PHYSICAL CHEMISTRY

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1961

SovietRxiv

Abstract

Full Text

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THE INFLUENCE OF THE ENERGY OF RADIOACTIVE RADIATION ON THE RATE OF EVAPORATION OF A SOLID

Previously, using molybdenum anhydride as an example, it was shown that the rate of evaporation of this substance depends on the level of its radioactivity ([1]). In the present work, the question of the influence on the evaporation rate of MoO_3 of additives of radioactive isotopes of various elements, as well as of the magnitude of their radiation energy, was studied. The following β-emitters were used: Y^{90} (E_{max} = 2.18 MeV), Mo^{99} (E_{max} = 1.23 MeV), and W^{185} (E_{max} = 0.43 MeV). To prepare molybdenum anhydride specimens with an addition of Y^{90}, MoO_3 powder was moistened with a definite amount of a solution of radioactive yttrium nitrate, dried, calcined to constant weight, and sieved; fractions with particle size 0.5–0.25 mm were selected. The specific radioactivities of the resulting specimens were referred to MoO_3, since the yttrium content in the mixture could be neglected. Control specimens of MoO_3 with additions of nonradioactive yttrium were prepared under analogous conditions.

Specimens of MoO_3 with the radioactive isotope W^{185} introduced into them were obtained by adding to a solution of ammonium molybdate a definite amount of radioactive ammonium tungstate. The solution was evaporated, the dry residue was moistened with several drops of HNO_3 to prevent the reduction of hexavalent Mo and W, and calcined. Fractions with particle size 0.5–0.25 mm were used for the work.

The procedure for preparing MoO_3 containing various amounts of Mo^{99} was described in ([1]).

The apparatus for studying the evaporation rate (Fig. 1) consisted of a vertically arranged quartz tube *(1)* placed in an electric furnace *(2)*. The upper end of the tube, located above the furnace, had a larger diameter. A quartz sleeve *(3)* with a ground joint *(4)* was sealed into it; into this sleeve was inserted a stopper *(5)* with a suspended quartz spring *(6)*. From the latter, on a quartz thread, a quartz cup *(7)* was suspended. On the side, to the upper part of the tube *(1)*, a tube *(8)* was sealed for introducing air or another gas. At the bottom, the working tube ended in a vapor trap *(9)* cooled with liquid nitrogen. Measurements of the elongation of the balance spring were made with a cathetometer equipped with a screw ocular micrometer, which made it possible to continuously observe the pointer *(10)*. The sensitivity of the quartz balance described was $7 \cdot 10^{-5}$ g

Fig. 1. Apparatus for studying the evaporation rate of MoO3

Figure 1: Fig. 1. Apparatus for studying the evaporation rate of MoO3

Fig. 2 and Fig. 3 graphs

Figure 2: Fig. 2 and Fig. 3 graphs

per one division of the ocular micrometer.

The experimental procedure was as follows. A weighed portion of the specimen under study (about 200 mg) was suspended in a quartz cup on the spring balance and placed in the working tube. At a temperature of $700 \pm 1^{\circ}$, a stream of dry air or nitrogen was passed through at a rate of 10 ml/min. Changes in weight were recorded every hour. From the data obtained, curves of the evaporation rate were plotted. In all cases, each value was obtained from several parallel experiments.

The results of measurements of the evaporation rate of MoO_3 in the presence of Y^{90} are presented in Fig. 2. For specimens with an addition of nonradioactive yttrium and with an initial specific radioactivity of 1.0 and 2.0 mCi/g, the evaporation rate of MoO_3 is practically constant. Beginning with a specific radioactivity of 3 mCi/g and higher, the evaporation rate of MoO_3 differs substantially from that of nonradioactive specimens and also from one specimen to another. With time, the evaporation rate of each specimen gradually increases, since, as MoO_3 evaporates, the specific radioactivity of the remaining preparation increases.

In Fig. 3 are presented data on the evaporation rate of MoO_3 specimens containing additions of W^{185}. It may be noted that in this case radioactive radiation also affects the evaporation rate of MoO_3. In preparations with a specific radioactivity of 5 mCi/g and higher, the evaporation rate differs noticeably from the evaporation rate of MoO_3 with nonradioactive tungsten additions and also from one preparation to another.

In the study of the evaporation rate of MoO_3 with additions of Y^{90} and W^{185}, no radioactive products were found in the sublimate.

Fig. 1. Apparatus for studying the evaporation rate of MoO_3

It is important to note that the dependence of the evaporation rate of MoO_3 on the magnitude of its specific radioactivity, found in this work using an apparatus with spring quartz balances and with a gas stream passed over a cup containing the substance (Fig. 4), does not differ from the previously published dependence ([1]), the data for which were obtained on an apparatus in which the gas was passed through a layer of MoO_3.

Fig. 2. Evaporation rate of MoO_3 preparations of different specific radioactivity, labeled with the isotope Y^{90}.

Fig. 4. Dependence of the evaporation rate of MoO3 with additions of various beta emitters on the specific radioactivity of the preparations: 1 –MoO3 with addition of W185, 2 –MoO3 with addition of Mo99, 3 –MoO3 with addition of Y90.

Figure 3: Fig. 4. Dependence of the evaporation rate of MoO3 with additions of various beta emitters on the specific radioactivity of the preparations: 1 – MoO3 with addition of W185, 2 –MoO3 with addition of Mo99, 3 –MoO3 with addition of Y90.

1 –MoO_3 with an addition of nonradioactive Y_2O_3; 2 –4 mCi/g; 3 –6 mCi/g; 4 –8 mCi/g; 5 –10 mCi/g; 6 –20 mCi/g.

Fig. 3. Evaporation rate of MoO_3 preparations of different specific radioactivity, labeled with the isotope W^{185}.
1 –MoO_3 with an addition of nonradioactive WO_3; 2 –7 mCi/g; 3 –10 mCi/g; 4 –12 mCi/g; 5 –15 mCi/g.

In Fig. 4 is presented the dependence of the evaporation rate of MoO_3 on the specific radioactivity of the preparations and on the nature of the radioactive additions. It may be concluded that radiation of different energy affects the evaporation rate in different ways. Of interest is the fact that the initial branches of all three curves coincide. This means that small amounts of radioactive isotopes introduced into MoO_3 do not exert any substantial influence on the evaporation rate of the latter. In the presence of W^{185}–the isotope with the lowest radiation energy in our experiments–the changes in the evaporation rate

noticeable at a specific radioactivity level of 5 mCi/g. After this, a slight decrease in the evaporation rate of molybdenum anhydride is observed, up to a radioactivity value of 7-8 mCi/g. A further increase in specific radioactivity gradually increases the evaporation rate of MoO_3. The mechanism of the indicated phenomena is evidently analogous to that described for MoO_3 in paper (1).

The evaporation-rate curve for MoO_3 containing different amounts of Mo^{99} differs considerably from the evaporation curve of preparations with introduced W^{185}. Noticeable changes in the evaporation rate occur at a lower level of radioactivity. The minimum on the curve is much more sharply expressed. A stronger increase in the evaporation rate of MoO_3 is observed at the same level of radioactivity in the region of high specific radioactivities. When the isotope Y^{90} is introduced into MoO_3, beginning with preparations having a specific radioactivity of 3 mCi/g, the evaporation rate increases without passing through a minimum, as was observed in the case of additions of Mo^{99} and W^{185}.

Fig. 4. Dependence of the evaporation rate of MoO_3 with additions of various β-emitters on the specific radioactivity of the preparations:
1 –MoO_3 with addition of W^{185},
2 –MoO_3 with addition of Mo^{99},

3 –MoO_3 with addition of Y^{90}.

The absence of a minimum in this case is apparently connected with the fact that the high-energy β-particles emitted by Y^{90} have a greater effect on the charge of the surface of the crystals and more strongly ionize the evaporating MoO_3 molecules, which are repelled from the positively charged surface, than was the case when radioactive isotopes of lower radiation energies were introduced.

Thus, the evaporation rate of solid molybdenum anhydride depends not only on the level of radioactivity of the preparations, but also on the radiation energy of the introduced radioactive additive. Radiation of higher energy promotes a stronger change in the evaporation rate of MoO_3 at the same level of radioactivity. It should be emphasized that the evaporation rate of MoO_3 is affected not only by the radiation of the molybdenum radioisotope itself, but also by the radiation of radioactive inclusions of foreign character located within the solid phase.

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Received
22 VII 1961

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1. Vikt. I. Spitsyn, I. E. Zimakov, DAN, **139**, No. 3 (1961)*.

* In paper (1) the following misprints must be corrected: (a) in Table 1, column 3, all numbers must be reduced by a factor of 10; (b) in Figs. 2, 3, 4, all numbers on the scales of the ordinate axes must be reduced by a factor of 10.

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