

TABLE A.1

Carbon monoxide (CO), mol. wt. = 28.010, enthalpy of formation @ 298 K  
(kJ/kmol) = -110,541

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 28.687                     | -2,835                                           | -111,308                      | 186.018                       | -128,532                      |
| 298    | 29.072                     | 0                                                | -110,541                      | 197.548                       | -137,163                      |
| 300    | 29.078                     | 54                                               | -110,530                      | 197.728                       | -137,328                      |
| 400    | 29.433                     | 2,979                                            | -110,121                      | 206.141                       | -146,332                      |
| 500    | 29.857                     | 5,943                                            | -110,017                      | 212.752                       | -155,403                      |
| 600    | 30.407                     | 8,955                                            | -110,156                      | 218.242                       | -164,470                      |
| 700    | 31.089                     | 12,029                                           | -110,477                      | 222.979                       | -173,499                      |
| 800    | 31.860                     | 15,176                                           | -110,924                      | 227.180                       | -182,473                      |
| 900    | 32.629                     | 18,401                                           | -111,450                      | 230.978                       | -191,386                      |
| 1000   | 33.255                     | 21,697                                           | -112,022                      | 234.450                       | -200,238                      |
| 1100   | 33.725                     | 25,046                                           | -112,619                      | 237.642                       | -209,030                      |
| 1200   | 34.148                     | 28,440                                           | -113,240                      | 240.595                       | -217,768                      |
| 1300   | 34.530                     | 31,874                                           | -113,881                      | 243.344                       | -226,453                      |
| 1400   | 34.872                     | 35,345                                           | -114,543                      | 245.915                       | -235,087                      |
| 1500   | 35.178                     | 38,847                                           | -115,225                      | 248.332                       | -243,674                      |
| 1600   | 35.451                     | 42,379                                           | -115,925                      | 250.611                       | -252,214                      |
| 1700   | 35.694                     | 45,937                                           | -116,644                      | 252.768                       | -260,711                      |
| 1800   | 35.910                     | 49,517                                           | -117,380                      | 254.814                       | -269,164                      |
| 1900   | 36.101                     | 53,118                                           | -118,132                      | 256.761                       | -277,576                      |
| 2000   | 36.271                     | 56,737                                           | -118,902                      | 258.617                       | -285,948                      |
| 2100   | 36.421                     | 60,371                                           | -119,687                      | 260.391                       | -294,281                      |
| 2200   | 36.553                     | 64,020                                           | -120,488                      | 262.088                       | -302,576                      |
| 2300   | 36.670                     | 67,682                                           | -121,305                      | 263.715                       | -310,835                      |
| 2400   | 36.774                     | 71,354                                           | -122,137                      | 265.278                       | -319,057                      |
| 2500   | 36.867                     | 75,036                                           | -122,984                      | 266.781                       | -327,245                      |
| 2600   | 36.950                     | 78,727                                           | -123,847                      | 268.229                       | -335,399                      |
| 2700   | 37.025                     | 82,426                                           | -124,724                      | 269.625                       | -343,519                      |
| 2800   | 37.093                     | 86,132                                           | -125,616                      | 270.973                       | -351,606                      |
| 2900   | 37.155                     | 89,844                                           | -126,523                      | 272.275                       | -359,661                      |
| 3000   | 37.213                     | 93,562                                           | -127,446                      | 273.536                       | -367,684                      |
| 3100   | 37.268                     | 97,287                                           | -128,383                      | 274.757                       | -375,677                      |
| 3200   | 37.321                     | 101,016                                          | -129,335                      | 275.941                       | -383,639                      |
| 3300   | 37.372                     | 104,751                                          | -130,303                      | 277.090                       | -391,571                      |
| 3400   | 37.422                     | 108,490                                          | -131,285                      | 278.207                       | -399,474                      |
| 3500   | 37.471                     | 112,235                                          | -132,283                      | 279.292                       | -407,347                      |
| 3600   | 37.521                     | 115,985                                          | -133,295                      | 280.349                       | -415,192                      |
| 3700   | 37.570                     | 119,739                                          | -134,323                      | 281.377                       | -423,008                      |
| 3800   | 37.619                     | 123,499                                          | -135,366                      | 282.380                       | -430,796                      |
| 3900   | 37.667                     | 127,263                                          | -136,424                      | 283.358                       | -438,557                      |
| 4000   | 37.716                     | 131,032                                          | -137,497                      | 284.312                       | -446,291                      |
| 4100   | 37.764                     | 134,806                                          | -138,585                      | 285.244                       | -453,997                      |
| 4200   | 37.810                     | 138,585                                          | -139,687                      | 286.154                       | -461,677                      |
| 4300   | 37.855                     | 142,368                                          | -140,804                      | 287.045                       | -469,330                      |
| 4400   | 37.897                     | 146,156                                          | -141,935                      | 287.915                       | -476,957                      |
| 4500   | 37.936                     | 149,948                                          | -143,079                      | 288.768                       | -484,558                      |
| 4600   | 37.970                     | 153,743                                          | -144,236                      | 289.602                       | -492,134                      |
| 4700   | 37.998                     | 157,541                                          | -145,407                      | 290.419                       | -499,684                      |

TABLE A.2

Carbon dioxide (CO<sub>2</sub>), mol. wt. = 44.011, enthalpy of formation @ 298 K  
(kJ/kmol) = -393,546

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 32.387                     | -3,423                                           | -393,483                      | 199.876                       | -394,126                      |
| 298    | 37.198                     | 0                                                | -393,546                      | 213.736                       | -394,428                      |
| 300    | 37.280                     | 69                                               | -393,547                      | 213.966                       | -394,433                      |
| 400    | 41.276                     | 4,003                                            | -393,617                      | 225.257                       | -394,718                      |
| 500    | 44.569                     | 8,301                                            | -393,712                      | 234.833                       | -394,983                      |
| 600    | 47.313                     | 12,899                                           | -393,844                      | 243.209                       | -395,226                      |
| 700    | 49.617                     | 17,749                                           | -394,013                      | 250.680                       | -395,443                      |
| 800    | 51.550                     | 22,810                                           | -394,213                      | 257.436                       | -395,635                      |
| 900    | 53.136                     | 28,047                                           | -394,433                      | 263.603                       | -395,799                      |
| 1000   | 54.360                     | 33,425                                           | -394,659                      | 269.268                       | -395,939                      |
| 1100   | 55.333                     | 38,911                                           | -394,875                      | 274.495                       | -396,056                      |
| 1200   | 56.205                     | 44,488                                           | -395,083                      | 279.348                       | -396,155                      |
| 1300   | 56.984                     | 50,149                                           | -395,287                      | 283.878                       | -396,236                      |
| 1400   | 57.677                     | 55,882                                           | -395,488                      | 288.127                       | -396,301                      |
| 1500   | 58.292                     | 61,681                                           | -395,691                      | 292.128                       | -396,352                      |
| 1600   | 58.836                     | 67,538                                           | -395,897                      | 295.908                       | -396,389                      |
| 1700   | 59.316                     | 73,446                                           | -396,110                      | 299.489                       | -396,414                      |
| 1800   | 59.738                     | 79,399                                           | -396,332                      | 302.892                       | -396,425                      |
| 1900   | 60.108                     | 85,392                                           | -396,564                      | 306.132                       | -396,424                      |
| 2000   | 60.433                     | 91,420                                           | -396,808                      | 309.223                       | -396,410                      |
| 2100   | 60.717                     | 97,477                                           | -397,065                      | 312.179                       | -396,384                      |
| 2200   | 60.966                     | 103,562                                          | -397,338                      | 315.009                       | -396,346                      |
| 2300   | 61.185                     | 109,670                                          | -397,626                      | 317.724                       | -396,294                      |
| 2400   | 61.378                     | 115,798                                          | -397,931                      | 320.333                       | -396,230                      |
| 2500   | 61.548                     | 121,944                                          | -398,253                      | 322.842                       | -396,152                      |
| 2600   | 61.701                     | 128,107                                          | -398,594                      | 325.259                       | -396,061                      |
| 2700   | 61.839                     | 134,284                                          | -398,952                      | 327.590                       | -395,957                      |
| 2800   | 61.965                     | 140,474                                          | -399,329                      | 329.841                       | -395,840                      |
| 2900   | 62.083                     | 146,677                                          | -399,725                      | 332.018                       | -395,708                      |
| 3000   | 62.194                     | 152,891                                          | -400,140                      | 334.124                       | -395,562                      |
| 3100   | 62.301                     | 159,116                                          | -400,573                      | 336.165                       | -395,403                      |
| 3200   | 62.406                     | 165,351                                          | -401,025                      | 338.145                       | -395,229                      |
| 3300   | 62.510                     | 171,597                                          | -401,495                      | 340.067                       | -395,041                      |
| 3400   | 62.614                     | 177,853                                          | -401,983                      | 341.935                       | -394,838                      |
| 3500   | 62.718                     | 184,120                                          | -402,489                      | 343.751                       | -394,620                      |
| 3600   | 62.825                     | 190,397                                          | -403,013                      | 345.519                       | -394,388                      |
| 3700   | 62.932                     | 196,685                                          | -403,553                      | 347.242                       | -394,141                      |
| 3800   | 63.041                     | 202,983                                          | -404,110                      | 348.922                       | -393,879                      |
| 3900   | 63.151                     | 209,293                                          | -404,684                      | 350.561                       | -393,602                      |
| 4000   | 63.261                     | 215,613                                          | -405,273                      | 352.161                       | -393,311                      |
| 4100   | 63.369                     | 221,945                                          | -405,878                      | 353.725                       | -393,004                      |
| 4200   | 63.474                     | 228,287                                          | -406,499                      | 355.253                       | -392,683                      |
| 4300   | 63.575                     | 234,640                                          | -407,135                      | 356.748                       | -392,346                      |
| 4400   | 63.669                     | 241,002                                          | -407,785                      | 358.210                       | -391,995                      |
| 4500   | 63.753                     | 247,373                                          | -408,451                      | 359.642                       | -391,629                      |
| 4600   | 63.825                     | 253,752                                          | -409,132                      | 361.044                       | -391,247                      |
| 4700   | 63.881                     | 260,138                                          | -409,828                      | 362.417                       | -390,851                      |

TABLE A.3

Hydrogen (H<sub>2</sub>), mol. wt. = 2.016, enthalpy of formation @ 298 K (kJ/kmol) = 0

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 28.522                     | -2,818                                           | 0                             | 119.137                       | 0                             |
| 298    | 28.871                     | 0                                                | 0                             | 130.595                       | 0                             |
| 300    | 28.877                     | 53                                               | 0                             | 130.773                       | 0                             |
| 400    | 29.120                     | 2,954                                            | 0                             | 139.116                       | 0                             |
| 500    | 29.275                     | 5,874                                            | 0                             | 145.632                       | 0                             |
| 600    | 29.375                     | 8,807                                            | 0                             | 150.979                       | 0                             |
| 700    | 29.461                     | 11,749                                           | 0                             | 155.514                       | 0                             |
| 800    | 29.581                     | 14,701                                           | 0                             | 159.455                       | 0                             |
| 900    | 29.792                     | 17,668                                           | 0                             | 162.950                       | 0                             |
| 1000   | 30.160                     | 20,664                                           | 0                             | 166.106                       | 0                             |
| 1100   | 30.625                     | 23,704                                           | 0                             | 169.003                       | 0                             |
| 1200   | 31.077                     | 26,789                                           | 0                             | 171.687                       | 0                             |
| 1300   | 31.516                     | 29,919                                           | 0                             | 174.192                       | 0                             |
| 1400   | 31.943                     | 33,092                                           | 0                             | 176.543                       | 0                             |
| 1500   | 32.356                     | 36,307                                           | 0                             | 178.761                       | 0                             |
| 1600   | 32.758                     | 39,562                                           | 0                             | 180.862                       | 0                             |
| 1700   | 33.146                     | 42,858                                           | 0                             | 182.860                       | 0                             |
| 1800   | 33.522                     | 46,191                                           | 0                             | 184.765                       | 0                             |
| 1900   | 33.885                     | 49,562                                           | 0                             | 186.587                       | 0                             |
| 2000   | 34.236                     | 52,968                                           | 0                             | 188.334                       | 0                             |
| 2100   | 34.575                     | 56,408                                           | 0                             | 190.013                       | 0                             |
| 2200   | 34.901                     | 59,882                                           | 0                             | 191.629                       | 0                             |
| 2300   | 35.216                     | 63,388                                           | 0                             | 193.187                       | 0                             |
| 2400   | 35.519                     | 66,925                                           | 0                             | 194.692                       | 0                             |
| 2500   | 35.811                     | 70,492                                           | 0                             | 196.148                       | 0                             |
| 2600   | 36.091                     | 74,087                                           | 0                             | 197.558                       | 0                             |
| 2700   | 36.361                     | 77,710                                           | 0                             | 198.926                       | 0                             |
| 2800   | 36.621                     | 81,359                                           | 0                             | 200.253                       | 0                             |
| 2900   | 36.871                     | 85,033                                           | 0                             | 201.542                       | 0                             |
| 3000   | 37.112                     | 88,733                                           | 0                             | 202.796                       | 0                             |
| 3100   | 37.343                     | 92,455                                           | 0                             | 204.017                       | 0                             |
| 3200   | 37.566                     | 96,201                                           | 0                             | 205.206                       | 0                             |
| 3300   | 37.781                     | 99,968                                           | 0                             | 206.365                       | 0                             |
| 3400   | 37.989                     | 103,757                                          | 0                             | 207.496                       | 0                             |
| 3500   | 38.190                     | 107,566                                          | 0                             | 208.600                       | 0                             |
| 3600   | 38.385                     | 111,395                                          | 0                             | 209.679                       | 0                             |
| 3700   | 38.574                     | 115,243                                          | 0                             | 210.733                       | 0                             |
| 3800   | 38.759                     | 119,109                                          | 0                             | 211.764                       | 0                             |
| 3900   | 38.939                     | 122,994                                          | 0                             | 212.774                       | 0                             |
| 4000   | 39.116                     | 126,897                                          | 0                             | 213.762                       | 0                             |
| 4100   | 39.291                     | 130,817                                          | 0                             | 214.730                       | 0                             |
| 4200   | 39.464                     | 134,755                                          | 0                             | 215.679                       | 0                             |
| 4300   | 39.636                     | 138,710                                          | 0                             | 216.609                       | 0                             |
| 4400   | 39.808                     | 142,682                                          | 0                             | 217.522                       | 0                             |
| 4500   | 39.981                     | 146,672                                          | 0                             | 218.419                       | 0                             |
| 4600   | 40.156                     | 150,679                                          | 0                             | 219.300                       | 0                             |
| 4700   | 40.334                     | 154,703                                          | 0                             | 220.165                       | 0                             |

TABLE A.4

H atom (H), mol. wt. = 1.008, enthalpy of formation @ 298 K (kJ/kmol) = 217,977

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 20.786                     | -2,040                                           | 217,346                       | 106.305                       | 207,999                       |
| 298    | 20.786                     | 0                                                | 217,977                       | 114.605                       | 203,276                       |
| 300    | 20.786                     | 38                                               | 217,989                       | 114.733                       | 203,185                       |
| 400    | 20.786                     | 2,117                                            | 218,617                       | 120.713                       | 198,155                       |
| 500    | 20.786                     | 4,196                                            | 219,236                       | 125.351                       | 192,968                       |
| 600    | 20.786                     | 6,274                                            | 219,848                       | 129.141                       | 187,657                       |
| 700    | 20.786                     | 8,353                                            | 220,456                       | 132.345                       | 182,244                       |
| 800    | 20.786                     | 10,431                                           | 221,059                       | 135.121                       | 176,744                       |
| 900    | 20.786                     | 12,510                                           | 221,653                       | 137.569                       | 171,169                       |
| 1000   | 20.786                     | 14,589                                           | 222,234                       | 139.759                       | 165,528                       |
| 1100   | 20.786                     | 16,667                                           | 222,793                       | 141.740                       | 159,830                       |
| 1200   | 20.786                     | 18,746                                           | 223,329                       | 143.549                       | 154,082                       |
| 1300   | 20.786                     | 20,824                                           | 223,843                       | 145.213                       | 148,291                       |
| 1400   | 20.786                     | 22,903                                           | 224,335                       | 146.753                       | 142,461                       |
| 1500   | 20.786                     | 24,982                                           | 224,806                       | 148.187                       | 136,596                       |
| 1600   | 20.786                     | 27,060                                           | 225,256                       | 149.528                       | 130,700                       |
| 1700   | 20.786                     | 29,139                                           | 225,687                       | 150.789                       | 124,777                       |
| 1800   | 20.786                     | 31,217                                           | 226,099                       | 151.977                       | 118,830                       |
| 1900   | 20.786                     | 33,296                                           | 226,493                       | 153.101                       | 112,859                       |
| 2000   | 20.786                     | 35,375                                           | 226,868                       | 154.167                       | 106,869                       |
| 2100   | 20.786                     | 37,453                                           | 227,226                       | 155.181                       | 100,860                       |
| 2200   | 20.786                     | 39,532                                           | 227,568                       | 156.148                       | 94,834                        |
| 2300   | 20.786                     | 41,610                                           | 227,894                       | 157.072                       | 88,794                        |
| 2400   | 20.786                     | 43,689                                           | 228,204                       | 157.956                       | 82,739                        |
| 2500   | 20.786                     | 45,768                                           | 228,499                       | 158.805                       | 76,672                        |
| 2600   | 20.786                     | 47,846                                           | 228,780                       | 159.620                       | 70,593                        |
| 2700   | 20.786                     | 49,925                                           | 229,047                       | 160.405                       | 64,504                        |
| 2800   | 20.786                     | 52,003                                           | 229,301                       | 161.161                       | 58,405                        |
| 2900   | 20.786                     | 54,082                                           | 229,543                       | 161.890                       | 52,298                        |
| 3000   | 20.786                     | 56,161                                           | 229,772                       | 162.595                       | 46,182                        |
| 3100   | 20.786                     | 58,239                                           | 229,989                       | 163.276                       | 40,058                        |
| 3200   | 20.786                     | 60,318                                           | 230,195                       | 163.936                       | 33,928                        |
| 3300   | 20.786                     | 62,396                                           | 230,390                       | 164.576                       | 27,792                        |
| 3400   | 20.786                     | 64,475                                           | 230,574                       | 165.196                       | 21,650                        |
| 3500   | 20.786                     | 66,554                                           | 230,748                       | 165.799                       | 15,502                        |
| 3600   | 20.786                     | 68,632                                           | 230,912                       | 166.384                       | 9,350                         |
| 3700   | 20.786                     | 70,711                                           | 231,067                       | 166.954                       | 3,194                         |
| 3800   | 20.786                     | 72,789                                           | 231,212                       | 167.508                       | -2,967                        |
| 3900   | 20.786                     | 74,868                                           | 231,348                       | 168.048                       | -9,132                        |
| 4000   | 20.786                     | 76,947                                           | 231,475                       | 168.575                       | -15,299                       |
| 4100   | 20.786                     | 79,025                                           | 231,594                       | 169.088                       | -21,470                       |
| 4200   | 20.786                     | 81,104                                           | 231,704                       | 169.589                       | -27,644                       |
| 4300   | 20.786                     | 83,182                                           | 231,805                       | 170.078                       | -33,820                       |
| 4400   | 20.786                     | 85,261                                           | 231,897                       | 170.556                       | -39,998                       |
| 4500   | 20.786                     | 87,340                                           | 231,981                       | 171.023                       | -46,179                       |
| 4600   | 20.786                     | 89,418                                           | 232,056                       | 171.480                       | -52,361                       |
| 4700   | 20.786                     | 91,497                                           | 232,123                       | 171.927                       | -58,545                       |

TABLE A.5

Hydroxyl (OH), mol. wt. = 17.007, enthalpy of formation @ 298 K (kJ/kmol)  
= 38,985

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 30.140                     | -2,948                                           | 38,864                        | 171.607                       | 35,808                        |
| 298    | 29.932                     | 0                                                | 38,985                        | 183.604                       | 34,279                        |
| 300    | 29.928                     | 55                                               | 38,987                        | 183.789                       | 34,250                        |
| 400    | 29.718                     | 3,037                                            | 39,030                        | 192.369                       | 32,662                        |
| 500    | 29.570                     | 6,001                                            | 39,000                        | 198.983                       | 31,072                        |
| 600    | 29.527                     | 8,955                                            | 38,909                        | 204.369                       | 29,494                        |
| 700    | 29.615                     | 11,911                                           | 38,770                        | 208.925                       | 27,935                        |
| 800    | 29.844                     | 14,883                                           | 38,599                        | 212.893                       | 26,399                        |
| 900    | 30.208                     | 17,884                                           | 38,410                        | 216.428                       | 24,885                        |
| 1000   | 30.682                     | 20,928                                           | 38,220                        | 219.635                       | 23,392                        |
| 1100   | 31.186                     | 24,022                                           | 38,039                        | 222.583                       | 21,918                        |
| 1200   | 31.662                     | 27,164                                           | 37,867                        | 225.317                       | 20,460                        |
| 1300   | 32.114                     | 30,353                                           | 37,704                        | 227.869                       | 19,017                        |
| 1400   | 32.540                     | 33,586                                           | 37,548                        | 230.265                       | 17,585                        |
| 1500   | 32.943                     | 36,860                                           | 37,397                        | 232.524                       | 16,164                        |
| 1600   | 33.323                     | 40,174                                           | 37,252                        | 234.662                       | 14,753                        |
| 1700   | 33.682                     | 43,524                                           | 37,109                        | 236.693                       | 13,352                        |
| 1800   | 34.019                     | 46,910                                           | 36,969                        | 238.628                       | 11,958                        |
| 1900   | 34.337                     | 50,328                                           | 36,831                        | 240.476                       | 10,573                        |
| 2000   | 34.635                     | 53,776                                           | 36,693                        | 242.245                       | 9,194                         |
| 2100   | 34.915                     | 57,254                                           | 36,555                        | 243.942                       | 7,823                         |
| 2200   | 35.178                     | 60,759                                           | 36,416                        | 245.572                       | 6,458                         |
| 2300   | 35.425                     | 64,289                                           | 36,276                        | 247.141                       | 5,099                         |
| 2400   | 35.656                     | 67,843                                           | 36,133                        | 248.654                       | 3,746                         |
| 2500   | 35.872                     | 71,420                                           | 35,986                        | 250.114                       | 2,400                         |
| 2600   | 36.074                     | 75,017                                           | 35,836                        | 251.525                       | 1,060                         |
| 2700   | 36.263                     | 78,634                                           | 35,682                        | 252.890                       | -275                          |
| 2800   | 36.439                     | 82,269                                           | 35,524                        | 254.212                       | -1,604                        |
| 2900   | 36.604                     | 85,922                                           | 35,360                        | 255.493                       | -2,927                        |
| 3000   | 36.759                     | 89,590                                           | 35,191                        | 256.737                       | -4,245                        |
| 3100   | 36.903                     | 93,273                                           | 35,016                        | 257.945                       | -5,556                        |
| 3200   | 37.039                     | 96,970                                           | 34,835                        | 259.118                       | -6,862                        |
| 3300   | 37.166                     | 100,681                                          | 34,648                        | 260.260                       | -8,162                        |
| 3400   | 37.285                     | 104,403                                          | 34,454                        | 261.371                       | -9,457                        |
| 3500   | 37.398                     | 108,137                                          | 34,253                        | 262.454                       | -10,745                       |
| 3600   | 37.504                     | 111,882                                          | 34,046                        | 263.509                       | -12,028                       |
| 3700   | 37.605                     | 115,638                                          | 33,831                        | 264.538                       | -13,305                       |
| 3800   | 37.701                     | 119,403                                          | 33,610                        | 265.542                       | -14,576                       |
| 3900   | 37.793                     | 123,178                                          | 33,381                        | 266.522                       | -15,841                       |
| 4000   | 37.882                     | 126,962                                          | 33,146                        | 267.480                       | -17,100                       |
| 4100   | 37.968                     | 130,754                                          | 32,903                        | 268.417                       | -18,353                       |
| 4200   | 38.052                     | 134,555                                          | 32,654                        | 269.333                       | -19,600                       |
| 4300   | 38.135                     | 138,365                                          | 32,397                        | 270.229                       | -20,841                       |
| 4400   | 38.217                     | 142,182                                          | 32,134                        | 271.107                       | -22,076                       |
| 4500   | 38.300                     | 146,008                                          | 31,864                        | 271.967                       | -23,306                       |
| 4600   | 38.382                     | 149,842                                          | 31,588                        | 272.809                       | -24,528                       |
| 4700   | 38.466                     | 153,685                                          | 31,305                        | 273.636                       | -25,745                       |

TABLE A.6

Water (H<sub>2</sub>O), mol. wt. = 18.016, enthalpy of formation @ 298 K (kJ/kmol) = -241,845, enthalpy of vaporization (kJ/kmol) = 44,010

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 32.255                     | -3,227                                           | -240,838                      | 175.602                       | -232,779                      |
| 298    | 33.448                     | 0                                                | -241,845                      | 188.715                       | -228,608                      |
| 300    | 33.468                     | 62                                               | -241,865                      | 188.922                       | -228,526                      |
| 400    | 34.437                     | 3,458                                            | -242,858                      | 198.686                       | -223,929                      |
| 500    | 35.337                     | 6,947                                            | -243,822                      | 206.467                       | -219,085                      |
| 600    | 36.288                     | 10,528                                           | -244,753                      | 212.992                       | -214,049                      |
| 700    | 37.364                     | 14,209                                           | -245,638                      | 218.665                       | -208,861                      |
| 800    | 38.587                     | 18,005                                           | -246,461                      | 223.733                       | -203,550                      |
| 900    | 39.930                     | 21,930                                           | -247,209                      | 228.354                       | -198,141                      |
| 1000   | 41.315                     | 25,993                                           | -247,879                      | 232.633                       | -192,652                      |
| 1100   | 42.638                     | 30,191                                           | -248,475                      | 236.634                       | -187,100                      |
| 1200   | 43.874                     | 34,518                                           | -249,005                      | 240.397                       | -181,497                      |
| 1300   | 45.027                     | 38,963                                           | -249,477                      | 243.955                       | -175,852                      |
| 1400   | 46.102                     | 43,520                                           | -249,895                      | 247.332                       | -170,172                      |
| 1500   | 47.103                     | 48,181                                           | -250,267                      | 250.547                       | -164,464                      |
| 1600   | 48.035                     | 52,939                                           | -250,597                      | 253.617                       | -158,733                      |
| 1700   | 48.901                     | 57,786                                           | -250,890                      | 256.556                       | -152,983                      |
| 1800   | 49.705                     | 62,717                                           | -251,151                      | 259.374                       | -147,216                      |
| 1900   | 50.451                     | 67,725                                           | -251,384                      | 262.081                       | -141,435                      |
| 2000   | 51.143                     | 72,805                                           | -251,594                      | 264.687                       | -135,643                      |
| 2100   | 51.784                     | 77,952                                           | -251,783                      | 267.198                       | -129,841                      |
| 2200   | 52.378                     | 83,160                                           | -251,955                      | 269.621                       | -124,030                      |
| 2300   | 52.927                     | 88,426                                           | -252,113                      | 271.961                       | -118,211                      |
| 2400   | 53.435                     | 93,744                                           | -252,261                      | 274.225                       | -112,386                      |
| 2500   | 53.905                     | 99,112                                           | -252,399                      | 276.416                       | -106,555                      |
| 2600   | 54.340                     | 104,524                                          | -252,532                      | 278.539                       | -100,719                      |
| 2700   | 54.742                     | 109,979                                          | -252,659                      | 280.597                       | -94,878                       |
| 2800   | 55.115                     | 115,472                                          | -252,785                      | 282.595                       | -89,031                       |
| 2900   | 55.459                     | 121,001                                          | -252,909                      | 284.535                       | -83,181                       |
| 3000   | 55.779                     | 126,563                                          | -253,034                      | 286.420                       | -77,326                       |
| 3100   | 56.076                     | 132,156                                          | -253,161                      | 288.254                       | -71,467                       |
| 3200   | 56.353                     | 137,777                                          | -253,290                      | 290.039                       | -65,604                       |
| 3300   | 56.610                     | 143,426                                          | -253,423                      | 291.777                       | -59,737                       |
| 3400   | 56.851                     | 149,099                                          | -253,561                      | 293.471                       | -53,865                       |
| 3500   | 57.076                     | 154,795                                          | -253,704                      | 295.122                       | -47,990                       |
| 3600   | 57.288                     | 160,514                                          | -253,852                      | 296.733                       | -42,110                       |
| 3700   | 57.488                     | 166,252                                          | -254,007                      | 298.305                       | -36,226                       |
| 3800   | 57.676                     | 172,011                                          | -254,169                      | 299.841                       | -30,338                       |
| 3900   | 57.856                     | 177,787                                          | -254,338                      | 301.341                       | -24,446                       |
| 4000   | 58.026                     | 183,582                                          | -254,515                      | 302.808                       | -18,549                       |
| 4100   | 58.190                     | 189,392                                          | -254,699                      | 304.243                       | -12,648                       |
| 4200   | 58.346                     | 195,219                                          | -254,892                      | 305.647                       | -6,742                        |
| 4300   | 58.496                     | 201,061                                          | -255,093                      | 307.022                       | -831                          |
| 4400   | 58.641                     | 206,918                                          | -255,303                      | 308.368                       | 5,085                         |
| 4500   | 58.781                     | 212,790                                          | -255,522                      | 309.688                       | 11,005                        |
| 4600   | 58.916                     | 218,674                                          | -255,751                      | 310.981                       | 16,930                        |
| 4700   | 59.047                     | 224,573                                          | -255,990                      | 312.250                       | 22,861                        |

TABLE A.7

Nitrogen ( $N_2$ ), mol. wt. = 28.013, enthalpy of formation @ 298 K (kJ/kmol) = 0

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 28.793                     | -2,841                                           | 0                             | 179.959                       | 0                             |
| 298    | 29.071                     | 0                                                | 0                             | 191.511                       | 0                             |
| 300    | 29.075                     | 54                                               | 0                             | 191.691                       | 0                             |
| 400    | 29.319                     | 2,973                                            | 0                             | 200.088                       | 0                             |
| 500    | 29.636                     | 5,920                                            | 0                             | 206.662                       | 0                             |
| 600    | 30.086                     | 8,905                                            | 0                             | 212.103                       | 0                             |
| 700    | 30.684                     | 11,942                                           | 0                             | 216.784                       | 0                             |
| 800    | 31.394                     | 15,046                                           | 0                             | 220.927                       | 0                             |
| 900    | 32.131                     | 18,222                                           | 0                             | 224.667                       | 0                             |
| 1000   | 32.762                     | 21,468                                           | 0                             | 228.087                       | 0                             |
| 1100   | 33.258                     | 24,770                                           | 0                             | 231.233                       | 0                             |
| 1200   | 33.707                     | 28,118                                           | 0                             | 234.146                       | 0                             |
| 1300   | 34.113                     | 31,510                                           | 0                             | 236.861                       | 0                             |
| 1400   | 34.477                     | 34,939                                           | 0                             | 239.402                       | 0                             |
| 1500   | 34.805                     | 38,404                                           | 0                             | 241.792                       | 0                             |
| 1600   | 35.099                     | 41,899                                           | 0                             | 244.048                       | 0                             |
| 1700   | 35.361                     | 45,423                                           | 0                             | 246.184                       | 0                             |
| 1800   | 35.595                     | 48,971                                           | 0                             | 248.212                       | 0                             |
| 1900   | 35.803                     | 52,541                                           | 0                             | 250.142                       | 0                             |
| 2000   | 35.988                     | 56,130                                           | 0                             | 251.983                       | 0                             |
| 2100   | 36.152                     | 59,738                                           | 0                             | 253.743                       | 0                             |
| 2200   | 36.298                     | 63,360                                           | 0                             | 255.429                       | 0                             |
| 2300   | 36.428                     | 66,997                                           | 0                             | 257.045                       | 0                             |
| 2400   | 36.543                     | 70,645                                           | 0                             | 258.598                       | 0                             |
| 2500   | 36.645                     | 74,305                                           | 0                             | 260.092                       | 0                             |
| 2600   | 36.737                     | 77,974                                           | 0                             | 261.531                       | 0                             |
| 2700   | 36.820                     | 81,652                                           | 0                             | 262.919                       | 0                             |
| 2800   | 36.895                     | 85,338                                           | 0                             | 264.259                       | 0                             |
| 2900   | 36.964                     | 89,031                                           | 0                             | 265.555                       | 0                             |
| 3000   | 37.028                     | 92,730                                           | 0                             | 266.810                       | 0                             |
| 3100   | 37.088                     | 96,436                                           | 0                             | 268.025                       | 0                             |
| 3200   | 37.144                     | 100,148                                          | 0                             | 269.203                       | 0                             |
| 3300   | 37.198                     | 103,865                                          | 0                             | 270.347                       | 0                             |
| 3400   | 37.251                     | 107,587                                          | 0                             | 271.458                       | 0                             |
| 3500   | 37.302                     | 111,315                                          | 0                             | 272.539                       | 0                             |
| 3600   | 37.352                     | 115,048                                          | 0                             | 273.590                       | 0                             |
| 3700   | 37.402                     | 118,786                                          | 0                             | 274.614                       | 0                             |
| 3800   | 37.452                     | 122,528                                          | 0                             | 275.612                       | 0                             |
| 3900   | 37.501                     | 126,276                                          | 0                             | 276.586                       | 0                             |
| 4000   | 37.549                     | 130,028                                          | 0                             | 277.536                       | 0                             |
| 4100   | 37.597                     | 133,786                                          | 0                             | 278.464                       | 0                             |
| 4200   | 37.643                     | 137,548                                          | 0                             | 279.370                       | 0                             |
| 4300   | 37.688                     | 141,314                                          | 0                             | 280.257                       | 0                             |
| 4400   | 37.730                     | 145,085                                          | 0                             | 281.123                       | 0                             |
| 4500   | 37.768                     | 148,860                                          | 0                             | 281.972                       | 0                             |
| 4600   | 37.803                     | 152,639                                          | 0                             | 282.802                       | 0                             |
| 4700   | 37.832                     | 156,420                                          | 0                             | 283.616                       | 0                             |

TABLE A.8

N atom (N), mol. wt. = 14.007, enthalpy of formation @ 298 K (kJ/kmol)  
= 472,629

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 20.790                     | -2,040                                           | 472,008                       | 144.889                       | 461,026                       |
| 298    | 20.786                     | 0                                                | 472,629                       | 153.189                       | 455,504                       |
| 300    | 20.786                     | 38                                               | 472,640                       | 153.317                       | 455,398                       |
| 400    | 20.786                     | 2,117                                            | 473,258                       | 159.297                       | 449,557                       |
| 500    | 20.786                     | 4,196                                            | 473,864                       | 163.935                       | 443,562                       |
| 600    | 20.786                     | 6,274                                            | 474,450                       | 167.725                       | 437,446                       |
| 700    | 20.786                     | 8,353                                            | 475,010                       | 170.929                       | 431,234                       |
| 800    | 20.786                     | 10,431                                           | 475,537                       | 173.705                       | 424,944                       |
| 900    | 20.786                     | 12,510                                           | 476,027                       | 176.153                       | 418,590                       |
| 1000   | 20.786                     | 14,589                                           | 476,483                       | 178.343                       | 412,183                       |
| 1100   | 20.792                     | 16,668                                           | 476,911                       | 180.325                       | 405,732                       |
| 1200   | 20.795                     | 18,747                                           | 477,316                       | 182.134                       | 399,243                       |
| 1300   | 20.795                     | 20,826                                           | 477,700                       | 183.798                       | 392,721                       |
| 1400   | 20.793                     | 22,906                                           | 478,064                       | 185.339                       | 386,171                       |
| 1500   | 20.790                     | 24,985                                           | 478,411                       | 186.774                       | 379,595                       |
| 1600   | 20.786                     | 27,064                                           | 478,742                       | 188.115                       | 372,996                       |
| 1700   | 20.782                     | 29,142                                           | 479,059                       | 189.375                       | 366,377                       |
| 1800   | 20.779                     | 31,220                                           | 479,363                       | 190.563                       | 359,740                       |
| 1900   | 20.777                     | 33,298                                           | 479,656                       | 191.687                       | 353,086                       |
| 2000   | 20.776                     | 35,376                                           | 479,939                       | 192.752                       | 346,417                       |
| 2100   | 20.778                     | 37,453                                           | 480,213                       | 193.766                       | 339,735                       |
| 2200   | 20.783                     | 39,531                                           | 480,479                       | 194.733                       | 333,039                       |
| 2300   | 20.791                     | 41,610                                           | 480,740                       | 195.657                       | 326,331                       |
| 2400   | 20.802                     | 43,690                                           | 480,995                       | 196.542                       | 319,612                       |
| 2500   | 20.818                     | 45,771                                           | 481,246                       | 197.391                       | 312,883                       |
| 2600   | 20.838                     | 47,853                                           | 481,494                       | 198.208                       | 306,143                       |
| 2700   | 20.864                     | 49,938                                           | 481,740                       | 198.995                       | 299,394                       |
| 2800   | 20.895                     | 52,026                                           | 481,985                       | 199.754                       | 292,636                       |
| 2900   | 20.931                     | 54,118                                           | 482,230                       | 200.488                       | 285,870                       |
| 3000   | 20.974                     | 56,213                                           | 482,476                       | 201.199                       | 279,094                       |
| 3100   | 21.024                     | 58,313                                           | 482,723                       | 201.887                       | 272,311                       |
| 3200   | 21.080                     | 60,418                                           | 482,972                       | 202.555                       | 265,519                       |
| 3300   | 21.143                     | 62,529                                           | 483,224                       | 203.205                       | 258,720                       |
| 3400   | 21.214                     | 64,647                                           | 483,481                       | 203.837                       | 251,913                       |
| 3500   | 21.292                     | 66,772                                           | 483,742                       | 204.453                       | 245,099                       |
| 3600   | 21.378                     | 68,905                                           | 484,009                       | 205.054                       | 238,276                       |
| 3700   | 21.472                     | 71,048                                           | 484,283                       | 205.641                       | 231,447                       |
| 3800   | 21.575                     | 73,200                                           | 484,564                       | 206.215                       | 224,610                       |
| 3900   | 21.686                     | 75,363                                           | 484,853                       | 206.777                       | 217,765                       |
| 4000   | 21.805                     | 77,537                                           | 485,151                       | 207.328                       | 210,913                       |
| 4100   | 21.934                     | 79,724                                           | 485,459                       | 207.868                       | 204,053                       |
| 4200   | 22.071                     | 81,924                                           | 485,779                       | 208.398                       | 197,186                       |
| 4300   | 22.217                     | 84,139                                           | 486,110                       | 208.919                       | 190,310                       |
| 4400   | 22.372                     | 86,368                                           | 486,453                       | 209.431                       | 183,427                       |
| 4500   | 22.536                     | 88,613                                           | 486,811                       | 209.936                       | 176,536                       |
| 4600   | 22.709                     | 90,875                                           | 487,184                       | 210.433                       | 169,637                       |
| 4700   | 22.891                     | 93,155                                           | 487,573                       | 210.923                       | 162,730                       |

TABLE A.9

Nitric oxide (NO), mol. wt. = 30.006, enthalpy of formation @ 298 K (kJ/kmol) = 90,297

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 29.374                     | -2,901                                           | 90,234                        | 198.856                       | 87,811                        |
| 298    | 29.728                     | 0                                                | 90,297                        | 210.652                       | 86,607                        |
| 300    | 29.735                     | 55                                               | 90,298                        | 210.836                       | 86,584                        |
| 400    | 30.103                     | 3,046                                            | 90,341                        | 219.439                       | 85,340                        |
| 500    | 30.570                     | 6,079                                            | 90,367                        | 226.204                       | 84,086                        |
| 600    | 31.174                     | 9,165                                            | 90,382                        | 231.829                       | 82,828                        |
| 700    | 31.908                     | 12,318                                           | 90,393                        | 236.688                       | 81,568                        |
| 800    | 32.715                     | 15,549                                           | 90,405                        | 241.001                       | 80,307                        |
| 900    | 33.489                     | 18,860                                           | 90,421                        | 244.900                       | 79,043                        |
| 1000   | 34.076                     | 22,241                                           | 90,443                        | 248.462                       | 77,778                        |
| 1100   | 34.483                     | 25,669                                           | 90,465                        | 251.729                       | 76,510                        |
| 1200   | 34.850                     | 29,136                                           | 90,486                        | 254.745                       | 75,241                        |
| 1300   | 35.180                     | 32,638                                           | 90,505                        | 257.548                       | 73,970                        |
| 1400   | 35.474                     | 36,171                                           | 90,520                        | 260.166                       | 72,697                        |
| 1500   | 35.737                     | 39,732                                           | 90,532                        | 262.623                       | 71,423                        |
| 1600   | 35.972                     | 43,317                                           | 90,538                        | 264.937                       | 70,149                        |
| 1700   | 36.180                     | 46,925                                           | 90,539                        | 267.124                       | 68,875                        |
| 1800   | 36.364                     | 50,552                                           | 90,534                        | 269.197                       | 67,601                        |
| 1900   | 36.527                     | 54,197                                           | 90,523                        | 271.168                       | 66,327                        |
| 2000   | 36.671                     | 57,857                                           | 90,505                        | 273.045                       | 65,054                        |
| 2100   | 36.797                     | 61,531                                           | 90,479                        | 274.838                       | 63,782                        |
| 2200   | 36.909                     | 65,216                                           | 90,447                        | 276.552                       | 62,511                        |
| 2300   | 37.008                     | 68,912                                           | 90,406                        | 278.195                       | 61,243                        |
| 2400   | 37.095                     | 72,617                                           | 90,358                        | 279.772                       | 59,976                        |
| 2500   | 37.173                     | 76,331                                           | 90,303                        | 281.288                       | 58,711                        |
| 2600   | 37.242                     | 80,052                                           | 90,239                        | 282.747                       | 57,448                        |
| 2700   | 37.305                     | 83,779                                           | 90,168                        | 284.154                       | 56,188                        |
| 2800   | 37.362                     | 87,513                                           | 90,089                        | 285.512                       | 54,931                        |
| 2900   | 37.415                     | 91,251                                           | 90,003                        | 286.824                       | 53,677                        |
| 3000   | 37.464                     | 94,995                                           | 89,909                        | 288.093                       | 52,426                        |
| 3100   | 37.511                     | 98,744                                           | 89,809                        | 289.322                       | 51,178                        |
| 3200   | 37.556                     | 102,498                                          | 89,701                        | 290.514                       | 49,934                        |
| 3300   | 37.600                     | 106,255                                          | 89,586                        | 291.670                       | 48,693                        |
| 3400   | 37.643                     | 110,018                                          | 89,465                        | 292.793                       | 47,456                        |
| 3500   | 37.686                     | 113,784                                          | 89,337                        | 293.885                       | 46,222                        |
| 3600   | 37.729                     | 117,555                                          | 89,203                        | 294.947                       | 44,992                        |
| 3700   | 37.771                     | 121,330                                          | 89,063                        | 295.981                       | 43,766                        |
| 3800   | 37.815                     | 125,109                                          | 88,918                        | 296.989                       | 42,543                        |
| 3900   | 37.858                     | 128,893                                          | 88,767                        | 297.972                       | 41,325                        |
| 4000   | 37.900                     | 132,680                                          | 88,611                        | 298.931                       | 40,110                        |
| 4100   | 37.943                     | 136,473                                          | 88,449                        | 299.867                       | 38,900                        |
| 4200   | 37.984                     | 140,269                                          | 88,283                        | 300.782                       | 37,693                        |
| 4300   | 38.023                     | 144,069                                          | 88,112                        | 301.677                       | 36,491                        |
| 4400   | 38.060                     | 147,873                                          | 87,936                        | 302.551                       | 35,292                        |
| 4500   | 38.093                     | 151,681                                          | 87,755                        | 303.407                       | 34,098                        |
| 4600   | 38.122                     | 155,492                                          | 87,569                        | 304.244                       | 32,908                        |
| 4700   | 38.146                     | 159,305                                          | 87,379                        | 305.064                       | 31,721                        |

TABLE A.10

Nitrogen dioxide ( $\text{NO}_2$ ), mol. wt. = 46.006, enthalpy of formation @ 298 K  
(kJ/kmol) = 33,098

| $T(\text{K})$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|---------------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200           | 32.936                     | -3,432                                           | 33,961                        | 226.016                       | 45,453                        |
| 298           | 36.881                     | 0                                                | 33,098                        | 239.925                       | 51,291                        |
| 300           | 36.949                     | 68                                               | 33,085                        | 240.153                       | 51,403                        |
| 400           | 40.331                     | 3,937                                            | 32,521                        | 251.259                       | 57,602                        |
| 500           | 43.227                     | 8,118                                            | 32,173                        | 260.578                       | 63,916                        |
| 600           | 45.737                     | 12,569                                           | 31,974                        | 268.686                       | 70,285                        |
| 700           | 47.913                     | 17,255                                           | 31,885                        | 275.904                       | 76,679                        |
| 800           | 49.762                     | 22,141                                           | 31,880                        | 282.427                       | 83,079                        |
| 900           | 51.243                     | 27,195                                           | 31,938                        | 288.377                       | 89,476                        |
| 1000          | 52.271                     | 32,375                                           | 32,035                        | 293.834                       | 95,864                        |
| 1100          | 52.989                     | 37,638                                           | 32,146                        | 298.850                       | 102,242                       |
| 1200          | 53.625                     | 42,970                                           | 32,267                        | 303.489                       | 108,609                       |
| 1300          | 54.186                     | 48,361                                           | 32,392                        | 307.804                       | 114,966                       |
| 1400          | 54.679                     | 53,805                                           | 32,519                        | 311.838                       | 121,313                       |
| 1500          | 55.109                     | 59,295                                           | 32,643                        | 315.625                       | 127,651                       |
| 1600          | 55.483                     | 64,825                                           | 32,762                        | 319.194                       | 133,981                       |
| 1700          | 55.805                     | 70,390                                           | 32,873                        | 322.568                       | 140,303                       |
| 1800          | 56.082                     | 75,984                                           | 32,973                        | 325.765                       | 146,620                       |
| 1900          | 56.318                     | 81,605                                           | 33,061                        | 328.804                       | 152,931                       |
| 2000          | 56.517                     | 87,247                                           | 33,134                        | 331.698                       | 159,238                       |
| 2100          | 56.685                     | 92,907                                           | 33,192                        | 334.460                       | 165,542                       |
| 2200          | 56.826                     | 98,583                                           | 32,233                        | 337.100                       | 171,843                       |
| 2300          | 56.943                     | 104,271                                          | 33,256                        | 339.629                       | 178,143                       |
| 2400          | 57.040                     | 109,971                                          | 33,262                        | 342.054                       | 184,442                       |
| 2500          | 57.121                     | 115,679                                          | 33,248                        | 344.384                       | 190,742                       |
| 2600          | 57.188                     | 121,394                                          | 33,216                        | 346.626                       | 197,042                       |
| 2700          | 57.244                     | 127,116                                          | 33,165                        | 348.785                       | 203,344                       |
| 2800          | 57.291                     | 132,843                                          | 33,095                        | 350.868                       | 209,648                       |
| 2900          | 57.333                     | 138,574                                          | 33,007                        | 352.879                       | 215,955                       |
| 3000          | 57.371                     | 144,309                                          | 32,900                        | 354.824                       | 222,265                       |
| 3100          | 57.406                     | 150,048                                          | 32,776                        | 356.705                       | 228,579                       |
| 3200          | 57.440                     | 155,791                                          | 32,634                        | 358.529                       | 234,898                       |
| 3300          | 57.474                     | 161,536                                          | 32,476                        | 360.297                       | 241,221                       |
| 3400          | 57.509                     | 167,285                                          | 32,302                        | 362.013                       | 247,549                       |
| 3500          | 57.546                     | 173,038                                          | 32,113                        | 363.680                       | 253,883                       |
| 3600          | 57.584                     | 178,795                                          | 31,908                        | 365.302                       | 260,222                       |
| 3700          | 57.624                     | 184,555                                          | 31,689                        | 366.880                       | 266,567                       |
| 3800          | 57.665                     | 190,319                                          | 31,456                        | 368.418                       | 272,918                       |
| 3900          | 57.708                     | 196,088                                          | 31,210                        | 369.916                       | 279,276                       |
| 4000          | 57.750                     | 201,861                                          | 30,951                        | 371.378                       | 285,639                       |
| 4100          | 57.792                     | 207,638                                          | 30,678                        | 372.804                       | 292,010                       |
| 4200          | 57.831                     | 213,419                                          | 30,393                        | 374.197                       | 298,387                       |
| 4300          | 57.866                     | 219,204                                          | 30,095                        | 375.559                       | 304,772                       |
| 4400          | 57.895                     | 224,992                                          | 29,783                        | 376.889                       | 311,163                       |
| 4500          | 57.915                     | 230,783                                          | 29,457                        | 378.190                       | 317,562                       |
| 4600          | 57.925                     | 236,575                                          | 29,117                        | 379.464                       | 323,968                       |
| 4700          | 57.922                     | 242,367                                          | 28,761                        | 380.709                       | 330,381                       |

TABLE A.11

Oxygen (O<sub>2</sub>), mol. wt. = 31.999, enthalpy of formation @ 298 K (kJ/kmol) = 0

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 28.473                     | -2,836                                           | 0                             | 193.518                       | 0                             |
| 298    | 29.315                     | 0                                                | 0                             | 205.043                       | 0                             |
| 300    | 29.331                     | 54                                               | 0                             | 205.224                       | 0                             |
| 400    | 30.210                     | 3,031                                            | 0                             | 213.782                       | 0                             |
| 500    | 31.114                     | 6,097                                            | 0                             | 220.620                       | 0                             |
| 600    | 32.030                     | 9,254                                            | 0                             | 226.374                       | 0                             |
| 700    | 32.927                     | 12,503                                           | 0                             | 231.379                       | 0                             |
| 800    | 33.757                     | 15,838                                           | 0                             | 235.831                       | 0                             |
| 900    | 34.454                     | 19,250                                           | 0                             | 239.849                       | 0                             |
| 1000   | 34.936                     | 22,721                                           | 0                             | 243.507                       | 0                             |
| 1100   | 35.270                     | 26,232                                           | 0                             | 246.852                       | 0                             |
| 1200   | 35.593                     | 29,775                                           | 0                             | 249.935                       | 0                             |
| 1300   | 35.903                     | 33,350                                           | 0                             | 252.796                       | 0                             |
| 1400   | 36.202                     | 36,955                                           | 0                             | 255.468                       | 0                             |
| 1500   | 36.490                     | 40,590                                           | 0                             | 257.976                       | 0                             |
| 1600   | 36.768                     | 44,253                                           | 0                             | 260.339                       | 0                             |
| 1700   | 37.036                     | 47,943                                           | 0                             | 262.577                       | 0                             |
| 1800   | 37.296                     | 51,660                                           | 0                             | 264.701                       | 0                             |
| 1900   | 37.546                     | 55,402                                           | 0                             | 266.724                       | 0                             |
| 2000   | 37.788                     | 59,169                                           | 0                             | 268.656                       | 0                             |
| 2100   | 38.023                     | 62,959                                           | 0                             | 270.506                       | 0                             |
| 2200   | 38.250                     | 66,773                                           | 0                             | 272.280                       | 0                             |
| 2300   | 38.470                     | 70,609                                           | 0                             | 273.985                       | 0                             |
| 2400   | 38.684                     | 74,467                                           | 0                             | 275.627                       | 0                             |
| 2500   | 38.891                     | 78,346                                           | 0                             | 277.210                       | 0                             |
| 2600   | 39.093                     | 82,245                                           | 0                             | 278.739                       | 0                             |
| 2700   | 39.289                     | 86,164                                           | 0                             | 280.218                       | 0                             |
| 2800   | 39.480                     | 90,103                                           | 0                             | 281.651                       | 0                             |
| 2900   | 39.665                     | 94,060                                           | 0                             | 283.039                       | 0                             |
| 3000   | 39.846                     | 98,036                                           | 0                             | 284.387                       | 0                             |
| 3100   | 40.023                     | 102,029                                          | 0                             | 285.697                       | 0                             |
| 3200   | 40.195                     | 106,040                                          | 0                             | 286.970                       | 0                             |
| 3300   | 40.362                     | 110,068                                          | 0                             | 288.209                       | 0                             |
| 3400   | 40.526                     | 114,112                                          | 0                             | 289.417                       | 0                             |
| 3500   | 40.686                     | 118,173                                          | 0                             | 290.594                       | 0                             |
| 3600   | 40.842                     | 122,249                                          | 0                             | 291.742                       | 0                             |
| 3700   | 40.994                     | 126,341                                          | 0                             | 292.863                       | 0                             |
| 3800   | 41.143                     | 130,448                                          | 0                             | 293.959                       | 0                             |
| 3900   | 41.287                     | 134,570                                          | 0                             | 295.029                       | 0                             |
| 4000   | 41.429                     | 138,705                                          | 0                             | 296.076                       | 0                             |
| 4100   | 41.566                     | 142,855                                          | 0                             | 297.101                       | 0                             |
| 4200   | 41.700                     | 147,019                                          | 0                             | 298.104                       | 0                             |
| 4300   | 41.830                     | 151,195                                          | 0                             | 299.087                       | 0                             |
| 4400   | 41.957                     | 155,384                                          | 0                             | 300.050                       | 0                             |
| 4500   | 42.079                     | 159,586                                          | 0                             | 300.994                       | 0                             |
| 4600   | 42.197                     | 163,800                                          | 0                             | 301.921                       | 0                             |
| 4700   | 42.312                     | 168,026                                          | 0                             | 302.829                       | 0                             |

TABLE A.12

Oxygen atom (O), mol. wt. = 16.000, enthalpy of formation @ 298 K (kJ/kmol) = 249,197

| $T(K)$ | $\bar{c}_p$<br>(kJ/kmol-K) | $(\bar{h}^o(T) - \bar{h}_f^o(298))$<br>(kJ/kmol) | $\bar{h}_f^o(T)$<br>(kJ/kmol) | $\bar{s}^o(T)$<br>(kJ/kmol-K) | $\bar{g}_f^o(T)$<br>(kJ/kmol) |
|--------|----------------------------|--------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 200    | 22.477                     | -2,176                                           | 248,439                       | 152.085                       | 237,374                       |
| 298    | 21.899                     | 0                                                | 249,197                       | 160.945                       | 231,778                       |
| 300    | 21.890                     | 41                                               | 249,211                       | 161.080                       | 231,670                       |
| 400    | 21.500                     | 2,209                                            | 249,890                       | 167.320                       | 225,719                       |
| 500    | 21.256                     | 4,345                                            | 250,494                       | 172.089                       | 219,605                       |
| 600    | 21.113                     | 6,463                                            | 251,033                       | 175.951                       | 213,375                       |
| 700    | 21.033                     | 8,570                                            | 251,516                       | 179.199                       | 207,060                       |
| 800    | 20.986                     | 10,671                                           | 251,949                       | 182.004                       | 200,679                       |
| 900    | 20.952                     | 12,768                                           | 252,340                       | 184.474                       | 194,246                       |
| 1000   | 20.915                     | 14,861                                           | 252,698                       | 186.679                       | 187,772                       |
| 1100   | 20.898                     | 16,952                                           | 253,033                       | 188.672                       | 181,263                       |
| 1200   | 20.882                     | 19,041                                           | 253,350                       | 190.490                       | 174,724                       |
| 1300   | 20.867                     | 21,128                                           | 253,650                       | 192.160                       | 168,159                       |
| 1400   | 20.854                     | 23,214                                           | 253,934                       | 193.706                       | 161,572                       |
| 1500   | 20.843                     | 25,299                                           | 254,201                       | 195.145                       | 154,966                       |
| 1600   | 20.834                     | 27,383                                           | 254,454                       | 196.490                       | 148,342                       |
| 1700   | 20.827                     | 29,466                                           | 254,692                       | 197.753                       | 141,702                       |
| 1800   | 20.822                     | 31,548                                           | 254,916                       | 198.943                       | 135,049                       |
| 1900   | 20.820                     | 33,630                                           | 255,127                       | 200.069                       | 128,384                       |
| 2000   | 20.819                     | 35,712                                           | 255,325                       | 201.136                       | 121,709                       |
| 2100   | 20.821                     | 37,794                                           | 255,512                       | 202.152                       | 115,023                       |
| 2200   | 20.825                     | 39,877                                           | 255,687                       | 203.121                       | 108,329                       |
| 2300   | 20.831                     | 41,959                                           | 255,852                       | 204.047                       | 101,627                       |
| 2400   | 20.840                     | 44,043                                           | 256,007                       | 204.933                       | 94,918                        |
| 2500   | 20.851                     | 46,127                                           | 256,152                       | 205.784                       | 88,203                        |
| 2600   | 20.865                     | 48,213                                           | 256,288                       | 206.602                       | 81,483                        |
| 2700   | 20.881                     | 50,300                                           | 256,416                       | 207.390                       | 74,757                        |
| 2800   | 20.899                     | 52,389                                           | 256,535                       | 208.150                       | 68,027                        |
| 2900   | 20.920                     | 54,480                                           | 256,648                       | 208.884                       | 61,292                        |
| 3000   | 20.944                     | 56,574                                           | 256,753                       | 209.593                       | 54,554                        |
| 3100   | 20.970                     | 58,669                                           | 256,852                       | 210.280                       | 47,812                        |
| 3200   | 20.998                     | 60,768                                           | 256,945                       | 210.947                       | 41,068                        |
| 3300   | 21.028                     | 62,869                                           | 257,032                       | 211.593                       | 34,320                        |
| 3400   | 21.061                     | 64,973                                           | 257,114                       | 212.221                       | 27,570                        |
| 3500   | 21.095                     | 67,081                                           | 257,192                       | 212.832                       | 20,818                        |
| 3600   | 21.132                     | 69,192                                           | 257,265                       | 213.427                       | 14,063                        |
| 3700   | 21.171                     | 71,308                                           | 257,334                       | 214.007                       | 7,307                         |
| 3800   | 21.212                     | 73,427                                           | 257,400                       | 214.572                       | 548                           |
| 3900   | 21.254                     | 75,550                                           | 257,462                       | 215.123                       | -6,212                        |
| 4000   | 21.299                     | 77,678                                           | 257,522                       | 215.662                       | -12,974                       |
| 4100   | 21.345                     | 79,810                                           | 257,579                       | 216.189                       | -19,737                       |
| 4200   | 21.392                     | 81,947                                           | 257,635                       | 216.703                       | -26,501                       |
| 4300   | 21.441                     | 84,088                                           | 257,688                       | 217.207                       | -33,267                       |
| 4400   | 21.490                     | 86,235                                           | 257,740                       | 217.701                       | -40,034                       |
| 4500   | 21.541                     | 88,386                                           | 257,790                       | 218.184                       | -46,802                       |
| 4600   | 21.593                     | 90,543                                           | 257,840                       | 218.658                       | -53,571                       |
| 4700   | 21.646                     | 92,705                                           | 257,889                       | 219.123                       | -60,342                       |

Graphite (C)  
(Standard state element)  
( $\Delta H_f^\circ$ )<sub>298.15</sub> = 0.00 kJ/mole  
Log  $K_p$  = 0.00  
M.W. = 0.012011

Cyano (CN)  
( $\Delta H_f^\circ$ )<sub>298.15</sub> = 435.14 kJ/mole  
M.W. = 0.026018

| T,<br>K | $C_p^\circ$ ,<br>J/mole K | $H^\circ - H_{298}^\circ$ ,<br>kJ/mole | $S^\circ$ ,<br>J/mole K | $C_p^\circ$ ,<br>J/mole K | $H^\circ - H_{298}^\circ$ ,<br>kJ/mole | $S^\circ$ ,<br>J/mole K |
|---------|---------------------------|----------------------------------------|-------------------------|---------------------------|----------------------------------------|-------------------------|
| 100     | 1.67                      | -.99                                   | .95                     | 29.10                     | -5.77                                  | 170.72                  |
| 200     | 5.00                      | -.67                                   | 3.08                    | 29.11                     | -2.86                                  | 190.90                  |
| 298     | 8.52                      | 0.00                                   | 5.74                    | 29.15                     | 0.00                                   | 202.53                  |
| 300     | 8.58                      | .02                                    | 5.79                    | 29.16                     | .05                                    | 202.71                  |
| 400     | 11.82                     | 1.04                                   | 8.72                    | 29.41                     | 2.98                                   | 211.12                  |
| 500     | 14.62                     | 2.36                                   | 11.66                   | 29.94                     | 5.95                                   | 217.74                  |
| 600     | 16.84                     | 3.94                                   | 14.54                   | 30.65                     | 8.97                                   | 223.26                  |
| 700     | 18.54                     | 5.72                                   | 17.26                   | 31.42                     | 12.08                                  | 228.04                  |
| 800     | 19.83                     | 7.64                                   | 19.83                   | 32.17                     | 15.26                                  | 232.29                  |
| 900     | 20.82                     | 9.67                                   | 22.22                   | 32.85                     | 18.51                                  | 236.12                  |
| 1000    | 21.61                     | 11.79                                  | 24.46                   | 33.46                     | 21.82                                  | 239.61                  |
| 1100    | 22.24                     | 13.99                                  | 26.55                   | 33.99                     | 25.20                                  | 242.82                  |
| 1200    | 22.77                     | 16.24                                  | 28.51                   | 34.46                     | 28.62                                  | 245.80                  |
| 1300    | 23.20                     | 18.54                                  | 30.35                   | 34.88                     | 32.09                                  | 248.58                  |
| 1400    | 23.58                     | 20.88                                  | 32.08                   | 35.28                     | 35.60                                  | 251.18                  |
| 1500    | 23.90                     | 23.25                                  | 33.72                   | 35.66                     | 39.14                                  | 253.62                  |
| 1600    | 24.19                     | 25.66                                  | 35.27                   | 36.03                     | 42.73                                  | 255.94                  |
| 1700    | 24.45                     | 28.09                                  | 36.74                   | 36.41                     | 46.35                                  | 258.13                  |
| 1800    | 24.68                     | 30.55                                  | 38.15                   | 36.79                     | 50.01                                  | 260.22                  |
| 1900    | 24.89                     | 33.02                                  | 39.49                   | 37.20                     | 53.71                                  | 262.22                  |
| 2000    | 25.09                     | 35.53                                  | 40.77                   | 37.61                     | 57.45                                  | 264.14                  |
| 2100    | 25.28                     | 38.05                                  | 42.00                   | 38.03                     | 61.23                                  | 265.99                  |
| 2200    | 25.45                     | 40.58                                  | 43.18                   | 38.47                     | 65.06                                  | 267.77                  |
| 2300    | 25.62                     | 43.13                                  | 44.32                   | 38.92                     | 68.93                                  | 269.49                  |
| 2400    | 25.77                     | 45.71                                  | 45.41                   | 39.38                     | 72.84                                  | 271.15                  |
| 2500    | 25.92                     | 48.29                                  | 46.46                   | 39.83                     | 76.80                                  | 272.77                  |
| 2600    | 26.07                     | 50.89                                  | 47.48                   | 40.28                     | 80.81                                  | 274.34                  |
| 2700    | 26.21                     | 53.50                                  | 48.47                   | 40.73                     | 84.86                                  | 275.87                  |
| 2800    | 26.35                     | 56.13                                  | 49.43                   | 41.17                     | 88.95                                  | 277.36                  |
| 2900    | 26.48                     | 58.77                                  | 50.35                   | 41.60                     | 93.09                                  | 278.81                  |
| 3000    | 26.61                     | 61.43                                  | 51.25                   | 42.01                     | 97.27                                  | 280.23                  |
| 3100    | 26.74                     | 64.09                                  | 52.13                   | 42.40                     | 101.49                                 | 281.61                  |
| 3200    | 26.86                     | 66.78                                  | 52.98                   | 42.78                     | 105.75                                 | 282.96                  |
| 3300    | 26.99                     | 69.47                                  | 53.81                   | 43.14                     | 110.05                                 | 284.29                  |
| 3400    | 27.10                     | 72.17                                  | 54.61                   | 43.47                     | 114.38                                 | 285.58                  |
| 3500    | 27.23                     | 74.89                                  | 55.40                   | 43.78                     | 118.74                                 | 286.84                  |

Appendix B1—(continued)

| Methane (CH <sub>4</sub> )<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = -74.87 kJ/mole<br>M.W. = 0.016043 |                                    |                                                                           |                                     | Methyl (CH <sub>3</sub> )<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 145.69 kJ/mole<br>M.W. = 0.015035 |                                                                           |                                     |
|------------------------------------------------------------------------------------------------------------|------------------------------------|---------------------------------------------------------------------------|-------------------------------------|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------|
| <i>T</i> ,<br>K                                                                                            | <i>C<sub>p</sub></i> ,<br>J/mole K | <i>H</i> <sup>°</sup> - <i>H</i> <sub>298</sub> <sup>°</sup> ,<br>kJ/mole | <i>S</i> <sup>°</sup> ,<br>J/mole K | <i>C<sub>p</sub></i> ,<br>J/mole K                                                                        | <i>H</i> <sup>°</sup> - <i>H</i> <sub>298</sub> <sup>°</sup> ,<br>kJ/mole | <i>S</i> <sup>°</sup> ,<br>J/mole K |
| 100                                                                                                        | 33.26                              | -6.70                                                                     | 149.39                              | 33.40                                                                                                     | -6.81                                                                     | 155.79                              |
| 200                                                                                                        | 33.48                              | -3.37                                                                     | 172.47                              | 35.64                                                                                                     | -3.46                                                                     | 179.00                              |
| 298                                                                                                        | 35.64                              | 0.00                                                                      | 186.15                              | 0.00                                                                                                      | 0.00                                                                      | 0.00                                |
| 300                                                                                                        | 35.71                              | .07                                                                       | 186.37                              | 38.75                                                                                                     | .07                                                                       | 193.26                              |
| 400                                                                                                        | 40.50                              | 3.86                                                                      | 197.25                              | 42.04                                                                                                     | 3.92                                                                      | 204.34                              |
| 500                                                                                                        | 46.34                              | 8.20                                                                      | 206.91                              | 45.25                                                                                                     | 8.16                                                                      | 213.78                              |
| 600                                                                                                        | 52.23                              | 13.13                                                                     | 215.88                              | 48.29                                                                                                     | 12.79                                                                     | 222.20                              |
| 700                                                                                                        | 57.79                              | 18.64                                                                     | 224.35                              | 51.17                                                                                                     | 17.78                                                                     | 229.89                              |
| 800                                                                                                        | 62.93                              | 24.67                                                                     | 232.41                              | 53.92                                                                                                     | 23.12                                                                     | 237.02                              |
| 900                                                                                                        | 67.60                              | 31.20                                                                     | 240.10                              | 56.53                                                                                                     | 28.78                                                                     | 243.68                              |
| 1000                                                                                                       | 71.80                              | 38.18                                                                     | 247.45                              | 58.95                                                                                                     | 34.73                                                                     | 249.94                              |
| 1100                                                                                                       | 75.53                              | 45.55                                                                     | 254.47                              | 61.19                                                                                                     | 40.93                                                                     | 255.85                              |
| 1200                                                                                                       | 78.83                              | 53.27                                                                     | 261.18                              | 63.22                                                                                                     | 47.36                                                                     | 261.45                              |
| 1300                                                                                                       | 81.75                              | 61.30                                                                     | 267.61                              | 65.05                                                                                                     | 53.99                                                                     | 266.75                              |
| 1400                                                                                                       | 84.31                              | 69.61                                                                     | 273.76                              | 66.69                                                                                                     | 60.79                                                                     | 271.79                              |
| 1500                                                                                                       | 86.56                              | 78.15                                                                     | 279.66                              | 68.15                                                                                                     | 67.74                                                                     | 276.59                              |
| 1600                                                                                                       | 88.54                              | 86.91                                                                     | 285.31                              | 69.46                                                                                                     | 74.83                                                                     | 281.16                              |
| 1700                                                                                                       | 90.29                              | 95.86                                                                     | 290.73                              | 70.63                                                                                                     | 82.03                                                                     | 285.52                              |
| 1800                                                                                                       | 91.83                              | 104.96                                                                    | 295.93                              | 71.67                                                                                                     | 89.32                                                                     | 289.69                              |
| 1900                                                                                                       | 93.19                              | 114.21                                                                    | 300.94                              | 72.59                                                                                                     | 96.71                                                                     | 293.69                              |
| 2000                                                                                                       | 94.40                              | 123.60                                                                    | 305.75                              | 73.42                                                                                                     | 104.18                                                                    | 297.52                              |
| 2100                                                                                                       | 95.48                              | 133.09                                                                    | 310.38                              | 74.17                                                                                                     | 111.72                                                                    | 301.19                              |
| 2200                                                                                                       | 96.44                              | 142.69                                                                    | 314.85                              | 74.83                                                                                                     | 119.32                                                                    | 304.73                              |
| 2300                                                                                                       | 97.30                              | 152.37                                                                    | 319.15                              | 75.43                                                                                                     | 126.97                                                                    | 308.13                              |
| 2400                                                                                                       | 98.08                              | 162.14                                                                    | 323.31                              | 75.97                                                                                                     | 134.67                                                                    | 311.41                              |
| 2500                                                                                                       | 98.78                              | 171.99                                                                    | 327.33                              | 76.46                                                                                                     | 142.41                                                                    | 314.57                              |
| 2600                                                                                                       | 99.40                              | 181.90                                                                    | 331.21                              | 76.90                                                                                                     | 150.20                                                                    | 317.62                              |
| 2700                                                                                                       | 99.97                              | 191.87                                                                    | 334.98                              | 77.30                                                                                                     | 158.02                                                                    | 320.57                              |
| 2800                                                                                                       | 100.49                             | 201.89                                                                    | 338.62                              | 77.67                                                                                                     | 165.87                                                                    | 323.43                              |
| 2900                                                                                                       | 100.96                             | 211.96                                                                    | 342.16                              | 78.00                                                                                                     | 173.76                                                                    | 326.20                              |
| 3000                                                                                                       | 101.39                             | 222.08                                                                    | 345.59                              | 78.31                                                                                                     | 181.67                                                                    | 328.88                              |
| 3100                                                                                                       | 101.78                             | 232.24                                                                    | 348.92                              | 78.59                                                                                                     | 189.60                                                                    | 331.48                              |
| 3200                                                                                                       | 102.14                             | 242.44                                                                    | 352.15                              | 78.84                                                                                                     | 197.56                                                                    | 334.00                              |
| 3300                                                                                                       | 102.48                             | 252.67                                                                    | 355.31                              | 79.08                                                                                                     | 205.53                                                                    | 336.46                              |
| 3400                                                                                                       | 102.78                             | 262.93                                                                    | 358.37                              | 79.30                                                                                                     | 213.53                                                                    | 338.85                              |
| 3500                                                                                                       | 103.06                             | 273.22                                                                    | 361.35                              | 79.50                                                                                                     | 221.54                                                                    | 341.17                              |

## Appendix B1—(continued)

| Acetylene ( $C_2H_2$ )<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 226.73 kJ/mole<br>M.W. = 0.026038 |                           |                                        |                         | Ethylene ( $C_2H_4$ )<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 52.47 kJ/mole<br>M.W. = 0.028054 |                                        |                         |
|--------------------------------------------------------------------------------------------------------|---------------------------|----------------------------------------|-------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------|-------------------------|
| T,<br>K                                                                                                | $C_p^\circ$ ,<br>J/mole K | $H^\circ - H_{298}^\circ$ ,<br>kJ/mole | $S^\circ$ ,<br>J/mole K | $C_p^\circ$ ,<br>J/mole K                                                                            | $H^\circ - H_{298}^\circ$ ,<br>kJ/mole | $S^\circ$ ,<br>J/mole K |
| 100                                                                                                    | 29.35                     | -7.10                                  | 163.18                  | 33.27                                                                                                | -7.19                                  | 180.44                  |
| 200                                                                                                    | 35.58                     | -3.92                                  | 184.99                  | 35.36                                                                                                | -3.80                                  | 203.85                  |
| 298                                                                                                    | 44.10                     | 0.00                                   | 200.85                  | 42.89                                                                                                | 0.00                                   | 219.22                  |
| 300                                                                                                    | 44.23                     | .08                                    | 201.12                  | 43.06                                                                                                | .08                                    | 219.49                  |
| 400                                                                                                    | 50.48                     | 4.83                                   | 214.75                  | 53.05                                                                                                | 4.88                                   | 233.24                  |
| 500                                                                                                    | 54.87                     | 10.12                                  | 226.52                  | 62.48                                                                                                | 10.67                                  | 246.11                  |
| 600                                                                                                    | 58.29                     | 15.78                                  | 236.83                  | 70.66                                                                                                | 17.33                                  | 258.24                  |
| 700                                                                                                    | 61.15                     | 21.75                                  | 246.04                  | 77.71                                                                                                | 24.76                                  | 269.68                  |
| 800                                                                                                    | 63.76                     | 28.00                                  | 254.38                  | 83.84                                                                                                | 32.85                                  | 280.47                  |
| 900                                                                                                    | 66.11                     | 34.50                                  | 262.02                  | 89.20                                                                                                | 41.51                                  | 290.65                  |
| 1000                                                                                                   | 68.27                     | 41.22                                  | 269.10                  | 93.90                                                                                                | 50.66                                  | 300.18                  |
| 1100                                                                                                   | 70.25                     | 48.15                                  | 275.70                  | 98.02                                                                                                | 60.27                                  | 309.45                  |
| 1200                                                                                                   | 72.05                     | 55.26                                  | 281.90                  | 101.63                                                                                               | 70.25                                  | 318.13                  |
| 1300                                                                                                   | 73.69                     | 62.55                                  | 287.73                  | 104.78                                                                                               | 80.58                                  | 326.40                  |
| 1400                                                                                                   | 75.18                     | 69.99                                  | 293.24                  | 107.55                                                                                               | 91.20                                  | 334.27                  |
| 1500                                                                                                   | 76.53                     | 77.58                                  | 298.48                  | 109.98                                                                                               | 102.08                                 | 341.77                  |
| 1600                                                                                                   | 77.75                     | 85.30                                  | 303.46                  | 112.11                                                                                               | 113.18                                 | 348.94                  |
| 1700                                                                                                   | 78.85                     | 93.13                                  | 308.21                  | 113.98                                                                                               | 124.49                                 | 355.79                  |
| 1800                                                                                                   | 79.85                     | 101.06                                 | 312.74                  | 115.63                                                                                               | 135.97                                 | 362.36                  |
| 1900                                                                                                   | 80.76                     | 109.09                                 | 317.08                  | 117.09                                                                                               | 147.61                                 | 368.65                  |
| 2000                                                                                                   | 81.60                     | 117.21                                 | 321.25                  | 118.39                                                                                               | 159.39                                 | 374.69                  |
| 2100                                                                                                   | 82.36                     | 125.41                                 | 325.25                  | 119.54                                                                                               | 171.28                                 | 380.49                  |
| 2200                                                                                                   | 83.06                     | 133.68                                 | 329.10                  | 120.57                                                                                               | 183.29                                 | 386.08                  |
| 2300                                                                                                   | 83.70                     | 142.02                                 | 332.80                  | 121.49                                                                                               | 195.39                                 | 391.46                  |
| 2400                                                                                                   | 84.31                     | 150.42                                 | 336.38                  | 122.32                                                                                               | 207.58                                 | 396.65                  |
| 2500                                                                                                   | 84.86                     | 158.88                                 | 339.83                  | 123.07                                                                                               | 219.85                                 | 401.66                  |
| 2600                                                                                                   | 85.37                     | 167.39                                 | 343.17                  | 123.74                                                                                               | 232.20                                 | 406.50                  |
| 2700                                                                                                   | 85.85                     | 175.96                                 | 346.40                  | 124.35                                                                                               | 244.60                                 | 411.18                  |
| 2800                                                                                                   | 86.29                     | 184.56                                 | 349.53                  | 124.90                                                                                               | 257.06                                 | 415.71                  |
| 2900                                                                                                   | 86.72                     | 193.21                                 | 352.56                  | 125.41                                                                                               | 269.58                                 | 420.10                  |
| 3000                                                                                                   | 87.11                     | 201.91                                 | 355.51                  | 125.87                                                                                               | 282.14                                 | 424.36                  |
| 3100                                                                                                   | 87.49                     | 210.64                                 | 358.38                  | 126.29                                                                                               | 294.75                                 | 428.50                  |
| 3200                                                                                                   | 87.85                     | 219.40                                 | 361.16                  | 126.67                                                                                               | 307.40                                 | 432.51                  |
| 3300                                                                                                   | 88.19                     | 228.20                                 | 363.87                  | 127.03                                                                                               | 320.08                                 | 436.41                  |
| 3400                                                                                                   | 88.51                     | 237.04                                 | 366.50                  | 127.35                                                                                               | 332.80                                 | 440.21                  |
| 3500                                                                                                   | 88.81                     | 245.91                                 | 369.07                  | 127.65                                                                                               | 345.56                                 | 443.91                  |

| Methylene (CH <sub>2</sub> )<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 386.39 kJ/mole<br>M.W. = 0.014027 |                                           |                                                            |                              | Methylidyne (CH)<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 594.13 kJ/mole<br>M.W. = 0.013019 |                                                            |                              | T,<br>K |
|--------------------------------------------------------------------------------------------------------------|-------------------------------------------|------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------|---------|
| T,<br>K                                                                                                      | C <sub>p</sub> <sup>o</sup> ,<br>J/mole K | H <sup>o</sup> -H <sub>298</sub> <sup>o</sup> ,<br>kJ/mole | S <sup>o</sup> ,<br>J/mole K | C <sub>p</sub> <sup>o</sup> ,<br>J/mole K                                                        | H <sup>o</sup> -H <sub>298</sub> <sup>o</sup> ,<br>kJ/mole | S <sup>o</sup> ,<br>J/mole K |         |
| 100                                                                                                          | 33.26                                     | -6.67                                                      | 157.18                       | 29.26                                                                                            | -5.78                                                      | 151.04                       | 100     |
| 200                                                                                                          | 33.50                                     | -3.33                                                      | 180.26                       | 29.17                                                                                            | -2.86                                                      | 171.28                       | 200     |
| 298                                                                                                          | 34.60                                     | 0.00                                                       | 193.82                       | 29.17                                                                                            | 0.00                                                       | 182.93                       | 298     |
| 300                                                                                                          | 34.63                                     | .06                                                        | 194.03                       | 29.17                                                                                            | .05                                                        | 183.11                       | 300     |
| 400                                                                                                          | 36.14                                     | 3.60                                                       | 204.20                       | 29.22                                                                                            | 2.97                                                       | 191.51                       | 400     |
| 500                                                                                                          | 37.66                                     | 7.29                                                       | 212.43                       | 29.40                                                                                            | 5.90                                                       | 198.04                       | 500     |
| 600                                                                                                          | 39.20                                     | 11.13                                                      | 219.43                       | 29.76                                                                                            | 8.86                                                       | 203.43                       | 600     |
| 700                                                                                                          | 40.81                                     | 15.13                                                      | 225.59                       | 30.29                                                                                            | 11.86                                                      | 208.06                       | 700     |
| 800                                                                                                          | 42.44                                     | 19.30                                                      | 231.15                       | 30.97                                                                                            | 14.92                                                      | 212.15                       | 800     |
| 900                                                                                                          | 44.05                                     | 23.62                                                      | 236.24                       | 31.74                                                                                            | 18.06                                                      | 215.84                       | 900     |
| 1000                                                                                                         | 45.57                                     | 28.10                                                      | 240.96                       | 32.56                                                                                            | 21.27                                                      | 219.22                       | 1000    |
| 1100                                                                                                         | 46.98                                     | 32.73                                                      | 245.37                       | 33.41                                                                                            | 24.57                                                      | 222.36                       | 1100    |
| 1200                                                                                                         | 48.25                                     | 37.50                                                      | 249.52                       | 34.25                                                                                            | 27.95                                                      | 225.31                       | 1200    |
| 1300                                                                                                         | 49.38                                     | 42.38                                                      | 253.42                       | 35.06                                                                                            | 31.42                                                      | 228.08                       | 1300    |
| 1400                                                                                                         | 50.38                                     | 47.37                                                      | 257.12                       | 35.83                                                                                            | 34.97                                                      | 230.71                       | 1400    |
| 1500                                                                                                         | 51.26                                     | 52.45                                                      | 260.63                       | 36.55                                                                                            | 38.58                                                      | 233.20                       | 1500    |
| 1600                                                                                                         | 52.04                                     | 57.62                                                      | 263.96                       | 37.21                                                                                            | 42.27                                                      | 235.58                       | 1600    |
| 1700                                                                                                         | 52.72                                     | 62.86                                                      | 267.14                       | 37.81                                                                                            | 46.02                                                      | 237.86                       | 1700    |
| 1800                                                                                                         | 53.33                                     | 68.16                                                      | 270.17                       | 38.35                                                                                            | 49.83                                                      | 240.04                       | 1800    |
| 1900                                                                                                         | 53.86                                     | 73.52                                                      | 273.06                       | 38.83                                                                                            | 53.69                                                      | 242.12                       | 1900    |
| 2000                                                                                                         | 54.34                                     | 78.93                                                      | 275.84                       | 39.25                                                                                            | 57.60                                                      | 244.12                       | 2000    |
| 2100                                                                                                         | 54.76                                     | 84.38                                                      | 278.50                       | 39.63                                                                                            | 61.54                                                      | 246.05                       | 2100    |
| 2200                                                                                                         | 55.14                                     | 89.88                                                      | 281.06                       | 39.96                                                                                            | 65.52                                                      | 247.90                       | 2200    |
| 2300                                                                                                         | 55.48                                     | 95.41                                                      | 283.52                       | 40.25                                                                                            | 69.53                                                      | 249.68                       | 2300    |
| 2400                                                                                                         | 55.80                                     | 100.98                                                     | 285.88                       | 40.49                                                                                            | 73.57                                                      | 251.40                       | 2400    |
| 2500                                                                                                         | 56.08                                     | 106.57                                                     | 288.17                       | 40.71                                                                                            | 77.63                                                      | 253.06                       | 2500    |
| 2600                                                                                                         | 56.34                                     | 112.19                                                     | 290.37                       | 40.89                                                                                            | 81.71                                                      | 254.66                       | 2600    |
| 2700                                                                                                         | 56.58                                     | 117.84                                                     | 292.50                       | 41.05                                                                                            | 85.81                                                      | 256.21                       | 2700    |
| 2800                                                                                                         | 56.79                                     | 123.50                                                     | 294.57                       | 41.19                                                                                            | 89.92                                                      | 257.70                       | 2800    |
| 2900                                                                                                         | 56.99                                     | 129.19                                                     | 296.56                       | 41.30                                                                                            | 94.04                                                      | 259.15                       | 2900    |
| 3000                                                                                                         | 57.18                                     | 134.90                                                     | 298.50                       | 41.40                                                                                            | 98.18                                                      | 260.55                       | 3000    |
| 3100                                                                                                         | 57.35                                     | 140.63                                                     | 300.38                       | 41.49                                                                                            | 102.32                                                     | 261.91                       | 3100    |
| 3200                                                                                                         | 57.50                                     | 146.37                                                     | 302.20                       | 41.56                                                                                            | 106.47                                                     | 263.23                       | 3200    |
| 3300                                                                                                         | 57.65                                     | 152.13                                                     | 303.97                       | 41.63                                                                                            | 110.63                                                     | 264.51                       | 3300    |
| 3400                                                                                                         | 57.79                                     | 157.90                                                     | 305.70                       | 41.68                                                                                            | 114.80                                                     | 265.75                       | 3400    |
| 3500                                                                                                         | 57.91                                     | 163.69                                                     | 307.37                       | 41.74                                                                                            | 118.97                                                     | 266.96                       | 3500    |

| Real air (App. C4)<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = -0.13 kJ/mole<br>M.W. = 0.028964 |                                           |                                                            |                              | 21% O <sub>2</sub> air<br>( $\Delta H_f^\circ$ ) <sub>298.15</sub> = 0.00 kJ/mole<br>M.W. = 0.028850 |                                                            |                              | T,<br>K |  |
|---------------------------------------------------------------------------------------------------|-------------------------------------------|------------------------------------------------------------|------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------|---------|--|
| T,<br>K                                                                                           | C <sub>p</sub> <sup>o</sup> ,<br>J/mole K | H <sup>o</sup> -H <sub>298</sub> <sup>o</sup> ,<br>kJ/mole | S <sup>o</sup> ,<br>J/mole K | C <sub>p</sub> <sup>o</sup> ,<br>J/mole K                                                            | H <sup>o</sup> -H <sub>298</sub> <sup>o</sup> ,<br>kJ/mole | S <sup>o</sup> ,<br>J/mole K |         |  |
| 100                                                                                               | 29.02                                     | -5.76                                                      | 162.28                       | 29.10                                                                                                | -5.77                                                      | 162.54                       | 100     |  |
| 200                                                                                               | 29.03                                     | -2.85                                                      | 182.40                       | 29.11                                                                                                | -2.86                                                      | 182.71                       | 200     |  |
| 298                                                                                               | 29.10                                     | 0.00                                                       | 194.00                       | 29.18                                                                                                | 0.00                                                       | 194.34                       | 298     |  |
| 300                                                                                               | 29.10                                     | .05                                                        | 194.17                       | 29.18                                                                                                | .05                                                        | 194.52                       |         |  |
| 400                                                                                               | 29.33                                     | 2.97                                                       | 202.58                       | 29.41                                                                                                | 2.98                                                       | 202.94                       | 300     |  |
| 500                                                                                               | 29.82                                     | 5.93                                                       | 209.18                       | 29.90                                                                                                | 5.95                                                       | 209.56                       | 400     |  |
|                                                                                                   |                                           |                                                            |                              |                                                                                                      |                                                            |                              | 500     |  |
| 600                                                                                               | 30.44                                     | 8.95                                                       | 214.66                       | 30.53                                                                                                | 8.97                                                       | 215.07                       | 600     |  |
| 700                                                                                               | 31.13                                     | 12.02                                                      | 219.41                       | 31.22                                                                                                | 12.05                                                      | 219.82                       | 700     |  |
| 800                                                                                               | 31.82                                     | 15.17                                                      | 223.61                       | 31.92                                                                                                | 15.21                                                      | 224.04                       | 800     |  |
| 900                                                                                               | 32.47                                     | 18.38                                                      | 227.40                       | 32.57                                                                                                | 18.43                                                      | 227.84                       | 900     |  |
| 1000                                                                                              | 33.05                                     | 21.66                                                      | 230.85                       | 33.15                                                                                                | 21.72                                                      | 231.30                       | 1000    |  |
| 1100                                                                                              | 33.56                                     | 25.00                                                      | 234.02                       | 33.67                                                                                                | 25.07                                                      | 234.48                       | 1100    |  |
| 1200                                                                                              | 34.02                                     | 28.37                                                      | 236.97                       | 34.13                                                                                                | 28.46                                                      | 237.43                       | 1200    |  |
| 1300                                                                                              | 34.41                                     | 31.79                                                      | 239.71                       | 34.53                                                                                                | 31.89                                                      | 240.18                       | 1300    |  |
| 1400                                                                                              | 34.76                                     | 35.25                                                      | 242.27                       | 34.89                                                                                                | 35.36                                                      | 242.75                       | 1400    |  |
| 1500                                                                                              | 35.07                                     | 38.75                                                      | 244.68                       | 35.20                                                                                                | 38.87                                                      | 245.17                       | 1500    |  |
| 1600                                                                                              | 35.35                                     | 42.27                                                      | 246.95                       | 35.48                                                                                                | 42.40                                                      | 247.45                       | 1600    |  |
| 1700                                                                                              | 35.60                                     | 45.81                                                      | 249.10                       | 35.73                                                                                                | 45.96                                                      | 249.61                       | 1700    |  |
| 1800                                                                                              | 35.82                                     | 49.39                                                      | 251.14                       | 35.95                                                                                                | 49.54                                                      | 251.66                       | 1800    |  |
| 1900                                                                                              | 36.02                                     | 52.98                                                      | 253.08                       | 36.15                                                                                                | 53.15                                                      | 253.60                       | 1900    |  |
| 2000                                                                                              | 36.21                                     | 56.59                                                      | 254.94                       | 36.34                                                                                                | 56.77                                                      | 255.47                       | 2000    |  |
| 2100                                                                                              | 36.38                                     | 60.22                                                      | 256.71                       | 36.51                                                                                                | 60.42                                                      | 257.24                       | 2100    |  |
| 2200                                                                                              | 36.53                                     | 63.86                                                      | 258.40                       | 36.67                                                                                                | 64.08                                                      | 258.95                       | 2200    |  |
| 2300                                                                                              | 36.68                                     | 67.53                                                      | 260.03                       | 36.82                                                                                                | 67.75                                                      | 260.58                       | 2300    |  |
| 2400                                                                                              | 36.82                                     | 71.20                                                      | 261.60                       | 36.96                                                                                                | 71.44                                                      | 262.15                       | 2400    |  |
| 2500                                                                                              | 36.94                                     | 74.89                                                      | 263.10                       | 37.09                                                                                                | 75.14                                                      | 263.66                       | 2500    |  |
| 2600                                                                                              | 37.07                                     | 78.59                                                      | 264.55                       | 37.21                                                                                                | 78.86                                                      | 265.12                       | 2600    |  |
| 2700                                                                                              | 37.18                                     | 82.30                                                      | 265.95                       | 37.32                                                                                                | 82.58                                                      | 266.52                       | 2700    |  |
| 2800                                                                                              | 37.28                                     | 86.03                                                      | 267.31                       | 37.43                                                                                                | 86.32                                                      | 267.88                       | 2800    |  |
| 2900                                                                                              | 37.38                                     | 89.76                                                      | 268.62                       | 37.53                                                                                                | 90.07                                                      | 269.20                       | 2900    |  |
| 3000                                                                                              | 37.48                                     | 93.50                                                      | 269.88                       | 37.62                                                                                                | 93.83                                                      | 270.47                       | 3000    |  |
| 3100                                                                                              | 37.57                                     | 97.25                                                      | 271.11                       | 37.71                                                                                                | 97.60                                                      | 271.71                       | 3100    |  |
| 3200                                                                                              | 37.66                                     | 101.02                                                     | 272.31                       | 37.80                                                                                                | 101.37                                                     | 272.91                       | 3200    |  |
| 3300                                                                                              | 37.74                                     | 104.78                                                     | 273.47                       | 37.89                                                                                                | 105.15                                                     | 274.07                       | 3300    |  |
| 3400                                                                                              | 37.81                                     | 108.56                                                     | 274.60                       | 37.96                                                                                                | 108.95                                                     | 275.20                       | 3400    |  |
| 3500                                                                                              | 37.89                                     | 112.35                                                     | 275.69                       | 38.03                                                                                                | 112.75                                                     | 276.30                       | 3500    |  |