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Fig. 1. Kinetics of dissolution in water at 25° of yttrium oxide preparations of different specific radioactivity. 1–0.05 mCi/g, 2–4.08 mCi/g, 3–20 mCi/g, 4–96.70 mCi/g, 5–150 mCi/g Y90

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Abstract

Full Text

CHEMISTRY

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THE EFFECT OF RADIOACTIVE RADIATION OF Y^{90} AND Y^{91} ON THE SOLUBILITY OF YTTRIUM HYDROXIDE

As has been established by investigations in recent years, the radioactive radiation of solids has a noticeable effect on their physicochemical properties and, in particular, on dissolution processes^{1,2}. In the present work the solubility in water of radioactive yttrium oxide samples has been studied, as well as the effect on this quantity of the energy of β -radiation. Preparations of Y_2O_3 were used, containing in one case Y^{90} , and in the other Y^{91} . These isotopes are β -emitters (Y^{90} : $E_{\max} = 2.18$ MeV, $T_{1/2} = 64.6$ hours; Y^{91} : $E_{\max} = 1.55$ MeV, $T_{1/2} = 57.5$ days). In the case of Y^{91} , γ -radiation is insignificant, while in the case of Y^{90} it is absent altogether. Measurement of the half-lives and of the absorption pattern of β -rays by aluminum showed that we were dealing with isotopes that were sufficiently pure radiochemically.

Fig. 1. Kinetics of dissolution in water at 25° of yttrium oxide preparations of different specific radioactivity. 1–0.05 mCi/g, 2–4.08 mCi/g, 3–20 mCi/g, 4–96.70 mCi/g, 5–150 mCi/g Y^{90} .

Preparations of yttrium oxide of various specific activities (from 0.004 to 260 mCi/g) were prepared under identical conditions by precipitating yttrium hydroxide from a solution of the nitrate salt with NH_4OH , washing the precipitate with bidistilled water, and calcining it at a temperature of 950°.

The solubility was studied in a thermostated vessel (25°) with a screw-type stirrer and an oil seal. A 0.5 g quantity of the preparation was placed in 75 ml of bidistilled water, stirring was carried out, and every 30 min samples of the solution were withdrawn with a separatory pipette fitted with a glass filter. The pipette was first rinsed several times with the solution under study in order to

Fig. 2. Effect of additions of Y^{90} on the solubility of yttrium oxide in water at 25°

Figure 2: Fig. 2. Effect of additions of Y^{90} on the solubility of yttrium oxide in water at 25°

avoid losses of dissolved substance through adsorption. The sample taken (about 0.5 ml) was transferred to an aluminum cup, the solution was weighed, and then evaporated to dryness under a special lamp. From the activity values of the dry residue, the weight of the samples taken, and the activity of the standard, the solubility was calculated. The standard was prepared by evaporating in an aluminum cup a definite volume of solution with a known yttrium content.

In water, yttrium oxide is completely hydrated. The solubility values obtained by us evidently refer to yttrium hydroxide, which, apparently, undergoes further hydration in solution. Therefore, for simplicity, the solubility values are given below in milligrams of Y_2O_3 per 100 g of water.

As for the kinetics of dissolution of Y_2O_3 , no noticeable differences among the preparations studied were observed. Fig. 1 gives the curves for the establishment of equilibrium, characteristic of all the radioactivity levels studied. No supersaturation phenomena are detected. Equilibrium of the solid phase with the solution is reached in 7-8 h.

Table 1 and Fig. 2 give data on the solubility of $Y_2O_3^*$ containing different amounts of Y^{90} . If the specific radioactivity lies within the range 0.05-1.0 mCi/g, the solubility of yttrium oxide remains practically constant (0.18-0.17 mg per 100 g H_2O) and does not differ from the value found in [3] by the method of electrometric titration of a saturated solution at 29° of a nonradioactive Y_2O_3 preparation ($8.00 \cdot 10^{-6}$ mole/liter, or 0.18 mg/100 g H_2O). With a further increase in the specific activity up to 20 mCi/g, the solubility decreases by approximately a factor of two. Above 20 mCi/g a sharp increase in solubility begins. All the data in Table 1 are averages from 3-5 experiments. The magnitude of the maximum deviations from the mean values is $\pm 6\%$.

Fig. 2. Effect of additions of Y^{90} on the solubility of yttrium oxide in water at 25° .

Table 1 also shows the effect on the solubility of Y_2O_3 of the isotope Y^{91} , characterized by a lower maximum radiation energy. It may be concluded that the β -radiation of Y^{91} also affects the magnitude of the solubility of yttrium oxide, decreasing it, but at equal

Table 1

Effect of radiation from Y^{90} and Y^{91} on the solubility of $Y_2O_3^*$ in water at 25°

Fig. 3. Effect of the energy of β -radiation on the solubility of yttrium oxide preparations in water at 25°. 1 –preparation containing Y^{91} ; 2 –preparation containing Y^{90} .

Figure 3: Fig. 3. Effect of the energy of β -radiation on the solubility of yttrium oxide preparations in water at 25°. 1 –preparation containing Y^{91} ; 2 –preparation containing Y^{90} .

Specific radioactivity, mCi/g	Solubility of Y_2O_3 , mg per 100 g H_2O	Specific radioactivity, mCi/g	Solubility of Y_2O_3 , mg per 100 g H_2O
Radiation Y^{90}	Radiation Y^{90}	Radiation Y^{90}	Radiation Y^{90}
0.05	0.18	25.00	0.12
0.50	0.17	34.70	0.13
1.04	0.17	44.64	0.16
2.35	0.15	60.00	0.17
3.10	0.14	77.50	0.19
4.08	0.12	96.70	0.22
7.10	0.12	126.50	0.26
12.10	0.12	150.00	0.28
16.50	0.11	211.00	0.35
20.00	0.11	260.00	0.41
Radiation Y^{91}	Radiation Y^{91}	Radiation Y^{91}	Radiation Y^{91}
0.004	0.18	2.09	0.17
0.042	0.18	2.91	0.16
0.10	0.18	3.50	0.15
1.00	0.17	4.00	0.14
1.50	0.17	4.60	0.13

specific radioactivities of the preparations, the solubility of $Y_2O_3^*$ changes more strongly under the action of radiation of the higher energy from Y^{90} , as is seen in Fig. 3.

The following preliminary considerations may be expressed concerning the mechanism of the observed phenomena: as a result of the emission of β -particles, point positive charges are formed on the surface of the solid phase Y_2O_3 , which exert an effect on the negatively charged OH-groups of incompletely ionized $Y(OH)_3$ molecules in solution. For this reason

Fig. 3. Effect of the energy of β -radiation on the solubility of yttrium oxide preparations in water at 25°. 1 –preparation containing Y^{91} ; 2 –preparation containing Y^{90} .

there is a decrease in the solubility of yttrium hydroxide in the presence of the radioactive isotopes Y^{90} or Y^{91} . When the emission of β -particles reaches a

certain high level, ionization phenomena are intensified in the solution under the influence of electron bombardment, including, apparently, the dissociation of $Y(OH)_3$ molecules. Repulsion of Y^{3+} ions from the positively charged surface of the Y_2O_3 precipitate should lead to an increase in the solubility of yttrium hydroxide preparations having high specific radioactivity.

Only in the case of very low specific radioactivity of Y_2O_3 samples (less than 0.1 mCu/g) does the presence of the radioactive isotope have no effect on the solubility of the compound.

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