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Specific Heat of Solid Oxygen between 20° and 4° K

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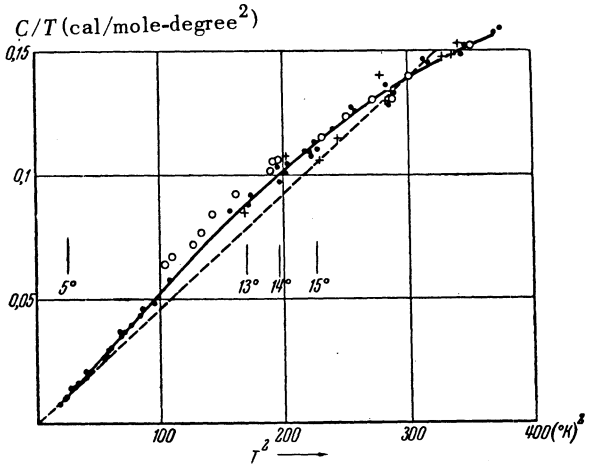
WE have previously reported measurements of the heat capacity of solid oxygen below 4° K [1]. These were undertaken to clarify the question of the character of the magnetic anomalies in solid oxygen. The absence (in the expression for the heat capacity) of a term which depends linearly on the temperature suggested that, at liquid helium temperatures, solid oxygen is in an antiferromagnetic state. It was surmised that a transition of the oxygen to an antiferromagnetic state took place in the temperature interval between 4° and 10° K. In order to verify this surmise, measurements of the heat capacity of solid oxygen have been carried out between 4° and 20° K in the present work.

A calorimeter similar to that described in Ref. 2 was used for the measurement of the heat capacity [2]. A high vacuum was produced in the container as a result of the adsorption by activated charcoal of heat-exchanging helium or hydrogen introduced therein. The temperature scale in these experiments was established with the aid of a carbon resistance thermometer, which was calibrated before each experiment in terms of the vapor pressure of helium and hydrogen*.

TABLE

First series of measurements		Second series of measurements		Third series of measurements	
$T°$ K	C cal/mole-degree	$T°$ K	C cal/mole-degree	$T°$ K	C cal/mole-degree
4.325	0.0343	4.275	0.0361	12.50	1.06
4.387	0.0372	4.32	0.0367	13.06	1.16
4.723	0.0481	4.66	0.0463	13.15	1.21
4.89	0.0544	4.685	0.0485	13.93	1.43
4.947	0.0556	4.727	0.0481	14.02	1.36
5.235	0.0686	5.01	0.0592	14.09	1.51
5.282	0.0756	5.12	0.0575	14.17	1.42
5.47	0.0788	5.67	0.0840	14.26	1.48
5.52	0.0798	5.71	0.0883	14.73	1.61
5.76	0.0937	6.49	0.140	14.8	1.62
5.81	0.0961	6.55	0.140	14.89	1.60
6.32	0.118	7.41	0.213	14.97	1.69
6.37	0.132	7.46	0.215	15.06	1.66
6.95	0.167	8.14	0.285	15.39	1.80
7.67	0.227	8.19	0.304	15.47	1.83
7.78	0.236	8.25	0.296	15.95	2.03
8.70	0.346	8.43	0.312	16.04	2.01
8.75	0.350	8.63	0.350	16.13	1.98
9.25	0.424	8.68	0.343	16.78	2.28
9.72	0.470	8.76	0.359	16.88	2.15
—	—	8.82	0.364	16.97	2.25
—	—	8.97	0.397	17.68	2.59
—	—	10.38	0.599	17.77	2.58
—	—	—	—	18.52	2.74
—	—	—	—	18.61	2.82
—	—	—	—	19.25	3.03
—	—	—	—	19.35	3.08



●-Data of author, O-Data of Clusius, +-Data of Giauque and Johnston.

The results of three series of measurements of the heat capacity of solid oxygen between 20° and 4° K are given in the Table. These same results are plotted in the graph (which gives C/T as a function of T^2) and are compared with the results of the measurements of Clusius[3] and Giauque and Johnston[4] which extend, respectively, to 10° and 13° K. The dotted line in the drawing represents an extrapolation of the cubic temperature dependence of the heat capacity of oxygen, found in measurements between 4° and 1.6° K [1]. It is evident from these results that the heat capacity of solid oxygen increases smoothly for the temperature range 4°-20° K, while, beginning at 5°K, the departure from the cubic law of change of heat capacity with temperature increases. The smooth character of the change in the heat capacity between 4° and 10° K bears witness to the absence of any antiferromagnetic transformation in solid oxygen in the temperature range investigated.

The measurements were carried out at the Institute for Physical Problems of the Academy of Sciences, USSR.

* A thermometer made from a radio resistor was kindly lent by B. N. Samoilov.

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The Theory of Cyclotron Resonance In Metals

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THE present work predicts and studies theoretically a new form of resonance in metals, which differs fundamentally from diamagnetic resonance.[1] In metals close to resonance, the skin-depth δ is much less than the radius r of the orbit in the magnetic field.* Thus in a constant magnetic field $H(H_x=H,\ H_y=H_z=0)$, parallel to the surface of the metal $z=0$, an electron which moves in a helical orbit through a number of revolutions ($l/2\pi r >> 1$ where l is the mean free path) will return several times into the layer of thickness $\delta << r$ where the electric field is large. Thus the motion is similar to that of an electron in a cyclotron with a single dec, so that for a value of ω which is a multiple of the 'cyclotron' frequency $\Omega_0 = eH/mc$ ($\omega = q\Omega_0, q = 1, 2, \ldots$) we shall have resonance. This resonance in metals we shall call cyclotron resonance (as distinct from diamagnetic resonance,** which occurs only in semiconductors, for $\omega = \Omega_0$).

If the magnetic field is not parallel to the surface of the metal, the electrons will pass through the layer once only, and resonance will be absent since the impedance does not depend on the magnetic field.

The condition for cyclotron resonance $\delta << r << l$ corresponds to the anomalous skin effect, so that the system is governed by Maxwell's equations together with the kinetic equation for $f_1(z, E, p, \tau)$, the perturbation to the Fermi distribution function (E – energy, p – momentum, $\tau = (eH/m_0 c)t$, t – periodic time of electron in orbit[2], m_0 – effective mass of electron). The role of boundary condition on f_1 is played by the requirement that f_1 shall be periodic with respect to τ with period $\theta = m_0^{-1} dS/dE$, together with the condition of diffuse reflection at the surface.[3] The problem is solved under the most general conditions of the electron theory of metals – for arbitrary energy dependence $E = E(p)$ and arbitrary collision term $(df_1/dT)_{coll.}$. It turns out that in the anomalous skin effect region, because of the particular form of f_1, the collision