s de fuligem.

as emissões de:

.1. Calcule:

le $O_2$ nos produtos de

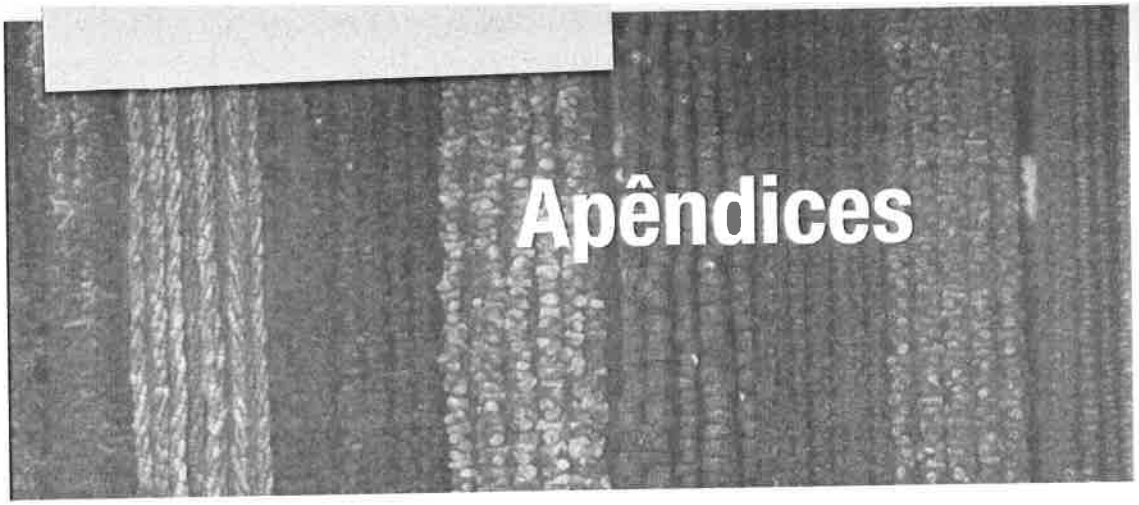
ustão de uma caldeira
$_{O_2} = 0{,}097$, $x_{H_2O} = 0{,}13$,
) que o gás natural que
essencialmente consti-

as a 8% de $O_2$ nos pro-

: alimentada com um
nposição mássica ele-
zoto: 0,35%; enxofre:
siderando combustão
ıcentração mássica de

caldeiras de centrais
s emissões de $SO_2$ de
% de $O_2$ nos produtos
rar nas condições do
o às emissões de $SO_2$.
2.4, para o cálculo da

Calcule, justificando,
os de combustão.



# Apêndices

## APÊNDICE 1
## ENTALPIAS DE FORMAÇÃO PADRÃO

| Espécie | $\bar{h}_f^o$ (25 °C) (kJ/kmol) | Espécie | $\bar{h}_f^o$ (25 °C) (kJ/kmol) |
|---|---|---|---|
| CO | −110 527 | $O_2$ | 0 |
| $CO_2$ | −393 522 | OH | 38 987 |
| H | 217 999 | $CH_4$ (metano) | −74 873 |
| $H_2$ | 0 | $C_2H_2$ (acetileno) | 226 731 |
| $H_2O$ | −241 826 | $C_2H_4$ (eteno) | 52 467 |
| $H_2O_2$ | −136 110 | $C_2H_6$ (etano) | −83 860 |
| N | 472 683 | $C_3H_6$ (propeno) | 20 460 |
| $N_2$ | 0 | $C_3H_8$ (propano) | −103 850 |
| $N_2O$ | 82 050 | $C_4H_8$ (buteno) | 1172 |
| NO | 90 291 | $C_4H_{10}$ (n-butano) | −124 733 |
| $NO_2$ | 33 095 | $C_6H_6$ (benzeno) | 82 927 |
| O | 249 173 | $CH_3OH$ (metanol) | −201 100 |

**Tabela A1.1**
*Entalpias de formação padrão. (Dados extraídos de JANAF Thermochemical Tables, 1985.)*

# APÊNDICE 2
# PROPRIEDADES TERMOQUÍMICAS DE ESPÉCIES QUÍMICAS RELEVANTES EM COMBUSTÃO

$$\bar{c}_p / R_o = a_1 + a_2 T + a_3 T^2 + a_4 T^3 + a_5 T^4$$

$$\frac{\bar{h}^o}{R_o T} = a_1 + \frac{a_2}{2} T + \frac{a_3}{3} T^2 + \frac{a_4}{4} T^3 + \frac{a_5}{5} T^4 + \frac{a_6}{T}$$

$$\frac{\bar{s}^o}{R_o} = a_1 \ln T + a_2 T + \frac{a_3}{2} T^2 + \frac{a_4}{3} T^3 + \frac{a_5}{4} T^4 + a_7$$

| Espécie | T (K) | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|---|---|---|---|---|---|---|---|---|
| CO | 1000 – 5000 | 3,0250780E+00 | 1,4426885E–03 | –5,6308270E–07 | 1,0185813E–10 | –6,9109510E–15 | –1,4268350E+04 | 6,1082170E+00 |
| | 300 – 1000 | 3,2624510E+00 | 1,5119409E–03 | –3,8817550E–06 | 5,5819440E–09 | –2,4749510E–12 | –1,4310539E+04 | 4,8488970E+00 |
| $CO_2$ | 1000 – 5000 | 4,4536230E+00 | 3,1401680E–03 | –1,2784105E–06 | 2,3939960E–10 | –1,6690333E–14 | –4,8966960E+04 | –9,5539590E–01 |
| | 300 – 1000 | 2,2757240E+00 | 9,9220720E–03 | –1,0409113E–05 | 6,8666860E–09 | –2,1172800E–12 | –4,8373140E+04 | 1,0188488E+01 |
| H | 1000 – 5000 | 2,5000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 2,5471620E+04 | –4,6011760E–01 |
| | 300 – 1000 | 2,5000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 0,0000000E+00 | 2,5471620E+04 | –4,6011760E–01 |
| $H_2$ | 1000 – 5000 | 2,9914230E+00 | 7,0006440E–04 | –5,6338280E–08 | –9,2315780E–12 | 1,5827519E–15 | –8,3503400E+02 | –1,3551101E+00 |
| | 300 – 1000 | 3,2981240E+00 | 8,2494410E–04 | –8,1430150E–07 | –9,4754340E–11 | 4,1348720E–13 | –1,0125209E+03 | –3,2940940E+00 |
| $H_2O$ | 1000 – 5000 | 2,6721450E+00 | 3,0562930E–03 | –8,7302600E–07 | 1,2009964E–10 | –6,3916180E–15 | –2,9899210E+04 | 6,8628170E+00 |
| | 300 – 1000 | 3,3868420E+00 | 3,4749820E–03 | –6,3546960E–06 | 6,9685810E–09 | –2,5065880E–12 | –3,0208110E+04 | 2,5902320E+00 |
| $H_2O_2$ | 1000 – 5000 | 4,5731670E+00 | 4,3361360E–03 | –1,4746888E–06 | 2,3489030E–10 | –1,4316536E–14 | –1,8006960E+04 | 5,0113690E–01 |
| | 300 – 1000 | 3,3887530E+00 | 6,5692260E–03 | –1,4850125E–07 | –4,6258050E–09 | 2,4715140E–12 | –1,7663140E+04 | 6,7853630E+00 |
| N | 1000 – 5000 | 2,4502680E+00 | 1,0661458E–04 | –7,4653370E–08 | 1,8796520E–11 | –1,0259839E–15 | 5,6116040E+04 | 4,4487580E+00 |
| | 300 – 1000 | 2,5030710E+00 | –2,1800180E–05 | 5,4205290E–08 | –5,6475600E–11 | 2,0999040E–14 | 5,6098900E+04 | 4,1675660E+00 |
| $N_2$ | 1000 – 5000 | 2,9266400E+00 | 1,4879768E–03 | –5,6847600E–07 | 1,0097038E–10 | –6,7533510E–15 | –9,2279770E+02 | 5,9805280E+00 |
| | 300 – 1000 | 3,2986770E+00 | 1,4082404E–03 | –3,9632220E–06 | 5,6415150E–09 | –2,4448540E–12 | –1,0208999E+03 | 3,9503720E+00 |

| Espécie | T (K) | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|---|---|---|---|---|---|---|---|---|
| $N_2O$ | 1000 – 5000 | 4,7189770E+00 | 2,8737130E–03 | –1,1974958E–06 | 2,2505510E–10 | –1,5753370E–14 | 8,1658110E+03 | –1,6572504E+00 |
| | 300 – 1000 | 2,5430570E+00 | 9,4921930E–03 | –9,7927750E–06 | 6,2638440E–09 | –1,9018250E–12 | 8,7651000E+03 | 9,5112220E+00 |
| NO | 1000–5000 | 3,2454350E+00 | 1,2691383E–03 | –5,0158900E–07 | 9,1692830E–11 | –6,2754190E–15 | 9,8008400E+03 | 6,4172930E+00 |
| | 300–1000 | 3,3765410E+00 | 1,2530634E–03 | –3,3027500E–06 | 5,2178100E–09 | –2,4462620E–12 | 9,8179610E+03 | 5,8295900E+00 |
| | 1000–5000 | 4,6828590E+00 | 2,4624290E–03 | –1,0422585E–06 | 1,9769020E–10 | –1,3917168E–14 | 2,2612920E+03 | 9,8859850E–01 |
| | | | | –9,0638640E–06 | 6,1617140E–09 | –2,3201500E–12 | 2,8962900E+03 | 1,1612071E+01 |
| | | | | | | | | 4,9203080E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $H_2O$ | 1000 – 5000 | 2,6721450E+00 | 3,0562930E–03 | –8,7302600E–07 | 1,2009964E–10 | –6,3916180E–15 | –2,9899210E+04 | 6,8628170E+00 |
| | 300 – 1000 | 3,3868420E+00 | 3,4749820E–03 | –6,3546960E–06 | 6,9685810E–09 | –2,5065880E–12 | –3,0208110E+04 | 2,5902320E+00 |
| $H_2O_2$ | 1000 – 5000 | 4,5731670E+00 | 4,3361360E–03 | –1,4746888E–06 | 2,3489030E–10 | –1,4316536E–14 | –1,8006960E+04 | 5,0113690E–01 |
| | 300 – 1000 | 3,3887530E+00 | 6,5692260E–03 | –1,4850125E–07 | –4,6258050E–09 | 2,4715140E–12 | –1,7663140E+04 | 6,7853630E+00 |
| N | 1000 – 5000 | 2,4502680E+00 | 1,0661458E–04 | –7,4653370E–08 | 1,8796520E–11 | –1,0259839E–15 | 5,6116040E+04 | 4,4487580E+00 |
| | 300 – 1000 | 2,5030710E+00 | –2,1800180E–05 | 5,4205290E–08 | –5,6475600E–11 | 2,0999040E–14 | 5,6098900E+04 | 4,1675660E+00 |
| $N_2$ | 1000 – 5000 | 2,9266400E+00 | 1,4879768E–03 | –5,6847600E–07 | 1,0097038E–10 | –6,7533510E–15 | –9,2279770E+02 | 5,9805280E+00 |
| | 300 – 1000 | 3,2986770E+00 | 1,4082404E–03 | –3,9632220E–06 | 5,6415150E–09 | –2,4448540E–12 | –1,0208999E+03 | 3,9503720E+00 |

| Espécie | T (K) | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|---|---|---|---|---|---|---|---|---|
| $N_2O$ | 1000 – 5000 | 4,7189770E+00 | 2,8737130E–03 | –1,1974958E–06 | 2,2505510E–10 | –1,5753370E–14 | 8,1658110E+03 | –1,6572504E+00 |
| | 300 – 1000 | 2,5430570E+00 | 9,4921930E–03 | –9,7927750E–06 | 6,2638440E–09 | –1,9018250E–12 | 8,7651000E+03 | 9,5112220E+00 |
| NO | 1000–5000 | 3,2454350E+00 | 1,2691383E–03 | –5,0158900E–07 | 9,1692830E–11 | –6,2754190E–15 | 9,8008400E+03 | 6,4172930E+00 |
| | 300–1000 | 3,3765410E+00 | 1,2530634E–03 | –3,3027500E–06 | 5,2178100E–09 | –2,4462620E–12 | 9,8179610E+03 | 5,8295900E+00 |
| $NO_2$ | 1000–5000 | 4,6828590E+00 | 2,4624290E–03 | –1,0422585E–06 | 1,9769020E–10 | –1,3917168E–14 | 2,2612920E+03 | 9,8859850E–01 |
| | 300–1000 | 2,6706000E+00 | 7,8385000E–03 | –8,0638640E–06 | 6,1617140E–09 | –2,3201500E–12 | 2,8962900E+03 | 1,1612071E+01 |
| O | 1000–5000 | 2,5420590E+00 | –2,7550610E–05 | –3,1028030E–09 | 4,5510670E–12 | –4,3680510E–16 | 2,9230800E+04 | 4,9203080E+00 |
| | 300–1000 | 2,9464280E+00 | –1,6381665E–03 | 2,4210310E–06 | –1,6028431E–09 | 3,8906960E–13 | 2,9147640E+04 | 2,9639950E+00 |
| $O_2$ | 1000–5000 | 3,6975780E+00 | 6,1351970E–04 | –1,2588420E–07 | 1,7752810E–11 | –1,1364354E–15 | –1,2339301E+03 | 3,1891650E+00 |
| | 300–1000 | 3,2129360E+00 | 1,1274864E–03 | –5,7561500E–07 | 1,3138773E–09 | –8,7685540E–13 | –1,0052490E+03 | 6,0347370E+00 |
| OH | 1000–5000 | 2,8827300E+00 | 1,0139743E–03 | –2,2768770E–07 | 2,1746830E–11 | –5,1263050E–16 | 3,8868880E+03 | 5,5957120E+00 |
| | 300–1000 | 3,6372660E+00 | 1,8509100E–04 | –1,6761646E–06 | 2,3872020E–09 | –8,4314420E–13 | 3,6067810E+03 | 1,3588605E+00 |
| $SO_2$ | 1000–5000 | 5,2544980E+00 | 1,9785450E–03 | –8,2042260E–07 | 1,5763830E–10 | –1,1204512E–14 | –3,7568850E+04 | –1,1460563E+00 |
| | 300–1000 | 2,9114380E+00 | 8,1030220E–03 | –6,9067100E–06 | 3,3290150E–09 | –8,7771210E–13 | –3,6878810E+04 | 1,1117403E+01 |
| $CH_4$ (metano) | 1000–5000 | 1,6834780E+00 | 1,0237236E–02 | –3,8751280E–06 | 6,7855850E–10 | –4,5034230E–14 | –1,0080787E+04 | 9,6233950E+00 |
| | 300–1000 | 7,7874150E–01 | 1,7476680E–02 | –2,7834090E–05 | 3,0497080E–08 | –1,2239307E–11 | –9,8252290E+03 | 1,3722195E+01 |
| $C_2H_2$ (acetileno) | 1000–5000 | 4,4367700E+00 | 5,3760390E–03 | –1,9128160E–06 | 3,2863790E–10 | –2,1567090E–14 | 2,5667660E+04 | –2,8003380E+00 |
| | 300–1000 | 2,0135620E+00 | 1,5190446E–02 | –1,6163189E–05 | 9,0789920E–09 | –1,9127460E–12 | 2,6124440E+04 | 8,8053780E+00 |
| $C_2H_4$ (eteno) | 1000–5000 | 3,5284180E+00 | 1,1485185E–02 | –4,4183850E–06 | 7,8446000E–10 | –5,2668480E–14 | 4,4282880E+03 | 2,2303890E+00 |
| | 300–1000 | –8,6148800E–01 | 2,7961620E–02 | –3,3886770E–05 | 2,7851520E–08 | –9,7378790E–12 | 5,5730460E+03 | 2,4211480E+01 |

**Tabela A2.1**

*Coeficientes polinomiais para a determinação do calor específico, entalpia específica e entropia específica. (Dados extraídos de Kee* et al.*, 1987.) (continua)*

| Espécie | T (K) | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|---|---|---|---|---|---|---|---|---|
| $C_2H_6$ (etano) | 1000–5000 | 4,8259380E+00 | 1,3840429E–02 | –4,5572580E–06 | 6,7249670E–10 | –3,5981610E–14 | –1,2717793E+04 | –5,2395060E+00 |
| | 300–1000 | 1,4625388E+00 | 1,5494667E–02 | 5,7805070E–06 | –1,2578319E–08 | 4,5862670E–12 | –1,1239176E+04 | 1,4432295E+01 |
| $C_3H_6$ (propeno) | 1000–5000 | 6,7322570E+00 | 1,4908336E–02 | –4,9498990E–06 | 7,2120220E–10 | –3,7662040E–14 | –9,2357030E+02 | –1,3313348E+01 |
| | 300–1000 | 1,4933071E+00 | 2,0925170E–02 | 4,4867940E–06 | –1,6689121E–08 | 7,1581460E–12 | 1,0748264E+03 | 1,6145340E+01 |
| $C_3H_8$ (propano) | 1000–5000 | 7,5252170E+00 | 1,8890340E–02 | –6,2839240E–06 | 9,1793730E–10 | –4,8124100E–14 | –1,6464548E+04 | –1,7843900E+01 |
| | 300–1000 | 8,9692080E–01 | 2,6689860E–02 | 5,4314250E–06 | –2,1260000E–08 | 9,2433300E–12 | –1,3954918E+04 | 1,9355330E+01 |
| $C_4H_8$ (buteno) | 1000–5000 | 2,0535840E+00 | 3,4350500E–02 | –1,5883196E–05 | 3,3089660E–09 | –2,5361040E–13 | –2,1397230E+03 | 1,5543201E+01 |
| | 300–1000 | 1,1811380E+00 | 3,0853380E–02 | 5,0865240E–06 | –2,4654880E–08 | 1,1110192E–11 | –1,7904000E+03 | 2,1062470E+01 |
| $C_4H_{10}$ (n–butano) | 1000–5000 | 1,9987840E+01 | 1,0372807E–02 | –9,6108180E–07 | –4,6230170E–10 | 8,2028280E–14 | –2,6255710E+04 | –8,8379070E+01 |
| | 300–1000 | –2,2566180E+00 | 5,8817320E–02 | –4,5257820E–05 | 2,0371150E–08 | –4,0794580E–12 | –1,7602330E+04 | 3,3295950E+01 |
| $C_6H_6$ (benzeno) | 1000–5000 | 1,2910740E+01 | 1,7232960E–02 | –5,0242100E–06 | 5,8934970E–10 | –1,9475210E–14 | 3,6645110E+03 | –5,0026990E+01 |
| | 300–1000 | –3,1380120E+00 | 4,7231030E–02 | –2,9622070E–06 | –3,2628190E–08 | 1,7186910E–11 | 8,8900310E+03 | 3,6575730E+01 |
| $CH_3OH$ (metanol) | 1000–5000 | 4,0290610E+00 | 9,3765930E–03 | –3,0502540E–06 | 4,3587930E–10 | –2,2247230E–14 | –2,6157910E+04 | 2,3781950E+00 |
| | 300–1000 | 2,6601150E+00 | 7,3415080E–03 | 7,1700500E–06 | –8,7931940E–09 | 2,3905700E–12 | –2,5353480E+04 | 1,1232631E+01 |

**Tabela A2.1**

*Coeficientes polinomiais para a determinação do calor específico, entalpia específica e entropia específica. (Dados extraídos de Kee* et al., *1987.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (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 |

**Tabela A2.2**

*Monóxido de carbono* (CO). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 38,019 | 161 342 | –146 589 | 291,219 | –507 210 |
| 4900 | 38,031 | 165 145 | –147 783 | 292,003 | –514 710 |
| 5000 | 38,033 | 168 948 | –148 987 | 292,771 | –522 186 |

**Tabela A2.2**
*Monóxido de carbono* (CO). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| | −335 399 |
| | −343 519 |
| | −351 606 |
| | −359 661 |
| | −367 684 |
| | −375 677 |
| | −383 639 |
| | −391 571 |
| | −399 474 |
| | −407 347 |
| | −415 192 |
| | −423 008 |
| | −430 796 |
| | −438 557 |
| | −446 291 |
| | −453 997 |
| | −461 677 |
| | −469 330 |
| | −476 957 |
| | −484 558 |
| | −492 134 |
| | −499 684 |
| | −507 210 |
| | −514 710 |
| | −522 186 |

*ice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left\{\bar{h}^o(T) - \bar{h}_f^o(298)\right\}$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ [kJ/(kmol K)] |
|---|---|---|---|---|---|
| 200 | 32,387 | −3423 | −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 | 4003 | −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 |

**Tabela A2.3**

*Dióxido de carbono* ($CO_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 63,918 | 266 528 | –410 539 | 363,763 | –390 440 |
| 4900 | 63,932 | 272 920 | –411 267 | 365,081 | –390 014 |
| 5000 | 63,919 | 279 313 | –412 010 | 366,372 | –389 572 |

**Tabela A2.3**

*Dióxido de carbono* ($CO_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ /(kmol K)] | $\bar{g}_f^{\,o}(T)$ (kJ/kmol) |
|---|---|
| 27,590 | –395 957 |
| 29,841 | –395 840 |
| 32,018 | –395 708 |
| 34,124 | –395 562 |
| 36,165 | –395 403 |
| 38,145 | –395 229 |
| 40,067 | –395 041 |
| 41,935 | –394 838 |
| 43,751 | –394 620 |
| 45,519 | –394 388 |
| 47,242 | –394 141 |
| 48,922 | –393 879 |
| 50,561 | –393 602 |
| 52,161 | –393 311 |
| 53,725 | –393 004 |
| 55,253 | –392 683 |
| 56,748 | –392 346 |
| 58,210 | –391 995 |
| 59,642 | –391 629 |
| 61,044 | –391 247 |
| 62,417 | –390 851 |
| 63,763 | –390 440 |
| 65,081 | –390 014 |
| 66,372 | –389 572 |

*ıdice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{\,o}(T) - \bar{h}_f^{\,o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^{\,o}(T)$ (kJ/kmol) | $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^{\,o}(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 28,522 | –2818 | 0 | 119,137 | 0 |
| 298 | 28,871 | 0 | 0 | 130,595 | 0 |
| 300 | 28,877 | 53 | 0 | 130,773 | 0 |
| 400 | 29,120 | 2954 | 0 | 139,116 | 0 |
| 500 | 29,275 | 5874 | 0 | 145,632 | 0 |
| 600 | 29,375 | 8807 | 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 |

**Tabela A2.4**

*Hidrogénio* ($H_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 | 145 672 | 0 | 218,419 | 0 |
| 4600 | 40,156 | 150 679 | 0 | 219,300 | 0 |
| 4700 | 40,334 | 154 703 | 0 | 220,165 | 0 |
| 4800 | 40,516 | 158 746 | 0 | 221,016 | 0 |
| 4900 | 40,702 | 162 806 | 0 | 221,853 | 0 |
| 5000 | 40,895 | 166 886 | 0 | 222,678 | 0 |

**Tabela A2.4**

*Hidrogénio* ($H_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 20,786 | −2040 | 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 | 2117 | 218 617 | 120,713 | 198 155 |
| 500 | 20,786 | 4196 | 219 236 | 125,351 | 192 968 |
| 600 | 20,786 | 6274 | 219 848 | 129,141 | 187 657 |
| 700 | 20,786 | 8353 | 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 |

**Tabela A2.5**

*Átomo de hidrogénio* (H). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $^o(T)$ mol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| ,926 | 0 |
| ,253 | 0 |
| ,542 | 0 |
| ,796 | 0 |
| ,017 | 0 |
| ,206 | 0 |
| ,365 | 0 |
| ,496 | 0 |
| ,600 | 0 |
| ,679 | 0 |
| ,733 | 0 |
| ,764 | 0 |
| ,774 | 0 |
| ,762 | 0 |
| ,730 | 0 |
| ,679 | 0 |
| ,609 | 0 |
| ,522 | 0 |
| ,419 | 0 |
| ,300 | 0 |
| ,165 | 0 |
| ,016 | 0 |
| ,853 | 0 |
| ,678 | 0 |

*ntinuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 20,786 | 93 575 | 232 180 | 172,364 | –64 730 |
| 4900 | 20,786 | 95 654 | 232 228 | 172,793 | –70 916 |
| 5000 | 20,786 | 97 733 | 232 267 | 173,213 | –77 103 |

**Tabela A2.5**

*Átomo de hidrogénio* (H). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ J/(kmol K)] | $\bar{g}_f^{\,o}(T)$ (kJ/kmol) |
|---|---|
| 160,405 | 64 504 |
| 161,161 | 58 405 |
| 161,890 | 52 298 |
| 162,595 | 46 182 |
| 163,276 | 40 058 |
| 163,936 | 33 928 |
| 164,576 | 27 792 |
| 165,196 | 21 650 |
| 165,799 | 15 502 |
| 166,384 | 9 350 |
| 166,954 | 3 194 |
| 167,508 | –2 967 |
| 168,048 | –9 132 |
| 168,575 | –15 299 |
| 169,088 | –21 470 |
| 169,589 | –27 644 |
| 170,078 | –33 820 |
| 170,556 | –39 998 |
| 171,023 | –46 179 |
| 171,480 | –52 361 |
| 171,927 | –58 545 |
| 172,364 | –64 730 |
| 172,793 | –70 916 |
| 173,213 | –77 103 |

*pêndice 2.) (continuação)*

| $T$(K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{\,o}(T) - \bar{h}_f^{\,o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^{\,o}(T)$ (kJ/kmol) | $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^{\,o}(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 30,140 | –2948 | 38 864 | 171,607 | 35 808 |
| 298 | 29,932 | 0 | 39 985 | 183,604 | 34 279 |
| 300 | 29,928 | 55 | 38 987 | 183,789 | 34 250 |
| 400 | 29,718 | 3037 | 39 030 | 192,369 | 32 662 |
| 500 | 29,570 | 6001 | 39 000 | 198,983 | 31 072 |
| 600 | 29,527 | 8955 | 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 |

**Tabela A2.6**

*Hidróxilo* (OH). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 2700 | 36,263 | 78 634 | 35 682 | 252,890 | –275 |
| 2800 | 36,439 | 82 269 | 35 524 | 254,212 | –1604 |
| 2900 | 36,604 | 85 922 | 35 360 | 255,493 | –2927 |
| 3000 | 36,759 | 89 590 | 35 191 | 256,737 | –4245 |
| 3100 | 36,903 | 93 273 | 35 016 | 257,945 | –5556 |
| 3200 | 37,039 | 96 970 | 34 835 | 259,118 | –6862 |
| 3300 | 37,166 | 100 681 | 34 648 | 260,260 | –8162 |
| 3400 | 37,285 | 104 403 | 34 454 | 261,371 | –9457 |
| 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 |
| 4800 | 38,552 | 157 536 | 31 017 | 274,446 | –26 956 |
| 4900 | 38,640 | 161 395 | 30 722 | 275,242 | –28 161 |
| 5000 | 38,732 | 165 264 | 30 422 | 276,024 | –29 360 |

**Tabela A2.6**
*Hidróxilo* (OH). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{o}(T)$ kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| 2,890 | –275 |
| 4,212 | –1604 |
| 5,493 | –2927 |
| 6,737 | –4245 |
| 7,945 | –5556 |
| 9,118 | –6862 |
| 0,260 | –8162 |
| 1,371 | –9457 |
| 2,454 | –10 745 |
| 3,509 | –12 028 |
| 4,538 | –13 305 |
| 5,542 | –14 576 |
| 6,522 | –15 841 |
| 7,480 | –17 100 |
| 8,417 | –18 353 |
| 9,333 | –19 600 |
| 0,229 | –20 841 |
| 1,107 | –22 076 |
| 1,967 | –23 306 |
| 2,809 | –24 528 |
| 3,636 | –25 745 |
| 4,446 | –26 956 |
| 5,242 | –28 161 |
| 6,024 | –29 360 |

*continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{o}(T) - \bar{h}_f^{o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^{o}(T)$ (kJ/kmol) | $\bar{s}^{o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^{o}(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 32,255 | –3227 | –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 | 3458 | –242 858 | 198,686 | –223 929 |
| 500 | 35,337 | 6947 | –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 |

**Tabela A2.7**

*Água* ($H_2O$). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 | –6742 |
| 4300 | 58,496 | 201 061 | –255 093 | 307,022 | –831 |
| 4400 | 58,641 | 206 918 | –255 303 | 308,368 | 5085 |
| 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 |
| 4800 | 59,173 | 230 484 | –256 239 | 313,494 | 28 796 |
| 4900 | 59,295 | 236 407 | –256 501 | 314,716 | 34 737 |
| 5000 | 59,412 | 242 343 | –256 774 | 215,915 | 40 684 |

**Tabela A2.7**

*Água* ($H_2O$). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{o}(T)$ J/(kmol K)] | $\bar{g}_f^{o}(T)$ (kJ/kmol) |
|---|---|
| 280,597 | –94 878 |
| 282,595 | –89 031 |
| 284,535 | –83 181 |
| 286,420 | –77 326 |
| 288,254 | –71 467 |
| 290,039 | –65 604 |
| 291,777 | –59 737 |
| 293,471 | –53 865 |
| 295,122 | –47 990 |
| 296,733 | –42 110 |
| 298,305 | –36 226 |
| 299,841 | –30 338 |
| 301,341 | –24 446 |
| 302,808 | –18 549 |
| 304,243 | –12 648 |
| 305,647 | –6742 |
| 307,022 | –831 |
| 308,368 | 5085 |
| 309,688 | 11 005 |
| 310,981 | 16 930 |
| 312,250 | 22 861 |
| 313,494 | 28 796 |
| 314,716 | 34 737 |
| 215,915 | 40 684 |

*ntinuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{o}(T)-\bar{h}_f^{o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^{o}(T)$ (kJ/kmol) | $\bar{s}^{o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^{o}(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 28,793 | –2841 | 0 | 179,959 | 0 |
| 298 | 29,071 | 0 | 0 | 191,511 | 0 |
| 300 | 29,075 | 54 | 0 | 191,691 | 0 |
| 400 | 29,319 | 2973 | 0 | 200,088 | 0 |
| 500 | 29,636 | 5920 | 0 | 206,662 | 0 |
| 600 | 30,086 | 8905 | 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 |

**Tabela A2.8**

*Azoto* ($N_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 37,854 | 160 205 | 0 | 284,412 | 0 |
| 4900 | 37,868 | 163 991 | 0 | 285,193 | 0 |
| 5000 | 37,873 | 167 778 | 0 | 285,958 | 0 |

**Tabela A2.8**

*Azoto* ($N_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ J/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| 262,919 | 0 |
| 264,259 | 0 |
| 265,555 | 0 |
| 266,810 | 0 |
| 268,025 | 0 |
| 269,203 | 0 |
| 270,347 | 0 |
| 271,458 | 0 |
| 272,539 | 0 |
| 273,590 | 0 |
| 274,614 | 0 |
| 275,612 | 0 |
| 276,586 | 0 |
| 277,536 | 0 |
| 278,464 | 0 |
| 279,370 | 0 |
| 280,257 | 0 |
| 281,123 | 0 |
| 281,972 | 0 |
| 282,802 | 0 |
| 283,616 | 0 |
| 284,412 | 0 |
| 285,193 | 0 |
| 285,958 | 0 |

*tinuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 20,790 | −2040 | 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 | 2117 | 473 258 | 159,297 | 449 557 |
| 500 | 20,786 | 4196 | 473 864 | 163,935 | 443 562 |
| 600 | 20,786 | 6274 | 474 450 | 167,725 | 437 446 |
| 700 | 20,786 | 8353 | 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 | 20,729 | 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 |

**Tabela A2.9**

*Átomo de azoto* (N). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 | 193 310 |
| 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 |
| 4800 | 23,082 | 95 454 | 487 979 | 211,407 | 155 814 |
| 4900 | 23,282 | 97 772 | 488 405 | 211,885 | 148 890 |
| 5000 | 23,491 | 100 111 | 488 850 | 212,358 | 141 956 |

**Tabela A2.9**

*Átomo de azoto* (N). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 29,374 | –2901 | 90 234 | 198,856 | 87 811 |
| 298 | 29,728 | 0 | 90 297 | 210,652 | 86 607 |
| 300 | 29,735 | 55 | 90 298 | 210,836 | 96 584 |
| 400 | 30,103 | 3046 | 90 341 | 219,439 | 85 340 |
| 500 | 30,570 | 6079 | 90 367 | 226,204 | 84 086 |
| 600 | 31,174 | 9165 | 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 |

**Tabela A2.10**
*Óxido de azoto* (NO). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| )] | |
| | 299 394 |
| | 292 636 |
| | 285 870 |
| | 279 094 |
| | 272 311 |
| | 265 519 |
| | 258 720 |
| | 251 913 |
| | 245 099 |
| | 238 276 |
| | 231 447 |
| | 224 610 |
| | 217 765 |
| | 210 913 |
| | 204 053 |
| | 197 186 |
| | 193 310 |
| | 183 427 |
| | 176 536 |
| | 169 637 |
| | 162 730 |
| | 155 814 |
| | 148 890 |
| | 141 956 |

*ontinuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 38,162 | 163 121 | 87 184 | 305,868 | 30 539 |
| 4900 | 38,171 | 166 938 | 86 984 | 306,655 | 29 361 |
| 5000 | 38,170 | 170 755 | 86 779 | 307,426 | 28 187 |

**Tabela A2.10**

*Óxido de azoto* (NO). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| 284,154 | 56 188 |
| 285,512 | 54 931 |
| 286,824 | 53 677 |
| 288,093 | 52 426 |
| 289,322 | 51 178 |
| 290,514 | 49 934 |
| 291,670 | 48 693 |
| 292,793 | 47 456 |
| 293,885 | 46 222 |
| 294,947 | 44 992 |
| 295,981 | 43 766 |
| 296,989 | 42 543 |
| 297,972 | 41 325 |
| 298,931 | 40 110 |
| 299,867 | 38 900 |
| 300,782 | 37 693 |
| 301,677 | 36 491 |
| 302,551 | 35 292 |
| 303,407 | 34 098 |
| 304,244 | 32 908 |
| 305,064 | 31 721 |
| 305,868 | 30 539 |
| 306,655 | 29 361 |
| 307,426 | 28 187 |

*ıdice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 32,936 | −3432 | 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 | 3937 | 32 521 | 251,259 | 57 602 |
| 500 | 43,227 | 8118 | 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 | 398,850 | 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 |

**Tabela A2.11**

*Dióxido de azoto* ($NO_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 2700 | 57,244 | 127 116 | 33 165 | 348,785 | 203 344 |
| 2800 | 57,291 | 132 843 | 33 095 | 350,868 | 309 648 |
| 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 |
| 4800 | 57,902 | 248 159 | 28 389 | 381,929 | 336 803 |
| 4900 | 57,862 | 253 947 | 27 998 | 383,122 | 343 232 |
| 5000 | 57,798 | 259 730 | 27 586 | 384,290 | 349 670 |

**Tabela A2.11**

*Dióxido de azoto* ($NO_2$). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| 348,785 | 203 344 |
| 350,868 | 309 648 |
| 352,879 | 215 955 |
| 354,824 | 222 265 |
| 356,705 | 228 579 |
| 358,529 | 234 898 |
| 360,297 | 241 221 |
| 362,013 | 247 549 |
| 363,680 | 253 883 |
| 365,302 | 260 222 |
| 366,880 | 266 567 |
| 368,418 | 272 918 |
| 369,916 | 279 276 |
| 371,378 | 285 639 |
| 372,804 | 292 010 |
| 374,197 | 298 387 |
| 375,559 | 304 772 |
| 376,889 | 311 163 |
| 378,190 | 317 562 |
| 379,464 | 323 968 |
| 380,709 | 330 381 |
| 381,929 | 336 803 |
| 383,122 | 343 232 |
| 384,290 | 349 670 |

*ɔêndice 2.) (continuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{\,o}(T) - \bar{h}_f^{\,o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^{\,o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 28,473 | –2836 | 0 | 193,518 | 0 |
| 298 | 29,315 | 0 | 0 | 205,043 | 0 |
| 300 | 29,331 | 54 | 0 | 205,224 | 0 |
| 400 | 30,210 | 3031 | 0 | 213,782 | 0 |
| 500 | 31,114 | 6097 | 0 | 220,620 | 0 |
| 600 | 32,030 | 9254 | 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 |

**Tabela A2.12**

*Oxigénio ($O_2$). (Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 42,421 | 172 262 | 0 | 303,721 | 0 |
| 4900 | 42,527 | 176 510 | 0 | 304,597 | 0 |
| 5000 | 42,627 | 180 767 | 0 | 305,457 | 0 |

**Tabela A2.12**

*Oxigénio ($O_2$). (Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{o}(T)$ (kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|
| 30,218 | 0 |
| 31,651 | 0 |
| 33,039 | 0 |
| 34,387 | 0 |
| 35,697 | 0 |
| 36,970 | 0 |
| 38,209 | 0 |
| 39,417 | 0 |
| 90,594 | 0 |
| 91,742 | 0 |
| 92,863 | 0 |
| 93,959 | 0 |
| 95,029 | 0 |
| 96,076 | 0 |
| 97,101 | 0 |
| 98,104 | 0 |
| 99,087 | 0 |
| 00,050 | 0 |
| 00,994 | 0 |
| 01,921 | 0 |
| 02,829 | 0 |
| 03,721 | 0 |
| 04,597 | 0 |
| 05,457 | 0 |

*ontinuação)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^{o}(T)-\bar{h}_f^{o}(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^{o}(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 200 | 22,477 | –2176 | 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 | 2209 | 249 890 | 167,320 | 225 719 |
| 500 | 21,256 | 4345 | 250 494 | 172,089 | 219 605 |
| 600 | 21,113 | 6463 | 251 033 | 175,951 | 213 375 |
| 700 | 21,033 | 8570 | 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 |

**Tabela A2.13**

*Átomo de oxigénio* (O). *(Valores determinados a partir das expressões do Apêndice 2.) (continua)*

| $T$ (K) | $\bar{c}_p$ [kJ/(kmol K)] | $\left(\bar{h}^o(T) - \bar{h}_f^o(298)\right)$ (kJ/kmol) | $\bar{h}_f^o(T)$ (kJ/kmol) | $\bar{s}^o(T)$ [kJ/(kmol K)] | $\bar{g}_f^o(T)$ (kJ/kmol) |
|---|---|---|---|---|---|
| 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 |
| 4800 | 21,699 | 94 872 | 257 938 | 219,580 | –67 113 |
| 4900 | 21,752 | 97 045 | 257 987 | 220,028 | –73 886 |
| 5000 | 21,805 | 99 223 | 258 036 | 220,468 | –80 659 |

**Tabela A2.13**

*Átomo de oxigénio* (O). *(Valores determinados a partir das expressões do Apêndice 2.) (continuação)*

| $\bar{s}^{\,o}(T)$ kJ/(kmol K)] | $\bar{g}_f^{\,o}(T)$ (kJ/kmol) |
|---|---|
| 207,390 | 74 757 |
| 208,150 | 68 027 |
| 208,884 | 61 292 |
| 209,593 | 54 554 |
| 210,280 | 47 812 |
| 210,947 | 41 068 |
| 211,593 | 34 320 |
| 212,221 | 27 570 |
| 212,832 | 20 818 |
| 213,427 | 14 063 |
| 214,007 | 7 307 |
| 214,572 | 548 |
| 215,123 | –6 212 |
| 215,662 | –12 974 |
| 216,189 | –19 737 |
| 216,703 | –26 501 |
| 217,207 | –33 267 |
| 217,701 | –40 034 |
| 218,184 | –46 802 |
| 218,658 | –53 571 |
| 219,123 | –60 342 |
| 219,580 | –67 113 |
| 220,028 | –73 886 |
| 220,468 | –80 659 |

*pêndice 2.) (continuação)*





## APÊNDICE 3
## PROPRIEDADES TERMOFÍSICAS DO AR, AZOTO, OXIGÉNIO E ALGUNS COMBUSTÍVEIS

| T (K) | $\rho$ (kg/m$^3$) | $c_p$ [kJ/(kg K)] | $\mu \times 10^7$ (N s/m$^2$) | $\nu \times 10^6$ (m$^2$/s) | $\lambda \times 10^3$ [W/(m K)] | $\alpha \times 10^6$ (m$^2$/s) |
|---|---|---|---|---|---|---|
| 300 | 1,1614 | 1,007 | 184,6 | 15,89 | 26,3 | 22,5 |
| 350 | 0,9950 | 1,009 | 208,2 | 20,92 | 30,0 | 29,9 |
| 400 | 0,8711 | 1,014 | 230,1 | 26,41 | 33,8 | 38,3 |
| 450 | 0,7740 | 1,021 | 250,7 | 32,39 | 37,3 | 47,2 |
| 500 | 0,6964 | 1,030 | 270,1 | 38,79 | 40,7 | 56,7 |
| 550 | 0,6329 | 1,040 | 288,4 | 45,57 | 43,9 | 66,7 |
| 600 | 0,5804 | 1,051 | 305,8 | 52,69 | 46,9 | 76,9 |
| 650 | 0,5356 | 1,063 | 322,5 | 62,21 | 49,7 | 87,3 |
| 700 | 0,4975 | 1,075 | 338,8 | 68,10 | 52,4 | 98,0 |
| 750 | 0,4643 | 1,087 | 354,6 | 76,37 | 54,9 | 109 |
| 800 | 0,4354 | 1,099 | 369,8 | 84,93 | 57,3 | 120 |
| 850 | 0,4097 | 1,110 | 384,3 | 93,80 | 59,6 | 131 |
| 900 | 0,3868 | 1,121 | 398,1 | 102,9 | 62,0 | 143 |
| 950 | 0,3666 | 1,131 | 411,3 | 112,2 | 64,3 | 155 |
| 1000 | 0,3482 | 1,141 | 424,4 | 121,9 | 66,7 | 168 |
| 1100 | 0,3166 | 1,159 | 449,0 | 141,8 | 71,5 | 195 |
| 1200 | 0,2902 | 1,175 | 473,0 | 162,9 | 76,3 | 224 |
| 1300 | 0,2679 | 1,189 | 496,0 | 185,1 | 82 | 238 |
| 1400 | 0,2488 | 1,207 | 530 | 213 | 91 | 303 |
| 1500 | 0,2322 | 1,230 | 557 | 240 | 100 | 350 |
| 1600 | 0,2177 | 1,248 | 584 | 268 | 106 | 390 |
| 1700 | 0,2049 | 1,267 | 611 | 298 | 113 | 435 |
| 1800 | 0,1935 | 1,286 | 637 | 329 | 120 | 482 |
| 1900 | 0,1833 | 1,307 | 663 | 362 | 128 | 534 |
| 2000 | 0,1741 | 1,337 | 689 | 396 | 137 | 589 |
| 2100 | 0,1658 | 1,372 | 715 | 431 | 147 | 646 |
| 2200 | 0,1582 | 1,417 | 740 | 468 | 160 | 714 |
| 2300 | 0,1513 | 1,478 | 766 | 506 | 175 | 783 |
| 2400 | 0,1448 | 1,558 | 792 | 547 | 196 | 869 |
| 2500 | 0,1389 | 1,665 | 818 | 589 | 222 | 960 |
| 3000 | 0,1135 | 2,726 | 955 | 841 | 486 | 1570 |

**Tabela A3.1**

*Propriedades do ar a 1 atm. (Dados extraídos de Incropera e DeWitt, 1990.)*

| T (K) | $\rho$ (kg/m³) | $c_p$ [kJ/(kg K)] | $\mu \times 10^7$ (N s/m²) | $\nu \times 10^6$ (m²/s) | $\lambda \times 10^3$ [W/(m K)] | $\alpha \times 10^6$ (m²/s) |
|---|---|---|---|---|---|---|
| 300 | 1,1233 | 1,041 | 178,2 | 15,86 | 25,9 | 22,1 |
| 350 | 0,9625 | 1,042 | 200,0 | 20,78 | 29,3 | 29,2 |
| 400 | 0,8425 | 1,045 | 220,4 | 26,16 | 32,7 | 37,1 |
| 450 | 0,7485 | 1,050 | 239,6 | 32,01 | 35,8 | 45,6 |
| 500 | 0,6739 | 1,056 | 257,7 | 38,24 | 38,9 | 54,7 |
| 550 | 0,6124 | 1,065 | 274,7 | 44,86 | 41,7 | 63,9 |
| 600 | 0,5615 | 1,075 | 290,8 | 51,79 | 44,6 | 73,9 |
| 700 | 0,4812 | 1,098 | 321,0 | 66,71 | 49,9 | 94,4 |
| 800 | 0,4211 | 1,220 | 349,1 | 82,90 | 54,8 | 116 |
| 900 | 0,3743 | 1,146 | 375,3 | 100,3 | 59,7 | 139 |
| 1000 | 0,3368 | 1,167 | 399,9 | 118,7 | 64,7 | 165 |
| 1100 | 0,3062 | 1,187 | 423,2 | 138,2 | 70,0 | 193 |
| 1200 | 0,2807 | 1,204 | 445,3 | 158,6 | 75,8 | 224 |
| 1300 | 0,2591 | 1,219 | 466,2 | 179,9 | 81,0 | 256 |

**Tabela A3.2**

*Propriedades do azoto a 1 atm. (Dados extraídos de Incropera e DeWitt, 1990.)*

| T (K) | $\rho$ (kg/m³) | $c_p$ [kJ/(kg K)] | $\mu \times 10^7$ (N s/m²) | $\nu \times 10^6$ (m²/s) | $\lambda \times 10^3$ [W/(m K)] | $\alpha \times 10^6$ (m²/s) |
|---|---|---|---|---|---|---|
| 300 | 1,284 | 0,920 | 207,2 | 16,14 | 26,8 | 22,7 |
| 350 | 1,100 | 0,929 | 233,5 | 21,23 | 29,6 | 29,0 |
| 400 | 0,9620 | 0,942 | 258,2 | 26,84 | 33,0 | 36,4 |
| 450 | 0,8554 | 0,956 | 281,4 | 32,90 | 36,3 | 44,4 |
| 500 | 0,7698 | 0,972 | 303,3 | 39,40 | 41,2 | 55,1 |
| 550 | 0,6998 | 0,988 | 324,0 | 46,30 | 44,1 | 63,8 |
| 600 | 0,6414 | 1,003 | 343,7 | 53,59 | 47,3 | 73,5 |
| 700 | 0,5498 | 1,031 | 380,8 | 69,26 | 52,8 | 93,1 |
| 800 | 0,4810 | 1,054 | 415,2 | 86,32 | 58,9 | 116 |
| 900 | 0,4275 | 1,074 | 447,2 | 104,6 | 64,9 | 141 |
| 1000 | 0,3848 | 1,090 | 477,0 | 124,0 | 71,0 | 169 |
| 1100 | 0,3498 | 1,103 | 505,5 | 144,5 | 75,8 | 196 |
| 1200 | 0,3206 | 1,115 | 532,5 | 166,1 | 81,9 | 229 |
| 1300 | 0,2960 | 1,125 | 588,4 | 188,6 | 87,1 | 262 |

**Tabela A3.3**

*Propriedades do oxigénio a 1 atm. (Dados extraídos de Incropera e DeWitt, 1990.)*

| $\alpha \times 10^6$ (m²/s) | $\lambda \times 10^3$ [W/(m K)] |
|---|---|
| 22,1 | 25,9 |
| 29,2 | 29,3 |
| 37,1 | 32,7 |
| 45,6 | 35,8 |
| 54,7 | 38,9 |
| 63,9 | 41,7 |
| 73,9 | 44,6 |
| 94,4 | 49,9 |
| 116 | 54,8 |
| 139 | 59,7 |
| 165 | 64,7 |
| 193 | 70,0 |
| 224 | 75,8 |
| 256 | 81,0 |

*190.)*

| $\alpha \times 10^6$ (m²/s) | $\lambda \times 10^3$ [W/(m K)] |
|---|---|
| 22,7 | 26,8 |
| 29,0 | 29,6 |
| 36,4 | 33,0 |
| 44,4 | 36,3 |
| 55,1 | 41,2 |
| 63,8 | 44,1 |
| 73,5 | 47,3 |
| 93,1 | 52,8 |
| 116 | 58,9 |
| 141 | 64,9 |
| 169 | 71,0 |
| 196 | 75,8 |
| 229 | 81,9 |
| 262 | 87,1 |

*itt, 1990.)*

| Combustível | Fórmula química | Massa molar (kg/kmol) | PCI (MJ/kg) | PCS (MJ/kg) | $T_{BP}$ (°C) | $h_{fg}$ (kJ/kg) | $\rho_{liq}^{*}$ (kg/m³) |
|---|---|---|---|---|---|---|---|
| Metano | $CH_4$ | 16,043 | 50,016 | 55,528 | –164,0 | 509 | 300 |
| Acetileno | $C_2H_2$ | 23,038 | 48,225 | 49,923 | –84,0 | – | – |
| Eteno | $C_2H_4$ | 28,054 | 47,161 | 50,313 | –103,7 | – | – |
| Etano | $C_2H_6$ | 30,069 | 47,489 | 51,901 | –88,6 | 488 | 370 |
| Propeno | $C_3H_6$ | 42,080 | 45,784 | 48,936 | –47,4 | 437 | 514 |
| Propano | $C_3H_8$ | 44,096 | 46,357 | 50,368 | –42,1 | 425 | 500 |
| 1-Buteno | $C_4H_8$ | 56,107 | 45,319 | 48,471 | –63,0 | 391 | 595 |
| n-Butano | $C_4H_{10}$ | 58,123 | 45,742 | 49,546 | –0,5 | 386 | 579 |
| 1-Penteno | $C_5H_{10}$ | 70,134 | 45,000 | 48,152 | 30,0 | 358 | 641 |
| n-Pentano | $C_5H_{12}$ | 72,150 | 45,355 | 49,032 | 36,1 | 358 | 626 |
| Benzeno | $C_6H_6$ | 78,113 | 40,579 | 42,277 | 80,1 | 393 | 879 |
| 1-Hexeno | $C_6H_{12}$ | 84,161 | 44,803 | 47,955 | 63,4 | 335 | 673 |
| n-Hexano | $C_6H_{14}$ | 86,177 | 45,100 | 48,696 | 69,0 | 335 | 659 |
| 1-Hepteno | $C_7H_{14}$ | 98,188 | 44,665 | 47,817 | 93,6 | – | – |
| n-Heptano | $C_7H_{16}$ | 100,203 | 44,926 | 48,456 | 98,4 | 316 | 684 |
| 1-Octeno | $C_8H_{16}$ | 112,214 | 44,560 | 47,712 | 121,3 | – | – |
| n-Octano | $C_8H_{18}$ | 114,230 | 44,791 | 48,275 | 125,7 | 300 | 703 |

* Para líquidos à temperatura de 20 °C e para gases à temperatura de ebulição do gás liquefeito.

**Tabela A3.4**

*Propriedades de alguns combustíveis à temperatura de 25 °C (excepto $T_{BP}$ e $\rho_{liq}$) e à pressão de 1 atm. (Dados extraídos de Turns, 2000.)*

| Combustível | Fórmula química | Propriedade | Temperatura (K) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 |
| Metano | $CH_4$ | $\lambda$ [W/(m K)] | 0,034 | 0,048 | 0,067 | 0,089 | 0,110 | 0,133 | 0,155 | 0,169 | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 11,175 | 14,248 | 16,982 | 19,436 | 21,685 | 23,792 | 25,767 | 27,545 | – | – |
| | | $c_p$ [J/(kg K)] | 2198 | 2568 | 2905 | 3237 | 3574 | 3912 | 4231 | 4498 | 4712 | 4906 |
| Propano | $C_3H_8$ | $\lambda$ [W/(m K)] | 0,019 | 0,031 | 0,046 | 0,065 | 0,086 | 0,110 | 0,164 | – | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 8,196 | 10,819 | 13,290 | 15,585 | 17,695 | 19,619 | 21,361 | – | – | – |
| | | $c_p$ [J/(kg K)] | 1677 | 2134 | 2549 | 2917 | 3237 | 3512 | 3749 | 3960 | 4120 | 4267 |
| n-Hexano | $C_6H_{14}$ | $\lambda$ [W/(m K)] | 0,013 | 0,023 | 0,035 | 0,050 | 0,067 | 0,087 | 0,109 | 0,135 | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 6,666 | 8,731 | 10,797 | 12,803 | 14,717 | 16,538 | 18,293 | – | – | – |
| | | $c_p$ [J/(kg K)] | 1715 | 2140 | 2539 | 2884 | 3176 | 3423 | 3638 | 3834 | 4027 | 4231 |
| n-Heptano | $C_7H_{16}$ | $\lambda$ [W/(m K)] | 0,012 | 0,021 | 0,032 | 0,045 | 0,057 | 0,071 | 0,085 | 0,097 | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 6,078 | 7,929 | 9,813 | – | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1671 | 2112 | 2509 | 2858 | 3156 | 3405 | 3621 | 3809 | 3974 | 4117 |
| n-Octano | $C_8H_{18}$ | $\lambda$ [W/(m K)] | 0,014 | 0,023 | 0,033 | – | – | – | – | – | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 5,641 | 7,403 | 9,178 | 10,923 | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1698 | 2124 | 2512 | 2855 | 3149 | 3393 | 3608 | 3795 | 3957 | 4098 |
| Metanol | $CH_3OH$ | $\lambda$ [W/(m K)] | 0,014 | 0,025 | 0,035 | – | – | – | – | – | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 9,871 | 13,141 | 16,470 | 19,779 | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1373 | 1620 | 1862 | 2091 | 2302 | 2491 | 2656 | 2795 | 2906 | 3009 |
| Etanol | $C_2H_5OH$ | $\lambda$ [W/(m K)] | 0,047 | 0,025 | 0,033 | – | – | – | – | – | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 8,995 | 11,765 | 14,410 | 16,929 | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1620 | 1905 | 2169 | 2410 | 2631 | 2829 | 3006 | 3161 | 3294 | 3406 |

**Tabela A3.5**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Metanol | $CH_3OH$ | $\lambda$ [W/(m K)] | 0,014 | 0,025 | 0,035 | – | – | – | | | |
| | | $\mu \times 10^6$ (N s/m²) | 9,871 | 13,141 | 16,470 | 19,779 | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1373 | 1620 | 1862 | 2091 | 2302 | 2491 | 2656 | 2795 | 2906 | 3009 |
| Etanol | $C_2H_5OH$ | $\lambda$ [W/(m K)] | 0,047 | 0,025 | 0,033 | – | – | – | – | – | – | – |
| | | $\mu \times 10^6$ (N s/m²) | 8,995 | 11,765 | 14,410 | 16,929 | – | – | – | – | – | – |
| | | $c_p$ [J/(kg K)] | 1620 | 1905 | 2169 | 2410 | 2631 | 2829 | 3006 | 3161 | 3294 | 3406 |

**Tabela A3.5**
*Propriedades de alguns combustíveis na fase gasosa à pressão de 1 atm. (Dados extraídos de Turns, 2000.)*

# APÊNDICE 4
# CONSTANTES DE EQUILÍBRIO

| $T$ (K) | $\log_{10} K_p$ com as pressões parciais em atmosferas | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $\frac{p_{H_2O}}{p_{H_2}\sqrt{p_{O_2}}}$ | $\frac{p_{CO_2}}{p_{CO}\sqrt{p_{O_2}}}$ | $\frac{(p_{H_2O})(p_{CO})}{(p_{H_2})(p_{CO_2})}$ | $\frac{p_{H_2O}}{p_{OH}\sqrt{p_{H_2}}}$ | $\frac{p_{NO}}{\sqrt{p_{O_2}}\sqrt{p_{N_2}}}$ | $\frac{p_{H_2}}{(p_H)^2}$ | $\frac{p_{O_2}}{(p_O)^2}$ | $\frac{p_{N_2}}{(p_N)^2}$ |
| 298 | 40,048 | 45,066 | –5,018 | 46,181 | –15,171 | 71,232 | 81,202 | 159,600 |
| 300 | 39,786 | 44,760 | –4,974 | 45,876 | –15,073 | 70,762 | 80,664 | 158,578 |
| 400 | 29,240 | 32,431 | –3,191 | 33,600 | –11,142 | 51,758 | 58,944 | 117,408 |
| 600 | 18,633 | 20,087 | –1,454 | 21,264 | –7,210 | 32,676 | 37,146 | 76,162 |
| 800 | 13,289 | 13,916 | –0,627 | 15,060 | –5,243 | 23,082 | 26,202 | 55,488 |
| 1000 | 10,062 | 10,221 | –0,159 | 11,322 | –4,062 | 17,294 | 19,612 | 43,056 |
| 1200 | 7,899 | 7,764 | 0,135 | 8,822 | –3,275 | 13,416 | 15,208 | 34,754 |
| 1400 | 6,347 | 6,014 | 0,333 | 7,030 | –2,712 | 10,632 | 12,054 | 28,812 |
| 1600 | 5,180 | 4,706 | 0,474 | 5,686 | –2,290 | 8,534 | 9,684 | 24,350 |
| 1800 | 4,270 | 3,693 | 0,577 | 4,638 | –1,962 | 6,896 | 7,836 | 20,874 |
| 2000 | 3,540 | 2,884 | 0,656 | 3,799 | –1,699 | 5,582 | 6,356 | 18,092 |
| 2200 | 2,942 | 2,226 | 0,716 | 3,113 | –1,484 | 4,504 | 5,142 | 15,810 |
| 2400 | 2,443 | 1,679 | 0,764 | 2,541 | –1,305 | 3,602 | 4,130 | 13,908 |

**Tabela A4.1**
*Constantes de equilíbrio. (Dados extraídos de Rogers e Mayhew, 1994.) (continua)*

| $T$ (K) | $\log_{10} K_p$ com as pressões parciais em atmosferas | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $\frac{p_{H_2O}}{p_{H_2}\sqrt{p_{O_2}}}$ | $\frac{p_{CO_2}}{p_{CO}\sqrt{p_{O_2}}}$ | $\frac{(p_{H_2O})(p_{CO})}{(p_{H_2})(p_{CO_2})}$ | $\frac{p_{H_2O}}{p_{OH}\sqrt{p_{H_2}}}$ | $\frac{p_{NO}}{\sqrt{p_{O_2}}\sqrt{p_{N_2}}}$ | $\frac{p_{H_2}}{(p_H)^2}$ | $\frac{p_{O_2}}{(p_O)^2}$ | $\frac{p_{N_2}}{(p_N)^2}$ |
| 2600 | 2,021 | 1,219 | 0,802 | 2,057 | –1,154 | 2,836 | 3,272 | 12,298 |
| 2800 | 1,658 | 0,825 | 0,833 | 1,642 | –1,025 | 2,178 | 2,536 | 10,914 |
| 3000 | 1,343 | 0,485 | 0,858 | 1,282 | –0,913 | 1,608 | 1,898 | 9,716 |
| 3200 | 1,067 | 0,189 | 0,878 | 0,967 | –0,815 | 1,108 | 1,340 | 8,664 |
| 3400 | 0,824 | –0,071 | 0,895 | 0,690 | –0,729 | 0,664 | 0,846 | 7,736 |
| 3600 | 0,607 | –0,302 | 0,909 | 0,444 | –0,653 | 0,270 | 0,408 | 6,910 |
| 3800 | 0,413 | –0,508 | 0,921 | 0,223 | –0,585 | –0,082 | 0,014 | 6,172 |
| 4000 | 0,238 | –0,692 | 0,930 | 0,025 | –0,524 | –0,400 | –0,340 | 5,504 |
| 4500 | –0,133 | –1,079 | 0,946 | –0,394 | –0,397 | –1,072 | –1,086 | 4,094 |
| 5000 | –0,430 | –1,386 | 0,956 | –0,728 | –0,296 | –1,612 | –1,686 | 2,962 |
| 5500 | –0,675 | –1,635 | 0,960 | –1,002 | –0,214 | –2,054 | –2,176 | 2,032 |
| 6000 | –0,880 | –1,841 | 0,961 | –1,230 | –0,147 | –2,422 | –2,584 | 1,250 |

**Tabela A4.1**
*Constantes de equilíbrio. (Dados extraídos de Rogers e Mayhew, 1994.) (continuação)*