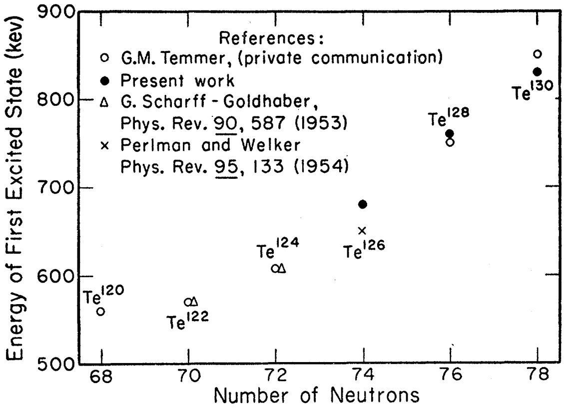

FIG. 5. Energy of the first excited state of the several tellurium isotopes.

using 6.5 Mev alpha particles.[10] Figure 5 shows the energy of the first levels of the various tellurium isotopes, as determined by these and other experiments, and illustrates the behavior expected as the number of neutrons approaches 82.[11]

Nickel

The previously reported[6,7,12] 1.35-Mev and 1.46-Mev gamma rays were both observed from a normal nickel sample, while only the latter was emitted by the Ni^{58} sample. The 1.46-Mev gamma ray is therefore assigned to Ni^{58} and the other, by elimination, to Ni^{60}. These confirm assignments[7] made on the basis of energy comparison with the known first levels in Ni^{58} at 1.453 Mev[13] and Ni^{60} at 1.3325 Mev.[14] The 1.01-Mev gamma ray, detected from both the normal nickel and Ni^{58} samples, is tentatively assigned to the second-first state transition in Ni^{58}.

Copper

The gamma rays observed from Cu^{63} and Cu^{65} have been reported previously.[6,7] The present isotopic assignments again confirm those made by energy comparison[7] as ground-state transitions from known states in Cu^{63} at 0.669, 0.968, 1.326, and 1.410 Mev[13] and in Cu^{65} at 1.12 Mev.[15]

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Decay of Rn^{220} and Rn^{222}†

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A gamma ray of energy 510±2 kev and approximate intensity 7×10^{-4} quanta per decay is emitted in the alpha decay of Rn^{222}. A gamma ray of energy 542±2 kev and approximate intensity 2.5×10^{-4} quanta per decay is emitted in the alpha decay of Rn^{220}. The intensities are considered accurate only to within a factor of two.

THE alpha spectra of the radium and thorium emanations have been reported as simple, and no gamma rays were observed in the decay of these isotopes. Presuming that weak gamma rays, if present, might easily have escaped previous observations, we investigated the decay of Rn^{220} and Rn^{222} by the following arrangement. The emanation was left to accumulate in an air volume of a few cubic centimeters above a solution containing about one millicurie of radiothorium or radium, respectively. In the case of radiothorium, owing to the short half-life of the emanation (54.5 seconds) it was important to spread the solution in a thin layer on the bottom of a wide vessel, to allow the emanation to diffuse out of the liquid before decay. By opening a stopcock, the emanation could be quickly transferred through a long capillary tube to a previously evacuated, flat glass vessel placed immediately above an NaI(Tl) crystal 2 in. in diameter and 1 in. thick. Visual examination and photographs of the pulses on an oscilloscope screen immediately revealed in either case a gamma-ray photopeak of about 0.5-Mev energy.

With Rn^{220}, the gamma ray decayed with the half-life of the emanation, indicating that it was emitted either in its decay, or in the decay of the short-lived (0.14-second) daughter nucleus, Po^{216}. To distinguish between

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these alternatives, we performed a similar experiment, using a cylindrical glass tube 8 cm long, closed at either end by metal electrodes. One electrode was placed immediately above the scintillating crystal. By measuring the intensity of the 238-kev line of ThB, we found that the effect was enhanced by a factor of four when a potential difference of 1000 volts was applied to the electrodes, the one in contact with the crystal being the cathode; whereas a decrease of the effect by a factor of three was observed by reversing the polarity. These results are consistent with the geometry of the apparatus, if one assumes that all the active deposit occurs as positive ions and is collected at the cathode. Since the collection time of the ions at the pressure of about 10-cm Hg used in these experiments is short compared with the 0.14-second half-life of Po^{216} (ThA), the intensity of the effect will be strongly influenced by the electric field if the line is emitted in the decay of Po^{216}, whereas it will remain unaffected if the line is due to the decay of Rn^{220}. Experiments showed no change to within the statistical error of 10%, indicating that the line is emitted in the decay of Rn^{220}.

In the case of Rn^{222}, the intensity of the line remained constant for the first two minutes, showing that the gamma-ray is emitted in the decay of Rn^{222} and not in the decay of the 3.05-minute daughter nucleus, Po^{218} (RaA). After a longer time, the rapid growth of the strong lines of RaB and RaC made observations difficult.

To measure the intensities of the lines, we compared them with the known intensities of lines of the decay products. In the case of Rn^{220}, the channel of the scintillation spectrometer was set to cover the photopeak of the line, and the counts above background taken for three minutes after the emanation had been admitted to the glass vessel. After the emanation had completely decayed, the almost constant intensity of the 238-kev line of ThB was recorded. For this line the number of quanta per decay is known to be 0.7. Knowing the half-lives of the isotopes involved and the approximate efficiencies and percentages of pulses in the photopeak for each of the lines, we evaluated the intensity of the Rn^{220} line as 2.5×10^{-4} per decay. Owing to uncertainty of these correction factors under the poor geometry used, this value may be considered accurate only to within a factor of two.

In the case of Rn^{222}, the photopeak of the radon line was compared with that of the 352-kev line of RaB. Both lines were measured simultaneously using two single-channel pulse analyzers, readings being taken every 30 seconds for 3 minutes after the emanation had been admitted into the vessel. The intensity of the RaB line increased with time in excellent agreement with calculations based on the known mean lives, while the intensity of the radon line remained constant. From the count of the RaB line in the first three minutes, the equilibrium intensity (too strong to be directly measured) was calculated. The uncorrected ratio of the intensities of the RaB and radon lines was 1200. When one corrects for the aforementioned factors, this ratio becomes 700. The absolute intensity of the 352-kev line of RaB is not accurately known. However, it is clear from the work of Ellis[1] and Muller, Hoyt, Klein, and DuMond,[2] that: (1), the gamma-ray spectrum of RaB mainly consists of three strong lines at 242, 295, and 352 kev; (2), all or nearly all beta decays lead to excited states; (3), the conversion coefficients of these three lines are low. Attempts to observe coincidences between any pairs of these lines showed us that they are not in cascade. We conclude that the sum of the intensities of the three lines is approximately one. An estimate obtained from an incompletely resolved scintillation spectrum showed that the intensity of the 352-kev line is about the same as that of the two other lines together, hence about 0.5. This value would yield an intensity of 7×10^{-4} for the radon line. In view of many uncertainties in the correction factors, the result may also be in error by a factor of two.

Energy measurements were performed on oscilloscope photographs and, more accurately, by means of a 20-channel Atomic Instrument Company pulse analyzer, using the annihilation radiation and the 609-kev line of RaC as standards. The results are 542±2 kev for the Rn^{220} line and 510±2 kev for the Rn^{222} line.

Within the accuracy of our experiments, the energy of the radon line could not be distinguished from that of the annihilation radiation. Although positron emission in alpha decay seems unlikely, we tested the radiation for coincidences. The totally negative result proves that it is a nuclear gamma ray.

In either decay, the observed energy almost certainly corresponds to the first excited state in Po^{216} and Po^{218}, respectively. The position of these levels fits the trend of the energy of the first excited state as function of neutron number in that region, as indicated by the two Po isotopes, Po^{212} and Po^{214}, for which excited states were previously known.[3] Failure to observe higher energy lines in either case indicates that excitation of higher levels must be weaker by at least a factor of ten.

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