## Energies of Gamma-Rays from $Br^{82}$, $I^{131}$, $I^{130}$ $Mn^{56}$, $Mn^{54}$, $As^{74}$

MARTIN DEUTSCH AND ARTHUR ROBERTS
*Massachusetts Institute of Technology, Cambridge, Massachusetts*
July 31, 1941

IN many cases, the best method available for the determination of gamma-ray energies is a study of the energy distribution of secondary electrons by means of a magnetic spectrometer. The "short magnetic lens" spectrometer[1] has been found to be very well suited for this purpose because of the great distance between source and counter, the high transmission factor, and the use of circular sources. The gamma-ray source strengths required are about the same as those needed for reasonably good absorption measurements, namely, from two to ten micrograms radium equivalent per gamma-ray line present, depending on the energy range. With appropriate precautions, very much weaker activities could undoubtedly be measured. Sources weighing as much as several hundred milligrams can readily be used if necessary.

For energies up to about 1.4 Mev the photoelectrons produced in thin (8 to 100 mg/cm²) radiators of high atomic number (Sn, Pt, Au, Pb) permit accurate determination, even if several gamma-rays are present. Above 1 Mev the maximum energy of the Compton electrons can be measured,[2] but only the hardest gamma-ray can be determined accurately by this method because of the low energy tail on the Compton secondary distribution.

The estimated probable error is now about 3 percent of the gamma-ray energy, in the range from 0.3 Mev to 1 Mev, and slightly larger outside this range. About half of this allows for systematic errors, mainly uncertainty about the effect of energy losses in the radiator, and can certainly be greatly reduced by studying these factors. The rest of the error is due to uncertainty in picking the peak of a line in the presence of secondaries from other gamma-rays and can be reduced by adjusting the spectrometer for better resolution.

TABLE I. *Energies of gamma-rays.*

| ISOTOPE | PERIOD | GAMMA-RAYS (MEV) | METHOD | REFERENCE |
|---|---|---|---|---|
| $Br^{82}$ | 36 hr. | 0.547<br>0.787<br>1.35 | *P*<br>*P, C*?<br>*C, P*? | 1 |
| $I^{131}$ | 7.8 days | 0.367±0.007 | *IC, P, C* | 2 |
| $I^{130}$ | 12.6 hr. | 0.417<br>0.535±0.01<br>0.670<br>0.740 | *P*<br>*IC, P*<br>*P, IC*?<br>*P* | 3 |
| $Mn^{56}$ | 2.6 hr. | 0.832<br>2.20 | *P*<br>*C* | 4 |
| $Mn^{54}$ | 310 days | 0.850<br>0.120 | *P, C*<br>*P* | 5 |
| $As^{74}$ | 17 days | 0.582 | *P* | 6 |

[1] These gamma-rays have been shown to be in cascade and associated with the entire beta-spectrum by J. R. Downing and A. Roberts, Phys. Rev. **59**, 940A (1941).
[2] This gamma-ray accompanies the entire beta-spectrum [M. Deutsch, Phys. Rev. **59**, 940A (1941)]. Mr. J. R. Downing has shown it to be in cascade with another gamma-ray of 0.080±0.002 Mev by critical absorption (private communication).
[3] Previous absorption measurements gave 0.6 Mev for these gamma-rays [J. J. Livingood and G. T. Seaborg, Phys. Rev. **54**, 775 (1938)].
[4] Previous measurements by Curran, Dee, and Strothers (reference 2 of text), in a semi-circular focusing spectrometer gave 0.91±0.05 and 2.03±0.05 Mev.
[5] The assignment at 0.120 Mev, obtained with a radiator of Sn assumes the observed absorption to be in the *K* shell. If it were in the *L* shell, the *K* line would not have been observed, due to counter window thickness.
[6] The annihilation radiation was also observed.

In this series of measurements we have not, in general, attempted to measure energies less than 0.18 Mev. The letters following the energy values in Table I indicate the method of measurement, in the order of accuracy, *IC* indicating internal conversion, *P* photoelectrons, *C* Compton electrons. A question mark signifies that the particular method confirmed the existence of the gamma-ray but did not yield adequate accuracy. The probable errors are those given in the preceding discussion unless otherwise indicated. Because of uncertainty as to how to correct for the momentum interval with radiators giving line widths comparable to the momentum interval, we can say little concerning intensities at present.

These investigations have been supported in part by a grant from the John and Mary R. Markle Foundation for physiological studies with radioactive iodine. It is a pleasure to acknowledge the friendly interest of Professor Robley D. Evans in these experiments.

[1] M. Deutsch, Phys. Rev. **59**, 684A (1941).
[2] S. C. Curran, P. I. Dee and J. E. Strothers, Proc. Roy. Soc. **A174**, 546 (1940).

## Degenerate Non-Ideal Gases and Liquid Helium

L. I. SCHIFF
*Randal Morgan Laboratory of Physics, University of Pennsylvania, Philadelphia, Pennsylvania*
July 14, 1941

IN two recent papers,[1] the theory of degenerate non-ideal quantum gases was developed in an approximation that considered binary collisions, and an application was made to a simplified model of liquid helium. The present note corrects an error in the evaluation of an integral in I, and discusses an alternative solution for the particle distribution function in II.

The $G_1$ integral defined by I (29) actually contains a residue as well as a principal value part when expressed as in integral over $k'$. Thus I (34) should have added to it a term: $(8\pi/\Omega)\sum_{\text{even } l}(2l+1)(\beta\hbar^2/m)(\sin 2\delta_k{}^l)/2$. Similarly, I (35) should have added to it a term: $4\pi\beta\hbar^2\Delta/m\Omega$, where: $\Delta \equiv \lim_{k\to 0}(\sin\delta_k{}^0)/k$. These residue terms dominate in the perturbation theory limit ($V\to 0$),[2] and also in the low temperature limit considered explicitly in II.

In the application to liquid helium, there exists a temperature $T_c > T_0$ below which an alternative solution of the particle distribution equation II (5) appears. Since this solution has lower free energy than I (19), it must be regarded as the appropriate description of the equilibrium state. The calculation is particularly simple in the low temperature limit, in which the range of the two-particle interaction $\ll h/(mkT)^{\frac{1}{2}}$. The leading term in $G_1$ is then the residue term given above, and condensation takes place if $\Delta < 0$, that is, if there is no bound state of the $He_2$ molecule ($\Delta = -a$ for a rigid sphere interaction). The parameter $x$