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Figure 2. Solubility of various elements in aluminum at the temperature of the eutectic or peritectic by periods of the system of elements.

Figure 1: Figure 2. Solubility of various elements in aluminum at the temperature of the eutectic or peritectic by periods of the system of elements.

Abstract

Full Text

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CHEMISTRY OF SOLID SOLUTIONS BASED ON ALUMINUM

(Presented by Academician A. N. Frumkin, June 3, 1965)

To date, 50 binary phase diagrams of aluminum with other elements have been studied. They contain complete information on 36 solid solutions based on aluminum and partial information on another 20 solutions, obtained with varying degrees of reliability. It is of interest to consider these data from a unified point of view.

The proposed generalization is constructed on the basis of modern reference literature ([1]-[3]).

Figure 1 presents parts of binary phase diagrams of aluminum with other elements, relating to primary solid solutions, their eutectics and peritectics, plotted on the periodic table of the elements of D. I. Mendeleev.

Fig. 2. Solubility of various elements in aluminum at the eutectic or peritectic temperature by periods of the system of elements.
a –periods 1 and 2, *b* –3rd period, *v* –4th period, *g* –5th period, *d* –6th period.

of the elements of D. I. Mendeleev. Solid lines indicate the liquidus and solidus lines, as well as the solubility limits in the solid state, constructed from experimental data; dashed lines indicate the lines of transformation boundaries constructed on the basis of predictions made according to the method described below. Numbers not enclosed in parentheses correspond to experimental data; numbers placed in parentheses were obtained on the basis of predictions.

The crystallization regions of solid solutions that have a complete set of characteristics obtained experimentally are hatched.

Figures 2 and 3 present the solubility limits of various elements in aluminum at the temperatures of eutectics or peritectics and the concentrations of the first eutectic and peritectic points of these solid solu-

···by periods of D. I. Mendeleev' s system of the elements. The points and

Figure 3

Figure 2: Figure 3

the solid lines connecting them correspond to experimental data; the expected values are plotted with a dotted line. All concentrations in Figs. 1, 2, and 3 are given in atomic percent. In Figs. 2 and 3 the concentrations are presented on a logarithmic scale in order to make it possible to compare values of different orders of magnitude.

Extrapolation of the available data to the inert gases gives, for their solubility, values on the order of 10^{-7}%, and for the concentrations of monotectic

Fig. 3. Concentration of eutectic and peritectic points of primary solid solutions of various elements in aluminum, by periods of the system of elements. Designations as in Fig. 2

points—10^{-4}%. It follows from Figs. 2 and 3 that the dependences of solubilities and of the concentrations of eutectics and peritectics on atomic number for the corresponding periods agree satisfactorily with one another.

Figure 4 shows the relationship between the concentration of eutectics and peritectics and the difference between the melting temperature of aluminum and the temperatures of these eutectics or peritectics for various aluminum alloys. In the right-hand part of the diagram are the eutectics, and in the left-hand part the peritectics, for which the temperature of the eutectic transformation lies above the melting temperature of aluminum and the corresponding temperature difference has a negative value.

It follows from Fig. 4 that there is a linear dependence between the indicated quantities, covering three orders of magnitude.

The greater the concentration of the eutectic or peritectic, the lower its crystallization temperature. This diagram makes it possible to determine approximately the crystallization temperatures of eutectics or peritectics if their concentrations are known. It is especially interesting to determine by this method the solubility of elements that dissolve only slightly in aluminum. For example, the solubility of hydrogen, oxygen, and nitrogen in liquid aluminum at the crystallization temperature is 0.001–0.01%; in accordance with Fig. 4, the temperatures of their monotectics should lie 0.01–0.1° below the melting point of aluminum. For inert gases this temperature difference should be about 0.001°. Naturally, with the existing technique of pyrometry we do not yet have the possibility of measuring such quantities.

Fig. 1. Binary phase diagrams of aluminum in the periodic table of the elements. Solid lines correspond to experimental determinations; dashed lines and numbers in parentheses are the results of predictions.

On the basis of the diagrams in Figs. 2, 3, and 4, predictions can be made

Fig. 4. Ratio of the concentrations of the first eutectics and peritectics of aluminum-based solid solutions to the differences between the melting temperature of aluminum and the corresponding temperatures of eutectic and peritectic crystallization

Figure 3: Fig. 4. Ratio of the concentrations of the first eutectics and peritectics of aluminum-based solid solutions to the differences between the melting temperature of aluminum and the corresponding temperatures of eutectic and peritectic crystallization

concerning the parameters of aluminum-based solid solutions for systems which, for various reasons, have not yet been investigated. Such predictions make it possible to cover the entire system of binary aluminum alloys as a whole and facilitate the planning of further experimental studies. The results of such predictions, as already indicated, are plotted in Fig. 1.

As can be seen from the summary diagram in Fig. 1, aluminum does not form continuous solid solutions with any element; for 11 systems formed

Fig. 4. Ratio of the concentrations of the first eutectics and peritectics of aluminum-based solid solutions to the differences between the melting temperature of aluminum and the corresponding temperatures of eutectic and peritectic crystallization

by aluminum with refractory metals, it gives peritectics; with the remaining 91 elements it gives eutectics or monotectics. Aluminum forms extensive regions of solid solutions (not less than 1%) with the elements surrounding it in the periodic system—lithium, magnesium, silicon, germanium, gallium, zinc, copper, silver, and mercury.

The farther an element is removed from aluminum in the periodic system, the less soluble it is in aluminum. The inert gases have the lowest solubility; they are followed, on the one hand, by the halogens and, on the other, by the alkali elements. Despite numerous attempts, it has so far not been possible to establish an unambiguous dependence between the solubility of various elements in a given element on the basis of any single parameter of the atoms of the dissolved element (the difference between the atomic radii of the dissolved and base elements, the difference between their melting temperatures, similarity of lattice type and parameters, electron concentrations, electronegativities, etc.). The listed characteristics of elements, as well as many others, are determined by their position in the periodic system; consequently, it is much more convenient and correct to relate solubility directly to the position of the element in the system of D. I. Mendeleev.

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REFERENCES

1. M. Hansen, K. Anderko, *Structures of Binary Alloys*, 1962.

2. A. E. Vol, *Structure and Properties of Binary Metallic Systems*, 1959.

3. *Phase Diagrams of Metallic Systems*. Edited by N. V. Ageev. All-Union Institute of Scientific and Technical Information, 1959–1963 (1–7).

Note: Figure translations are in progress. See original paper for figures.