scope" for exploring small areas of the sky is being investigated. The intensity of the penetrating radiation is very low for such a purpose if the definition of really small areas is desired unless, of course, later observations show the penetrating radiation to come from particular small areas of the sky rather than uniformly from all directions. An estimate hazarded on the basis of present data, assuming uniform intensity per unit solid angle, gives as the order of magnitude one true coincidence per 1,000 minutes for counters of cross-section 50 cm^2, subtending one square degree in the sky. Automatic recording of the amount of the penetrating radiation coming from particular areas of the sky, using two tube-counters and a special "coincidence circuit" somewhat similar to that recently published by Bothe [Zeits. f. Physik, **59**, 1 (1929)] was begun here early last November. The resolving power (for our circuit between 0.005 and 0.001 second) of such an arrangement without *multiple* coincidences constitutes a severe limitation on the smallness of the area which can be observed.

A few practical notes on a brief oscillographic study of the recovery-time of a tube-counter and associated amplifier-circuits under various conditions may be of interest to others who are using the instrument. The high resistances (5×10^9 ohms) used by Geiger and Müller and others require the tube-counter to operate at a variable voltage, since the time-constant of the circuit is even larger than the average time between counts, whereas lower resistances restrict the range of voltages which give satisfactory counting. By connecting the central wire of the tube-counter directly to the grid of the amplifier-tube, the recovery-time of the tube-counter may be observed. Oscillograms have been taken using this circuit with resistances from 1 to 5,000 megohms. The recovery-time increases rapidly as the voltage is raised above the minimum critical voltage at which counts begin (which is the same for all values of R), and varies by a factor of perhaps five for different single counts at any given voltage. The average recovery-time (to within five volts of the initial potential on the central wire) varies from perhaps 0.002 second at a voltage midway in the working range (of only a few volts) for $R=1$ megohm, to two seconds or more for $R=5{,}000$ megohms, where the true working range (actual voltage between central wire and tube) is considerably more than 100 volts. In spite of this very long recovery time of the tube-counter itself, however, a $0.00004\mu f$ blocking condenser between the tube-counter and the amplifier-grid, and a grid-resistance of 10 megohms, as used by Bothe, gives satisfactory counts on the first amplifier-tube up to several hundred per minute, and the recovery-time of this amplifier-tube is of the order of 0.001 second. The oscillograms using this arrangement show that of two counts 0.01 second apart the second one will be usually missed, but counts 0.1 second apart give ample impulses (UX201A tubes were used). These results could have been safely inferred, but perhaps some interest may be attached to their demonstration by oscillograms.

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Temperature Shift of Spectral Lines and Pole Effect in Vacuum Arc

The work of many investigators has shown that the wave-length of most emission lines is a linear function of the total pressure acting when the vapor is in an arc, a furnace, or an absorption tube. It has been considered that the pressure shift per atmosphere is independent of the temperature. This implies that the experimental wave-length of a line from a source operating at constant pressure is independent of temperature. The chief purpose of this note is to report experimental evidence indicating that this view may be incorrect.

Two conclusions may be drawn from previous work: (1) that the wave-length of a line under given conditions of temperature and pressure is, at least for low values, independent of the partial pressure of the vapor, and (2) that ionic density plays a small part, if any, in the phenomenon of pressure shift. The first is justified by the conclusion of Babcock[1] that pressure shift is independent of changes in vapor density. The second may be justified by consideration of the results of King[2] and of Füchtbauer, Joos, and Dinkelacker.[3] King found a larger pressure shift per

[1] Babcock, Astrophys. J. **67**, 240 (1928).
[2] King, Astrophys. J. **35**, 183 (1912).
[3] Füchtbauer, Joos, and Dinkelacker, Ann. d. Physik **71**, 204 (1923).

atmosphere in the furnace than Babcock[1] found for the same iron lines in the arc. The value of the mean ratio for the pressure shift of lines common to the two lists is 2.3 with an average deviation of 0.3. The second paper reports pressure shifts for λ2537 of mercury in absorption at room temperature. These results indicate that molecular density, while not the ultimate cause, is probably the controlling factor in pressure shift.

An increase in pressure at constant temperature indicates an increased density of molecules. This change usually causes an increase in wave-length. A decrease in temperature at constant pressure might be expected to operate similarly.

The core of an iron arc of the Pfund type with cathode below is surrounded by a rather thick envelope of iron vapor and iron oxide dust. In an effort to establish the existence of a temperature shift a layer of this envelope was used by the author as a low temperature source of iron lines, while the central section of the arc with polarity reversed was used as a high temperature source. Two of the three lines selected for this test showed a shift in the direction indicated above, and of the right order of magnitude.

In order to check these results plates were taken of λ5890 of sodium. Shifts measured between four different types of sources gave results qualitatively in agreement with that indicated by the previous paragraph. It is considered that neither line asymmetry nor fine structure, as reported by Minkowski[4] and Schüler[5] respectively, can account for all the experimental data as easily as the hypothesis here suggested.

[4] Minkowski, Zeits. f. Physik **55,** 16 (1929).

[5] Schüler, Naturwiss. **16,** 512 (1928).

It therefore seems possible to measure, by means of this phenomenon, effective flame, arc, and furnace temperatures when the pressure is known. Assuming that the wave-length of a line is a linear function of the number of molecules per unit volume, that ionic fields of high value were absent from the sources of Babcock and King, and that the effective temperature of King's furnace was 2000°C, the calculated temperature of the effective emission point of Babcock's iron arc for the lines common to both lists is 5000°C ±700°C.

St. John and Babcock[6] found that a 6 mm iron arc was practically free from pole effect at pressures below 10 cm. However, an anomalous behavior of the yellow sodium lines has been reported by Kiess.[7] Both lines showed a shift of 0.004A between absorption in a low pressure tube and emission in a vacuum arc at 6 cm pressure. This indicates either that the pressure shift is non-linear at low pressures or that a positive pole effect existed in the arc used. Two sets of plates of λ5890 taken by the author showed a positive pole effect of 0.005A and 0.006A respectively in a carbon arc operated at about 10 cm pressure. Therefore it is suggested that care be used in applying this result of St. John and Babcock to any conditions other than those investigated by them.

All plates were taken at Yale University.

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[6] St. John and Babcock, Astrophys. J. **42,** 231 (1915).

[7] Kiess, J.O.S.A. and R.S.I. **18,** 169 (1929).

Emission of Positive Ions From Thoriated Tungsten

In an earlier note, it was reported that tungsten when heated gave off positively charged tungsten ions. The emission from thoriated tungsten has been investigated and in addition to tungsten ions of mass 184, thorium ions of mass 232 and an ion of mass 247 ± 2 have been obtained. This latter ion may be thorium monoxide, although all attempts to reduce it with H_2 have failed. It appears at an estimated temperature of about 2300°C. The alternative explanation is that it is some other extremely stable compound or an element. An x-ray investigation of various thorium sources is under way to settle this last possibility.

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