

# Module 3: Water

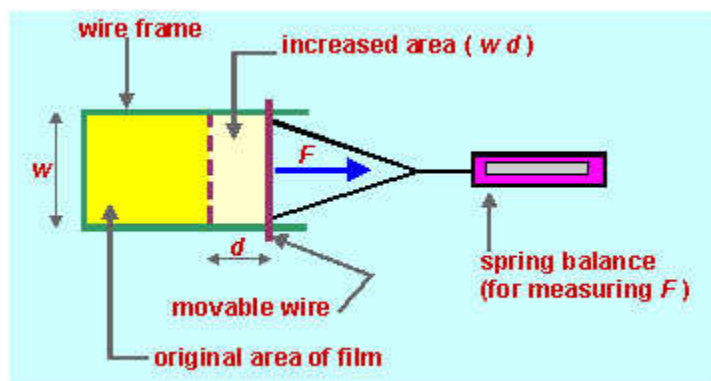
## Supplementary material

*As in previous modules most of the material in this section is not required by the HSC syllabus. It is presented here either because it provides better understanding of syllabus material or because of its inherent interest to HSC students.*

### 1. Surface tension and viscosity

The definitions in *Conquering Chemistry* page 184 are adequate for HSC purposes, but to understand how these quantities get the units they have, we need more precise definitions.

**Surface tension** is the energy (work) required to increase the area of a surface by unit area. It can be measured by making a film of liquid (e.g. a soap bubble) on a frame with a movable side as in the following diagram.

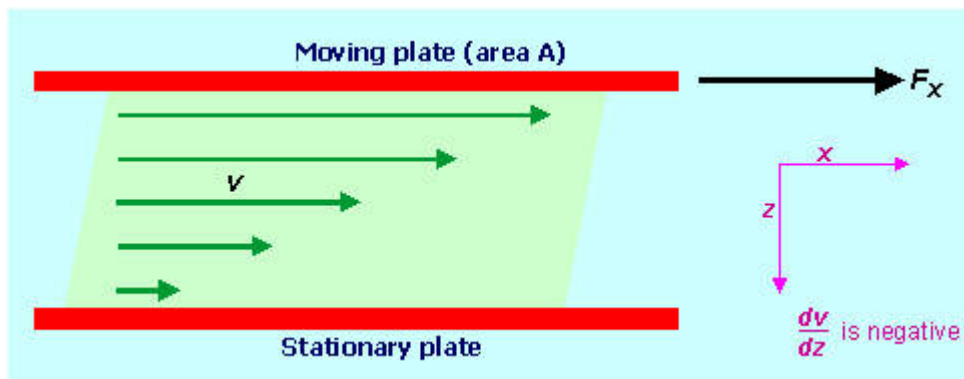


A sensitive spring balance is used to increase the area of the film (pull on the movable wire) by a measured amount. The force required is measured by the spring balance, and the distance moved by the wire and the width of the film are measured. The work done is  $F \times d$  and the increase in area of the film is  $2 \times d \times w$  (2 because the film in this case has two sides). Surface tension  $\sigma$  is work done per unit area so

$$\sigma = \frac{Fd}{2dw} = \frac{F}{2w}$$

Force is measured in newtons, N, and distance (or width)  $w$  in metres, m, so surface tension  $\sigma$  has the units of  $\text{N m}^{-1}$ . Because of the small magnitude of  $\sigma$ , it is often given in  $\text{mN m}^{-1}$  (millinewtons per metre).

In a liquid flowing across a stationary surface or through a tube, **viscosity** is the force per unit area needed to maintain a unit velocity gradient perpendicular to the direction of flow. In the diagram below we have a liquid (e.g. treacle) sandwiched between two plates. One plate is stationary while a force  $F_x$  is applied to move the other plate.



The movement of one plate relative to the other sets up a velocity gradient: liquid near the stationary plate is not moving while liquid near the moving plate has the same velocity as the moving plate. The velocity gradient is  $dv/dz$ . If the area of the moving plate in contact with the liquid is  $A$ , then viscosity  $\eta$  is given by

$$\eta = \frac{F/A}{-dv/dz}$$

(minus because  $dv/dz$  is negative with the origin for  $x$  and  $z$  defined as in the diagram).  $F/A$  has the units  $\text{N m}^{-2}$  and  $dv/dz$  has the units  $\text{m s}^{-1} \text{m}^{-1}$ . This gives viscosity  $\eta$  the units  $\text{N m}^{-2} (\text{m s}^{-1} \text{m}^{-1})^{-1} = \text{N m}^{-2} \text{s} = \text{Pa s}$  where Pa is a pascal (unit of pressure, and equal to  $\text{N m}^{-2}$ ). Again because of the magnitude of common viscosities, they are often given in millipascal seconds, mPa s.

Older books may use the Poise as the unit of viscosity. 1 Poise = 0.1 Pa s.

## 2. Supersaturated solutions

Despite what was said about saturated solutions on page 208, it is sometimes possible to obtain solutions which contain more solute per unit volume of solvent than is 'allowed' by the solubility! If a saturated aqueous solution of sodium thiosulfate (photographer's hypo or fixer) is prepared at 80 or 90°C, it will contain about 70 g/100 g water. If it is slowly cooled to room temperature, it stays as a clear solution. Although at 25°C the solubility is only about 40 g/100 g, the excess thiosulfate does not crystallise out. Such a solution is said to be supersaturated.

**A supersaturated solution** is one that contains a greater concentration of solute than is expected from the solubility.

Such supersaturated solutions are not particularly stable. The excess solute can be made to crystallise out sometimes by vigorously shaking the solution, or scratching the walls of the container with a sharp rod, or sometimes just by letting some dust from the air settle on its surface. The best way to crystallise out the excess solute is to add a few small crystals of the solute to the solution. These act as 'seed' crystals which quickly cause the excess solute to crystallise out. *Supersaturated solutions cannot exist in contact with crystals of the pure solute.* This then is the difference between a saturated solution and a supersaturated one:

*A saturated solution is the one with the highest concentration of solute which can exist indefinitely in contact with crystals of pure solute.*

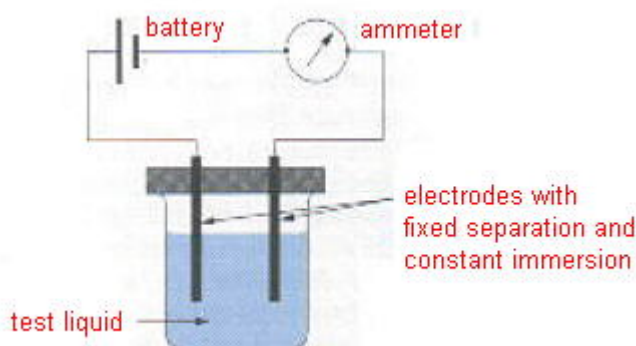
Honey is an everyday example of a supersaturated solution. It is a supersaturated solution of glucose and fructose (common sugars). If it is seeded with crystals of glucose or fructose, as often inadvertently

happens if some honey around the mouth of the jar dries out to form crystals, the excess solid crystallises out and forms candied honey. It can be clarified again by heating in hot water. At the high temperature, the amounts of glucose and fructose present can all dissolve without supersaturating the hot solution. Once all the solids have dissolved the honey can be slowly cooled. Provided care is taken to remove all traces of solids (seed crystals) from around the mouth of the jar, the honey will remain clear, that is supersaturated.

### 3. Conductivity of solutions; electrolytes and non-electrolytes

The syllabus does not specifically mention conductivity of solutions or the terms, electrolyte, strong and weak electrolyte, non-electrolyte, and so these are not discussed in *Conquering Chemistry Preliminary Course*, although passing reference is made to conductivity of solutions of ionic and covalent substances on pages 57–9. Because these concepts are used in the HSC course, perhaps they should be discussed in this module.

If the apparatus shown in the figure below is used to measure the relative conductivity of some common solutions, the results shown in the table are obtained. Relative conductivity in this experiment would be the current measured on the ammeter for a constant voltage from the battery and constant area, separation and depth of immersion of the electrodes in the test solution; the test solutions should have approximately the same concentration. Some solutions do not conduct electricity at all (left-hand column), some have relatively low conductivities (middle column), while others have relatively high conductivities (right-hand column).



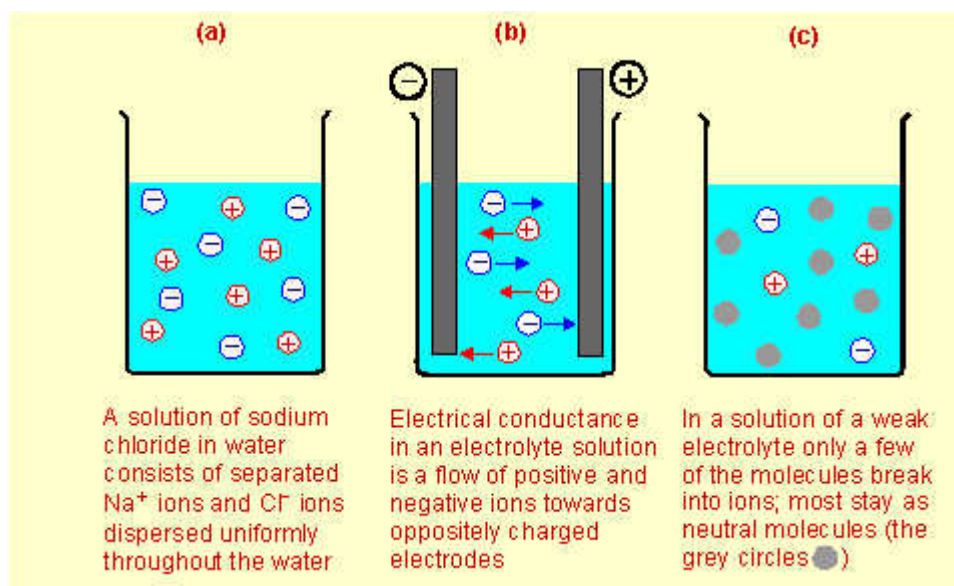
Relative electrical conductivities (REC) of some solutions					
Solution	REC	Solution	REC	Solution	REC
sucrose in water	0	acetic acid in water	5	<b>aqueous solutions of</b>	
urea in water	0			sodium chloride	100
		ammonia in water	10	magnesium sulfate	180
iodine in hexane	0			potassium nitrate	110
paraffin oil in	0	CO <sub>2</sub> in water	2	hydrochloric acid	300
chloroform				nitric acid	290
				sodium hydroxide	200
				ammonium chloride	100

On the basis of these results, the technical term electrolyte is introduced.

An **electrolyte** is a substance which in solution conducts electricity. Substances which in solution do not conduct electricity are called **non-electrolytes**. Substances in the middle and right-hand columns of the table are electrolytes. The substances in the left-hand column are non-electrolytes.

The good conductors (right-hand column) are called **strong electrolytes**, while those which conduct, but not very well (middle column), are called **weak electrolytes**.

The reason some solutions conduct electricity is that the solutes, instead of being made up of neutral molecules like sucrose, urea or iodine, are made up of positive and negative particles called ions. As was explained in Section 2.15 on pages 49–51, solid sodium chloride, for which the formula is NaCl, consists of positive  $\text{Na}^+$  ions and negative  $\text{Cl}^-$  ions packed into an orderly array in the salt crystal. This was shown in Figure 2.11 (page 50). When crystals of sodium chloride dissolve in water, they break up into individual ions which move freely and independently through the solution, as shown in Figure 7.10 (page 195) and in Figure (a) below. When electrodes (electrical conductors) are placed in the solution, the positive ions are attracted towards the negative electrode and the negative ions are attracted towards the positive electrode as shown in Figure (b). This flow of ions through the solution constitutes an electric current and therefore the solution is a good conductor.



**Strong electrolytes** are made up of positive and negative ions which become completely dispersed in aqueous solution.

Some substances such as acetic acid (in vinegar),  $\text{CH}_3\text{CO}_2\text{H}$ , exist in the pure liquid state as neutral molecules, but when they are dissolved in water, some of the molecules react with water to form positive and negative ions (though the vast majority remain as neutral molecules). Of every 100 molecules of acetic acid dissolved in water, typically 99 remain as  $\text{CH}_3\text{CO}_2\text{H}$  molecules while the other one forms a positive  $\text{H}_3\text{O}^+$  ion (sometimes written just as  $\text{H}^+$ ) and a negative  $\text{CH}_3\text{CO}_2^-$  ion as shown in Figure (c) above. These ions cause the solution to have a small but significant electrical conductivity.

Substances in which only a small fraction of the molecules break up into positive and negative ions when they are dissolved in water are called **weak electrolytes**. This is in contrast to **strong electrolytes** which exist in solution totally as ions.

Exercises based on these ideas are under the Page 212 sub-heading in *Further exercises* below (F5 and F7).