Precision Measurements of Gamma-Rays from I^{131} with the 2-Meter Focusing Curved Crystal Spectrometer*

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With the 2-meter curved crystal focusing spectrometer three nuclear gamma-ray lines from I^{131} have been found to have wave-lengths $(34.033\pm0.01)\cdot10^{-11}$ cm, $(154.671\pm0.01)\cdot10^{-11}$ cm, $(43.622\pm0.02)\cdot10^{-11}$ cm which when converted to energies give 364.18 ± 0.1, 80.133 ± 0.005, 284.13 ± 0.1 expressed in kev. The sum of the last two energies equals the first to an accuracy of a part in 4500, thus verifying a decay scheme proposed by Metzger and Deutsch in which the 80- and 284-kev lines form a cascade between the same pair of excited levels of Xe^{131} as the initial and final levels for the 364-kev line. An alternative proposal seems also thus to be invalidated. The intensities of the lines are discussed, and a method of calibrating the efficiency of the multicellular Geiger counter as a function of wave-length depending on the use of such cascades is proposed. This is probably the first time that a precision test of the Ritz combination principle as applied to nuclear gamma-rays has been possible. It also furnishes an excellent internal check of the reliability of the wave-length scale of the 2-meter curved crystal spectrometer.

USING a nearly "carrier-free" source of I^{131}, five independent precision measurements of its 364-kev and three of its 80-kev lines had been made at this laboratory with the 2-meter focusing curved crystal spectrometer,[1] when news reached us of a new disintegration scheme of F. Metzger and M. Deutsch[2] showing at least two additional lines. The stronger of these at 284-kev was immediately sought and, in spite of considerable source decay, we were still able to obtain one precision measurement on it. Two weeks later, G. E. Owen, D. Moe, and C. S. Cook published[3] results indicating four gamma-ray lines from this same source, only three of which coincide with those of Metzger and Deutsch to the precision to be expected. It seems likely that at least five lines exist, and each of these groups has missed one line that the other has found. In both cases the work was done with magnetic β-ray spectrometers, the precision of the energy determinations being probably of the order of a percent or so. The Metzger-Deutsch proposal indicates that the sum of the quantum energies of the 284- and 80-kev lines, which form a cascade, should just equal the energy of the 364-kev line whereas the Owen-Moe-Cook proposal suggests that exact equality should exist between two cascade pairs, 80 kev+364 kev and 284 kev+163 kev. The two schemes are shown in Fig. 1. The higher precision of the 2-meter focusing spectrometer offers an opportunity to test and discriminate between these schemes. To give an idea of the high reproducibility of these measurements we give in Table I the results of the individual measurements before and after corrections for small errors in the screw and in the carriage mechanism of the instrument. Each "reading" measures the distance in nominal scale x units between the centers of two complete delineations of the line profile (as reflected to the left and to the right of the (310) planes of the quartz crystal). This, divided by two and by the instrument screw conversion factor (1.000230 rev. per x.u. obtained by calibration with x-rays[4]), gives the wave-length in x.u. (Siegbahn scale). This is then converted to absolute units (10^{-11} cm) in the column, λ_g, by means of the factor $\lambda_g/\lambda_s=1.002030$ and the final column gives the energy in kev from the formula kev$=(12394.2\times10^{-11})/(\lambda_g$ cm).

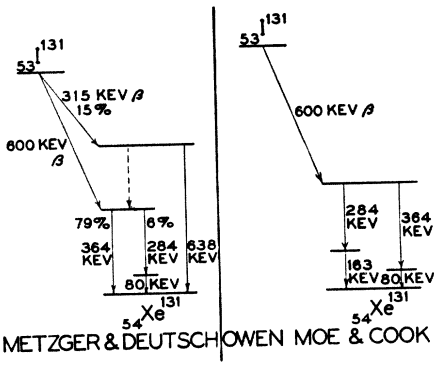

FIG. 1. Disintegration schemes of I^{131} of Metzger and Deutsch and Owen, Moe, and Cook.

It is easy to verify that the energies of the 80- and 284-kev lines add up to equality with that of the 364-kev line *to a part in 4500* which is about the precision to be expected from the single observation on the weak 284-kev line. The precision measures we have assigned are based chiefly on possible systematic errors in the calibration of the instru-

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[1] Jesse W. M. DuMond, Rev. Sci. Inst. **18**, 626 (1947); Jesse W. M. DuMond, David A. Lind and E. Richard Cohen, Rev. Sci. Inst. **18**, 617 (1947); DuMond, Lind, and Watson, Phys. Rev. **73**, 1392 (1948).

[2] F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948).

[3] Owen, Moe, and Cook, Phys. Rev. **74**, 1879 (1948).

[4] Watson, West, Lind and DuMond, Phys. Rev. **75**, 505 (1949).

TABLE I. Results of independent measurements before and after corrections for small errors in the screw and in the carriage mechanism of the instrument.

Run No.	Reading	Screw	Corrections Periodic	Level	Corrected reading	Wt.	Average	X.U. (Siegbahn)	λ_a in 10^{-11} cm	Energy kev
1	67.950	−0.001	+0.001	+0.014	67.964	1				
2	67.940	−0.001	+0.001	+0.002	67.942	1				
3	67.921	−0.001	+0.001	+0.006	67.927	1				
4	67.950	−0.001	+0.001	+0.010	67.960	1			34.033	364.18
5	67.933	−0.001	+0.001	+0.004	67.937	1	67.946	33.965	±0.01	±0.1
1	308.785	+0.002	+0.002	+0.008	308.797	1				
2	308.785	+0.002	+0.001	+0.010	308.798	1			154.671	80.133
3	308.765	+0.002	+0.001	+0.018	308.786	½	308.795	154.362	±0.01	±0.005
									43.622	284.13
1	87.096	−0.002	+0.003	−0.006	87.091	1	87.091	43.535	±0.02	±0.1

ment rather than on the excellent reproducibility. We shall only be able to measure Owen, Moe, and Cook's 163-kev line when our program permits a repetition experiment with a new source, but the present results obviously give strong positive support to the Metzger and Deutsch scheme and seem, therefore, to exclude the other. The advantage of the higher precision crystal method is well exemplified here.

We have also estimated the intensity ratios (photons per unit time) of the three lines we have measured with the following results (Table II).

TABLE II. Estimated intensity ratios.

Line	*R* observed	*N*	Counter efficiency
364 kev	1.000	1.000	25% (Estimated)
80 kev	0.273	0.049	6.8%
284 kev	0.143	0.087	25% (Estimated)

R is the relative intensity (in counts per unit time) *taken from the spectral curves* after subtracting background and making correction for source decay. This result must still be corrected (1) for the differing efficiency of the multicellular Geiger counter, and (2) for the differing reflection coefficient of the crystal at different wave-lengths. Fortunately, the law as regards the crystal reflection coefficient is quite well established by the work of D. A. Lind,[5] as yet unpublished, done in this laboratory. It has been shown to vary as λ^2. To date we have measured the efficiency of the nine-cell multicellular Geiger counter at one energy only, 510-kev. The result obtained was 30 percent. This was done by coincidence methods with two such counters utilizing the simultaneous, oppositely directed pairs of annihilation photons from the same source of Cu^{64} with which a precision study of annihilation radiation was recently made.[6] From theory we estimate that the efficiency for the 364- and 284-kev lines should be only slightly less than this, about 25 percent, but the counter efficiency for the 80-kev line should be quite low, about 4 or 5 percent, because many photoelectrons will fail to be ejected into the gas from the 15-mil thick lead partitions. The column in Table II marked *N* gives the relative activities (photons per unit time) of the three lines after the crystal and estimated counter corrections have been made. This then represents the relative activities of the lines *at the source.* (Because of the small depth and high specific activity of our source we believe its self-absorption is negligible.) In computing the column, *N*, the cascade relationship of the 80- and 284-kev lines seems so firmly established by our wave-length measurements that we feel justified in taking *as a valuable datum* the exact *equality* of the activities associated with these two lines. The relative numbers of quanta associated with the two lines must be corrected for their internal conversion coefficients, however. We thus obtain with considerable certainty *the absolute efficiency of the counter at 80-kev*, namely, 6.8 percent. By the use of a number of such cascades it seems possible that quite reliable curves of counter efficiency *vs.* energy can eventually be obtained. These results indicate then that the ratio of the activity associated with the 284- +80-kev cascade to the activity of the 364-kev line is as 0.087 to 1.00, which agrees as well as can be expected with the ratio reported by Metzger and Deutsch, 0.076 to 1.00.

[5] David A. Lind, thesis, Pasadena (1948).
[6] DuMond, Lind and Watson, Phys. Rev. **75**, 1226 (1949).