A HANDBOOK OF

LABORATORY SOLUTIONS

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Foreword

The purpose of this book is to provide a concise and handy reference guide to the numerous 'recipes' for the making up of chemical solutions used in laboratories. It is intended for the laboratory worker in industry and in research as well as in teaching institutions. It is hoped that it will meet most of the everyday requirements of such workers—in chemistry, physics, biology and in engineering laboratories. The book has been divided into chapters in which preparations of one particular use, or related uses (e.g. histology), are grouped together alphabetically. Where appropriate, the uses of the solution are stated, and cross-reference made. The comprehensive index includes both the names and uses of the solutions covered, and a list of further references is provided.

We should like to acknowledge with thanks the assistance given by Messrs B.D.H. Ltd, George T. Gurr Ltd and May & Baker Ltd, who provided technical literature from which much useful information was drawn.

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Abbreviations

A = analytical reagent purity
alc = alcoholic
B = ordinary purity
aq = in water
conc = concentrated
D = weight of 1 ml of liquid at 20°C
dil = dilute
Eq = equivalent (weight) of the substance
eth = ethanolic
F.W. = formula weight or molecular weight
g = gram or grams
ml = millilitre
M = molar concentration
mg = milligram
N = normal concentration
ppt = precipitate
R.I. = refractive index
sat = saturated
s.g. = specific gravity
soln = solution
vol = volume
ws = water soluble

The following information, where relevant, is given for the solute used in making each solution: name; alternative name; F.W. and Eq; relationship between them e.g. M = N; D (if liquid); instructions for making the solution; other concentrations in use; specific uses.

Authors' Note

The majority of bench solutions are common to chemistry, biology and other laboratories. To avoid unnecessary duplication, the reader is cross-referred from one section to another, for instructions on the making up of such solutions. The uses are given in each section, however, when specific to a particular discipline. The reader should refer to the index in the first place, because this includes uses as well as names of the solutions.

The modern convention of using 'ethanol' in place of 'alcohol' has been followed except where a particular solution is still commonly known by the alcoholic name. Where ethanol is mentioned and no strength specified, 95% upwards is suitable. Industrial methylated spirit 74° o.p. is a satisfactory substitute in UK. Distilled or deionized water is invariably to be used in aqueous solutions unless it is specifically stated to the contrary.

It is necessary to add that where uses of solutions are given, this does not imply that these are the sole uses. Some solutions have so many uses that it would be superfluous to include any.

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W. E. L.

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Solutions—Basic Definitions

Many of the reagents used in science are in the form of solution, usually in water, but also in other solvents or mixtures of solvents. For many purposes, as in ordinary bench reagents, the exact value of concentration is not of critical importance; in other cases, such as the preparation of a standard solution, the concentration must be as accurate as possible. Solutions of known concentration are called standard solutions. Concentration can be expressed in several ways: as the weight of solute in a given volume of solution; as the weight in a given weight of solvent or solution; by stating the weight of solute as a percentage of the weight of solvent or by stating the density of the solution.

MOLAR AND NORMAL SOLUTIONS

The actual weight of the solute is normally expressed as a fraction of *molar* or *normal*. Weights of solute required for molar or normal solutions are calculated from the *molecular formulae*.

The *symbol* of an element is the letter, or letters, which stand for one atom of it.

The *atomic weight* of an element is the weight of its atom on a scale on which the carbon atom of mass number 12 weighs exactly 12·000 units.*

A list of atomic weights is on page 100. They are usually written by using the symbol of the element, e.g. the atomic weight of carbon, representing the average weight of all the atoms present in it, is written C = 12·011 to three places of decimals, or 12·01115 to five places. Similarly for hydrogen, H = 1·00797 and O = 15·9994, or to three places of decimals, H = 1·008 and O = 15·999.

* The carbon scale replaced the oxygen scale in 1961.

The *formula* of a compound or element shows the composition of its *molecule*, or smallest possible particle.

For example, the formula of glucose, $C_6H_{12}O_6$, shows its molecule to contain six carbon atoms, twelve hydrogen atoms and six oxygen atoms. On the atomic weight scale the molecule will weigh $(6 \times 12{\cdot}011)+(12 \times 1{\cdot}008)+(6 \times 15{\cdot}999) = 180{\cdot}156$ atomic weight units, or 180·159 if the atomic weights used are taken to four places of decimals and the total corrected to three places. The number 180·159 is called the molecular weight or formula weight of glucose.

Although it consists of a conglomeration of ions, the conventional formula of sodium chloride is written NaCl. On the atomic weight scale this weighs 22·9898 (Na) + 35·453 (Cl) = 58·443. As, strictly speaking, a molecule of sodium chloride does not exist, 58·443 should always be called the *formula weight*. For the sake of uniformity the term formula weight, defined below, is used throughout for all substances.

Formula weight of a substance is the sum of the atomic weights of the atoms present in its conventional formula.

Formula weights such as 58·443 for sodium chloride are all numbers; 58·443 grams of sodium chloride is called its *gram formula weight* or ONE MOLE.

A *molar solution* is one which contains one mole of the dissolved substance in a litre of solution.

The concentration of any solution can be expressed as a fraction of molar and this fraction is called the molarity of the solution. For example, a solution of glucose containing 18·0159 g per litre is said to be 0·1 M, one-tenth molar, decimolar or $\frac{M}{10}$.

A *normal solution* is one which contains the gram-equivalent of the dissolved substance in a litre of solution.

The *gram-equivalent* is the weight in grams which combines with or displaces 8 (strictly 7·9997) g of oxygen, or the gram-equivalent of any other substance, for example 1·00797 g of hydrogen.

Concentrations are expressed as *molarities*. For those who wish to use normalities (concentrations expressed as fractions of normal) the relationship between the two is shown in the text as M = N etc. For example, sulphuric acid, H_2SO_4, has a formula weight of 98·078. A solution containing 98·078 g per litre is molar. Its equivalent, the number of grams which contain 1·008 g of replaceable or ionizable hydrogen, is 49·039; a solution containing

98·078 g per litre is therefore 2 N. This is shown in the text by M = 2 N.

Except where concentration is quoted as a percentage, the units of concentration used are indicated; a percentage concentration means that this number of grams is present in 100 ml of the solvent. For example, a 5% solution in ethanol means that 5 g of solute are dissolved in 100 ml of ethanol; unless otherwise stated, the ethanol intended is industrial spirit. The water used for making solutions is distilled, or de-ionized, unless otherwise stated.

STANDARD SOLUTIONS

A *standard solution* is one of known concentration, expressed as a fraction of molar or normal.

Substances which are pure enough to be weighed out and dissolved in distilled or de-ionized water to give a solution of accurately known concentration are called *primary standards*. For convenience in weighing they should, for preference, be solids and should have the following characteristics:

they must be obtainable in a very pure state;
readily soluble in the solvent to be used;
stable and unchanged in air at ordinary or moderate temperatures;
of reasonably high formula weight and, preferably, colourless in solution.

A list of primary standards is given on page 12.

Slightly less suitable substances, sometimes called secondary standards, are also listed on page 14.

To make a standard solution a suitable primary standard is chosen and its formula weight is taken from the list. The correct weight required to make a solution of the concentration and volume needed is calculated and this amount is carefully and accurately weighed. For example, the formula weight of sodium chloride is 58·443; a litre of molar solution would need 58·443 g of the pure solid. A litre of 0·1 M solution needs 5·8443 g and if only 250 ml of 0·1 M solution is to be made, the amount weighed would be a quarter of 5·8443, or 1·4611 g. How accurately this is weighed depends on how accurate the concentration of the solution needs to be.

THE PURITY OF CHEMICAL SUBSTANCES

Chemicals are manufactured to three grades of purity. Many are available in a very pure state suitable for use in analysis. A

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