THE MOST MARVELLOUS OF SUBSTANCES

Photo Colin Barker

***Ian Stewart** gives us an insight into the substance that is not only most abundant on Earth, but also one of the most remarkable*

To most of us, water is a substance that we drink, wash and cook with, fish and swim in, and generally take for granted. However, few realise what an eccentric, remarkable substance it actually is. It renders the Earth fit to live on and its involvement in life processes is a major reason we can populate this planet today.

As life first developed in water, it will come as no surprise that it plays a major role in the many biological processes that maintain living organisms. For example, respiration takes place in about fourteen consecutive steps and in each one of these steps water is a significant reactant. In terms of facts and figures, photosynthesis and respiration in plants have an annual turnover running to millions of tonnes of water. On average, about 60% of the human body, approximately 85% of the brain, 80% of blood and 70% of muscle consists of water. Jellyfish are almost totally composed of this remarkable substance (95%). Its origin is uncertain, but its condensation from the early atmosphere formed today's oceans, which cover about 75% of the Earth's surface. So much water is still floating around in the air as vapour, it is estimated that if this also condensed it could raise sea levels by 45 cm.

Water is the second-most common molecule in the universe (behind hydrogen) and is the only inorganic liquid found on this planet. It is also the only substance on Earth that occurs naturally in all three physical states (solid, liquid and vapour): and this, with many other surprising properties, is only touched upon in the present UK school curricula.

Liquids usually contract when they get colder, as the molecules lose energy and move closer together. Water is different in that this only happens until it reaches 4 °C. At this point it

Photo Colin Barker

reaches its maximum density, after which it gets less dense as it begins to expand. More hydrogen bonds (forces of attraction) form between the water molecules, which move themselves into a three-dimensional hexagonal open structure (similar to diamond). In doing this it expands, because the water molecules are separated by a greater distance, resulting in lots of space between them. This phenomenon explains why ice cubes float in your gin and tonic, icebergs float in the sea and snowflakes are hexagonal.

This strong force of attraction also accounts for the fact that water, placed on greaseproof paper, will form a bead of liquid. The molecules are more attracted to each other than the paper and consequently pull themselves into a sphere, so that the water behaves more like mercury! The water molecules at the surface create what is called 'surface tension' which allows insects to walk on it or needles to float on it. Break the attractions by adding washing-up liquid (molecules of water will now attract to this as well) and the needle will sink!

Water has an unusually high heat capacity (ability to store heat) and this is particularly noticeable in the oceans of the world. The massive amounts of heat energy stored by volumes of water, such as the Gulf Stream, mean that as this energy is slowly released it can maintain temperate climates over much of the Earth's surface. All the coal mined in the world would only be able to supply an equivalent amount of energy for about 12 hours!

Drinking water is essential to our wellbeing; it is the most important nutrient throughout the living world. It is estimated that we cannot live without it for more than about 100 hours, whereas, the absence of most other nutrients can be tolerated for up to one month. Only about 3% of the available water on the planet is fresh, which means that it is an extremely precious commodity; and much of this is in Antarctica! The water cycle helps to preserve available drinking water but it is an interesting thought that the water we drink will have been drunk by others in the past! There is a distinct possibility, therefore, that one of the water molecules in your glass at lunchtime will have slaked the thirst of Julius Caesar!

Simple experiments with water

Effect of surface tension (call it the water surface and not 'skin')

• Very gently push the point of the cocktail stick into the surface of the water and observe that the needle does not sink.

• Coat the end of the stick with washing-up liquid and repeat. The needle will sink. Perhaps this could be done without telling the students what you have done to the cocktail stick! You could then claim to be the only one skilled enough to do this, or simply confess! Links can be made to the ability of a pond skater to walk on water.

Difference between hot and cold water

• Half fill a clear container with water.

• Colour the water with ink or food colouring and chill overnight.

• Colour hot water using a different colour and gently pour down the side of the tilted glass of chilled water. The liquids will form two layers, with the less dense hot water floating on top.

• Alternatively, make a coloured ice cube and float it on the surface of water at room temperature. As the ice cube melts the cold water will sink to the bottom of the container taking with it the colour.

Difference between fresh and salt (sea) water

• A similar experiment can be used to show that salt water is heavier than fresh water. Use coloured salt water and differently coloured tap water in a similar way to that described above (there is no need to heat/chill the liquids).

Importance of water for life

• Use two slices of bread. Place one slice in a sealed plastic bag.

• Completely dry the other slice by placing it on a radiator or in an oven before sealing it in another plastic bag. Over a period of about one week mould will be seen to grow on the first slice whereas no mould will be observed on the dry one.

Ability of water molecules to attract other molecules

• Place a tower of sugar lumps in a beaker containing coloured water. The coloured water will be seen to move up the tower as it absorbed by the sugar.

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