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Thermodynamic Properties of Nickel

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This work reviews and discusses the data and information on the thermodynamic properties of nickel available through May 1984. These properties include heat capacity, enthalpy, enthalpy of transition and melting, vapor pressure, and enthalpy of vaporization. The recommended values for heat capacity cover the temperature range from 1 to 3200 K. The recommended values for enthalpy, entropy, Gibbs energy function, and vapor pressure cover the temperature range from 298.15 to 3200 K.

KEY WORDS: critical evaluation; enthalpy; enthalpy of transition; enthalpy of melting; enthalpy of vaporization; entropy; Gibbs energy function; heat capacity; nickel; recommended values; vapor pressure.

1. INTRODUCTION

The principal objective of this work is to critically evaluate and analyze available data and information on the heat capacity, enthalpy and vapor pressure of nickel and to generate the recommended values of these and other thermodynamic properties from 298.15 to 3200 K. The recommended values for the heat capacity are reported from 1 to 3200 K.

The discussion of the thermodynamic properties and the details of data analysis are reported in Section 2.

It is worth noting that the effect of conversion to IPTS-68 on these properties is small and well within the uncertainties of these values. The measurements on the thermodynamic properties which have been carried out on the International Practical Temperature Scale of 1948 or 1958 were not converted to IPTS-68. The value of the gas constant, $R = 8.31441\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$, is used in all calculations. The details of the data analysis have been discussed elsewhere [1].

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2. THERMODYNAMIC PROPERTIES OF NICKEL

2.1. Phases and Structures

Nickel has a fcc (A1) structure isotypic with Cu and its atomic weight is 58.69 ± 0.01. It is ferromagnetic; Maszkiewicz [2] gives 625 K for the Curie temperature based on his recent and very careful heat capacity measurements. This value differs from the previously accepted value of 631 K. Its melting point is 1728 K, which is the secondary reference point on IPTS-68 [3]. This compares well with the literature values (IPTS-1968) listed in Table I.

2.2. Low-Temperature Heat Capacity

There have been numerous measurements on the heat capacity of nickel at low temperatures, from which the values for the electronic heat capacity coefficient, γ, and the Debye temperature, θ_D, are derived. The recommended values of γ and θ are based on some of the studies listed in Table II, with considerable weight given to those of Petrovic et al. [18], Bower et al. [24], and Dixon et al. [25].

The recommended values for the heat capacity below 4 K are calculated from the recommended values for γ and θ_D using the following equation:

$$C_p^0 = \gamma T + [1943.75/\theta_D^3]\, T^3 \tag{1}$$

Table I. Melting Point of Nickel

Source	T_{fus} (K)
Cezairliyan and Miiller [4]	1728 ± 4
Vollmer et al. [5]	1727
Geoffray et al. [6]	1728
Singleton et al. [7]	1737
Alley and Shell [8]	1721
Deardorff and Hayes [9]	1730
Oriani and Jones [10]	1727 ± 4
Schofield and Bacon [11]	1726
Kubaschewski [12]	1730
Van Dusan and Dahl [13]	1728 ± 1
Wensel and Roeser [14]	1728 ± 1
Umino [15]	1755
Burgess and Waltenberg [16]	1727 ± 3
Day and Sosman [17]	1727 ± 3
Recommended value	1728

Table II. Electronic Specific Heat Coefficient and Debye Temperature of Nickel

Source	$\gamma(mJ \cdot mol^{-1} \cdot K^{-2})$	θ_D (K)
Petrovic et al. [18]	7.050 ± 0.006	473
	7.056 ± 0.009	473
Viswanathan [19]	7.10	467
Gregory and Moody [20]	7.034 ± 0.003	444
Caudron et al. [21]	7.02	
Ehrat et al. [22]	7.12 ± 0.02	462 ± 19
Ehrat and Rivier [23]	7.16 ± 0.02	469 ± 16
Bower et al. [24]	7.053 ± 0.031	472
Dixon et al. [25]	7.039 ± 0.16	477.4 ± 6
	7.028 ± 0.027	470.9 ± 10
	7.052 ± 0.001	472 ± 1
	7.059 ± 0.002	459 ± 2
Gupta et al. [26]	7.20 ± 0.01	334
Walling and Bunn [27]	6.70 ± 0.05	348 ± 15
Rayne and Kemp [28]	7.05	468
	7.02 ± 0.06	441 ± 15
Keesom and Kurrelmeyer [29]	7.155	413
Keesom and Clark [30]	7.3	456
	7.3 ± 0.2	413 ± 15
Recommended value	7.055 ± 0.050	472 ± 5

Table III. Percentage Deviation in Heat Capacity of Nickel from Recommended Values Given in Table IV

Source	Deviation (%)
Rayne and Kemp [28]	1
Busey and Giauque [31]	2
Eucken and Worth [33]	±2
Schmidt and Leidenfrost [34]	−0.5
Bronson and Wilson [35]	±1.5
Vecher et al. [36]	±1.0
Ohsawa et al. [37]	2.5
Lapp [38]	−2 (<250 K)
	2 (>250 K)
Larikov et al. [39]	−6
Rodebush and Michalek [40]	Up to 3
Urzendowski and Guenther [41]	−4
Aoyama and Kanda [42]	2 (<250 K)
	−3 (273 K)
Grew [43]	5 to 10
Simon and Ruhemann [44]	2

Table IV. Recommended Low-Temperature Heat Capacity of Nickel

T (K)	C_p^0 ($J \cdot mol^{-1} \cdot K^{-1}$)
1	0.007029
2	0.01423
3	0.02167
4	0.02946
5	0.03807
6	0.0477
7	0.0583
8	0.0698
9	0.0826
10	0.0963
15	0.181
20	0.328
25	0.574
30	0.968
40	2.207
50	4.067
60	6.090
70	8.153
75	9.185
80	10.169
90	11.987
100	13.599
110	15.041
120	16.325
125	16.898
130	17.433
140	18.429
150	19.320
160	20.112
170	20.815
175	21.132
180	21.431
190	21.978
200	22.457
210	22.894
220	23.306
225	23.507
230	23.702
240	24.079
250	24.438
260	24.783
270	25.124
273.15	25.223
280	25.453
290	25.763
298.15	26.009

$C_{(electronic)} = \gamma T$, $\gamma = 7.055 \pm 0.050\ mJ \cdot mol^{-1} \cdot K^{-2}$

	Crystal, Ni(s)	Gas, Ni(g)
$H^0(298.15\ K) - H^0(0\ K)$	4787 ($\pm$10) $J \cdot mol^{-1}$	6824 $\pm$ 0.3 $J \cdot mol^{-1}$
$S^0(298.15\ K)$	29.864 ($\pm$0.08) $J \cdot mol^{-1} \cdot K^{-1}$	182.083 $\pm$ 0.003 $J \cdot mol^{-1} \cdot K^{-1}$

The recommended values from 4 to 25 K are based on the data of Viswanathan [19], Keesom and Clark [30], Busey and Giauque [31], Clusius and Goldman [32], and Eucken and Werth [33]. The recommended values from 20 to 298.15 K agree well with the data of Rayne and Kemp [28], Busey and Giauque [31], Eucken and Werth [33], Schmidt and Leidenfrost [34], Bronson and Wilson [35], and Vecher et al. [36]. Literature C_p^0 data deviate from the recommended values as listed in Table III.

Integration of the recommended C_p^0 values yielded $H^0(298.15\ \mathrm{K}) - H^0(0\ \mathrm{K}) = 4787\ \mathrm{J \cdot mol^{-1}}$ and that of C_p^0/T values yielded $S^0(298.15\ \mathrm{K}) = 29.864\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$. These values are tabulated in Table IV, and C_p^0 values are shown in Fig. 1 along with the experimental data.

2.3. High-Temperature Heat Capacity (Solid)

There have been numerous measurements of the heat capacity of nickel. There is a general agreement of most of the data sets with one another. Near the Curie temperature, C_p^0 varies rapidly with temperature. In this region, from 600 to 650 K, comparatively large deviations in C_p^0 occur which, in many cases, could be reconciled by changing the temperature only slightly.

The recommended C_p^0 values below 550 K are based on the closely agreeing ($\pm 1.5\%$) data of Bronson and Wilson [35], Vecher et al. [36], Ohsawa et al. [37], Novikov et al. [45], Pawel and Stansbury [46], Stansbury and McElroy [47], Krauss and Warncke [48], Arledge [49], Bronson et al. [50], Braun et al. [51], and Jaeger and Rosenbohm [52]. The deviations of literature C_p^0 data from the recommended values are listed in Table V.

The recommended values from 550 to 750 K are based on the data of Vollmer et al. [5], Schmidt and Leidenfrost [34], Novikov et al. [45], Pawel and Stansbury [46], Arledge [49], Bronson et al. [50], Jaeger and Rosenbohm [52], Moser [53], Hagel et al. [73], and Korn and Kohlhaas [102]. The data of Connelly et al. [101] also agree well except near the Curie temperature (11% higher), while those of Maszkiewicz [2] are up to 5% higher below 626 K and 7% lower above 626 K.

The recommended C_p^0 values above 750 K to the melting point (1728 K) similarly are based on the closely agreeing ($\pm 1.5\%$) data of Vollmer et al. [5], Novikov et al. [45], Pawel and Stansbury [46], Stansbury and McElroy [47], Arledge [49], Jaeger and Rosenbohm [52], Moser [53], Engel et al. [57], Cezairliyan and Miiller [71], and Hultgren

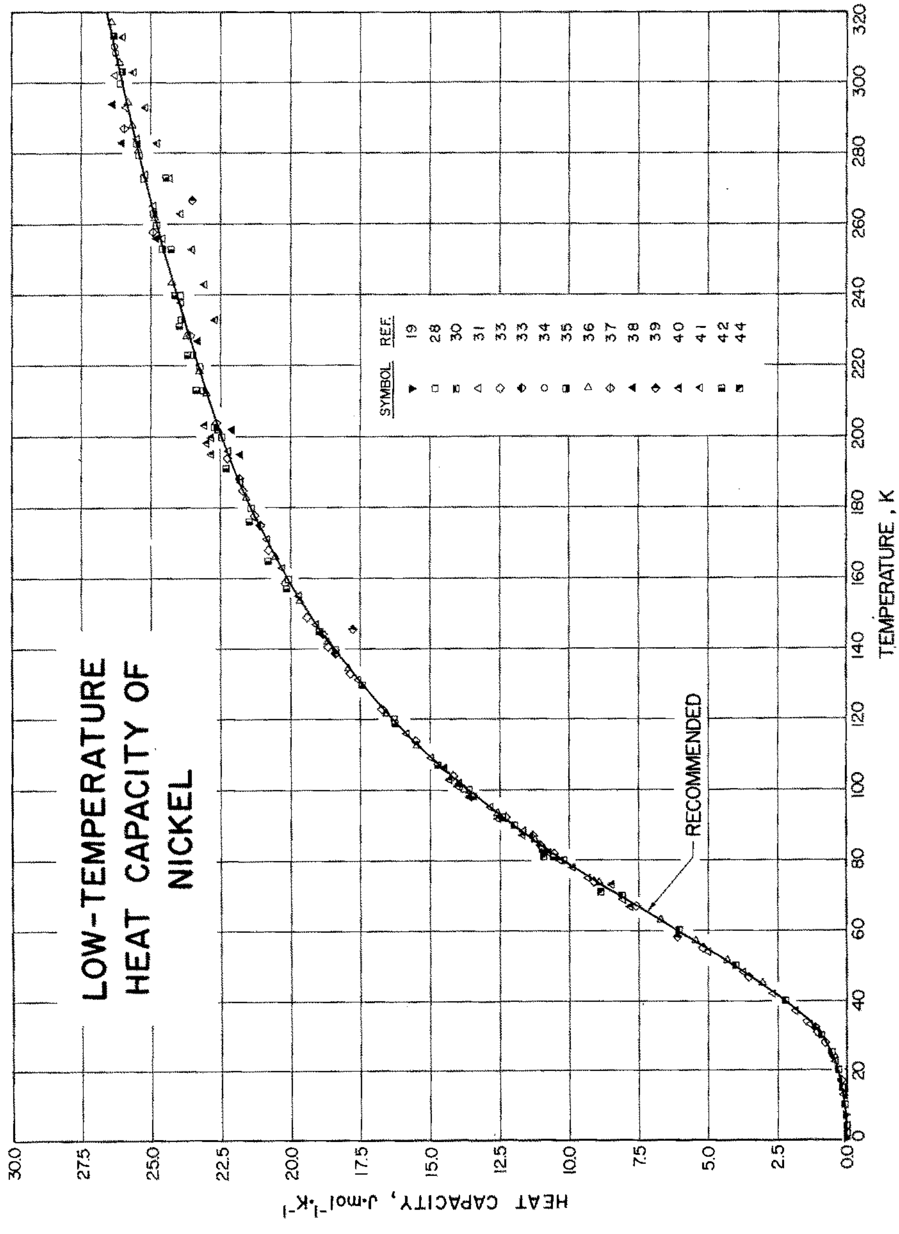

Fig. 1. Low-temperature heat capacity of nickel.

and Land [100]. The deviations of literature C_p^0 data from the recommended values are listed in Table VI.

Below 900 K, the enthalpy measurements of Bronson et al. [50], Ewert [58], Kendall and Hultgren [75], and Naccari [76] agree well with the recommended values. Similar studies of Schubel [77] also agree well with the exception of the high value near the Curie temperature. However,

Table V. Percentage Deviation in Heat Capacity of Nickel Below 550 K from Recommended Values given in Table VII

Source	Deviation (%)
Bronson and Wilson [35]	−0.5
Vecher et al. [36]	−0.6
Braun et al [51]	1
Rosenbohm [52]	±1
Krauss and Warncke [48]	±1.1
Pawel and Stansbury [46]	±1.2
Novikov et al. [45]	±1.3
Ohsawa et al. [37]	±1.4
Bronson et al. [50]	±1.4
Stansbury and McElroy [47]	±1.5
Arledge [49]	±1.5
Schmidt and Leidenfrost [34]	Up to 2.5 (>500 K)
Vollmer et al. [5]	2.3 (at 500 K)
Lapp [38]	2 (at 530 K)
Grew [43]	2
Moser [53]	Up to −2 (<450 K)
Valentiner [54]	Up to −2 (<400 K)
Wright [55]	Up to −2 (<450 K)
Klinkhardt [56]	2
Engel et al. [57]	Up to −2
Larikov et al. [39]	−2 to 4
Ewert [58]	Up to 3
Butler and Inn [59]	Up to 3
Anderson [60]	Up to 3
Neél [61]	Up to 3
Ahrens [62]	Up to 3 (>450 K)
Sykes and Wilkinson [63]	Up to −4 (<400 K)
Velisek and Vrestal [64]	1 to 5
Ali-Zade and Mamedov [65]	Up to −4
Umino [15]	Up to −5
Tanji et al. [66]	Up to 5
Booker et al. [67]	−6
Weiss et al. [68]	−10
Strittmater and Danielson [69]	11
Blough [70]	−14

Table VI. Percentage Deviation in Heat Capacity of Nickel Above 750 K from Recommended Values Given in Table VII

Source	Deviation (%)
Pawel and Stansbury [46]	−0.2
Engel et al. [57]	±0.6
Cezairliyan and Miiller [71]	−0.7
Vollmer et al. [5]	−1
Arledge [49]	−1
Jaeger and Rosenbohm [52]	±1
Hultgren and Land [100]	±1.1
Moser [53]	−1.4
Novikov et al. [45]	±1.5
Stansbury and McElroy [47]	−1.5
Braun et al. [51]	Up to −2
Wright [55]	2
Booker et al. [67]	Up to 2 (<1100 K), −4 (>100 K)
Ewert [58]	2 (<1000 K), −4 (>1000 K)
Kollie [72]	Up to 3
Anderson [60]	4
Krauss and Warncke [48]	Up to 4
Sykes and Wilkinson [63]	Up to 4
Velisek and Vrestal [64]	Up to 4
Neél [61]	4
Butler and Inn [59]	±4
Hagel et al. [73]	Up to 4
Klinkhardt [56]	1 to 6
Tanji et al. [66]	6
Larikov et al. [39]	4 to 8
Persoz [74]	Up to 8
Umino [15]	6 (<850 K), up to −9.5 (>850 K)
Blough [70]	−11
Strittmater and Danielson [69]	11

the data of Kendall and Hultgren [75], Ewert [58], and Geoffray et al. [6] are up to 1.3% higher than the recommended values. Enthalpy data of Umino [15] are about 8% lower, and those of Wust et al. [78] are as much as 9% higher below 1300 K and 4% lower above 1300 K.

A plot of percentage deviation (up to ±4%) of various measurements from the recommended C_{p}^{0} is shown in Fig. 2. Other thermodynamic properties are calculated from the recommended C_{p}^{0} values and $S^{0}(298.15\ \mathrm{K}) = 29.864\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$. These values are tabulated in Table VII.

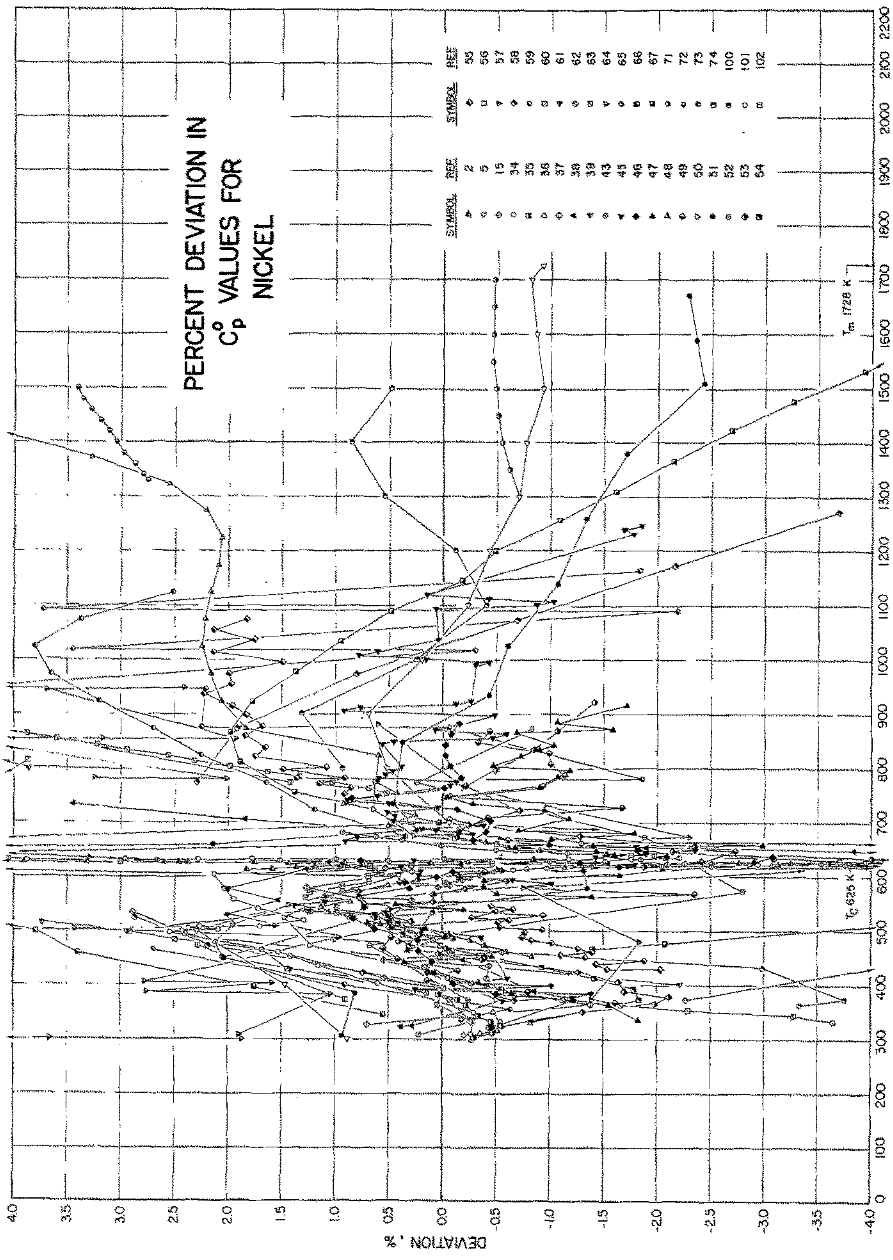

Fig. 2. Percentage deviation in C_p^0 values for nickel from recommended values given in Table VII.

2.4. High-Temperature Heat Capacity (Liquid)

The recommended value for the enthalpy of melting, $\Delta_{\mathrm{fus}}H^0 = 17{,}470 \pm 200\ \mathrm{J \cdot mol^{-1}}$, was obtained from the literature data reported in Table VIII.

A constant value of $43.1 \pm 1.3\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$ recommended for the heat capacity of molten nickel is based on the values listed in Table IX.

Other quantities in Table VII are calculated by integrating C_p^0 values. The recommended C_p^0 values are shown in Fig. 3 along with the selected

Table VII. Recommended High-Temperature Thermodynamic Properties of Nickel[a]

	Condensed phase				Gas phase Ni(g)			
T (K)	C_p^o ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)	$H^o - H^o(T_r)$ ($\mathrm{J \cdot mol^{-1}}$)	S^o ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)	$-[G^o - H^o(T_r)]/T$ ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)	C_p^o ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)	$H^o - H^o(T_r)$ ($\mathrm{J \cdot mol^{-1}}$)	S^o ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)	$-[G^o - H^o(T_r)]/T$ ($\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$)
298.15	26.009	0	0.000	29.864	23.359	0	0.000	182.083
300	26.064	48	0.161	29.864	23.368	43	0.145	182.083
325	26.773	709	2.276	29.959	23.477	629	2.019	182.168
350	27.377	1386	4.282	30.186	23.600	1218	3.763	182.368
375	27.937	2077	6.190	30.514	23.725	1809	5.395	182.655
400	28.484	2783	8.010	30.917	23.857	2404	6.932	183.006
425	29.013	3501	9.753	31.378	23.993	3001	8.380	183.401
450	29.545	4233	11.426	31.882	24.125	3603	9.757	183.832
475	30.137	4979	13.039	32.420	24.257	4208	11.063	184.288
500	30.790	5741	14.602	32.985	24.376	4816	12.313	184.764
525	31.528	6520	16.122	33.568	24.484	5426	13.504	185.251
550	32.389	7318	17.608	34.166	24.582	6040	14.645	185.746
575	33.430	8141	19.071	34.778	24.664	6655	15.740	186.248
600	34.753	8992	20.521	35.398	24.736	7273	16.792	186.753
610	35.474	9343	21.101	35.648	24.762	7520	17.199	186.953
615	36.009	9522	21.393	35.774	24.774	7644	17.401	187.054
620	36.883	9708	21.695	35.901	24.787	7768	17.602	187.156
625	38.925	9897	21.998	36.027	24.798	7892	17.801	187.256
630	36.355	10085	22.297	36.154	24.809	8016	17.998	187.357
635	34.502	10262	22.576	36.280	24.820	8140	18.194	187.458
640	33.402	10431	22.842	36.408	24.830	8264	18.389	187.559
650	32.115	10758	23.349	36.662	24.850	8513	18.776	187.762
675	31.108	11546	24.539	37.298	24.891	9135	19.713	188.263
700	30.817	12319	25.664	37.929	24.924	9758	20.621	188.765
750	30.713	13856	27.786	39.175	24.968	11005	22.342	189.751
800	30.838	15394	29.772	40.394	24.983	12254	23.954	190.720
900	31.382	18503	33.435	42.740	24.941	14751	26.895	192.589
1000	32.136	21678	36.778	44.964	24.840	17240	29.518	194.361
1100	32.979	24933	39.880	47.078	24.702	19714	31.876	196.037
1200	33.844	28274	42.790	49.092	24.539	22176	34.019	197.622
1300	34.746	31704	45.532	51.009	24.363	24621	35.976	199.120
1400	35.676	35225	48.142	52.845	24.188	27049	37.775	200.537
1500	36.638	38841	50.634	54.604	24.012	29458	39.438	201.882
1600	37.627	42554	53.032	56.300	23.840	31851	40.982	203.158
1700	38.610	46366	55.342	57.932	23.677	34226	42.422	204.372
1728(s)	38.889	47451	55.975	58.379	23.629	34888	42.808	204.701
1728(ℓ)	43.100	64921	66.085	58.379	23.629	34888	42.808	204.701
1800	43.100	68024	67.845	59.918	23.522	36586	43.771	205.528
1900	43.100	72334	70.175	61.969	23.380	38931	45.038	206.632
2000	43.100	76644	72.386	63.928	23.246	41262	46.234	207.686
2100	43.100	80954	74.489	65.803	23.121	43580	47.365	208.696
2200	43.100	85264	76.494	67.601	23.008	45887	48.438	209.664
2400	43.100	93884	80.244	70.990	22.811	50467	50.431	211.486
2600	43.100	102504	83.694	74.133	22.652	55013	52.251	213.175
2800	43.100	111124	86.888	77.065	22.531	59531	53.925	214.747
3000	43.100	119744	89.862	79.811	22.443	64028	55.476	216.216
3100	43.100	124054	91.275	81.121	22.414	66270	56.211	216.917
3160	43.100	126640	92.101	81.889	22.401	67614	56.641	217.327
3200	43.100	128364	92.643	82.393	22.393	68513	56.924	217.596

$T_{fus} = 1728\ \mathrm{K}$[b] $\Delta_{fus}H^o = 17470 \pm 200\ \mathrm{J \cdot mol^{-1}}$ $\Delta_{fus}S^o = 10.11 \pm 0.12\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$ $T_c = 625\ \mathrm{K}$ (Curie temperature)

[a] Enthalpy reference temperature = T_r = 298.15 K.

[b] Secondary reference point on International Practical Temperature Scale (IPTS-68).

Table VIII. Enthalpy of Melting of Nickel

Source	$\Delta_{\text{fus}}H^0$ (J · mol^{-1})
Vollmer et al. [5]	16,900
Geoffray et al. [6]	17,470
Umino [15]	17,615
Braun et al. [51]	16,900
Wust et al. [78]	13,850
Lebedev et al. [79]	18,410
Predel and Mohs [80]	17,030
Bonnell [123]	17,200
Recommended value	17,470 ± 200

experimental data. Attention of the readers is directed to Refs. 82–99 for additional information and data on the heat capacity of nickel.

The estimated uncertainties in C_p^0 values are ±3% below 10 K, ±1.5% from 10 to 298.15 K, ±2% from 298.15 to 550 K and above 750 K, ±3% in the liquid region, and as much as ±5% from 550 to 750 K (Curie temperature region).

2.5. Ideal-Gas Properties

$C_p^0(g)$ values reported in Table VII are taken from Chase et al. [81]. Other thermodynamic quantities are calculated from $C_p^0(g)$ values using $S^0(298.15\ \text{K}) = 182.083 \pm 0.003\ \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ reported by Chase et al. [81].

Table IX. Heat Capacity of Molten Nickel

Source	C_p^0 (J · mol^{-1} · K^{-1})
Geoffray et al. [6]	43.07
Umino [15]	38.49
Braun et al. [51]	39.00
Wust et al. [78]	32.89
Chemykhin et al. [124]	39.04
Recommended value	43.1 ± 1.3

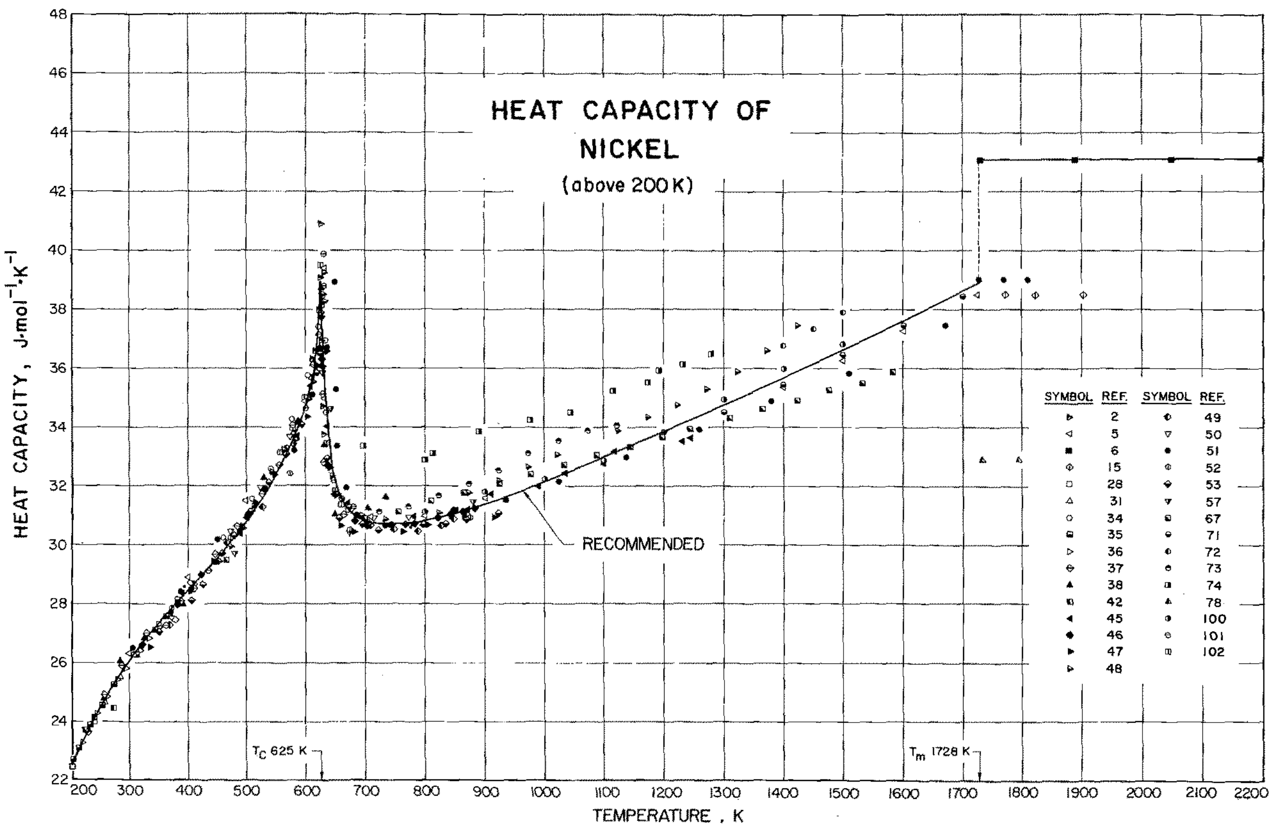

Fig. 3. Heat capacity of nickel (above 200 K).

Table X. Enthalpy of Sublimation of Nickel at 298.15 K

Source	$\Delta_{\text{sub}}H^0$(298.15 K) (kJ · mol^{-1})
Bodrov et al. [103], 1489–2110 K, absorption spectroscopy	420.00 ± 1.27
Bochkova et al. [104], 1573–1713 K	424.34 ± 0.33
Chegodaev et al. [105], 1273–2223 K, Langmuir method	443.41 ± 1.33
Farber and Srivastava [106], 1583–1723 K, mass spectrometric method	423.41 ± 0.39
Vatolin et al. [107], 1400–1600 K, Knudsen method	357.38 ± 1.25
Vrestal and Kucera [108], 1445–1590 K, Knudsen method	421.95 ± 0.41
Lindscheid and Lange [109], 1938–2064 K	464.83 ± 5.35
Alcock and Kubik [110], 1835–1882 K, Knudsen method	430.03 ± 0.32
McKinley [111], 1250–1500 K, mass spectrometric method	439.32
Babeliosky [112], 1384–1601 K, mass spectrometric method	450.62 ± 5.0
Man and Nesmeyanov [113], 1320–1550 K, Knudsen method	338.38 ± 1.99
Morris et al. [114], 1816–1895 K, gas transport method	429.95 ± 0.26
Kovtum et al. [115], 1463–1628 K, Knudsen method	427.08 ± 0.56
Johnston and Marshall [116], 1307–1583 K, Langmuir method	423.91 ± 0.81
Bryce [117], 1252–1423 K, Langmuir method	421.92 ± 3.68
Jones et al. [118], 1318–1602 K, Langmuir method	410.23 ± 4.84
Recommended value	428.00 ± 2.00

2.6. Vapor Pressure Data

Application of the Third Law test to the vapor pressure measurements gave the $\Delta_{\text{sub}}H^0$(298.15 K) values listed in Table X. The recommended value was derived giving considerable weight to the measurements of Alcock and Kubik [110], Morris et al. [114], Kovtum et al. [115], and Johnstone and Marshall [116]. Additional information on vapor pressure is reported by Burtsev and Grigor'ev [120], Pulatova and Gorbatyi [121], and Karasev et al. [122].

Table XI. Recommended Vapor Pressure of Nickel,[a,b] Ni(s, l) = Ni(g)

T (K)	p (atm)	ΔG^0 ($\mathrm{J \cdot mol^{-1}}$)	ΔH^0 ($\mathrm{J \cdot mol^{-1}}$)	p (atm)	T (K)
298.15	9.27×10^{-68}	382,616	428,000	10^{-10}	1260
300	2.69×10^{-67}	382,334	427,995	10^{-9}	1336
400	1.13×10^{-48}	367,164	427,621	10^{-8}	1423
500	1.64×10^{-37}	352,111	427,075	10^{-7}	1522
600	4.42×10^{-30}	337,187	426,281	10^{-6}	1636
				10^{-5}	1771
700	8.73×10^{-25}	322,415	425,439	10^{-4}	1938
800	8.07×10^{-21}	307,739	424,860	10^{-3}	2140
900	9.70×10^{-18}	293,136	424,248	10^{-2}	2393
1000	2.80×10^{-15}	278,603	423,562	10^{-1}	2720
1100	2.86×10^{-13}	264,145	422,781	1	3160
1200	1.34×10^{-11}	249,764	421,902		
1300	3.46×10^{-10}	235,456	420,917		
1400	5.57×10^{-9}	221,231	419,824		
1500	6.15×10^{-8}	207,083	418,617		
1600	4.99×10^{-7}	193,027	417,297		
1700	3.15×10^{-6}	179,052	415,860		
1728(s)	5.07×10^{-6}	175,156	415,437		
1728(l)	5.07×10^{-6}	175,156	397,967		
1800	1.53×10^{-5}	165,900	396,562		
1900	6.16×10^{-5}	153,140	394,597		
2000	2.14×10^{-4}	140,484	392,618		
2100	6.58×10^{-4}	127,925	390,626		
2200	1.81×10^{-3}	115,461	388,623		
2400	1.06×10^{-2}	90,810	384,583		
2600	4.62×10^{-2}	66,491	380,509		
2800	0.161	42,490	376,407		
3000	0.471	18,785	372,284		
3100	0.761	7,032	370,216		
3160	1.000	0	368,974		
3200	1.191	−4,650	368,149		

$\Delta_{\mathrm{vap}} S^0(3160\ \mathrm{K}) = 116.76 \pm 0.63\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

$\Delta_{\mathrm{sub}} H^0(0\ \mathrm{K}) = 425.963 \pm 2.00\ \mathrm{kJ \cdot mol^{-1}}$

[a] atm = 101,325 Pa.

[b] ΔG^0 refers to $\Delta_{\mathrm{sub}} G^0$ when $T < T_{\mathrm{fus}}$ and $\Delta_{\mathrm{vap}} G^0$ when $T > T_{\mathrm{fus}}$ (and similarly for ΔH^0).

The values for ΔG^0, p, and ΔH^0 reported in Table XI are calculated using $\Delta_{\text{sub}}H^0$(298.15 K) and the Gibbs and the enthalpy values for Ni(s, l) and Ni(g) from Table VII.

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