

# Metallurgical Comment

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Correspondence and Discussion Invited

## FURTHER NOTES ON THE NATURE OF SOLID SOLUTIONS.\*

By C. A. Edwards, M.Sc.

In a paper read at the annual general meeting in January, 1911, the author briefly discussed the nature of a constituent which so frequently occurs in metallic alloys, and which is usually described as a solid solution. This gave rise to a most interesting discussion; and though some few points were alluded to which supported the conclusions embodied in the paper, for the most part these conclusions were received with little favor. The objections to the author's views were numerous, and, if valid, indeed very serious. Owing to the magnitude of the criticism, the author considered it advisable to make his reply in the form of a short paper, because it would be easier to handle, and also because it would afford another opportunity for further criticism. Before again opening this interesting question, the author would like to make it perfectly clear that it is not one of nomenclature, for it is of little consequence whether we use the term "solid solution" or "mixed crystal"; but whichever term is used, it is most important for metallurgists to acquire a true and clear conception of the nature of that constituent, and thus remove the ambiguity which is now undoubtedly associated with the use of those terms. Solid solutions are probably of more frequent occurrence in industrial alloys than in any other constituent, and if their internal architecture could be conceived, it would be a step of some scientific value which may lead to an explanation of phenomena that have been hitherto inexplicable. In his previous paper the author's main conclusion was that "a solid solution of two metals or intermetallic compounds is an intimate crystalline mixture, and whilst the crystals are so small that the mass appears quite homogeneous, they are nevertheless sufficiently large to retain their identity." The most serious objection to this view was that it was opposed to the phase rule, and it is to this objection that the present paper is chiefly directed. Therefore, in order to decide if this definition is correct, or even theoretically possible, depends upon the answer supplied to the following questions:—

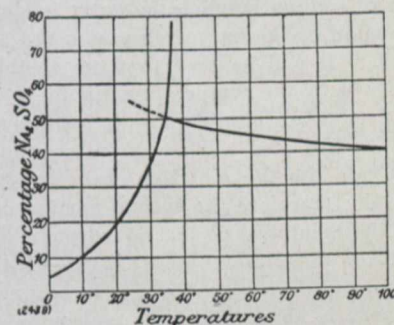
1. Are there any physico-chemical laws opposed to such a conception?
2. Is this definition in accordance with what is known of other types of solution?

Since solid solutions are regarded as being analogous to ordinary aqueous solutions, it is necessary to define the condition in which a salt exists when in solution before the state of a metal in solid solution is definable. It will be advisable, therefore, carefully to consider each kind of solution, after which it may be possible to fix the precise physical meaning of the term "solution." That there is, indeed, some uncertainty as to the meaning of this term will be evident on reading a quotation from Findlay's book on the phase rule. He says:—"With the conception of gaseous and liquid solutions everyone is familiar. Gases can dissolve in, or be absorbed by, liquids; and solids also, when brought into contact with

liquids, 'pass into solution,' and yield a homogeneous liquid phase. On the other hand, the conception of a solid solution is one which, in many cases, is found more difficult to appreciate; and the existence and behavior of solid solutions, in spite of their not uncommon occurrence and importance, are in general comparatively little known. The reason of this is to be found, to some extent, no doubt, in the fact that the term 'solid solution' was introduced at a comparatively recent date, but it is probably due in some measure to a somewhat hazy comprehension of the definition of the term 'solution' itself."

A solution is usually defined as a homogeneous phase the composition and properties of which may be varied within certain limits. This is, however, only a general definition, which does not signify the condition of a substance when in solution.

**Gaseous Solutions.**—The first, and perhaps most perfect, class of solution is that of gases in gases. In gaseous solutions the molecules of each gas move freely round each other without producing any change in their respective properties. If we take, for example, a solution of nitrogen and oxygen, we know that the individual properties of these two gases are absolutely the same when in solution as when separated. Moreover, gaseous solutions are capable of being separated into their constituents by diffusion. Hence we are quite justified in concluding that gaseous solutions are finely-divided mixtures.



**Solutions of Gases in Liquids.**—With regard to solutions coming under this class, it is well known that all gases are more or less soluble in liquids. The amount of gas actually taken up by any liquid upon which that gas has no chemical action depends upon:—First, the nature of the gas; second, the temperature of the liquid; and, third, the pressure of the gas.

1. At 0 deg. Cent. water dissolves 2.1 volumes of hydrogen and 1.9 volumes of oxygen, proving that the amount of gas dissolved is different for different gases.
2. On raising the temperature it is found that the volume of gas dissolved by the liquid decreases.
3. From Henry's law, we know that the volume of gas which can be absorbed by a liquid varies directly with the pressure, but since the volume of a gas is inversely proportional to the pressure, it follows that at equal temperatures the volume of a gas dissolved by a liquid is the same at all pressures.

Dalton considered that the particles of a gas dissolved in a liquid were held between the molecules of the liquid. While this explanation does not account for the fact that a liquid dissolves dissimilar gases to different degrees, nor the fact that the solubility decreases as the temperature increases, yet it requires less assumption than any other explanation so far advanced, and for this reason, and also because it falls into line with the other types of solution, the author is inclined to believe in Dalton's opinion.

**Solutions of Solids in Liquids.**—In his previous paper, in discussing the action of the separation of water from an

\*Paper read before the Institute of Metals at Newcastle.