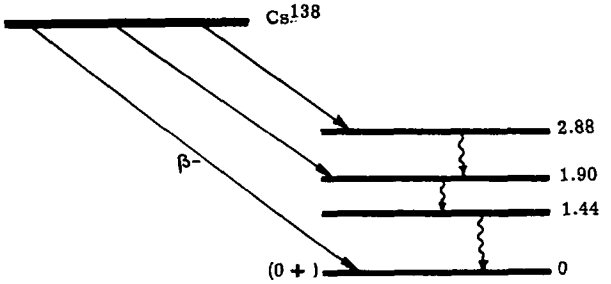
Determination of the Maximum β-Ray Energy of Xe^{138} (17 min) And Xe^{137} (3.8 min) by Absorption

By Sonia J. Nassiff and W. Seelman-Eggebert,* Argentina

The main difficulty in measuring the maximum beta energy of Xe^{138} is that it can only be determined in the presence of its daughter nuclide, Cs^{138}, whose disintegration pattern is known and reproduced in Fig. 1, and which has a half-life of 32 minutes with a maximum energy of 2.65 Mev, as determined by absorption.

The same is not true of Xe^{137}, since its disintegration product, Cs^{137} (33 years), is not formed in detectable amounts in the time needed for readings to be made on the gas. In this case, it was sufficient to eliminate the interference due to Xe^{138} and Cs^{138} with a suitable absorption plate, or to separate it from the I^{137} previously extracted from the irradiated uranium.



Cs^{138} Disintegration Diagram

Figure 1

EXPERIMENTAL

Xe^{138} was obtained by the fission of a uranium solution brought about by thermal neutrons produced by the $Li(d,n)Be$ reaction in the C. N. E. A. accelerator, with an irradiation time of 15 minutes; also by fission of natural uranium in the synchro-cyclotron with 28 Mev deuterons for three minutes, with a current of 10 μa.

With the selected irradiation times, the proportion of long lived isotopes is kept very low. Other fission gases, mainly the Kr isotopes, are obtained together with the Xe.

A series of preliminary tests led us to the conclusion that Kr free Xe may be obtained by absorption with activated carbon at a temperature somewhere between −12° and −15°C, although the recovery is not quantitative, since some of the Xe is carried away by the Kr.

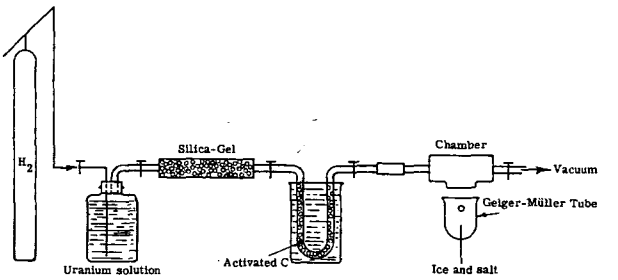


Figure 1'

Therefore, by circulating H_2 for 2 minutes in an apparatus similar to the one illustrated on Fig. 1', the Xe is absorbed in a "U" shaped tube containing activated carbon and submerged in a bath at −12° to −15°C.

In order to eliminate the gases not absorbed by the carbon and remaining in the tube, a current of H_2 is circulated. Only the Xe isotopes produced by the fission are obtained under such conditions; the very short lived ones are completely disintegrated during the treatment following irradiation. The 9.6-hour Xe^{135} and 15-minute Xe^{135m} isotopes appear in the tube in very small proportions, firstly because their direct formation is very small (Chien-shiung-Wu and Segrè[3]), and particularly if the washing with H_2 is done immediately after the radiation, there only being the small amount formed during the operation, from the 6.7-hour I^{135} produced during the fission.

On the other hand, the Xe^{137} is almost totally absorbed in the activated carbon, and it is necessary to wait for its complete disintegration.

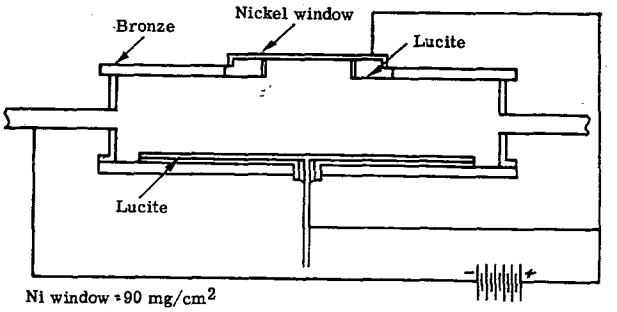


Figure 2

Original language: Spanish.

* Comisión Nacional de la Energía Atómica, Argentina.

The Xe^{138} was introduced into the gas chamber (Fig. 2) 30 minutes after the end of irradiation; the system including the U-tube and gas chamber having previously been evacuated, and the tube heated in a sulfuric acid bath.

The activity of the Xe^{138}, plus that of the Cs^{138} formed by the disintegration of the former, was measured directly as a function of time (Fig. 3).

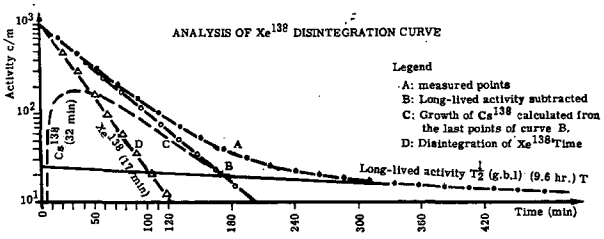


Figure 3

The long-lived activity seen in the curve corresponds to Xe^{135} (9.6 hours). In the irradiation with deuterons in the synchrocyclotron, we found at $t = 0$, 2.5% Xe^{135} activity relative to Xe^{138}; on the other hand, we found only 0.4% when irradiating in the accelerator. In a new experiment we managed to increase the Xe^{138}/Cs^{138} ratio (Fig. 4) by applying 600 volts to the terminals of a gas chamber so constructed that the Cs^{138} could be electrically deposited outside the measuring angle (Fig. 2).

This enabled us to construct an absorption curve

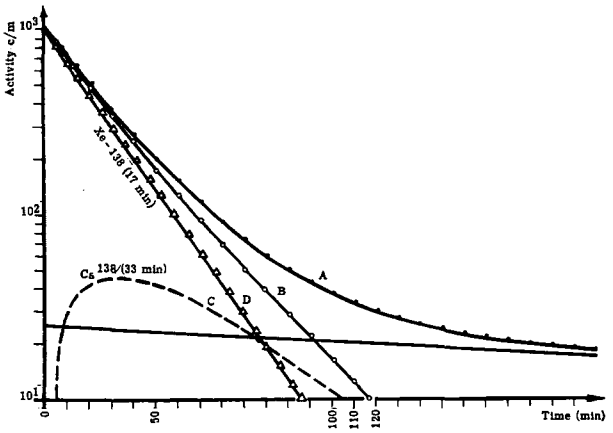


Figure 4. Analysis of the Xe^{138} disintegration curve obtained by applying 600 volts to the chamber

for Xe^{138} in which the correction for the influence of Cs is much smaller.

The construction of this curve was as follows:

Figure 5 shows the family of curves, obtained with different thicknesses of aluminum. For clarity, only a few points were marked on it, drawing only the curve corresponding to 274 mg/cm². The numbers indicate the thickness of Al used.

At the points corresponding to Cs^{138} activity (i.e., after the Xe^{138} had completely disintegrated), the activity of the Xe^{135} was subtracted, obtaining in this way the reduction in the activity of the Cs^{138} for that thickness.

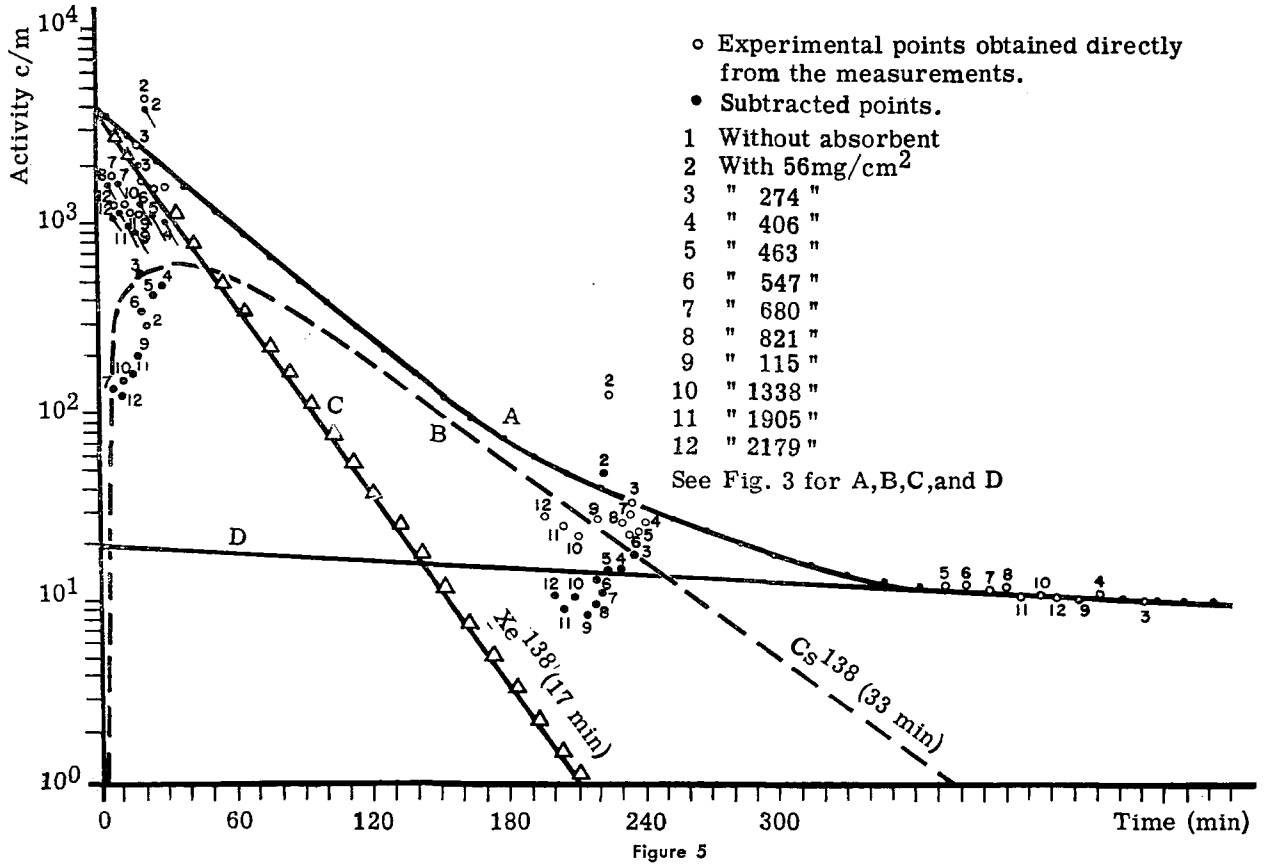


Figure 5

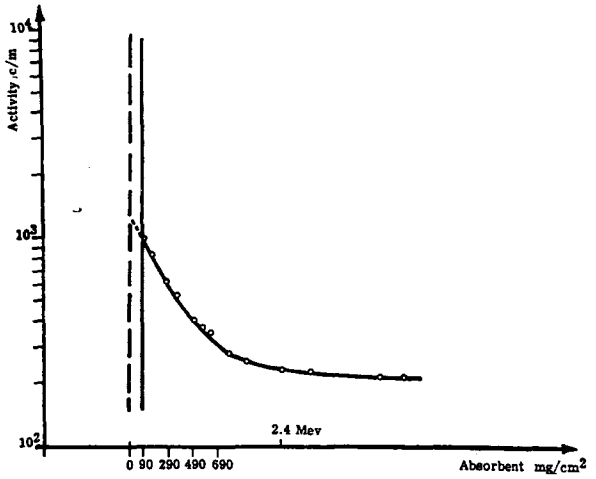


Figure 6. Xe^{138} absorption curve

From the activities obtained with the same Al thickness in the first minutes when the Xe/Cs is higher (Fig. 4), we subtracted the activity of Cs for that time. The data obtained from different irradiations were normalized to the same value for the initial activity. Figure 6 illustrates the values obtained in this way.

It shows a range of 1135 mg/cm², i.e., an E_{max} of about 2.4 Mev, if we compare it with the absorption curve for pure Cs^{138} (Fig. 7), measured with the same geometry as for the gas. If there are more penetrating β-rays, they must be found in a smaller proportion.

The daughter product was measured in another experiment as follows: after injecting the gas into the chamber, the Cs^{138} was allowed to grow until it reached a maximum, after 30 minutes; the Xe^{138} was then washed by circulating H_2 and the remaining Cs was measured using different Al thicknesses.

We also found that Xe^{138} emits γ-radiations, although we are unable, at this date, to make any statement as to its energy.

We compared our results: $Q_\beta = 2.4 + A$ with the Q_β data found in a paper by Way and Wood,[5] and we believe that our experimental value is acceptable, since a discontinuity is observed due to a magic number of neutrons (82) in Xe^{136}.

The absorption curve for Xe^{137} was measured, separating the gas as was done for Xe^{138}, but placing it in the chamber as soon as possible after irradiation. The Al plates used always exceeded the range of the Xe^{138} and Cs^{188}. A range of about 1790 mg/cm² was determined, corresponding to a maximum β energy of 3.5 Mev.

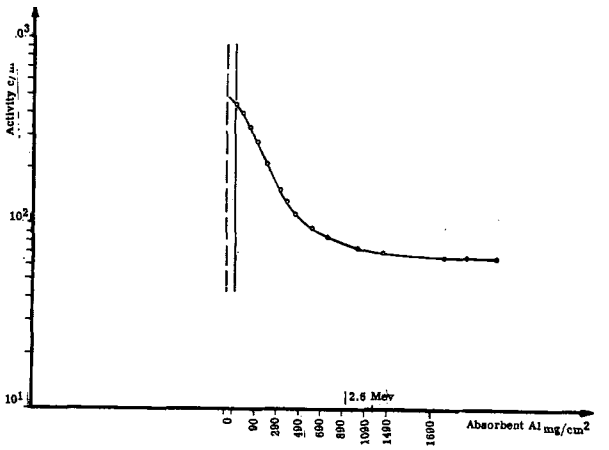


Figure 7. Cs^{138} absorption curve

We also checked, with a scintillation counter, that this Xe isotope is a γ-emitter.

CONCLUSIONS

The maximum beta energies of the isotopes of Xe having mass numbers 138 and 137 were determined by absorption in Al. The values found were as follows: for Xe^{138}: 2.4 Mev; for Xe^{137}: 3.5 Mev.

It was very useful, in the first case, to enclose the gas in a special chamber and to apply a potential difference in order to have the Cs electrically deposited outside of the angle of measurement.

γ-radiation was detected in the two Xe isotopes.

REFERENCES

1. Bleuler, E. and Zünti, W., Helv. Phys. Acta *19,* 375 (1946).
2. Langer, L. M., Duffield, R. B. and Stanley, C. W., *Radioactivity of Cesium 138,* Phys. Rev. *89,* 907 A (1953).
3. Wu, Chien-shiung and Segré, Emilio, *Radioactive Xenons,* Phys. Rev. *67,* 142 (1945).
4. Thulin, S., *Decay Schema of Xe^{135},* Phys. Rev. *94,* 734 (1954).
5. Way and Wood, *A Decay Energy Systematics,* Phys. Rev. *94,*—119-28 (1954).
6. Seelman-Eggbert, W., Naturwissenschaften *31,* 491 (1943).
7. Han, O. and Strassmann, F., Naturwissenschaften *27,* 529 (1939).
8. Heyn, F. H., Aten, A. H. W., Jr., and Bakker, C. J., Nature, *143,* 516-679 (1939).
9. Glasoe, G. N. and Steigman, J., *Radioactive Products from Gases Produced in Uranium Fission,* Phys. Rev. *58,* 1 (1940).
10. Hahn, O. and Strassmann, F., Naturwissenschaften, *28,* 54 (1940).