

## Pressions de vapeur et points d'ébullition Cd, Cr, Pb, U, Zn, Zr

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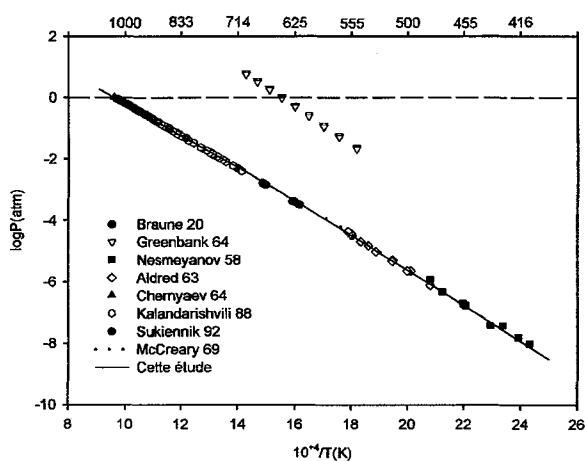
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**Abstract.** Thermodynamic properties of some gaseous metallic elements are revisited and reassessed taking into consideration the new experimental knowledge obtained in the last thirty years, mainly in the high temperatures field. Thermochemical properties are provided in consistency with SGTE data for pure condensed elements.

### 1. INTRODUCTION

Les données thermodynamiques des espèces gazeuses des éléments métalliques datent en général des années 70. Or il faut noter que ces trente dernières années ont été très fructueuses en nouveaux résultats expérimentaux, particulièrement dans le domaine des hautes températures. Il a donc semblé intéressant de revisiter les propriétés thermodynamiques des espèces gazeuses des éléments métalliques au vu de ces nouvelles connaissances. Une analyse fine des mesures expérimentales des pressions de vapeur saturante, associée à une procédure de mise en cohérence ont permis de redéfinir la température d'ébullition de ces métaux et de préciser les pressions de vapeur en fonction de la température. A partir de ces valeurs sélectionnées les propriétés thermochimiques fondamentales,  $\Delta H^\circ_{298}$  et  $S^\circ_{298}$ , des espèces gazeuses peuvent être fixées en cohérence avec les propriétés retenues par le SGTE pour les phases condensées [41].

### 2. CADMIUM



Auteurs	Intervalle T	Tb(K)
(1) Braune 1920	618-845	1033
(2) Nesmeyanov 1958	411-481	975
(3) Aldred 1963	480-559	962
(4) Chernyagv 1964	963-1040	1039
(5) Greenbank 1964	550-700	644
(6) Mc Creary 1969	525-590	981
	525-590	972
(7) Kalandarishvili 1988	708-912	1037
(8) Sukiennik 1992	822-1030	1038

Cette étude

T(K)	P(atm)
298.15	3.51e-14
400	3.09e-9
500	2.33e-6
594.22	1.51e-4
600	1.85e-4
700	3.47e-3
800	3.07e-2
900	1.65e-1
1000	6.24e-1
1041.23	1.00

CDI (G) M=112.41100 P = 1 bar

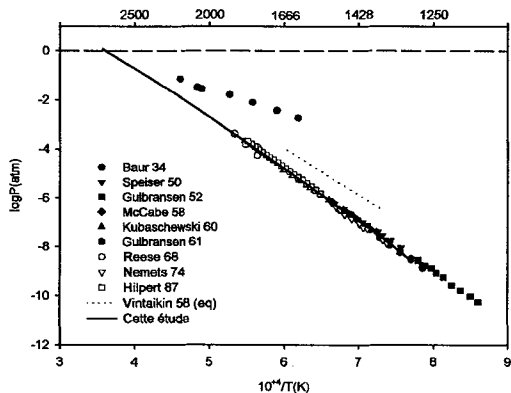
SGTE/THERMODYNAMICS 2000  
Gaseous Standard State.  
T max :10000.00K

ETAT STANDARD :  
dh°298 J/mol 111087.125  
s°298 J/mol\*K 166.915

H°298-H°0 J/mol 6196.504  
Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T.trans K	L.trans J/mol	S.trans J/mol*K	a	b	c	d
RG	298.15	0	0.000	+2.0786112000e+01	+0.0000000000e+00	+0.0000000000e+00	+0.0000000000e+00
FC	2660.00	0	0.000	+2.0907140000e+01	-1.4592380000e-04	+3.7767270000e-08	-8.3991730000e+03
FC	4100.00	0	0.000	+2.9172450000e+01	-4.1203280000e-03	+5.2129500000e-07	-1.6179770000e+06
FC	8000.00	0	0.000	-5.3613110000e+01	+1.0420700000e-02	-2.0042530000e-07	+8.0778950000e+08

### 3. CHROME



Auteurs	Intervalle T	Tb(K)
(9) Baur 1934	1615-2170	3011
(10) Speiser 1950	1283-1561	2758
(11) Gulbransen 1952	1162-1282	2673
(12) Mc Cabe 1958	1381-1505	2665
(13) Vintaikin 1958	1373-1673	2566
(14) Kubaschewski 1960	1443-1673	2847
(15) Gulbransen 1962	1273-1348	2769
(16) Reese 1968	1773-1873	2578
(17) Nemets 1974	1355-1491	2661
(18) Hilpert 1987	1542-1819	2616

## Cette étude

T(K)	P(atm)
298.15	8.61e-66
1000	3.85e-14
1500	6.09e-7
1750	6.40e-5
2000	2.00e-3
2180.00	1.41e-2
2250	2.66e-2
2500	1.87e-1
2750	9.05e-1
2767.78	1.00

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 CR1 (G) M=51.99610 P = 1 bar  
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SGTE/THERMODATA 2000  
 Gaseous Standard State.  
 T max :10000.00K

ETAT STANDARD :  
 dH°298 J/mol 421151.217  
 S°298 J/mol\*K 190.552  
 H°298-H°0 J/mol 6197.002  
 Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T.trans K	L.trans J/mol	S.trans J/mol*K	a	b	c	d
RG	298.15	0	0.000	+2.1360830000e+01	-1.4506430000e-03	+9.5320740000e-07	-2.0570300000e+04
FC	1100.00	0	0.000	+1.9960030000e+01	-3.0261780000e-03	+2.5418900000e-06	+1.4450300000e+06
FC	2000.00	0	0.000	-5.3628860002e+00	+1.6977540000e-02	-1.7907810000e-06	+1.2030810000e+07
FC	3300.00	0	0.000	+5.5203039999e+01	-1.0649170000e-02	+1.7102430000e-06	-6.9902970000e+07
FC	5100.00	0	0.000	-1.7505080000e+02	+5.1148370000e-02	-2.9666820000e-06	+8.8552710002e+08
FC	7600.00	0	0.000	+2.0455890000e+02	-1.4950450000e-02	+2.7712470000e-07	-2.8470080000e+09

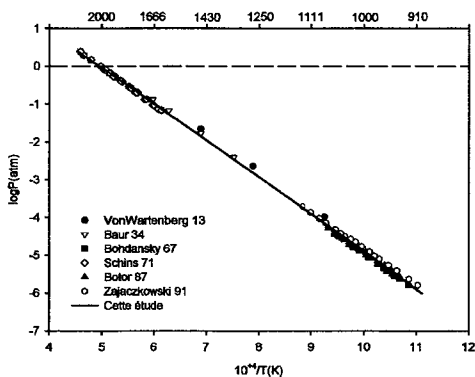
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 CR2 (G) M=103.99220 P = 1 bar  
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SGTE/THERMODATA 2000  
 DIATOMIC Gaseous Standard State.  
 T max :6000.00K

ETAT STANDARD :  
 dH°298 J/mol 630723.421  
 S°298 J/mol\*K 243.297  
 H°298-H°0 J/mol 9387.001  
 Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T. trans K	L. trans J/mol	S. trans J/mol*K	a	b
				c	d
RG	298.15	0	0.000	+4.0567980000e+01 +9.6730030001e-06	-9.9236940001e-03 -3.0884570000e+05
FC	800.00	0	0.000	+1.9764300000e+01 +2.8192980000e-06	+1.4170170000e-02 +3.4761330000e+06
FC	1400.00	0	0.000	-1.7647430000e+01 -9.6354360001e-06	+5.5346420001e-02 +1.1663310000e+07
FC	2300.00	0	0.000	+5.2079689999e+01 -9.5639550002e-07	+8.4588020002e-03 -2.9587250000e+07
FC	3900.00	0	0.000	+1.0504280000e+02 -9.1070090002e-07	-7.9399090000e-04 -2.9687530000e+08
FC	5800.00	0	0.000	+3.3471450000e+02 +2.9851210000e-06	-5.7195250001e-02 -1.4271610000e+09

## 4. PLOMB



Auteurs	Intervalle T	Tb(K)
(19) Von Wartenberg 1913	1081-1451	1922
(9) Baur 1934	1329-1673	1967
(20) Bohdanský 1967	1628-2177	2015
(21) Schins 1971	1628-2177	2015
(22) Botor 1987	922-1073	2003
(23) Zajaczkowski 1991	907-1132	2041

Cette étude

T(K)	P(atm)
298.15	1.27e-29
600.59	3.39e-12
1000	1.33e-5
1500	2.29e-2
2000	9.00e-1
2019.4	1.00

Pb1 (G) M=207.20000 P = 1 bar

SGTE/THERMODYNAMICS 2000  
Gaseous Standard State.  
T max :10000.00K

ETAT STANDARD :

dH°298 J/mol 198337.432  
S°298 J/mol\*K 176.888  
H°298-H°0 J/mol 6197.000

Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T. trans K	L. trans J/mol	S. trans J/mol*K	a	b
				c	d
RG	298.15	0	0.000	+2.1306430000e+01 +8.5849770000e-07	-1.3102930000e-03 -1.8674420000e+04
FC	1100.00	0	0.000	+2.6434630000e+01 +4.4160190000e-06	-9.6727560000e-03 -3.0234040000e+05
FC	2000.00	0	0.000	-4.6903690000e+01 -4.7810520000e-06	+3.9203160000e-02 +4.9198020000e+07
FC	3700.00	0	0.000	+1.0294790000e+02 +9.3370600000e-07	-1.5856150000e-02 -2.8439150000e+08
FC	5200.00	0	0.000	+1.3421510000e+02 +1.6238320000e-06	-2.4565740000e-02 -4.0980450000e+08
FC	8200.00	0	0.000	-1.6123870000e+02 -6.0979990000e-07	+2.3810870000e-02 +2.8819440000e+09

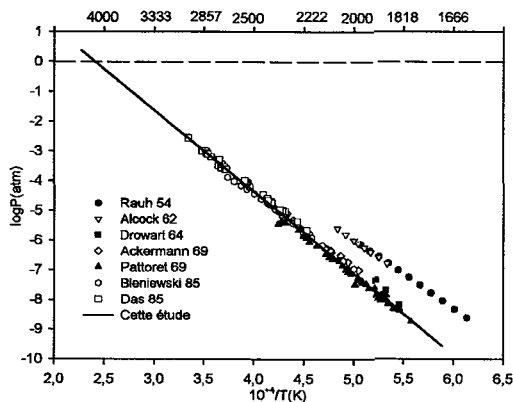
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 PB2 (G)            M=414.40000            P = 1 bar  
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SGTE/THERMODATA 2000  
 DIATOMIC Gaseous Standard State.  
 T max :6000.00K

ETAT STANDARD :  
 dH°298 J/mol                            307001.946  
 S°298 J/mol\*K                            278.306  
 H°298-H°0 J/mol                        10559.000  
 Transformations :            Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T. trans K	L. trans J/mol	S. trans J/mol*K	a	b
				c	d
RG	298.15	0	0.000	+3.6885000000e+01 +1.1594090000e-07	+2.0883120000e-03 +1.6691720000e+03
FC	1400.00	0	0.000	+2.9463990000e+01 +1.7304150000e-06	+2.3733440000e-03 +7.5617740000e+06
FC	2300.00	0	0.000	-4.3769390000e+01 -7.6261040000e-06	+5.2329320000e-02 +4.8988950000e+07
FC	3500.00	0	0.000	+1.7800270000e+02 +2.4238410000e-06	-3.6724210000e-02 -3.5766910000e+08

## 5. URANIUM



Auteurs	Intervalle T	Tb(K)
(24) Rauh 1954	1630-1970	4091
(25) Alcock 1962	1874-2067	3989
(26) Drowart 1964	1833-2061	4799
(27) Ackermann 1969	1980-2416	4418
(28) Pattoret 1969	1720-2340	4495
(29) Bieniewski 1984	1999-2675	4835
(30) Das 1985	2210-2989	4240

Cette étude

T(K)	P(atm)
298.15	8.17e-92
1408	1.08e-13
2000	7.83e-8
3000	2.92e-3
3500	5.84e-2
4000	5.58e-1
4149.70	1.00

U1 (G) M=238.02890 P = 1 bar

SGTE/THERMODYN 2000

Gaseous Standard State.

T max :12000.00K

ETAT STANDARD :

dH°298 J/mol 569387.360

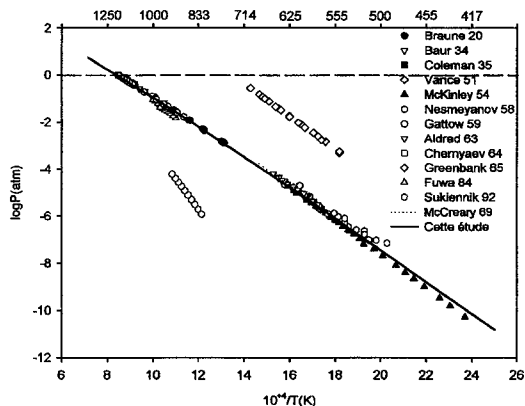
S°298 J/mol\*K 216.308

H°298-H°0 J/mol 6499.007

Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T.trans K	L.trans J/mol	S.trans J/mol*K	a	b	c	d
RG	298.15	0	0.000	+3.2607046251e+01	-2.2732875533e-02	+1.4695086420e-05	-3.0601880154e+05
FC	1000.00	0	0.000	+2.6615892917e+00	+1.6802944153e-02	-2.9714759478e-07	+5.0958524874e+06
FC	2300.00	0	0.000	-4.4240623227e+01	+4.3972511320e-02	-4.7816791571e-06	+4.8132012682e+07
FC	4300.00	0	0.000	+1.5634510622e+02	-1.7753212833e-02	+6.0066175675e-07	-5.9318622445e+08
FC	6800.00	0	0.000	+1.4877714168e+02	-1.7865666814e-02	+7.0209927303e-07	-4.2477178153e+08
FC	9800.00	0	0.000	-1.7335303565e+01	+4.5448916486e-03	-1.5871341482e-07	+2.3758912693e+09

## 6. ZINC



Auteurs	Intervalle T	Tb(K)
(1) Braune 1020	767-994	1177
(9) Baur 1934	955-1089	1180
(31) Coleman 1935	302-356	1114
(32) Vance 1951	577-630	1087
(33) Mc Kinley 1954	421-626	1162
(2) Nesmeyanov 1958	493-633	1211
(34) Gattow 1959	550-650	1320
(3) Aldred 1963	580-654	1117
(4) Chernyaev 1964	1086-1178	1179
(5) Greenbank 1964	550-800	742
(6) Mc Creary 1969	610-690	1310
	610-690	1356
(35) Fuwa 1984	910-1000	1166
(8) Sukiennik 1992	881-1173	1182

## Cette étude

T(K)	P(atm)
298.15	2.54e-17
400	1.54e-11
500	3.62e-8
600	6.24e-6
692.68	1.91e-4
700	2.38e-4
800	3.09e-4
900	2.23e-2
1000	1.07e-1
1191.52	1.00

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 ZN1 (G)            M=65.39000            P = 1 bar  
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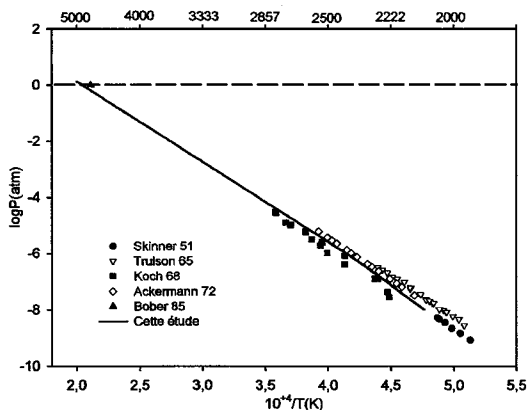
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 Gaseous Standard State.  
 T max :10000.00K

ETAT STANDARD :  
 dH°298 J/mol            129851.698  
 S°298 J/mol\*K            159.572  
 H°298-H°0 J/mol            6197.000  
 Transformations :            Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T.trans K	L.trans J/mol	S.trans J/mol*K	a	b
				c	d
RG	298.15	0	0.000	+2.0786111958e+01	+0.0000000000e+00
				+0.0000000000e+00	+0.0000000000e+00
FC	2800.21	0	0.000	+2.0903170000e+01	-1.3672820000e-04
				+3.4034100000e-08	-8.2945140000e+03
FC	4300.00	0	0.000	+3.1557620000e+01	-4.6084790000e-03

+5.2939570000e-07 -1.0778720000e+07  
 FC 8200.00 0 0.000 -7.7463550000e+01 +1.3971170000e-02  
 -3.6446150000e-07 +1.1168790000e+09

## 7. ZIRCONIUM



Auteurs	Intervalle T	Tb(K)
(36) Skinner 1951	1949-2054	4713
(37) Trulson 1965	1968-2274	4491
(38) Koch 1968	2229-2795	4757
(39) Ackermann 1972	2134-2550	4577
(40) Bober 1985	4732	4732

Cette étude

T(K)	P(atm)
298.15	1.65e-95
2000	3.25e-9
2125.00	2.45e-8
2500	2.58e-6
3000	2.08e-4
3500	4.77e-3
4000	5.01e-2
4500	3.13e-1
4885.9	1.00

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 ZRI (G) M=91.22400 P = 1 bar  
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SGTE/THERMODYNAMICS 2000  
 Gaseous Standard State.  
 T max :10000.00K

ETAT STANDARD :  
 dH°298 J/mol 580136.848  
 S°298 J/mol\*K 170.293  
 H°298-H°0 J/mol 6816.000  
 Transformations : Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2) J/mol\*K

code	T. trans K	L. trans J/mol	S. trans J/mol*K	a	b	c	d
RG	298.15	0	0.000	+3.8691110000e+01	-2.3056920000e-02	+1.0159530000e-05	-5.4127760000e+05
FC	700.00	0	0.000	+2.4061060000e+01	-3.4872820000e-03	+3.5658740000e-06	+1.4978950000e+06



FC	1300.00	0	0.000	+2.0463610000e+01	+5.9221680000e-03	-6.5034860000e-07	-1.0527050000e+06
FC	2700.00	0	0.000	+6.6473430000e+00	+9.3477910000e-03	-6.4100150000e-07	+3.1744680000e+07
FC	6600.00	0	0.000	+4.0688010000e+01	+1.2767140000e-03	-1.0747520000e-07	-1.4299390000e+08

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 ZR2 (G)            M=182.44800            P = 1 bar  
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SGTE/THERMADATA 2000

DIATOMIC Gaseous Standard State.

T max :6000.00K

ETAT STANDARD :

dh°298 J/mol                            898453.856

s°298 J/mol\*K                            259.390

H°298-H°0 J/mol                        9515.000

Transformations :                      Cp= a + b\*T + c\*T\*\*2 + d\*T\*\*(-2)    J/mol\*K

code	T.trans K	L.trans J/mol	S.trans J/mol*K				
				a c	b d		
RG	298.15	0	0.000	+3.7136720000e+01	+6.4079310000e-04	+2.5836310000e-08	-1.7084430000e+05
FC	3600.00	0	0.000	+3.9333560000e+01	+2.0393380000e-03	-3.6587980000e-07	-2.8131610000e+07

## Remerciements

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