Technische Aardwetenschappen

Tentamen ta3210 : Extractieve Metallurgie

Datum : 9 januari 2004
Tijd : 9h00-12h00

Dit tentamen bevat 10 bladzijden.

VRAAG 1

Van een reeks vloeibare mengsels van aluminium en magnesium bij 800^0C zijn de volgende gegevens bekend:

N_{Mg} (mol)	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
ΔH_M (cal.mol$^{-1)}$	-312	-555	-719	-803	-806	-740	-614	-439	-230
ΔG_M (cal.mol^{-1})	-1006	-1574	-1908	-2065	-2072	-1949	-1707	-1342	-831

a) Is de menging exotherm, endotherm of ideaal? Verklaar kort uw antwoord.

b) Bepaal de raoultiaanse activiteit en activiteitscoëfficiënt van magnesium bij molfracties van respectievelijk 0,3; 0,6; en 1,0. Gebruik hierbij, indien nodig, het bijgevoegde grafiekenpapier.

VRAAG 2

Van een reeks vloeibare mengsels van calcium en magnesium bij 1200K zijn de volgende gegevens bepaald:

N_{Mg}	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
a_{Mg}	0,041	0,089	0,145	0,209	0,278	0,348	0,442	0,572	0,730
a_{Ca}	0,897	0,786	0,671	0,551	0,437	0,331	0,212	0,096	0,022

a) Verklaar kort, waarom deze mengsels wel, of juist niet, ideaal zijn.

b) Wat zijn de activiteiten van Mg en Ca bij N_{Mg}=0?

c) Ofschoon de γ^o_{Mg} uit deze gegevens niet zonder meer te bepalen is, wordt u verzocht een redelijke en beredeneerde schatting ervan te geven.

d) Bereken de relatieve partiële molaire Gibbs energieën voor Mg en Ca, voor elk van de bovenstaande mengsels, in J. gramatoom^{-1} Gebruik de hierbij behorende symbolen op correcte wijze.

e) Bereken de relatieve integrale molaire vrije enthalpieën voor bovenstaande mengsels, en beredeneer deze tevens voor N_{Mg}=0 en N_{Mg}=1. Ook hier wordt correct gebruik van de bijbehorende symbolen verwacht.

VRAAG 3

Zinkoxide (ZnO) wordt met CO gereduceerd bij 1200K. Tabelgegevens zijn aangehecht.

a) Is deze reactie exotherm of endotherm? Verklaar kort uw antwoord.

b) Stel het activiteitsquotiënt voor de bijbehorende reactie op bij bovenstaande temperatuur.

c) Bereken de evenwichtsconstante bij 1200K.

d) Wanneer de totale gasdruk 1 atmosfeer is, wat zijn dan bij benadering de significante gasdrukken bij 1200K?

e) Is temperatuurverhoging gunstig of ongunstig voor voortgang van de reactie in de gewenste richting? Waarom is dit het geval? Bespreek kort, waarom u dit wel of niet zinvol vindt.

f) Zinkoxide Is drukverhoging gunstig of ongunstig voor voortgang van de reactie in de gewenste richting?

VRAAG 4

The Outokumpu process is a process for the flash smelting of copper concentrates. Based on 1000kg concentrate derive a set of mass and energy balance equations that describe this process. Present your equations in the form of a matrix that can be solved by a matrix solver.

DATA

Concentrate
100%$CuFeS_2$ and SiO_2 (Flux) at 298K.

Blast air
40Mass%O_2/60Mass%N_2 at 800K

Fuel (to balance heat)
Oil (87%C and 13%H) 10kg/t $CuFeS_2$: Enthalpy = -1.2MJ/kg Oil.

Matte
FeS and Cu_2S (1500K).

Slag
30%SiO_2 and 70%FeO (1500K).

Off gas
SO_2, CO_2 and H_2O (1500K).

Heat loss
500MJ/t $CuFeS_2$ (radiation, convection).

Enthalpy values
See tables at the end of this paper.

Table 1: Enthalpy values at 298K

Substance	Enthalpy, MJ/kg
	298 K
Al_2O_3	−16.43
C	0.0
CH_4	−4.67
C_2H_6	−2.82
C_3H_8	−2.36
C_4H_{10}	−2.16
C_5H_{12}	−2.03
C_6H_{14}	−1.94
CO	−3.95
CO_2	−8.94
$CaCO_3$	−12.06
$CaCO_3 \cdot MgCO_3$	−12.61
CaO	−11.32
Cr_2O_3	−7.47
Cu	0.0
$CuCO_3 \cdot Cu(OH)_2$	−4.77
$(CuCO_3)_2 \cdot Cu(OH)_2$	−4.74
$CuFeS_2$	−1.04
Cu_5FeS_4	−0.76
CuO	−1.96
Cu_2O	−1.19
CuS	−0.51
Cu_2S	−0.50
$CuSO_4$	−4.82
$CuO \cdot CuSO_4$	−3.88
FeO	−3.79
Fe_2O_3	−5.17
Fe_3O_4	−4.84
FeS	−1.16
$FeS_{1.14}$	−1.30
FeS_2	−1.43
$FeSO_4$	−6.11
$Fe_2(SO_4)_3$	−6.44
H_2O_2	−15.86
H_2O_g	−13.42
Hydrocarbons (approximate)	
coal	+0.1
petroleum	−1.2

Substance	Enthalpy, MJ/kg
$MgCO_3$	−13.18
MgO	−14.92
N_2	0.0
NiS	−0.97
Ni_3S_2	−0.90
$NiSO_4$	−5.64
O_2	0.0
PbO	−0.98
PbS	−0.41
$PbSO_4$	−3.03
SO_2	−4.63
SiO_2 (quartz)	−15.16
ZnO	−4.31
ZnS	−2.12
$ZnSO_4$	−6.09

Table 2: Enthalpy values at 1400K, 1500K, 1600K and 1700K

Substance	Enthalpy content, MJ/kg			
	1400 K	1500 K	1600 K	1700 K
$Al_2O_{3\ell}$	−14.48	−14.35	−14.22	−14.03
	metastable liquid, melting point 2327K			
CO_2	−7.67	−7.54	−7.41	−7.27
CaO_ℓ	−8.92	−8.82	−8.72	−8.62
	metastable liquid, melting point 3200 K			
Cu_ℓ	0.70	0.75	0.79	0.85
CuO_s	−1.23	−1.15	−1.08	−1.00
Cu_2O_s	−0.59	−0.52		
Cu_2O_ℓ	−0.14	−0.07	0	+0.07
	metastable liquid, melting point = 1517 K			
Cu_2S_ℓ	0.19	0.25	0.31	0.36
FeO_ℓ	−2.59	−2.49	−2.40	−2.30
	metastable liquid, melting point = 1650 K			
Fe_2O_{3s}	−4.18	−4.09	−4.00	−3.91
Fe_3O_{4s}	−3.86	−3.77	−3.68	−3.60
$Fe_3O_{4\ell}$	−3.26	−3.17	−3.09	−3.00
	metastable liquid, melting point = 1870 K: enthalpy of fusion = +0.60 MJ/kg			
FeS_ℓ	+0.03	+0.11	+0.18	+0.25
	metastable liquid, melting point = 1463 K			
H_2O_g	−11.00	−10.75	−10.49	−10.22
MgO_ℓ	−11.88	−11.74	−11.61	−11.48
	metastable liquid; melting point 3105 K			
N_{2g}	1.25	1.37	1.50	1.62
NiO_ℓ	−1.83	−1.75	−1.67	−1.59
	metastable liquid; melting point 2260 K			
$Ni_3S_{2\ell}$	0.17	0.25	0.33	0.41
Pb_ℓ	0.16	0.17	0.18	0.20
PbO_ℓ	−0.59	−0.56	−0.53	−0.50
PbS_ℓ	−0.01	−0.01	0.0	0.0
SiO_{2s}	−13.90	−13.78	−13.65	−13.53
$SiO_{2\ell}$	−13.82	−13.70	−13.57	−13.43
	metastable liquid, melting point 1996 K			
SO_{2g}	−3.75	−3.66	−3.57	−3.48
ZnO_ℓ	−3.4	−3.3	−3.2	−3.2
	metastable liquid, melting point 2250 K; enthalpy of fusion 0.25 MJ/kg			
ZnS_ℓ		(−1.3) estimate		

Table 3: Enthalpy values of O_2 and N_2 between 298K and 1300K

Temperature	Enthalpy, MJ/kg ($H°_T$/MW)	
	O_2	N_2
298	0	0.00
400	0.09	0.11
500	0.19	0.21
600	0.29	0.32
700	0.39	0.43
800	0.50	0.54
900	0.60	0.65
1000	0.71	0.77
1100	0.82	0.88
1200	0.93	1.00
1300	1.04	1.12

OXYGEN (GAS)

Phase	T	C_p	S	$-(G-H298)/T$	H	H–H298	G	ΔH_f	ΔG_f	log K_f
	[K]	[J / (K mol)]			[kJ / mol]					[–]
GAS	298.15	29.376	205.147	205.147	0.000	0.000	−61.165	0.000	0.000	0.000
	300.00	29.385	205.329	205.148	0.054	0.054	−61.544	0.000	0.000	0.000
	400.00	30.106	213.871	206.307	3.025	3.025	−82.523	0.000	0.000	0.000
	500.00	31.091	220.693	208.524	6.084	6.084	−104.262	0.000	0.000	0.000
	600.00	32.089	226.451	211.044	9.244	9.244	−126.626	0.000	0.000	0.000
	700.00	32.981	231.466	213.611	12.499	12.499	−149.528	0.000	0.000	0.000
	800.00	33.734	235.921	216.126	15.836	15.836	−172.901	0.000	0.000	0.000
	900.00	34.354	239.931	218.552	19.241	19.241	−196.697	0.000	0.000	0.000
	1000.00	34.870	243.578	220.875	22.703	22.703	−220.875	0.000	0.000	0.000
	1100.00	35.302	246.922	223.093	26.212	26.212	−245.402	0.000	0.000	0.000
	1200.00	35.667	250.010	225.209	29.761	29.761	−270.251	0.000	0.000	0.000
	1300.00	35.987	252.878	227.228	33.344	33.344	−295.397	0.000	0.000	0.000
	1400.00	36.276	255.555	229.157	36.957	36.957	−320.820	0.000	0.000	0.000
	1500.00	36.543	258.067	231.002	40.598	40.598	−346.503	0.000	0.000	0.000
	1600.00	36.797	260.434	232.768	44.266	44.266	−372.429	0.000	0.000	0.000
	1700.00	37.041	262.672	234.462	47.957	47.957	−398.585	0.000	0.000	0.000
	1800.00	37.278	264.796	236.089	51.673	51.673	−424.959	0.000	0.000	0.000
	1900.00	37.511	266.818	237.653	55.413	55.413	−451.541	0.000	0.000	0.000
	2000.00	37.741	268.748	239.160	59.176	59.176	−478.320	0.000	0.000	0.000
	2100.00	37.969	270.595	240.613	62.961	62.961	−505.288	0.000	0.000	0.000
	2200.00	38.194	272.366	242.017	66.769	66.769	−532.436	0.000	0.000	0.000
	2300.00	38.418	274.069	243.373	70.600	70.600	−559.759	0.000	0.000	0.000
	2400.00	38.638	275.709	244.687	74.453	74.453	−587.248	0.000	0.000	0.000
	2500.00	38.855	277.290	245.959	78.327	78.327	−614.898	0.000	0.000	0.000
	2600.00	39.069	278.818	247.194	82.224	82.224	−642.704	0.000	0.000	0.000
	2700.00	39.277	280.297	248.393	86.141	86.141	−670.660	0.000	0.000	0.000
	2800.00	39.479	281.729	249.558	90.079	90.079	−698.762	0.000	0.000	0.000
	2900.00	39.675	283.118	250.691	94.037	94.037	−727.005	0.000	0.000	0.000
	3000.00	39.862	284.466	251.795	98.013	98.013	−755.384	0.000	0.000	0.000
	3100.00	40.047	285.776	252.870	102.009	102.009	−783.897	0.000	0.000	0.000
	3200.00	40.224	287.050	253.918	106.023	106.023	−812.538	0.000	0.000	0.000
	3300.00	40.395	288.291	254.941	110.054	110.054	−841.306	0.000	0.000	0.000
	3400.00	40.559	289.499	255.940	114.101	114.101	−870.195	0.000	0.000	0.000
	3500.00	40.717	290.677	256.916	118.165	118.165	−899.204	0.000	0.000	0.000
	3600.00	40.868	291.826	257.869	122.245	122.245	−928.330	0.000	0.000	0.000
	3700.00	41.014	292.948	258.802	126.339	126.339	−957.569	0.000	0.000	0.000
	3800.00	41.154	294.044	259.715	130.447	130.447	−986.919	0.000	0.000	0.000
	3900.00	41.290	295.114	260.609	134.569	134.569	−1016.377	0.000	0.000	0.000
	4000.00	41.421	296.161	261.485	138.705	138.705	−1045.941	0.000	0.000	0.000
	4100.00	41.549	297.186	262.343	142.854	142.854	−1075.608	0.000	0.000	0.000
	4200.00	41.674	298.189	263.185	147.015	147.015	−1105.377	0.000	0.000	0.000
	4300.00	41.797	299.171	264.011	151.188	151.188	−1135.245	0.000	0.000	0.000
	4400.00	41.919	300.133	264.821	155.374	155.374	−1165.211	0.000	0.000	0.000
	4500.00	42.041	301.076	265.616	159.572	159.572	−1195.271	0.000	0.000	0.000
	4600.00	42.164	302.002	266.397	163.782	163.782	−1225.425	0.000	0.000	0.000
	4700.00	42.288	302.910	267.164	168.005	168.005	−1255.671	0.000	0.000	0.000
	4800.00	42.414	303.801	267.918	172.240	172.240	−1286.007	0.000	0.000	0.000
	4900.00	42.543	304.677	268.659	176.488	176.488	−1316.431	0.000	0.000	0.000
	5000.00	42.676	305.538	269.388	180.748	180.748	−1346.942	0.000	0.000	0.000

References

Phase	H / S	C_p
GAS	Ja2	Ja2

Phase	T [K]	C_p	S	−(G−H298)/T	H	H−H298	G	ΔH_f	ΔG_f	log K_f
		J / (K mol)			kJ / mol					[−]
SOL	298.15	25.402	41.631	41.631	0.000	0.000	−12.412	0.000	0.000	0.000
	300.00	25.414	41.788	41.631	0.047	0.047	−12.489	0.000	0.000	0.000
	400.00	26.260	49.207	42.637	2.628	2.628	−17.055	0.000	0.000	0.000
	500.00	27.324	55.178	44.566	5.306	5.306	−22.283	0.000	0.000	0.000
	600.00	28.473	60.261	46.769	8.095	8.095	−28.061	0.000	0.000	0.000
	692.65	29.575	64.427	48.857	10.784	10.784	−33.841	0.000	0.000	0.000
			10.571		7.322					
LIQ	692.65	31.380	74.998	48.857	18.106	18.106	−33.841	0.000	0.000	0.000
	700.00	31.380	75.329	49.133	18.337	18.337	−34.393	0.000	0.000	0.000
	800.00	31.380	79.519	52.675	21.475	21.475	−42.140	0.000	0.000	0.000
	900.00	31.380	83.215	55.867	24.613	24.613	−50.280	0.000	0.000	0.000
	1000.00	31.380	86.521	58.770	27.751	27.751	−58.770	0.000	0.000	0.000
	1100.00	31.380	89.512	61.431	30.889	30.889	−67.574	0.000	0.000	0.000
	1179.00	31.380	91.688	63.386	33.368	33.368	−74.733	0.000	0.000	0.000

References

Phase	H / S	C_p	Remarks	
SOL	Hu1	Hu1	Hu1	MPT= 692.655
LIQ	Hu1	Hu1	Hu1	BPT= 1179., L= 115.33 kJ

Zn[g] ZINC (GAS) 65.390

Phase	T [K]	C_p	S	−(G−H298)/T	H	H−H298	G	ΔH_f	ΔG_f	log K_f
		[J / (K mol)]			[kJ / mol]					[−]
GAS	298.15	20.786	160.984	160.984	130.415	0.000	82.418	130.415	94.830	−16.614
	300.00	20.786	161.113	160.985	130.453	0.038	82.120	130.406	94.609	−16.473
	400.00	20.786	167.093	161.800	132.532	2.117	65.695	129.904	82.750	−10.806
	500.00	20.786	171.731	163.340	134.611	4.196	48.745	129.305	71.028	−7.420
	600.00	20.786	175.521	165.063	136.689	6.274	31.377	128.594	59.438	−5.175
	700.00	20.786	178.725	166.792	138.768	8.353	13.661	120.431	48.054	−3.586
	800.00	20.786	181.500	168.461	140.847	10.432	−4.354	119.372	37.786	−2.467
	900.00	20.786	183.949	170.049	142.925	12.510	−22.629	118.312	27.652	−1.605
	1000.00	20.786	186.139	171.550	145.004	14.589	−41.135	117.253	17.635	−0.921
	1100.00	20.786	188.120	172.968	147.082	16.667	−59.849	116.193	7.725	−0.367
	1200.00	20.786	189.928	174.307	149.161	18.746	−78.753	0.000	0.000	0.000
	1300.00	20.786	191.592	175.573	151.240	20.825	−97.830	0.000	0.000	0.000
	1400.00	20.786	193.133	176.773	153.318	22.903	−117.068	0.000	0.000	0.000
	1500.00	20.786	194.567	177.912	155.397	24.982	−136.453	0.000	0.000	0.000
	1600.00	20.786	195.908	178.995	157.475	27.060	−155.978	0.000	0.000	0.000
	1700.00	20.786	197.168	180.028	159.554	29.139	−175.632	0.000	0.000	0.000
	1800.00	20.786	198.356	181.013	161.633	31.218	−195.409	0.000	0.000	0.000
	1900.00	20.786	199.480	181.956	163.711	33.296	−215.301	0.000	0.000	0.000
	2000.00	20.786	200.547	182.859	165.790	35.375	−235.303	0.000	0.000	0.000

References

Phase	H / S	C_p
GAS	Hu1	Hu1

ZnO ZINC OXIDE

Phase	T [K]	C_p	S	$-(G-H298)/T$	H	H–H298	G	ΔH_f	ΔG_f	log K_f [–]
		[J / (K mol)]			[kJ / mol]					
SOL	298.15	41.086	43.639	43.639	−350.460	0.000	−363.471	−350.460	−320.476	56.146
	300.00	41.179	43.894	43.640	−350.384	0.076	−363.552	−350.458	−320.290	55.768
	400.00	44.684	56.277	45.305	−346.071	4.389	−368.582	−350.212	−310.265	40.517
	500.00	46.698	66.480	48.550	−341.495	8.965	−374.735	−349.843	−300.321	31.374
	600.00	48.125	75.126	52.277	−336.750	13.710	−381.826	−349.468	−290.452	25.286
	700.00	49.274	82.633	56.089	−331.879	18.581	−389.722	−356.465	−280.565	20.936
	800.00	50.276	89.280	59.830	−326.900	23.560	−398.324	−356.293	−269.734	17.612
	900.00	51.192	95.255	63.440	−321.826	28.634	−407.556	−356.060	−258.927	15.028
	1000.00	52.055	100.694	66.897	−316.664	33.796	−417.357	−355.766	−248.150	12.962
	1100.00	52.883	105.694	70.200	−311.417	39.043	−427.680	−355.412	−237.405	11.273
	1200.00	53.687	110.330	73.353	−306.088	44.372	−438.484	−470.129	−224.605	9.777
	1300.00	54.475	114.659	76.366	−300.680	49.780	−449.736	−468.591	−204.207	8.205
	1400.00	55.250	118.724	79.248	−295.193	55.267	−461.407	−466.990	−183.930	6.862
	1500.00	56.017	122.562	82.009	−289.630	60.830	−473.473	−465.326	−163.769	5.703
	1600.00	56.776	126.202	84.658	−283.990	66.470	−485.913	−463.598	−143.721	4.692
	1700.00	57.531	129.666	87.205	−278.275	72.185	−498.708	−461.808	−123.783	3.803
	1800.00	58.281	132.976	89.656	−272.484	77.976	−511.841	−459.954	−103.952	3.017
	1900.00	59.028	136.147	92.020	−266.619	83.841	−525.298	−458.036	−84.226	2.316
	2000.00	59.772	139.194	94.303	−260.679	89.781	−539.066	−456.056	−64.603	1.687
	2100.00	60.514	142.128	96.511	−254.664	95.796	−553.133	−454.013	−45.081	1.121
	2200.00	61.255	144.960	98.649	−248.576	101.884	−567.489	−451.908	−25.657	0.609
	2248.00	61.609	146.286	99.652	−245.627	104.833	−574.479	−450.875	−16.368	0.380
			24.196		54.392					
LIQ	2248.00	60.668	170.482	99.652	−191.235	159.225	−574.479	−396.483	−16.368	0.380
	2300.00	60.668	171.869	101.270	−188.080	162.380	−583.380	−395.406	−7.587	0.172
	2400.00	60.668	174.451	104.265	−182.014	168.446	−600.697	−393.344	9.230	−0.201
	2500.00	60.668	176.928	107.123	−175.947	174.513	−618.267	−391.293	25.962	−0.542

References

Phase	H / S	C_p	Remarks	
SOL	Co1	Pa1	Ku1,Tk1	MPT= 2248.
LIQ	e	e		

28.010

CARBON MONOXIDE (GAS)

CO[g]

Phase	T [K]	C_p	S	−(G−H298)/T	H	H−H298	G	ΔH_f	ΔG_f	log K_f
		J / (K mol)			kJ / mol					[−]
GAS	298.15	29.140	197.661	197.661	−110.541	0.000	−169.474	−110.541	−137.180	24.033
	300.00	29.144	197.841	197.662	−110.487	0.054	−169.840	−110.530	−137.345	23.914
	400.00	29.342	206.250	198.807	−107.564	2.977	−190.064	−110.129	−146.354	19.112
	500.00	29.794	212.841	200.977	−104.609	5.932	−211.030	−110.035	−155.426	16.237
	600.00	30.444	218.328	203.424	−101.599	8.942	−232.596	−110.185	−164.494	14.320
	700.00	31.171	223.075	205.900	−98.518	12.023	−254.671	−110.510	−173.522	12.948
	800.00	31.898	227.285	208.315	−95.364	15.177	−277.193	−110.949	−182.494	11.916
	900.00	32.578	231.082	210.637	−92.140	18.401	−300.114	−111.460	−191.408	11.109
	1000.00	33.183	234.547	212.857	−88.851	21.690	−323.398	−112.021	−200.261	10.461
	1100.00	33.710	237.735	214.976	−85.506	25.035	−347.014	−112.619	−209.056	9.927
	1200.00	34.172	240.688	216.997	−82.111	28.430	−370.937	−113.245	−217.796	9.480
	1300.00	34.573	243.440	218.926	−78.674	31.867	−395.145	−113.890	−226.482	9.100
	1400.00	34.919	246.015	220.770	−75.199	35.342	−419.619	−114.551	−235.118	8.772
	1500.00	35.220	248.434	222.535	−71.691	38.850	−444.343	−115.224	−243.707	8.487
	1600.00	35.481	250.716	224.225	−68.156	42.385	−469.302	−115.906	−252.250	8.235
	1700.00	35.710	252.874	225.848	−64.596	45.945	−494.482	−116.596	−260.751	8.012
	1800.00	35.912	254.921	227.407	−61.015	49.526	−519.873	−117.293	−269.210	7.812
	1900.00	36.090	256.868	228.906	−57.415	53.126	−545.463	−117.997	−277.631	7.633
	2000.00	36.249	258.723	230.351	−53.797	56.744	−571.243	−118.708	−286.015	7.470
	2100.00	36.391	260.495	231.745	−50.165	60.376	−597.205	−119.429	−294.362	7.322
	2200.00	36.519	262.191	233.090	−46.520	64.021	−623.340	−120.157	−302.675	7.186
	2300.00	36.634	263.817	234.391	−42.862	67.679	−649.641	−120.893	−310.955	7.062
	2400.00	36.740	265.378	235.650	−39.193	71.348	−676.101	−121.639	−319.203	6.947
	2500.00	36.836	266.880	236.869	−35.514	75.027	−702.714	−122.393	−327.419	6.841
	2600.00	36.924	268.326	238.052	−31.826	78.715	−729.475	−123.157	−335.605	6.742
	2700.00	37.005	269.722	239.199	−28.130	82.411	−756.378	−123.929	−343.762	6.650
	2800.00	37.081	271.069	240.313	−24.425	86.116	−783.418	−124.712	−351.889	6.565
	2900.00	37.151	272.371	241.396	−20.714	89.827	−810.590	−125.503	−359.989	6.484
	3000.00	37.216	273.632	242.450	−16.995	93.546	−837.891	−126.305	−368.061	6.409

References

Phase	H / S	C_p
GAS	Co1	Ja1

CO2[g] CARBON DIOXIDE (GAS) 44.010

Phase	T [K]	C_p	S	−(G−H298)/T	H	H−H298	G	ΔH_f	ΔG_f	$\log K_f$ [−]
		[J / (K mol)]			[kJ / mol]					
GAS	298.15	37.132	213.770	213.770	−393.505	0.000	−457.240	−393.505	−394.364	69.091
	300.00	37.217	214.000	213.770	−393.436	0.069	−457.636	−393.506	−394.370	68.666
	400.00	41.326	225.291	215.282	−389.501	4.004	−479.618	−393.580	−394.646	51.535
	500.00	44.625	234.880	218.266	−385.198	8.307	−502.638	−393.666	−394.903	41.255
	600.00	47.323	243.262	221.748	−380.596	12.909	−526.554	−393.805	−395.139	34.400
	700.00	49.563	250.731	225.364	−375.749	17.756	−551.260	−393.990	−395.347	29.501
	800.00	51.434	257.475	228.963	−370.696	22.809	−576.676	−394.198	−395.527	25.825
	900.00	52.999	263.626	232.478	−365.472	28.033	−602.735	−394.412	−395.680	22.965
	1000.00	54.308	269.280	235.879	−360.105	33.400	−629.384	−394.626	−395.810	20.675
	1100.00	55.412	274.509	239.156	−354.617	38.888	−656.577	−394.837	−395.918	18.801
	1200.00	56.342	279.371	242.307	−349.028	44.477	−684.274	−395.042	−396.007	17.238
	1300.00	57.130	283.913	245.335	−343.354	50.151	−712.441	−395.242	−396.079	15.915
	1400.00	57.803	288.172	248.244	−337.606	55.899	−741.047	−395.437	−396.136	14.780
	1500.00	58.381	292.180	251.041	−331.796	61.709	−770.067	−395.628	−396.179	13.796
	1600.00	58.883	295.965	253.732	−325.932	67.573	−799.476	−395.815	−396.210	12.935
	1700.00	59.321	299.548	256.322	−320.022	73.483	−829.253	−396.000	−396.229	12.175
	1800.00	59.705	302.950	258.819	−314.070	79.435	−859.379	−396.185	−396.237	11.499
	1900.00	60.046	306.187	261.228	−308.082	85.423	−889.837	−396.371	−396.235	10.893
	2000.00	60.349	309.275	263.553	−302.062	91.443	−920.612	−396.561	−396.223	10.348
	2100.00	60.620	312.226	265.801	−296.013	97.492	−951.688	−396.757	−396.201	9.855
	2200.00	60.864	315.052	267.976	−289.939	103.566	−983.053	−396.961	−396.170	9.406
	2300.00	61.086	317.762	270.082	−283.841	109.664	−1014.694	−397.173	−396.129	8.996
	2400.00	61.288	320.366	272.124	−277.722	115.783	−1046.602	−397.394	−396.079	8.620
	2500.00	61.473	322.872	274.104	−271.584	121.921	−1078.764	−397.627	−396.020	8.274
	2600.00	61.644	325.286	276.026	−265.428	128.077	−1111.173	−397.870	−395.951	7.955
	2700.00	61.804	327.616	277.894	−259.256	134.249	−1143.819	−398.126	−395.872	7.659
	2800.00	61.953	329.866	279.710	−253.068	140.437	−1176.694	−398.393	−395.784	7.383
	2900.00	62.094	332.043	281.477	−246.865	146.640	−1209.790	−398.673	−395.686	7.127
	3000.00	62.228	334.150	283.198	−240.649	152.856	−1243.100	−398.965	−395.578	6.888

References

Phase	H / S	C_p
GAS	Co1	Ja1