Tritium Decay Energy*

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(Received June 23, 1960; revised manuscript received September 6, 1960)

The heat output of tritium has been determined by calorimetry as 0.3240±0.0009 watt/gram. This value is about 1 to 4% higher than those previously reported. If the half-life of tritium is 12.43±0.04 years, then its average beta energy is 5.73±0.03 kev.

WE have measured the value of the heat output of tritium in the course of numerous investigations. This value was consistent with the value obtained from the data of Jenks *et al.*[1] Other investigators[2,3] have recently published values that are appreciably lower than our value. In view of the disagreement and the availability of a large quantity of pure tritium gas, a new, carefully controlled determination was made with an associated analysis of all sources of error.

High-purity tritium gas was used to flush and pressurize a loading manifold and four attached calorimeter sample containers. The purity of the gas was studied by mass spectrometry before sealing off three of the containers (hereinafter referred to as samples or sample containers) and after, by expanding the contents of the fourth container; gas was introduced to several mass spectrometers from the loading manifold through viscous flow leaks. A summary of these analyses is given in Table I. In addition, a P_2O_5 electrolytic water analyzer was used to determine that the water vapor content was less than 100 parts per million, by volume. The purity of the gas was thus found to be $(99.86_{-0.12}^{+0.09})$% tritium, by weight.

The weight change in each sample container, which was due to the addition of about 10 grams of the gas, was determined with a precision of better than ±0.10% with 95% statistical confidence. In these determinations the sample containers and spare containers, which were similarly processed except for gas filling, were weighed before and after processing; National Bureau of Standards Class S weights were employed as standards and all weighings were corrected to *in vacuo*, including correction for the studied effect of sample heat output within the balance chambers.

TABLE I. Summary of gas analyses by mass spectrometry.

Mass number	Concentration (wt %)	Precision at 95% confidence limit (wt %)
2	0.000	0.001
3 (He^3)	0.070	0.003
3 (HD)[a]	0.000	0.002
4 (HT)	0.050	0.012
4 (D_2)[a]	0.000	0.002
4 (He^4)	0.000	...
5	0.096	0.003
6	99.761	...
24	0.016	0.012
28	0.002	0.014
32	0.000	...
40	0.003	0.020
44	0.002	0.022
Total T	99.865	0.091 = Total error at 95% confidence limit

[a] Calculated using equilibrium constants [W. M. Jones, J. Chem. Phys. 17, 1062 (1949)].

The heat power output from each sample container was determined with a high-precision (±0.02% reproducibility) isothermal twin calorimeter of the type[4] developed by Mound Laboratory. The calibration standard was known, i.e., conventionally measured, electrical power that was dissipated in a resistance wire heater which was distributed throughout the sample cavity of a spare container. All calorimetric work was completed within 130 days after sample assay; correction for the concurrent beta decay was made using a half-life of 12.262 years.[5] If this half-life value were in error by ±2%, then the additional error in the final result would be about ∓0.0001 watt/gram. The accuracy of these power determinations, which was estimated to be within limits of ±0.10%, was confirmed to within limits of ±0.11% as described in the next paragraph, in which the statements of the preceding two sentences also apply.

The power output from each sample container was

* The information contained in this article was developed during the course of work under contract with the U. S. Atomic Energy Commission.

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[2] D. P. Gregory and D. A. Landsman, Phys. Rev. **109**, 2090 (1958).

[3] M. M. Popov, Iu. V. Gagarinskii, M. D. Senin, I. P. Mikhalenko, and Iu. M. Morozov, Atomnaya Energ. 4, 296 (1958) [translation: Soviet J. Atomic Energy **4**, 393 (1958)].

[4] J. R. Parks, Mound Laboratory Report MLM-595, August 15, 1951 (unpublished); S. R. Gunn, University of California Radiation Laboratory Report UCRL-4547, July 1, 1955 (unpublished).

[5] W. M. Jones, Phys. Rev. **100**, 124 (1955).

TABLE II. Heat of decay of tritium.

Reference	Tritium heat output (watt/gram)	
Jenks *et al.*[1]		0.321 ±0.003[a]
Gregory and Landsman[2]		0.319 ±0.001
Popov *et al.*[3]		0.312 ±0.001[b]
Present work	Sample No. 1: $0.3239_{-0.0011}^{+0.0010}$	0.3240 ±0.0009
	Sample No. 2: 0.3241 ±0.0010	
	Sample No. 3: 0.3240 ±0.0010	

[a] Calculated from entries on the third and fourth lines within Table VIII of reference 1.
[b] Calculated from entries on the fourth and fifth lines within Table II of reference 3.

also determined locally using two other isothermal twin calorimeters, which are similar, but lower precision instruments having separate precision electrical instrumentation; for each sample, the average of these two values and that value obtained with the high-precision calorimeter agreed with the latter value within limits of ±0.10%. In addition, the first sample, No. 1 in Table II, was sent to the Mount Laboratory for an independent power measurement; the value obtained was 0.11% lower than our determination.

RESULTS

The results obtained in this experiment are compared with values obtained by others in Table II.

The result of the present work agrees with our previous investigations and is consistent with the value obtained by Jenks *et al.*[1] A significant disagreement exists between the value obtained in the present work and that of Popov *et al.*[3] and, to a lesser degree, that of Gregory and Landsman.[2]

OBSERVATIONS

The value for the heat output of tritium determined in the present work, together with the most precisely reported half-life value, 12.262±0.004 years,[5] leads to an average beta energy of 5.65±0.02 kev. Use of the method of Slack *et al.*[6] yields a maximum beta energy of 18.46±0.06 kev. However, it should be noted that longer half-life values have appeared in the literature.

If the grand average half-life value, 12.43±0.04 years, which is given by Popov *et al.*,[3] is used instead of 12.262±0.004 years, then, similarly as above, one obtains an average beta energy of 5.73±0.03 kev and a maximum beta energy of 18.7±0.1 kev. This latter value for the maximum beta energy is in somewhat better agreement with the value, 18.61±0.1 kev, given in the work and summary of Porter[7]; hence, we have given the grand average half-life[3] precedence in the abstract.

ACKNOWLEDGMENTS

The authors wish to acknowledge the valuable local contributions of P. J. P. Chastagner, J. E. Conaway, R. H. Gaddy, Jr., B. S. Johnson, Jr., N. H. Parsons, and F. G. Rust. We wish also to express our indebtedness to K. C. Jordan of the Mound Laboratory for performing independent verification of the power measurement.

[6] L. Slack, G. E. Owen, and H. Primakoff, Phys. Rev. **75**, 1448 (1949).
[7] F. T. Porter, Phys. Rev. **115**, 450 (1959).