

chemistry: principles and properties

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McGRAW-HILL

BOOK COMPANY

New York

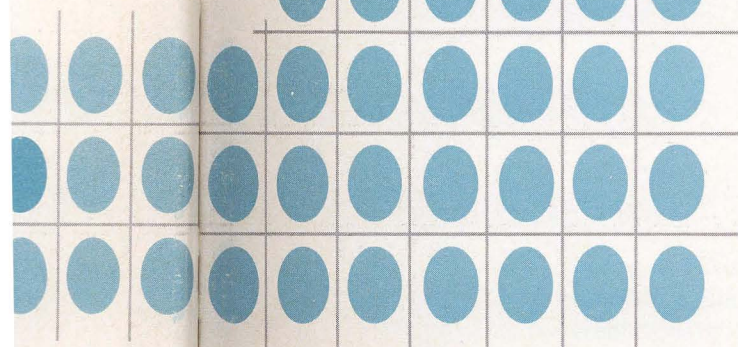
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Library of Congress Catalog Card Number 65-28366
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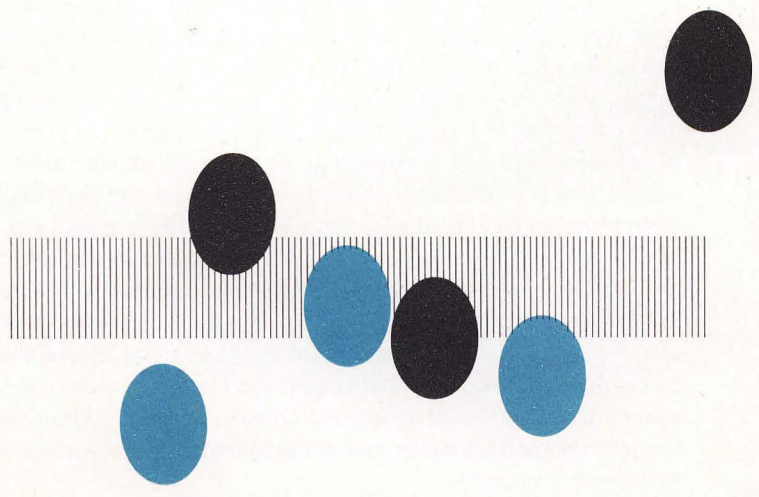
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8 solutions



The preceding discussion of the solid, liquid, and gaseous states was limited to pure substances. In practice, we continually deal with mixtures; hence the question that arises is the effect of mixing in a second component. A mixture is classified as heterogeneous or homogeneous. By its nature, a heterogeneous mixture consists of distinct phases, and the observed properties are largely the sum of those of the individual phases. However, a homogeneous mixture consists of a single phase which has properties that may differ drastically from those of the individual components. These homogeneous mixtures, or solutions, are of widespread importance in chemistry and deserve intensive study.

8.1 TYPES OF SOLUTIONS

Solutions, defined as *homogeneous mixtures of two or more components*, can be gaseous, liquid, or solid. Gaseous solutions are made by dissolving one gas in another. Since all gases mix in all proportions, any mixture of gases is homogeneous and is a solution. The kinetic picture of a gaseous solution is like that of a pure gas, except that the molecules are of different kinds. Ideally, the molecules move independently of each other.

Liquid solutions are made by dissolving a gas, liquid, or solid in a liquid. If the liquid is water, the solution is called an *aqueous* solution. In the kinetic picture of a sugar-water solution, sugar molecules are distributed at random throughout the bulk of the solution. It is evident that on this molecular scale the term "homogeneous" has little significance. However, experiments cannot be performed with less than billions of molecules, so for practical purposes the solution is homogeneous.

Solid solutions are solids in which one component is randomly dispersed on an atomic or molecular scale throughout another component. As in any crystal, the packing of atoms is orderly, even though there is no particular order as to which lattice points are occupied by which kind of atom. Solid solutions are of great practical importance, since they make up a large fraction of the class of substances known as alloys. An *alloy* may be defined as a combination of two or more elements which has metallic properties. Sterling silver, for example, is an alloy consisting of a solid solution of copper in silver. In brass, an alloy of copper and zinc, it is possible to have a solid solution in which some copper atoms of the face-centered-cubic structure of pure copper have been replaced by zinc atoms. Some kinds of steel are alloys of iron and carbon and can be considered as solid solutions in which carbon atoms are located in some of the spaces between iron atoms. The iron atoms are arranged in the regular structure of pure iron. It should be pointed out, however, that not all alloys are solid solutions. Some alloys, such as bismuth-cadmium, are heterogeneous mixtures containing tiny crystals of the constituent elements. Others, such as $MgCu_2$, are intermetallic compounds which contain atoms of different metals combined in definite proportions.

Two terms that are convenient in the discussion of solutions are *solute* and *solvent*. Accepted procedure is to refer to the substance present in larger amount as the solvent and to the substance present in smaller amount as the solute. However, the terms can be interchanged whenever it is convenient. For example, in speaking of solutions of sulfuric acid and water, sulfuric acid is sometimes referred to as the solute and water as the solvent even when the water molecules are in the minority.

8.2 Concentration

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8.2 CONCENTRATION

The properties of solutions, e.g., the color of a dye solution or the sweetness of a sugar solution, depend on the solution concentration. There are several common methods for describing concentration.

8.8 COLLOIDS

In introducing the topic of solutions it was more or less implied that it is easily possible to distinguish between a homogeneous mixture and a heterogeneous mixture. However, this distinction is not a sharp one. There are systems which are neither obviously homogeneous nor obviously heterogeneous. They are classed as intermediate and are known as *colloids*. In order to get an idea of what a colloid is, we imagine a process in which a sample of solid is placed in a liquid and subdivided. So long as distinct particles of solid are visible to the naked eye, there is no question that the system is heterogeneous. On standing, these visible particles separate out. Depending on the relative density of the solid and the liquid, the solid particles float to the top or settle to the bottom. They can be separated easily by filtration. As the solid is progressively subdivided, a state in which the dispersed particles have been broken down to individual molecules or atoms is eventually reached. In this limit, a solution in which two phases can no longer be distinguished is produced. No matter how powerful a microscope is used, a solution appears uniform throughout, and individual molecules cannot be seen. On standing, the dispersed particles do not separate out, nor can they be separated by filtration.

Between coarse suspensions and true solutions there is a region of change from heterogeneity to homogeneity. In this region dispersed particles are so small that they do not form an obviously separate phase, but they are not so small that they can be said to be in true solution. This state of subdivision is called the *colloidal state*. On standing, the particles of a colloid do not separate out at any appreciable rate; they cannot be seen under a microscope; nor can they be separated by filtration. The dividing lines between colloids and solutions and between colloids and discrete phases are not rigorously fixed, since a continuous gradation of particle size is possible. Usually, however, colloids are defined as a separate class on the basis of size. When the particle size lies between about 10^{-7} and 10^{-4} cm, the dispersion is called a *colloid*, a *colloidal suspension*, or a *colloidal solution*.

The size of a dispersed particle does not tell anything about the constitution of the particle. The particle may consist of atoms, of small molecules, or of one giant molecule sometimes called a macromolecule. For example, colloidal gold consists of various-sized particles each containing a million or more gold atoms. Colloidal sulfur can be made with particles containing a thousand or so S_8 molecules. An example of a macromolecule is hemoglobin, the protein responsible for the red color of blood. The molecular mass of this molecule is 66800, and the diameter is approximately 3×10^{-7} cm.

Colloids are frequently classified on the basis of the states of aggregation of the component phases, even though the separate phases are not visibly distinguishable once the colloid is formed. The more important classifications are *sols*, *emulsions*, *gels*, and *aerosols*. In *sols* a solid is dispersed through a liquid, so that the liquid forms the continuous phase and bits of solid form the discontinuous phase. Milk of

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