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Thermodynamic Data for Arsenic Sulfide Reactions

By A. D. Mah

UNITED STATES DEPARTMENT OF THE INTERIOR

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THERMODYNAMIC DATA FOR ARSENIC SULFIDE REACTIONS

By A. D. Mah [1]

ABSTRACT

Thermodynamic data on compounds of arsenic and sulfur were critically evaluated by the Bureau of Mines. Changes of standard enthalpy and Gibbs energy, and logarithms of the equilibrium constants were tabulated as a function of temperature for reactions involving these compounds.

INTRODUCTION

Thermodynamic analyses of reactions involving arsenic sulfides were made to aid Bureau of Mines research on the safe disposal or economical recovery of arsenic and its compounds from metallurgical melts and flue emissions. Thermodynamic properties of arsenic compounds involved in the reaction calculations were reviewed and critically evaluated.

[1]Research chemist, Albany Research Center, Bureau of Mines, Albany, Oreg.

SOURCES OF DATA

Thermodynamic properties of arsenic sulfides reported in the literature are incomplete and discordant. Values reported on the standard enthalpy of formation of realgar, $As_4S_4(c)$, differ by 35 kcal/mol. Britzke (3)[2] obtained a value of -57.9 kcal/mol of As_4S_4 by means of oxygen combustion calorimetry. The products of combustion were complex and difficult to identify quantitatively. The National Bureau of Standards' reinterpretation of Britzke's results yielded the value -63.8 kcal/mol, in NBS Circular 500 (24), and a later recalculation of the same data led to -68.2 kcal/mol, in Technical Note 270-3 (30). Mills (12) selected a similar value, -68 ±10 kcal/mol of As_4S_4. Barton (1), however, by means of equilibrium studies, gave evidence that these values are in error and estimated the standard enthalpy of formation of $As_4S_4(c)$ to be -34.8 kcal/mol. Analyses of vapor phase data also indicate a value closer to Barton's. The values of the standard enthalpy of formation of α- and β-As_4S_4 adopted for this report were derived from fluorine bomb calorimetry by Johnson (9). These values are, for the monoclinic compound,

$$\Delta Hf^\circ_{298}\ [As_4S_4(\alpha)]$$

$$= -33.0 \pm 1.6 \text{ kcal/mol},$$

and, for the orthorhombic compound,

$$\Delta Hf^\circ_{298}\ [As_4S_4(\beta)]$$

$$= -32.2 \pm 1.6 \text{ kcal/mol}.$$

Neither low-temperature heat capacity nor high-temperature relative enthalpy data were available for α-As_4S_4. Weller and Kelley (31) determined the heat capacity of the beta compound from 53 to 279 K. Extrapolation to 0 K by means of Debye and Einstein functions yielded the absolute entropy,

$$S^\circ_{298}[As_4S_4(\beta)] = 60.72 \pm 0.6 \text{ cal/mol·K}.$$

Johnson (9) measured high-temperature enthalpy increments of beta and liquid As_4S_4 from 374 to 849 K.

Basic thermodynamic properties of beta and liquid As_4S_4 together with standard-state enthalpies and Gibbs energies of formation, from 298 to 850 K, are summarized in table 1. Formation data, from $S_2(g)$ and $As_4(g)$, are provided in table 9.

Literature values of the standard enthalpy of formation of orpiment, As_2S_3, also vary widely. Britzke (3) obtained -34.8 kcal/mol of As_2S_3 from combustion in oxygen. The NBS adopted this value in Circular 500 (24), but a later recalculation of Britzke's data in Technical Note 270-3 (30) yielded -40.4 kcal/mol. Mills (12) selected a value similar to that of NBS (30), -40 ±5 kcal/mol. Again, Barton (1) disagreed with these figures and estimated the standard enthalpy of formation of As_2S_3 to be -23 kcal/mol. The value of the standard enthalpy of formation of crystalline As_2S_3 adopted in this report was derived from the energy of combustion of vitreous As_2S_3 in fluorine by Johnson (9),

$$\Delta Hf^\circ_{298}\ [As_2S_3(\text{orpiment})]$$

$$= -21.9 \pm 1.1 \text{ kcal/mol}.$$

The standard enthalpy of formation of the vitreous trisulfide from Johnson's investigation is

$$\Delta Hf^\circ_{298}\ [As_2S_3(\text{glass})]$$

$$= -16.6 \pm 1.0 \text{ kcal/mol}.$$

Romanovskii and Tarasov (23) measured the low-temperature heat capacity of crystalline As_2S_3 from 65 to 300 K.

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

Tarasov and Zhdanov (29) measured the heat capacity of vitreous As_2S_3 from 53 to 305 K. Absolute entropies recalculated from these data yielded

$$S^\circ_{298}\ [As_2S_3(orpiment)] = 39.0\ cal/mol\cdot K,$$

and

$$S^\circ_{298}\ [As_2S_3(glass)] = 40.0\ cal/mol\cdot K.$$

High-temperature enthalpy increments of vitreous As_2S_3 were determined by Johnson (9) by means of the drop calorimeter. High-temperature data were not available for the crystalline compound. The equilibrium calculations involving As_2S_3 in this report, therefore, were made employing the vitreous form of the trisulfide. Table 2 summarizes the thermodynamic properties of vitreous and liquid As_2S_3 from 298 to 850 K. Table 10 provides formation data from the gaseous elements.

Analysis of appearance potentials by Sullivan (28) yielded a value of the dissociation energy of arsenic monosulfide, $D^\circ_0\ [AsS(g)] = 92 \pm 9$ kcal/mol. This value, combined with enthalpy data for S(g) from CODATA (5), for As(g) from Hultgren (8), and for AsS(g) from this report, furnished the standard enthalpy of formation of gaseous arsenic monosulfide,

$$\Delta Hf^\circ_{298}\ [AsS(g)] = 45.2 \pm 9.0\ kcal/mol.$$

Heat capacity, entropy, and relative enthalpy of AsS as an ideal gas were calculated from spectroscopic and molecular constant data by the procedure given in a previous compilation (10). Electronic data and the vibration-rotation interaction constant were from Shimauchi and Karasawa (27). Vibrational frequency, anharmonicity constant, and interatomic distance were from Shimauchi (26) and Shimauchi and Karasawa (27). Results of calculations in the temperature range 298 to 3,000 K are summarized in table 3. Formation properties from 0 to 3,000 K, from the gaseous elements, are provided in table 11.

A standard enthalpy of sublimation of β-As_4S_4 equal to 31.7 ± 1.5 kcal/mol was derived from the sublimation studies of Munir (15), and Gospodinov and Pashinkin (7). Combination with the enthalpy of formation of β-As_4S_4 yielded the standard enthalpy of formation of the gaseous compound,

$$\Delta Hf^\circ_{298}\ [As_4S_4(g)] = -0.5 \pm 2.5\ kcal/mol.$$

Heat capacities, entropies, and relative enthalpies of gaseous As_4S_4 were derived from spectroscopic and molecular constant data. The product of the three principal moments of inertia used, $I_aI_bI_c = 7.86494 \times 10^{-111} g^3cm^6$, was calculated on the basis of the molecular configuration proposed by Lu and Donohue (11), a bisphenoid of arsenic atoms bisected by a square of sulfur atoms. Since fundamental frequencies were not available for the gaseous compound, the 18 frequencies employed were taken from the Raman studies of Scheuermann and Ritter (25) on the crystalline state. Results of calculations in the temperature range 298 to 3,000 K are summarized in table 4. Formation properties from the gaseous elements, from 0 to 3,000 K, are listed in table 12.

Thermodynamic data were evaluated also for some auxiliary elements and compounds employed in the equilibria calculations. Heat capacities, entropies, and enthalpy increments of $As_4(g)$, given in table 5, were calculated assuming a tetrahedral rigid-rotator, harmonic-oscillator. Vibrational wave numbers, degeneracies, and electronic data were adopted from Brumbach and Rosenblatt (4) and the product of the principal moments of inertia, $I_aI_bI_c = 4.0139 \times 10^{-112} g^3cm^6$, was calculated from

the internuclear distance given by Morino (14). The standard enthalpy of formation was from Hultgren (8).

Molecular constant data from Davis and Oetjen (6) and Yost and Sherborne (33) were used to calculate the thermodynamic functions of $AsCl_3(g)$. The standard enthalpy of formation was from NBS (30). The results of the calculations are given in table 6.

The standard enthalpy of formation of $As_4O_6(g)$ and the molecular constants used to calculate the thermodynamic functions listed in table 7 were taken from Behrens and Rosenblatt (2). Thermodynamic properties of orthorhombic, monoclinic and liquid sulfur (table 8) were derived from heat capacity investigations of Montgomery (13) and West (32).

Other auxiliary data used in making calculations were obtained from various compilations. Entropy and relative enthalpy data for $SO_2(g)$ were taken from the JANAF Thermochemical Tables (16) and combined with the standard enthalpy of formation from CODATA (5); entropy and enthalpy increments of $SO_3(g)$ from the JANAF tables were combined with the standard enthalpy of formation from NBS (30); entropy and relative enthalpy data for $H_2S(g)$ from JANAF supplement 48 (19) were combined with the standard enthalpy of formation from CODATA (5); and data on chlorine (16) were combined with the CODATA (5) value of the absolute entropy of chlorine. Thermodynamic properties of the following elements and compounds also were from JANAF supplements: CS(g) and $CS_2(g)$ (17); $H_2(g)$ and $O_2(g)$ (18); SO(g) (19); $S_2(g)$ (20); C(graphite) (21); $SCl_2(g)$ and $S_2Cl_2(g)$ (22). Thermodynamic data for crystalline arsenic oxides were from Pankratz,[3] and data for alpha arsenic were from Hultgren (8).

DISCUSSION

Standard enthalpy and Gibbs energy changes and the logarithms of the equilibrium constants of some reactions involving arsenic sulfides are given, as a function of temperature, in tables 13 to 78. Although some conclusions can be derived from the data in these tables, in the practical application of thermodynamic interpretations, the metallurgist should keep in mind the limitations of thermodynamic information. A particular reaction may be a simplification of a particular process, and other reactions may be occurring simultaneously. In addition, kinetic, transport, and other factors may exist to prevent attainment of equilibrium.

Reactions of Realgar

Thermodynamic data on reactions of realgar with various substances are contained in tables 13 to 29. Tables 13 to 16 provide the data for reactions of realgar with oxygen. These reactions are highly exothermic, and at equilibrium the sulfide will be completely converted to solid oxide below 551 K, and liquid or gaseous oxide at higher temperatures, with formation of SO_2 (tables 13 and 14) or SO_3 (tables 15 and 16), depending on the availability of oxygen.

Enthalpy and Gibbs energy data on the hydrogen reduction of realgar are given in tables 17 and 18. Table 17 shows that hydrogen can reduce realgar to metallic arsenic, the reaction being endothermic below 650 K. Carbon does not reduce realgar in the temperature range of tables 19 to 22.

[3]Pankratz, L. B. Thermodynamic Properties of Elements and Oxides. BuMines report to be published; for information, contact L. B. Pankratz, Bureau of Mines, Albany, Oreg.

According to data in tables 23 and 24, $AsCl_3$ should be produced upon chlorination of realgar, together with S_2Cl_2 or SCl_2, depending on the supply of chlorine. The reactions are exothermic.

Vaporization data for realgar are in tables 25 and 26. The vapor pressure of liquid realgar reaches 0.5 atm at 750 K and 1 atm near 800 K. Standard Gibbs energy changes in tables 27 to 29 indicate that, within the temperature range of the calculations, realgar is stable with respect to thermal dissociation into its constituent elements.

Reactions of Orpiment

Results of calculations for reactions of orpiment with various substances are given in tables 30 to 41. Data on oxidation reactions, tables 30 to 33, show the process to be exothermic, and at equilibrium it will proceed virtually to completion, forming the crystalline trioxide below 551 K and the liquid and gaseous oxide at higher temperatures, together with SO_2 or SO_3, depending on the amount of oxygen present.

Equilibrium calculations on the hydrogen reduction of orpiment, tables 34 and 35, indicate that As and H_2S will be the reaction products at the temperatures listed, the reaction becoming exothermic around 450 K. Carbon will not reduce orpiment in the temperature range of tables 36 to 39 and at 1 atm pressure.

Thermodynamic data in tables 40 and 41 indicate that, in the temperature range listed, chlorination of orpiment is exothermic and will proceed practically to completion if equilibrium is attained, yielding $AsCl_3$, plus SCl_2 or S_2Cl_2.

Thermodynamic data on some dissociation equilibria involving orpiment, tables 42 to 45, provide information that, in the temperature range covered by the tables, orpiment is stable with respect to decomposition into its elements or into the monosulfide. However, Gibbs energy data in tables 46 and 47 indicate that, at the higher temperatures, liquid orpiment will lose significant amounts of $S_2(g)$ to form tetrameric arsenic monosulfide.

Reactions of Arsenic Monosulfide

Thermodynamic data provided in tables 48 to 59 point out that monomeric arsenic monosulfide vapor can be easily oxidized, reduced, or chlorinated with evolvement of heat. In carbon reduction, carbon will be oxidized to CS_2 (tables 54 to 57). Tetrameric arsenic monosulfide vapor (tables 63 to 74) also can be readily oxidized, reduced by H_2, or chlorinated exothermically, but carbon is not an efficient reductant below 1,000 K (tables 69 and 70). Under most conditions, the vapor phase concentration of monomeric arsenic monosulfide is small. Data in tables 60 and 61 show the monomeric vapor to be unstable with respect to decomposition into its constituent elements, whereas table 62 shows reversal of the dissociation at higher temperatures. The tetrameric vapor is more stable (tables 75 to 77) and dissociates significantly only at higher temperatures. Standard Gibbs energy changes in table 78 confirm that, at lower temperatures, the tetramer is more stable than the monomer.

Table 1. - Thermodynamic properties of $As_4S_4(\beta,\ell)$

[Formation: 4 As(α) + 4 S(or,mon,ℓ) = $As_4S_4(\beta,\ell)$]

T, K	cal/mol•K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	44.960	60.720	60.720	0	-32.200	-30.990	22.716
300	45.025	60.999	60.722	.083	-32.201	-30.983	22.571
350	46.129	68.015	61.272	2.360	-32.234	-30.779	19.219
368.30	46.515	70.376	61.666	3.208	-32.246	-30.702	18.218
368.30	46.515	70.376	61.666	3.208	-32.630	-30.702	18.218
388.36	46.938	72.854	62.181	4.145	-32.653	-30.594	17.216
388.36	46.938	72.854	62.181	4.145	-34.305	-30.594	17.216
400	47.183	74.244	62.512	4.693	-34.391	-30.482	16.654
432.02	47.796	77.902	63.517	6.215	-34.701	-30.159	15.257
450	48.140	79.858	64.131	7.077	-35.166	-29.958	14.549
500	49.037	84.977	65.965	9.506	-35.778	-29.345	12.826
550	49.894	89.691	67.909	11.980	-36.296	-28.674	11.394
580.15	50.397	92.367	69.113	13.491	-36.569	-28.250	10.642
580.15	63.700	103.356	69.113	19.866	-30.194	-28.250	10.642
600	64.206	105.507	70.280	21.136	-30.084	-28.185	10.266
650	65.981	110.712	73.192	24.388	-29.726	-28.041	9.428
700	68.312	115.684	76.051	27.743	-29.237	-27.929	8.720
717.82	69.290	117.414	77.057	28.969	-29.021	-27.897	8.493
750	71.056	120.489	78.854	31.226			
800	74.114	125.171	81.604	34.854			
850	77.413	129.762	84.302	38.641			

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; ΔH° = 0.096 kcal/mol.
388.36 K, melting point of S; ΔH° = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.
717.82 K, boiling point of S.

Table 2. - Thermodynamic properties of $As_2S_3(gl,\ell)$

[Formation: 2 As(α) + 3 S(or,mon,ℓ) = $As_2S_3(gl,\ell)$]

T, K	cal/mol°K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	27.657	40	40	0	-16.630	-16.615	12.179
300	27.689	40.171	40.001	.051	-16.631	-16.615	12.104
350	28.264	44.487	40.341	1.451	-16.665	-16.611	10.372
368.30	28.521	45.934	40.584	1.971	-16.680	-16.608	9.855
368.30	28.521	45.934	40.584	1.971	-16.968	-16.608	9.855
388.36	28.803	47.448	40.898	2.544	-16.994	-16.585	9.333
388.36	28.803	47.448	40.898	2.544	-18.233	-16.585	9.333
400	28.967	48.301	41.101	2.880	-18.302	-16.536	9.035
432.02	29.883	50.558	41.720	3.818	-18.543	-16.387	8.290
450	30.398	51.787	42.098	4.360	-18.887	-16.289	7.911
478	31.642	53.657	42.720	5.228	-19.079	-16.117	7.369
500	43.421	55.576	43.242	6.167	-19.052	-15.981	6.985
550	45.548	59.831	44.560	8.399	-18.752	-15.687	6.233
585	45.560	62.654	45.558	10.001	-18.481	-15.500	5.791
600	45.116	63.799	46.001	10.679	-18.365	-15.426	5.619
650	44.569	67.388	47.510	12.921	-17.975	-15.196	5.109
700	44.135	70.674	49.048	15.138	-17.586	-14.997	4.682
717.82	44.010	71.782	49.599	15.924	-17.442	-14.932	4.546
750	43.785	73.707	50.592	17.336			
800	43.498	76.523	52.126	19.518			
850	43.260	79.153	53.640	21.686			

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; ΔH° = 0.096 kcal/mol.
388.36 K, melting point of S; ΔH° = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.
717.82 K, boiling point of S.

Table 3. - Thermodynamic properties of AsS(g)

[Formation: As(α) + S(or,mon,ℓ) = AsS(g)]

T, K	cal/mol•K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	8.324	57.824	57.824	0	45.200	32.788	-24.034
300	8.337	57.875	57.825	.015	45.194	32.711	-23.830
368.30	8.750	59.631	58.000	.601	44.987	29.891	-17.737
368.30	8.750	59.631	58.000	.601	44.891	29.891	-17.737
388.36	8.871	60.098	58.096	.777	44.828	29.076	-16.363
388.36	8.871	60.098	58.096	.777	44.415	29.076	-16.363
400	8.941	60.361	58.159	.881	44.360	28.617	-15.636
432.02	9.068	61.054	58.348	1.169	44.190	27.363	-13.842
500	9.337	62.402	58.808	1.797	43.726	24.756	-10.820
600	9.555	64.126	59.556	2.742	43.187	21.012	-7.654
700	9.653	65.608	60.317	3.704	42.709	17.355	-5.418
717.82	9.657	65.851	60.451	3.876	42.629	16.711	-5.088
800	9.678	66.899	61.060	4.671			
900	9.665	68.038	61.774	5.638			
1000	9.632	69.055	62.452	6.603			
1100	9.593	69.971	63.095	7.564			
1200	9.552	70.804	63.703	8.521			
1300	9.512	71.567	64.279	9.475			
1400	9.477	72.271	64.825	10.424			
1500	9.445	72.924	65.344	11.370			
1600	9.416	73.532	65.836	12.313			
1700	9.392	74.102	66.306	13.253			
1800	9.371	74.639	66.755	14.191			
1900	9.353	75.145	67.183	15.128			
2000	9.337	75.624	67.593	16.062			
2100	9.324	76.079	67.986	16.995			
2200	9.313	76.513	68.364	17.927			
2300	9.304	76.926	68.727	18.858			
2400	9.296	77.322	69.077	19.788			
2500	9.290	77.702	69.415	20.717			
2600	9.285	78.066	69.741	21.646			
2700	9.281	78.416	70.055	22.574			
2800	9.279	78.754	70.360	23.502			
2900	9.277	79.079	70.655	24.430			
3000	9.276	79.394	70.942	25.357			

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; $\Delta H°$ = 0.096 kcal/mol.
388.36 K, melting point of S; $\Delta H°$ = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
717.82 K, boiling point of S.

Table 4. - Thermodynamic properties of $As_4S_4(g)$

[Formation: 4 As(α) + 4 S(or,mon,ℓ) = $As_4S_4(g)$]

T, K	cal/mol•K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	39.240	106.590	106.590	0	-0.500	-12.966	9.504
300	39.290	106.833	106.590	.073	-.511	-13.043	9.502
368.30	40.534	115.048	107.419	2.810	-.944	-15.853	9.407
368.30	40.534	115.048	107.419	2.810	-1.328	-15.853	9.407
388.36	40.900	117.208	107.870	3.627	-1.471	-16.637	9.363
388.36	40.900	117.208	107.870	3.627	-3.123	-16.637	9.363
400	41.112	118.419	108.159	4.104	-3.280	-17.041	9.311
432.02	41.401	121.596	109.039	5.425	-3.791	-18.125	9.169
500	42.014	127.700	111.170	8.265	-5.319	-20.247	8.850
600	42.521	135.409	114.586	12.494	-7.026	-23.068	8.402
700	42.832	141.989	118.042	16.763	-8.517	-25.623	8.000
717.82	42.869	143.066	118.650	17.527	-8.763	-26.053	7.932
800	43.037	147.723	121.402	21.057			
900	43.178	152.800	124.613	25.368			
1000	43.280	157.355	127.663	29.692			
1100	43.355	161.484	130.554	34.023			
1200	43.413	165.259	133.291	38.362			
1300	43.458	168.735	135.884	42.706			
1400	43.493	171.957	138.348	47.053			
1500	43.522	174.959	140.690	51.404			
1600	43.546	177.769	142.921	55.757			
1700	43.565	180.409	145.048	60.113			
1800	43.582	182.900	147.083	64.470			
1900	43.596	185.256	149.030	68.829			
2000	43.608	187.493	150.898	73.190			
2100	43.618	189.621	152.692	77.551			
2200	43.627	191.650	154.417	81.913			
2300	43.635	193.590	156.079	86.276			
2400	43.641	195.447	157.680	90.640			
2500	43.647	197.228	159.226	95.004			
2600	43.653	198.940	160.721	99.369			
2700	43.658	200.588	162.168	103.735			
2800	43.662	202.176	163.568	108.101			
2900	43.666	203.708	164.926	112.467			
3000	43.669	205.188	166.243	116.834			

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; ΔH° = 0.096 kcal/mol.
388.36 K, melting point of S; ΔH° = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
717.82 K, boiling point of S.

Table 5. - Thermodynamic properties of $As_4(g)$

[Formation: 4 As(α) = $As_4(g)$]

T, K	cal/mol°K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	18.450	78.188	78.188	0	36.640	23.506	-17.230
300	18.466	78.302	78.189	.034	36.630	23.423	-17.064
400	19.052	83.706	78.921	1.914	36.110	19.100	-10.435
500	19.338	87.992	80.322	3.835	35.579	14.911	-6.518
600	19.498	91.533	81.905	5.777	35.013	10.828	-3.944
700	19.595	94.546	83.500	7.732	34.408	6.843	-2.137
800	19.659	97.167	85.048	9.695	33.759	2.950	-.806
876	19.693	98.953	86.177	11.191	33.235	.041	-.010
900	19.704	99.485	86.525	11.664			
1000	19.735	101.563	87.927	13.636			
1100	19.759	103.445	89.254	15.610			
1200	19.777	105.165	90.509	17.587			
1300	19.791	106.749	91.698	19.566			
1400	19.802	108.216	92.827	21.545			
1500	19.811	109.583	93.899	23.526			
1600	19.818	110.861	94.919	25.508			
1700	19.824	112.063	95.892	27.490			
1800	19.830	113.196	96.823	29.472			
1900	19.834	114.269	97.713	31.456			
2000	19.838	115.286	98.567	33.439			
2100	19.841	116.254	99.386	35.423			
2200	19.844	117.177	100.174	37.407			
2300	19.846	118.059	100.932	39.392			
2400	19.848	118.904	101.664	41.376			
2500	19.850	119.714	102.370	43.361			
2600	19.852	120.493	103.052	45.346			
2700	19.853	121.242	103.712	47.332			
2800	19.854	121.964	104.351	49.317			
2900	19.856	122.661	104.970	51.303			
3000	19.857	123.334	105.571	53.288			

Phase change: 876.0 K, sublimation point of As.

Table 6. - Thermodynamic properties of $AsCl_3(g)$

[Formation: $As(\alpha) + 1.5\ Cl_2(g) = AsCl_3(g)$]

T, K	cal/mol°K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	18.358	78.941	78.941	0	-61.800	-58.959	43.218
300	18.374	79.054	78.941	.034	-61.799	-58.942	42.938
400	18.985	84.435	79.670	1.906	-61.773	-57.994	31.686
500	19.291	88.708	81.066	3.821	-61.750	-57.050	24.936
600	19.463	92.241	82.641	5.760	-61.742	-56.111	20.438
700	19.569	95.250	84.233	7.712	-61.747	-55.173	17.226
800	19.639	97.868	85.778	9.672	-61.768	-54.234	14.816
876	19.675	99.652	86.905	11.167	-61.793	-53.517	13.352
900	19.687	100.184	87.252	11.639			
1000	19.722	102.260	88.651	13.609			
1100	19.748	104.141	89.975	15.583			
1200	19.767	105.860	91.228	17.558			
1300	19.783	107.443	92.415	19.536			
1400	19.795	108.910	93.542	21.515			
1500	19.805	110.276	94.613	23.495			
1600	19.813	111.554	95.632	25.476			
1700	19.820	112.755	96.604	27.457			
1800	19.825	113.889	97.533	29.440			
1900	19.830	114.961	98.423	31.422			
2000	19.834	115.978	99.275	33.406			
2100	19.838	116.946	100.094	35.389			
2200	19.841	117.868	100.880	37.373			
2300	19.843	118.751	101.639	39.357			
2400	19.846	119.595	102.369	41.342			
2500	19.848	120.405	103.075	43.326			
2600	19.850	121.184	103.757	45.311			
2700	19.851	121.933	104.416	47.296			
2800	19.853	122.655	105.055	49.281			
2900	19.854	123.352	105.674	51.267			
3000	19.855	124.025	106.274	53.252			

Phase change: 876.0 K, sublimation point of As.

Table 7. - Thermodynamic properties of $As_4O_6(g)$

[Formation: 4 As(α) + 3 $O_2(g)$ = $As_4O_6(g)$]

T, K	cal/mol•K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
298.15	41.488	97.814	97.814	0	-285.910	-261.063	191.362
300	41.610	98.071	97.814	.077	-285.916	-260.909	190.070
400	46.556	110.788	99.516	4.509	-286.014	-252.549	137.985
500	49.388	121.508	102.870	9.319	-285.849	-244.193	106.736
600	51.113	130.677	106.760	14.350	-285.591	-235.888	85.921
700	52.226	138.646	110.759	19.521	-285.314	-227.627	71.067
800	52.980	145.672	114.692	24.784	-285.057	-219.406	59.938
876	53.385	150.499	117.592	28.827	-284.886	-213.182	53.185
900	53.513	151.944	118.488	30.110			
1000	53.902	157.604	122.122	35.482			
1100	54.195	162.756	125.586	40.887			
1200	54.420	167.481	128.883	46.318			
1300	54.596	171.844	132.022	51.769			
1400	54.738	175.896	135.013	57.236			
1500	54.852	179.676	137.865	62.716			
1600	54.946	183.219	140.590	68.206			
1700	55.025	186.553	143.197	73.705			
1800	55.090	189.700	145.694	79.211			
1900	55.146	192.680	148.089	84.723			
2000	55.194	195.510	150.390	90.240			
2100	55.235	198.204	152.604	95.761			
2200	55.271	200.774	154.735	101.286			
2300	55.302	203.232	156.791	106.815			
2400	55.330	205.586	158.775	112.347			
2500	55.354	207.845	160.693	117.881			
2600	55.376	210.017	162.549	123.418			
2700	55.395	212.107	164.346	128.956			
2800	55.412	214.122	166.088	134.496			
2900	55.428	216.067	167.778	140.038			
3000	55.442	217.946	169.419	145.582			

Phase change: 876.0 K, sublimation point of As.

Table 8. - Thermodynamic properties of S(or,mon,ℓ)

T, K	cal/mol•K			kcal/mol			Log Kf
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔHf°	ΔGf°	
0	0	0	∞	-1.054	0	0	0
100	3.052	2.992	11.892	-0.890	0	0	0
200	4.629	5.649	8.134	-.497	0	0	0
298.15	5.425	7.661	7.661	.000	0	0	0
300	5.436	7.695	7.662	.010	0	0	0
368.30	5.795	8.846	7.776	.394	0	0	0
368.30	5.921	9.106	7.776	.490	0	0	0
388.36	6.015	9.423	7.855	.609	0	0	0
388.36	7.423	10.486	7.855	1.022	0	0	0
400	7.687	10.709	7.934	1.110	0	0	0
432.02	12.860	11.340	8.162	1.373	0	0	0
500	9.078	12.797	8.703	2.047	0	0	0
600	8.200	14.362	9.522	2.904	0	0	0
700	7.799	15.596	10.305	3.704	0	0	0
717.82	7.694	15.790	10.439	3.841	0	0	0

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; ΔH° = 0.096 kcal/mol.
388.36 K, melting point of S; ΔH° = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
717.82 K, boiling point of S.

Table 9. - Thermodynamic properties of $As_4S_4(\beta,\ell)$

[Reaction: $As_4(g) + 2\ S_2(g) = As_4S_4(\beta,\ell)$]

T, K	cal/mol•K			kcal/mol			Log K
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔH°	ΔG°	
0	0	0	∞	-8.810	-130.518	-130.518	∞
100	25.842	20.904	96.524	-7.562	-131.657	-118.352	258.655
200	39.601	43.773	64.688	-4.183	-131.213	-105.148	114.899
298.15	44.960	60.720	60.720	0	-130.260	-92.550	67.840
300	45.025	60.999	60.722	.083	-130.239	-92.315	67.251
350	46.129	68.015	61.272	2.360	-129.687	-86.040	53.725
400	47.183	74.244	62.512	4.693	-129.105	-79.844	43.624
450	48.140	79.858	64.131	7.077	-128.500	-73.721	35.803
500	49.037	84.977	65.965	9.506	-127.867	-67.668	29.577
550	49.894	89.691	67.909	11.980	-127.207	-61.680	24.509
580.15	50.397	92.367	69.113	13.491	-126.794	-58.100	21.887
580.15	63.700	103.356	69.113	19.866	-120.419	-58.100	21.887
600	64.206	105.507	70.280	21.136	-119.875	-55.976	20.389
650	65.981	110.712	73.192	24.388	-118.458	-50.709	17.050
700	68.312	115.684	76.051	27.743	-116.945	-45.553	14.222
750	71.056	120.489	78.854	31.226	-115.312	-40.509	11.804
800	74.114	125.171	81.604	34.854	-113.539	-35.579	9.720
850	77.413	129.762	84.302	38.641	-111.615	-30.768	7.911

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 10. - Thermodynamic properties of As_2S_3(gl,ℓ)

[Reaction: 0.5 As_4(g) + 1.5 S_2(g) = As_2S_3(gl,ℓ)]

T, K	cal/mol°K			kcal/mol			Log K
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔH°	ΔG°	
0	0	0	∞	-5.511	-81.159	-81.159	∞
100	16.241	15.401	62.071	-4.667	-81.875	-73.388	160.387
200	24.374	29.574	42.449	-2.575	-81.605	-64.960	70.984
298.15	27.657	40	40	0	-81.015	-56.909	41.715
300	27.689	40.171	40.001	.051	-81.002	-56.758	41.348
350	28.264	44.487	40.341	1.451	-80.662	-52.747	32.936
400	28.967	48.301	41.101	2.880	-80.310	-48.782	26.653
450	30.398	51.787	42.098	4.360	-79.925	-44.863	21.788
478	31.642	53.657	42.720	5.228	-79.675	-42.689	19.518
500	43.421	55.576	43.242	6.167	-79.224	-40.996	17.919
550	45.548	59.831	44.560	8.399	-78.110	-37.228	14.793
585	45.560	62.654	45.558	10.001	-77.295	-34.651	12.945
600	45.116	63.799	46.001	10.679	-76.955	-33.562	12.225
650	44.569	67.388	47.510	12.921	-75.845	-29.991	10.084
700	44.135	70.674	49.048	15.138	-74.765	-26.505	8.275
750	43.785	73.707	50.592	17.336	-73.709	-23.093	6.729
800	43.498	76.523	52.126	19.518	-72.673	-19.752	5.396
850	43.260	79.153	53.640	21.686	-71.656	-16.479	4.237

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 11. - Thermodynamic properties of AsS(g)

[Reaction: 0.25 $As_4(g)$ + 0.5 $S_2(g)$ = AsS(g)]

T, K	cal/mol•K			kcal/mol			Log K
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔH°	ΔG°	
0	0	0	∞	-2.202	20.621	20.621	∞
100	6.996	49.655	64.715	-1.506	20.720	19.604	-42.843
200	7.586	54.655	58.560	-.781	20.712	18.485	-20.200
298.15	8.324	57.824	57.824	0	20.685	17.398	-12.753
300	8.337	57.875	57.825	.015	20.684	17.378	-12.660
400	8.941	60.361	58.159	.881	20.682	16.277	-8.893
500	9.337	62.402	58.808	1.797	20.704	15.175	-6.633
600	9.555	64.126	59.556	2.742	20.739	14.064	-5.123
700	9.653	65.608	60.317	3.704	20.782	12.949	-4.043
800	9.678	66.899	61.060	4.671	20.823	11.828	-3.231
900	9.665	68.038	61.774	5.638	20.858	10.700	-2.598
1000	9.632	69.055	62.452	6.603	20.886	9.570	-2.092
1100	9.593	69.971	63.095	7.564	20.906	8.438	-1.676
1200	9.552	70.804	63.703	8.521	20.918	7.303	-1.330
1300	9.512	71.567	64.279	9.475	20.923	6.169	-1.037
1400	9.477	72.271	64.825	10.424	20.918	5.034	-.786
1500	9.445	72.924	65.344	11.370	20.907	3.899	-.568
1600	9.416	73.532	65.836	12.313	20.889	2.766	-.378
1700	9.392	74.102	66.306	13.253	20.864	1.634	-.210
1800	9.371	74.639	66.755	14.191	20.835	.503	-.061
1900	9.353	75.145	67.183	15.128	20.800	-.625	.072
2000	9.337	75.624	67.593	16.062	20.760	-1.751	.191
2100	9.324	76.079	67.986	16.995	20.716	-2.876	.299
2200	9.313	76.513	68.364	17.927	20.668	-3.999	.397
2300	9.304	76.926	68.727	18.858	20.617	-5.117	.486
2400	9.296	77.322	69.077	19.788	20.563	-6.235	.568
2500	9.290	77.702	69.415	20.717	20.507	-7.352	.643
2600	9.285	78.066	69.741	21.646	20.448	-8.465	.712
2700	9.281	78.416	70.055	22.574	20.387	-9.575	.775
2800	9.279	78.754	70.360	23.502	20.324	-10.684	.834
2900	9.277	79.079	70.655	24.430	20.260	-11.788	.888
3000	9.276	79.394	70.942	25.357	20.194	-12.896	.939

Table 12. - Thermodynamic properties of $As_4S_4(g)$

[Reaction: $As_4(g) + 2\ S_2(g) = As_4S_4(g)$]

T, K	cal/mol•K			kcal/mol			Log K
	Cp°	S°	$-(G°- H°_{298})/T$	$H°- H°_{298}$	ΔH°	ΔG°	
0	0	0	∞	-7.891	-97.899	-97.899	∞
100	22.052	71.707	138.027	-6.632	-99.027	-90.802	198.446
200	34.879	91.712	110.067	-3.671	-99.001	-82.524	90.177
298.15	39.240	106.590	106.590	0	-98.560	-74.526	54.628
300	39.290	106.833	106.590	.073	-98.549	-74.375	54.182
400	41.112	118.419	108.159	4.104	-97.994	-66.403	36.281
500	42.014	127.700	111.170	8.265	-97.408	-58.571	25.601
600	42.521	135.409	114.586	12.494	-96.817	-50.859	18.525
700	42.832	141.989	118.042	16.763	-96.225	-43.247	13.502
800	43.037	147.723	121.402	21.057	-95.636	-35.718	9.757
900	43.178	152.800	124.613	25.368	-95.054	-28.266	6.864
1000	43.280	157.355	127.663	29.692	-94.476	-20.874	4.562
1100	43.355	161.484	130.554	34.023	-93.909	-13.542	2.690
1200	43.413	165.259	133.291	38.362	-93.351	-6.260	1.140
1300	43.458	168.735	135.884	42.706	-92.804	.975	-.164
1400	43.493	171.957	138.348	47.053	-92.270	8.170	-1.275
1500	43.522	174.959	140.690	51.404	-91.748	15.325	-2.233
1600	43.546	177.769	142.921	55.757	-91.239	22.444	-3.066
1700	43.565	180.409	145.048	60.113	-90.743	29.535	-3.797
1800	43.582	182.900	147.083	64.470	-90.256	36.597	-4.443
1900	43.596	185.256	149.030	68.829	-89.783	43.633	-5.019
2000	43.608	187.493	150.898	73.190	-89.319	50.643	-5.534
2100	43.618	189.621	152.692	77.551	-88.866	57.628	-5.997
2200	43.627	191.650	154.417	81.913	-88.422	64.595	-6.417
2300	43.635	193.590	156.079	86.276	-87.986	71.540	-6.798
2400	43.641	195.447	157.680	90.640	-87.558	78.467	-7.145
2500	43.647	197.228	159.226	95.004	-87.137	85.378	-7.464
2600	43.653	198.940	160.721	99.369	-86.723	92.269	-7.756
2700	43.658	200.588	162.168	103.735	-86.313	99.145	-8.025
2800	43.662	202.176	163.568	108.101	-85.910	106.008	-8.274
2900	43.666	203.708	164.926	112.467	-85.512	112.857	-8.505
3000	43.669	205.188	166.243	116.834	-85.116	119.688	-8.719

Table 13. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 7\ O_2(g) = 2\ As_2O_3(cubic) + 4\ SO_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-565.600	-531.250	389.412
300	-565.616	-531.033	386.852
350	-565.994	-525.237	327.968
400	-566.234	-519.397	283.782
450	-566.348	-513.535	249.403
500	-566.360	-507.664	221.897
550	-566.275	-501.797	199.393
551	-566.272	-501.679	198.985

Phase change: 551 K, melting point of As_2O_3.

Table 14. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) + 7\ O_2(g) = As_4O_6(g) + 4\ SO_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-531.512	-531.512	∞
100	-533.370	-528.867	1155.824
200	-535.743	-523.414	571.953
298.15	-537.470	-516.975	378.948
300	-537.495	-516.845	376.516
350	-538.117	-513.349	320.546
400	-538.651	-509.775	278.525
450	-539.077	-506.136	245.810
500	-539.463	-502.455	219.620
550	-539.801	-498.737	198.177
580.15	-540.001	-496.480	187.028
580.15	-546.376	-496.480	187.028
600	-546.771	-494.767	180.217
650	-547.784	-490.393	164.883
700	-548.869	-485.938	151.715
750	-550.053	-481.408	140.281
800	-551.359	-476.790	130.251
850	-552.802	-472.082	121.379

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.

Table 15. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 9\ O_2(g) = 2\ As_2O_3(cubic) + 4\ SO_3(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-660.160	-599.026	439.092
300	-660.186	-598.646	436.108
350	-660.699	-588.341	367.372
400	-661.016	-577.982	315.791
450	-661.141	-567.591	275.656
500	-661.128	-557.195	243.547
550	-660.978	-546.808	217.279
551	-660.973	-546.600	216.802

Phase change: 551 K, melting point of As_2O_3.

Table 16. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 9\ O_2(g) = As_4O_6(g) + 4\ SO_3(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-623.018	-623.018	∞
100	-626.260	-613.798	1341.437
200	-629.737	-599.919	655.553
298.15	-632.030	-584.751	428.628
300	-632.065	-584.457	425.771
350	-632.822	-576.454	359.949
400	-633.433	-568.360	310.534
450	-633.870	-560.192	272.063
500	-634.231	-551.986	241.270
550	-634.504	-543.749	216.063
580.15	-634.654	-538.769	202.959
580.15	-641.029	-538.769	202.959
600	-641.385	-535.265	194.968
650	-642.281	-526.383	176.984
700	-643.235	-517.432	161.548
750	-644.271	-508.418	148.151
800	-645.417	-499.325	136.408
850	-646.694	-490.153	126.025

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 17. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 4\ H_2(g) = 4\ As(\alpha) + 4\ H_2S(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	12.480	-0.994	0.729
300	12.449	-1.078	.785
350	11.634	-3.264	2.038
400	10.799	-5.335	2.915
450	9.953	-7.309	3.550
500	9.118	-9.181	4.013
550	8.293	-10.968	4.358
580.15	7.800	-12.010	4.524
580.15	1.425	-12.010	4.524
600	.836	-12.461	4.539
650	-.663	-13.508	4.542
700	-2.211	-14.439	4.508
750	-3.836	-15.255	4.445
800	-5.554	-15.961	4.360
850	-7.380	-16.551	4.255

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H° = 6.375$ kcal/mol.

Table 18. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) + 4\ H_2(g) = As_4(g) + 4\ H_2S(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	52.314	52.314	∞
100	52.299	41.789	-91.328
200	51.039	31.691	-34.630
298.15	49.120	22.512	-16.501
300	49.079	22.346	-16.279
350	48.003	17.979	-11.227
400	46.909	13.764	-7.520
450	45.802	9.683	-4.703
500	44.697	5.730	-2.504
550	43.593	1.887	-.750
580.15	42.928	-.381	.143
580.15	36.553	-.380	.143
600	35.849	-1.633	.595
650	34.053	-4.685	1.575
700	32.197	-7.595	2.371
750	30.254	-10.369	3.021
800	28.205	-13.011	3.554
850	26.039	-15.521	3.991

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 19. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 2\ C(gr) = 4\ As(\alpha) + 2\ CS_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	88.100	62.943	-46.138
300	88.093	62.788	-45.741
350	87.910	58.587	-36.583
400	87.683	54.413	-29.730
540	87.422	50.265	-24.412
500	87.132	46.153	-20.173
550	86.811	42.071	-16.717
580.15	86.603	39.625	-14.927
580.15	80.228	39.625	-14.927
600	79.818	38.242	-13.930
650	78.742	34.821	-11.708
700	77.575	31.486	-9.830
750	76.292	28.239	-8.229
800	74.878	25.080	-6.852
850	73.314	22.018	-5.661

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.

Table 20. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 2\ C(gr) = As_4(\alpha) + 2\ CS_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	124.756	124.756	∞
100	125.807	112.466	-245.790
200	125.477	99.199	-108.399
298.15	124.740	86.449	-63.368
300	124.723	86.212	-62.804
350	124.280	79.830	-49.848
400	123.793	73.513	-40.165
450	123.272	67.257	-32.664
500	122.711	61.064	-26.690
550	122.111	54.927	-21.826
580.15	121.731	51.255	-19.308
580.15	115.356	51.255	-19.308
600	114.831	49.070	-17.873
650	113.458	43.644	-14.674
700	111.983	38.329	-11.967
750	110.382	33.125	-9.652
800	108.637	28.031	-7.658
850	106.732	23.048	-5.926

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 21. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 4\ C(gr) = 4\ As(\alpha) + 4\ CS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	300.200	249.778	-183.090
300	300.197	249.466	-181.733
350	300.103	241.019	-150.497
400	299.915	232.590	-127.080
450	299.643	224.186	-108.878
500	299.306	215.820	-94.334
550	298.903	207.494	-82.450
580.15	298.634	202.492	-76.280
580.15	292.259	202.492	-76.280
600	291.804	199.427	-72.640
650	290.594	191.776	-64.480
700	289.277	184.224	-57.517
750	287.826	176.772	-51.511
800	286.230	169.420	-46.283
850	284.467	162.172	-41.697

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.

Table 22. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) + 4\ C(gr) = As_4(g) + 4\ CS(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	334.142	334.142	∞
100	336.535	315.574	-689.678
200	337.147	294.283	-321.573
298.15	336.840	273.284	-200.320
300	336.827	272.889	-198.797
350	336.472	262.261	-163.761
400	336.025	251.690	-137.515
450	335.493	241.178	-117.131
500	334.885	230.732	-100.851
550	334.204	220.350	-87.558
580.15	333.762	214.121	-80.661
580.15	327.387	214.121	-80.661
600	326.817	210.255	-76.584
650	325.310	200.600	-67.447
700	323.685	191.067	-59.653
750	321.916	181.658	-52.934
800	319.989	172.370	-47.089
850	317.885	163.201	-41.961

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 23. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 8\ Cl_2 = 4\ AsCl_3(g) + 2\ S_2Cl_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-221.428	-221.428	∞
100	-222.496	-221.316	483.680
200	-222.843	-219.962	240.360
298.15	-223.000	-218.553	160.201
300	-223.003	-218.525	159.193
350	-223.082	-217.773	135.982
400	-223.175	-217.009	118.567
450	-223.276	-216.229	105.014
500	-223.410	-215.438	94.167
550	-223.572	-214.630	85.285
580.15	-223.684	-214.136	80.667
580.15	-230.059	-214.136	80.667
600	-230.406	-213.586	77.798
650	-231.324	-212.151	71.331
700	-232.341	-210.638	65.763
750	-233.490	-209.058	60.919
800	-234.770	-207.388	56.655
850	-236.201	-205.626	52.869

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.

Table 24. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) + 10\ Cl_2(g) = 4\ AsCl_3 + 4\ SCl_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-229.858	-229.858	∞
100	-230.906	-230.564	503.891
200	-231.429	-229.985	251.313
298.15	-231.800	-229.201	168.007
300	-231.805	-229.182	166.957
350	-232.002	-228.733	142.826
400	-232.215	-228.253	124.710
450	-232.436	-227.740	110.604
500	-232.694	-227.204	99.310
550	-232.980	-226.638	90.056
580.15	-233.169	-226.284	85.243
580.15	-239.544	-226.284	85.243
600	-239.942	-225.825	82.256
650	-240.990	-224.611	75.520
700	-242.141	-223.308	69.719
750	-243.429	-221.928	64.669
800	-244.848	-220.449	60.223
850	-246.421	-218.869	56.274

Phase change: 580.15 K, melting point of As_4S_4; ΔH° = 6.375 kcal/mol.

Table 25. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) = 4\ AsS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	213.002	213.002	∞
100	214.538	196.766	-430.027
200	214.059	179.090	-195.698
298.15	213.000	162.143	-118.852
300	212.977	161.827	-117.889
350	212.406	153.349	-95.754
400	211.831	144.951	-79.197
450	211.263	136.628	-66.355
500	210.682	128.367	-56.108
550	210.088	120.159	-47.746
580.15	209.720	115.240	-43.412
580.15	203.345	115.240	-43.412
600	202.832	112.234	-40.881
650	201.502	104.740	-35.216
700	200.073	97.349	-30.393
750	198.524	90.066	-26.245
800	196.830	82.890	-22.644
850	194.977	75.825	-19.496

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H° = 6.375$ kcal/mol.

Table 26. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) = As_4S_4(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	32.619	32.619	∞
100	32.630	27.550	-60.209
200	32.212	22.624	-24.722
298.15	31.700	18.024	-13.212
300	31.690	17.940	-13.069
350	31.411	15.670	-9.785
400	31.111	13.441	-7.344
450	30.799	11.251	-5.464
500	30.459	9.098	-3.976
550	30.094	6.978	-2.773
580.15	29.860	5.718	-2.154
580.15	23.485	5.718	-2.154
600	23.058	5.117	-1.864
650	21.937	3.667	-1.233
700	20.720	2.307	-.720
750	19.382	1.037	-.302
800	17.903	-.139	.038
850	16.270	-1.216	.313

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H° = 6.375$ kcal/mol.

Table 27. - Thermodynamic data for the reaction

$As_4S_4(\beta,\ell) = As_4(g) + 4\ S(or,mon,\ell)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	69.246	69.246	∞
100	69.575	64.393	-140.728
200	69.283	59.302	-64.802
298.15	68.840	54.495	-39.946
300	68.831	54.406	-39.634
350	68.604	52.021	-32.483
368.30	68.521	51.156	-30.356
368.30	68.905	51.156	-30.356
388.36	68.823	50.189	-28.244
388.36	70.475	50.189	-28.244
400	70.501	49.582	-27.090
432.02	70.643	47.904	-24.233
450	71.016	46.950	-22.802
500	71.357	44.256	-19.344
550	71.596	41.530	-16.502
580.15	71.697	39.880	-15.023
580.15	65.322	39.880	-15.023
600	65.097	39.013	-14.210
650	64.442	36.865	-12.395
700	63.645	34.773	-10.856
717.82	63.316	34.040	-10.364

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; $\Delta H°$ = .096 kcal/mol.
388.36 K, melting point of S; $\Delta H°$ = .413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.
717.82 K, boiling point of S.

Table 28. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) = 4\ As(\alpha) + 2\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	93.620	69.044	-50.610
300	93.609	68.892	-50.187
350	93.318	64.798	-40.461
400	92.995	60.745	-33.189
450	92.650	56.729	-27.551
500	92.288	52.757	-23.060
550	91.907	48.825	-19.401
580.15	91.666	46.470	-17.506
580.15	85.291	46.470	-17.506
600	84.862	45.149	-16.445
650	83.742	41.885	-14.083
700	82.537	38.710	-12.086
750	81.221	35.622	-10.380
800	79.780	32.629	-8.914
850	78.196	29.739	-7.646

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H° = 6.375$ kcal/mol.

Table 29. - Thermodynamic data for the reaction

$$As_4S_4(\beta,\ell) = As_4(g) + 2\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	130.518	130.518	∞
100	131.657	118.352	-258.655
200	131.213	105.148	-114.899
298.15	130.260	92.550	-67.840
300	130.239	92.315	-67.251
350	129.687	86.040	-53.725
400	129.105	79.844	-43.624
450	128.500	73.721	-35.803
500	127.867	67.668	-29.577
550	127.207	61.680	-24.509
580.15	126.794	58.100	-21.887
580.15	120.419	58.100	-21.887
600	119.875	55.976	-20.389
650	118.458	50.709	-17.050
700	116.945	45.553	-14.222
750	115.312	40.509	-11.804
800	113.539	35.579	-9.720
850	111.615	30.768	-7.911

Phase change: 580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.

Table 30. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 4.5\ O_2(g) = As_2O_3(cubic) + 3\ SO_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
298.15	-353.210	-336.230	246.460
300	-353.223	-336.123	244.862
350	-353.537	-333.245	208.085
400	-353.768	-330.331	180.482
450	-353.945	-327.390	159.000
478	-354.047	-325.735	148.930
500	-354.365	-324.425	141.804
550	-355.127	-321.393	127.708
551	-355.142	-321.331	127.452

Phase changes: 478 K, glass transition temperature of As_2S_3.
551 K, melting point of As_2O_3.

Table 31. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 4.5\ O_2(g) = 0.5\ As_4O_6(g) + 3\ SO_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-335.507	-335.507	∞
100	-336.553	-334.661	731.391
200	-338.006	-332.195	363.001
298.15	-339.145	-329.093	241.228
300	-339.162	-329.028	239.694
350	-339.598	-327.302	204.374
400	-339.976	-325.520	177.854
450	-340.310	-323.691	157.204
478	-340.514	-322.651	147.520
500	-340.917	-321.821	140.666
550	-341.890	-319.863	127.100
585	-342.592	-318.440	118.964
600	-342.879	-317.817	115.763
650	-343.795	-315.691	106.143
700	-344.665	-313.496	97.877
750	-345.497	-311.245	90.696
800	-346.297	-308.936	84.396
850	-347.067	-306.574	78.824

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 32. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 6\ O_2(g) = As_2O_3(cubic) + 3\ SO_3(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-424.130	-387.062	283.721
300	-424.150	-386.832	281.803
350	-424.565	-380.574	237.638
400	-424.854	-374.270	204.489
450	-425.040	-367.932	178.690
478	-425.135	-364.376	166.597
500	-425.441	-361.574	158.042
550	-426.154	-355.151	141.122
551	-426.168	-355.022	140.815

Phase changes: 478 K, glass transition temperature of As_2S_3.
551 K, melting point of As_2O_3.

Table 33. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 6\ O_2(g) = 0.5\ As_4O_6(g) + 3\ SO_3(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-404.137	-404.137	∞
100	-406.221	-398.359	870.601
200	-408.501	-389.574	425.701
298.15	-410.065	-379.925	278.489
300	-410.090	-379.738	276.635
350	-410.627	-374.630	233.927
400	-411.063	-369.459	201.860
450	-411.404	-364.233	176.893
478	-411.602	-361.293	165.187
500	-411.992	-358.969	156.903
550	-412.917	-353.621	140.514
585	-413.575	-349.828	130.690
600	-413.839	-348.190	126.826
650	-414.668	-342.683	115.219
700	-415.440	-337.117	105.251
750	-416.160	-331.502	96.598
800	-416.840	-325.837	89.013
850	-417.486	-320.127	82.309

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 34. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 3\ H_2(g) = 2\ As(\alpha) + 3\ H_2S(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	1.840	-7.373	5.404
300	1.817	-7.430	5.413
350	1.214	-8.920	5.570
400	.608	-10.328	5.643
450	-.023	-11.661	5.663
478	-.399	-12.374	5.658
500	-.943	-12.914	5.645
550	-2.251	-14.045	5.581
585	-3.185	-14.767	5.517
600	-3.571	-15.059	5.485
650	-4.816	-15.965	5.368
700	-6	-16.779	5.238
750	-7.130	-17.508	5.102
800	-8.207	-18.165	4.962
850	-9.235	-18.753	4.822

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 35. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 3\ H_2(g) = 0.5\ As_4(g) + 3\ H_2S(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	22.506	22.506	∞
100	22.356	15.965	-34.892
200	21.475	9.867	-10.782
298.15	20.160	4.380	-3.211
300	20.132	4.281	-3.119
350	19.399	1.701	-1.062
400	18.663	-.778	.425
450	17.901	-3.165	1.537
478	17.451	-4.463	2.040
500	16.846	-5.459	2.386
550	15.400	-7.617	3.027
585	14.365	-9.050	3.381
600	13.936	-9.645	3.513
650	12.542	-11.554	3.885
700	11.204	-13.357	4.170
750	9.915	-15.065	4.390
800	8.672	-16.690	4.560
850	7.474	-18.238	4.689

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 36. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 1.5\ C(gr) = 2\ As(\alpha) + 1.5\ CS_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	58.555	40.580	-29.746
300	58.550	40.469	-29.481
350	58.422	37.468	-23.396
400	58.271	34.484	-18.841
450	58.079	31.519	-15.308
478	57.936	29.871	-13.657
500	57.568	28.587	-12.495
550	56.638	25.735	-10.226
585	55.951	23.789	-8.887
600	55.666	22.968	-8.366
650	54.737	20.281	-6.819
700	53.840	17.665	-5.515
750	52.967	15.112	-4.404
800	52.117	12.616	-3.446
850	51.285	10.174	-2.616

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 37. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 1.5\ C(gr) = 0.5\ As_4(g) + 1.5\ CS_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	76.838	76.838	∞
100	77.488	68.973	-150.738
200	77.304	60.498	-66.109
298.15	76.875	52.333	-38.361
300	76.865	52.181	-38.013
350	76.607	48.089	-30.028
400	76.326	44.034	-24.059
450	76.004	40.015	-19.434
478	75.785	37.782	-17.274
500	75.357	36.042	-15.754
550	74.288	32.162	-12.780
585	73.501	29.506	-11.023
600	73.172	28.382	-10.338
650	72.095	24.693	-8.302
700	71.044	21.086	-6.583
750	70.012	17.555	-5.116
800	68.996	14.091	-3.849
850	67.994	10.689	-2.748

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 38. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 3\ C(gr) = 2\ As(\alpha) + 3\ CS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	217.630	180.706	-132.460
300	217.628	180.477	-131.476
350	217.566	174.291	-108.831
400	217.445	168.117	-91.853
450	217.245	161.960	-78.658
478	217.085	158.525	-72.479
500	216.698	155.838	-68.116
550	215.708	149.802	-59.525
585	214.966	145.631	-54.405
600	214.655	143.857	-52.399
650	213.626	137.998	-46.398
700	212.616	132.218	-41.280
750	211.618	126.512	-36.865
800	210.631	120.870	-33.020
850	209.649	115.289	-29.643

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 39. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 3\ C(gr) = 0.5\ As_4(g) + 3\ CS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	233.877	233.877	∞
100	235.534	221.304	-483.654
200	236.056	206.811	-225.990
298.15	235.950	192.459	-141.075
300	235.943	192.189	-140.008
350	235.751	184.913	-115.463
400	235.500	177.666	-97.071
450	235.169	170.456	-82.784
478	234.934	166.436	-76.097
500	234.488	163.293	-71.374
550	233.358	156.230	-62.079
585	232.516	151.348	-56.541
600	232.161	149.271	-54.371
650	230.984	142.410	-47.882
700	229.820	135.640	-42.348
750	228.663	128.955	-37.577
800	227.510	122.345	-33.423
850	226.359	115.804	-29.775

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 40. - Thermodynamic data for the reaction

$$As_2S_3(gl,\ell) + 4.5\ Cl_2(g) = 2\ AsCl_3(g) + 1.5\ S_2Cl_2(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-111.951	-111.951	∞
100	-112.578	-112.345	245.527
200	-112.831	-111.993	122.379
298.15	-112.970	-111.583	81.791
300	-112.972	-111.574	81.281
350	-113.036	-111.336	69.520
400	-113.100	-111.090	60.696
450	-113.186	-110.830	53.826
478	-113.269	-110.682	50.605
500	-113.589	-110.557	48.324
550	-114.405	-110.211	43.793
585	-115.011	-109.926	41.067
600	-115.261	-109.792	39.991
650	-116.070	-109.305	36.751
700	-116.851	-108.755	33.955
750	-117.613	-108.156	31.516
800	-118.351	-107.502	29.368
850	-119.068	-106.796	27.459

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 41. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) + 6\ Cl_2(g) = 2\ AsCl_3(g) + 3\ SCl_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-118.273	-118.273	∞
100	-118.885	-119.281	260.686
200	-119.270	-119.511	130.594
298.15	-119.570	-119.569	87.645
300	-119.574	-119.567	87.103
350	-119.726	-119.556	74.653
400	-119.880	-119.522	65.303
450	-120.056	-119.464	58.019
478	-120.192	-119.424	54.602
500	-120.552	-119.381	52.181
550	-121.461	-119.217	47.372
585	-122.134	-119.054	44.477
600	-122.413	-118.971	43.335
650	-123.320	-118.650	39.893
700	-124.201	-118.258	36.921
750	-125.067	-117.808	34.329
800	-125.909	-117.297	32.044
850	-126.733	-116.728	30.013

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 42. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) = 0.5\ As_4(g) + 3\ S(or,mon,\ell)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	35.205	35.205	∞
100	35.313	32.918	-71.941
200	35.158	30.575	-33.411
298.15	34.950	28.368	-20.794
300	34.946	28.326	-20.636
350	34.850	27.233	-17.005
368.30	34.818	26.835	-15.924
368.30	35.106	26.835	-15.924
388.36	35.080	26.383	-14.847
388.36	36.319	26.383	-14.847
400	36.357	26.085	-14.252
432.02	36.514	25.259	-12.778
450	36.812	24.785	-12.037
478	36.929	24.029	-10.986
500	36.841	23.436	-10.244
550	36.402	22.115	-8.787
585	36.031	21.217	-7.926
600	35.871	20.839	-7.591
650	35.333	19.608	-6.593
700	34.790	18.419	-5.751
717.82	34.590	18.003	-5.481

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; $\Delta H°$ = .096 kcal/mol.
388.36 K, melting point of S; $\Delta H°$ = .413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.
717.82 K, boiling point of S.

Table 43. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) = 2\ As(\alpha) + 1.5\ S_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
298.15	62.695	45.156	-33.100
300	62.687	45.047	-32.816
350	62.477	42.126	-26.304
400	62.255	39.232	-21.435
450	62	36.367	-17.662
478	61.825	34.777	-15.900
500	61.435	33.540	-14.660
550	60.460	30.800	-12.239
585	59.745	28.934	-10.809
600	59.448	28.148	-10.253
650	58.487	25.579	-8.600
700	57.561	23.083	-7.207
750	56.664	20.650	-6.017
800	55.794	18.277	-4.993
850	54.947	15.965	-4.105

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 44. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) = 0.5\ As_4(g) + 1.5\ S_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	81.159	81.159	∞
100	81.875	73.388	-160.387
200	81.605	64.960	-70.984
298.15	81.015	56.909	-41.715
300	81.002	56.758	-41.348
350	80.662	52.747	-32.936
400	80.310	48.782	-26.653
450	79.925	44.863	-21.788
478	79.675	42.689	-19.518
500	79.224	40.996	-17.919
550	78.110	37.228	-14.793
585	77.295	34.651	-12.945
600	76.955	33.562	-12.225
650	75.845	29.991	-10.084
700	74.765	26.505	-8.275
750	73.709	23.093	-6.729
800	72.673	19.752	-5.396
850	71.656	16.479	-4.237

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 45. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) = 2\ AsS(g) + 0.5\ S_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	122.401	122.401	∞
100	123.315	112.595	-246.073
200	123.029	101.931	-111.383
298.15	122.385	91.705	-67.221
300	122.371	91.514	-66.667
350	122.022	86.401	-53.951
400	121.673	81.336	-44.439
450	121.306	76.317	-37.064
478	121.070	73.524	-33.616
500	120.632	71.345	-31.184
550	119.551	66.467	-26.411
585	118.761	63.113	-23.578
600	118.434	61.691	-22.471
650	117.367	57.007	-19.167
700	116.329	52.403	-16.361
750	115.315	47.872	-13.950
800	114.319	43.408	-11.858
850	113.337	39.007	-10.029

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 46. - Thermodynamic data for the reaction

$$As_2S_3(gl,\ell) = 0.5\ As_4S_4(\beta,\ell) + 0.5\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	15.900	15.900	∞
100	16.046	14.212	-31.059
200	15.999	12.386	-13.534
298.15	15.885	10.634	-7.795
300	15.882	10.601	-7.723
350	15.819	9.727	-6.074
400	15.757	8.860	-4.841
450	15.675	8.003	-3.887
478	15.600	7.527	-3.441
500	15.290	7.161	-3.130
550	14.507	6.387	-2.538
580.15	14.009	5.955	-2.243
580.15	17.197	5.955	-2.243
585	17.151	5.861	-2.190
600	17.017	5.574	-2.030
650	16.616	4.637	-1.559
700	16.292	3.728	-1.164
750	16.053	2.839	-.827
800	15.903	1.963	-.536
850	15.849	1.095	-.282

Phase changes: 478 K, glass transition temperature of As_2S_3.
580.15 K, melting point of As_4S_4; $\Delta H°$ = 6.375 kcal/mol.
585 K, melting point of As_2S_3.

Table 47. - Thermodynamic data for the reaction

$As_2S_3(gl,\ell) = 0.5\ As_4S_4(g) + 0.5\ S_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	32.209	32.209	∞
100	32.361	27.986	-61.164
200	32.105	23.698	-25.895
298.15	31.735	19.646	-14.400
300	31.727	19.571	-14.257
350	31.524	17.562	-10.966
400	31.313	15.581	-8.513
450	31.074	13.628	-6.619
478	30.906	12.547	-5.737
500	30.520	11.710	-5.118
550	29.554	9.877	-3.925
585	28.842	8.646	-3.230
600	28.546	8.132	-2.962
650	27.585	6.470	-2.175
700	26.653	4.881	-1.524
750	25.744	3.357	-.978
800	24.855	1.893	-.517
850	23.984	.487	-.125

Phase changes: 478 K, glass transition temperature of As_2S_3.
585 K, melting point of As_2S_3.

Table 48. - Thermodynamic data for the reaction

$AsS(g) + 1.75\ O_2(g) = 0.5\ As_2O_3(cubic) + SO_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-194.650	-173.348	127.066
300	-194.648	-173.215	126.185
350	-194.600	-169.646	105.931
400	-194.516	-166.087	90.745
450	-194.403	-162.541	78.939
500	-194.261	-159.008	69.501
550	-194.091	-155.489	61.785
551	-194.087	-155.419	61.645

Phase change: 551 K, melting point of As_2O_3.

Table 49. - Thermodynamic data for the reaction

$AsS(g) + 1.75\ O_2(g) = 0.25\ As_4O_6(g) + SO_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-186.129	-186.129	∞
100	-186.977	-181.408	396.463
200	-187.451	-175.626	191.913
298.15	-187.618	-169.779	124.450
300	-187.618	-169.668	123.601
400	-187.621	-163.682	89.430
500	-187.536	-157.705	68.932
600	-187.401	-151.750	55.274
700	-187.236	-145.822	45.527
800	-187.047	-139.920	38.224
900	-186.839	-134.041	32.549
1000	-186.617	-128.186	28.015
1100	-186.383	-122.353	24.309
1200	-186.141	-116.543	21.225
1300	-185.890	-110.754	18.619
1400	-185.634	-104.983	16.388
1500	-185.374	-99.232	14.458
1600	-185.112	-93.498	12.771
1700	-184.847	-87.780	11.285
1800	-184.583	-82.074	9.965
1900	-184.322	-76.389	8.787
2000	-184.061	-70.717	7.727
2100	-183.803	-65.055	6.770
2200	-183.549	-59.405	5.901
2300	-183.299	-53.771	5.109
2400	-183.053	-48.144	4.384
2500	-182.811	-42.524	3.717
2600	-182.575	-36.922	3.104
2700	-182.343	-31.324	2.535
2800	-182.116	-25.730	2.008
2900	-181.895	-20.151	1.519
3000	-181.680	-14.577	1.062

Table 50. - Thermodynamic data for the reaction

$AsS(g) + 2.25\ O_2(g) = 0.5\ As_2O_3(cubic) + SO_3(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
298.15	-218.290	-190.292	139.486
300	-218.291	-190.118	138.499
350	-218.276	-185.423	115.782
400	-218.212	-180.733	98.747
450	-218.101	-176.055	85.503
500	-217.953	-171.390	74.914
550	-217.766	-166.742	66.256
551	-217.762	-166.649	66.099

Phase change: 551 K, melting point of As_2O_3.

Table 51. - Thermodynamic data for the reaction

$$AsS(g) + 2.25\ O_2(g) = 0.25\ As_4O_6(g) + SO_3(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-209.005	-209.005	∞
100	-210.200	-202.641	442.866
200	-210.949	-194.752	212.813
298.15	-211.258	-186.723	136.870
300	-211.260	-186.571	135.915
400	-211.316	-178.328	97.433
500	-211.228	-170.088	74.345
600	-211.054	-161.875	58.962
700	-210.827	-153.695	47.985
800	-210.562	-145.554	39.763
900	-210.268	-137.444	33.376
1000	-209.951	-129.370	28.273
1100	-209.619	-121.328	24.105
1200	-209.273	-113.316	20.637
1300	-208.919	-105.334	17.708
1400	-208.559	-97.380	15.202
1500	-208.193	-89.451	13.033
1600	-207.827	-81.547	11.139
1700	-207.459	-73.665	9.470
1800	-207.093	-65.801	7.989
1900	-206.732	-57.965	6.667
2000	-206.372	-50.144	5.479
2100	-206.020	-42.342	4.407
2200	-205.673	-34.556	3.433
2300	-205.333	-26.788	2.545
2400	-205.001	-19.032	1.733
2500	-204.675	-11.288	.987
2600	-204.357	-3.562	.299
2700	-204.047	4.155	-.336
2800	-203.746	11.868	-.926
2900	-203.454	19.561	-1.474
3000	-203.170	27.246	-1.985

Table 52. - Thermodynamic data for the reaction

$$AsS(g) + H_2(g) = As(\alpha) + H_2S(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-50.130	-40.784	29.895
300	-50.132	-40.726	29.669
400	-50.258	-37.572	20.528
500	-50.391	-34.387	15.030
600	-50.499	-31.174	11.355
700	-50.571	-27.947	8.725
800	-50.596	-24.713	6.751
876	-50.581	-22.253	5.552

Phase change: 876 K, sublimation point of As.

Table 53. - Thermodynamic data for the reaction

$$AsS(g) + H_2(g) = 0.25\ As_4(g) + H_2S(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-40.172	-40.172	∞
100	-40.560	-38.744	84.675
200	-40.755	-36.850	40.267
298.15	-40.970	-34.908	25.588
300	-40.975	-34.870	25.403
400	-41.231	-32.797	17.919
500	-41.496	-30.659	13.401
600	-41.746	-28.467	10.369
700	-41.969	-26.236	8.191
800	-42.156	-23.975	6.550
900	-42.305	-21.693	5.268
1000	-42.420	-19.398	4.239
1100	-42.501	-17.091	3.396
1200	-42.556	-14.777	2.691
1300	-42.590	-12.461	2.095
1400	-42.603	-10.142	1.583
1500	-42.601	-7.824	1.140
1600	-42.585	-5.507	.752
1700	-42.559	-3.188	.410
1800	-42.525	-.873	.106
1900	-42.485	1.439	-.165
2000	-42.437	3.750	-.410

Table 54. - Thermodynamic data for the reaction

$$AsS(g) + 0.5\ C(gr) = As(\alpha) + 0.5\ CS_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-31.225	-24.800	18.179
300	-31.221	-24.760	18.037
400	-31.037	-22.634	12.367
500	-30.888	-20.554	8.984
600	-30.754	-18.498	6.738
700	-30.624	-16.466	5.141
800	-30.488	-14.452	3.948
876	-30.377	-12.933	3.227

Phase change: 876 K, sublimation point of As.

Table 55. - Thermodynamic data for the reaction

$AsS(g) + 0.5\ C(gr) = 0.25\ As_4(g) + 0.5\ CS_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-22.062	-22.062	∞
100	-22.183	-21.075	46.059
200	-22.146	-19.973	21.825
298.15	-22.065	-18.923	13.871
300	-22.063	-18.904	13.771
400	-22.010	-17.860	9.758
500	-21.993	-16.826	7.354
600	-22	-15.791	5.752
700	-22.022	-14.755	4.607
800	-22.048	-13.715	3.747
900	-22.073	-12.672	3.077
1000	-22.095	-11.626	2.541
1100	-22.112	-10.573	2.101
1200	-22.124	-9.529	1.735
1300	-22.133	-8.479	1.425
1400	-22.137	-7.428	1.160
1500	-22.138	-6.377	.929
1600	-22.135	-5.327	1.728
1700	-22.130	-4.277	.550
1800	-22.122	-3.225	.392
1900	-22.113	-2.177	.250
2000	-22.101	-1.127	.123

Table 56. - Thermodynamic data for the reaction

$$AsS(g) + C(gr) = As(\alpha) + CS(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	21.800	21.909	-16.059
300	21.805	21.910	-15.961
400	22.021	21.910	-11.971
500	22.156	21.864	-9.556
600	22.243	21.798	-7.940
700	22.301	21.719	-6.781
800	22.350	21.632	-5.910
876	22.385	21.563	-5.380

Phase change: 876 K, sublimation point of As.

Table 57. - Thermodynamic data for the reaction

$$AsS(g) + C(gr) = 0.25\ As_4(g) + CS(g)$$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	30.285	30.285	∞
100	30.499	29.702	-64.913
200	30.772	28.798	-31.469
298.15	30.960	27.785	-20.367
300	30.963	27.766	-20.227
400	31.049	26.685	-14.580
500	31.051	25.591	-11.186
600	30.996	24.505	-8.926
700	30.903	23.429	-7.315
800	30.790	22.370	-6.111
900	30.663	21.323	-5.178
1000	30.531	20.293	-4.435
1100	30.395	19.286	-3.832
1200	30.256	18.272	-3.328
1300	30.114	17.279	-2.905
1400	29.973	16.297	-2.544
1500	29.832	15.325	-2.233
1600	29.689	14.364	-1.962
1700	29.546	13.408	-1.724
1800	29.401	12.465	-1.513
1900	29.256	11.529	-1.326
2000	29.109	10.598	-1.158

Table 58. - Thermodynamic data for the reaction

$AsS(g) + 2\ Cl_2(g) = AsCl_3(g) + 0.5\ S_2Cl_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-108.607	-108.607	∞
100	-109.259	-104.521	228.427
200	-109.226	-99.763	109.014
298.15	-109	-95.174	69.763
300	-108.995	-95.088	69.271
400	-108.752	-90.490	49.441
500	-108.523	-85.951	37.569
600	-108.310	-81.455	29.670
700	-108.104	-76.997	24.039
800	-107.900	-72.570	19.825
900	-107.690	-68.164	16.552
1000	-107.477	-63.786	13.940
1100	-107.257	-59.426	11.807
1200	-107.037	-55.088	10.033
1300	-106.814	-50.768	8.535
1400	-106.589	-46.465	7.253
1500	-106.363	-42.177	6.145

Table 59. - Thermodynamic data for the reaction

$$AsS(g) + 2.5\ Cl_2(g) = AsCl_3(g) + SCl_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-110.715	-110.715	∞
100	-111.361	-106.833	233.480
200	-111.372	-102.269	111.753
298.15	-111.200	-97.836	71.715
300	-111.196	-97.752	71.212
400	-111.012	-93.301	50.977
500	-110.844	-88.893	38.854
600	-110.694	-84.515	30.784
700	-110.554	-80.164	25.028
800	-110.420	-75.835	20.717
900	-110.281	-71.518	17.367
1000	-110.142	-67.220	14.691
1100	-109.998	-62.934	12.504
1200	-109.854	-58.663	10.684
1300	-109.707	-54.404	9.146
1400	-109.557	-50.154	7.829
1500	-109.407	-45.916	6.690
1600	-109.256	-41.689	5.694
1700	-109.104	-37.465	4.816
1800	-108.952	-33.259	4.038
1900	-108.802	-29.056	3.342
2000	-108.654	-24.861	2.717

Table 60. - Thermodynamic data for the reaction

$$AsS(g) = 0.25\ As_4(g) + S(or,mon,\ell)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-35.939	-35.939	∞
100	-36.241	-33.093	72.325
200	-36.194	-29.947	32.724
298.15	-36.040	-26.912	19.727
300	-36.036	-26.855	19.564
368.30	-35.918	-24.777	14.703
368.30	-35.822	-24.777	14.703
388.36	-35.785	-24.178	13.606
388.36	-35.372	-24.178	13.606
400	-35.333	-23.842	13.027
432.02	-35.205	-22.927	11.598
500	-34.831	-21.028	9.191
600	-34.434	-18.305	6.668
700	-34.107	-15.644	4.884
717.82	-34.055	-15.175	4.620

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; $\Delta H°$ = 0.096 kcal/mol.
388.36 K, melting point of S; $\Delta H°$ = 0.413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
717.82 K, boiling point of S.

Table 61. - Thermodynamic data for the reaction

$$AsS(g) = As(\alpha) + 0.5\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-29.845	-23.275	17.061
300	-29.842	-23.234	16.926
400	-29.709	-21.052	11.502
500	-29.599	-18.902	8.262
600	-29.493	-16.771	6.109
700	-29.384	-14.660	4.577
800	-29.263	-12.565	3.433
876	-29.158	-10.981	2.740

Phase change: 876 K, sublimation point of As.

Table 62. - Thermodynamic data for the reaction

$$4\ AsS(g) = As_4(g) + 2\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-82.484	-82.484	∞
100	-82.881	-78.414	171.372
200	-82.846	-73.941	80.798
298.15	-82.740	-69.593	51.012
300	-82.738	-69.512	50.639
400	-82.726	-65.107	35.572
500	-82.815	-60.698	26.531
600	-82.957	-56.258	20.492
700	-83.128	-51.796	16.171
800	-83.291	-47.311	12.925
900	-83.430	-42.801	10.393
1000	-83.544	-38.281	8.366
1100	-83.624	-33.751	6.706
1200	-83.671	-29.214	5.320
1300	-83.690	-24.676	4.148
1400	-83.673	-20.135	3.143
1500	-83.628	-15.595	2.272
1600	-83.556	-11.065	1.511
1700	-83.456	-6.536	.840
1800	-83.338	-2.010	.244
1900	-83.200	2.499	-.288
2000	-83.039	7.005	-.765
2100	-82.863	11.503	-1.197
2200	-82.673	15.995	-1.589
2300	-82.470	20.467	-1.945
2400	-82.254	24.940	-2.271
2500	-82.027	29.408	-2.571
2600	-81.792	33.859	-2.846
2700	-81.548	38.300	-3.100
2800	-81.297	42.737	-3.336
2900	-81.041	47.154	-3.554
3000	-80.778	51.582	-3.758

Table 63. - Thermodynamic data for the reaction

$As_4S_4(g) + 7\ O_2(g) = 2\ As_2O_3(cubic) + 4\ SO_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
298.15	-597.300	-549.274	402.623
300	-597.306	-548.973	399.921
350	-597.405	-540.906	337.753
400	-597.345	-532.838	291.126
450	-597.147	-524.786	254.867
500	-596.819	-516.762	225.873
550	-596.369	-508.775	202.166
551	-596.358	-508.616	201.736

Phase change: 551 K, melting point of As_2O_3.

Table 64. - Thermodynamic data for the reaction

$$As_4S_4(g) + 7\ O_2(g) = As_4O_6(g) + 4\ SO_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	-564.131	-564.131	∞
100	-566	-556.417	1216.033
200	-567.955	-546.038	596.675
298.15	-569.170	-534.999	392.160
300	-569.185	-534.784	389.585
400	-569.762	-523.216	285.868
500	-569.922	-511.552	223.597
600	-569.829	-499.884	182.080
700	-569.589	-488.244	152.435
800	-569.262	-476.652	130.213
900	-568.873	-465.095	112.939
1000	-568.446	-453.589	99.131
1100	-568.001	-442.119	87.840
1200	-567.541	-430.700	78.440
1300	-567.066	-419.316	70.492
1400	-566.594	-407.968	63.686
1500	-566.119	-396.658	57.792
1600	-565.653	-385.373	52.639
1700	-565.188	-374.118	48.096
1800	-564.739	-362.883	44.060
1900	-564.304	-351.688	40.453
2000	-563.885	-340.515	37.209
2100	-563.484	-329.349	34.275
2200	-563.099	-318.210	31.611
2300	-562.741	-307.091	29.180
2400	-562.400	-295.983	26.953
2500	-562.080	-284.882	24.904
2600	-561.785	-273.814	23.016
2700	-561.509	-262.740	21.267
2800	-561.258	-251.665	19.643
2900	-561.028	-240.613	18.133
3000	-560.824	-229.579	16.725

Table 65. - Thermodynamic data for the reaction

$As_4S_4(g) + 9\ O_2(g) = 2\ As_2O_3(cubic) + 4\ SO_3(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-691.860	-617.050	452.304
300	-691.876	-616.586	449.177
350	-692.110	-604.011	377.157
400	-692.127	-591.423	323.135
450	-691.940	-578.842	281.120
500	-691.587	-566.293	247.523
550	-691.072	-553.787	220.052
551	-691.060	-553.536	219.553

Phase change: 551 K, melting point of As_2O_3.

Table 66. - Thermodynamic data for the reaction

$As_4S_4(g) + 9\ O_2(g) = As_4O_6(g) + 4\ SO_3(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-655.637	-655.637	∞
100	-658.890	-641.348	1401.646
200	-661.949	-622.544	680.275
298.15	-663.730	-602.775	441.840
300	-663.755	-602.397	438.840
400	-664.544	-581.801	317.877
500	-664.690	-561.084	245.246
600	-664.443	-540.382	196.831
700	-663.955	-519.739	162.268
800	-663.320	-499.186	136.370
900	-662.587	-478.711	116.245
1000	-661.782	-458.325	100.166
1100	-660.943	-438.019	87.025
1200	-660.071	-417.789	76.089
1300	-659.180	-397.636	66.848
1400	-658.292	-377.556	58.938
1500	-657.397	-357.535	52.092
1600	-656.513	-337.567	46.109
1700	-655.636	-317.659	40.837
1800	-654.779	-297.792	36.156
1900	-653.944	-277.993	31.976
2000	-653.131	-258.225	28.217
2100	-652.352	-238.499	24.821
2200	-651.595	-218.813	21.737
2300	-650.877	-199.157	18.924
2400	-650.190	-179.533	16.349
2500	-649.534	-159.937	13.981
2600	-648.913	-140.374	11.799
2700	-648.325	-120.823	9.780
2800	-647.776	-101.275	7.905
2900	-647.262	-81.768	6.162
3000	-646.784	-62.285	4.537

Table 67. - Thermodynamic data for the reaction

$$As_4S_4(g) + 4\ H_2(g) = 4\ As(\alpha) + 4\ H_2S(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	-19.220	-19.018	13.940
300	-19.241	-19.017	13.854
400	-20.312	-18.776	10.259
500	-21.341	-18.279	7.990
600	-22.222	-17.577	6.402
700	-22.931	-16.745	5.228
800	-23.457	-15.823	4.322
876	-23.733	-15.079	3.762

Phase change: 876.0 K, sublimation point of As.

Table 68. - Thermodynamic data for the reaction

$As_4S_4(g) + 4\ H_2(g) = As_4(g) + 4\ H_2S(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	19.695	19.695	∞
100	19.669	14.239	-31.119
200	18.827	9.067	-9.908
298.15	17.420	4.488	-3.290
300	17.389	4.406	-3.210
400	15.798	.323	-.177
500	14.238	-3.368	1.472
600	12.791	-6.750	2.459
700	11.477	-9.902	3.091
800	10.302	-12.872	3.517
900	9.264	-15.706	3.814
1000	8.340	-18.436	4.029
1100	7.527	-21.070	4.186
1200	6.797	-23.633	4.304
1300	6.136	-26.143	4.395
1400	5.532	-28.604	4.465
1500	4.974	-31.026	4.520
1600	4.455	-33.407	4.563
1700	3.965	-35.750	4.596
1800	3.494	-38.079	4.623
1900	3.043	-40.378	4.644
2000	2.609	-42.649	4.660

Table 69. - Thermodynamic data for the reaction

$$As_4S_4(g) + 2\ C(gr) = 4\ As(\alpha) + 2\ CS_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	56.400	44.919	-32.926
300	56.403	44.849	-32.672
400	56.572	40.972	-22.386
500	56.673	37.055	-16.197
600	56.760	33.125	-12.066
700	56.855	29.179	-9.110
800	56.975	25.219	-6.889
876	57.086	22.200	-5.539

Phase change: 876 K, sublimation point of As.

Table 70. - Thermodynamic data for the reaction

$As_4S_4(g) + 2\ C(gr) = As_4(g) + 2\ CS_2(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	92.137	92.137	∞
100	93.177	84.916	-185.581
200	93.265	76.575	-83.676
298.15	93.040	68.425	-50.156
300	93.033	68.272	-49.735
400	92.682	60.072	-32.821
500	92.252	51.966	-22.714
600	91.773	43.953	-16.010
700	91.263	36.022	-11.247
800	90.734	28.169	-7.695
900	90.190	20.378	-4.948
1000	89.640	12.650	-2.765
1100	89.085	5.000	-.993
1200	88.525	-2.641	.481
1300	87.960	-10.216	1.717
1400	87.394	-17.747	2.770
1500	86.824	-25.238	3.677
1600	86.255	-32.686	4.465
1700	85.681	-40.109	5.156
1800	85.108	-47.487	5.766
1900	84.533	-54.841	6.308
2000	83.953	-62.157	6.792

Table 71. - Thermodynamic data for the reaction

$$As_4S_4(g) + 4\ C(gr) = 4\ As(\alpha) + 4\ CS(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	268.500	231.754	-169.878
300	268.507	231.526	-168.664
400	268.804	219.149	-119.736
500	268.847	206.723	-90.357
600	268.746	194.311	-70.777
700	268.557	181.917	-56.796
800	268.327	169.558	-46.321
876	268.133	160.184	-39.963

Phase change: 876 K, sublimation point of As.

Table 72. - Thermodynamic data for the reaction

$As_4S_4(g) + 4\ C(gr) = As_4(g) + 4\ CS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	301.523	301.523	∞
100	303.905	288.024	-629.469
200	304.935	271.659	-296.851
298.15	305.140	255.260	-187.108
300	305.137	254.949	-185.728
400	304.914	238.249	-130.171
500	304.426	221.634	-96.875
600	303.759	205.138	-74.721
700	302.965	188.761	-58.933
800	302.086	172.508	-47.126
900	301.136	156.361	-37.969
1000	300.144	140.328	-30.668
1100	299.111	124.439	-24.723
1200	298.045	108.563	-19.772
1300	296.952	92.818	-15.604
1400	295.836	77.152	-12.044
1500	294.702	61.572	-8.971
1600	293.551	46.076	-6.294
1700	292.381	30.632	-3.938
1800	291.198	15.272	-1.854
1900	290.007	-.019	.002
2000	288.793	-15.257	1.667

Table 73. - Thermodynamic data for the reaction

$As_4S_4(g) + 8\ Cl_2(g) = 4\ AsCl_3(g) + 2\ S_2Cl_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-254.047	-254.047	∞
100	-255.126	-248.866	543.889
200	-255.055	-242.586	265.082
298.15	-254.700	-236.577	173.413
300	-254.693	-236.465	172.262
400	-254.286	-230.450	125.911
500	-253.869	-224.536	98.143
600	-253.464	-218.703	79.661
700	-253.061	-212.945	66.483
800	-252.673	-207.250	56.617
900	-252.274	-201.588	48.952
1000	-251.886	-195.987	42.832
1100	-251.497	-190.410	37.830
1200	-251.128	-184.877	33.670
1300	-250.762	-179.373	30.155
1400	-250.411	-173.894	27.146
1500	-250.076	-168.439	24.541

Table 74. - Thermodynamic data for the reaction

$As_4S_4(g) + 10\ Cl_2(g) = 4\ AsCl_3(g) + 4\ SCl_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	-262.477	-262.477	∞
100	-263.536	-258.114	564.100
200	-263.641	-252.609	276.035
298.15	-263.500	-247.225	181.219
300	-263.495	-247.122	180.026
400	-263.326	-241.694	132.054
500	-263.153	-236.302	103.286
600	-263	-230.941	84.119
700	-262.861	-225.615	70.439
800	-262.751	-220.310	60.185
900	-262.638	-215.005	52.210
1000	-262.546	-209.727	45.835
1100	-262.459	-204.443	40.619
1200	-262.394	-199.179	36.275
1300	-262.334	-193.914	32.599
1400	-262.285	-188.649	29.449
1500	-262.252	-183.393	26.720
1600	-262.229	-178.135	24.332
1700	-262.215	-172.858	22.222
1800	-262.214	-167.624	20.352
1900	-262.225	-162.357	18.675
2000	-262.256	-157.094	17.166

Table 75. - Thermodynamic data for the reaction

$$As_4S_4(g) = As_4(g) + 4\ S(or,mon,\ell)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	36.627	36.627	∞
100	36.945	36.843	-80.519
200	37.071	36.678	-40.079
298.15	37.140	36.472	-26.734
300	37.141	36.466	-26.565
368.30	37.219	36.307	-21.544
368.30	37.603	36.307	-21.544
388.36	37.642	36.233	-20.390
388.36	39.294	36.233	-20.390
400	39.390	36.141	-19.746
432.02	39.732	35.870	-18.146
500	40.898	35.158	-15.367
600	42.039	33.896	-12.346
700	42.925	32.466	-10.136
717.82	43.059	32.196	-9.802

Phase changes: 368.3 K, orthorhombic-monoclinic transition point of S; $\Delta H°$ = .096 kcal/mol.
388.36 K, melting point of S; $\Delta H°$ = .413 kcal/mol.
432.02 K, lambda anomaly heat capacity maximum of liquid S.
717.82 K, boiling point of S.

Table 76. - Thermodynamic data for the reaction

$$As_4S_4(g) = 4\ As(\alpha) + 2\ S_2(g)$$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
298.15	61.920	51.020	-37.398
300	61.919	50.952	-37.118
400	61.884	47.304	-25.845
500	61.829	43.660	-19.084
600	61.804	40.032	-14.581
700	61.817	36.403	-11.366
800	61.877	32.767	-8.952
876	61.958	30.007	-7.486

Phase change: 876 K, sublimation point of As.

Table 77. - Thermodynamic data for the reaction

$As_4S_4(g) = As_4(g) + 2\ S_2(g)$

T, K	ΔH°, kcal	ΔG°, kcal	Log K
0	97.899	97.899	∞
100	99.027	90.802	-198.446
200	99.001	82.524	-90.177
298.15	98.560	74.526	-54.628
300	98.549	74.375	-54.182
400	97.994	66.403	-36.281
500	97.408	58.571	-25.601
600	96.817	50.859	-18.525
700	96.225	43.247	-13.502
800	95.636	35.718	-9.757
900	95.054	28.266	-6.864
1000	94.476	20.874	-4.562
1100	93.909	13.542	-2.690
1200	93.351	6.260	-1.140
1300	92.804	-.975	.164
1400	92.270	-8.170	1.275
1500	91.748	-15.325	2.233
1600	91.239	-22.444	3.066
1700	90.743	-29.535	3.797
1800	90.256	-36.597	4.443
1900	89.783	-43.633	5.019
2000	89.319	-50.643	5.534
2100	88.866	-57.628	5.997
2200	88.422	-64.595	6.417
2300	87.986	-71.540	6.798
2400	87.558	-78.467	7.145
2500	87.137	-85.378	7.464
2600	86.723	-92.269	7.756
2700	86.313	-99.145	8.025
2800	85.910	-106.008	8.274
2900	85.512	-112.857	8.505
3000	85.116	-119.688	8.719

Table 78. - Thermodynamic data for the reaction

$As_4S_4(g) = 4\ AsS(g)$

T, K	$\Delta H°$, kcal	$\Delta G°$, kcal	Log K
0	180.383	180.383	∞
100	181.908	169.217	-369.818
200	181.847	156.465	-170.975
298.15	181.300	144.119	-105.641
300	181.287	143.887	-104.820
400	180.720	131.510	-71.853
500	180.223	119.269	-52.132
600	179.774	107.117	-39.017
700	179.353	95.043	-29.673
800	178.927	83.029	-22.682
900	178.484	71.067	-17.257
1000	178.020	59.155	-12.928
1100	177.533	47.293	-9.396
1200	177.022	35.474	-6.461
1300	176.494	23.701	-3.984
1400	175.943	11.965	-1.868
1500	175.376	.270	-.039
1600	174.795	-11.379	1.554
1700	174.199	-22.999	2.957
1800	173.594	-34.587	4.199
1900	172.983	-46.133	5.306
2000	172.358	-57.648	6.299
2100	171.729	-69.130	7.194
2200	171.095	-80.589	8.006
2300	170.456	-92.006	8.742
2400	169.812	-103.406	9.416
2500	169.164	-114.786	10.034
2600	168.515	-126.127	10.602
2700	167.861	-137.444	11.125
2800	167.207	-148.745	11.610
2900	166.553	-160.010	12.059
3000	165.894	-171.270	12.477

REFERENCES

1. Barton, P. B., Jr. Thermochemical Study of the System Fe-As-S. Geochim. et Cosmochim. Acta, v. 33, No. 7, 1969, pp. 841-857.

2. Behrens, R. G., and G. M. Rosenblatt. Vapor Pressure and Thermodynamics of Octahedral Arsenic Trioxide (Arsenolite). J. Chem. Thermodyn., v. 4, 1972, pp. 175-190.

3. Britzke, E. V., A. F. Kapustinsky, and L. G. Tschenzowa. Die Affinität von Metallen zu Schwefel, III. Mitteilung. Verbrennungs-und Bildungswärmen der Sulfide von Arsen und der Verbindungen $As_2O_3 \cdot As_2O_5$ und $As_2O_3 \cdot SO_3$ (The Affinity of Metal for Sulfur, Part III. Heats of Combustion and Formation of the Sulfides of Arsenic and the Compounds $As_2O_3 \cdot As_2O_5$ and $As_2O_3 \cdot SO_3$). Z. Anorg. Allg. Chem., v. 213, 1933, pp. 58-64.

4. Brumbach, S. B., and G. M. Rosenblatt. In-Cavity Laser Raman Spectroscopy of Vapors at Elevated Temperatures. As_4 and As_4O_6. J. Chem. Phys., v. 56, 1972, pp. 3110-3117.

5. CODATA Task Group on Key Values for Thermodynamics. CODATA Recommended Key Values for Thermodynamics 1977. CODATA Bull. 28, 1978, 17 pp.

6. Davis, P. W., and R. A. Oetjen. The Infrared Spectra of Several Pyramidal Trihalides. J. Mol. Spectrosc., v. 2, 1958, pp. 253-258.

7. Gospodinov, G. G., and A. S. Pashinkin. Saturated Vapor Pressure of Solid AsS. Inorg. Mater. (Engl. Transl.), v. 9, No. 1, 1973, pp. 15-17.

8. Hultgren, R., P. D. Desai, D. T. Hawkins, M. Gleiser, K. K. Kelley, and D. D. Wagman. Selected Values of the Thermodynamic Properties of the Elements. American Society for Metals, Metals Park, Ohio, 1973, 636 pp.

9. Johnson, G. K., G. N. Papatheodova, and C. E. Johnson. The Enthalpies of Formation and High-Temperature Functions of As_4S_4 and As_2S_3. J. Chem. Thermodyn., v. 12, 1980, pp. 545-557.

10. King, E. G., A. D. Mah, and L. B. Pankratz. INCRA Series on the Metallurgy of Copper. Monograph II. Thermodynamic Properties of Copper and Its Inorganic Compounds. The International Copper Research Association, Inc., New York, 1973, 257 pp.

11. Lu, C. S., and J. Donohue. An Electron Diffraction Investigation of Sulfur Nitride, Arsenic Disulfide (Realgar), Arsenic Trisulfide (Orpiment) and Sulfur. J. ACS, v. 66, 1944, pp. 818-827.

12. Mills, K. C. Thermodynamic Data for Inorganic Sulphides, Selenides, and Tellurides. Butterworths, London, 1974, 845 pp.

13. Montgomery, R. The Low Temperature Heat Capacity of Sulfur. Ph.D. Dissertation, Okla. State Univ., Stillwater, Okla., 1975, 82 pp.; available from Xerox University Microfilms, Ann Arbor, Mich.

14. Morino, Y., T. Ukaji, and T. Ito. Molecular Structure Determination of Gas Electron Diffraction at High Temperatures. I. Arsenic. Bull. Chem. Soc. Jpn., v. 39, No. 1, 1966, pp. 64-71.

15. Munir, Z. A., G. B. Street, and H. F. Winters. Mass-Spectrometric and Vapor Pressure Studies on the Sublimation of Realgar (As_4S_4). J. Chem. Phys., v. 55, 1971, pp. 4520-4527.

16. National Bureau of Standards. JANAF Thermochemical Tables, NSRDS-NBS 37, 2d ed., 1971, 1141 pp.

17. _____. JANAF Thermochemical Tables, Supplement 46, December 1976.

18. _____. JANAF Thermochemical Tables, Supplement 47, March 1977.

19. _____. JANAF Thermochemical Tables, Supplement 48, June 1977.

20. _____. JANAF Thermochemical Tables, Supplement 49, September 1977.

21. _____. JANAF Thermochemical Tables, Supplement 51, March 1978.

22. _____. JANAF Thermochemical Tables, Supplement 52, June 1978.

23. Romanovskii, V. A., and V. V. Tarasov. Low-Temperature Heat Capacity and Entropy at 298.15° K of the Sulfides of Elements in Group V of the D. I. Mendeleev Periodic Table. Sov. Phys.-Solid State (Engl. Transl.), v. 2, No. 6, 1960, pp. 1294-1299.

24. Rossini, F. D., D. D. Wagman, W. H. Evans, S. Levine, and I. Jaffe. Selected Values of Chemical Thermodynamic Properties. NBS Circ. 500, 1268 pp.

25. Scheuermann, W., and G. J. Ritter. Raman Spectra of Cinnabar (HgS), Realgar (As_4S_4) and Orpiment (As_2S_3). Z. Naturforsch. Teil A, v. 24, No. 3, 1969, pp. 409-412.

26. Shimauchi, M., H. Iwata, T. Matsuno, Y. Sakaba, S. K. Lee, and S. Karasawa. Spectrum of AsS III. Analysis of the $A^{12}II-X^2II$ Band System. Sci. Light (Tokyo), v. 21, No. 2, 1972, pp. 145-161.

27. Shimauchi, M., and S. Karasawa. Spectrum of AsS IV. Reassignment of the $A'^2II_i-X^2II_r$ Band System as a Result of the Isotope Effect Study. Sci. Light (Tokyo), v. 22, No. 2, 1973, pp. 127-145.

28. Sullivan, C. L. Dissociation Energies of New Group Va Chalcogenide Molecules. Case Western Reserve Univ., Cleveland, Ohio, 1971, 144 pp.; available from University Microfilms International, Ann Arbor, Mich., 72-6341.

29. Tarasov, V. V., and V. M. Zhdanov. Low-Temperature Heat Capacity of Vitreous Arsenic Trisulphide. Zh. Fiz. Khim., v. 44, No. 9, 1970, pp. 2384-2387.

30. Wagman, D. D., W. H. Evans, V. B. Parker, I. Halow, S. M. Bailey, and R. H. Schumm. Selected Values of Chemical Thermodynamic Properties. NBS Tech. Note 270-3, 1968, 264 pp.

31. Weller, W. W., and K. K. Kelley. Low-Temperature Heat Capacities and Entropies at 298.15 K of Sulfides of Arsenic, Germanium, and Nickel. BuMines RI 6511, 1964, 7 pp.

32. West, E. D. The Heat Capacity of Sulfur From 25 to 450°, the Heats and Temperatures of Transition and Fusion. J. ACS, v. 81, 1959, pp. 29-37.

33. Yost, D. M., and J. E. Sherborne. The Raman Spectrum of Arsenic Trifluoride and Molecular Constants of AsF_3, $AsCl_3$, and PCl_3. J. Chem. Phys., v. 2, 1934, pp. 125-127.

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