Chemistry

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UNIT 11

Solutions and Solubility

Contents

11.1	Solubility	170
11.2	Dynamic nature of dissolution	176
11.3	Solubility of sparingly soluble ionic compounds	176
11.4	Distribution of a solute between two solvents	182
11.5	Solubility of gases in water	183
11.6	Osmosis	187
11.7	Colloids	190
	Revision questions	192

Objectives

- ▶ Examines solvent miscibility and immiscibility
- ▶ Explains the idea of solubility product
- ▶ Looks at distribution ratios and gas solubility
- ▶ Discusses osmosis and its applications
- ▶ Introduces colloids

11.1 Solubility

A **solution** is a mixture consisting of a **solvent** (the 'dissolver') and the **solute** (the substance that is being dissolved). For example, if we dissolve sugar in water, the water is the solvent, the sugar the solute and the sugary water is the solution. If we keep adding sugar to some water, a point will be reached when the water will not be able to hold any more sugar. The solution is now said to be **saturated**. Adding more sugar simply results in sugar settling on the bottom of the container. Raising the temperature of the solution allows the water to hold more sugar before it becomes saturated. Many solids, like sugar, are more soluble at higher temperatures, although the reverse usually applies to gases, which are less soluble in hot water than in cold water.

Rules of solubility

The word 'polar' was introduced in Unit 5 (see page 71). A polar substance is a substance that contains ions or consists of polar molecules. A polar solvent is a solvent which consists of polar molecules.

We start by reminding ourselves of the following:

1. If a *polar substance* dissolves, it dissolves only in *polar solvents*.

2. If a *non-polar substance* dissolves, it dissolves only in *non-polar solvents*.

These generalizations are summarized in the rule *like dissolves like*. Solvents may be placed in order of polarity by testing their solubility in each other. The order of

Table 11.1 Polarity of common solvents – in order of increasing polarity with heptane the least polar and water the most polar

Solvent	Formula	Density at 25°C/$g\,cm^{-3}$
Heptane	$CH_3(CH_2)_5CH_3$	0.68
Hexane	$CH_3(CH_2)_4CH_3$	0.66
Cyclohexane	C_6H_{12}	0.77
Tetrachloromethane[1]	CCl_4	1.58
Methyl benzene[2]	$C_6H_5CH_3$	0.86
Ethoxyethane[3]	$C_2H_5OC_2H_5$	0.71
Dichloromethane	CH_2Cl_2	1.32
Propan-2-ol	$CH_3CH(OH)CH_3$	0.78
Tetrahydrofuran	C_4H_8O	0.89
Trichloromethane[4]	$CHCl_3$	1.48
Ethanol[5] (absolute)	CH_3CH_2OH	0.79
Ethyl ethanoate[6]	$CH_3COOC_2H_5$	0.90
Propanone[7]	CH_3COCH_3	0.79
Methanol[8]	CH_3OH	0.79
Ethanenitrile[9]	CH_3CN	0.78
Dimethyl sulfoxide	CH_3SOCH_3	1.10
Water	H_2O	1.00

Alternative names: [1]Carbon tetrachloride, [2]Toluene, [3]Diethyl ether, [4]Chloroform, [5]Ethyl alcohol, [6]Ethyl acetate, [7]Acetone, [8]Methyl alcohol, [9]Acetonitrile.

solvents in Table 11.1 was obtained in this way. Of the common solvents, water is the most polar and the hydrocarbons heptane and hexane the least polar.

Miscibility

If, when two solvents are mixed, a single layer (consisting of a solution of the two solvents) is produced, the solvents are said to be **miscible.** If two layers are produced and both layers consist of pure solvent, the liquids are said to be **immiscible** (Fig. 11.1). If two layers are produced, the solvent with the lowest density floats on the top.

The word 'layer' is often replaced by the word **phase.** Thus, a mixture of hexane and water produces two phases.

Table 11.2 shows which pairs of common solvents are miscible, with ● denoting immiscibility. For example, the table shows that water is immiscible with trichloromethane and with ethyl ethanoate.

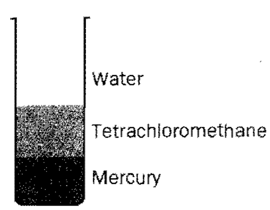

Fig. 11.1 Three immiscible liquids—tetrachloromethane, mercury and water: mercury (density 13.6 $g\,cm^{-3}$ at 25°C) sinks to the bottom; tetrachloromethane (density 1.6 $g\,cm^{-3}$) occupies the middle position; and water (density 1.0 $g\,cm^{-3}$) floats on top.

Partially miscible solvents

Few solvents are truly immiscible, and even though two liquids may not appear to mix, there will still be a tiny amount of each solvent present in the other layer. Table 11.3 shows the solubilities of organic solvents in water, and of water in organic solvents. The units of the solubilities are grams of organic solvent per 100 g of saturated water, and grams of water per 100 g of saturated organic solvent.