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Abstract

Full Text

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ON THE FORM OF EXISTENCE OF SILICON IN LIQUID IRON

The question of the form of existence of elements dissolved in liquid metals, despite its great importance for the theory of the liquid state and for the practice of metallurgical production, is among the least studied. This is explained by the difficulties of experiment at high temperatures, and chiefly by the fact that most investigators who have tried to solve this question have approached it from the standpoint of formal thermodynamics. An example is the work of Darken (⁀1), who came to the conclusion that silicon is present in the melt in the form of Fe_3Si molecules, partially dissociated into atoms. However, the calculated value of the heat of dissolution of silicon in iron (⁀1) is in contradiction with direct thermochemical measurements.

Data on the structure of liquid metals and their alloys may be obtained by means of X-ray analysis (⁀2), or indirectly from data on the solubility of gases and individual elements in the liquid metal (⁀3). X-ray analysis of liquids at high temperatures and over a wide temperature range is associated with great experimental difficulties and is not free from systematic errors that make it difficult to interpret the results obtained; as a result, conclusions about the features of one or another structure of liquid metallic melts are not unambiguous (⁀4). A simpler and no less reliable approach is to study the structure of metallic melts by measuring their structure-sensitive properties–electrical conductivity, viscosity, and magnetic susceptibility. These properties can be measured by contactless methods, which is of decisive importance in high-temperature investigations.

Fig. 1. Change in the magnetic susceptibility of liquid alloys of the Fe–Si system as a function of composition at a temperature of 1600°.

In order to establish the forms in which silicon is present in liquid iron, the magnetic susceptibility of liquid alloys of the Fe–Si system was measured (from 0 to 60 wt.% Si).

The measurements were carried out by the Faraday method in a special apparatus (~5). The results of the measurements at a temperature of 1600° are presented in relative units in Fig. 1. It follows from them that the magnetic susceptibility χ is the lower, the higher the degree of order in the solution. Indeed, a minimum of χ is observed for melts containing 34% silicon and corresponding to the stable chemical compound FeSi. This iron silicide is also stable in the steelmaking temperature range (1500-1700°).

The presence of FeSi is also confirmed as a result of determining other characteristics of iron-silicon melts. The value of the e.m.f. in the Fe—Si—C system changes sharply at 32.5% silicon[6]. In determining the surface tension in the Fe—Si system[7] and the interfacial tension at the FeSi—slag boundary[8], an extremal point was found corresponding to an alloy containing 34% silicon. The compound FeSi is evidently so stable that its presence was detected even by comparatively crude measurements, as a result of which the presence of other structural formations in Fe—Si melts has not been established.

It was noted[9, 10] that the Kurnakov point, which characterizes the order—disorder transformation, lies in alloys of the Fe—Si system and in an alloy of iron, aluminum, and silicon close to the melting temperature, and possibly above it. Indeed, a definite and apparently rather high degree of order is retained even when alloys containing 12-16% silicon are superheated by 150° above the liquidus line.

It is of interest to compare the results of magnetic analysis, which reflect structural changes in the liquid as a function of composition, with the chemical properties of the melts. According to available data[3], all isotherms up to 1650° for the solubility of hydrogen at atmospheric pressure have a clearly expressed minimum at 34 wt.% silicon, which corresponds to the minimum of magnetic susceptibility. It was shown[11] that the curve for the solubility of nitrogen at 1600° in iron-silicon melts as a function of their composition passes through a minimum at a silicon content of 13-15%, which also corresponds to the minimum of magnetic susceptibility. Subsequently, with an increase in the silicon content to 20%, the solubility of nitrogen increases, as does the magnetic susceptibility.

Conclusions. 1. The magnetic susceptibility of melts of the Fe—Si system has minimum values for compositions corresponding to the chemical compounds: Fe_3Si; Fe_3Si_2; FeSi and $FeSi_2$, which is direct evidence of the presence of structural formations similar to silicides in the melts.

2. Magnetic susceptibility in melts decreases with an increase in the degree of order. It is minimal for chemical compounds and maximal for solutions with complete atomic mixing.

3. Structural changes in melts are connected with their chemical properties, in particular with the solubility of gases.

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