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The Capacity for Heat of Metals at Low Temperatures.

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(Abstract.)

In the first part of the paper of which this is an abstract, an account is given of the apparatus and the method employed in determining the atomic heats of the metals Na, Al, Fe, Zn, Ag, Cd, and Pb, at various points in the range from 0° to about −160° C.

A new method of maintaining an enclosure for long periods at any desired temperature within this range is described, the Joule-Thomson cooling effect of air on expansion being utilised for this purpose.

Details of the method of controlling the temperature are given; here it suffices to say that there was little difficulty in keeping the oscillations in temperature of the exterior walls of the copper enclosure within a hundredth of a degree in magnitude.

In the case of sodium special experimental difficulties presented themselves, and the internal portion of the apparatus differed in design from that used with the other metals. The platinum thermometer was in the centre of the block, while the heating coil, consisting of insulated manganin wire enclosed in fine metal tubing, was distributed throughout the mass of the metal. This form of heating coil promises to be of considerable service in the investigation of poor conductors of heat.

We may remark that the method employed in this investigation, although differing in fundamental respects from the one used in the previous work,* gave values which closely confirmed those results where the temperature ranges overlapped.

A study of the observations of Nernst on the metals silver and lead has led us to the conclusion that no difference, greater than the probable error of experiment, exists between the values given by his method (electrical) and those obtained in our own investigations. Hence, for the metals Al, Cu, Zn, Ag, and Pb, it is possible to extend the atomic heat curves through the observations of Nernst at liquid air and hydrogen temperatures.

The only data available, at very low temperatures, for Na, Cd, and Fe are those of Dewar at about 50° Abs. But, for reasons given in the paper, we

* 'Phil. Trans.,' A, 800, vol. 213, p. 119 (1913).

are unable to attach to the absolute values obtained by Dewar's method the same weight as to those of Nernst.

In Table I the values of the atomic heats are given at convenient intervals of temperature, so as to facilitate the testing of any theory over an extended range. These values have been obtained from smoothed curves drawn through our observations from 400° to 120° Abs., and extended through the observations of Nernst or Dewar above mentioned.

Table I.

Aluminium.

T (Abs.)	32·4	80	120	200	250	300	340	380
C_p	0·25	2·27	3·74	5·14	5·54	5·81	5·98	6·13

Iron.

T	50	110	150	210	250	310	350	390
C_p	0·98	3·47	4·50	5·36	5·70	6·09	6·28	6·41

Copper.

T	23·5	50	90	130	170	210	250	290	390
C_p	0·22	1·32	3·48	4·78	5·23	5·50	5·70	5·83	6·09

Zinc.

T	30	80	120	160	210	250	310	350	390
C_p	0·94	4·09	5·15	5·61	5·82	5·95	6·10	6·19	6·25

Silver.

T	35	60	100	150	200	260	300	340	380
C_p	1·58	3·32	4·83	5·55	5·83	5·98	6·05	6·12	6·21

Cadmium.

T	50	100	140	200	260	300	340	380
C_p	3·46	5·37	5·79	5·99	6·14	6·24	6·33	6·44

Lead.

T	23	37	50	80	100	140	200	300	380
C_p	2·96	4·50	5·14	5·72	5·87	5·97	6·10	6·32	6·49

Sodium.

T	50	90	150	240	300	330	360	368	373	393	413
C_p	3·50	5·04	5·90	6·36	6·66	6·85	7·33	7·48	7·44	7·39	7·34

In the second part of the paper a brief review is given of the various formulæ which have been proposed for the representation of the atomic heat.

Einstein's theory, based on the conception of the atoms as consisting of a number of Planck's resonators with a single frequency, gives values which are too small at low temperatures.

Nernst and Lindemann's formula, which is an empirical modification of Einstein's expression, taking into account two frequencies, the one the octave of the other, gives values which are, in general, too high at low temperatures.

Debye has given a solution of the general case in which there is a continuous series of frequencies from zero to a certain limiting value characteristic of the substance. The value of this limit frequency can be calculated from the elastic constants. His theory is based on a number of hypotheses which cannot be accepted as being strictly valid, but of the formulæ hitherto published for the representation of the atomic heat curves of the metals, that of Debye gives the closest approximation to the experimental results.

The following three examples show the order of agreement between the observed and the calculated values, and it will be observed that the discrepancies exceed the possible errors of experiment.

Temperature.	C_p (observed).	C_p (calculated).	Difference.
		Aluminium.	
°			
35	0·33	0·35	−0·02
80	2·27	2·33	−0·06
140	4·26	4·26	
200	5·14	5·10	+0·04
250	5·53	5·47	+0·06
300	5·81	5·74	+0·07
380	6·13	6·01	+0·12
		Silver.	
35	1·58	1·64	−0·06
85	4·42	4·53	−0·11
120	5·20	5·21	−0·01
200	5·84	5·78	+0·06
280	6·01	6·01	
360	6·16	6·15	+0·01
		Lead.	
23	2·96	2·95	+0·01
80	5·72	5·64	+0·08
120	5·93	5·91	+0·02
200	6·10	6·13	−0·03
280	6·28	6·28	
360	6·45	6·45	

Of the metals considered in the paper, lead has the lowest frequency and aluminium the highest. In the comparison above given, the limit frequency inserted in Debye's formula is such that the calculated value coincides with the observed value at about 120° Abs., this being the lowest temperature to which we carried our investigation.

The elastic constants of the metals are in some cases so discordant that the calculated values of the frequencies can only be regarded as confirmatory of the value inserted in the atomic heat formulæ.

The following comparison shows the order of agreement between the values obtained by the two methods:—

$V_m \times 10^{-12}$

Metal.	Al.	Ag.	Pb.
V_m (specific heat)	8·0	4·3	1·9
V_m (elastic constants)	8·3	4·4	1·5

Prof. Callendar has kindly inserted a note regarding his theory of atomic heat.

Dilute Solutions of Aluminium in Gold.

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(Abstract.)

The paper deals with the solid condition of alloys containing not more than 5 per cent. by weight of aluminium. The diagram is a concentration-temperature diagram, the atomic percentage of aluminium being measured horizontally from left to right, and the temperature, in degrees Centigrade, being measured vertically.

The alloys melt at varying temperatures, but below the upper line A*abcd* of the diagram they are wholly solid; we may say, approximately, that they are wholly solid below 525° C. Between this temperature and the level of the point L there is a range of 100°. The diagram shows four compartments in this area and records the following facts:—The first area, on the left, indicates the fact that gold can dissolve rather more than 2 per cent. by weight of aluminium to form uniform solid solutions; these we call α. With rather more aluminium we have the complex alloys of the second area, containing, in addition to α, a second constituent β. In the alloys of the third compartment, β is the sole constituent, while in the fourth a new