THE EFFECT OF PRESSURE ON THE SOLUBILITY OF MOLECULAR HYDROGEN IN NIOBIUM AND TANTALUM*

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Abstract

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THE EFFECT OF PRESSURE ON THE SOLUBILITY OF MOLECULAR HYDROGEN IN NIOBIUM AND TANTALUM*

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In the article (^{1}), devoted to the effect of pressure on the solubility of molecular hydrogen in the β-phase of the palladium—hydrogen system, the existence of a linear relation between the amount of dissolved hydrogen and the logarithm of the pressure was shown up to a concentration of 0.92 g-atom H per 1 g-atom Pd. At the same time, the supposition was advanced that, in all probability, a logarithmic regularity also exists in the case of other solutions of gases in metals in the regions of high lattice filling.

To verify this supposition, a study was undertaken of the systems Ta—H and Nb—H, in which, as is known, the hydrogen concentration reaches values close to atomic ratios of 1 : 1. For a number of reasons, the present investigation was limited to measuring the solubility of hydrogen only at high temperatures, 620—680°, at which the equilibrium saturation values are rapidly established and a hysteresis loop is completely absent in measurements with increasing and decreasing pressure.

Chemically pure powdered metallic niobium and tantalum in the form of foil 0.1 mm thick were used for the investigations. Both metals were subjected to preliminary treatment (activation) with hydrogen at a temperature of 700° by successive repeated increases of the pressure to 500—600 atm and subsequent reduction of it to 1 atm. This procedure was repeated until the amount of hydrogen released upon lowering the pressure reached a constant value.

The determination of the solubility of hydrogen was carried out by the method used for studying the Pd—H system. The bombs used in the investigation were made of a special chromium-nickel-molybdenum-siliceous valve steel, retaining sufficiently high mechanical properties at a temperature of 700—800°. In the experiments, 3 bombs were used, each with a volume of 15 cm^3. Into one of them were placed 56.790 g of niobium, into another 74.119 g of tantalum, and into the third a copper calibration specimen, with a volume equal to the volume of the niobium or tantalum specimens. As in the case of the Pd—H system, each experimental point was determined 3—4 times from two sides: with increasing and decreasing pressure. The experimental data obtained are given in Table 1 and in Fig. 1.

It is seen from Fig. 1 that, in both systems studied, as the pressure is raised above atmospheric, there is at first a relatively sharp increase in solubility, corresponding, possibly, to the formation of new phases richer in hydrogen, and then a slow increase according to a logarithmic regularity.

For the Nb—H system, the logarithmic dependence is observed in the filling range from 0.53 to 0.73 g-atom H per 1 g-atom Nb. In the Ta—H system, the limits of applicability of the logarithmic law cover a broader interval—from 0.2 to 0.72 g-atom H per 1 g-atom Ta. The absolute values of solubility at atmospheric pressure, in the case of the Ta—H system, correspond to the known data of Sieverts and Brüning (²). The values of hydrogen solubility in niobium obtained by us under the same conditions correspond to the old observations of Cruss and Nilson (³) and Bolton (⁴), and exceed by approximately a factor of 2 the data of the later measurements of Hagen and Sieverts (⁵), which is probably connected with differences in the prior history of the objects studied.

Table 1

Dependence of the solubility of hydrogen in powdered metallic niobium and in tantalum foil (0.1 mm thick) on pressure

P, atm	Solubility, g-at H per 1 g-at Nb at 673°	Solubility, g-at H per 1 g-at Ta at 622°	Solubility, g-at H per 1 g-at Ta at 679°	*P*, atm	Solubility, g-at H per 1 g-at Nb at 673°	Solubility, g-at H per 1 g-at Ta at 622°	Solubility, g-at H per 1 g-at Ta at 679°
1	0,126	0,0759	0,0605	100	0,643	0,5118	0,4673
2,5	—	0,15	—	200	—	—	0,5262
3	—	—	0,1540	300	0,690	—	0,5622
5	0,534	—	0,1955	400	—	0,6350	0,5860
10	0,558	—	0,2508	500	0,715	—	0,5870
11,5	—	0,3324	—	550	—	—	0,6056
20	0,593	—	—	600	—	0,6714	—
25	—	0,3950	0,3360	610	0,721	—	—
30	0,595	—	—	750	—	—	0,6110
50	0,620	—	0,3812	800	0,728	—	—
80	—	0,4902	—	1000	0,732	0,7186	—

Fig. 1. Dependence of the logarithm of pressure on the atomic content of hydrogen in niobium (*a*) and tantalum (*b, c*)

For technical reasons we were unable to extend the limits of the investigation to the region of higher pressures and lower temperatures. However, judging

* The experimental part of the work was carried out jointly with A. A. Orlova.

Fig. 1. Dependence of the logarithm of pressure on the atomic content of hydrogen in niobium (a) and tantalum (b, c)

Figure 1: Fig. 1. Dependence of the logarithm of pressure on the atomic content of hydrogen in niobium (a) and tantalum (b, c)

from the Pd—H system, for which the logarithmic regularity has been traced up to fillings of 0.92 g-at H/g-at Pd, there is every reason to expect that further saturation of the Nb and Ta lattices will also proceed according to a logarithmic law.

The experimental data obtained, as it seems to us, are convincing confirmation of the supposition stated at the beginning of the article that the logarithmic regularity is applicable over a wide range of pressures and is characteristic of metal—gas systems in regions of large lattice fillings.

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