

**SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY  
DEPARTMENT OF MATERIALS AND METALLURGICAL ENGINEERING**

Met 320

HQ 2

Oct 27, 2005

**CLOSED BOOK and NOTES - NO CALCULATORS - SHOW ALL WORK ON THIS SHEET - DISCARD ALL OTHER WORK SHEETS. If there seems to be an error in the problem statement, suggest a correction and proceed with your assumed correction.**

**ALWAYS BROWSE THE ENTIRE EXAM FIRST. THEN WORK THE SHORTEST, EASIEST PROBLEMS FIRST. Each problem is worth 16 points.**

1. One mole of ideal gas at 2 atm and 300 K is expanded isothermally to 1 atm while in contact with a heat sink at 400 K. Find  $\Delta S$  for the 1) gas and 2) the heat sink if the
- a) Expansion is reversible

$$\Delta S_g = \int_i^f dS = \int_i^f \frac{dq}{T_g} \Bigg|_{\text{Rev}} = \int_i^f \frac{dw_{\text{Max}}}{T_g} = \int_i^f \frac{PdV}{T_g} = \int_i^f \frac{nRdV}{V} = nR \ln \left[ \frac{V_f}{V_i} \right] = nR \ln \left[ \frac{P_i}{P_f} \right] = R \ln(2)$$

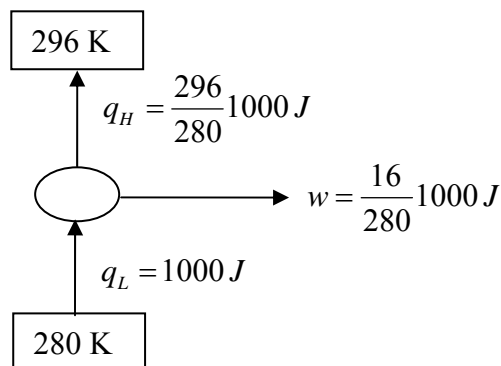
$$\Delta S_s = \int_i^f dS = \int_i^f \frac{dq}{T_s} \Bigg|_{\text{Rev}} = \int_i^f \frac{-dq_g}{T_s} = - \int_i^f \frac{PdV}{T_s} = - \int_i^f \frac{nRT_g dV}{T_s V} = -nR \frac{T_g}{T_s} \ln \left[ \frac{P_i}{P_f} \right] = -0.75R \ln(2)$$

- b) Expansion results in no work being performed.

$\Delta S_g$  = same as part a) - State Function

$$\Delta S_s = \int_i^f dS = \int_i^f \frac{dq}{T_s} \Bigg|_{\text{Rev}} = \int_i^f \frac{-dq_g}{T_s} = - \int_i^f \frac{0}{T_s} = 0$$

2. On a theoretical basis, how much work must be supplied to a heat pump to move 1000 Joules of heat from a lake at 280 K to a home at 23°C?



3. Find the configurational entropy change when 30 gram moles of Ag are alloyed with 70 gram moles of Au.

$$\begin{aligned}\Delta S^{Mix} &= -Rn_{Total} (x_A \ln x_A + x_B \ln x_B) \\ &= -100R(0.3 \ln 0.3 + 0.7 \ln 0.7)\end{aligned}$$

4. Tool Kit Problems:

- a) Write the Fundamental equations emanating from the definitions of H, A, and G.

$$dU = TdS - PdV$$

$$H=U+PV, \quad A=U-TS, \quad G=H-TS$$

$$dH = TdS - PdV + PdV + VdP = TdS + VdP$$

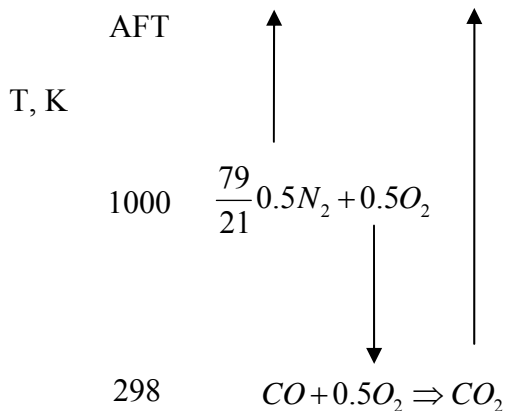
$$dA = TdS - PdV - TdS - SdT = -PdV - SdT$$

$$dG = TdS + VdP - TdS - SdT = VdP - SdT$$

- b) What is the Maxwell Relation from  $dU = TdS - PdV$ ?

$$\left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

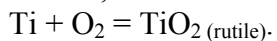
5. Draw a calculation schematic for determining the adiabatic flame temperature for the combustion of CO gas with dry air (21% O<sub>2</sub>, 79% N<sub>2</sub>) to form CO<sub>2</sub> gas. The air is preheated to 1000 K. The CO is at 298 K and the only heat of formation data available are at 298 K. Heat capacities are known.



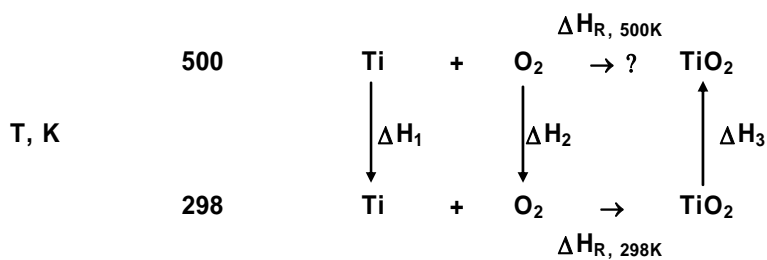
6. Using the JANAF data provided, how much heat would be required to raise one mole of solid Cu at 298 K to pure gaseous Cu at 3000 K? (*It is a good idea to describe briefly how you obtained this number and to mark the data sheet(s) at the appropriate place(s) so partial credit may be assigned in the event your write the answer incorrectly.*)

See JANAF Tables: 94.991 Kcal

7. Using the textbook data provided, find the heat of reaction at 500 K for the reaction



*Complete all steps except the arithmetic.*



Cp Data	a	bX10 <sup>3</sup>	cX10 <sup>-5</sup>
+TiO <sub>2</sub>	73.35	3.05	-17.03
-Ti	24.94	6.57	-1.63
-O <sub>2</sub>	29.96	4.18	-1.67
ΔCp	18.45	-7.7	-13.73

ΔH <sub>R, 298K</sub> = ΔH <sub>f, TiO<sub>2</sub>, 298K</sub> = -944,000 Joules
Δa    18.5
Δb    -7.7 X10 <sup>3</sup>
Δc    -13.7 X10 <sup>-5</sup>

$$\Delta H_{R, 500K}^{\circ} = \Delta H_{R, 298K}^{\circ} + \int_{298}^{500} \Delta C_p dT = \Delta a(500 - 298) + \frac{\Delta b}{2}(500^2 - 298^2) - \Delta c \left( \frac{1}{500} - \frac{1}{298} \right)$$

Copper (Cu)

(Reference State) At. Wt. = 63.54

T. °K.	C <sub>p</sub>	S° - (S° - H° <sub>298</sub> )/T	H° - H° <sub>298</sub>	ΔH <sub>f</sub> <sup>0</sup>	ΔF <sub>f</sub> <sup>0</sup>	Log K <sub>p</sub>
0	.000	INFINITE	1.495	.000	.000	.000
100	2.326	12.745	1.036	.000	.000	.000
200	5.339	8.637	.555	.000	.000	.000
298	5.843	7.913	.000	.000	.000	.000
300	5.846	7.949	.011	.000	.000	.000
400	6.077	9.665	1.224	.000	.000	.000
500	6.250	11.040	1.857	.000	.000	.000
600	6.394	12.193	2.502	.000	.000	.000
700	6.516	13.188	3.159	.000	.000	.000
800	6.620	14.064	3.826	.000	.000	.000
900	6.725	14.850	4.504	.000	.000	.000
1000	6.822	15.564	5.190	.000	.000	.000
1100	6.910	16.218	5.891	.000	.000	.000
1200	6.998	16.823	6.590	.000	.000	.000
1300	7.086	17.387	7.288	.000	.000	.000
1400	7.170	17.910	7.985	.000	.000	.000
1500	7.250	18.400	8.680	.000	.000	.000
1600	7.326	18.860	9.372	.000	.000	.000
1700	7.400	19.290	10.060	.000	.000	.000
1800	7.470	19.690	10.744	.000	.000	.000
1900	7.538	20.060	11.424	.000	.000	.000
2000	7.602	20.400	12.100	.000	.000	.000
2100	7.662	20.710	12.772	.000	.000	.000
2200	7.718	21.000	13.440	.000	.000	.000
2300	7.770	21.270	14.104	.000	.000	.000
2400	7.818	21.520	14.764	.000	.000	.000
2500	7.862	21.750	15.420	.000	.000	.000
2600	7.902	21.960	16.072	.000	.000	.000
2700	7.938	22.150	16.720	.000	.000	.000
2800	7.970	22.320	17.364	.000	.000	.000
2900	7.998	22.470	18.004	.000	.000	.000
3000	8.022	22.600	18.640	.000	.000	.000
3100	8.042	22.710	19.272	.000	.000	.000
3200	8.058	22.800	19.900	.000	.000	.000
3300	8.070	22.870	20.524	.000	.000	.000
3400	8.078	22.920	21.144	.000	.000	.000
3500	8.082	22.960	21.760	.000	.000	.000
3600	8.084	22.990	22.372	.000	.000	.000
3700	8.084	23.010	22.980	.000	.000	.000
3800	8.082	23.020	23.584	.000	.000	.000
3900	8.078	23.020	24.184	.000	.000	.000
4000	8.072	23.010	24.780	.000	.000	.000
4100	8.064	22.990	25.372	.000	.000	.000
4200	8.054	22.960	25.960	.000	.000	.000
4300	8.042	22.920	26.544	.000	.000	.000
4400	8.028	22.870	27.124	.000	.000	.000
4500	8.012	22.810	27.700	.000	.000	.000
4600	8.000	22.740	28.272	.000	.000	.000
4700	7.990	22.660	28.840	.000	.000	.000
4800	7.980	22.570	29.404	.000	.000	.000
4900	7.970	22.470	29.964	.000	.000	.000
5000	7.960	22.360	30.520	.000	.000	.000
5100	7.950	22.240	31.072	.000	.000	.000
5200	7.940	22.110	31.620	.000	.000	.000
5300	7.930	21.970	32.164	.000	.000	.000
5400	7.920	21.830	32.704	.000	.000	.000
5500	7.910	21.680	33.240	.000	.000	.000
5600	7.900	21.530	33.772	.000	.000	.000
5700	7.890	21.370	34.300	.000	.000	.000
5800	7.880	21.210	34.824	.000	.000	.000
5900	7.870	21.040	35.344	.000	.000	.000
6000	7.860	20.870	35.860	.000	.000	.000

COPPER (Cu)

AT. WT. = 63.54

(REFERENCE STATE)

0 to 1356.6°K. Crystal  
1356.6 to 2848°K. Liquid  
2848 to 6000°K. Ideal Monatomic Gas

See crystal, liquid and monatomic gas tables for details.

(Crystal) At. Wt. = 63.54

COPPER (Cu)

(CRYSTAL)

AT. WT. = 63.54

T, °K.	cal. mole <sup>-1</sup> deg. <sup>-1</sup>		kcal. mole <sup>-1</sup>		Log K <sub>p</sub>
	C <sub>p</sub>	S° - (F° - H° <sub>298</sub> )/T	H° - H° <sub>298</sub>	ΔF <sup>‡</sup>	
0	0.000	INFINITE	1.195	0.000	INFINITE
100	3.826	2.392	1.036	0.000	0.000
200	5.999	5.661	0.555	0.000	0.000
288	5.843	7.913	0.000	0.000	0.000
300	5.846	7.913	0.011	0.000	0.000
400	6.077	9.665	0.608	0.000	0.000
500	6.250	11.040	1.274	0.000	0.000
600	6.394	12.194	1.857	0.000	0.000
700	6.516	13.188	2.302	0.000	0.000
800	6.620	14.064	2.659	0.000	0.000
900	6.725	14.850	3.026	0.000	0.000
1000	6.822	15.564	3.404	0.000	0.000
1100	6.910	16.216	3.790	0.000	0.000
1200	6.988	16.824	4.186	0.000	0.000
1300	7.066	17.397	4.590	0.000	0.000
1400	7.134	17.933	5.000	0.000	0.000
1500	7.202	18.433	5.413	0.000	0.000
1600	7.270	18.895	5.830	0.000	0.000
1700	7.338	19.323	6.250	0.000	0.000
1800	7.406	19.717	6.675	0.000	0.000
1900	7.474	20.077	7.100	0.000	0.000
2000	7.542	20.403	7.525	0.000	0.000

$$\Delta H_f^\circ = 0 \text{ kcal. mole}^{-1}$$

$$\Delta H_f^\circ 298.15 = 0 \text{ kcal. mole}^{-1}$$

$$\Delta H_m^\circ = 3.17 \pm 0.15 \text{ kcal. mole}^{-1}$$

$$\Delta H_s^\circ 298.15 = 81 \pm 0.4 \text{ kcal. mole}^{-1}$$

$$S^\circ 298.15 = 7.913 \pm 0.04 \text{ cal. deg.}^{-1} \text{ mole}^{-1}$$

$$T_m = 1356.6^\circ \text{K.}$$

Heat of Formation.

Zero by definition.

Heat Capacity and Entropy.

The low temperature specific heat of copper has been measured by several workers and generally there is good agreement. The selected values lie close to the determinations of J. A. Kok and W. H. Keason (1.2-20°K), Physics 2, 1035 (1936); D. L. Martin (20-300°K), Can. J. Phys. 39, 17 (1960); C. B. Satterthwaite, R. S. Craig and W. E. Wallace, J. Am. Chem. Soc. 75, 232 (1954), and S. M. Docketty, Can. J. Research 9, 84 (1933) and ISA, 59 (1937). Several other workers have reported values of  $C_p$  slightly higher than the adopted values especially W. F. Giauque and P. F. Meads, J. Am. Chem. Soc. 52, 1897 (1941), however these measurements were not used for reasons discussed by Martin. The heat capacity above room temperature has been determined directly by several workers, the values of R. E. Fawell and E. E. Stansbury, J. Phys. Chem. Solids 26, 607 (1965) join well with the low temperature data and are adopted. These values lie within 1% of the values adopted by R. Hultgren, R. L. Orr, P. D. Anderson, and K. K. Kelley "Selected Values of Thermodynamic Properties of Metals and Alloys", John Wiley and Sons, Inc., New York, 1963. Several determinations of the solid enthalpy are also in good agreement with selected heat capacity curve. For references to these determinations refer to Hultgren et al. loc. cit.

Melting Data.

The melting point of copper is well established and the recent determination of W. Heyne, Exptl. Tech. Physik. 12, 87 (1964) is adopted. The heat of fusion was obtained from the calculated enthalpy of the solid at the melting point and the liquid enthalpy measurements of P. Wust, A. Meuthen and R. Durrer, Forsch. Geb. Ingenieurw. VDI-Forsch. 204 (1918). The liquid enthalpies of I. B. Fieldhouse, J. C. Hedge, J. I. Lang and T. E. Waterman, ASTIA Doc. No. A. D. 150954 are somewhat higher than the adopted values.

Sublimation Data.

See Cu(g) for details.

## Copper (Cu)

(Liquid) At. wt. = 63.54

T, °K.	C <sub>p</sub> cal. mole <sup>-1</sup> deg. <sup>-1</sup>	S° -(F°-H° <sub>298</sub> )/T	H°-H° <sub>298</sub>	ΔH <sub>f</sub> <sup>o</sup> kcal. mole <sup>-1</sup>	ΔF <sub>f</sub> <sup>o</sup>	Log K <sub>f</sub>
0						
100	7.500	8.663	0.000	2.224	2.000	1.466
200	7.500	8.663	0.014	2.227	1.999	1.456
300	7.500	8.663	0.050	2.280	1.899	1.038
400	7.500	8.663	0.113	2.514	1.763	0.771
500	7.500	8.663	0.204	2.631	1.602	0.583
600	7.500	8.663	0.314	2.736	1.423	0.444
700	7.500	8.663	0.444	2.829	1.227	0.335
800	7.500	8.663	0.594	2.912	1.023	0.248
900	7.500	8.663	0.764	2.984	0.809	0.177
1000	7.500	8.663	0.954	3.048	0.588	0.117
1100	7.500	8.663	1.162	3.102	0.361	0.066
1200	7.500	8.663	1.387	3.148	0.132	0.022
1300	7.500	8.663	1.627	3.186	0.000	0.000
1400	7.500	8.663	1.880	3.216	0.000	0.000
1500	7.500	8.663	2.144	3.239	0.000	0.000
1600	7.500	8.663	2.418	3.256	0.000	0.000
1700	7.500	8.663	2.700	3.267	0.000	0.000
1800	7.500	8.663	2.988	3.273	0.000	0.000
1900	7.500	8.663	3.281	3.275	0.000	0.000
2000	7.500	8.663	3.578	3.274	0.000	0.000
2100	7.500	8.663	3.879	3.270	0.000	0.000
2200	7.500	8.663	4.183	3.263	0.000	0.000
2300	7.500	8.663	4.490	3.254	0.000	0.000
2400	7.500	8.663	4.799	3.243	0.000	0.000
2500	7.500	8.663	5.110	3.230	0.000	0.000
2600	7.500	8.663	5.422	3.215	0.000	0.000
2700	7.500	8.663	5.735	3.200	0.000	0.000
2800	7.500	8.663	6.048	3.184	0.000	0.000
2900	7.500	8.663	6.361	3.167	0.000	0.000
3000	7.500	8.663	6.674	3.150	0.000	0.000
3100	7.500	8.663	6.987	3.132	0.000	0.000
3200	7.500	8.663	7.300	3.114	0.000	0.000
3300	7.500	8.663	7.613	3.096	0.000	0.000
3400	7.500	8.663	7.926	3.078	0.000	0.000
3500	7.500	8.663	8.239	3.060	0.000	0.000
3600	7.500	8.663	8.552	3.042	0.000	0.000
3700	7.500	8.663	8.865	3.024	0.000	0.000
3800	7.500	8.663	9.178	3.006	0.000	0.000
3900	7.500	8.663	9.491	2.988	0.000	0.000
4000	7.500	8.663	9.804	2.970	0.000	0.000

COPPER (Cu)

(LIQUID)

AT. WT. = 63.54

S°<sub>298.15</sub> = 8.663 cal. deg.<sup>-1</sup> mole<sup>-1</sup>ΔH<sub>f</sub><sup>o</sup><sub>298.15</sub> = 2.224 kcal. mole<sup>-1</sup>T<sub>m</sub><sup>o</sup> = 1356.6°K.ΔH<sub>m</sub><sup>o</sup> = 3.17 ± 0.15 kcal. mole<sup>-1</sup>T<sub>b</sub><sup>o</sup> = 2848°K.ΔH<sub>v</sub><sup>o</sup> = 72.745 kcal. mole<sup>-1</sup>Heat of Formation.

The heat of formation was calculated from that of the crystal by adding ΔH<sub>m</sub><sup>o</sup> and the difference between H<sub>1356.6</sub>-H<sub>298</sub> for (c) and (l).

Heat Capacity and Entropy.

The heat capacity was calculated from the enthalpy data of P. Wust, A. Meuthen and R. Durrer, Forsch. Geb. Ingenieurw. VDI-Forsch. 204 (1918). The entropy was obtained in a manner analogous to the heat of formation.

Melting Data.

See crystal table for details.

Vaporization Data.

The boiling point and heat of vaporization were calculated from the adopted functions and heat of sublimation in order to maintain proper thermodynamic consistency.

Ground State Configuration  $3s^1 3d^9$   
 $\Delta H_f^0 = 80.714 \pm 0.5 \text{ kcal. mole}^{-1}$   
 $\Delta H_f^0 = 39.744 \text{ cal. deg.}^{-1} \text{ mole}^{-1}$   
 $\Delta H_f^0 = 298.15 = 81.0 \pm 0.5 \text{ kcal. mole}^{-1}$

Electronic Levels and Quantum Weight

$E_1, \text{ cm.}^{-1}$	$E_2, \text{ cm.}^{-1}$	$E_3, \text{ cm.}^{-1}$	$E_4, \text{ cm.}^{-1}$	$E_5, \text{ cm.}^{-1}$	$E_6, \text{ cm.}^{-1}$	$E_7, \text{ cm.}^{-1}$	$E_8, \text{ cm.}^{-1}$	$E_9, \text{ cm.}^{-1}$	$E_{10}, \text{ cm.}^{-1}$	$E_{11}, \text{ cm.}^{-1}$	$E_{12}, \text{ cm.}^{-1}$	$E_{13}, \text{ cm.}^{-1}$	$E_{14}, \text{ cm.}^{-1}$	$E_{15}, \text{ cm.}^{-1}$	$E_{16}, \text{ cm.}^{-1}$	$E_{17}, \text{ cm.}^{-1}$	$E_{18}, \text{ cm.}^{-1}$	$E_{19}, \text{ cm.}^{-1}$	$E_{20}, \text{ cm.}^{-1}$
0.0	0.0	11202.6	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4	13245.4
2	2	44406.3	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2	44544.2
4	4	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0	57884.0
6	6	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2	57905.2
8	8	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5	58249.5
2	2	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8	58429.8
4	4	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0	58530.0
6	6	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3	58119.3
4	4	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7	58743.7
2	2	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3	59275.3
2	2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2	59523.2
2	2	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9	59647.9
2	2	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0	60070.0
16	16	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0	60595.0
2	2	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0	61150.0

Heat of Formation.

The heat of sublimation has been determined by second and third law analysis of the vapor pressure data of a large number of investigators. The results are summarized below:

Ref.	Range°K.	Method	Points	$\Delta H_{\text{subl}}^0, 298.15 \text{ kcal. mole}^{-1}$	3rd law	Drift
1.	1242-1340	Knudsen	6	80.6 ± 0.2	81.39 ± 0.04	0.3 ± 0.2
1.	1370-1563	Knudsen	10*	83.0 ± 0.6	81.34 ± 0.2	-1.0 ± 0.5
2.	1567-1523	Langmuir	8	79.8 ± 1.6	80.20 ± 0.3	0.5 ± 1.2
3.	1605-1879	Transport	21*	79.7 ± 0.6	80.55 ± 0.25	0.5 ± 1.0
4.	1192-1360	Knudsen	13	80.6 ± 4.0	81.16 ± 1.2	0.4 ± 3.1
5.	1143-1282	Langmuir	5	81.5 ± 1.0	80.61 ± 0.2	-0.6 ± 0.8
6.	1475-1707	Knudsen	14	83.2 ± 1.3	81.05 ± 0.4	-1.4 ± 0.8
7.	987-1330	Knudsen	5	79.1 ± 2.3	79.86 ± 0.5	1.1 ± 1.8
8.	1356-1466	Langmuir	7*	82.5 ± 3.5	81.26 ± 0.5	-0.9 ± 2.6
8.	1423-1640	Knudsen	7	82.6 ± 11.0	80.80 ± 0.8	12.9 ± 8.2
10.	1083-1485	Knudsen	7	78.9 ± 1.7	78.9 ± 1.7	
12.	2138-2643	Boiling	4	93.5 ± 4.3	77.25 ± 2.8	-6.3 ± 1.7
13.	2378-2573	Boiling	5	120.0 ± 8.0	76.1 ± 2.8	-18.0 ± 3.3
14.	2253-2583	Boiling	3	76.3 ± 13.8	75.0 ± 2.0	-0.9 ± 5.9
15.	1768-2116	Boiling	6	66.2 ± 2.5	73.5 ± 1.3	3.5 ± 1.3

\*1 Point rejected due to failure of statistical test.

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The first eight references may be considered to have reasonable drifts and second and third law agreement. The three Langmuir values are grouped closely together at about 80.3 kcal. mole<sup>-1</sup>. The Knudsen values all lie a little higher averaging 81.4 kcal. mole<sup>-1</sup>, the single transport determination is at 80.55 kcal. mole<sup>-1</sup>. If the evaporation coefficient is not unity in the Langmuir experiments then one would observe lower pressures and higher heats of sublimation, thus it appears that the coefficient must be unity and that all techniques are measuring valid heats of sublimation. A value of 81 ± 0.5 kcal. mole<sup>-1</sup> was chosen weighted toward the more precise Knudsen work of Hersh.

Heat Capacity and Entropy.

The electronic ground state configuration and higher electronic levels were taken from C. E. Moore "Atomic Energy Levels", Natl. Bur. Stds. Circular 467, Washington 1952.

