# NATIONAL BUREAU OF STANDARDS REPORT

9089

SEVENTH PRELIMINARY REPORT ON A SURVEY OF
THERMODYNAMIC PROPERTIES OF THE COMPOUNDS OF THE ELEMENTS CHNOPS

PROGRESS REPORT FOR THE PERIOD 1 JANUARY TO 31 MARCH 1966

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## U. S. DEPARTMENT OF COMMERCE
## NATIONAL BUREAU OF STANDARDS

N66 24993

CR 24712

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# NATIONAL BUREAU OF STANDARDS REPORT

**NBS PROJECT**

221-11-0429

1 April 1966

**NBS REPORT**

9089

SEVENTH PRELIMINARY REPORT ON

A SURVEY OF

THERMODYNAMIC PROPERTIES OF THE COMPOUNDS OF THE ELEMENTS CHNOPS

George T. Furukawa, Mary K. Buresh, Martin L. Reilly
George T. Armstrong and Gerald D. Mitchell

Heat Division, Institute for Basic Standards

Progress Report for the Period 1 January to 31 March 1966

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract No. R-138, Amendment-1

**U. S. DEPARTMENT OF COMMERCE**

**NATIONAL BUREAU OF STANDARDS**

Table of Contents

A study at the National Bureau of Standards (NBS), of which this is the seventh progress report, has been undertaken to meet the need of the National Aeronautics and Space Administration (NASA) for thermodynamic information on biologically related materials important to the space program for several reasons. Among these reasons are the necessity of inferring the maximum amount of useful chemistry of incompletely accessible environments, for which only limited information is available, the possiblity of the occurrence of organic compounds naturally synthesized under primitive conditions, and the possibility of theoretically recovering part of the pre-biological history of the earth.

This program is being carried out under the technical supervision of Dr. George Jacobs of NASA, and with the consultation of Dr. Harold Morowitz of the Yale University, Department of Molecular Biology and Biophysics, and Dr. C. W. Beckett of the Heat Division, Institute for Basic Standards (NBS). The contract (Contract No. R-138) was initiated 1 May 1964 and extended 29 April 1965. The program was extended by Amendment 1 for an additional year, beginning 1 July 1965. This report covers the third quarter of the extended contract.

George T. Armstrong
Supervisory Chemist
Project Leader

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# 1. Survey and Analysis of Heat-Capacity Data of Some CHNOPS Compounds

George T. Furukawa and Martin L. Reilly

The survey and analysis of heat-capacity data of CHNOPS compounds have been in progress and have been devoted particularly to some important organic compounds. Efforts were made to develop a method for extrapolating to 0°K the heat-capacity data on a number of poly-hydroxy compounds which terminate at about 80°K. To date a satisfactory procedure has not been devised. Once a method is found, thermodynamic functions on about eight polyhydroxy substances should be obtained.

The analysis of the heat capacity data of $l$-serine, $l$-methionine, furan, and urea had been completed and tables of thermodynamic properties calculated. These tables are given in Chapter 2.

In the following sections of this chapter are described the sources of data used to obtain the thermodynamic properties. At the beginning of the descriptive text on each compound are given: compound name, structural formula, and molecular weight. The temperature range of the available experimental data is given within the parentheses following the author's names in the descriptive text. The data were analyzed on the IBM 7094 computer. The molal values were calculated using the 1961 atomic weights based on carbon-12. The energy unit, one calorie, is equal to 4.1840 joules.

## 2. Tables of Thermodynamic Functions

### 2.1 $l$-Serine, $HOCH_2CH(NH_2)COOH$, 105.09414

Hutchens, Cole, and Stout (11-302°K) [6] reported heat-capacity measurements on $l$-serine. The thermodynamic properties given in table 18 are based on the data obtained by Hutchens, et al. No heat of combustion measurements have apparently been available at the time (1964). Hutchens et al estimated from structural factors $\Delta H_f^\circ(298°K) = -173.60$ kcal mol$^{-1}$ and calculated $\Delta G_f^\circ(298°K) = -121.6$ kcal mol$^{-1}$. The value of entropy obtained in table 18 for $l$-serine yields the same result for $\Delta G_f^\circ(298°K)$.

### 2.2 $l$-Methionine, $CH_3SCH_2CH_2CH(NH_2)COOH$, 149.21292

Hutchens, Cole, and Stout (11-348°K) [5] determined the heat capacity of $l$-methionine. A transition is shown that extends approximately from 180°K to 350°K with the heat capacity maximum at 305.5°K. Hutchens, et al. estimated the entropy of this transition to be 4.2 cal deg$^{-1}$ mol$^{-1}$ ($\sim R \ln 8$). Table 19 is based on the data reported by Hutchens, et al.

## 2.3 Furan, CHCHCHCHO, 68.07588

Heat-capacity measurements on furan were reported by Guthrie, et al. (12-300°K) [3]. The measurements shown a $\lambda$-point at 56°K, a first-order solid-phase transition at 150°K, and a melting point at 187.55°K. The thermodynamic properties given in table 20 are based on the data obtained by Guthrie, et al. The same authors determined $\Delta H_f^o(298°K)(\ell) = -14.90$ kcal mol$^{-1}$ and $\Delta H_f^o(298°K)(g) = -8.29$ kcal mol$^{-1}$ from heats of combustion measurements. From statistical thermodynamic calculations, based on rigid-rotator, harmonic-oscillator approximation, and the calorimetric data Guthrie, et al. obtained $\Delta H_f^o$ and $\Delta G_f^o$ for gaseous furan up to 1500°K. The following are some of the values that were reported:

| T °K | $-\Delta H_f^o$ kcal/mol | $\Delta G_f^o$ kcal/mol |
|---|---|---|
| 298 | 8.293 | 0.208 |
| 400 | 9.191 | 3.258 |
| 500 | 9.872 | 6.452 |
| 800 | 11.13 | 16.61 |

In a more recent paper, Blinc and Pahor [1] described statistical thermodynamic calculations based on new molecular data. Values of $C_p^o$ are shown to be slightly lower than those obtained by Guthrie, et al.

## 2.4 Urea, NH$_2$CONH$_2$, 60.05583

Measurements of the heat capacity of urea have been reported by the following:

a. Gibson, Latimer, and Parks (86-300°K) [2]
b. Parks, Huffman, and Barmore (93-298°K) [7]
c. Ruehrwein and Huffman (19-318°K) [8]

The more extensive data of Ruehrwein and Huffman were analyzed to obtain the thermodynamic properties given in table 21. Using Huffman's [4] heat of combustion data, Ruehrwein and Huffman obtained $\Delta H_f^o(298°K) = -79.634$ kcal mol$^{-1}$ and $\Delta G_f^o(298°K) = -47.118$ kcal mol$^{-1}$. The $S^o(298°K)$ of table 21 and appropriate recent thermodynamic data yield essentially the same $\Delta G_f^o(298°K)$ as obtained by Ruehrwein and Huffman. The National Bureau of Standards Technical Note 270-1 [9] gives $\Delta H_f^o(298°K) = -79.56$ and $\Delta G_f^o(298°K) = -47.04$ kcal mol$^{-1}$.

# References

[1] Blinc, R. and Pahor, J., Some thermodynamic functions of gaseous furan, thiophene and pyrrol, calculated from spectroscopic data and molecular structure, "J. Stefan" Inst. Rep. (Ljubljana) 4, 123-31 (1957).

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[3] Guthrie, G. B., Jr., Scott, D. W., Hubbard, W. N., Katz, C., McCullough, J. P., Gross, M. E., Williamson, K. D. and Waddington, G., Thermodynamic properties of furan, J. Am. Chem. Soc. 74, 4662-4669 (1952).

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[8] Ruehrwein, R. A. and Huffman, H. M., Thermal data. XIX. The heat capacity, entropy and free energy of urea, J. Am. Chem. Soc. 68, 1759-1761 (1946).

[9] Wagman, D. D., Evans, W. H., Halow, I., Parker, V. B., Bailey, S.M., and Schumm, R. H., Selected Values of Chemical Thermodynamic Properties, Tech. Note 270-1, National Bureau of Standards, October 1, 1965.

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## TABLE 18

### MOLAL THERMODYNAMIC FUNCTIONS FOR L-SERINE
### $HOCH_2CH(NH_2)COOH$
### SOLID PHASE

GRAM MOLECULAR WT. = 105.09414 GRAMS      CAL = 4.1840 ABS J

$T$ DEG K = 273.15 + $T$ DEG C

| $T$ | $C_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| DEG K | CAL/DEG | CAL | CAL/DEG | CAL/DEG | CAL | CAL/DEG |
| 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5.00 | 0.024 | 0.030 | 0.006 | 0.008 | 0.010 | 0.002 |
| 10.00 | 0.195 | 0.487 | 0.049 | 0.065 | 0.162 | 0.016 |
| 15.00 | 0.646 | 2.456 | 0.164 | 0.218 | 0.821 | 0.055 |
| 20.00 | 1.328 | 7.332 | 0.367 | 0.494 | 2.554 | 0.128 |
| 25.00 | 2.166 | 16.013 | 0.641 | 0.878 | 5.943 | 0.238 |
| 30.00 | 3.112 | 29.174 | 0.972 | 1.356 | 11.492 | 0.383 |
| 35.00 | 4.115 | 47.226 | 1.349 | 1.910 | 19.628 | 0.561 |
| 40.00 | 5.126 | 70.330 | 1.758 | 2.526 | 30.694 | 0.767 |
| 45.00 | 6.126 | 98.469 | 2.188 | 3.187 | 44.960 | 0.999 |
| 50.00 | 7.098 | 131.54 | 2.631 | 3.883 | 62.625 | 1.252 |
| 55.00 | 8.025 | 169.37 | 3.079 | 4.604 | 83.834 | 1.524 |
| 60.00 | 8.916 | 211.74 | 3.529 | 5.341 | 108.69 | 1.811 |
| 65.00 | 9.760 | 258.45 | 3.976 | 6.088 | 137.26 | 2.112 |
| 70.00 | 10.552 | 309.25 | 4.418 | 6.840 | 169.58 | 2.423 |
| 75.00 | 11.306 | 363.91 | 4.852 | 7.594 | 205.66 | 2.742 |
| 80.00 | 12.033 | 422.27 | 5.278 | 8.347 | 245.52 | 3.069 |
| 85.00 | 12.723 | 484.17 | 5.696 | 9.098 | 289.13 | 3.402 |
| 90.00 | 13.371 | 549.42 | 6.105 | 9.844 | 336.49 | 3.739 |
| 95.00 | 13.990 | 617.84 | 6.504 | 10.583 | 387.56 | 4.080 |
| 100.00 | 14.588 | 689.29 | 6.893 | 11.316 | 442.31 | 4.423 |
| 105.00 | 15.166 | 763.69 | 7.273 | 12.042 | 500.71 | 4.769 |
| 110.00 | 15.719 | 840.91 | 7.645 | 12.760 | 562.71 | 5.116 |
| 115.00 | 16.246 | 920.83 | 8.007 | 13.471 | 628.30 | 5.463 |
| 120.00 | 16.756 | 1003.3 | 8.361 | 14.173 | 697.41 | 5.812 |
| 125.00 | 17.259 | 1088.4 | 8.707 | 14.867 | 770.01 | 6.160 |
| 130.00 | 17.759 | 1175.9 | 9.046 | 15.554 | 846.07 | 6.508 |
| 135.00 | 18.255 | 1266.0 | 9.378 | 16.233 | 925.54 | 6.856 |
| 140.00 | 18.742 | 1358.5 | 9.703 | 16.906 | 1008.4 | 7.203 |
| 145.00 | 19.217 | 1453.4 | 10.023 | 17.572 | 1094.6 | 7.549 |
| 150.00 | 19.678 | 1550.6 | 10.337 | 18.231 | 1184.1 | 7.894 |
| 155.00 | 20.128 | 1650.1 | 10.646 | 18.884 | 1276.9 | 8.238 |
| 160.00 | 20.571 | 1751.9 | 10.949 | 19.530 | 1372.9 | 8.581 |
| 165.00 | 21.010 | 1855.8 | 11.248 | 20.170 | 1472.2 | 8.922 |
| 170.00 | 21.450 | 1962.0 | 11.541 | 20.804 | 1574.6 | 9.262 |
| 175.00 | 21.894 | 2070.4 | 11.831 | 21.432 | 1680.2 | 9.601 |
| 180.00 | 22.343 | 2180.9 | 12.116 | 22.055 | 1788.9 | 9.938 |
| 185.00 | 22.798 | 2293.8 | 12.399 | 22.673 | 1900.8 | 10.274 |
| 190.00 | 23.254 | 2408.9 | 12.679 | 23.287 | 2015.7 | 10.609 |
| 195.00 | 23.708 | 2526.3 | 12.956 | 23.897 | 2133.6 | 10.942 |
| 200.00 | 24.155 | 2646.0 | 13.230 | 24.503 | 2254.6 | 11.273 |
| 205.00 | 24.589 | 2767.9 | 13.502 | 25.105 | 2378.6 | 11.603 |
| 210.00 | 25.011 | 2891.9 | 13.771 | 25.703 | 2505.7 | 11.932 |
| 215.00 | 25.421 | 3018.0 | 14.037 | 26.296 | 2635.7 | 12.259 |
| 220.00 | 25.824 | 3146.1 | 14.300 | 26.885 | 2768.6 | 12.585 |
| 225.00 | 26.222 | 3276.2 | 14.561 | 27.470 | 2904.5 | 12.909 |
| 230.00 | 26.622 | 3408.3 | 14.819 | 28.050 | 3043.3 | 13.232 |
| 235.00 | 27.024 | 3542.4 | 15.074 | 28.627 | 3185.0 | 13.553 |
| 240.00 | 27.432 | 3678.5 | 15.327 | 29.200 | 3329.6 | 13.873 |
| 245.00 | 27.845 | 3816.7 | 15.578 | 29.770 | 3477.0 | 14.192 |
| 250.00 | 28.263 | 3957.0 | 15.828 | 30.337 | 3627.3 | 14.509 |
| 255.00 | 28.684 | 4099.4 | 16.076 | 30.901 | 3780.4 | 14.825 |
| 260.00 | 29.108 | 4243.8 | 16.322 | 31.462 | 3936.3 | 15.140 |
| 265.00 | 29.535 | 4390.5 | 16.568 | 32.021 | 4095.0 | 15.453 |
| 270.00 | 29.962 | 4539.2 | 16.812 | 32.577 | 4256.5 | 15.765 |
| 273.15 | 30.233 | 4634.0 | 16.965 | 32.926 | 4359.6 | 15.961 |
| 275.00 | 30.392 | 4690.1 | 17.055 | 33.130 | 4420.7 | 16.075 |
| 280.00 | 30.822 | 4843.1 | 17.297 | 33.682 | 4587.8 | 16.385 |
| 285.00 | 31.255 | 4998.3 | 17.538 | 34.231 | 4757.6 | 16.693 |
| 290.00 | 31.689 | 5155.7 | 17.778 | 34.778 | 4930.1 | 17.000 |
| 295.00 | 32.124 | 5315.2 | 18.018 | 35.324 | 5105.3 | 17.306 |
| 298.15 | 32.400 | 5416.8 | 18.168 | 35.667 | 5217.1 | 17.498 |
| 300.00 | 32.562 | 5476.9 | 18.256 | 35.867 | 5283.3 | 17.611 |
| 310.00 | 33.440 | 5806.9 | 18.732 | 36.949 | 5647.4 | 18.217 |

$H_0^C$ IS THE ENTHALPY OF THE SOLID AT 0 DEG AND 1 ATM PRESSURE.

## TABLE 19

### MOLAL THERMODYNAMIC FUNCTIONS FOR L-METHIONINE
### $CH_3SCH_2CH_2CH(NH_2)COOH$
### SOLID PHASE

GRAM MOLECULAR WT.= 149.21292 GRAMS                    CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

| T | $C_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| DEG K | CAL/DEG | CAL | CAL/DEG | CAL/DEG | CAL | CAL/DEG |
| 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5.00 | 0.062 | 0.077 | 0.015 | 0.021 | 0.026 | 0.005 |
| 10.00 | 0.481 | 1.225 | 0.122 | 0.164 | 0.411 | 0.041 |
| 15.00 | 1.409 | 5.744 | 0.383 | 0.518 | 2.019 | 0.135 |
| 20.00 | 2.746 | 16.022 | 0.801 | 1.100 | 5.971 | 0.299 |
| 25.00 | 4.251 | 33.477 | 1.339 | 1.872 | 13.333 | 0.533 |
| 30.00 | 5.794 | 58.581 | 1.953 | 2.784 | 24.925 | 0.831 |
| 35.00 | 7.328 | 91.430 | 2.612 | 3.793 | 41.333 | 1.181 |
| 40.00 | 8.771 | 131.72 | 3.293 | 4.867 | 62.963 | 1.574 |
| 45.00 | 10.143 | 179.03 | 3.978 | 5.980 | 90.068 | 2.002 |
| 50.00 | 11.445 | 233.03 | 4.661 | 7.117 | 122.80 | 2.456 |
| 55.00 | 12.666 | 293.34 | 5.333 | 8.265 | 161.25 | 2.932 |
| 60.00 | 13.838 | 359.62 | 5.994 | 9.418 | 205.46 | 3.424 |
| 65.00 | 14.960 | 431.64 | 6.641 | 10.570 | 255.43 | 3.930 |
| 70.00 | 16.003 | 509.08 | 7.273 | 11.718 | 311.16 | 4.445 |
| 75.00 | 16.971 | 591.52 | 7.887 | 12.855 | 372.59 | 4.968 |
| 80.00 | 17.968 | 678.87 | 8.486 | 13.982 | 439.69 | 5.496 |
| 85.00 | 18.926 | 771.14 | 9.072 | 15.101 | 512.40 | 6.028 |
| 90.00 | 19.785 | 867.95 | 9.644 | 16.207 | 590.68 | 6.563 |
| 95.00 | 20.602 | 968.93 | 10.199 | 17.299 | 674.45 | 7.099 |
| 100.00 | 21.391 | 1073.9 | 10.739 | 18.376 | 763.64 | 7.636 |
| 105.00 | 22.160 | 1182.8 | 11.265 | 19.438 | 858.18 | 8.173 |
| 110.00 | 22.921 | 1295.5 | 11.777 | 20.487 | 957.99 | 8.709 |
| 115.00 | 23.657 | 1412.0 | 12.278 | 21.522 | 1063.0 | 9.244 |
| 120.00 | 24.361 | 1532.0 | 12.767 | 22.544 | 1173.2 | 9.777 |
| 125.00 | 25.048 | 1655.6 | 13.244 | 23.552 | 1288.4 | 10.307 |
| 130.00 | 25.732 | 1782.5 | 13.712 | 24.548 | 1408.7 | 10.836 |
| 135.00 | 26.408 | 1912.9 | 14.169 | 25.532 | 1533.9 | 11.362 |
| 140.00 | 27.067 | 2046.6 | 14.618 | 26.504 | 1664.0 | 11.886 |
| 145.00 | 27.715 | 2183.5 | 15.059 | 27.465 | 1798.9 | 12.406 |
| 150.00 | 28.359 | 2323.7 | 15.491 | 28.416 | 1938.6 | 12.924 |
| 155.00 | 29.000 | 2467.1 | 15.917 | 29.356 | 2083.1 | 13.439 |
| 160.00 | 29.633 | 2613.7 | 16.336 | 30.287 | 2232.2 | 13.951 |
| 165.00 | 30.258 | 2763.4 | 16.748 | 31.208 | 2385.9 | 14.460 |
| 170.00 | 30.881 | 2916.3 | 17.155 | 32.121 | 2544.2 | 14.966 |
| 175.00 | 31.506 | 3072.2 | 17.556 | 33.025 | 2707.1 | 15.469 |
| 180.00 | 32.131 | 3231.3 | 17.952 | 33.921 | 2874.5 | 15.969 |
| 185.00 | 32.757 | 3393.5 | 18.343 | 34.810 | 3046.3 | 16.466 |
| 190.00 | 33.387 | 3558.9 | 18.731 | 35.692 | 3222.5 | 16.961 |
| 195.00 | 34.030 | 3727.4 | 19.115 | 36.567 | 3403.2 | 17.452 |
| 200.00 | 34.699 | 3899.2 | 19.496 | 37.437 | 3588.2 | 17.941 |
| 205.00 | 35.388 | 4074.4 | 19.875 | 38.302 | 3777.5 | 18.427 |
| 210.00 | 36.097 | 4253.1 | 20.253 | 39.163 | 3971.2 | 18.910 |
| 215.00 | 36.831 | 4435.4 | 20.630 | 40.021 | 4169.2 | 19.391 |
| 220.00 | 37.592 | 4621.5 | 21.007 | 40.877 | 4371.4 | 19.870 |
| 225.00 | 38.387 | 4811.4 | 21.384 | 41.730 | 4577.9 | 20.346 |
| 230.00 | 39.223 | 5005.4 | 21.763 | 42.583 | 4788.7 | 20.820 |
| 235.00 | 40.111 | 5203.7 | 22.144 | 43.436 | 5003.8 | 21.293 |
| 240.00 | 41.065 | 5406.6 | 22.528 | 44.290 | 5223.1 | 21.763 |
| 245.00 | 42.107 | 5614.5 | 22.916 | 45.148 | 5446.7 | 22.231 |
| 250.00 | 43.263 | 5827.9 | 23.312 | 46.010 | 5674.6 | 22.698 |
| 255.00 | 44.566 | 6047.4 | 23.715 | 46.879 | 5906.8 | 23.164 |
| 260.00 | 46.055 | 6273.9 | 24.130 | 47.759 | 6143.4 | 23.628 |
| 265.00 | 47.777 | 6508.3 | 24.560 | 48.652 | 6384.4 | 24.092 |
| 270.00 | 49.785 | 6752.1 | 25.008 | 49.563 | 6629.9 | 24.555 |
| 273.15 | 51.223 | 6911.2 | 25.302 | 50.149 | 6786.9 | 24.847 |
| 275.00 | 52.137 | 7006.8 | 25.479 | 50.497 | 6880.0 | 25.018 |
| 280.00 | 54.894 | 7274.2 | 25.979 | 51.461 | 7134.6 | 25.482 |
| 285.00 | 58.123 | 7556.5 | 26.514 | 52.460 | 7394.7 | 25.946 |
| 290.00 | 61.890 | 7856.3 | 27.091 | 53.503 | 7659.6 | 26.412 |
| 295.00 | 66.263 | 8176.4 | 27.717 | 54.597 | 7929.8 | 26.881 |
| 298.15 | 69.360 | 8389.9 | 28.140 | 55.317 | 8102.9 | 27.177 |
| 300.00 | 71.310 | 8520.0 | 28.400 | 55.752 | 8205.7 | 27.352 |
| 305.00 | 77.098 | 8890.7 | 29.150 | 56.978 | 8487.5 | 27.828 |
| 305.50 | 77.721 | 8929.4 | 29.229 | 57.105 | 8516.0 | 27.876 |
| 310.00 | 70.117 | 9261.4 | 29.875 | 58.183 | 8775.5 | 28.308 |
| 315.00 | 63.800 | 9595.3 | 30.461 | 59.252 | 9069.1 | 28.791 |
| 320.00 | 59.387 | 9902.5 | 30.945 | 60.220 | 9367.8 | 29.274 |
| 325.00 | 56.525 | 10192. | 31.359 | 61.117 | 9671.2 | 29.757 |
| 330.00 | 54.864 | 10470. | 31.727 | 61.966 | 9978.9 | 30.239 |
| 335.00 | 54.051 | 10742. | 32.065 | 62.784 | 10291. | 30.719 |
| 340.00 | 53.736 | 11011. | 32.386 | 63.582 | 10607. | 31.196 |
| 345.00 | 53.566 | 11279. | 32.694 | 64.365 | 10927. | 31.671 |
| 350.00 | 53.191 | 11546. | 32.990 | 65.134 | 11250. | 32.144 |

$H_0^C$ IS THE ENTHALPY OF THE SOLID AT 0 DEG AND 1 ATM PRESSURE.

# TABLE 20

## MOLAL THERMODYNAMIC FUNCTIONS FOR FURAN
### CHCHCHCHCHO
### SOLID AND LIQUID PHASES

GRAM MOLECULAR WT.= 68.07588 GRAMS                     CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

| T | $c_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| DEG K | CAL/DEG | CAL | CAL/DEG | CAL/DEG | CAL | CAL/DEG |

### SOLID PHASE I

| T | $c_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5.00 | 0.078 | 0.097 | 0.019 | 0.026 | 0.032 | 0.006 |
| 10.00 | 0.597 | 1.532 | 0.153 | 0.205 | 0.517 | 0.052 |
| 15.00 | 1.636 | 6.980 | 0.465 | 0.632 | 2.506 | 0.167 |
| 20.00 | 2.807 | 18.082 | 0.904 | 1.263 | 7.180 | 0.359 |
| 25.00 | 3.965 | 35.034 | 1.401 | 2.015 | 15.336 | 0.613 |
| 30.00 | 5.040 | 57.589 | 1.920 | 2.834 | 27.440 | 0.915 |
| 35.00 | 6.032 | 85.308 | 2.437 | 3.687 | 43.733 | 1.250 |
| 40.00 | 6.913 | 117.72 | 2.943 | 4.551 | 64.328 | 1.608 |
| 45.00 | 7.675 | 154.23 | 3.427 | 5.411 | 89.237 | 1.983 |
| 50.00 | 8.336 | 194.30 | 3.886 | 6.253 | 118.35 | 2.367 |
| 55.00 | 8.922 | 237.46 | 4.317 | 7.076 | 151.72 | 2.759 |
| 57.50 | 9.204 | 260.12 | 4.524 | 7.479 | 169.92 | 2.955 |

### LAMBDA TRANSITION

| T | $c_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| 57.50 | 9.084 | 260.12 | 4.524 | 7.479 | 169.92 | 2.955 |
| 60.00 | 9.302 | 283.11 | 4.718 | 7.870 | 189.11 | 3.152 |
| 65.00 | 9.699 | 330.63 | 5.087 | 8.631 | 230.38 | 3.544 |
| 70.00 | 10.056 | 380.03 | 5.429 | 9.363 | 275.37 | 3.934 |
| 75.00 | 10.386 | 431.15 | 5.749 | 10.068 | 323.96 | 4.319 |
| 80.00 | 10.689 | 483.85 | 6.048 | 10.748 | 376.01 | 4.700 |
| 85.00 | 10.953 | 537.99 | 6.329 | 11.405 | 431.40 | 5.075 |
| 90.00 | 11.207 | 593.43 | 6.594 | 12.038 | 490.02 | 5.445 |
| 95.00 | 11.430 | 650.02 | 6.842 | 12.650 | 551.75 | 5.808 |
| 100.00 | 11.643 | 707.71 | 7.077 | 13.242 | 616.49 | 6.165 |
| 105.00 | 11.857 | 766.46 | 7.300 | 13.815 | 684.14 | 6.516 |
| 110.00 | 12.078 | 826.29 | 7.512 | 14.372 | 754.61 | 6.860 |
| 115.00 | 12.311 | 887.26 | 7.715 | 14.914 | 827.83 | 7.199 |
| 120.00 | 12.553 | 949.42 | 7.912 | 15.443 | 903.73 | 7.531 |
| 125.00 | 12.803 | 1012.8 | 8.102 | 15.960 | 982.24 | 7.858 |
| 130.00 | 13.058 | 1077.5 | 8.288 | 16.467 | 1063.3 | 8.179 |
| 135.00 | 13.314 | 1143.4 | 8.470 | 16.965 | 1146.9 | 8.496 |
| 140.00 | 13.570 | 1210.6 | 8.647 | 17.454 | 1233.0 | 8.807 |
| 145.00 | 13.822 | 1279.1 | 8.821 | 17.935 | 1321.4 | 9.113 |
| 150.00 | 14.070 | 1348.8 | 8.992 | 18.407 | 1412.3 | 9.415 |

### SOLID PHASE II

| T | $c_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| 150.00 | 17.028 | 1838.0 | 12.253 | 21.669 | 1412.3 | 9.415 |
| 155.00 | 17.290 | 1923.8 | 12.412 | 22.231 | 1522.0 | 9.820 |
| 160.00 | 17.572 | 2010.9 | 12.568 | 22.785 | 1634.6 | 10.216 |
| 165.00 | 17.881 | 2099.6 | 12.725 | 23.330 | 1749.9 | 10.605 |
| 170.00 | 18.230 | 2189.8 | 12.881 | 23.869 | 1867.9 | 10.987 |
| 175.00 | 18.627 | 2281.9 | 13.040 | 24.403 | 1988.5 | 11.363 |
| 180.00 | 19.085 | 2376.2 | 13.201 | 24.934 | 2111.9 | 11.733 |
| 185.00 | 19.614 | 2472.9 | 13.367 | 25.464 | 2237.9 | 12.097 |
| 187.55 | 19.916 | 2523.3 | 13.454 | 25.734 | 2303.2 | 12.280 |

### LIQUID PHASE

| T | $c_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| 187.55 | 23.816 | 3432.1 | 18.300 | 30.580 | 2303.2 | 12.280 |
| 190.00 | 23.843 | 3490.5 | 18.371 | 30.889 | 2378.5 | 12.518 |
| 195.00 | 23.907 | 3609.9 | 18.512 | 31.509 | 2534.5 | 12.997 |
| 200.00 | 23.982 | 3729.6 | 18.648 | 32.116 | 2693.5 | 13.468 |
| 205.00 | 24.067 | 3849.7 | 18.779 | 32.709 | 2855.6 | 13.930 |
| 210.00 | 24.162 | 3970.3 | 18.906 | 33.290 | 3020.6 | 14.384 |
| 215.00 | 24.269 | 4091.3 | 19.029 | 33.860 | 3188.5 | 14.830 |
| 220.00 | 24.386 | 4213.0 | 19.150 | 34.419 | 3359.2 | 15.269 |
| 225.00 | 24.514 | 4335.2 | 19.268 | 34.968 | 3532.6 | 15.701 |
| 230.00 | 24.652 | 4458.1 | 19.383 | 35.509 | 3708.8 | 16.125 |
| 235.00 | 24.800 | 4581.7 | 19.497 | 36.040 | 3887.7 | 16.543 |
| 240.00 | 24.959 | 4706.1 | 19.609 | 36.564 | 4069.2 | 16.955 |
| 245.00 | 25.127 | 4831.3 | 19.720 | 37.080 | 4253.3 | 17.361 |
| 250.00 | 25.304 | 4957.4 | 19.830 | 37.590 | 4440.0 | 17.760 |
| 255.00 | 25.490 | 5084.4 | 19.939 | 38.093 | 4629.2 | 18.154 |
| 260.00 | 25.685 | 5212.3 | 20.047 | 38.590 | 4820.9 | 18.542 |
| 265.00 | 25.888 | 5341.3 | 20.156 | 39.081 | 5015.1 | 18.925 |
| 270.00 | 26.098 | 5471.2 | 20.264 | 39.567 | 5211.7 | 19.303 |
| 273.15 | 26.234 | 5553.7 | 20.332 | 39.870 | 5336.8 | 19.538 |
| 275.00 | 26.315 | 5602.3 | 20.372 | 40.047 | 5410.8 | 19.676 |
| 280.00 | 26.538 | 5734.4 | 20.480 | 40.524 | 5612.2 | 20.044 |
| 285.00 | 26.767 | 5867.6 | 20.588 | 40.995 | 5816.0 | 20.407 |
| 290.00 | 27.000 | 6002.1 | 20.697 | 41.463 | 6022.1 | 20.766 |
| 295.00 | 27.237 | 6137.7 | 20.806 | 41.926 | 6230.6 | 21.121 |
| 298.15 | 27.388 | 6223.7 | 20.874 | 42.216 | 6363.1 | 21.342 |
| 300.00 | 27.478 | 6274.4 | 20.915 | 42.386 | 6441.4 | 21.471 |

$H_0^C$ IS THE ENTHALPY OF THE SOLID AT 0 DEG AND 1 ATM PRESSURE.

# TABLE 21

## MOLAL THERMODYNAMIC FUNCTIONS FOR UREA
### $NH_2CONH_2$
### SOLID PHASE

GRAM MOLECULAR WT.= 60.05583 GRAMS                    CAL=4.1840 ABS J

T DEG K = 273.15 + T DEG C

| T | $C_P^C$ | $(H_T^0-H_0^C)$ | $(H_T^0-H_0^C)/T$ | $S_T^0$ | $-(G_T^0-H_0^C)$ | $-(G_T^0-H_0^C)/T$ |
|---|---|---|---|---|---|---|
| DEG K | CAL/DEG | CAL | CAL/DEG | CAL/DEG | CAL | CAL/DEG |
| 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5.00 | 0.021 | 0.026 | 0.005 | 0.007 | 0.009 | 0.002 |
| 10.00 | 0.169 | 0.423 | 0.042 | 0.056 | 0.141 | 0.014 |
| 15.00 | 0.557 | 2.122 | 0.141 | 0.189 | 0.712 | 0.047 |
| 20.00 | 1.212 | 6.453 | 0.323 | 0.434 | 2.219 | 0.111 |
| 25.00 | 1.988 | 14.430 | 0.577 | 0.786 | 5.230 | 0.209 |
| 30.00 | 2.789 | 26.363 | 0.879 | 1.219 | 10.216 | 0.341 |
| 35.00 | 3.580 | 42.300 | 1.209 | 1.709 | 17.518 | 0.501 |
| 40.00 | 4.319 | 62.067 | 1.552 | 2.236 | 27.368 | 0.684 |
| 45.00 | 5.015 | 85.423 | 1.898 | 2.785 | 39.914 | 0.887 |
| 50.00 | 5.653 | 112.12 | 2.242 | 3.347 | 55.242 | 1.105 |
| 55.00 | 6.237 | 141.86 | 2.579 | 3.914 | 73.394 | 1.334 |
| 60.00 | 6.787 | 174.44 | 2.907 | 4.480 | 94.380 | 1.573 |
| 65.00 | 7.284 | 209.64 | 3.225 | 5.044 | 118.19 | 1.818 |
| 70.00 | 7.726 | 247.18 | 3.531 | 5.600 | 144.80 | 2.069 |
| 75.00 | 8.137 | 286.85 | 3.825 | 6.147 | 174.18 | 2.322 |
| 80.00 | 8.537 | 328.54 | 4.107 | 6.685 | 206.26 | 2.578 |
| 85.00 | 8.911 | 372.17 | 4.378 | 7.214 | 241.01 | 2.835 |
| 90.00 | 9.256 | 417.60 | 4.640 | 7.733 | 278.38 | 3.093 |
| 95.00 | 9.573 | 464.68 | 4.891 | 8.242 | 318.33 | 3.351 |
| 100.00 | 9.870 | 513.30 | 5.133 | 8.741 | 360.79 | 3.608 |
| 105.00 | 10.165 | 563.38 | 5.366 | 9.230 | 405.72 | 3.864 |
| 110.00 | 10.463 | 614.95 | 5.590 | 9.709 | 453.07 | 4.119 |
| 115.00 | 10.765 | 668.02 | 5.809 | 10.181 | 502.80 | 4.372 |
| 120.00 | 11.068 | 722.61 | 6.022 | 10.646 | 554.87 | 4.624 |
| 125.00 | 11.369 | 778.70 | 6.230 | 11.104 | 609.25 | 4.874 |
| 130.00 | 11.670 | 836.29 | 6.433 | 11.555 | 665.90 | 5.122 |
| 135.00 | 11.973 | 895.40 | 6.633 | 12.001 | 724.79 | 5.369 |
| 140.00 | 12.277 | 956.02 | 6.829 | 12.442 | 785.90 | 5.614 |
| 145.00 | 12.581 | 1018.2 | 7.022 | 12.879 | 849.21 | 5.857 |
| 150.00 | 12.886 | 1081.8 | 7.212 | 13.310 | 914.68 | 6.098 |
| 155.00 | 13.194 | 1147.0 | 7.400 | 13.738 | 982.30 | 6.337 |
| 160.00 | 13.505 | 1213.8 | 7.586 | 14.161 | 1052.1 | 6.575 |
| 165.00 | 13.818 | 1282.1 | 7.770 | 14.582 | 1123.9 | 6.812 |
| 170.00 | 14.132 | 1352.0 | 7.953 | 14.999 | 1197.9 | 7.046 |
| 175.00 | 14.446 | 1423.4 | 8.134 | 15.413 | 1273.9 | 7.279 |
| 180.00 | 14.761 | 1496.4 | 8.313 | 15.825 | 1352.0 | 7.511 |
| 185.00 | 15.076 | 1571.0 | 8.492 | 16.233 | 1432.1 | 7.741 |
| 190.00 | 15.391 | 1647.2 | 8.669 | 16.640 | 1514.3 | 7.970 |
| 195.00 | 15.705 | 1724.9 | 8.846 | 17.043 | 1598.5 | 8.198 |
| 200.00 | 16.019 | 1804.2 | 9.021 | 17.445 | 1684.7 | 8.424 |
| 205.00 | 16.332 | 1885.1 | 9.196 | 17.844 | 1773.0 | 8.649 |
| 210.00 | 16.643 | 1967.6 | 9.369 | 18.242 | 1863.2 | 8.872 |
| 215.00 | 16.952 | 2051.5 | 9.542 | 18.637 | 1955.4 | 9.095 |
| 220.00 | 17.258 | 2137.1 | 9.714 | 19.030 | 2049.6 | 9.316 |
| 225.00 | 17.564 | 2224.1 | 9.885 | 19.421 | 2145.7 | 9.536 |
| 230.00 | 17.871 | 2312.7 | 10.055 | 19.811 | 2243.8 | 9.756 |
| 235.00 | 18.181 | 2402.8 | 10.225 | 20.198 | 2343.8 | 9.974 |
| 240.00 | 18.496 | 2494.5 | 10.394 | 20.585 | 2445.7 | 10.191 |
| 245.00 | 18.814 | 2587.8 | 10.562 | 20.969 | 2549.6 | 10.407 |
| 250.00 | 19.136 | 2682.7 | 10.731 | 21.353 | 2655.4 | 10.622 |
| 255.00 | 19.460 | 2779.2 | 10.899 | 21.735 | 2763.2 | 10.836 |
| 260.00 | 19.785 | 2877.3 | 11.066 | 22.116 | 2872.8 | 11.049 |
| 265.00 | 20.109 | 2977.0 | 11.234 | 22.496 | 2984.3 | 11.262 |
| 270.00 | 20.433 | 3078.4 | 11.401 | 22.875 | 3097.7 | 11.473 |
| 273.15 | 20.637 | 3143.1 | 11.507 | 23.113 | 3170.2 | 11.606 |
| 275.00 | 20.757 | 3181.4 | 11.569 | 23.252 | 3213.1 | 11.684 |
| 280.00 | 21.080 | 3285.9 | 11.736 | 23.629 | 3330.3 | 11.894 |
| 285.00 | 21.403 | 3392.2 | 11.902 | 24.005 | 3449.3 | 12.103 |
| 290.00 | 21.727 | 3500.0 | 12.069 | 24.380 | 3570.3 | 12.311 |
| 295.00 | 22.052 | 3609.4 | 12.235 | 24.755 | 3693.1 | 12.519 |
| 298.15 | 22.256 | 3679.2 | 12.340 | 24.990 | 3771.5 | 12.650 |
| 300.00 | 22.377 | 3720.5 | 12.402 | 25.128 | 3817.9 | 12.726 |
| 310.00 | 23.027 | 3947.5 | 12.734 | 25.872 | 4072.9 | 13.138 |
| 320.00 | 23.674 | 4181.0 | 13.066 | 26.613 | 4335.3 | 13.548 |

$H_0^C$ IS THE ENTHALPY OF THE SOLID AT 0 DEG AND 1 ATM PRESSURE.

### 3. Survey of Heats and Free Energies of Formation

In the review of heats and free energies of formation, primary attention was devoted in this period to the inorganic compounds and to organic compounds containing one carbon atom or less. A survey of existing tables of thermodynamic functions was made by reference to prior authoritative compilations. The information found in the survey is summarized in Section 4 of this report. The information is presented in the form of charts in which the occurrence of tabulated data is indicated by coded letters referring to the source. The following functions are listed as headings:

| | |
|---|---|
| $\Delta H^o_{f_T}$ | Enthalpy of formation tabulated as a function of T |
| $\Delta H^o_{f_{298}}$ | Enthalpy of formation at $T = 298°K$ |
| $\Delta H^o_{f_0}$ | Enthalpy of formation at $T = 0°K$ |
| $\Delta H^o_{A0}$ | Enthalpy of atomization at $T = 0°K$ |
| $\Delta H^o_{A_{298}}$ | Enthalpy of atomization at $T = 298°K$ |
| $\Delta G^o_{f_T}$ | Gibbs energy of formation tabulated as a function of T |
| $\Delta G^o_{f_{298}}$ | Gibbs energy of formation at $T = 298°K$ |
| $\log K_p$ | Logarithm (base 10) of the equilibrium constant of formation |
| I.P. | Ionization potential |
| $\Delta H_{vap}$ | Enthalpy of vaporization |
| $\Delta H_{fus}$ | Enthalpy of fusion |
| $\Delta H_{trans}$ | Enthalpy of transition (solid-solid) |
| $P_T$ | Vapor pressure tabulated as a function of T |
| $H^o_{298} - H^o_0$ | Enthalpy increment from $T = 0°K$ to $T = 298°K$ |
| $H^o_T - H^o_{298}$ | Enthalpy increment above $T = 298°K$ tabulated as a function of T |
| $H^o_T - H^o_0$ | Enthalpy increment above $T = 0°K$ tabulated as a function of T |
| $(H^o_T - H^o_0)/T$ | Enthalpy function, based on $T = 0°K$, tabulated as a function of T |
| $(H^o_T - H^o_{298})/T$ | Enthalpy function, based on $T = 298°K$, tabulated as a function of T |
| $G^o_T - H^o_0$ | Gibbs energy increment above $T = 0°K$ tabulated as a function of T |

| | |
|---|---|
| $G_T^o - H_{298}^o$ | Gibbs energy increment above $T = 298°K$ tabulated as a function of $T$ |
| $(G_T^o - H_{298}^o)/T$ | Gibbs energy function, based on $T = 298°K$, tabulated as a function of $T$ |
| $(G_T^o - H_0^o)/T$ | Gibbs energy function, based on $T = 0°K$, tabulated as a function of $T$ |
| $C_p^o$ | Heat capacity at constant pressure tabulated as a function of $T$ |
| $C_{p298}^o$ | Heat capacity at constant pressure at $T = 298°K$ |
| $S_{298}^o$ | Entropy at $T = 298°K$ |
| $S_T^o$ or $S_T^o - S_0^o$ | Entropy increment above $T = 0°K$ tabulated as a function of temperature |

Some of the above functions give essentially the same information in different ways, as for instance $(H_T^o - H_{298}^o)$ and $H_T^o - H_{298}^o)/T$. However, the various modes of presenting the data are listed separately for the purposes of this survey because the functions are not strictly interchangeable. The sources of data covered thus far in this portion of the study are listed, together with their keyed letters in the first page of Section 4. NBS Circular 500, keyed as letter C, has been searched only through Series I, and has been included only to the extent that data in it has not been superseded by NBS Tech. Note 270-1 (W). Enthalpies of phase changes which are found in Series II have not yet been included, but will be in future summaries.

The compound formulas listed in the left-most column are in strictly alphabetic-numeric order following the scheme used in the Chemical Abstracts Formula Index and in previous reports of this series. Ions were listed if data for them were found. No attempt is made in the charts presented in this report to distinguish the various phases of a compound. Names are given for a few compounds for which the alphabetical formula leaves the nature of the compound unclear.

A cursory scan of the charts in Section 4 shows large vacant areas. They are to be filled in further by additional searches. It is certain that other sources of data will provide additional information, particularly in the columns listed as functions of temperature; however, large gaps are expected to remain after the search has been completed. Structural formulas or names for many of the other compounds can be found by reference to NBS Report 8595 (Table 1, Section 2) or to the sources listed for data.

4. Status of Coverage of Thermodynamic Functions for Inorganic CHNOPS Compounds and Organic CHNOPS Compounds Containing One Carbon Atom per Molecule

Key to Sources of Thermodynamic Functions

W   Wagman, D. C., Evans, W. H., Halow, I, Parker, V. B., Bailey, S. M., and Schumm, R. H., Selected values of chemical thermodynamic properties. Part I. Tables for the first twenty-three elements in the standard order of arrangement. NBS Tech. Note 270-1 (U.S. Government Printing Office, Washington, D. C., October 1965).

C   Rossini, F. D., Wagman, D. D., Evans, W. H., Levine, S., and Jaffe, I., Selected values of chemical-thermodynamic properties. NBS Circular 500 (U. S. Government Printing Office, Washington, D. C., 1952).

D   Dow Chemical Co., (D. R. Stull and collaborators) JANAF Thermochemical Tables, (The Dow Chemical Company, Midland, Michigan, Dec. 31, 1960 to Dec. 31, 1965), available through Supplement 17 as publication PB-168370 (Clearinghouse for Federal Scientific and Technical Information, Washington, D. C., Aug. 1965).

A   Beckett, C. W., and collaborators, NBS Reports as follows:

1.   Preliminary report on the thermodynamic properties of lithium, beryllium, magnesium, aluminum and their compounds with oxygen, hydrogen, fluorine, and chlorine.
         NBS Report 6297, January 1959
         NBS Report 6484, July 1959

2.   Preliminary report on the thermodynamic properties of selected light element compounds.
         NBS Report 6645, January 1960
         NBS Report 6928, July 1960

3.   Preliminary report on the thermodynamic properties of selected light-element and some related compounds.
         NBS Report 7093, January 1961
         NBS Report 7192, July 1961
         NBS Report 7437, January 1962
         NBS Report 7587, July 1962
         NBS Report 7796, January 1963
         NBS Report 8033, July 1963
         NBS Report 8186, January 1964
         NBS Report 8504, July 1964
         NBS Report 8628, January 1965
         NBS Report 8919, July 1965
         NBS Report 9028, January 1966

For an explanation of the tables see Section 3 of this report.

| Empirical Formula | $\Delta H_f^o \, T$ | $\Delta H_{f298}^o$ | $\Delta H_f^o \, O$ | $\Delta H_A \, O$ | $\Delta H_{A298}$ | $\Delta G_f^o \, T$ | $\Delta G_{f298}^o$ | $\text{Log } K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | D | D W A | W A | A | A | D | W | D | A | | | | |
| $C^+$ | | W | W | | | | | | | | | | |
| $C^{+2}$ | | W | W | | | | | | | | | | |
| $C^{+3}$ | | W | W | | | | | | | | | | |
| $C^{+4}$ | | W | W | | | | | | | | | | |
| $C^{+5}$ | | W | W | | | | | | | | | | |
| $C^{+6}$ | | W | W | | | | | | | | | | |
| $C^-$ | D | D | | | | D | | D | A | | | | |
| CH | D | D W | W | | | D | | D | A | | | | |
| $CH^+$ | | W | W | | | | | | | | | | |
| $CH^-$ | | | | | | | | | A | | | | |
| CHN Hydrocyanic Acid | D | D W | | | | D | W | D | A | | | | |
| CHN Hydrogen Cyanide | W | W | W | | | | W | | | | | | |
| CHNO Hydrogen Cyanate | D | D | | | | D | | D | | | | | |
| CHNO Cyanic Acid | W | | | | | | W | | | | | | |

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| Empirical Formula | $H^0_{298}-H^0_0$ | $\dfrac{H^0_T-H^0_{298}}{T}$ | $\dfrac{H^0_T-H^0_0}{T}$ | $H^0_T-H^0_0$ | $\dfrac{H^0_T-H^0_{298}}{T}$ | $G^0_T-H^0_0$ | $\dfrac{G^0_T-H^0_0}{T}\,298$ | $\dfrac{G^0_T-H^0_0}{T}$ | $G^0_T-H^0_{298}$ | $C^0_p$ | $C^0_{p\ 298}$ | $S^0_{298}$ | $S^0_T$ or $S^0_T-S^0_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C |  W |  D |  A |  A |  |  A |  D |  A |  D |  D A |  W |  W D |  D A |
| C$^+$ |  |  |  A |  A |  |  |  A |  |  |  A |  |  |  A |
| C$^{+2}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| C$^{+3}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| C$^{+4}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| C$^{+5}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| C$^{+6}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| C$^-$ |  |  D |  |  |  |  |  D |  |  |  D |  |  D |  D |
| CH |  |  D |  |  |  |  |  D |  |  |  D |  |  D |  D |
| CH$^+$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CH$^-$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CHN Hydrocyanic Acid |  |  D |  |  |  |  |  D |  |  |  D |  |  D |  D |
| CHN Hydrogen Cyanide |  W |  |  |  |  |  |  |  |  |  |  W |  W |  |
| CHNO Hydrogen Cyanate |  |  D |  |  |  |  |  D |  |  |  D |  W |  D W |  D |
| CHNO Cyanic Acid |  |  |  |  |  |  |  |  |  |  |  |  W |  |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_A\ 0$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | $\log K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_2O_2$ | | W | | | | | W | | A | | | | |
| $CH_2O_2^+$ | W | | | | | | | | | | | | |
| $CH_2O_3$ | | W | | | | | W | | | | | | |
| $CH_2O_4S$ | | W | | | | | W | | | | | | |
| $CH_2S_3$ | | W | | | | | | | | | | | |
| $CH_3$ | D | D W | W | | | D | W | D | A | | | | |
| $CH_3^-$ | | | | | | | | | A | | | | |
| $CH_3NO$ | | W | | | | | W | | A | | | | |
| $CH_3NO_2$ Methyl nitrite | | W | | | | | | | A | | | | |
| $CH_3NO_2$ Nitromethane | | W | | | | | W | | A | | | | |
| $CH_3N_3$ | | W | | | | | | | | | | | |
| $CH_3N_3O_3$ | | W | | | | | | | | | | | |
| $CH_3N_6O_2$ | | W | | | | | | | | | | | |
| $CH_3N_6O_3$ | | | | | | | | | | | | | |

15

| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\frac{H^o_T-H^o_0}{T}$ | $\frac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\frac{G^o_T-H^o_{298}}{T}$ | $\frac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\,298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_2O_2$ | | | | | | | | | | | W | W | |
| $CH_2O_2^+$ | | | | | | | | | | | | | |
| $CH_2O_3$ | | | | | | | | | | | | W | |
| $CH_2O_4S$ | | | | | | | | | | | | | |
| $CH_2S_3$ | | | | | | | | | | | W | W | |
| $CH_3$ | D | | | | | | D | | | D | | D | D |
| $CH_3^-$ | | | | | | | | | | | | | |
| $CH_3NO$ | | | | | | | | | | | | W | |
| $CH_3NO_2$ Nitromethane | W | | | | | | | | | | W | W | |
| $CH_3NO_2$ Methyl-nitrite | | | | | | | | | | | | | |
| $CH_3N_3$ | | | | | | | | | | | | | |
| $CH_3N_3O_3$ | | | | | | | | | | | | | |
| $CH_3N_6O_2$ | | | | | | | | | | | | | |
| $CH_3N_6O_3$ | | | | | | | | | | | | | |

16

| Empirical Formula | $\Delta H_f^{\circ}\, T$ | $\Delta H_{f298}^{\circ}$ | $\Delta H_f^{\circ}\, 0$ | $\Delta H_{A}\, 0$ | $\Delta H_{A298}$ | $\Delta G_f^{\circ}\, T$ | $\Delta G_{f298}^{\circ}$ | $Log\ K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | D | D W | W | | | D | W | D | A | | | | |
| $CH_4^+$ | | W | W | | | | | | | | | | |
| $CH_4N_2$ | | W | | | | | W | | | | | | |
| $CH_4N_2O$ Urea | | W | | | | | W | | | | | | |
| $CH_4N_2O$ Ammonium Cyanate | | W | W | | | | | | | | | | |
| $CH_4N_2S$ Thiourea | | W | | | | | | | | | | | |
| $CH_4N_2S$ Ammonium Thiocyanate | | W | | | | | W | | | | | | |
| $CH_4N_2O_2$ | | W | | | | | | | | | | | |
| $CH_4N_6O_2$ 5-Aminotetrazole Nitrate | | W | | | | | | | | | | | |
| $CH_4N_6O_3$ Guanyl- azide Nitrate | | W | | | | | | | | | | | |
| $CH_4O$ | W | W | W | | | | W | | A | | | | |
| $CH_4O_2$ | | W | | | | | | | | | | | |
| $CH_4S$ | | W | | | | | W | | A | | | | |
| $CH_5N$ | | W A | | | | | W | | A | | | | |
| $CH_5NO_2$ | | W | | | | | W | | | | | | |

17

| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\frac{H^o_T-H^o_0}{T}$ | $\frac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\frac{G^o_T-H^o_{298}}{T}$ | $\frac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_p$ 298 | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | W | D | | | | | D | | D | D | W | D W | D |
| $CH_4^+$ | | | | | | | | | | | | | |
| $CH_4N_2$ | | | | | | | | | | | W | W | |
| $CH_4N_2O$ Urea | | | | | | | | | | | W | W | |
| $CH_4N_2O$ Ammonium Cyanate | | | | | | | | | | | | | |
| $CH_4N_2S$ Thiourea | | | | | | | | | | | | | |
| $CH_4N_2S$ Ammonium Thiocyanate | | | | | | | | | | | W | W | |
| $CH_4N_4O_2$ | | | | | | | | | | | | | |
| $CH_4N_6O_3$ 5-Aminotetrazole Nitrate | | | | | | | | | | | | | |
| $CH_4N_4O_3$ Guanylazide Nitrate | | | | | | | | | | | | | |
| $CH_4O$ | W | | | | | | | | | | W | W | |
| $CH_4O_2$ | | | | | | | | | | | | | |
| $CH_4S$ | W | | | | | | | | | | W | W | |
| $CH_4N$ | | | | | | | | | | | W | W | |
| $CH_5NO_2$ | | | | | | | | | | | W | W | |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_A\ 0$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | $\mathrm{Log}\ K_p$ | I. P. | $\Delta H\ vap$ | $\Delta H\ fus$ | $\Delta H\ trans$ | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_5NO_3$ | | W | | | | | W | | | | | | |
| $CH_5N_3$ | | W | | | | | | | | | | | |
| $CH_5N_3O$ | | W | | | | | W | | | | | | |
| $CH_5N_3O_3S$ | | W | | | | | | | | | | | |
| $CH_5N_5O_2$ | | W | | | | | W | | | | | | |
| $CH_6N^+$ | | W | W | | | | W | | | | | | |
| $CH_6N_2$ | | W A | | | | | W | | | | | | |
| $CH_6N_2O_2$ | | W | | | | | | | | | | | |
| $CH_6N_2O_3$ | | W | | | | | | | | | | | |
| $CH_6N_4O_3$ | | W | | | | | W | | | | | | |
| $CH_7NO$ | | W | | | | | W | | | | | | |
| $CH_8N_2O_3$ | | W | | | | | | | | | | | |
| $CH_{12}N_5O_4S$ | | W | | | | | | | | | | | |
| $CH_{12}O_8$ | | C | | | | | | | | | | | |

| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\dfrac{H^o_T-H^o_0}{T}$ | $\dfrac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\dfrac{G^o_T-H^o_0}{T}$ | $\dfrac{G^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_p$ 298 | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_5NO_3$ | | | | | | | | | | | | W | |
| $CH_5N_3$ | | | | | | | | | | | | | |
| $CH_5N_3O$ | | | | | | | | | | | | W | |
| $CH_5N_3O_3S$ | | | | | | | | | | | | | |
| $CH_5N_5O_2$ | | | | | | | | | | | | | |
| $CH_6N^+$ | | | | | | | | | | | W | W | |
| $CH_6N_2$ | W | | | | | | | | | | | W | |
| $CH_6N_2O_2$ | | | | | | | | | | | | W | |
| $CH_6N_2O_3$ | | | | | | | | | | | | | |
| $CH_6N_4O_3$ | | | | | | | | | | | W | | |
| $CH_7NO$ | | | | | | | | | | | | | |
| $CH_8N_2O_3$ | | | | | | | | | | | W | | |
| $CH_{12}N_5O_4S$ | | | | | | | | | | | | | |
| $CH_{12}O_8$ | | | | | | | | | | | | | |

20

| Empirical Formula | $\Delta H^\circ_f\,T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\,0$ | $\Delta H_{A\,0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\,T$ | $\Delta G^\circ_{f298}$ | $\mathrm{Log}\ K_p$ | I. P. | $\Delta H\ vap$ | $\Delta H\ fus$ | $\Delta H\ trans$ | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_{16}O_6$ | | C | | | | | | | | | | | |
| $CN$ | D | D | | | | D | | D | A | | | | |
| $CN^-$ | | | | | | | | | A | | | | |
| $CNO^-$ | | W | | | | | W | | | | | | |
| $CNS^-$ | | W | | | | | W | | | | | | |
| $CN_4$ | | W | | | | | | | | | | | |
| $1/n(CN_4)_x$ | | W | | | | | | | | | | | |
| $CN_4O_8$ | | W | | | | | | | | | | | |
| $CO$ | D | D W | W | | | D | W | D | A | | | | |
| $CO^+$ | | W | W | | | | | | | | | | |
| $CO^{+2}$ | | W | W | | | | | | | | | | |
| $COS$ | D | D W | W | | | D | W | D | A | | | | |
| $CO_2$ | D | D W | W | | | D | W | D | A | | | | |
| $CO_2^+$ | | W | W | | | | | | | | | | |
| $CO_2^-$ | | | | | | | | | A | | | | |

| Empirical Formula | H°298-H°0 | H°T-H°298 | H°T-H°0 | (H°T-H°0)/T | (H°T-H°298)/T | G°T-H°0 | (G°T-H°298)/T | (G°T-H°0)/T | G°T-H°298 | C°p | C°p 298 | S°298 | ST° or ST°-S0° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_{16}O_6$ | | | | | | | | | | | | | |
| $CN$ | | D | | | | | D | | | D | | D | D |
| $CN^-$ | W | | | | | | | | | | | W | |
| $CNO^-$ | W | | | | | | | | | | W | W | |
| $CNS^-$ | W | | | | | | | | | | | | |
| $CN_4$ | | | | | | | | | | | | | |
| $1/n(CN)_4\,x$ | | | | | | | | | | | | | |
| $CN_4O_8$ | | | | | | | | | | | | | |
| $CO$ | W | D | | | | | D | | | D | W | D W | D |
| $CO^+$ | W | . | | | | | | | | | | | |
| $CO^{+2}$ | W | | | | | | | | | | | | |
| $COS$ | W | D | | | | | D | | | D | W | D W | D |
| $CO_2$ | W | D | | | | | W | | | D | W | D W | D |
| $CO_2^+$ | W | | | | | | | | | | | | |
| $CO_2^-$ | | | | | | | | | | | | | |

22

| Empirical Formula | $\Delta H^\circ_f\,T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\,0$ | $\Delta H_{A\,0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\,T$ | $\Delta G^\circ_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_3^{-2}$ | | W | | | | | W | | | | | | |
| CP | D | D | | | | D | | D | | | | | |
| CS | D | D W | | | | D | W | D | | | | | |
| $CS_2$ | D | D W | | | | D | W | D | A | | | | |
| $C_2$ | D | D | | | | D | W | D | A | | | | |
| $C_2^-$ | | | | | | | | D | A | | | | |
| $C_2N_2$ | D | D | | | | D | | D | | | | | |
| $C_3$ | D | D | | | | D | | D | A | | | | |
| $C_3^-$ | | | | | | | | | A | | | | |
| $C_4$ | D | D | | | | D | | D | A | | | | |
| $C_4^-$ | | | | | | | | | A | | | | |
| $C_4N_2$ | D | D | | | | D | | D | | | | | |
| $C_5$ | D | D | | | | D | W | D | | | | | |
| H | D | D W A | W A | A | A | D | | D | A | | | | |
| $H^+$ | | W | W | A | A | | | | | | | | |

23

| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{G^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_{p\,298}$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_3^{-2}$ | | | | | | | | | | | | W | |
| $CP$ | | D | | | | | D | | | D | | D | D |
| $CS$ | | D | | | | | D | | | D | | D | D |
| $CS_2$ | | D | | | | | D | | | D | W | W D | D |
| $C_2$ | | D | | | | | D | | | D | | D | D |
| $C_2^-$ | | | | | | | | | | | | | |
| $C_2N_2$ | | D | | | | | D | | | D | | D | D |
| $C_3$ | | D | | | | | D | | | D | | D | D |
| $C_3^-$ | | | | | | | | | | | | | |
| $C_4$ | | D | | | | | D | | | D | | D | D |
| $C_4^-$ | | | | | | | | | | | | | |
| $C_4N_2$ | | D | | | | | D | | | D | | D | D |
| $C_5$ | | D | | | | | D | | | D | | D | D |
| $H$ | W | D | A | A | | A | D | A | | D | W | D W | D A |
| $H^+$ | | | A | A | | A | | A | | | | | A |

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| Empirical Formula | ΔH°f T | ΔH°f298 | ΔH°f 0 | ΔH A 0 | ΔH A298 | ΔG°f T | ΔG°f298 | Log Kp | I. P. | ΔH vap | ΔH fus | ΔH trans | PT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H^-$ | D | D W | W | | | D | | D | A | | | | |
| $HN$ | D | W | W | | | D | | D | A | | | | |
| $HNO$ | D | | | | | D | | D | | | | | |
| $HNO_2$ | D | W | W | | | D | W | D | | | | | |
| $HNO_3$ | D A | D W A | W | | | D | W | D | | | | | |
| $HN_2O_2^-$ | | W | W | | | | | | | | | | |
| $HN_3$ | | W A | W | | | | W | | A | | | | |
| $HN_3^+$ | | W | W | | | | | | | | | | |
| $HO$ | D | W D A | W | | | D | W | D | A | | | | |
| $HO^-$ | | W A | W | | | | | | A | | | | |
| $HO_2$ | D | D W | W | | | D | | D | A | | | | |
| $HO_2^+$ | | W | W | | | | | | | | | | |
| $HO_2^-$ | | W | | | | | W | | A | | | | |
| $HO_3P^{-2}$ | | W | | | | | | | | | | | |
| $HC_4^{-2}$ | | W | | | | | W | | | | | | |

| Empirical Formula | $H^0_{298}-H^0_0$ | $H^0_T-H^0_{298}$ | $H^0_T-H^0_0$ | $\dfrac{H^0_T-H^0_0}{T}$ | $\dfrac{H^0_T-H^0_{298}}{T}$ | $G^0_T-H^0_0$ | $\dfrac{G^0_T-H^0_{298}}{T}$ | $\dfrac{G^0_T-H^0_0}{T}$ | $G^0_T-H^0_{298}$ | $C^0_p$ | $C^0_p\ 298$ | $S^0_{298}$ | $S^0_T$ or $S^0_T-S^0_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H^-$ | | D | | | | | D | | | D | | D | D |
| $HN$ | | D | | | | | D | | | D | | D | D |
| $HNO$ | | D | | | | | D | | | D | | D | D |
| $HNO_2$ | W | D | | | | | D | | | D | W | D W | D |
| $HNO_3$ | W | D | A | A | | A | D | A | | D | W | D W | D |
| $HN_2O_2^-$ | W | | | | | | | | | | | | |
| $HN_3$ | W | | | | | | | | | | W | W | |
| $HN_3^+$ | | | | | | | | | | | | | |
| $HO$ | W | D | | | | | D | | | D | W | D W | D |
| $HO^-$ | | D | | | | | | | | | | | |
| $HO_2$ | | D | | | | | D | | | D | | D | D |
| $HO_2^+$ | | | | | | | | | | | | | |
| $HO_2^-$ | | | | | | | | | | | | W | |
| $HO_3P^{-2}$ | | | | | | | | | | | | | |
| $HO_4^{-2}$ | | | | | | | | | | | | W | |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $HO_4S_2^-$ | | | | | | | W | | | | | | |
| $HP$ | D | D | | | | D | | D | D | | | | |
| $HP_2$ | | C | | | | | C | | | | | | |
| $HPO_3$ | D | W | | | | | C | | | | | | |
| $HS$ | D | D W | W | | | D | W | D | A | | | | |
| $HS^-$ | | W | | | | | W | D | A | | | | |
| $H_2$ | D | D W A | | A | A | D | W | D | A | | | | |
| $H_2^+$ | | W | W | | | | | | | | | | |
| $H_2N$ | D | W D A | | | | D | | D | A | | | | |
| $H_2N^-$ | | | | | | | | | A | | | | |
| $H_2N_2$ | D | D | | | | D | | D | | | | | |
| $H_2N_2O_2$ Nitramide | | W | | | | | | | | | | | |
| $H_2N_2O_2$ Hyponitrous Acid | | W | | | | | | | | | | | |
| $H_2O$ | | W | W | | | | | | A | | | | |
| $H_2O^+$ | | | | | | | | | A | | | | |

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| Empirical Formula | $H_{298}^\circ - H_0^\circ$ | $H_T^\circ - H_{298}^\circ$ | $H_T^\circ - H_0^\circ$ | $\dfrac{H_T^\circ - H_0^\circ}{T}$ | $\dfrac{H_T^\circ - H_{298}^\circ}{T}$ | $G_T^\circ - H_0^\circ$ | $\dfrac{G_T^\circ - H_{298}^\circ}{T}$ | $\dfrac{G_T^\circ - H_0^\circ}{T}$ | $G_T^\circ - H_{298}^\circ$ | $C_p^\circ$ | $C_p^\circ\,298$ | $S_{298}^\circ$ | $S_T^\circ$ or $S_T^\circ - S_0^\circ$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $HO_4S_2^-$ | | | | | | | | | | | | | |
| $HP$ | | D | | | | | D | | | D | | D | D |
| $HP_2$ | | | | | | | | | | | | C | |
| $HPO_3$ | | | | | | | | | | | | | |
| $HS$ | W | D | | | | | D | | | D | W | D W | D |
| $HS^-$ | W | | | | | | | | | | | W | |
| $H_2$ | W | D | A | A | A | A | D A | A | | D A | | D | D |
| $H_2^+$ | | | | | | | | | | | | | |
| $H_2N$ | | D | | | | | D | | | D | | D | D |
| $H_2N^-$ | | | | | | | | | | | | | |
| $H_2N_2$ | | D | | | | | D | | | D | | D | D |
| $H_2N_2O_2$ Nitramide | | | | | | | | | | | | | |
| $H_2N_2O_2$ Hyponitrous Acid | | | | | | | | | | | | | |
| $H_2O$ | W | D | | | | | D | | | D | W | D | D |
| $H_2O^+$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f$ T | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f$ 0 | $\Delta H_A$ 0 | $\Delta H_{A298}$ | $\Delta G^\circ_f$ T | $\Delta G^\circ_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2O^-$ | D | | | | | | | | A | | | | |
| $H_2O_2$ | | D W A | W | | | D | W | D | A | | | | |
| $H_2O_2^+$ | | W | W | | | | | | | | | | |
| $H_2O_2P^-$ | | W | | | | | | | | | | | |
| $H_2O_3P^-$ | | W | | | | | W | | | | | | |
| $H_2O_4P^-$ | | W | | | | | W | | | | | | |
| $H_2O_7P_2^{-2}$ | | W | | | | | W | | | | | | |
| $H_2O_7P_2^{-3}$ | | W | | | | | W | | | | | | |
| $H_2O_3S$ | | W | | | | | W | | | | | | |
| $H_2O_4S$ | D | D W | | | | D | W | D | | | | | |
| $H_2O_4S_2$ | | | | | | | W | | | | | | |
| $H_2O_6S_2$ | | W | | | | | | | | | | | |
| $H_2O_7S_2$ | | W | | | | W | | | | | | | |
| $H_2O_8S_2$ | | W | | | | | | | | | | | |

| Empirical Formula | $H_{298}^o-H_0^o$ | $H_T^o-H_{298}^o$ | $H_T^o-H_0^o$ | $\dfrac{H_T^o-H_0^o}{T}$ | $\dfrac{H_T^o-H_{298}^o}{T}$ | $G_T^o-H_0^o$ | $\dfrac{G_T^o-H_{298}^o}{T}$ | $\dfrac{G_T^o-H_0^o}{T}$ | $G_T^o-H_{298}^o$ | $C_p^o$ | $C_{p\,298}^o$ | $S_{298}^o$ | $S_T^o$ or $S_T^o-S_0^o$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2O^-$ | | | | | | | | | | | | | |
| $H_2O_2$ | W | D | | | | | D | | | D | W | D W | D |
| $H_2O_2^+$ | | | | | | | | | | | | | |
| $H_2O_2P^-$ | | | | | | | | | | | | W | |
| $H_2O_3P^-$ | | | | | | | | | | | W | | |
| $H_2O_4P^-$ | | | | | | | | | | | | W | |
| $H_2O_7P_2^{-2}$ | | | | | | | | | | | | W | |
| $H_2O_7P_2^{-3}$ | | | | | | | | | | | | W | |
| $H_2O_3S$ | | | | | | | | | | | | W | |
| $H_2O_4S$ | W | D | | | | | D | | | D | W | D W | |
| $H_2O_4S_2$ | | | | | | | | | | | | | |
| $H_2O_6S_2$ | | | | | | | | | | | | | |
| $H_2O_7S_2$ | | | | | | | | | | | | W | |
| $H_2O_8S_2$ | | | | | | | | | | | | | |

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| Empirical Formula | $\Delta H^\circ_f$ T | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f$ 0 | $\Delta H_A$ 0 | $\Delta H_{A298}$ | $\Delta G^\circ_f$ T | $\Delta G^\circ_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2P$ | D | D | | | | D | | D | | | | | |
| $H_2S$ | D | D W | W | | | D | W | D | A | | | | |
| $H_2S_2$ | | W | | | | | | | | | | | |
| $H_2S_3$ | | W | | | | | | | | | | | |
| $H_2S_4$ | | W | | | | | | | | | | | |
| $H_2S_5$ | | W | | | | | | | | | | | |
| $H_2S_6$ | | W | | | | | | | | | | | |
| $H_3$ | | D W A | W | | | | | | A | | | | |
| $H_3N$ | D | W | W | | | D | W | D | A | | | | |
| $H_3N^+$ | | W | W | | | | | | | | | | |
| $H_3NO$ | | W | | | | | | | | | | | |
| $H_3NO^+$ | | W | | A | A | | | | | | | | |
| $H_3NO_3S$ | | W | | | | | W | | | | | | |
| $H_3NO_4$ | | | | | | | | | A | | | | |
| $H_3N_2$ | | | | | | | | | | | | | |

| Empirical Formula | $H_{298}^o - H_0^o$ | $H_T^o - H_{298}^o$ | $H_T^o - H_0^o$ | $\dfrac{H_T^o - H_0^o}{T}$ | $\dfrac{H_T^o - H_{298}^o}{T}$ | $G_T^o - H_0^o$ | $\dfrac{G_T^o - H_0^o}{T}$ | $\dfrac{G_T^o - H_{298}^o}{T}$ | $G_T^o - H_{298}^o$ | $C_p^o$ | $C_{p\,298}^o$ | $S_{298}^o$ | $S_T^o$ or $S_T^o - S_0^o$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_2P$ | D | | | | | | | D | | D | | D | D |
| $H_2S$ | D | W | | | | | | D | | D | W | D W | D |
| $H_2S_2$ | | | | | | | | | | | W | | |
| $H_2S_3$ | | | | | | | | | | | | | |
| $H_2S_4$ | | | | | | | | | | | | | |
| $H_2S_5$ | | | | | | | | | | | | | |
| $H_2S_6$ | | | | | | | | | | | | | |
| $H_3$ | | | | | | | | | | | | | |
| $H_3N$ | D | W | | | | | | D | | D | W | D W | D |
| $H_3N^+$ | | | | | | | | | | | | | |
| $H_3NO$ | | | | | | | | | | | | | |
| $H_3NO^+$ | | | | | | | | | | | | | |
| $H_3NO_3S$ | | | | | | | | | | | | | |
| $H_3NO_4$ | | | A | A | | A | A | A | | A W | A W | A W | A |
| $H_3N_2$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^{\circ}_f$ T | $\Delta H^{\circ}_{f298}$ | $\Delta H^{\circ}_f$ 0 | $\Delta H_{A\,0}$ | $\Delta H_{A298}$ | $\Delta G^{\circ}_f$ T | $\Delta G^{\circ}_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_3O$ | | | | | | | | | A | | | | |
| $H_3O_2P$ | | W | | | | | | | | | | | |
| $H_3O_4P$ | D | W D | | | | D | W | D | | | | | |
| $H_3O_7P_2^-$ | | W | | | | D | W | | | | | | |
| $H_3P$ | D | W M | W | | | D | W | D | | | | | |
| $H_3P^+$ | | W | | | | | | | | | | | |
| $H_4N$ | D | D | | | | D | | D | A | | | | |
| $H_4N^-$ | | W | | | | | W | | | | | | |
| $H_4NO_3P$ | | W | W | | | | | | | | | | |
| $H_4N_2$ | D | W D A | | | | D | W | D | | | | | |
| $H_4N_2O$ | | W | | | | | W | | | | | | |
| $H_4N_2O_2$ | | W | | | | | | | | | | | |
| $H_4N_2O_2S$ | | W | | | | W | | | | | | | |
| $H_4N_2O_3$ Ammonium Peroxynitrite | | W | | | | | | | | | | | |
| $H_4N_2O_3$ Ammonium Nitrate | | W A | | | | W | | | | | | | |

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| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $H^\circ_T-H^\circ_0$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{G^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_{p\,298}$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_3O$ | | | | | | | | | | | | | |
| $H_3O_2P$ | D | W | | | | | D | | | D | W | D W | D |
| $H_3O_4P$ | | | | | | | | | | | | W | |
| $H_3O_7P_2^-$ | D | W | | | | | D | | | D | W | W | D |
| $H_3P$ | | | | | | | | | | | | | |
| $H_3P^+$ | D | | | | | | D | | | D | W | W | D |
| $H_4N$ | D | | | | | | D | | | D | W | | D |
| $H_4N^-$ | | | | | | | | | | | W | W | |
| $H_4NO_3P$ | D | W | | | | | D | | | D | W | W | D |
| $H_4N_2$ | D | | | | | | D | | | D | W | W | D |
| $H_4N_2O$ | | | | | | | | | | | W | W | |
| $H_4N_2O_2$ | | | | | | | | | | | W | W | |
| $H_4N_2O_2S$ | | | | | | | | | | | | | |
| $H_4N_2O_3$ Ammonium Peroxy-Nitrite | | | | | | | | | | | W | W | |
| $H_4N_2O_3$ Ammonium Nitrate | | | | | | | | | | | | W | W A |

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| Empirical Formula | $\Delta H^\circ_f \, T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f \, O$ | $\Delta H_A \, O$ | $\Delta H_{A298}$ | $\Delta G^\circ_f \, T$ | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_4O_5S$ | | M | | | | | M | | | | | | |
| $H_4O_5P_2$ | | M | | | | | | | | | | | |
| $H_4P^+$ | | M | | | | | | | | | | | |
| $H_4P_2$ | | M A | | | | | | | | | | | |
| $H_4P_2O_7$ | | M | | | | | M | | | | | | |
| $H_5NO$ | | M | | | | | M | | | | | | |
| $H_5NO_2$ | | M | | | | | M | | | | | | |
| $H_5NS$ | | M | | | | | M | | | | | | |
| $H_5NO_3S$ | | M | | | | | M | | | | | | |
| $H_5NO_4S$ | | M | | | | | | | | | | | |
| $H_5NO_5S$ | | M | | | | | M | | | | | | |
| $H_5N_2^+$ | | M | | | | | | | | | | | |
| $H_5N_3O_2$ | | M | | | | | | | | | | | |
| $H_6NO_2P$ | | M | | | | | | | | | | | |
| $H_6NO_3P$ | | M | | | | | | | | | | | |

| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $H^\circ_T-H^\circ_0$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_p\ 298$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_4O_5S$ | | | | | | | | | | W | W | |
| $H_4O_5P_2$ | | | | | | | | | | | | |
| $H_4P^+$ | | | | | | | | | | | | |
| $H_4P_2$ | | | | | | | | | | | | |
| $H_4P_2O_7$ | | | | | | | | | | | W | |
| $H_5NO$ | | | | | A | | A | | A | W | W A | |
| $H_5NO_2$ | | | | | | | | | | | W | |
| $H_5NS$ | | | | | | | | | | | W | |
| $H_5NO_3S$ | | | | | | | | | | | W | |
| $H_5NO_4S_2$ | | | | | | | | | | | | |
| $H_5NO_5S$ | | | | | | | | | | W | W | |
| $H_5N_2^+$ | | | | | | | | | | | | |
| $H_5N_3O_2$ | | | | | | | | | | | | |
| $H_6NO_2P$ | | | | | | | | | | | | |
| $H_6NO_3P$ | | | | | | | | | | | | |

| Empirical Formula | $H^{\circ}_{298}-H^{\circ}_0$ | $H^{\circ}_T-H^{\circ}_{298}$ | $H^{\circ}_T-H^{\circ}_0$ | $\dfrac{H^{\circ}_T-H^{\circ}_0}{T}$ | $\dfrac{H^{\circ}_T-H^{\circ}_{298}}{T}$ | $G^{\circ}_T-H^{\circ}_0$ | $\dfrac{G^{\circ}_T-H^{\circ}_0}{T}$ | $\dfrac{G^{\circ}_T-H^{\circ}_{298}}{T}$ | $G^{\circ}_T-H^{\circ}_{298}$ | $C^{\circ}_p$ | $C^{\circ}_p\ 298$ | $S^{\circ}_{298}$ | $S^{\circ}_T$ or $S^{\circ}_T-S^{\circ}_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_6NO_4P$ | | | | | | | | | | | W | W | |
| $H_6N_2O$ | | | | | | | | | | | W | W | |
| $H_6N_2O_4S$ | | | | | | | | | | | | C | |
| $H_6O_6S$ | | | | | | | | | | | W | W | |
| $H_7NO_6$ | | | A | A | | A | A | | | A | W | W A | |
| $H_7O_{8.5}P_2$ | | | A | A | | A | A | | | A | | A | |
| $H_7NO_7P_2$ | | | | | | | | | | | | W | |
| $H_8N_2O$ | | | | | | | | | | | | W | |
| $H_8N_2O_3S$ | | | | | | | | | | | | | |
| $H_8N_2O_3S_2$ | | | | | | | | | | | | | |
| $H_8N_2O_4S$ | | | | | | | | | | | W | W | |
| $H_8N_2O_4S_2$ | | | | | | | | | | | | W | |
| $H_8N_2O_5S_2$ | | | | | | | | | | | | C | |
| $H_8N_2O_6S$ | | | | | | | | | | | | | |
| $H_8N_2O_6S_2$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f$ T | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f$ 0 | $\Delta H_A$ 0 | $\Delta H_{A298}$ | $\Delta G^\circ_f$ T | $\Delta S^\circ_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_6NO_4P$ | | W | | | | | W | | | | | | |
| $H_6N_2O$ | | W | | | | | W | | | | | | |
| $H_6N_2O_4S$ | | C | | | | | C | | | | | | |
| $H_6O_6S$ | | W | | | | | W | | | | | | |
| $H_7NO_6$ | | W | | | | | W | | | | | | |
| $H_7O_{8.5}P_2$ | | W | | | | | | | | | | | |
| $H_7NO_7P_2$ | | W | | | | | W | | | | | | |
| $H_8N_2O$ | | | | | | | | | | | | | |
| $H_8N_2O_3S$ | | W | | | | | | | | | | | |
| $H_8N_2O_3S_2$ | | W | | | | | W | | | | | | |
| $H_8N_2O_4S$ | | W | | | | | W | | | | | | |
| $H_8N_2O_4S_2$ | | W | | | | | C | | | | | | |
| $H_8N_2O_5S_2$ | | C | | | | | | | | | | | |
| $H_8N_2O_6S$ | | W | | | | | | | | | | | |
| $H_8N_2O_6S_2$ | | W | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f$ T | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f$ 0 | $\Delta H_{A\,0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f$ T | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_8N_2O_6S_3$ | | M | | | | | | | | | | | |
| $H_8N_2O_6S_4$ | | M | | | | | | | | | | | |
| $H_8N_2O_6S_5$ | | M | | | | | | | | | | | |
| $H_8N_2O_7S_2$ | | M | | | | | M | | | | | | |
| $H_8N_2O_8S_2$ | | M | | | | | M | | | | | | |
| $H_8N_2S$ | | M | | | | | M | | | | | | |
| $H_8N_2S_2$ | | M | | | | | M | | | | | | |
| $H_8N_2S_3$ | | M | | | | | M | | | | | | |
| $H_8N_2S_4$ | | M | | | | | M | | | | | | |
| $H_8N_2S_5$ | | M | | | | | M | | | | | | |
| $H_8N_2S_8$ | | M | | | | | | | | | | | |
| $H_8N_4O_2$ | | M | | | | | | | | | | | |
| $H_8O_7S$ | | M | | | | M | | | | | | | |
| $H_9N_2O_3P$ | | M | | | | | | | | | | | |
| $H_9N_2O_4P$ | | M | | | | M | | | | | | | |

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| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\dfrac{H^o_T-H^o_0}{T}$ | $\dfrac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\dfrac{G^o_T-H^o_0}{T}$ | $\dfrac{G^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\ 298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_8N_2O_6S_3$ | | | | | | | | | | | | | |
| $H_8N_2O_6S_4$ | | | | | | | | | | | | | |
| $H_8N_2O_6S_4$ | | | | | | | | | | | | | |
| $H_8N_2O_7S_2$ | | | | | | | | | | | | | |
| $H_8N_2O_8S_2$ | | | | | | | | | | | | W | |
| $H_8N_2S$ | | | | | | | | | | | | W | |
| $H_8N_2S_2$ | | | | | | | | | | | | W | |
| $H_8N_2S_3$ | | | | | | | | | | | | W | |
| $H_8N_2S_4$ | | | | | | | | | | | | W | |
| $H_8N_2S_5$ | | | | | | | | | | | | W | |
| $H_8N_2S_8$ | | | | | | | | | | | | | |
| $H_8N_4O_2$ | | | | | | | | | | | | | |
| $H_8O_7S$ | | | | | | | | | | | W | W | |
| $H_9N_2O_3P$ | | | | | | | | | | | | W | |
| $H_9N_2O_4P$ | | | | | | | | | | | | W | |
| | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta S^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_{10}N_2O_4S$ | W | | | | | | | | | | | | |
| $H_{10}N_2O_7P_2$ | W | | | | | | W | | | | | | |
| $H_{10}N_4O_4S$ | W | | | | | | | | | | | | |
| $H_{10}O_8S$ | W | | | | | | W | | | | | | |
| $H_{12}N_3O_4P$ | W | | | | | | | | | | | | |
| $H_{12}N_4O_5S$ | W | | | | | | | | | | | | |
| $H_{13}N_3O_7P_2$ | W | | | | | | W | | | | | | |
| $H_{14}O_6S$ | C | | | | | | C | | | | | | |
| $H_{15}O_6P$ | C | | | | | | C | | | | | | |
| $H_{16}N_4O_7P_2$ | W | | | | | | W | | | | | | |
| $H_{17}N_5O_4S$ | W | | | | | | W | | | | | | |
| $H_{18}N_3O_7P$ | W | | | | | | | | | | | | |
| N | D | D W A | W A | A | A | D | W | D | A | | | | |
| $N^+$ | | W | W | A | A | | W | | A | | | | |
| $N^-$ | | | | | | | | | A | | | | |

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| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\dfrac{H^o_T-H^o_0}{T}$ | $\dfrac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\dfrac{G^o_T-H^o_{298}}{T}$ | $\dfrac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\,298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_{10}N_2O_4S$ | | | | | | | | | | | | | |
| $H_{10}N_2O_7P_2$ | | | | | | | | | | | | W | |
| $H_{10}N_4O_4S$ | | | | | | | | | | | | | |
| $H_{10}O_8S$ | | | | | | | | | | | | W | |
| $H_{12}N_3O_4P$ | | | | | | | | | | | | | |
| $H_{12}N_4O_5S$ | | | | | | | | | | | | | |
| $H_{13}N_3O_7P_2$ | | | | | | | | | | | | W | |
| $H_{14}O_6S$ | | | | | | | | | | | | C | |
| $H_{15}O_6P$ | | | | | | | | | | | | C | |
| $H_{16}N_4O_7P_2$ | | | | | | | | | | | | W | |
| $H_{17}N_5O_4S$ | | | | | | | | | | | | W | |
| $H_{18}N_3O_7P$ | | | | | | | | | | | | | |
| N | W | D | A | A | | | D | A | | D A | W | W D | D A |
| $N^+$ | | | A | A | | | | A | | A | | | A |
| $N^-$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f$ T | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f$ O | $\Delta H_{A}$ O | $\Delta H_{A298}$ | $\Delta G^\circ_f$ T | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N^{+2}$ | | W | W | | | | | | | | | | |
| $N^{+3}$ | | W | W | | | | | | | | | | |
| $N^{+4}$ | | W | W | | | | | | | | | | |
| $N^{+5}$ | | W | W | | | | | | | | | | |
| $N^{+6}$ | | W | W | | | | | | | | | | |
| $N^{+7}$ | | W | W | | | | | | | | | | |
| NO | D | W D A | W | | | D | W | D | A | | | | |
| $NO^+$ | | W | W | | | | | | A | | | | |
| $NO^-$ | | | | | | | | | A | | | | |
| $NO_2$ | D | W D A | W | | | D | W | D | A | | | | |
| $NO_2^-$ | D | D W | | | | D | W | D | A | | | | |
| $NO_3$ | D | D W | | | | D | W | D | A | | | | |
| $NO_3^-$ | | W | | | | | W | | | | | | |
| NP | D | D | | | | D | | D | | | | | |
| $1/n(NP)_n$ | | W | | | | | | | | | | | |

| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\frac{H^o_T-H^o_0}{T}$ | $\frac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\frac{G^o_T-H^o_{298}}{T}$ | $\frac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\,298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N^{+2}$ | | | | | | | | | | | | | |
| $N^{+3}$ | | | | | | | | | | | | | |
| $N^{+4}$ | | | | | | | | | | | | | |
| $N^{+5}$ | | | | | | | | | | | | | |
| $N^{+6}$ | | | | | | | | | | | | | |
| $N^{+7}$ | | | | | | | | | | | | | |
| $NO$ | | D | | | | | D | | | D | | D W | D |
| $NO^{+}$ | | | | | | | | | | | | | |
| $NO^{-}$ | | | | | | | | | | | | | |
| $NO_2$ | W | D | | | | | D | | | D | W | D W | D |
| $NO_2^{-}$ | | D | | | | | D | | | D | W | D W | D |
| $NO_3$ | | D | | | | | D | | | D | W | D W | D |
| $NO_3^{-}$ | | | | | | | | | | | W | W | |
| $NP$ | | D | | | | | D | | | D | | D W | D |
| $1/n(NP)_n$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | $\log K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NS | D | D | | | | D | | D | | | | | |
| $N_2$ | D | D W A | W A | A | A | D | W | D | A | | | | |
| $NO_2$ | D | D W | W | | | D | W | D | A | | | | |
| $N_2O_2^{-2}$ | | W | | | | | | | | | | | |
| $N_2O_3$ | D | D W A | W | | | D | W | D | | | | | |
| $N_2O_4$ | D | D W | W | | | D | W | D | | | | | |
| $N_2O_5$ | D | D W A | W | | | D | W | D | | | | | |
| $N_2O_9S_2$ | | W | | | | | W | | | | | | |
| $N_3^+$ | | W | W | | | | | | | | | | |
| $N_3^-$ | | W | W | | | | | | A | | | | |
| $N_4$ | | | | | | | | | A | | | | |
| $N_4S_4$ | | W | | | | D | | | | | | | |
| $N_5P_3$ | D | D W | | | | D | | D | A | | | | |
| O | D | D W A | W | A | A | D | W | D | | | | | |
| $O^+$ | | W | W | | | | | | | | | | | |

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| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $H^\circ_T-H^\circ_0$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{G^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_{p\,298}$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NS | | D | | | | | D | | | L | | D | D |
| $N_2$ | W | D | A | A | | | D | A | | D A | W | D W | D A |
| $NO_2$ | W | D | | | | | D | | | D | W | D W | D |
| $N_2O_2^{-2}$ | | | | | | | | | | | | | |
| $N_2O_3$ | W | D | | | | | D | | | D | W | D W | D |
| $N_2O_4$ | W | D | | | | | D | | | D | W | D W | D |
| $N_2O_5$ | W | D | | | | | D | | | D | W | D W | D |
| $N_2O_9S_2$ | | | | | | | | | | | | W | |
| $N_3^+$ | | | | | | | | | | | | | |
| $N_3^-$ | | | | | | | | | | | | | |
| $N_4$ | | | | | | | | | | | | | |
| $N_4S_4$ | | | | | | | | | | | | | |
| $N_5P_3$ | | D | | | | | D | | | D | W | D | D |
| O | | D | A | A | | | D | A | | D A | | D | D A |
| $O^+$ | | | A | A | | | | A | | A | | | A |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O^{+2}$ | | W | W | | | | | | | | | | |
| $O^{+3}$ | | W | W | | | | | | | | | | |
| $O^{+4}$ | | W | W | | | | | | | | | | |
| $O^{+5}$ | | W | W | | | | | | | | | | |
| $O^{+6}$ | | W | W | | | | | | | | | | |
| $O^{+7}$ | | W | W | | | | | | | | | | |
| $O^{+8}$ | | W | W | | | | | | | | | | |
| $O^-$ | D | W D | W | | | D | | D | A | | | | |
| $OP$ | D | D | | | | D | W | D | | | | | |
| $OS$ | D | W D | W | | | D | W | D | A | | | | |
| $OS^-$ | | | | | | | | | A | | | | |
| $O_2$ | D | W D A | W A | A | A | D | W | D | A | | | | |
| $O_2^+$ | | W | W | | | | | | A | | | | |
| $O^-$ | | D | | | | D | | | A | | | | |
| $O_2^P$ | D | D | | | | D | | D | | | | | |

| Empirical Formula | $H^{\circ}_{298}-H^{\circ}_0$ | $H^{\circ}_T-H^{\circ}_{298}$ | $H^{\circ}_T-H^{\circ}_0$ | $\dfrac{H^{\circ}_T-H^{\circ}_0}{T}$ | $\dfrac{H^{\circ}_T-H^{\circ}_{298}}{T}$ | $G^{\circ}_T-H^{\circ}_0$ | $\dfrac{G^{\circ}_T-H^{\circ}_{298}}{T}$ | $\dfrac{G^{\circ}_T-H^{\circ}_0}{T}$ | $G^{\circ}_T-H^{\circ}_{298}$ | $C^{\circ}_p$ | $C^{\circ}_{p\,298}$ | $S^{\circ}_{298}$ | $S^{\circ}_T$ or $S^{\circ}_T-S^{\circ}_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O^{+2}$ | | | | | | | | | | | | | |
| $O^{+3}$ | | | | | | | | | | | | | |
| $O^{+4}$ | | | | | | | | | | | | | |
| $O^{+5}$ | | | | | | | | | | | | | |
| $O^{+6}$ | | | | | | | | | | | | | |
| $O^{+7}$ | | | | | | | | | | | | | |
| $O^{+8}$ | | | | | | | | | | | | | |
| $O^-$ | | D | | | | | D | | | D | | D | D |
| $OP$ | | D | | | | | D | | | D | | D | D |
| $OS$ | W | D | | | | | D | | | D | W | D | D |
| $OS^-$ | | | | | | | | | | | | | |
| $O_2$ | W | D | A | A | | | D | A | | D A | W | D W | D A |
| $O_2^+$ | | | | | | | | | | | | | |
| $O_2^-$ | | D | | | | | D | | | D | | D | D |
| $O_2^P$ | | | | | | | | | | | | | |

| Empirical Formula | $\Delta H^o_{f\ T}$ | $\Delta H^o_{f298}$ | $\Delta H^o_{f\ 0}$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^o_{f\ T}$ | $\Delta G^o_{f298}$ | Log $K_p$ | I.P. | $\Delta H_{vap}$ | $\Delta H_{fus}$ | $\Delta H_{trans}$ | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_2S$ | D | D W | W | | | D | W | D | A | | | | |
| $O_2S^+$ | | W | W | | | | | | | | | | |
| $O_3$ | D | W D A | W | | | D | W | D | A | | | | |
| $O_3^-$ | | | | | | | | | A | | | | |
| $O_3P^-$ | | W | | | | | W | | | | | | |
| $O_3S$ | D | W D | W | | | D | W | D | | | | | |
| $O_3S^-$ | | W | | | | | W | | | | | | |
| $O_3S^{-2}$ | | W | | | | | W | | | | | | |
| $O_3S_2^{-2}$ | | W | | | | | | | | | | | |
| $O_4$ | | | | | | | | | A | | | | |
| $O_4P^{-3}$ | | W | | | | | W | | | | | | |
| $O_4S^{-2}$ | | W | | | | | W | | | | | | |
| $O_4S_2^{-2}$ | | W | | | | | W | | | | | | |
| $O_6P_4$ | D | W M | | | | D | | D | | | | | |
| $O_6S_2^{-2}$ | | W | | | | | | | | | | | |

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| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $H^\circ_T-H^\circ_0$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{G^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_{p\,298}$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_2S$ | W | D | | | | | D | | | D | W | D W | D |
| $O_2S^+$ | | | | | | | | | | | | | |
| $O_3$ | W | D | | | | | D | | | D | W | D W | D |
| $O_3^-$ | | | | | | | | | | | | | |
| $O_3P^-$ | | | | | | | | | | | | | |
| $O_3S$ | W | D | | | | | D | | | D | W | D W | D |
| $O_3S^-$ | | | | | | | | | | | | M | |
| $O_3S^{-2}$ | | | | | | | | | | | | | |
| $O_3S_2^{-2}$ | | | | | | | | | | | | | |
| $O_4$ | | | | | | | | | | | | | |
| $O_4P^{-3}$ | | | | | | | | | | | | M | |
| $O_4S^{-2}$ | | | | | | | | | | | W | M | |
| $O_4S_2^{-2}$ | | | | | | | | | | | | M | |
| $O_6P_4$ | | D | | | | | D | | | D | | D | D |
| $O_6S_2^{-2}$ | | | | | | | | | | | | | |

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| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G_{f298}$ | Log $K_p$ | I.P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_6S_3^{-2}$ | | W | | | | | | | | | | | |
| $O_6S_4^{-2}$ | | W | | | | | | | | | | | |
| $O_6S_5^{-2}$ | | W | | | | | | | | | | | |
| $O_7P_2^{-4}$ | | W | | | | | W | | | | | | |
| $O_7S_2^{-2}$ | | W | W | | | | | | | | | | |
| $O_8S_2^{-2}$ | | W | W | | | D | W | | | | | | |
| $O_{10}P_4$ | D | D W | | | | D | W | D | A | | | | |
| $P$ | D | D W | | A | A | D | W | D | A | | | | |
| $P^+$ | | | | A | A. | | | | A | | | | |
| $P^-$ | | | | | | | | | A | | | | |
| $PS$ | D | D | | | | D | | D | A | | | | |
| $P_2$ | D | D | | | | D | W | D | A | | | | |
| $P_2^-$ | | W | | | | | | | | | | | |
| $P_2S_3$ | D | D W | W | | | D | W | D | A | | | | |
| $P_4$ | | | | | | | | | | | | | |

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| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\dfrac{H^o_T-H^o_0}{T}$ | $\dfrac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\dfrac{G^o_T-H^o_{298}}{T}$ | $\dfrac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\,298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $O_6S_3^{-2}$ | | | | | | | | | | | | | |
| $O_6S_4^{-2}$ | | | | | | | | | | | | | |
| $O_6S_5^{-2}$ | | | | | | | | | | | | W | |
| $O_7P_2^{-4}$ | | | | | | | | | | | | | |
| $O_7S_2^{-2}$ | | | | | | | | | | | | W | |
| $O_8S_2^{-2}$ | | | | | | | | | | | | | |
| $O_{10}P_4$ | W | D | | | | | D | | | D | W | W D | D |
| P | W | W | A | A | A | | D | | | D A | W | W D | D |
| $P^+$ | | | A | A | A | | | | | A | | | |
| $P^-$ | | | | | | | | | | | | | |
| P̈S | | D | | | | | D | | | D | | D | D |
| $P_2$ | | D | | | | | D | | | D | | W D | D |
| $P_2^-$ | | | | | | | | | | | | | |
| $P_2S_3$ | W | D | | | | | D | | | D | W | W D | D |
| $P_4$ | | | | | | | | | | | | | |

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| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_A\ 0$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | Log $K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_4S_3$ | D | D | | | | D | | D | | | | | |
| $S$ | D | D W | W | A | A | D | W | D | A | | | | |
| $S^+$ | | W | W | | | | | | A | | | | |
| $S^-$ | | W | W | | | | | | | | | | |
| $S^{+2}$ | | W | W | | | | | | | | | | |
| $S^{+3}$ | | W | W | | | | | | | | | | |
| $S^{+4}$ | | W | W | | | | | | | | | | |
| $S^{+5}$ | | W | W | | | | | | | | | | |
| $S^{+6}$ | | W | W | | | | | | | | | | |
| $S^{+7}$ | | W | W | | | | | | | | | | |
| $S^{+8}$ | | W | W | | | | | | | | | | |
| $S^{+9}$ | | W | W | | | | | | | | | | |
| $S^{-2}$ | | W | | | | | W | | | | | | |
| $S_2$ | D | D W | W | | | D | W | D | A | | | | |
| $S_2^+$ | | W | W | | | | | | | | | | |

| Empirical Formula | $H^\circ_{298}-H^\circ_0$ | $H^\circ_T-H^\circ_{298}$ | $H^\circ_T-H^\circ_0$ | $\dfrac{H^\circ_T-H^\circ_0}{T}$ | $\dfrac{H^\circ_T-H^\circ_{298}}{T}$ | $G^\circ_T-H^\circ_0$ | $\dfrac{G^\circ_T-H^\circ_{298}}{T}$ | $\dfrac{G^\circ_T-H^\circ_0}{T}$ | $G^\circ_T-H^\circ_{298}$ | $C^\circ_p$ | $C^\circ_{p\,298}$ | $S^\circ_{298}$ | $S^\circ_T$ or $S^\circ_T-S^\circ_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_4S_3$ | | D | | | | | | | D | D | | D | D |
| S | W | D | A | A | | | | A | D | D A | W | W D | D |
| $S^+$ | | | A | A | | | | A | | A | | | |
| $S^-$ | | | | | | | | | | | | | |
| $S^{+2}$ | | | | | | | | | | | | | |
| $S^{+3}$ | | | | | | | | | | | | | |
| $S^{+4}$ | | | | | | | | | | | | | |
| $S^{+5}$ | | | | | | | | | | | | | |
| $S^{+6}$ | | | | | | | | | | | | | |
| $S^{+7}$ | | | | | | | | | | | | | |
| $S^{+8}$ | | | | | | | | | | | | | |
| $S^{+9}$ | | | | | | | | | | | | | |
| $S^{-2}$ | | | | | | | | | | | | | |
| $S_2$ | W | D | | | | | | | D | D | W | D W | D |
| $S_2^+$ | | | | | | | | | | | | | |

| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\dfrac{H^o_T-H^o_0}{T}$ | $\dfrac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\dfrac{G^o_T-H^o_{298}}{T}$ | $\dfrac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\,298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $S_2^{-2}$ | | | | | | | | | | | | W | |
| $S_3$ | | | | | | | | | | | | W | |
| $S_3^+$ | | | | | | | | | | | | | |
| $S_3^{-2}$ | | | | | | | | | | | | W | |
| $S_4$ | | | | | | | | | | | | | |
| $S_4^+$ | | | | | | | | | | | | W | |
| $S_4^{-2}$ | | | | | | | | | | | | W | |
| $S_5$ | | | | | | | | | | | | | |
| $S_5^+$ | | | | | | | | | | | | W | |
| $S_5^{-2}$ | | | | | | | | | | | | | |
| $S_6$ | | | | | | | | | | | | | |
| $S_6^+$ | | | | | | | | | | | | | |
| $S_7$ | | | | | | | | | | | | | |
| $S_7^+$ | | | | | | | | | | | | | |
| $S_8$ | W | D | | | | | D | | | D | W | D W | S |

| Empirical Formula | $\Delta H^\circ_f\ T$ | $\Delta H^\circ_{f298}$ | $\Delta H^\circ_f\ 0$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^\circ_f\ T$ | $\Delta G^\circ_{f298}$ | $\text{Log } K_p$ | I. P. | $\Delta H$ vap | $\Delta H$ fus | $\Delta H$ trans | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $S_2^{-2}$ | | W | | | | | W | | | | | | |
| $S_3$ | | W | | | | | | | | | | | |
| $S_3^+$ | | W | | | | | | | | | | | |
| $S_3^{-2}$ | | W | | | | | W | | | | | | |
| $S_4$ | | W | | | | | | | | | | | |
| $S_4^+$ | | W | | | | | | | | | | | |
| $S_4^{-2}$ | | W | | | | | W | | | | | | |
| $S_5$ | | W | | | | | | | | | | | |
| $S_5^+$ | | W | | | | | | | | | | | |
| $S_5^{-2}$ | | W | | | | | W | | | | | | |
| $S_6$ | | W | | | | | | | | | | | |
| $S_6^+$ | | W | | | | | | | | | | | |
| $S_7$ | | W | | | | | | | | | | | |
| $S_7^+$ | | W | | | | | | | | | | | |
| $S_8$ | D | D W | W | | | D | W | D | A | | | | |

| Empirical Formula | $\Delta H^o_{f\ T}$ | $\Delta H^o_{f298}$ | $\Delta H^o_{f\ 0}$ | $\Delta H_{A\ 0}$ | $\Delta H_{A298}$ | $\Delta G^o_{f\ T}$ | $\Delta G^o_{f298}$ | Log $K_p$ | I. P. | $\Delta H_{vap}$ | $\Delta H_{fus}$ | $\Delta H_{trans}$ | $P_T$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $S_8^+$ | | M | M | | | | | | | | | | |

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| Empirical Formula | $H^o_{298}-H^o_0$ | $H^o_T-H^o_{298}$ | $H^o_T-H^o_0$ | $\frac{H^o_T-H^o_0}{T}$ | $\frac{H^o_T-H^o_{298}}{T}$ | $G^o_T-H^o_0$ | $\frac{G^o_T-H^o_{298}}{T}$ | $\frac{G^o_T-H^o_0}{T}$ | $G^o_T-H^o_{298}$ | $C^o_p$ | $C^o_{p\ 298}$ | $S^o_{298}$ | $S^o_T$ or $S^o_T-S^o_0$ |
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| $S^+_8$ | | | | | | | | | | | | | |
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