THE THERMIONIC WORK FUNCTION OF IRON—II

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INTRODUCTION.

In an earlier paper (Mathur, 1953), details have been given of a new method of determining the thermionic constants of molybdenum by measuring the electronic current effusing out of a small hole in an otherwise closed cylinder of the metal heated to various high temperatures in vacuum by being enclosed within a cylindrical graphite furnace tube through which heavy electric currents could be sent from a transformer. The present paper gives the results on iron investigated in the same way.

Iron is of some interest as it changes from the α-form to the β-form at 769° C., to γ-form at 906° C., and to δ-form at 1404° C. Since the measurements were made in the temperature range 1370°–1490°C., the effect of transition between the γ and the δ-forms alone could be investigated.

PREPARATION OF THE EMITTING SURFACE.

A cylindrical tube, with a tightly fitting plug at each end, was made out of an ordinary piece of iron in the laboratory. One of the plugs was solid, while the other was hollow except for a thin wall at the end which had a central hole of diameter 0·751 mm. The overall length of the iron cylinder, when fitted with the plugs, was 8·5 cms. and the outer diameter was 0·8 cms.

On the inner walls of the cylinder and the plugs a coating of iron was deposited by electrolysis from a solution of Ferrous chloride. The prepared surface was then cleansed of all greasy and other organic matter by chromic acid and washing. This was followed by a slight etching of the surface with dilute HCl washed away with hot distilled water. The iron cylinder was then dried and carefully placed on fused quartz rings within the previously de-gassed graphite furnace tube and the vacuum furnace chamber assembled as already described in the paper on molybdenum.

The de-gassing of the iron cylinder was a problem. Although iron melts at 1530° C., it softens at a much lower temperature. Hence there was always a risk of the iron cylinder sagging and short-circuiting the graphite furnace tube. A heavy electric current would then flow through the iron cylinder and melt it. This would not only ruin the graphite furnace but also the surface of the copper plate electrodes and make them unfit for further use. This behaviour of the iron may be due to the rearrangement of crystal planes on its surface on passing from the β- to the γ-form. H. B. Wahlin (1942) also remarks that 'each time the filament passed through the A_3 point, it warped and with repeated transitions twisted sufficiently to short circuit portions of the specimen'. In the light of the above experience, it was decided to do the major part of the de-gassing of the iron cylinder at temperatures lower than about 850° C. and to de-gas at higher temperatures only for very short durations until the value of the thermionic work function attained a steady value. It thus took several weeks to prepare the specimen for the final sets of observations.

When the iron cylinder was considered to be conditioned, the usual practice was to raise the temperature to about 750° C. in about an hour. The temperature was then raised to about 1500° C. and the readings of the thermionic emission were quickly taken with decreasing temperatures till about 1350° C. was reached when no appreciable current could be detected by a galvanometer connected to the Faraday cylinder which collected the effusion current. The furnace was then slowly lowered in temperature and the heating current finally switched off.

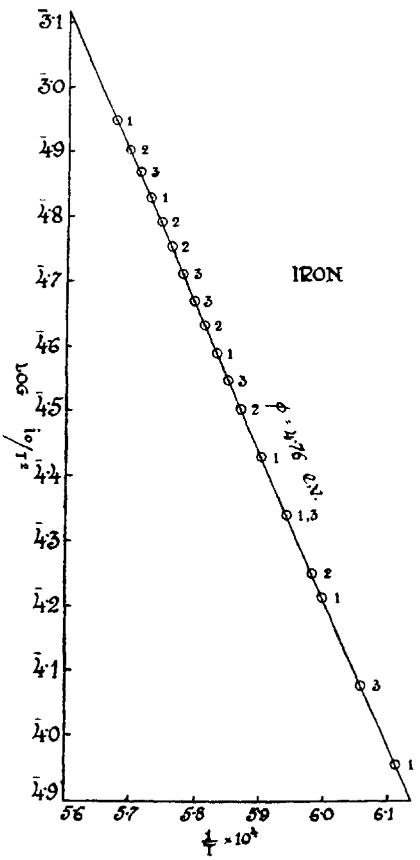
Calculations.

In the paper on molybdenum the following equation has been developed:

$$\log_{10} \frac{i_0}{T^2} = -\frac{\phi}{kT} \log_{10} e + \log_{10} A_0 \frac{Sr^2}{r^2+d^2}$$

where i_0 is the saturation electronic current collected by the Faraday cylinder with a diaphgram of radius r; T is the absolute temperature of the emitting surface; ϕ is the work function; A_0 is the constant in Richardson's T^2 equation of thermionic emission; S is the area of the effusion hole; d is the distance between the effusion hole and the diaphragm of the Faraday cylinder; and K is the well-known Boltzmann constant.

Hence, if a graph of $\log_{10} i_0/T^2$ is plotted against the corresponding values of $1/T$, the value of the work function ϕ can be found from the slope of the curve,



while knowing ϕ, r, d, and the radius of the effusion hole the value of the constant A_0 can be determined.

RESULTS.

The figure alongside gives the values of $\log_{10} i_0/T^2$ against the corresponding values of $1/T$ obtained from observations taken on three different days as indicated by the numbers given near the various points on the line. The value of the thermionic work function, as determined from the slope of the line, comes out to be 4·76 e.v.

Taking the above value of ϕ, and $r = 0{\cdot}426$ cms., $d = 1{\cdot}3$ cms., and the radius of the effusion hole $= 0{\cdot}0751$ cms., the average for different temperatures of the value of A_0 was found to be 705 amp./cm.^{2} deg.^{2}

It will be seen that since a straight line fits through the observations no particular change occurred in the value of the work function on account of transitions between the γ- and the δ-forms.

The following table gives the values of the thermionic constants of iron as found by different investigators. (Jentzch, 1908; Hamer, 1922; Roy, 1926; Welch, 1928; Cardwell, 1928; Siljeholm, 1931; Glasoe, 1931; Distler and Monch, 1933; Wahlin, 1942; Mathur, 1953).

Investigators.	Year.	Method.	ϕ in e.v.	A_0 in amp./cm. deg.
1. Jentzch ..	1908	Thermionic ..	4·04	..
2. Hamer ..	1924	Photoelectric ..	4·71	..
3. Roy	1926	,, ..	4·2	..
4. Welch ..	1928	,, ..	3·92	..
5. Cardwell ..	1928	,, ..	4·72 (γ-iron)	..
6. Siljeholm ..	1931	Thermionic ..	4·77 (γ-iron)	..
7. Glasoe ..	1931	Photoelectric & contact potential ..	4·77	..
8. Distler and Monch	1933	Thermioinc ..	4·04	..
9. Wahlin ..	1942	,, ..	4·48 (below β-γ transition).	26
			4·21 (above β-γ transition)	1·5
10. Mathur ..	1953	Effusion ..	4·76 (δ & γ-iron)	705

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SUMMARY.

From the rate of effusion of electrons from a small hole in an otherwise closed cylinder of iron heated in vacuum to different high temperatures the thermionic work function of iron was found to be 4·76 e.v., while the value of the constant A_0 was found to be 705 amp./cm.^{2} deg.^{2} between 1370° C. and 1490° C.

No particular effect of transition from the δ- to the γ-form of iron was noticeable. This was probably due to the comparatively quick changes in temperature during the investigations which did not allow any form of iron to become stable.

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