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Enthalpy of Formation and Low-Temperature Heat Capacities of Basic Aluminum Sulfite ($Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$)

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ENTHALPY OF FORMATION AND LOW-TEMPERATURE HEAT CAPACITIES OF BASIC ALUMINUM SULFITE ($Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$)

by

H. C. Ko,[1] J. M. Stuve,[1] and R. R. Brown[1]

ABSTRACT

Calorimetric determinations of low-temperature heat capacities and standard enthalpy of formation were made by the Federal Bureau of Mines for basic aluminum sulfite, $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$. The standard values of entropy (S°), enthalpy of formation (ΔHf°), and calculated Gibbs energy of formation (ΔGf°) at 298.15 K are 85.2±0.1 cal/deg-mole, -943.1±1.2 kcal/mole, and -820.7±1.2 kcal/mole, respectively.

INTRODUCTION

The Bureau of Mines is engaged in a program to investigate processes for recovering alumina from domestic resources. An important part of such process planning and evaluation is the use of basic thermodynamic data to determine energy requirements and efficiencies.

In recognition of the desirability of having such data available when needed, the Bureau of Mines some years ago instituted a program for the determination of various thermodynamic properties (low-temperature heat capacities, high-temperature enthalpies, and enthalpies of formation) of aluminum-bearing minerals. Data have been published for alumina (Al_2O_3) (9),[2] diaspore ($Al_2O_3 \cdot H_2O$) (11, 15), gibbsite ($Al_2O_3 \cdot 3H_2O$) (2, 15), kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) (2, 11), halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) (2, 11), dickite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) (2, 11), anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$) (1, 10, 12), and alunite ($K_2O \cdot 3Al_2O_3 \cdot 4SO_3 \cdot 6H_2O$) (9).

The Bureau, in cooperation with several aluminum producers, has constructed a small pilot plant for the purpose of intercomparing different processing techniques which yield alumina from four domestic raw materials--clay, anorthosite, alunite, and dawsonite. Thermodynamic data relating to the first three were mentioned previously. Additional data on dawsonite have been published by the Bureau (7).

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[1] Research chemist.

[2] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

The present investigation provides low-temperature heat capacities and the enthalpy of formation of monobasic aluminum sulfite, which is an intermediate compound precipitated during the sulfurous acid-caustic purification process for treating clay. The process is described in a Bureau publication by Peters (14).

Heat capacities from 11 to 311 K were determined by adiabatic calorimetry, and the standard enthalpy of formation at 298 K was determined by solution calorimetry. The results of the experimental investigations were combined with other pertinent entropy data to yield the standard Gibbs energy of formation.

No previous similar thermodynamic data have been reported in the literature for basic aluminum sulfite.

MATERIALS

The reference substances used in determining the enthalpy of formation of basic aluminum sulfite were Al(s), $H_2SO_4 \cdot 6H_2O(l)$, $H_2SO_3 \cdot 100H_2O(l)$, $Al_2(SO_4)_3 \cdot 12H_2O(s)$, and $H_2O(l)$.

The aluminum metal was in the form of fine filings which were obtained from a 99.998-pct-pure ingot.

Aluminum sulfate dodecahydrate, $Al_2(SO_4)_3 \cdot 12H_2O$, was prepared by first recrystallizing reagent-grade $Al_2(SO_4)_3 \cdot 18H_2O$, which was then slowly dehydrated for several days over the temperature range 65° to 90° C. Care was taken in adjusting the composition to 12 H_2O of hydration. Analysis by direct ignition showed 18.25 pct Al_2O_3, compared with the theoretical value of 18.26 pct. No significant impurities were detected spectrographically.

Sulfuric acid of the composition $H_2SO_4 \cdot 6H_2O$, sulfurous acid of the composition $H_2SO_3 \cdot 100H_2O$, and the two solvent media, $HCl \cdot 12.731H_2O$ (4.360 molal) and $H_2SO_4 \cdot H_3PO_4 \cdot 0.01Na_2Cr_2O_7 \cdot 15H_2O$ (3.70 molal H_2SO_4 and H_3PO_4, and 0.037 molal $Na_2Cr_2O_7$), were all prepared from reagent-grade materials. Analyses confirmed the compositions as given.

Basic aluminum sulfite, $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$, was prepared by slightly modifying the procedure described by E. Rosenkranz as summarized in the Handbook of Preparative Inorganic Chemistry (3). Aluminum hydroxide was first precipitated from a solution of 400 g $AlCl_3 \cdot 6H_2O$ in 3.2 liters of water. The $Al(OH)_3$ was filtered, washed, and slurried with 2.5 liters of water. Sulfur dioxide gas was then bubbled into the mixture until solution of the $Al(OH)_3$ was complete. The solution was heated to 80° C for 4 hours while stirring constantly. At this point a homogeneous-type precipitation of the basic sulfite occurred and considerable SO_2 was evolved. A plastic bag was used to nearly seal the beaker, thereby maintaining a slight positive pressure of SO_2 during the heating and precipitation step. The basic sulfite was vacuum-filtered, washed, and spread on trays to air-dry for 16 hours. A final treatment consisted of resuspending the basic sulfite in 1 liter of SO_2-saturated water. The mixture was again heated to 80° C for 4 hours. An SO_2 atmosphere was maintained above the solution during heating and cooling to room temperature, and also during the final filtering. The filter cake was then vacuum-dried at room temperature, first by water aspiration, and then by mechanical pump evacuation for several days until the pressure was reduced to 15 micrometers. Analysis of the basic sulfite showed 31.33 pct Al_2O_3, 39.23 pct SO_2, and 29.44 pct H_2O. These values correspond to a formula of $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$. No significant impurities were detected spectrographically. X-ray diffraction analysis showed the material to be well crystallized with a pattern similar to that observed by Rosenkranz, but with more lines and a slight shift in the observed d values. The pattern was indexed[3] on a hexagonal lattice with a_0 = 12.820 A and C_0 = 7.015 A. The relative line intensity (I) and the observed and calculated d values are presented in table 1.

TABLE 1. - Powder X-ray diffraction data of $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$

Observed		Calculated, d, A	hkl	Observed		Calculated, d, A	hkl
I	d, A			I	d, A		
100.........	5.581	5.556	200	2.........	2.1971	2.1970	113
20.........	4.715	4.734	111	2.........	2.1739	2.1776	402
72.........	4.366	4.355	201	4.........	2.1560	2.1553	203
8.........	4.199	4.200	210	8.........	2.1015	2.0998	420
7.........	3.601	3.603	211	4.........	2.0149	2.0116	421
1.........	3.505	3.508	002	1.........	1.9922	1.9945	412
5.........	3.212	3.208	220	3.........	1.8934	1.8896	223
10.........	3.063	3.082	310	8.........	1.8614	1.8628	313
		3.078	112	8.........	1.8476	1.8519	600
55.........	2.9631	2.9659	202	6.........	1.8039	1.8016	422
12.........	2.9233	2.9171	221	7.........	1.7887	1.7889	403
27.........	2.8087	2.8214	311	9.........	1.7543	1.7538	004
1.........	2.7681	2.7778	400	5.........	1.7313	1.7323	104
11.........	2.6936	2.6921	212	2.........	1.6831	1.6832	413
2.........	2.5945	2.5827	401	3.........	1.6737	1.6724	204
34.........	2.5579	2.5491	320	2.........	1.6455	1.6471	611
		2.5467	302	2.........	1.6340	1.6376	602
3.........	2.4219	2.4246	410	4.........	1.6237	1.6201	432
2.........	2.4044	2.3958	321	3.........	1.6078	1.6109	503
4.........	2.3607	2.3670	222			1.6038	440
2.........	2.3088	2.3151	312				
7.........	2.2897	2.2916	411				
		2.2883	103				

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[3] The X-ray diffraction analysis was made by Marion P. Krug, research physicist, Albany Metallurgy Research Center.

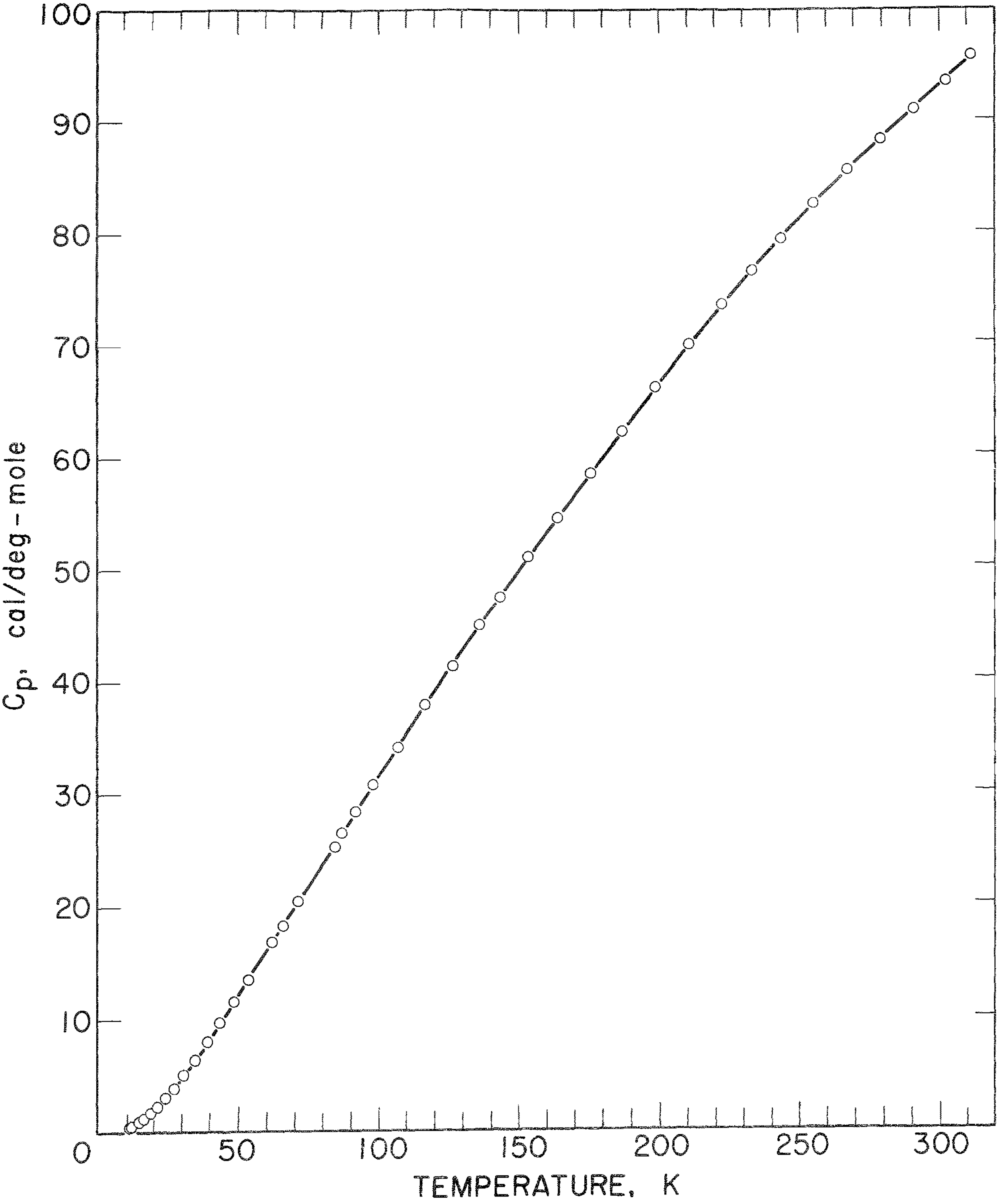

FIGURE 1. - Low-temperature heat capacity of $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$.

LOW-TEMPERATURE THERMAL PROPERTIES

Experimental

Low-temperature heat capacity measurements were determined by means of a precision adiabatic calorimeter. Detailed descriptions of the apparatus and operating procedure were given elsewhere (16). The experimental determinations were made from 11 to 311 K in three ranges as follows: liquid nitrogen range, 80 to 311 K; solid nitrogen range, 47 to 80 K; and liquid helium range, 11 to 50 K.

A nominal bulk volume of 90 ml of sample was used for the measurements. The sample weighed 64.090 g in vacuum. Temperatures reported are based on the International Practical Temperature Scale of 1968 (IPTS-68) (4). Energy units given in this paper refer to the thermochemical calorie (1 cal = 4.1840 joules). Atomic weights are taken from the 1973 Table of Atomic Weights (8).

Temperatures below 15 K were determined with a National Bureau of Standards (NBS) calibrated germanium resistance thermometer. A high-precision platinum resistance thermometer was used from 15 to 311 K. Accurate potentiometric measurements in conjunction with these thermometers permitted a temperature resolution of ±0.001 K or better.

The sample was loaded into a gold-plated copper calorimeter (sample container) in an argon-filled dry box. The argon was subsequently pumped out of the filled calorimeter and replaced with 0.0024 mole of helium gas to improve thermal conductivity within the sample mass.

Results

Experimental heat capacity data are listed in table 2. A plot of these data as a function of temperature is given in figure 1. Polynominal functions were fitted to the experimental data with a digital computer. The functions were used to calculate heat capacities at regular temperature intervals. Calculated heat capacities as well as the related functions S° and $H^\circ-H^\circ_0$ are given in table 3. Values of S° and $H^\circ-H^\circ_0$ at 10 K were determined by extrapolation to be 0.12 cal/deg-mole and 0.89 cal/mole, respectively.

TABLE 2. - Experimental low-temperature heat capacities of $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$

T, K	Cp, cal/deg-mole	T, K	Cp, cal/deg-mole
11.49	0.502	106.81	34.046
12.03	.568	116.75	37.854
14.86	.998	126.48	41.296
16.64	1.329	136.17	44.942
18.85	1.795	143.66	47.328
21.19	2.331	153.31	50.940
24.27	3.113	164.04	54.400
27.20	3.972	175.64	58.360
30.65	5.095	186.86	62.121
34.75	6.463	198.67	65.966
39.14	8.047	210.70	69.803
43.63	9.695	222.54	73.365
48.42	11.525	233.26	76.395
53.66	13.510	243.67	79.230
62.07	16.813	255.58	82.382
65.85	18.288	267.67	85.448
71.27	20.414	279.47	88.211
84.34	25.281	291.04	90.891
86.88	26.481	302.40	93.442
91.58	28.328	311.43	95.745
97.91	30.755		

TABLE 3. - Low-temperature thermodynamic properties of $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O(s)$

T, K	Cal/deg-mole		Cal/mole,	T, K	Cal/deg-mole		Cal/mole,
	Cp°	S°	$H^\circ-H_0^\circ$		Cp°	S°	$H^\circ-H_0^\circ$
10	0.329	0.120	0.890	160	53.11	40.21	3857
15	.995	.366	4.031	170	56.52	43.54	4405
20	2.042	.787	11.48	180	59.87	46.86	4987
25	3.369	1.381	24.92	190	63.16	50.19	5602
30	4.872	2.126	45.46	200	66.38	53.51	6250
35	6.526	2.999	73.89	210	69.52	56.83	6930
40	8.347	3.988	111.0	220	72.56	60.13	7640
45	10.26	5.081	157.5	230	75.49	63.42	8380
50	12.10	6.257	213.4	240	78.30	66.69	9149
60	15.98	8.806	353.8	250	80.98	69.94	9946
70	19.90	11.56	533.2	260	83.53	73.17	10770
80	23.83	14.48	751.9	270	85.97	76.37	11615
90	27.72	17.51	1010	273.15	86.72	77.37	11890
100	31.55	20.63	1306	280	88.32	79.54	12490
110	35.30	23.81	1640	290	90.62	82.68	13380
120	38.99	27.04	2012	298.15	92.50	85.21	14130
130	42.60	30.31	2420	300	92.93	85.79	14300
140	46.16	33.59	2864	310	95.36	88.87	15240
150	49.66	36.90	3343				

ENTHALPY OF FORMATION AT 298 K

Experimental

The enthalpy of formation was determined by solution calorimetry. The calorimeter employed and the method of operation were described by Ko (13). A few changes were made as follows:

1. The Hallikainen Thermotrol[4] temperature controller was replaced by a Precision temperature controller (Bayley Instrument Co., Danville, Calif.). With this controller the temperature of the water bath was maintained to ±0.002° C.

2. The stirring mechanism for the calorimeter formerly used a rubber O-ring. This was replaced by a geared-type pulley system employing a no-slip drive belt to give a more uniform stirring speed.

3. The FORTRAN computer program for calculating results from calorimetric experiments was replaced by a new program developed for a Wang 600 calculator system (Wang Laboratories, Inc.).

The calorimeter was calibrated by measuring the heats of solution of THAM [Tris (hydroxymethyl) aminomethane] in 0.10-N HCl and of ZnO in 4.360 molal HCl at 298 K. The results, -7.100±0.005 and -15.811±0.007 kcal/mole, respectively, were in good agreement with accepted values.

The solution media used in this study were 2.131.1 g of $HCl\cdot 12.731H_2O$ and 2,592.9 g of $H_2SO_4\cdot H_3PO_4\cdot 0.01Na_2Cr_2O_7\cdot 15H_2O$. The temperature of operation was 298.15 K. Weights were corrected to vacuum.

The assignment of precision uncertainties was based on the following criteria: (1) When several individual heat values were measured for a reaction, the precision uncertainty was taken as twice the standard deviation of the mean; (2) when the heats of two or more reactions were combined, the uncertainty of the resulting reaction was taken as the square root of the sum of the squares of the individual uncertainties.

Aluminum Sulfate Hydrate

No relevant thermodynamic data were available for the reference compound, $Al_2(SO_4)_3\cdot 12H_2O(s)$. Consequently, it was necessary to first determine the enthalpy of formation of this compound. The solution medium used was 2,131.1 g of $HCl\cdot 12.731H_2O$. The details of the reaction scheme for determining the enthalpy of formation of $Al_2(SO_4)_3\cdot 12H_2O$ are given in table 4. The symbols s, l, g, and sol denote substances that are crystalline, liquid, gaseous, and in solution. The reactions are written in an abbreviated form sufficient to show that stoichiometry was maintained. Also listed in table 4 are the average measured heat values and uncertainties for the individual reactions. A quantity of 0.005 g-mole of $Al_2(SO_4)_3\cdot 12H_2O$ was used as the weight basis for this scheme, and other substances conformed stoichiometrically with this quantity.

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[4] Reference to specific manufacturers and brands of equipment is made for identification only and does not imply endorsement by the Bureau of Mines.

TABLE 4. - Reaction scheme for $Al_2(SO_4)_3\cdot 12H_2O$ at 298 K

		ΔH, kcal	Uncertainty, kcal
(1)	$2Al(s) + 6H^+(sol) = 2Al^{+3}(sol) + 3H_2(g)$	-254.10	0.24
(2)	$3[H_2SO_4\cdot 6H_2O](l) = 6H^+(sol) + 3SO_4^{-2}(sol) + 18H_2O(sol)$	-3.64	.02
(3)	$6H_2O(l) = 6H_2O(sol)$	-0.46	.001
(4)	$Al_2(SO_4)_3\cdot 12H_2O(s) = 2Al^{+3}(sol) + 3SO_4^{-2}(sol) + 12H_2O(sol)$	-2.38	.03
	$\Delta H_5 = \Delta H_1 + \Delta H_2 - \Delta H_3 - \Delta H_4$		
(5)	$2Al(s) + [3\ H_2SO_4\cdot 6H_2O](l) = Al_2(SO_4)_3\cdot 12H_2O(s) + 6H_2O(l) + 3H_2(g)$	-254.90	.25

Reactions 1-2 were measured consecutively in 2,131.1 g of solvent. Reactions 3-4 were measured consecutively in a fresh portion of 2,131.1 g of solvent. Reactions 1 and 3 were both measured previously in this laboratory. Coughlin (5) reported a heat of solution value of -127.050±0.120 kcal/mole for reaction 1. Ko (13) determined the heat for reaction 3 to be -0.0761±0.0001 kcal/mole. These values are adopted here in the reaction scheme. The experimental heats of solution for reactions 2 and 4 are given in table 5 along with their mean values and uncertainties.

TABLE 5. - Experimental heats of solution at 298 K, kcal/mole

$H_2SO_4\cdot 6H_2O(l)$, reaction 2	$Al_2(SO_4)_3\cdot 12H_2O(s)$, reaction 4
-1.211	-2.434
-1.222	-2.360
-1.218	-2.355
-1.223	-2.393
-1.214	-2.331
-1.196	-2.343
-1.213	-2.329
[1]-1.214±0.007	[1]-2.377±0.034

[1] Mean.

Reactions 1-4 and their heats can be combined to give the overall calorimetric reaction 5 and a heat value of -254.90±0.25 kcal for ΔH_5 at 298.15 K. Combination of ΔH_5 with ΔH_6, the enthalpy of formation of $H_2SO_4\cdot 6H_2O$ at 298.15 K, gives the formation reaction 7 for $Al_2(SO_4)_3\cdot 12H_2O$.

$$H_2(g) + S(rh) + 2O_2(g) + 6H_2O(l) = H_2SO_4\cdot 6H_2O(l) \qquad (6)$$

$$\Delta H_6 = -208.944\pm 0.100\ \text{kcal/mole.}$$

The enthalpy change for reaction 6 was from Wagman (17).

$$2Al(s) + 3S(rh) + 6O_2(g) + 12H_2O(l) = Al_2(SO_4)_3\cdot 12H_2O(s) \qquad (7)$$

$$\Delta H_7 = \Delta H_5 + 3\Delta H_6$$

$$\Delta Hf^\circ(298.15\ K) = \Delta H_7 = -881.73\pm 0.39\ kcal/mole.$$

Basic Aluminum Sulfite

The details of the reaction scheme for $Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O$ are given in table 6. The solution medium was 2,592.9 g of $H_2SO_4\cdot H_3PO_4\cdot 0.01Na_2Cr_2O_7\cdot 15H_2O$. The presence of $Na_2Cr_2O_7$ insured the oxidation of sulfur of +4 to sulfate. A test was made for complete oxidation by titrating the excess $Na_2Cr_2O_7$ with ferrous ammonium sulfate solution. The amount of $Na_2Cr_2O_7$ actually consumed in oxidation of SO_3^{-2} to SO_4^{-2} confirmed the theoretical calculation according to stoichiometry. Also listed in table 6 are the average measured heat values and uncertainties for the individual reactions. A quantity of 0.005 g-mole of $Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O$ was used as the weight basis for this scheme. Other substances conformed stoichiometrically with this quantity.

TABLE 6. - Reaction scheme for $Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O$ at 298 K

Reaction	ΔH, kcal	Uncertainty, kcal
(8) $6[H_2SO_3\cdot 100H_2O](l) + 2Cr_2O_7^{-2}(sol) + 4H^+(sol) = 4Cr^{+3}(sol) + 6SO_4^{-2}(sol) + 608H_2O(sol)$	-516.90	2.42
(9) $3[Al_2(SO_4)_3\cdot 12H_2O](s) = 6Al^{+3}(sol) + 9SO_4^{-2}(sol) + 36H_2O(sol)$	8.75	0.11
(10) $563.1H_2O(l) = 563.1H_2O(sol)$	-122.92	.11
(11) $3[Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O](s) + 2Cr_2O_7^{-2}(sol) + 22H^+(sol) = 6Al^{+3}(sol) + 6SO_4^{-2}(sol) + 4Cr^{+3}(sol) + 26.9H_2O(sol)$	-484.06	.29
(12) $9[H_2SO_4\cdot 6H_2O](l) = 18H^+(sol) + 9SO_4^{-2}(sol) + 54H_2O(sol)$	-5.99	.06
$\Delta H_{13} = 1/3(\Delta H_8 + \Delta H_9 - \Delta H_{10} - \Delta H_{11} - \Delta H_{12})$ (13) $2[H_2SO_3\cdot 100H_2O](l) + Al_2(SO_4)_3\cdot 12H_2O(s) = 187.7H_2O(l) + Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O(s) + 3[H_2SO_4\cdot 6H_2O](l)$	34.94	.82

Reactions 8-9 were measured consecutively in 2,592.9 g of solvent. Reactions 10-12 were measured consecutively in a fresh portion of 2,592.9 g of solvent. The experimental heats of solution for these reactions are given in table 7 along with their mean values and uncertainties. Reactions 8-12 and their heats can be combined to give the overall calorimetric reaction 13 and a value of 34.94±0.82 kcal for ΔH_{13} at 298.15 K. Combination of ΔH_{13} with the enthalpies of formation of $Al_2(SO_4)_3 \cdot 12H_2O$, $H_2SO_3 \cdot 100H_2O$, $H_2SO_4 \cdot 6H_2O$, and H_2O at 298.15 K gives the formation reaction 16 for $Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O$.

$$H_2(g) + S(rh) + 3/2O_2(g) + 100H_2O(l) = H_2SO_3 \cdot 100H_2O(l) \qquad (14)$$

$$\Delta H_{14} = -146.369 \pm 0.100 \text{ kcal/mole;}$$

$$H_2(g) + 1/2O_2(g) = H_2O(l) \qquad (15)$$

$$\Delta H_{15} = -68.315 \pm 0.010 \text{ kcal/mole.}$$

The enthalpy changes for reactions 14-15 were from Wagman (<u>17</u>).

$$2Al(s) + 2S(rh) + 6.15O_2(g) + 5.3H_2(g)$$

$$= Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O(s) \qquad (16)$$

$$\Delta H_{16} = \Delta H_{13} + \Delta H_7 + 2\Delta H_{14} - 3\Delta H_8 + 6.3\Delta H_{15}$$

$$\Delta Hf°(298.15 \text{ K}) = \Delta H_{16} = -943.08 \pm 0.98 \text{ kcal/mole.}$$

TABLE 7. - Experimental heats of solution at 298 K, kcal/mole

$H_2SO_3 \cdot 100H_2O(l)$, reaction 8	$Al_2(SO_4)_3 \cdot 12H_2O(s)$, reaction 9	$H_2O(l)$, reaction 10	$Al_2O_3 \cdot 2.0SO_2 \cdot 5.3H_2O(s)$, reaction 11	$H_2SO_4 \cdot 6H_2O(l)$, reaction 12
-85.531	2.865	-0.2183	-161.407	-0.6830
-86.436	2.988	-.2185	-161.169	-.6623
-86.459	2.955	-.2183	-161.174	-.6667
-86.837	2.863	-.2183	-161.427	-.6495
-85.450	2.922	-.2184	-161.315	-.6670
-86.473	2.887	-.2183	-161.313	-.6661
-85.863	2.937	-.2187	-161.489	-.6737
-	-	-.2179	-161.541	-.6589
[1]-86.150 ±0.404	[1]2.917 ±0.036	[1]-0.2183 ±0.0002	[1]-161.354 ±0.097	[1]-0.6659 ±0.0070

[1] Mean.

SUMMARY OF RESULTS

No anomalous behavior of the heat capacity was noted within the experimental data range. The values of standard entropy and ($H°-H°_0$) at 298.15 K of basic aluminum sulfite are 85.2±0.1 cal/deg mole and 14.13 kcal/mole, respectively. The precision uncertainty of heat capacity measurements was estimated as ±0.1 pct at 50 to 311 K; ±0.2 pct at 20 to 50 K; and about ±5 pct at 11 K.

Owing to the lack of thermodynamic data on basic aluminum sulfite in the literature, no comparisons can be made with the results of this investigation.

Impurity corrections were not considered significant in deriving the formation enthalpy of basic aluminum sulfite. However, a larger uncertainty than the one calculated was assigned to the final value because of uncertainties associated with calibration measurements and auxiliary thermodynamic data. Based on the results of this investigation, the final value for the standard enthalpy of formation of basic aluminum sulfite at 298.15 K is -943.1±1.2 kcal/mole.

Combination of the entropy of basic aluminum sulfite with entropies of Al(s), S(rh), O_2(g), and H_2(g) (6) gives a value of -410.4±1.0 cal/deg-mole for the standard entropy of formation for reaction 16. The standard Gibbs energy of formation of basic aluminum sulfite is calculated to be -820.7±1.2 kcal/mole by combining the enthalpy of formation and entropy of formation for reaction 16.

A summary of the thermodynamic data for $Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O$ at 298.15 K is given in table 8.

TABLE 8. - Thermodynamic data for $Al_2O_3\cdot 2.0SO_2\cdot 5.3H_2O$ at 298.15 K

ΔHf°	-943.1±1.2 kcal/mole.
ΔGf°	-820.7±1.2 kcal/mole.
S°	85.2±0.1 cal/deg-mole.
ΔSf°	-410.4±1.0 cal/deg-mole.
$(H^\circ-H_0^\circ)$	14.13 kcal/mole.

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