about possible explanations for, and links between, the following facts:

- The mixing of ethanol and water is exothermic.
- The volume decrease for mixing methanol and water is slightly less than the volume decrease with ethanol and water. 50.0 cm^3 of water mixed with 50.0 cm^3 of methanol gives a total volume of 96.5 cm^3.
- Pentanol is only slightly soluble in water.
- Pentanol gets less soluble as the temperature increases.

Task 4 Thinking about thinking

- Each person in the group takes one student's thinking sheet for students A-D.
- They should read through the thinking sheet and describe to the rest of the group the thinking **tools** or **styles** used (not the actual conclusions or reasoning but the thinking strategy).
- Discuss the usefulness of the thinking tools used.
- Could any of the students have taken their thinking further by using alternative thinking tools?

Student A thought about statement 1: Mixing ethanol and water is exothermic

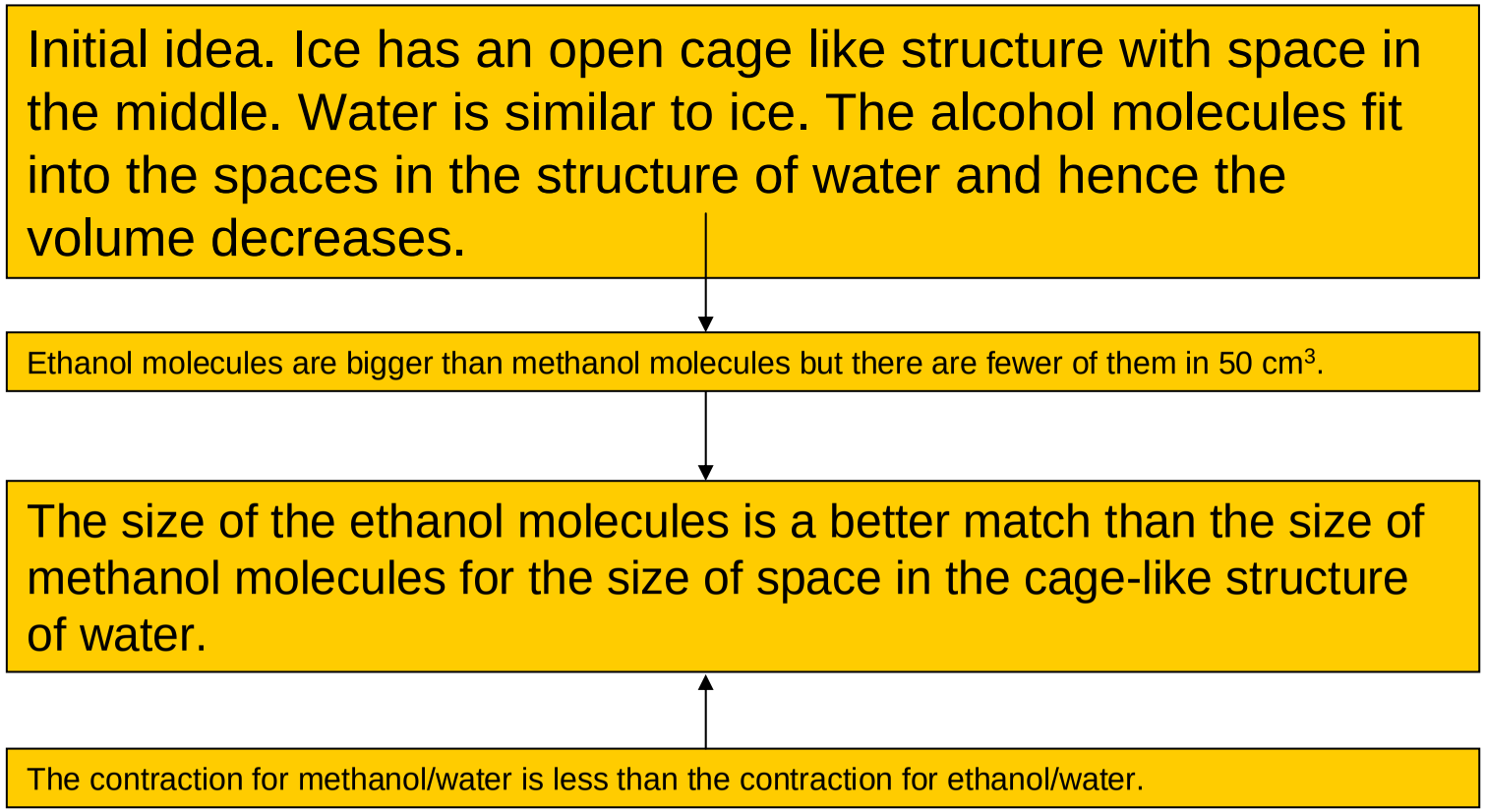
His thinking strategy was to list all that he knew about the relevant topics.

- Water forms hydrogen bonds.
- Each water molecule has two lone pairs of electrons and two δ^+ hydrogens.
- Ethanol can also form hydrogen bonds.
- Ethanol has two lone pairs of electrons and one δ^+ hydrogen.
- In pure ethanol there are not enough δ^+ hydrogens for every lone pair.
- Bond making is exothermic.
- Liquids expand when they are heated.

Having listed what he knew, he then chose ‘bond making is exothermic’ as a key concept to apply.
He concluded that mixing produced either more or stronger hydrogen bonds.

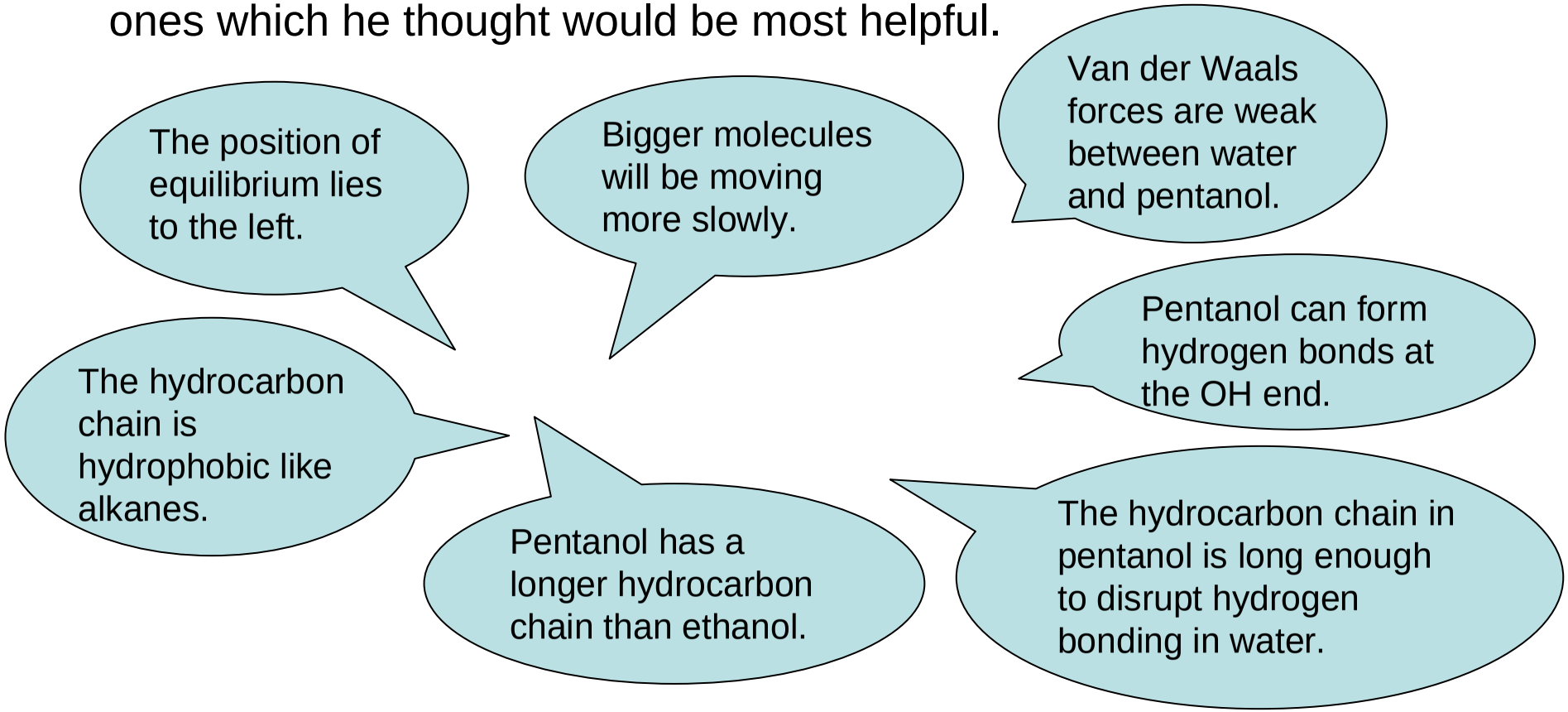
Student B thought about statement 2:
The volume decrease for mixing methanol and water is slightly less than the volume decrease with ethanol and water

Her thinking strategy was based on an initial idea which she worked forward from. At the same time she worked back from the observation. When the reasoning going forward could be linked to the reasoning coming back from the observation she had her conclusion. The diagram below represents her thinking. The size of the writing reflects the relative importance, to her, of the individual thoughts.



Student C thought about statement 3: Pentanol is only slightly soluble in water

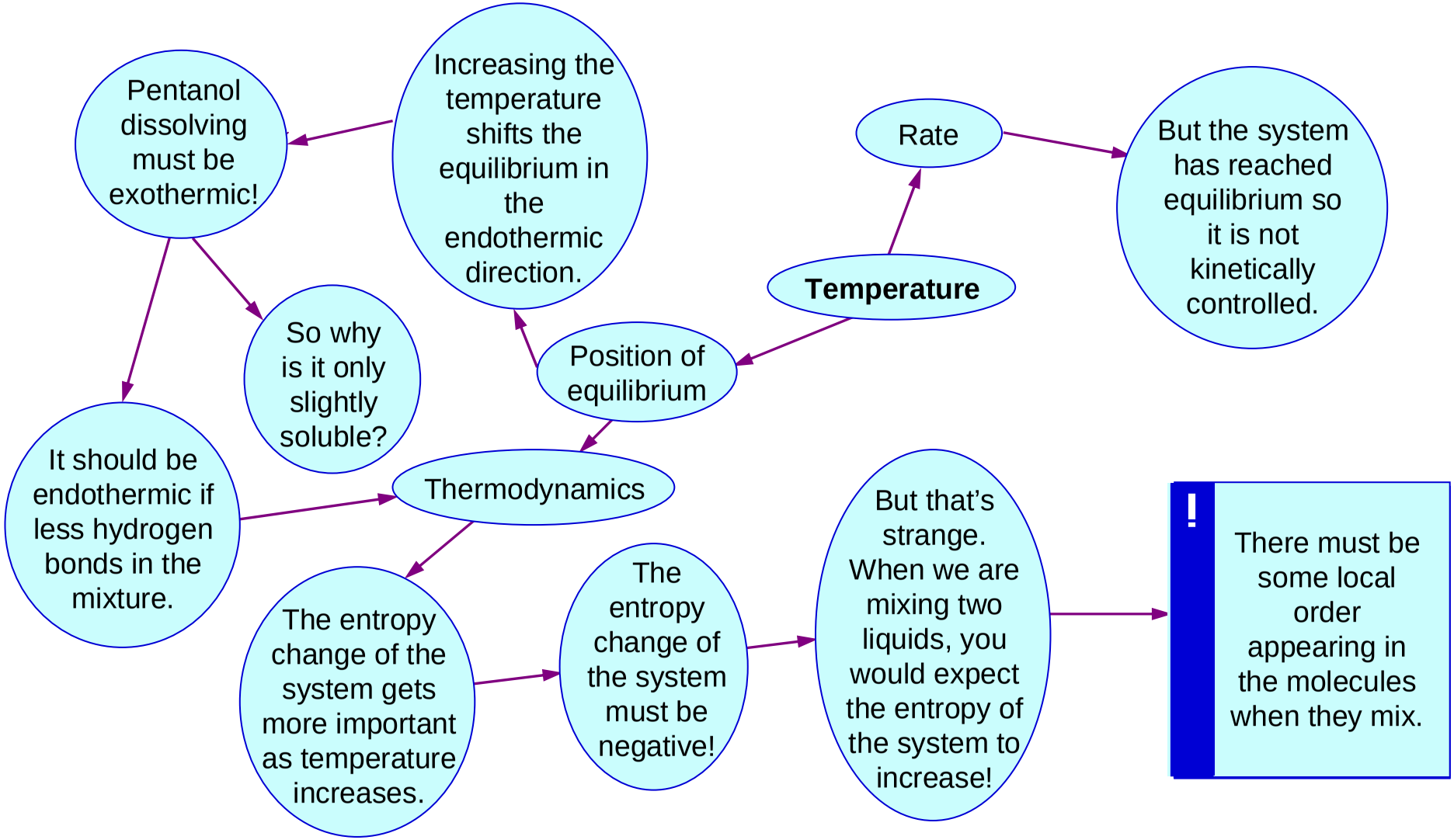
His strategy was to brainstorm ideas and then focus in on the ones which he thought would be most helpful.



He had met questions about solubility before and was familiar with the rule of thumb that ‘like dissolves like’ and so concluded that the pentanol disrupts opportunities for hydrogen bonding in the water.

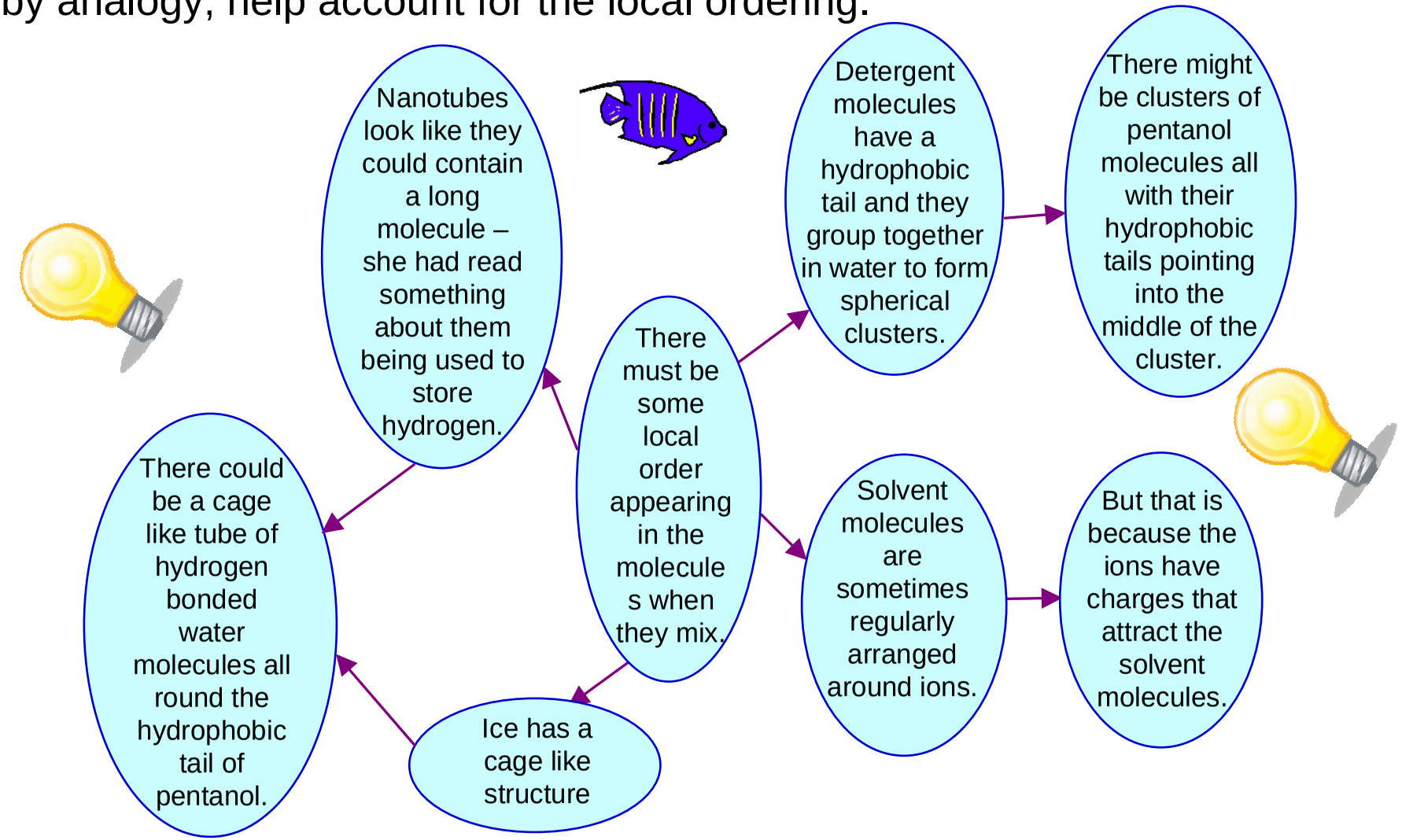
Student D thought about statement 4:
Pentanol gets less soluble as the temperature increases

Her thinking strategy is best represented as a mind map:



Student D cont'd.

Having concluded that there must be some local ordering when the liquids mix she went 'fishing' for chemistry that she had met that might, by analogy, help account for the local ordering.



Discussion of answers

Mixing drinks

Task 1

Some possible questions that could lead to investigations:

- How does the volume contraction vary with composition of the mixture (at what composition would the volume contraction be greatest)?
- How does the volume contraction vary with different alcohols?
- Is there a correlation between the volume contraction and the energy released for different alcohols?
- Do you still get a volume contraction if you mix ethanol with saturated salt solution?
- Is there a correlation between the volume contraction and any change to the melting point and boiling point of the mixture?
- If you reduce the pressure will they separate (Le Chatelier's principle)?
- Could the contraction power a hydraulic arm?

Did you put any constraints (not given in the question) on your suggested investigations. For example, did you only suggest investigations that could be easily done in a school laboratory?

Did you want there to be more clearly defined boundaries as to which investigations were **allowed**?

Task 2

We are often unaware of the different kinds of thinking we use as we are often more interested in what we have thought of than how we thought of it. You may have found this task difficult. It might be helpful to try to remember:

- if you rejected some thoughts as too far off the original or too close to other suggestions; and
- whether words images or concepts went through your mind as you were trying to find a third or fourth idea.

Thinking about thinking (called metacognition) can be very useful as it helps you develop discrete thinking tools to help you solve problems.

Task 3

1. The mixing of ethanol and water is exothermic:
   - More bonds are made than are broken, or stronger bonds are made than are broken (bonds here include intermolecular forces).
   - The increase in temperature leads to a temporary expansion.
   - The volume contraction means the molecules are on average closer together. In covalent bonding short bonds are strong bonds. Is the same true for intermolecular forces?

continued on page 2

2. The volume decrease for mixing methanol and water is slightly less than the volume decrease with ethanol and water. 50.0 cm^3 of water mixed with 50.0 cm^3 of methanol gives a total volume of 96.5 cm^3.
   - The methanol has a smaller hydrophobic tail. The methanol is closer in size to water. There are more methanol molecules than ethanol molecules in a volume of 50 cm^3.
   - It would be interesting to find out if the maximum contraction happens at a certain ratio of particles alcohol : water.
   - It would be interesting to find out if the trend continues with propanol and butanol.

3. Pentanol is only slightly soluble in water.
   - The hydrophobic tail is now quite long and the molecule as a whole is less polar than the shorter alcohols.

4. Pentanol gets less soluble as the temperature increases.
   - The water molecules from a cage like structure round the hydrophobic tail. This is quite ordered so the entropy of the system decreases when pentanol dissolves. This is analogous to gases. When gases dissolve the entropy of the system decreases because the entropy of substances in the gaseous state is generally high. The entropy change in the system becomes more dominant as the temperature increases ($\Delta G = \Delta H - T\Delta S$).
   - If you have not heard of entropy, ΔG or the second law of thermodynamics they might not be part of the specification you are studying. You should do some research and find out about them.