MAGIC RAINBOW

How does adding sugar to the water affect its density?

Which layer is the densest?

Why do the layers sit in the order they do?

Equipment required:

Tablespoon
5 glasses
Sugar
Water
4 x food colourings (i.e. blue, green, red, yellow)

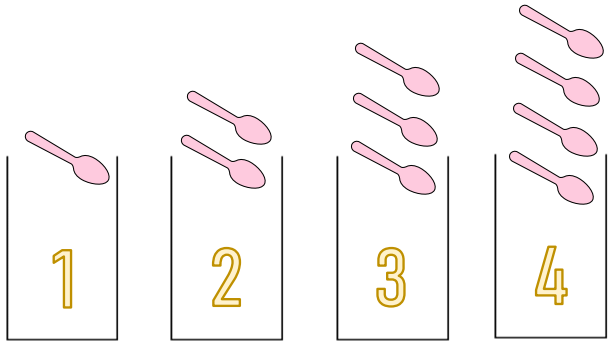
Can you explain the findings?

Magic Rainbow

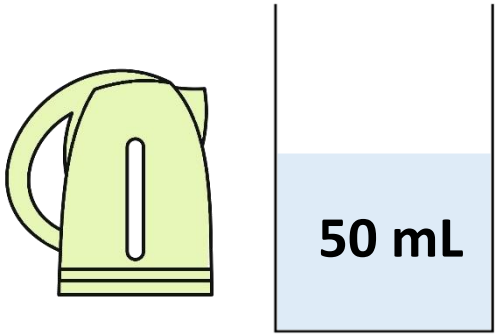
DEPARTMENT OF CHEMISTRY

UNIVERSITY OF OXFORD

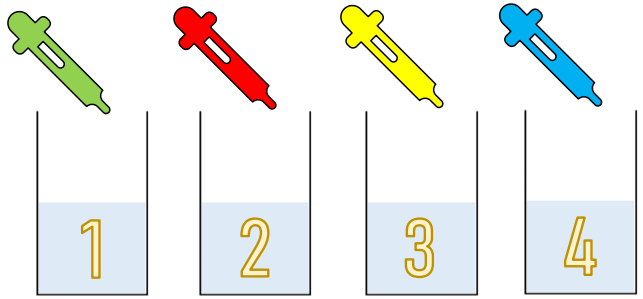
1 Add following amounts of sugar to separate glasses:
1 tbsp, 2 tbsp, 3 tbsp, 4 tbsp.



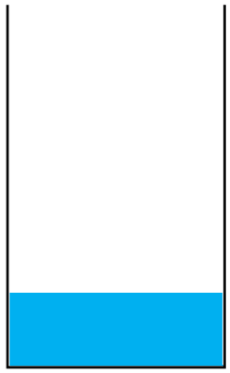
2 Add 50 mL warm water to each glass and stir to dissolve the sugar fully.



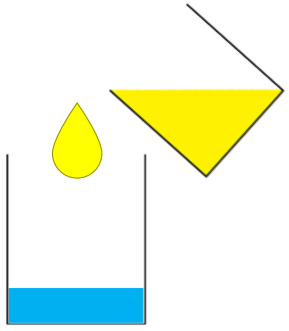
3 Add different coloured food colouring to each sugar solution as shown below:



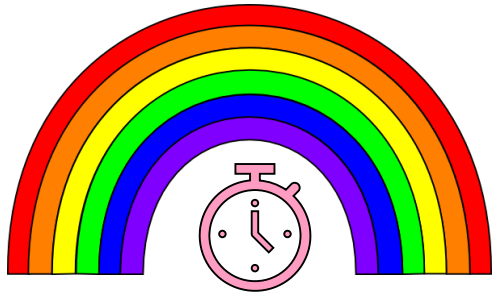
4 Carefully pour the blue solution into an empty glass to just under ¼ full.



5 Carefully pour the same amount of the yellow solution down the side of the glass. Repeat with red solution, then green.



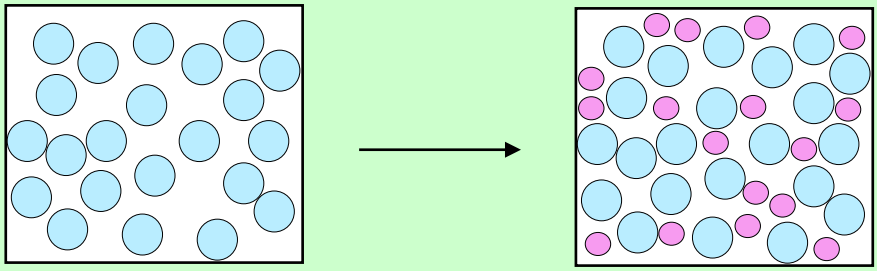
6 Allow the layers time to settle, then admire your rainbow!



The science behind the scenes…

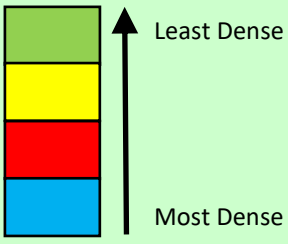
Density is a measure of a substance's mass per unit volume. Different substances have different densities, and these determine whether they **sink** or **float** in a specific medium. If a substance is less dense than the medium it is placed in, it will float, whereas it sinks if it is more dense than the medium it is placed in.

Water has a standard density of 1 g/mL, and can be made **denser** by dissolving solids in water. When the solid dissolves, the solid particles **fill the space** between the water molecules, increasing the mass per unit volume:



The **more solid** that is added to water, the **denser** the solution is that is made, as more of the space between the water molecules is being filled.

This experiment dissolves sugar in water to change the density of the water solutions and ultimately create the rainbow layers. The densest sugar solution is the solution in which the most sugar was dissolved into (4 tbsp), and this is added first. The next solution added is the second densest solution. This is less dense than the first solution added, so will float on top of the first solution, forming two distinct layers. This is repeated with the third densest and then least dense solution. Each solution being added is less dense than the last which it is being poured over, and so we get the formation of the **layers** of solutions of different densities.



Practical investigation:

Equipment:

- ☐ Tablespoon
- ☐ 5 glasses
- ☐ Sugar
- ☐ Water
- ☐ 4 x food colourings (i.e. blue, green, red, yellow)
- ☐ Measuring jug

Method:

1. Source 4 empty glasses. Add the following amounts of sugar into separate glasses: 1 tbsp, 2 tbsp, 3 tbsp and 4 tbsp.
2. Ask an adult to help: to each glass, add 50 mL hot water (from boiled kettle) and stir to ensure all the sugar has dissolved in each.
3. Add:
    - 2-3 drops of **green** food colouring to the 1 tbsp sugar solution
    - 2-3 drops of **red** food colouring to the 2 tbsp sugar solution
    - 2-3 drops of **yellow** food colouring to the 3 tbsp sugar solution
    - 2-3 drops of **blue** food colouring to the 4 tbsp sugar solution

    (Note: you do not have to use these exact colours, use whatever you have available- these colours listed above will be used to reference the solutions throughout this manual).
4. Carefully pour the blue 4 tbsp sugar solution into a 5th, empty glass to just under ¼ full.
5. Carefully pour the same amount of the yellow (3 tbsp sugar) solution down the side of the glass.
6. Repeat with the red (2 tbsp) solution, then the green (1tbsp) sugar solution.
7. Allow the layers to settle, and admire your rainbow!

Questions:

(a) How does adding sugar to the water affect its density?
[Sugar dissolves in water, filling the spaces between water molecules, which therefore increases the density.]

(b) Why do the layers form?
[the different solutions have different densities, so when poured carefully down the side of the glass (to avoid disturbing the layers) in order of most to least dense, layers form.]

(c) Which layer is the densest?
[The layer with the most sugar dissolved in, i.e. 4 tbsp sugar solution.]

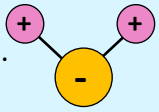
(d) Why do we use warm water?
[Increasing the temperature of the water makes it easier for the sugar molecules to dissolve. A higher temperature gives the molecules more energy and makes it easier for the sugar molecules to fit in between the water molecules, as the water molecules move around more.]

(e) Has the sugar reacted with the water?
[No: the sugar has only dissolved. A chemical reaction involves producing new molecules using two or more other molecules, called reactants, which has not happened here.]

Science isn't just useful in the labs…

As this experiment has shown, liquids of different densities form layers, with the least dense forming the top layer, and more dense liquid forming the layer at the bottom.

Oil and water are **immiscible** (they do not mix). Water is **polar**, which means it has both positively charged ends and negatively charged ends:



Oil is **non-polar**, which means it does not have any charged ends. Therefore, oil molecules prefer to sit next to other oil molecules as they are of the same type. Water molecules prefer to sit next to other water molecules as they can benefit from attraction of oppositely charged parts of neighbours:

The **electrostatic attraction** (the attraction between the positively charged and negatively charged parts) between water molecules brings them closer together, increasing the density of the liquid. Hence, oil is less dense than water. As they do not mix, oil forms a **layer** on top of water.

The differences in **density** between oil and water means that in the event of an oil spill into the ocean, the oil floats on top of the salty seawater. Oil **spills** are bad f0r the environment, so it is useful to reduce the harmful impact an oil spill can have by fast removal of the oil from the ocean. Scientists are working on perfecting technology that will allow us to effectively 'scrape' the layer of oil of the ocean. This is a real-world application of the difference in densities of liquids!

Photo citations:
http://clipart-library.com/clipart/rcLxdxyGi.htm
https://www.vectorstock.com/royalty-free-vector/electric-kettle-icon-outline-style-vector-9886021
https://www.istockphoto.com/vector/oil-spill-line-icon-fuel-and-storage-oil-barrel-sign-vector-graphics-a-linear-gm1159768272-317239880