moment when the temperature rise was stopped. The above phenomena could not be attributed to the decrease of the work function of the cathode surfaces by heating, because (1) the counting rate was not a function of the temperature itself but of its sense and rate of change, and (2) the photo-sensitivity (by yellowish-red light from *W* filament lamp) decreased by heating as shown in Fig. 1a, though it increased gradually with time when the counter was kept at room temperature, as was found by Nonaka.[1] A tentative explanation can be given along the lines of adsorption and evaporation of the quenching gas molecules and the negative ions from the cathode surfaces.[2] A full account will appear in the *Journal of the Physical Society of Japan*.

[1] I. Nonaka, J. Phys. Soc. Japan **3**, 322 (1948).
[2] The author is indebted to Professor I. Nonaka for his kind discussion on these points.

The Gamma-Rays from Neutron-Activated Gold

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WITH the advent of the study of photo-electron and pair production "lines" in the scintillation gamma-ray spectrometer,[1] there arise many fruitful applications of this new technique. Some new results in the low energy region, where the photoelectric effect predominates, have been obtained with neutron-activated gold and I^{131}. In the present spectrometer arrangement use is made of a small 1-cm cube crystal of NaI-Tl exposed to the uncollimated gamma-rays from the source, and an E.M.I. 5311 photo-multiplier operating at 1000 volts.

Figure 1 shows the differential pulse-height distribution curves obtained with a neutron-activated gold sample of 0.1 mC a few days after the irradiation. In *A* the features are the 69-kev Hg x-ray below 10 volts, the well-known 411-kev Au^{198} gamma-ray below 40 volts, and the unresolved hump between 10 and 20 volts. This is believed (see below) to correspond to the 159-kev and 209-kev lines known to belong to 3.3-day Au^{199}, which is formed by two successive (n,γ) reactions on Au^{197} during the irradiation,[2] and

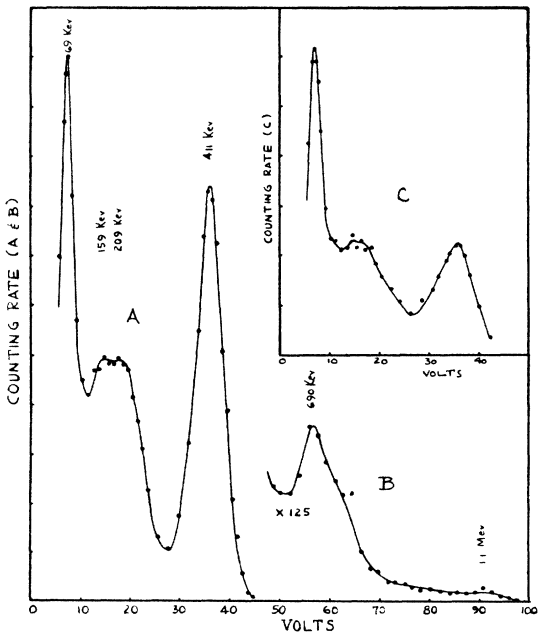

FIG. 1. Scintillation spectrometer pulse-height distributions for the gamma-rays from neutron-activated gold. *A*. Lower energy gamma-rays and x-ray. *B*. Counting rate scale ×125 to show new high energy components. *C*. Relative distribution of *A* after 11 half-lives of Au^{198}.

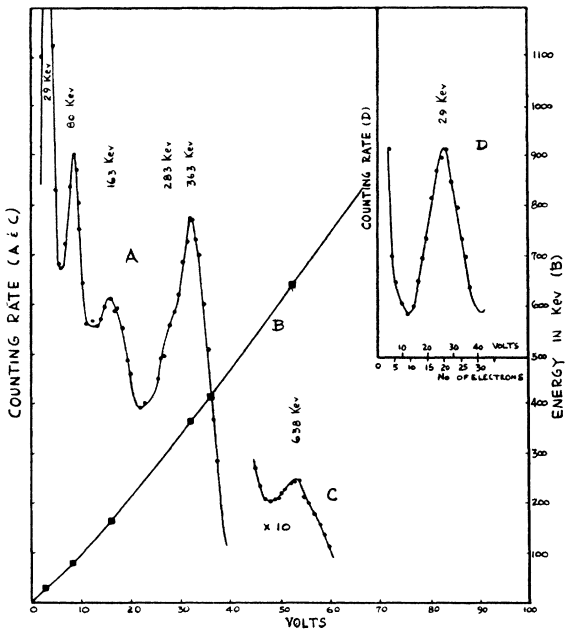

FIG. 2. Gamma-ray from I^{131}. *A*. Lower energy gamma-rays and x-ray. *B*. Energy-pulse-height relationship showing slight lack of linearity. *C*. Counting rate scale ×10 to show 638-kev component. *D*. X-ray at 29 kev shown on higher gain setting, with scale to show pulse heights estimated in terms of the number of electrons collected from the photo-multiplier cathode.

also to a contribution due to the Compton effect of the 411-kev gamma-ray. The lines occur at the full gamma-ray energies because of the trapping in the crystal of the low energy radiations and particles following the initial photoelectric effects. In *B* the counting rate scale has been magnified 125 times, and one can see clearly the presence of a new 690-kev gamma-ray below 60 volts and a new 1.1-Mev gamma-ray near 90 volts.[3] The calibration curve used to determine these energies is given in Fig. 2. In Fig. 1(*C*) the low energy region is given once again, this time after a lapse of 30 days from the observations of 1(*A*). The counting rate scale is given arbitrarily, but it is evident that the 2.7-day 411-kev component has decayed more rapidly than the rest of the curve. The decay rate for the curve below 20 volts agrees with that for a mixture of 3.3-day Au^{199} and 2.7-day Au^{198}. The relative sizes of the x-ray peaks in *A* and *C* suggest a large internal conversion coefficient for the Au^{199} 159-kev and 209-kev lines. Because of the much lower counting rates involved it has not been possible to follow the high energy components over more than 3 or 4 half-lives. The half-life of these appears, however, to be less than 3.0 days, and probably close to 2.7 days. One can therefore draw some interesting conclusions concerning the decay scheme for Au^{198}. The energy of the 411-kev line adds to the 690-kev line to give the component at 1.1 Mev, thus suggesting that the latter corresponds to a cross-over transition. We therefore visualize the existence of excited states in Hg^{198} at 411 kev and 1.1 Mev, and a complex beta-spectrum for Au^{198} which would consist of two components[4] of 960 kev and 270 kev (say two percent). This lower energy component has apparently not yet been detected.

The pulse-height-energy calibration curve for the scintillation spectrometer has been shown to be almost linear, but not exactly so. Figure 2 for I^{131} (gamma-rays 80 kev, 163 kev, 283 kev, 363 kev, and 638 kev, and x-ray 29 kev for Xe) illustrates the necessity of having such a curve (2(*B*)) for the instrument, using known gamma-ray energies. In the calibration curve a reference point corresponding to the Au^{198} 411-kev line is included. A slight curvature which is most marked below 150 kev may be observed, and thorough testing having shown that this curvature can only be

attributed to the photo-multiplier crystal combination, it may possibly represent a lack of exact linearity in the crystal light output-energy relationship for low energies.

In Fig. 2(*D*) is shown the 29-kev x-ray of Xe, obtained with a somewhat larger gain setting of the linear amplifier. From the resolution of this low energy line (50 percent), and other considerations, it has been possible to reconstruct approximately the pulse-height scale in terms of the numbers of electrons collected from the cathode. It is interesting to note that the noise level rises rapidly only below pulse heights corresponding to 3 or 4 electrons collected by the first dynode (or approximately 5 kev on the calibration curve[5]).

This project has been assisted by the National Research Council of Canada.

[1] R. W. Pringle, Nature **166**, 11 (1950). Pringle, Roulston, and Standil, Phys. Rev. **78**, 627 (1950). J. A. McIntyre and R. Hofstadter, Phys. Rev. **78**, 617 (1950). P. R. Bell and J. M. Cassidy, Phys. Rev. **79**, 173 (1950).
[2] R. D. Hill and J. W. Mihelich, Phys. Rev. **79**, 275 (1950).
[3] These results are in agreement with observations obtained recently by one of us (S.S.) with a beta-ray spectrometer in the laboratory of Dr. J. A. Gray.
[4] D. Saxon, Phys. Rev. **74**, 297 (1948).
[5] Pringle, Roulston, and Taylor, Rev. Sci. Inst. **21**, 216 (1950).

The Gamma-Radiation of Ba^{131}

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FOR determination of the energies of gamma-rays less abundant than the 496-kev gamma-ray of Ba^{131} barium nitrate was activated with the highest neutron flux available at the Oak Ridge National Laboratory. The gamma-radiation intensity of Ba^{131} received was about twice that of the previous activation. The barium was chemically purified and after disintegration of Ba^{133} was studied with a thin-lens spectrometer. A broad increase in the counting rate of photo-electrons was observed in the range corresponding to 180 to 220 kev indicating the presence of several gamma-rays. Only two peaks were sufficiently strong to define clearly the photo-electron energies. These peaks are shown in Fig. 1. The separation of peaks indicates that they are *K* and *L* peaks of a single gamma-ray of 213.5±2 kev. The energy values of this gamma-ray were calculated on the basis of averages, of several runs, for the *K* peak of 213.2±1 kev and for the *L* peak of 213.8±2 kev. The probable error was determined from the uncertainty in estimating exact peak positions. The 213.5-kev gamma-ray determined by the spectrometer probably corresponds to the previously reported gamma-ray of energy 220±10 kev found by absorption measurements.[1]

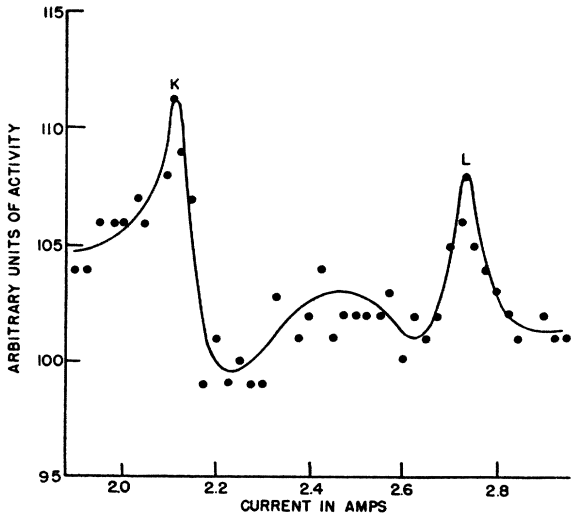

FIG. 1. Barium 131—*K* and *L* photo-electron peaks of 213.5±2-kev gamma-rays—lead radiator.

The authors sincerely appreciate the activation of the barium by the Oak Ridge National Laboratory.

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[1] Yu, Gideon, and Kurbatov, Phys. Rev. **71**, 382 (1947).

A Method for Measuring Paramagnetic Absorption on Small Samples

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October 2, 1950

WE have found it possible to make absorption measurements on very small samples of paramagnetic material.

In our apparatus, the two side arms of a magic tee are each terminated by a cavity. The cavity containing the sample is rectangular in shape and operates on the TE_{011} mode; the other one is a cylindrical TE_{011} resonator with means provided to vary its *Q*-factor within large limits, making it possible to set the resonance amplitude at the same value in both cavities. By tuning them to slightly different frequencies, and using a frequency sweep on the Klystron, we get the two resonance curves side by side on the oscilloscope. With a suitable vertical gain, amplitude comparison can thus be made quite accurately.

Using this apparatus, we found for the absorption of $MnSO_4 \cdot 4H_2O$ a value somewhat different from that given by Cummerow *et al.*[1] The shape of our curve (Fig. 1) seems to be

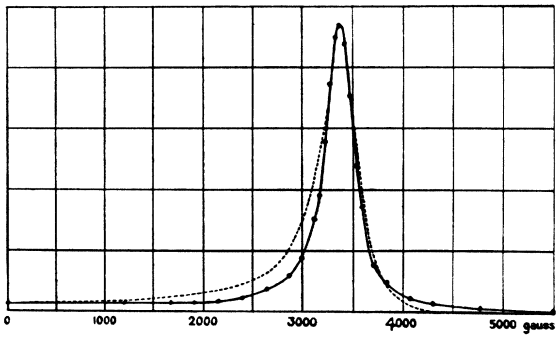

FIG. 1. Absorption curve of $MnSO_4 \cdot 4H_2O$.

closer to the theoretical curve of Frenkel; the normal paramagnetic susceptibility, χ, obtained from the integrated surface under the curve (0.25×10^{-25} cm³/ion) also fits better with direct measurement.

We would suggest as a possible explanation for this discrepancy that the resonant rotation of the polarization plane[2] in the cavity when it is filled with a paramagnetic salt will tend to change the *Q*-factor. Our method seems to be free from this objection, as we used only thin samples in the vicinity of the walls.

[1] Cummerow, Halliday, and Moore, Phys. Rev. **72**, 1233 (1947).
[2] This phenomenon was predicted theoretically by Kastler (Comptes Rendus **228**, 1640 (1949)) and has been observed experimentally by Ryter *et al.* (Physica, Comptes Rendus de la Conférence sur le Magnétisme, Amsterdam, 1950).