expressed with an average deviation of only 0.001% by the equations having the form suggested by Root.[7]

$$d^{25}_4 = 0.997074 + 0.041882c - 0.001878c^{3/2}$$
$$d^{0}_4 = 0.99987 + 0.04605c - 0.00307c^{3/2}$$

The fifth column shows that the "Grüneisen Effect" is shown by sodium chloride although it is not so pronounced as has been observed with salts of a higher valence type.

The results for the viscosity at 25° can be expressed by the equation $\eta = 1 + 0.00670 \sqrt{c} + 0.07866\ c$ up to 0.2 N with an average deviation of only 0.003%. By adding a term proportional to the square of the concentration the equation which is shown at the bottom of Table I may be obtained which fits the data with an average deviation of 0.005% up to 1 N. If the results are expressed in terms of fluidity, φ, instead of viscosity there is a slight improvement in that the simple two-parameter equation holds up to 0.5 N and the extended three-parameter equation holds up to 2 N.

At 0° we find that as usual the relative viscosity is less than at 25°. Here there is little to choose between the equations expressed in terms of viscosity or of fluidity. The average deviations are slightly greater than at 25°, probably because of the greater difficulty in maintaining temperature control during the hot summer weather when this work was done.

(7) W. C. Root, THIS JOURNAL, **55**, 850 (1933).

The coefficient of the square root term (A) computed by the Falkenhagen and Vernon[8] equation is 0.0060 at 25° and 0.0056 at 0°, whereas the experimentally determined values are 0.0067 and 0.0045, respectively. The agreement is not quite as good as has been found in several other cases, especially at 0°.

Summary

1. The absolute density and relative viscosity of many aqueous solutions of sodium chloride have been determined at 0 and 25°, covering the range of concentration from 0.002 to 2 N.

2. The density of these solutions as a function of the concentration can be expressed by the Root equation, and the viscosity by the Jones and Dole equation.

(8) H. Falkenhagen and E. L. Vernon, *Physik. Z.*, **33**, 140 (1932).

CAMBRIDGE, MASS. RECEIVED JANUARY 14, 1937

[CONTRIBUTION FROM THE METALLURGICAL DIVISION, U. S. BUREAU OF MINES]

The Heat Capacities of Molybdenite and Pyrite at Low Temperatures[1]

BY C. TRAVIS ANDERSON[2]

In previous papers[3] the writer has presented low temperature thermal data on manganese sulfide, ferrous sulfide, calcium sulfide and the sulfides of copper and lead. The present paper deals with the heat capacities of molybdenite and pyrite.

The methods, apparatus and accuracy have been described previously.[4]

Materials

Both samples used in this investigation were naturally occurring minerals. The pyrite used was taken from one large specimen. It was broken, and samples that did not show particles of quartz or discoloration were selected. The material was then crushed and screened, the fines being discarded. Analysis of the sample for iron content indicated a purity of 99.24% FeS_2. The only detectable impurity was 0.02% SiO_2. A 301.4-g. sample with a density of 4.951 at 22.4° was studied.

The sample of molybdenite consisted of laminated flakes about 5 mm. in diameter. Since they could not be crushed, the sample was put through a food chopper and screened to size. The only impurities found in the sample were 0.31% FeS_2 and 0.53% SiO_2, which were corrected for in the specific heat measurements. The calorimeter was filled with 166.4 g., with a density of 4.991 at 20.0°.

The Specific Heats

Specific heat measurements have been made on pyrite from 21.7 to 84°K. by Eucken and Schwers,[5] and three points have been measured by

(1) Published by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)

(2) Assistant physical chemist, Metallurgical Division, U. S. Bureau of Mines, Berkeley, California.

(3) Anderson, THIS JOURNAL, **53**, 476 (1931); **54**, 107 (1932).

(4) Anderson, *ibid.*, **52**, 2296, 2712 (1930); **54**, 107 (1932); **55**, 3621 (1933).

(5) Eucken and Schwers, *Ber. deut. physik. Ges.*, **15**, 582 (1913).

Ewald.[6] No previous low temperature measurements have been reported on molybdenite. The results obtained in this Laboratory on these two sulfides, expressed in gram calories (15°) per gram formula weight, as well as a number of Eucken and Schwers' and Ewald's determinations, are shown graphically in Fig. 1. The experimental values for the heat capacities are given in Tables I and II. The calculations were made on the basis of Fe = 55.84, Mo = 96.0 and S = 32.06.

TABLE I

HEAT CAPACITY PER GRAM FORMULA WEIGHT OF PYRITE (FeS_2)

T, °K.	C_p	T, °K.	C_p	T, °K.	C_p
55.8	1.004	121.2	6.467	252.6	13.91
60.5	1.275	144.2	8.356	273.3	14.40
68.4	1.802	180.1	10.72	286.9	14.60
82.3	2.859	204.9	12.01	292.8	14.77
100.0	4.484	227.5	12.90	297.0	14.79

TABLE II

HEAT CAPACITY PER GRAM FORMULA WEIGHT OF MOLYBDENITE (MoS_2)

T, °K.	C_p	T, °K.	C_p	T, °K.	C_p
56.1	2.297	100.2	5.764	220.4	13.28
60.7	2.601	118.7	7.368	249.5	14.14
70.5	3.264	143.5	9.318	279.7	14.88
80.6	3.944	161.3	10.57	292.3	15.08
		189.5	11.78		

Calculation of Entropies

The conventional method was used in calculating the entropy. The heat capacity curves were extrapolated from the lower points and coincided with Debye functions having the parameters (Θ) for FeS_2, 421, and MoS_2, 280. The following combinations of Debye and Einstein functions were found to fit the specific heat curves per formula weight of these sulfides.

$$C_{FeS_2} = D\left(\frac{421}{T}\right) + 2E\left(\frac{532}{T}\right)$$

$$C_{MoS_2} = D\left(\frac{280}{T}\right) + 2E\left(\frac{528}{T}\right)$$

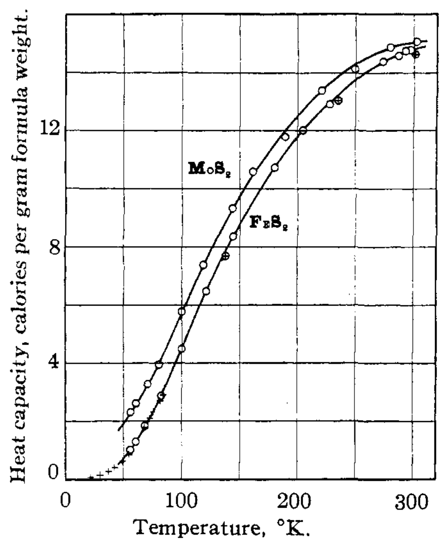

Fig. 1.—The heat capacities of pyrite and molybdenite, in calories per gram formula weight: ○, Anderson; +, Eucken and Schwers; ⊕, Ewald.

The results of the entropy calculations from the experimental heat capacity data and the function sums are given in Table III.

TABLE III

	FeS_2	MoS_2
Extrap. (0–56.2), °K.	0.34	0.99
Graph (56.2–298.1), °K.	12.38	14.07
$S°_{298.1}$ graphical	12.7 ± 0.1	15.1 ± 0.2
$S°_{298.1}$ calcd. from functions	12.7	15.0

Summary

The heat capacities of FeS_2 (pyrite) and MoS_2 (molybdenite) from about 56 to 300°K. have been measured and their corresponding entropies determined as 12.7 and 15.1, respectively.

BERKELEY, CALIF. RECEIVED DECEMBER 30, 1936

(6) Ewald, *Ann. Physik*, [4], **44**, 1213 (1914).