

GAMMA SPECTROSCOPY OF TELLURIUM ISOMERS USING A CHEMICAL SEPARATION OF THE GROUND FROM THE METASTABLE STATE.

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ABSTRACT:

The chemical effects produced by the isomeric transition from the metastable to the ground state tellurium isomers in telluric acid molecules, permit the separation of the material into two fractions, one containing the ground state isomers only and the other containing both the ground state and metastable isomers. The gamma spectra of the ground state tellurium isomers was easily separated from that of the metastable isomers in a mixture of tellurium isotopes. This method can be of importance in the detection and separation of energy levels in pairs of isomers that meet the requirements imposed by the procedure.

I. INTRODUCTION

The gamma spectra due to the decay of ^{121}Te , ^{127}Te and ^{129}Te into ^{121}Sb , ^{127}I and ^{129}I respectively have a large number of lines, some of them coming from the metastable tellurium isomers (^mTe) and others coming from the decay of the ground state isomers (^gTe). A number of different methods have been devised to distinguish between the gamma spectra of ^mTe from those of ^gTe using enriched tellurium isotopes (1-13). In this work it is pointed out that the chemical effects due to the isomeric transition from ^mTe to ^gTe in telluric acid molecules permits a separation of a fraction containing the ground state isomers only from another fraction containing both, the metastable and ground state isomers. In this way the gamma spectra due to the decay of ^gTe are actually separated from those due to the ^mTe decay.

The chemical effects are detected as a change from hexavalent (Te VI) to tetravalent (Te IV) tellurium (14-22) and produce a new chemical compound which can be easily separated from the original substance by solvent extraction. The new isolated compound contains only ground state isomers. This method is simple and when combined with a good energy resolution detector it makes possible the identification and separation of individual lines in the ground state gamma spectra from those in the metastable isomers spectra, even for a mixture of isotopes. In this way, the gamma spectra of a mixture of the tellurium isotopes 121, 127 and 129 has been measured in the energy range from 400 to 1200 kev.

II. MATERIALS AND EQUIPMENT

Natural tellurium samples were irradiated at the Nuclear Center reactor at Salazar, Mexico and were treated with commercial analytical reagents.

The measuring device was a "Nuclear Data" 1024 channel pulse height analyzer with a Ge-Li detector.

III. EXPERIMENT AND RESULTS

Twenty grams of natural tellurium were irradiated during 72 hours in the reactor with an approximate thermal neutron flux of 10^{12} neutrons/cm²s. The purification of the irradiated sample was done by a procedure reported elsewhere²³. This material was used to prepare telluric acid crystals

following the method of H. J. Horner and G. W. Leonard²⁴ and were dissolved in 0.1N hydrochloric acid. In this way a solution of telluric acid labelled with radioisotopes of tellurium was obtained. The tellurium isotopes used to make this study are the following: ^{121m}Te (154 days) — ^{121}Te (17 days), ^{127m}Te (108 days) — ^{127}Te (9.4 hours) and ^{129m}Te (33 days) — ^{129}Te (70 minutes).

These three pairs of nuclear isomers have characteristics that meet the requirements needed for the chemical treatment: the ground state isomers can be detected easily as they are radioactive; their radiation is easy to identify and discriminate from the radiation of the metastable isomers and the half lives of the metastable isomers are long enough to permit the preparation of the molecules of telluric acid. A critical condition for these experiments is the half life of the ground-state isomers: if they are too short, the chemical cannot be analyzed with precision; if they are too long, one must wait a long time to produce enough of the ground-state isomer from the decay of the metastable nuclei to give a sufficient activity of the ground state in the new chemical form.

The tellurium isotopes 127 and 129 are very convenient for this study but the isotope 121 can only be used after a long storing time, as the half life of the ground-state isomer is long.

The solution of telluric acid crystals containing the isomeric tellurium species was stored for 43 days to obtain radioactive equilibrium between the metastable and ground state isomers. The equilibrium was attained easily for ^{127}Te and ^{129}Te but it was not obtained in this period for ^{121}Te .

Tetravalent and hexavalent tellurium species were separated by solvent extraction with pure tributyl phosphate as suggested by Inanida Mariko²⁵, Te VI was found in the aqueous solution and Te IV in the organic phase. All samples were measured by gamma spectroscopy, the 1024 channel pulse height analyzer was calibrated to measure only high gamma energy radiation, from 400 to 1200 keV. After the separation of the two species the samples were counted for 10 minutes with the Ge-Li detector.

In figure (1) the continuous curve shows the gamma spectra of the telluric acid in radioactive equilibrium where peaks of ^{121}Te , ^{127}Te , ^{129}Te and ^{129m}Te can be observed. The peaks of ^{121m}Te and ^{127m}Te do not appear in this spectra as they are not in the measured energy range. The dashed curve shows the gamma spectra of tetravalent tellurium fraction after the chemical separation. In this curve only peaks of the ground state isomers can be observed and they can be identified by their half lives: 0.508 and 0.573 MeV from ^{121}Te , 0.418 MeV from ^{127}Te and 0.460, 0.487, 0.802, 1.084 and 1.112 MeV from ^{129}Te .

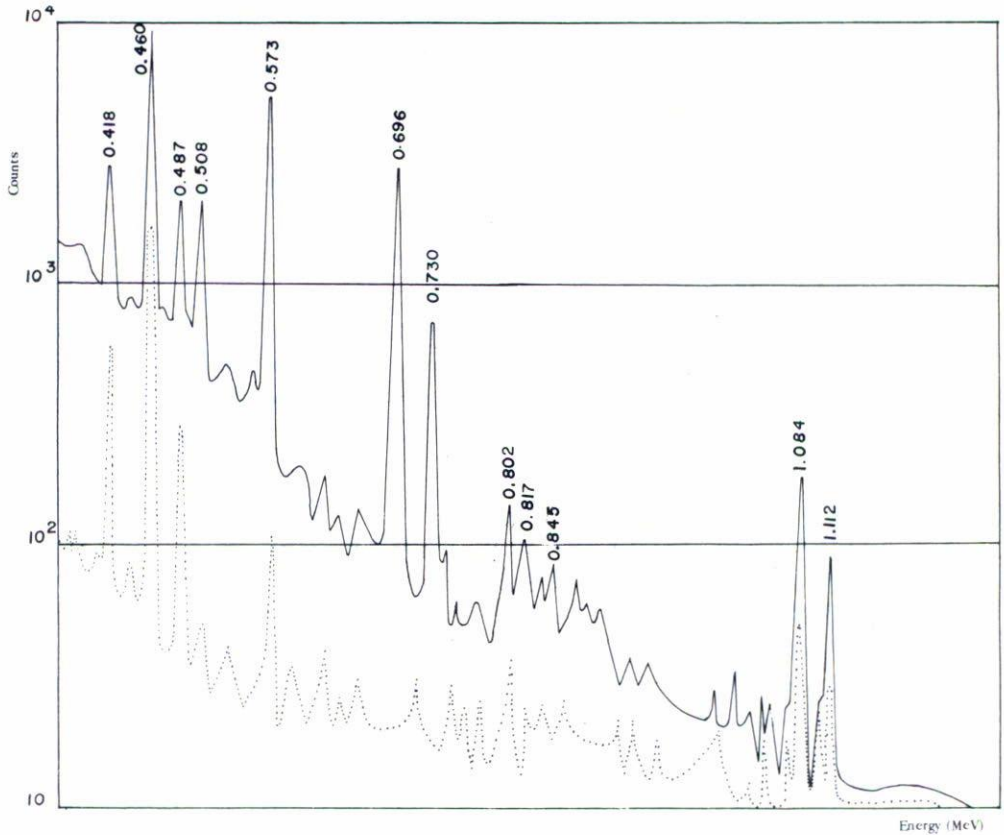


Fig. 1. Pulse height distribution of the gamma spectra of the organic phase, containing Te IV fraction, the dashed line gives the spectra after the chemical separation. The continuous line gives the spectra of the equilibrium mixture.

In figure (2) the continuous curve, as in the previous case, shows the gamma spectra of the telluric acid in radioactive equilibrium and the dashed curve shows the gamma spectra of the hexavalent tellurium fraction after the chemical separation. Peaks at 0.696 and 0.730 Mev from ^{129m}Te can be distinguished very well. The energy peaks of the ground-state isomers can also be observed; the presence of these peaks is due to the partial separation of the ground-state isomers and also to the formation of ground-state isomers by the decay of the metastable ones. The peaks at 0.696 and 0.730 Mev can be identified as belonging to ^{129m}Te since they appear in the Te VI fraction, they do not appear in the Te IV fraction and they decay with the ^{129m}Te half life. The absence of these peaks in the Te IV fraction shows how good the separation of tetravalent and hexavalent tellurium species is.

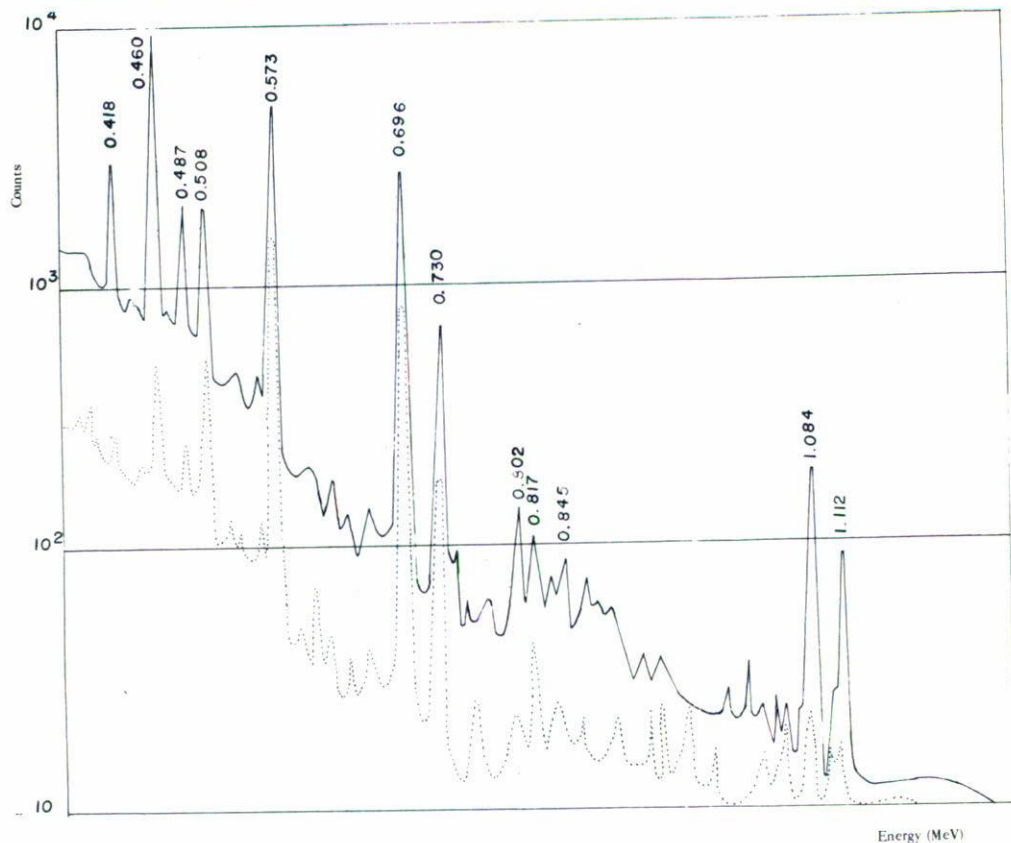


Fig. 2. Pulse height distribution of the gamma spectra of the aqueous phase, containing Te VI fraction, the dashed line gives the spectra after the chemical separation. The continuous line gives the spectra of the equilibrium mixture.

IV. CONCLUSIONS

The principal gamma energy peaks from tellurium 121, 127 and 129 isotopes in the observed energy range check with measurements made elsewhere (3, 5, 13). To determine these peaks, natural tellurium samples were irradiated by thermal neutrons and a simple measuring device was used, while for the values reported before, enriched tellurium samples have been used and the measurements of some of them were made using Ge-Li detectors with NaI(Tl) crystal in coincidence.

In these experiments there were produced six different activities ^{121m}Te , ^{127m}Te , ^{129m}Te and ^{121g}Te , ^{127g}Te , ^{129g}Te . Even with the complete chemical separation of the first three from the second three one still has to disentangle the gammas from three different activities. On the other

hand, if a separated Te isotope had been used, then only two activities are produced. Hence, the chemical separation method would be particularly suitable if combined with the use of enriched isotopes.

The use of the chemical effects of the isomeric transition to separate nuclear isomers can be an important tool in the detection of energy levels of pairs of nuclear isomers that meet the requirements mentioned before. Some typical examples where this technique might usefully be applied are the following pairs of isomers, ^{80m}Br - ^{80}Br , ^{82m}Br - ^{82}Br , ^{121m}Sn - ^{121}Sn , ^{195m}Hg - ^{195}Hg , ^{197m}Hg - ^{197}Hg .

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RESUMEN

Los efectos químicos producidos en las moléculas de ácido telúrico por las transiciones isoméricas en isótopos de telurio permiten separar el material en dos fracciones, una que contiene solamente los isómeros en el estado base y otra que contiene isómeros tanto en el estado base como en el metaestable. De esta manera, en una mezcla de radioisótopos del telurio, se separaron los espectros gama provenientes de los estados base de aquellos provenientes de los estados metaestables.

Este método puede ser importante para la observación de niveles de energía de isómeros nucleares que por sus características se presten a este tipo de separación radioquímica.

