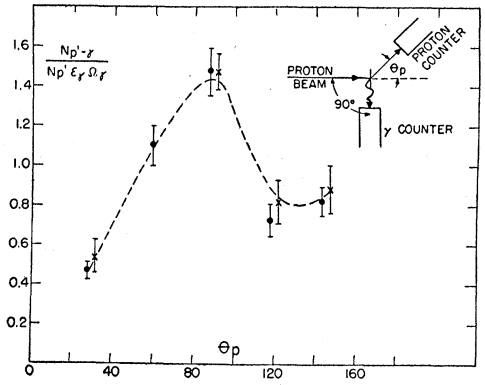

FIG. 2. Proton-gamma angular correlation from the reaction $Mg^{24}(p,p')Mg^{24*}\rightarrow\gamma+Mg^{24}+1.4$ Mev for $\theta_\gamma=-90°$. Two sets of data, one from a 0.7-mil and the other from a 1.4-mil magnesium target are shown.

a $\frac{1}{8}$-inch lead shield in front to eliminate low energy gamma-rays. The product of efficiency and solid angle for 1.2-Mev gamma-rays was determined by placing a calibrated Co^{60} source in the target position. It was found that this factor could be made as high as 0.5 percent corresponding to a 25 percent efficiency without background affecting the measurements seriously.

The chance coincidence rate was measured with a second gamma-counter similar to the first, installed adjacent to the beam catcher and shielded in such a way that no gammas from the target were counted. Its counting rate could be made approximately equal to that of the first, and both gamma-counter outputs were placed in coincidence with the proton counter. The coincidence resolving time was 0.4 microsecond.

Figure 1 shows the proton spectrum from magnesium with the proportional counter at 90° to the beam. The two low energy peaks correspond to inelastically scattered protons from the known 4.2 and 1.4-Mev levels in Mg^{24}. The observed $p-\gamma$ coincidences under each peak are also indicated, taken with the gamma-counter at $-90°$.

Before and after each coincidence point was measured, the proton peak was recorded to insure that it was well resolved and the scintillation counter efficiency and circuit resolving times were checked.

In the correlation measurements each coincidence point was taken with an absorber thickness corresponding to the proton peak inserted in front of the proportional counter. The proton beam intensity was kept low enough to reduce the chance coincidences to a value well below that of the true.

Figure 2 shows the $p-\gamma$ correlation with the gamma-counter at $-90°$ as a function of proton angle. Two sets of data, one from a 0.7-mil and the other from a 1.4-mil magnesium target are indicated to show the consistency of the results. The ordinate scale is chosen in such a way that unity is the value of $(p-\gamma)/p$ that would occur if the gamma-ray following the proton has the same probability of emission in any direction. This normalization was based on the calibrated Co^{60} source. It can be seen that the maximum correlation occurs when the proton and gamma-ray are emitted back to back at 90° to the beam.

Figure 3 shows the correlation for a gamma-ray angle of $-30°$ indicating much less pronounced variations.

It is planned to extend these measurements using improved counters and faster circuits.

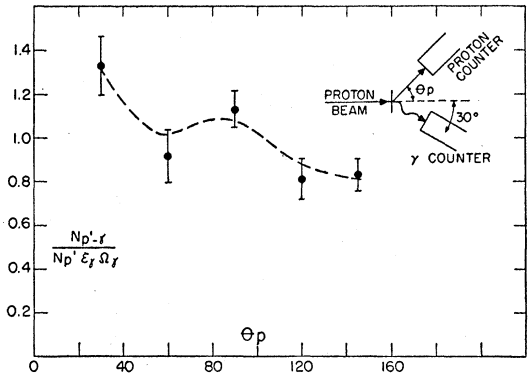

FIG. 3. Proton-gamma angular correlation from the reaction $Mg^{24}(p,p')Mg^{24*}\rightarrow\gamma+Mg^{24}+1.4$ Mev for $\theta_\gamma=-30°$.

† This work has been supported in part by the joint program of the AEC and ONR.

‡ Present address: Nobel Institute for Physics, Stockholm, Sweden. Participation in this work was made possible through the support of the American-Scandinavian Foundation and the Swedish Atomic Energy Committee.

[1] Boyer, Gove, Harvey, Deutsch, and Livingston, Rev. Sci. Instr. **22**, 310 (1951).

[2] K. Way *et al.*, *Nuclear Data*, National Bureau of Standards Circular No. 499 (1950).

The Radioactive Decay of Ruthenium 103†

J. M. CORK, J. M. LEBLANC, F. B. STUMPF, AND W. H. NESTER
Department of Physics, Univesrity of Michigan, Ann Arbor, Michigan
(Received April 4, 1952)

SINCE the early discovery[1] of a 46-day radioactivity in ruthenium and its subsequent assignment to the isotope of mass 103, many investigations have been made of the energies of its radiations. There has come to be a general agreement, to the extent shown in Table I, that two beta-rays and two gamma-rays are associated with the radioactive decay. Coincidence measurements indicate[2] that the higher energy gamma is associated with the lower energy beta-ray. The 40-kev gamma-ray showed no coincidence with either beta-ray or the other gamma and is believed to result from the well-known, 57-minute, isomeric transition in rhodium 103.

Using photographic spectrometers with sources of both Ru^{103} and Ru^{106}, obtained from Oak Ridge, several previously unreported gamma-rays are found to be present. The energies of the conversion electrons and their interpretations are shown in Table II. Some lines resulting from the long-lived Ru^{106} are always present and are identified by their relative increase intensity in aged specimens. Two of these have energies of 510.0 and 621.7 kev. By the use of a recording microphotometer and emulsion sensitivity data, the relative line intensities for several of the gamma-rays are evaluated as shown in column 5. From the empirical relationships noted[3] by Goldhaber and Sunyar and from "shell" theory it is possible to propose the type of transition for certain of the gamma-rays.

The 39.6-kev isomeric transition in Rh^{103} appears to be $E3$ as previously assigned;[3] however, the logarithm of the radiation lifetime τ_γ seems to be more nearly 6 than 7, as noted. From its K/L value of 8.5, the 499-kev transition might be $M3$, $E2$, or $E3$, but

TABLE I. Reported energies in ruthenium 103.

Item	BH[a]	H[b]	SSG[c]	MS[d]	MHM[e]	K[f]
Half-life, days	41		42		43	39.8
Energy in kev						
Beta 1		350	200	150	204	217
2	750	665	300	680	684	698
Gamma 1					40.4	40
2	400	312	530	520	494	498

[a] E. Bohr and N. Hole, Arkiv. Mat. Astr.-fys. **32A**, 15 (1945).
[b] N. Hole, Arkiv. Mat. Astr.-fys. **36A**, 2 (1948).
[c] Sullivan, Sleight, and Gladrow, *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1950), Paper No. 111, National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. IV.
[d] C. Mandeville and E. Shapiro, Phys. Rev. **77**, 439 (1950).
[e] Mei, Huddleston, and Mitchell, Phys. Rev. **79**, 429 (1950).
[f] See reference 2.

TABLE II. Energy of conversion electrons from ruthenium 103.

Electron energy, kev	Interpretation	Energy sum, kev	Gamma-energy, kev	K/L ratio
16.2	K(Rh)	39.4		
19.1	Auger			
29.8	K	53.0		
36.7	L_3	39.6		
39.0	M	39.6		
39.5	N	39.6	39.6	0.10±0.04
49.7	$L_{1,2}$	52.9	52.9	1.0±0.3
272.0	K	295.2	295.2	
475.5	K	498.7		
488.8	K	512.0		
495.1	L	498.4		
497.8	M	498.4	498.5	8.5±1.5
509.0	L	512.0		
587.2	K	610.7	610.6	4.0±1.5
598.5	K	621.7	510.0(106)	
607.2	L	610.6	621.7(106)	

from the very short lifetime the $E2$ process appears most probable. Similarly the 53-kev gamma-ray with a K/L ratio of unity must result from an $E2$ transition. The 610-kev gamma-ray, whose Z^2/W is 3.33, has a K/L ratio of approximately 4. This value is somewhat too small for an $M4$ transition and would best suit an $E4$ or $E5$ process. The very short radiation lifetime would be more in agreement with $E4$.

The proposed energy level scheme shown in Fig. 1 includes all of the gamma-rays except the 295-kev radiation for which only a

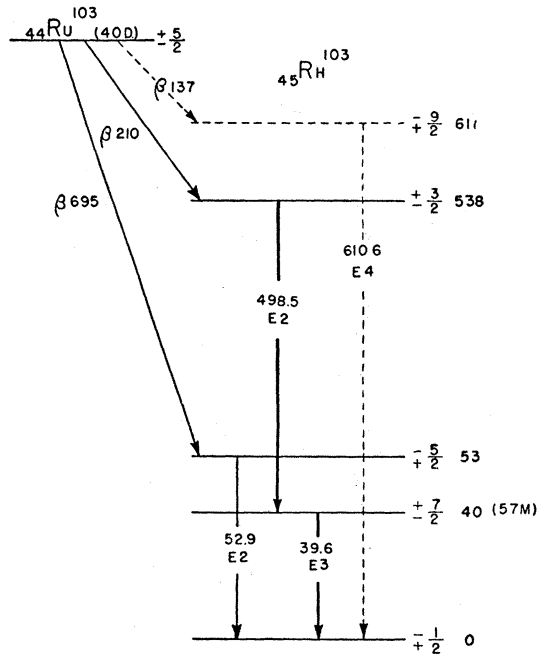

FIG. 1. Proposed decay scheme for Ru^{103}.

single electron line was observed. The 610-kev level suggests the existence of an additional beta-ray of lower energy. In view of the wide variation both in the energies and in the relative decay probabilities reported for the 210- and the 695-kev beta-rays, the existence of a 137-kev beta might have been overlooked. The 499-kev transition is now a better fit between the observed beta-energies than in the older, simpler level schemes, and the spin changes are compatible with the observed intensities, in that the 210-kev beta is allowed and the 499-kev is a first forbidden transition. The spin values of the states are not in disagreement with shell theory predictions.

† This project received the joint support of the AEC and ONR.
[1] J. Livingood, Phys. Rev. 50, 425 (1939).
[2] E. Kondaiah, Phys. Rev. 79, 891 (1950).
[3] M. Goldhaber and A. Sunyar, Phys. Rev. 83, 906 (1951).

Coexistence of Liquid Helium I and II

PHILIP CLOSMANN AND RICHARD T. SWIM
Rice Institute, Houston, Texas
(Received March 31, 1952)

SINCE the transition between liquid helium I and liquid helium II is one of the second order, showing no latent heat, no phase boundary between the liquids can be expected. The two liquids can never be coexistent at any given value of temperature and pressure. However, both liquid forms can be present at the same time if one of the variables of state has a gradient within the space of observation. It seems that in none of the experiments on liquid helium carried out so far did a gradient of temperature or pressure covering the transition region exist, and it is, therefore, of interest to carry out such an experiment.

In view of the difficulty of establishing a pressure gradient, an arrangement involving a temperature gradient was chosen. This arrangement consisted of a thermally isolated column of helium. In this way the radial heat flow is zero, and one end could be at temperatures below the lambda-point, while the other end could be above the critical point. It is to be expected that in such an arrangement the main contribution to the heat transport will be provided by the liquid helium II. In view of the complex nature of this heat flow and also because of the inversion of the thermal expansion at the lambda-point, the question of the temperature distribution cannot, however, be solved through mathematically rigorous procedures.

The apparatus (see Fig. 1) consisted of a vertical glass tube 55 cm long and 0.86-cm diameter which was enclosed in a vacuum jacket. The tube was thermally connected by means of copper-glass seals to a container with liquid nitrogen at the upper end and a bath of liquid helium II at the lower end. The whole arrangement was placed into a Dewar vessel which contained liquid helium II at the bottom and a metal reservoir with liquid nitrogen at the top. In this way the influence of radiation can be neglected. The tube could be filled with helium at more than the critical pressure, and the temperature at any place in it determined by a small resistance thermometer which could travel through the length of the tube. This temperature probe consisted of a hollow Lucite cylinder carrying on its outside a coiled resistance wire of leaded brass. Care was taken to make the heat resistance of the metal partition between the helium in the tube and that in the outer bath small enough to allow for a temperature below the lambda-point inside the lower end of the tube.

The results show that at pressures above 2.2 atmospheres and under equilibrium conditions, practically the whole of the tube was full of liquid helium II, leaving only about 4 cm at the top of the tube for the temperature gradient between 2.16°K and 80°K. The exact point where the liquid helium II ended was indeterminate to the extent of 1.5 cm, this being the length of the thermometer. As expected, the transition region between liquid helium II and liquid helium I as well as between liquid helium I and the gas

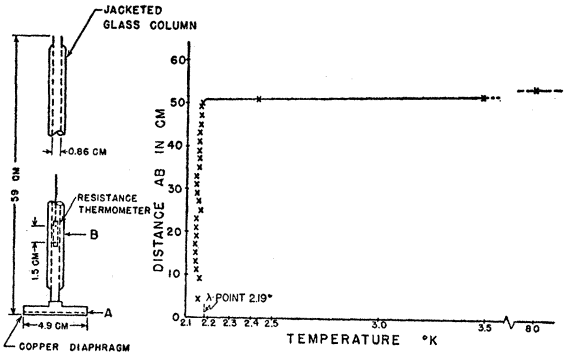

FIG. 1. Diagram of the apparatus and experimental results on liquid helium I and II.