ON YTTRIUM HYDRIDE

1962

SovietRxiv

Abstract

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CHEMISTRY

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(Presented by Academician I. I. Chernyaev, 12 X 1961)

The information available in the literature on the hydrogen compounds of yttrium is limited to two brief communications by Winkler ([1]) and Dialer ([2]). In both works, yttrium hydrides were obtained by reducing yttrium oxide with magnesium ([1]) or potassium ([2]) in the presence of hydrogen. The formulas Y_2H_3 ([1]) and $YH_{2.7}$ ([2]) were assigned to the reaction products with respect to the ratio Y : H.

In the present work, samples of yttrium prepared at Giredmet were used as the starting metal; according to spectral-analysis data, they contained the following impurities (in %):

Sample	Fe	Ca	Cu	Other rare-earth elements
I	0.04	0.05	0.03	~ 1
II	0.04	0.004	0.02	~ 8

The hydrides were obtained by direct interaction of the metal with hydrogen ([3], [4]). The hydrogen content was determined by a volumetric method ([4]). In carrying out the calculations, a correction was introduced for the accompanying

Table 1

Results of the hydriding of yttrium

Sample	Experiment No.	Charge, g	Pretreatment: temp., °C	Pretreatment: duration, min.	Induction period	Hydriding conditions: temp., °C	Hydriding conditions: pressure, initial, mm	Hydriding conditions: pressure, final, mm	Hydriding conditions: time	Hydride composition, at. H/at. Y
I	1	0.7385	–	–	60 min.	250	660	605	2 hours	1.60

Sample	Experiment No.	Charge, g	Pretreatment: temp., °C	Pretreatment: duration, min.	Induction period	Hydriding conditions: temp., °C	Hydriding conditions: pressure, initial, mm	Hydriding conditions: pressure, final, mm	Hydriding conditions: time	Hydride composition, at. H/at. Y
I	2	0.8456	—	—	90 min.	250	670	609	2 hours	1.55
I	3	0.9179	400	30	30 min.	20	656	597	—	1.57
I	4	0.6972	400	30	60 min.	20	662	610	—	1.62
I	5	0.7303	400	30	2 days	20	does not hydrate			
I	5	0.7303	400	30	5 min.	250	672	626	3 hours	1.58
I	6	1.8727	—	—	1 day	20	does not hydrate			
I	6	1.8727	400	30	20 min.	20	662	498	4 hours	1.59
II	7	0.5304	—	—	—	20	614	558	3 days	1.63
II	8	1.0493	—	—	8 hours	20	649	557	3 days	1.61
II	9	0.4693	—	—	1 day	20	does not hydrate			
II	9	0.4693	600	15	5 hours	20	617	599	4 days	
II	9	0.4693	700	5	2 min.	20	620	599	6 hours	1.60
II	10	0.7391	—	—	5 days	20	does not hydrate			
II	10	0.7391	400	30	—	20				1.54

Sample	Experiment No.	Charge, g	Pretreatment: temp., °C	Pretreatment: duration, min.	Induction period	Hydriding conditions: temp., °C	Hydriding conditions: pressure, initial, mm	Hydriding conditions: pressure, final, mm	Hydriding conditions: time	Hydride composition, at. H/at. Y
II	11	0.7739	400	30	1 min., strong heating	20	613	605	1 min.	0.78
II	12	0.8256	400	30	40 min.	20	664	596	4 days	1.85
II	13	2.7491	400	30	60 min.	20	668	574	3 days	1.69
II	14	0.6833	–	–	1 day	20	does not hydrate			
II	14	0.6833	–	–	repeated flushing of the system with hydrogen +1 day	20	645	601	3 days	1.51
II	15	0.8828	–	–	4 days	20	does not hydrate			
II	15	0.8828	–	–	5 min.	250	664	616	2 hours	1.28

impurities of other rare-earth metals, amounted, for sample I, to 0.02 and, for sample II, to 0.15 gram-atoms of hydrogen per 1 gram-atom of the starting

Fig. 1. Thermogram of decomposition of yttrium hydride $YH_{1·6}$. 1 —heating curve; 2 —differential heating curve; 3 —gas-evolution curve

Figure 1: Fig. 1. Thermogram of decomposition of yttrium hydride $YH_{1·6}$. 1 —heating curve; 2 —differential heating curve; 3 —gas-evolution curve

metal. A series of experiments carried out (Table 1) showed that pure yttrium (sample I) does not absorb hydrogen at room temperature. The less pure metal II is capable of reacting with hydrogen even at low temperatures, but in this case the results are insufficiently stable and the induction period in a number of experiments is so long that the reaction practically does not proceed. To reduce the induction period we applied heat treatment to the starting metal. The optimum conditions for hydriding are achieved by heating the metal in vacuum at 400° for 30 min. The induction period is then reduced to 40–60 min. In experiment 11, under the same conditions, such an active metal was obtained that the hydriding reaction, instead of 3–4 days, proceeded in only 1 min and was accompanied by heating of the sample to a red heat. However, as a result of such a high temperature, the hydrogen content in the hydride obtained proved to be very small (0.78 at. H/at. Y).

Fig. 1. Thermogram of decomposition of yttrium hydride $YH_{1.6}$. 1 —heating curve; 2 —differential heating curve; 3 —gas-evolution curve.

In all other cases yttrium absorbed hydrogen to a composition of approximately $YH_{1.6}$. The use of the purer metal gives well reproducible results, and the ratio at. H : at. Y is 1.59 ± 0.02, while the adsorption is not affected even by raising the reaction temperature to 250° (experiments 1, 2, 5). The presence of impurities of other rare-earth elements (sample II) leads to a significantly greater scatter of the data, and the composition of the hydride in this case varies within the limits 1.51—1.84 at. H/at. Y. However, in this case also the average composition of the hydride obtained corresponds to the formula $YH_{1.6}$. Raising the temperature leads to a substantial decrease in adsorption (experiment 15).

Yttrium hydride is a bluish-gray brittle substance of layered structure, readily ground into a powder, with a density of 4.24 ± 0.15, as compared with 4.91 ± 0.07 for the starting yttrium.

In its chemical properties yttrium hydride is a relatively stable substance. In air it does not change its composition over the course of 1 hour. It reacts with water very slowly.

According to thermographic analysis (Fig. 1), the decomposition of yttrium hydride proceeds in two stages. The first, at 360–410°, corresponds to the evolution of hydrogen in excess relative to the composition YH. The second, at 1100–1300°, characterizes the transition of the monohydride to metallic yttrium. This character of decomposition differs substantially from the decomposition of the hydrides of all other rare-earth elements studied up to the present time. The dihydrides of Ce, La, Nd, for example, decompose in one stage and at tempera-

around 1000° (4,5). The fundamental difference between the yttrium hydride obtained and hydrides of other rare-earth elements of the same composition also follows from X-ray data. Whereas the hydrides of cerium, lanthanum, neodymium, etc., in the Me–MeH_2 region are mixtures of the metal and the dihydride (6,7), the lines characteristic of metallic yttrium were not found in the Debye pattern of a sample of composition $YH_{1.6}$.

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Received
12 X 1961

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