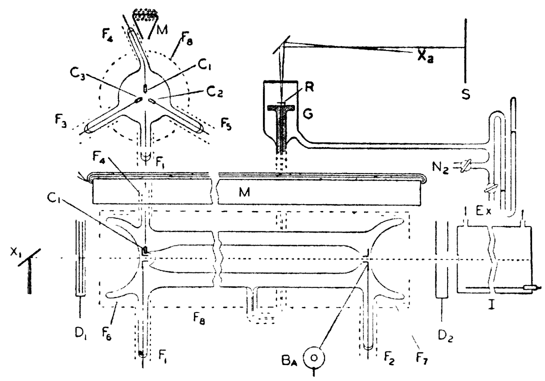

FIG. 1. Schematic diagram of the apparatus.

by a membrane manometer.[5] Furnaces F_2–F_7 prevent Hg from condensing in remote areas. The "cathode" and anode "buttons" of Mo have ∼3 mm holes and clear the windows by ∼1 mm.

The arc current is ∼5 amp. d.c. and the Hg pressure ∼1 atmos. (no rare gas). The x-ray tube current is ∼28 ma, and the primary voltage 80. The former is held to about 0.3 percent and the latter to about 0.1 percent. The length L of the tube between windows is ∼27 cm and the inside diameter 2.0 cm.

The method is to operate the arc at a pressure p_1, measuring the strength of the emergent x-rays, then to shut off the arc and adjust the Hg pressure downward to a pressure p_2, such that the x-ray reading is the same as before. Meanwhile heat is applied by the removable furnace, F_8, to keep the tube at a temperature T_2 well above the Hg condensation point. Then since the x-ray beam traverses the same number of Hg atoms in both cases, it follows that

$$p_1\left[\int\frac{dl}{T}+\frac{L_1}{T_1}\right]=\frac{p_2L}{T_2}, \tag{1}$$

where L_1 is the length of the uniform section of the arc (∼25.5 cm) and T_1 its axial temperature. The integral is taken graphically over the end sections, with the help of fine thermocouple measurements of window temperatures and pyrometer measurements of "button" temperatures, extrapolating the temperature curves so found smoothly to T_1. A value of T_1 is thus found by trial which will satisfy (1).

The mean of four series of runs occupying about 10 hours each gave for T_1 the value 6600±200°K. This appears to be at least 800° higher than would be predicted for this arc either from the work of Koch[4] or from the latest work of Elenbaas.[6]

A fuller account will be published elsewhere. We are indebted to Professor C. Nusbaum and the Case Institute of Technology Physics Department for the use of their x-ray facilities, and to Mr. P. D. Cargill for assistance in making the later measurements.

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[4] O. Koch, Zeits. f. Physik **126**, 507 (1949).
[5] C. Kenty, Rev. Sci. Inst. **11**, 377 (1940).
[6] W. Elenbaas, Philips Research Reports **2**, 20 (1947).

The Temperature of the Mercury Arc

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USING a quartz Hg lamp as its own gas thermometer,[1] the average temperature of the vapor is calculated from the volume of the bulb, the observed pressure, and the weight of Hg. Pressures are measured to 0.3 percent with a quartz membrane manometer.[2] Corrections are calculated for the relatively cold vapor in the end sections, with the aid of fine thermocouple measurements made all over the lamp. The lamps were 2.0 cm i.d., approximately 25 cm long, and contained about 3 mg Hg per cm of length. (No rare gas.)

The average temperature of the vapor in the uniform section, based on three different lamps operating horizontally with magnetic control on d.c. at 40 w/cm (∼5 amp.) is 2850±50°K. This is 12 percent higher than the value obtained by Elenbaas[1] for a similar arc. The difference is ascribed to differences in the method of making end corrections.

With an axial temperature of 6600°K determined by x-rays (see preceding letter), and a wall temperature of 845°K, taken from the thermocouple measurements, a $T(r)$ curve is now found by trial, using graphical integration, which will give an average temperature of 2850°K and satisfy a $T^{9/8}$ power law[3] of heat conductivity from the edge of the arc core (at $r\cong 0.5$ cm) to the wall.

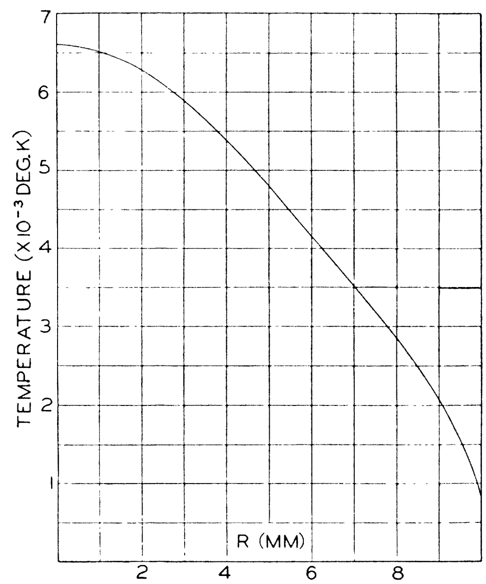

FIG. 1. Temperature distribution in the Hg arc.

This temperature curve (Fig. 1) and the measured gradient (7.94 v/cm) and current (5.07 amp.), together with the Saha and Langevin equations, are used to calculate the cross section σ for elastic collisions of electrons with Hg atoms. The result is 12×10^{-15} cm^2 (420 cm^2/cm^3) in quite good agreement with the results of Brode,[4] but threefold larger than the value found by Elenbaas in studying a dissimilar arc.[3]

With the above value of σ, Cravath's formula predicts the observed elastic heat loss[5] of ∼10 w/cm if the electron temperature exceeds the gas temperature by ∼40°K.

The output of the yellow lines as measured for a dissimilar arc by Elenbaas[3] can be accounted for on the basis of Boltzmann populations for the $6^3P_{2,1,0}$ states and cross sections for two-stage excitation of 6^3D which are tenfold greater[6] than for single-stage excitation, provided a temperature is used which is 450°K higher than that used by Elenbaas, whose calculations failed to account for the excitation by a factor of 100.

With this same temperature increase, σ as calculated from Elenbaas' experiments agrees with the value found here.

The present results indicate that the A values for the yellow lines, found by Schouten and Smit[7] and used by Elenbaas in calculating Hg arc temperatures are several-fold too high. This appears possible from calculations which indicate that there was self-absorption of the 2537A line in Schouten and Smit's experiments and that there were far too few electronic collisions to give

Boltzmann populations for the 6^3D states of Hg, as assumed by these authors for their Hg doped carbon arc.

Details will be published elsewhere.

[1] W. Elenbaas, Physica 1, 211 (1934).
[2] C. Kenty, Rev. Sci. Inst. 11, 377 (1940).
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[4] R. B. Brode, Rev. Mod. Phys. 5, 243 (1933).
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The Gamma-Rays from $Be^9(\alpha, n)$

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We have recently applied a scintillation gamma-ray spectrometer[1] to the study of high energy gamma-rays which give rise to electron pairs in the scintillation element of NaI (Tl), as a result of their interaction with the I atoms in the crystal lattice. The total kinetic energy of the pairs ($E_\gamma - 1.02$ Mev) appears as the energy of pair production lines when the differential pulse-height distribution of the crystal scintillations is examined in an arrangement similar to the one which we have been using in the lower energy region.[1] Used in this manner the device might be termed a scintillation pair spectrometer.

A satisfactory resolution has been achieved as a direct consequence of the high energies involved and of certain improvements to the original equipment, and we wish to report some interesting results which have been obtained with the very weak gamma-rays produced in the bombardment of beryllium with polonium alpha-particles. These gamma-rays are attributed to the de-excitation of the excited levels of the residual C^{12} nucleus which is formed in the reaction. Previous measurements of these gamma-ray energies[2] have yielded somewhat confusing results, but much work has been done on the level scheme involved by a study of the neutron groups which are produced.[2] It was therefore thought to be of interest to investigate the gamma-rays with the scintillation pair spectrometer, which is ideally suited to a study of very weak sources.

The ThC″ gamma-ray of 2.62 Mev was used for the purpose of calibration (Fig. 1), and a small pair production peak, A, due to this gamma-ray can be identified at 1.60 Mev on the pulse-height scale. This is superimposed on a well-defined Compton distribution, B. As the pair production cross section is relatively low for this gamma-ray energy, an accurately known gamma-ray of somewhat higher energy, if available, would be better suited for calibration purposes. The source used was about 10 grams of thorium nitrate, which illustrates the extreme sensitivity of the device. The Po-Be source strength was not known accurately but was believed to give approximately 5×10^3 neutrons/sec. The direct effect of these neutrons on the crystal was shown to be small and the pulse-height distribution curve obtained with this source is substantially due to gamma-rays alone. The predominant feature of the C^{12} curve is the pair production peak, C, corresponding to a gamma-ray energy of 4.40 ± 0.05 Mev superimposed on a sharp Compton distribution, D. The resolution of this line, defined in terms of its full width at half-height, appears to be about eight percent. This sharply resolved peak gives us confidence that the linear relation[1] between pulse height and energy extends to this region, as otherwise a broad distribution would be obtained as a result of the nature of the pair production process. No significant gamma-ray of energy in the range 2 to 4 Mev is found. However, there is evidence for the existence of a very weak gamma-ray at approximately 7.2 Mev. A detailed study of this region was difficult because of the weakness of the available source, and the low relative intensity of the gamma-ray which has been estimated as about one percent of the lower energy component.

The existence of an excited level of C^{12} at 4.40 ± 0.05 Mev and the absence of other levels except the weak high energy 7.2-Mev level is in complete agreement with results which have been obtained recently by Bradford and Bennett[3] from a study of the neutron groups involved.

A considerable amount of work has been done on the study of the photo-electron lines produced by low energy gamma-rays in the scintillation spectrometer and a report of this work will be published shortly. The National Research Council of Canada has given us support in this project.

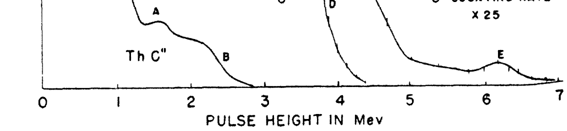

Fig. 1. Differential pulse-height distributions, showing the pair production peaks obtained with high energy gamma-rays. The ThC″ 2.62-Mev gamma-ray has been used to calibrate the pulse-height scale. A. Pair production due to ThC″ 2.62-Mev gamma-ray. B. Compton edge due to ThC″ 2.62-Mev gamma-ray. C. Pair production due to C^{12} gamma-ray (4.40 Mev). D. Compton edge due to C^{12} gamma-ray (4.40 Mev). E. Pair production due to weak C^{12} gamma-ray (7.2 Mev).

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[2] See W. F. Hornyak and T. L. Lauritsen, Rev. Mod. Phys. 20, 191 (1948). T. L. Lauritsen, Nuclear Science Series, No. 5.
[3] C. E. Bradford and W. E. Bennett, Phys. Rev. 77, 753 (1950).

Can the Rectifier Become a Thermodynamical Demon?

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A resistor R, maintained at the absolute temperature T, is a source of random electromotive forces e_ν

$$\langle e_\nu^2\rangle_{\text{Av}} = 4RkTd\nu \tag{1}$$

for a small frequency interval $d\nu$. This is the well-known Nyquist formula. Let us connect the resistor in series with a rectifier. It seems as if the rectifier should rectify these random oscillations and produce a direct voltage. With a large number of such circuits in series one might obtain a voltage high enough to charge a battery. This means a possibility of doing work with just one source of heat at one temperature, in obvious contradiction with the second principle of thermodynamics.

Let us investigate how this problem can be solved. We consider the circuit of Fig. 1 with an impedance, at frequency ν,

$$Z = R + jX \tag{2}$$

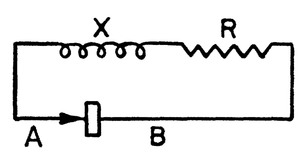

Fig. 1. Circuit with rectifier.