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PREPARATION OF CARRIER-FREE YTTRIUM-90

(Information Report)

BY

M. L. SALUTSKY AND H. W. KIRBY

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ABSTRACT

A rapid method is described for obtaining a continual supply of carrier-free yttrium-90 (64-hour half-life) from its long-lived parent strontium-90 (19.9-year half-life). In the recommended procedure the strontium-90 is purified and after yttrium-90 grows in, the strontium-90 is precipitated with strontium nitrate carrier from 80 per cent nitric acid. Yttrium-90 is recovered from the filtrate. The strontium nitrate is saved for preparation of other quantities of yttrium-90. A yield of about 95 per cent was obtained and a high purity was indicated by the fact that the yttrium-90 decayed with a 64-hour half-life for about 26 days. By use of this method a continual supply of yttrium-90 is available when needed for an indefinite period of time.

INTRODUCTION

Radiochemical methods are useful in the determination of yttrium because many of the physical methods used in rare earth analyses, such as absorption spectroscopy, magnetic susceptibility, and the like, are not applicable. Yttrium-90 is a suitable nuclide in tracer analyses because it has a convenient half-life of 64.029 hours;¹ is a pure beta-emitter which decays to a stable isotope (zirconium-90); and because a continual supply of yttrium-90 can be obtained by separating it at desired intervals from its long-lived parent, strontium-90.

Although carrier-free yttrium-90 can be separated from strontium-90 by radiocolloidal formation of yttrium in basic solution;^{3, 4, 5, 6} by electrochromatographic methods;⁷ by mass spectroscopy;⁸ and by vacuum evaporation;⁹ carrier-free yttrium-90 can be separated rapidly with a high yield and purity by precipitation of strontium-90 with inert strontium carrier in 80 per cent nitric acid. The method is similar to that previously reported¹⁰ for the separation of carrier-free lanthanum-140 from barium-140.

In the recommended procedure the parent strontium-90 is purified. This is accomplished by a nitrate precipitation in 80 per cent nitric acid with inert strontium carrier followed by two homogeneous chromate precipitations¹¹ with barium carrier. The strontium is recovered from the chromate filtrate by precipitation of strontium nitrate in 70 per cent nitric acid. The strontium-90 need be purified only once, after which yttrium-90 can be extracted as needed for an indefinite period of time. The nitrate precipitation in 80 per cent nitric acid removes all possible contaminants with the exception of isotopes of strontium, barium, radium, and lead.¹² The chromate precipitations remove barium, radium, and lead. Strontium-89, which may still be present as an impurity, does not interfere since it decays to a stable isotope, yttrium-89.

The purified strontium is reconverted to the nitrate and set aside to allow for the growth of yttrium-90. The yttrium-90 is then separated from strontium-90 by reprecipitation of the strontium nitrate in 80 per cent nitric acid. Carrier-free yttrium-90 is recovered from the filtrate.

RECOMMENDED PROCEDURE

REAGENTS

Ten millicuries of strontium-yttrium-90 equilibrium mixture as the chlorides in dilute hydrochloric acid solution was obtained from the Radioisotopes Division of Oak Ridge National

Laboratory. The isotopes were reported to be carrier-free. Strontium-89 (less than 0.1 per cent) was the only radioactive impurity reported. Spectrographic analysis indicated that trace amounts of the following elements were present: boron, chromium, nickel, lead, aluminum, iron, magnesium, calcium, and strontium.

The red fuming nitric acid was Baker and Adamson reagent grade and assayed 93.1 per cent nitric acid and 7.05 per cent nitrogen sesquioxide. The concentrated (70%) nitric acid, strontium nitrate, potassium dichromate, and potassium cyanate were analytical reagent grade.

PURIFICATION OF STRONTIUM-90

Dissolve 0.75 gram of strontium nitrate in two milliliters of water and add to the solution the desired quantity of strontium-yttrium-90. Add dropwise two milliliters of concentrated nitric acid and evaporate with stirring until the volume of the mixture is approximately two milliliters. Cool in an ice bath and add three milliliters of red fuming nitric acid. Digest in an ice bath for 15 minutes with stirring. Filter the strontium nitrate and wash three times with one-milliliter portions of 80 per cent nitric acid. Discard the filtrate and washings.

Dissolve the strontium nitrate in two milliliters of water, add 20 milligrams of barium nitrate, and 50 milligrams of potassium dichromate. Adjust the acidity of the solution by the dropwise addition of either dilute nitric acid or ammonium hydroxide until a slight precipitate of barium chromate just redissolves in one drop of dilute nitric acid. Add 0.5 milliliter of glacial acetic acid. Dilute the solution to 5 milliliters with water. Add 50 milligrams of potassium cyanate. Heat to about 60°C and stir for 30 minutes. Cool and filter, but do not wash the barium chromate. Discard the precipitate. Add 20 milligrams of barium nitrate to the filtrate, readjust the acidity with dilute nitric acid and ammonium hydroxide, and carry out a second barium chromate precipitation by the procedure just described. No additional potassium dichromate need be added to the filtrate for the second precipitation, as a considerable excess was used in the first precipitation.

Add two milliliters of concentrated nitric acid to the filtrate from the second barium chromate precipitation and precipitate the strontium nitrate by evaporating the solution to two milliliters. Cool the mixture in an ice bath, filter, and wash the strontium nitrate with a few milliliters of cold concentrated (70%) nitric acid until the washings are free of the orange dichromate color. Discard the filtrate and wash. Set aside the strontium nitrate containing the purified strontium-90 for about two weeks to permit the growth of yttrium-90. In the preceding step, strontium nitrate was precipitated from 70 per cent rather than from 80 per cent nitric acid because red fuming acid was observed to reduce chromate ion to an insoluble brown oxide.

SEPARATION OF YTTRIUM-90

After fresh yttrium-90 has grown in, dissolve the strontium nitrate in two milliliters of water. Reprecipitate the strontium nitrate from 80 per cent nitric acid as described in the strontium-90 purification. Filter the strontium nitrate, but do not wash it. Evaporate the filtrate to dryness in a small beaker (20 or 30 milliliters). Dissolve the slight residue in dilute nitric acid and dilute the solution to the desired volume. Save the strontium nitrate for future extractions of yttrium-90.

The separation can be carried out in small beakers using small sintered-glass funnels for the filtrations or, more conveniently, in a modified filter-beaker.¹⁰ The filter-beakers

are particularly suitable since the strontium-90 is confined and need not be removed. In either case, reagents are best added with medicine droppers, stirring effected with a magnetic stirrer, and heat supplied by an infrared lamp.

One millicurie is a convenient quantity of strontium-yttrium-90 to use, although larger quantities may be used. It is recommended that at least two weeks be allowed between successive extractions.

DISCUSSION

The purity of the carrier-free yttrium-90 prepared by the recommended procedure was determined by following its decay. Samples were mounted on two-inch stainless steel disks, and the beta activity was counted periodically in a Nuclear Measurements Corporation Model PC-1 Proportional Counter. The yttrium-90 showed no significant deviation from a half-life of 64.029 hours for at least 26 days as indicated in Figure 1. After this length of time less than 0.2 per cent of the original yttrium-90 remained.

A yield of 96 per cent was obtained when the separation was carried out in a filter-beaker. If small beakers and sintered-glass funnels are used, the yield is lower¹⁰ due to a greater retention of filtrate on the strontium nitrate crystals. Although washing the crystals in 80 per cent nitric acid would increase the yield, it would also increase slightly the amount of strontium-90 impurity. Therefore, washing of the strontium nitrate crystals is not recommended.

The quantitateness of precipitation of strontium nitrate in 80 per cent nitric acid was determined by analyzing the filtrates for strontium-90 by the method of differential decay¹³ and by allowing the yttrium-90 to decay to equilibrium and counting the residual strontium-yttrium-90 activity. The average strontium concentration in the 80 per cent nitric acid filtrates was 0.004 milligram of strontium per milliliter. Since the total volume was 5 milliliters, and about 300 milligrams of strontium carrier was used, the amount of strontium-90 remaining in the filtrate as a radioactive impurity in the yttrium-90 was found to be about 0.007 per cent. The quantitateness value for strontium nitrate precipitation in 80 per cent nitric acid solution is approximately the same as that previously found¹⁰ for barium nitrate (0.05 millimoles of strontium nitrate per milliliter as compared to 0.07 millimoles of barium nitrate per milliliter).

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DECAY OF YTTRIUM-90 PREPARED BY THE
RECOMMENDED PROCEDURE

FIGURE 1