radiation was observed. This result has been verified by means of photographic spectra, which show a maximum of the general radiation at about 0.95 Å.U., which is about 35 per cent. greater than the wave-length of the exciting ray.

The energy in this general radiation is roughly 30 per cent. as great as the energy of the scattered K rays. Previous experiments have shown that when shorter wave-lengths are employed, the energy in the fluorescent rays may be even more prominent than the truly scattered rays. If we suppose that the incident x-ray beam ejects electrons moving forward with a kinetic energy hC/λ, where λ is the wave-length of the exciting ray, and if the ejected electron is oscillating at such a frequency that as observed in the direction of motion the wave-length is λ, on account of the Doppler effect the wave-length of the radiation at right angles with the primary beam will be very close to that of the fluorescent rays observed in these experiments.

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OSCILLATIONS OF TEMPERATURE OF AN INCANDESCENT FILAMENT, AND THE SPECIFIC HEAT OF TUNGSTEN.

BY K. K. SMITH AND P. W. BIGLER.

THE primary object of this experiment was to test the practicability of using thermionic currents to record rapid changes in the temperature of a filament. By means of a double high-frequency oscillograph we have obtained continuous photographic records showing simultaneously the cyclic variations in thermionic emission from an incandescent tungsten filament in vacuo, and the variations in the alternating voltage across the filament. The thermionic current is a direct current on which are superposed oscillations of twice the supply frequency, which is 60 cycles per second. The constant potential difference, 220 volts, between the filament and the cylindrical anode was more than sufficient to secure saturation, and consequently variations in the thermionic current were produced wholly by changes in temperature. The thermionic current was returned through one strip of the oscillograph to the middle of a high resistance, and thence to the two ends of the filament so that the disturbing effect of the thermionic current was negligibly small. The other strip of the oscillograph was in series with a voltmeter, and this strip and the voltmeter formed a second shunt across the filament.

From observations on the change in the mean thermionic current resulting from a known change in the mean temperature, the measured variations on the plates have been translated into oscillations of temperature above and below the mean value. The lag of temperature behind the power has been found on the assumption that the thermionic emission is in phase with the temperature.

The theoretical relation between the oscillation in temperature and the heat capacity of the filament was deduced by Corbino[1]

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[1] Phys. Zeitschr., XI., pp. 413–7, 1910.

Writing c = mean heat capacity of the wire in joules per degree,
$e_0 \sin \omega t$ = voltage between the ends of the filament,
T = instantaneous temperature,
$f(T)$ = total rate of loss of energy from the wire,
a = temperature coefficient of resistance,
r_m = resistance at mean temperature T_m,
θ = variation in temperature from T_m.

he has, from the energy principle,

$$c\frac{dT}{dt} + f(T) = \frac{e_0^2 \sin^2 \omega t}{r_m(1 + a\theta)}.$$

When θ is small in comparison with T_m, and Q is written in place of $a \cdot f(T_m) + df(T)/dT$, the differential equation reduces to

$$c\frac{d\theta}{dt} + Q \cdot \theta = -f(T_m) \cos 2\omega t.$$

The solution of this equation can be expressed in the form

$$\theta = \Theta \cdot \cos (2\omega t - \phi),$$

where Θ = the amplitude of the oscillation of temperature $= [-f(T_m) \cos \phi]/Q$, and $\tan \phi = 2c\omega/Q$.

Eliminating Q between the last two equations, and replacing $f(T_m)$ by W, the mean power spent in the wire, Corbino expressed the heat capacity in the form $c = -(W \sin \phi)/(2\omega\Theta)$.

The mean temperature of the filament was calculated from Langmuir's data on the volt-ampere characteristics of tungsten.[1] The filament, 0.004 cm. in diameter and 14.25 cm. long, was mounted along the axis of a pyrex tube 2.5 cm. in diameter, which contained a concentric cylinder of copper gauze 2.28 cm. in diameter. The evacuated lamp was heated in a furnace for a number of hours to free it from gases, and a very high vacuum was maintained while the experiments were performed.

The results for the plates on which measurements have been completed are as follows:

Plate.	Mean Temp. T_m.	Watts W.	Θ °	ϕ °	Spec. Heat $S = \dfrac{c}{(\text{mass of filament}) \times 4.18}$
1	2485 K.	13.75	28.5 K.	(91.5)	.0450
2	2455	12.99	24.5	86.4	.0495
3	2435	12.49	24.5	87.1	.0477
4	2413	11.91	22.6	86.8	.0491
5	2368	11.03	21.2	86.1	.0485

$$\text{Mean value of specific heat} = .0479 \; \frac{\text{calories}}{\text{gm. degree}}$$

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[1] Physical Review, VII., pp. 315–6, 1916.

Hence the atomic heat at constant pressure is 8.75 calories per gm. atom per degree. This agrees within the limits of experimental error with the results which Worthing[1] obtained by observing the way in which the resistance of a tungsten filament varied when the heating current was suddenly changed.

An attempt is being made in this laboratory to increase the accuracy of the oscillographic method, and to apply it to the determination of the specific heats of other metals.

An oscillograph might also be used to record the variation in temperature of a filament when a direct current is varied.

NORTHWESTERN UNIVERSITY,
November 7, 1921.

EFFECT OF TENSION ON THERMOELECTROMOTIVE FORCES BY MAGNETIZATION.

BY ALPHEUS W. SMITH.

THE application of tension to nickel at first lessens the change in resistance, length and thermoelectromotive force produced by a longitudinal magnetic field. For larger magnetic fields the reverse is true. In the case of nickel there is a proportionality between the change of length, resistance and thermoelectromotive force. In iron there is a parallelism between the effect of tension on the change of length and change of thermoelectromotive force. The greater the tension, the smaller the initial increase in the thermoelectromotive force and the smaller the magnetic field at which the reversal of the direction of the change takes place. At sufficiently large values of the magnetic field the initial increase in the thermoelectromotive force disappears and there is a decrease for all values of the magnetic field.

The variation of thermoelectromotive forces in iron-copper alloys is very similar to its variation in pure iron. The addition of copper to iron at first increases the fractional change of the thermoelectromotive force. When the alloy contains about 1.5 per cent. copper this fractional change is largest. Beyond this concentration there is a decrease. In these alloys there is a similarity between the Hall constant, the specific resistance and the fractional change of thermoelectromotive force. The first addition of nickel produces an increase in the fractional change of thermoelectromotive force. This is followed by a decrease and a later reversal both in the direction of the thermoelectromotive force and in the sign of its change.

Neither the gas-free theory of electric conduction and thermoelectromotive force nor the gap theory of Bridgman give satisfactory explanations of the effect of longitudinal magnetic fields on thermoelectromotive forces, length and resistance and their variation with tension. The assumption that the number of free electrons is determined by the frequency of the atom and that this number decreases with increasing frequency would lead naturally to the conclusion that an elongation would produce a decrease in frequency, an increase in the number of free electrons and a decrease in resistance. Where

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[1] PHYS. REV., XII., p. 216, 1918.