

UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1997/98

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KIT 253 - Termodinamik Kejuruteraan Kimia

Masa : 3 jam

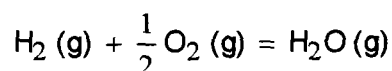
Jawab sebarang LIMA soalan.

Hanya LIMA jawapan yang pertama sahaja akan diperiksa.

Jawab tiap-tiap soalan pada muka surat yang baru.

Kertas ini mengandungi TUJUH soalan semuanya (6 muka surat).

1. Diberi haba pembentukan wap air pada 100 °C ialah -241.8 kJ/mol. Tindak balas pembentukan ialah



dan semua gas dianggapkan unggul.

- (a) Kiralah haba pembentukan wap air pada 300 °C dengan menggunakan purata muatan haba, $C_p(\text{H}_2\text{O}, \text{g}) = 4R$, $C_p(\text{H}_2, \text{g}) = \frac{7}{2}R$, dan

$$C_p(\text{O}_2, \text{g}) = \frac{7}{2}R.$$

(10 markah)

- (b) Terbitkan pernyataan umum bagi entalpi pembentukan pada sebarang suhu bagi tindak balas tersebut. Diberi muatan haba bersandarkan suhu ialah

$$C_p (\text{H}_2\text{O}, \text{g}) = a + bT + cT^2$$

$$C_p (\text{H}_2, \text{g}) = a - \frac{b}{10}T + 3cT^2$$

$$C_p (\text{O}_2, \text{g}) = a + bT + 4cT^2$$

(10 markah)

2. Sebuah tangki dilengkapi dengan piston mengandungi n mol suatu gas sempurna dalam keseimbangan termodinamik dengan $C_p = \frac{7}{2}R$ pada tekanan 1 atm dan suhu 250 K.

- (a) Tekanan luar ditambah dengan tiba-tiba kepada 5 atm dengan menggunakan piston dan gas dimampatkan secara *adiabatik* dan *takberbalik* pada tekanan luar tetap. Kiralah suhu akhir gas selepas sahaja pemampatan tamat.
- (b) Tangki kemudiannya ditutup rapat dan selepas tempoh yang panjang suhu gas kembali kepada 250 K. Kiralah tekanan gas di dalam tangki tersebut.
- (c) Andaikan proses (a) dilakukan secara *adiabatik* dan *berbalik*. Kiralah suhu gas selepas pemampatan kepada 5 atm dan tekanan selepas keseimbangan terma.

Diberi: $T_2^\gamma P_1^{1-\gamma} = T_1^\gamma P_2^{1-\gamma}$ dengan $\gamma = C_p/C_v$.

(20 markah)

3. Suatu campuran argon dan ozon ($n_{Ar}/n_{O_3} = 40$) dialirkan melalui mangkin (pada keadaan piawai) untuk menukarkan ozon kepada oksigen. Keseluruhan alatan ditebatkan dan jisim mangkin diabaikan. Selepas aliran berterusan dalam masa yang agak lama, pertambahan suhu ialah 162.25 K. Kiralah entalpi pembentukan bagi ozon. Anda boleh gunakan C_p bagi Ar dan O_2 masing-masing 2.5 R dan 3.5 R, dan bagi campuran $C_p = n_1C_{p1} + n_2C_{p2}$.

(20 markah)

4. (a) Sebuah tangki berisipadu 0.4 m^3 mengandungi 2.0 kg campuran keseimbangan air dan wapnya pada tekanan 600 kPa. Kiralah

- (i) isipadu dan jisim air, dan
(ii) isipadu dan jisim wap air.

(6 markah)

- (b) Tentukan serta ulaskan sama ada air bagi setiap keadaan berikut adalah dalam bentuk cecair termampatkan, wap lampau panas atau campuran cecair dan wap tepu.

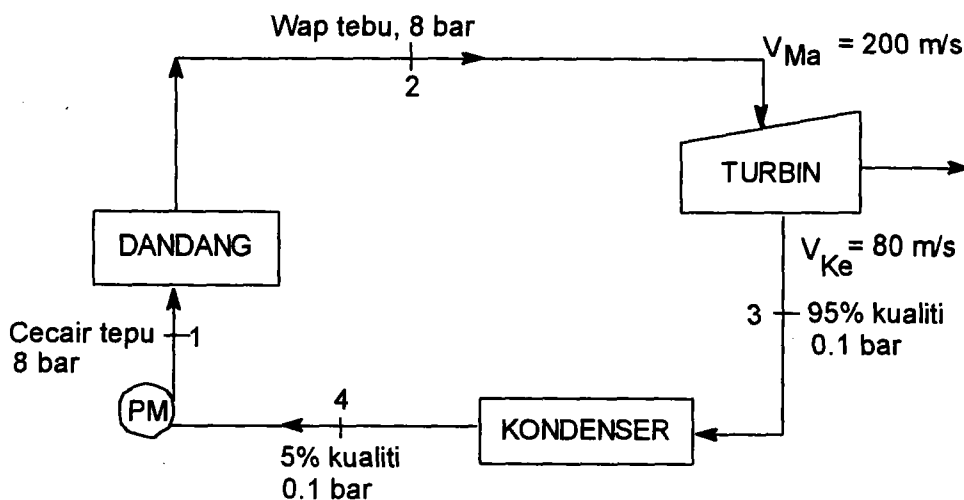
- (i) $T = 120 \text{ }^\circ\text{C}$, $P = 150 \text{ kPa}$,
(ii) $P = 0.35 \text{ MPa}$, isipadu tentu, $(v) = 0.4 \text{ m}^3/\text{kg}$
(iii) $P = 2.0 \text{ MPa}$, $T = 350 \text{ }^\circ\text{C}$.

(9 markah)

- (c) Suatu kitaran wap-pemampatan yang menggunakan bahan penyejuk 717 sebagai bendalir berfungsi telah direkabentuk untuk beroperasi pada suhu pengewap $15 \text{ }^\circ\text{C}$ dan suhu kondenser $45 \text{ }^\circ\text{C}$. Kiralah pekali prestasi (COP) bagi sistem tersebut yang bertindak sebagai *pam haba berbalik*.

(5 markah)

5. (a) Pertimbangkan sebuah loji kuasa stim dalam Rajah berikut. Stim mengalami kitaran dengan data-data seperti yang ditunjukkan di dalam Rajah.



Kiralah

- (i) haba diserap pada dandang,
- (ii) haba dibebaskan pada kondenser, dan
- (iii) kerja yang dihasilkan oleh turbin dengan andaian bahawa proses adalah adiabatik berbalik dan aliran keadaan mantap.

(14 markah)

- (b) Dengan menggunakan persamaan-persamaan keadaan dan terbitan termodinamik yang sesuai, buktikan

$$(i) \quad \left(\frac{\partial h}{\partial P}\right)_T = v - T\left(\frac{\partial v}{\partial T}\right)_P$$

$$(ii) \quad du = C_v dT + [T\left(\frac{\partial P}{\partial T}\right)_v - P] dv$$

(6 markah)

6. (a) Persamaan keabadian tenaga hukum pertama bagi proses keadaan mantap, aliran mantap dengan satu saluran keluar-masuk dinyatakan sebagai

$$q + \left(h + \frac{V^2}{2} + gZ \right)_{\text{masuk}} = \left(h + \frac{V^2}{2} + gZ \right)_{\text{keluar}} + w$$

Bermula dengan persamaan di atas, dan hubungan-hubungan termodinamik yang sesuai, buktikan Persamaan Bernoulli bagi proses berbalik, keadaan mantap, aliran mantap dengan kerja sifar dinyatakan sebagai

$$v(P_{\text{keluar}} - P_{\text{masuk}}) + \frac{(V_{\text{keluar}}^2 - V_{\text{masuk}}^2)}{2} + g(Z_{\text{keluar}} - Z_{\text{masuk}})$$

(4 markah)

- (b) Stim memasuki suatu nozel pada halaju 30 m/s pada tekanan 1000 kPa, suhu 400 °C. Pada saluran keluar tekanan stim susut sebanyak 700 kPa. Kiralah halaju stim keluar daripada nozel dengan mengabaikan perubahan tenaga keupayaan, dan dengan andaian bahawa aliran adalah adiabatik berbalik dan keadaan mantap.
- (10 markah)
- (c) Terangkan dengan ringkas kaedah analisis kitaran berdasarkan Kitaran Carnot sebagai contoh.

(6 markah)

7. (a) Analisis kering bagi suatu sampel hidrokarbon adalah seperti berikut:

| Unsur | Komposisi, % jisim |
|----------|--------------------|
| Sulfur | 0.6 |
| Hidrogen | 5.7 |
| Karbon | 79.2 |
| Oksigen | 10.0 |
| Nitrogen | 1.5 |
| Abu | 3.0 |

Sampel tersebut dibakar dengan 200% udara teori. Kiralah nisbah udara-bahan api berasaskan jisim bahan api.

(10 markah)

- (b) Suatu kuantiti udara pada tekanan 1 MPa dan suhu 70 °C dimampatkan secara adiabatik sehingga tekanan menjadi 7 MPa di dalam kitaran enjin Otto. Sebanyak 460 kJ haba per kg udara telah ditambah ke dalam kitaran pada isipadu tetap. Kiralah

- (i) nisbah pemampatan enjin,
- (ii) suhu pada akhir pemampatan, dan
- (iii) suhu pada akhir penambahan haba.

Bagi udara $C_p = 1.0035 \text{ kJ/kg K}$, $C_v = 0.7165 \text{ kJ/kg K}$.

(10 markah)

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KIT 253: TERMODINAMIK KEJURUTERAAN KIMIA

SIFAT-SIFAT TERMODINAMIK STIM (UNIT SI)

TABLE A.1.1SI Saturated Steam: Temperature Table (SI Units)

| Temp. °C T | Press. kPa P | Specific Volume m ³ /kg | | Internal Energy kJ/kg | | | Enthalpy kJ/kg | | | Entropy kJ/kg K | | |
|------------------|--------------------|---------------------------------------|----------------------------------|---------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|----------------------------------|--------------------------|---------------------------------|
| | | Sat. Liquid v _f | Sat. Liquid v _g | Sat. Vapor u _f | Evap. u _{fg} | Sat. Vapor u _g | Sat. Liquid h _f | Evap. h _{fg} | Sat. Vapor h _g | Sat. Liquid s _f | Evap. s _{fg} | Sat. Vapor s _g |
| 0.01 | 0.6113 | 0.001 000 | 206.14 | .00 | 2375.3 | 2375.3 | .01 | 2501.3 | 2501.4 | .0000 | 9.1562 | 9.1562 |
| 5 | 0.8721 | 0.001 000 | 147.12 | 20.97 | 2361.3 | 2382.3 | 20.98 | 2489.6 | 2510.6 | .0761 | 8.9496 | 9.0257 |
| 10 | 1.2276 | 0.001 000 | 106.38 | 42.00 | 2347.2 | 2389.2 | 42.01 | 2477.7 | 2519.8 | .1510 | 8.7498 | 8.9008 |
| 15 | 1.7051 | 0.001 001 | 77.93 | 62.99 | 2333.1 | 2396.1 | 62.99 | 2465.9 | 2528.9 | .2245 | 8.5569 | 8.7814 |
| 20 | 2.339 | 0.001 002 | 57.79 | 83.95 | 2319.0 | 2402.9 | 83.96 | 2454.1 | 2538.1 | .2966 | 8.3706 | 8.6672 |
| 25 | 3.169 | 0.001 003 | 43.36 | 104.88 | 2304.9 | 2409.8 | 104.89 | 2442.3 | 2547.2 | .3674 | 8.1905 | 8.5580 |
| 30 | 4.246 | 0.001 004 | 32.89 | 125.78 | 2290.8 | 2416.6 | 125.79 | 2430.5 | 2556.3 | .4369 | 8.0164 | 8.4533 |
| 35 | 5.628 | 0.001 006 | 25.22 | 146.67 | 2276.7 | 2423.4 | 146.68 | 2418.6 | 2565.3 | .5053 | 7.8478 | 8.3531 |
| 40 | 7.384 | 0.001 008 | 19.52 | 167.56 | 2262.6 | 2430.1 | 167.57 | 2406.7 | 2574.3 | .5725 | 7.6845 | 8.2570 |
| 45 | 9.593 | 0.001 010 | 15.26 | 188.44 | 2248.4 | 2436.8 | 188.45 | 2394.8 | 2583.2 | .6387 | 7.5261 | 8.1648 |
| 50 | 12.349 | 0.001 012 | 12.03 | 209.32 | 2234.2 | 2443.5 | 209.33 | 2382.7 | 2592.1 | .7038 | 7.3725 | 8.0763 |
| 55 | 15.758 | 0.001 015 | 9.568 | 230.21 | 2219.9 | 2450.1 | 230.23 | 2370.7 | 2600.9 | .7679 | 7.2234 | 7.9913 |
| 60 | 19.940 | 0.001 017 | 7.671 | 251.11 | 2205.5 | 2456.6 | 251.13 | 2358.5 | 2609.6 | .8312 | 7.0784 | 7.9096 |
| 65 | 25.03 | 0.001 020 | 6.197 | 272.02 | 2191.1 | 2463.1 | 272.06 | 2346.2 | 2618.3 | .8935 | 6.9375 | 7.8310 |
| 70 | 31.19 | 0.001 023 | 5.042 | 292.95 | 2176.6 | 2469.6 | 292.98 | 2333.8 | 2626.8 | .9549 | 6.8004 | 7.7553 |
| 75 | 38.58 | 0.001 026 | 4.131 | 313.90 | 2162.0 | 2475.9 | 313.93 | 2321.4 | 2635.3 | 1.0155 | 6.6669 | 7.6824 |
| 80 | 47.39 | 0.001 029 | 3.407 | 334.86 | 2147.4 | 2482.2 | 334.91 | 2308.8 | 2643.7 | 1.0753 | 6.5369 | 7.6122 |
| 85 | 57.83 | 0.001 033 | 2.828 | 355.84 | 2132.6 | 2488.4 | 355.90 | 2296.0 | 2651.9 | 1.1343 | 6.4102 | 7.5445 |
| 90 | 70.14 | 0.001 036 | 2.361 | 376.85 | 2117.7 | 2494.5 | 376.92 | 2283.2 | 2660.1 | 1.1925 | 6.2866 | 7.4791 |
| 95 | 84.55 | 0.001 040 | 1.982 | 397.88 | 2102.7 | 2500.6 | 397.96 | 2270.2 | 2668.1 | 1.2500 | 6.1659 | 7.4159 |
| 100 | 0.101 35 | 0.001 044 | 1.6729 | 418.94 | 2087.6 | 2506.5 | 419.04 | 2257.0 | 2676.1 | 1.3069 | 6.0480 | 7.3549 |
| 105 | 0.120 82 | 0.001 048 | 1.4194 | 440.02 | 2072.3 | 2512.4 | 440.15 | 2243.7 | 2683.8 | 1.3630 | 5.9328 | 7.2958 |
| 110 | 0.143 27 | 0.001 052 | 1.2102 | 461.14 | 2057.0 | 2518.1 | 461.30 | 2230.2 | 2691.5 | 1.4185 | 5.8202 | 7.2387 |
| 115 | 0.169 06 | 0.001 056 | 1.0366 | 482.30 | 2041.4 | 2523.7 | 482.48 | 2216.5 | 2699.0 | 1.4734 | 5.7100 | 7.1833 |
| 120 | 0.198 53 | 0.001 060 | 0.8919 | 503.50 | 2025.8 | 2529.3 | 503.71 | 2202.6 | 2706.3 | 1.5276 | 5.6020 | 7.1296 |
| 125 | 0.2321 | 0.001 065 | 0.7706 | 524.74 | 2009.9 | 2534.6 | 524.99 | 2188.5 | 2713.5 | 1.5813 | 5.4962 | 7.0775 |
| 130 | 0.2701 | 0.001 070 | 0.6685 | 546.02 | 1993.9 | 2539.9 | 546.31 | 2174.2 | 2720.5 | 1.6344 | 5.3925 | 7.0269 |
| 135 | 0.3130 | 0.001 075 | 0.5822 | 567.35 | 1977.7 | 2545.0 | 567.69 | 2159.6 | 2727.3 | 1.6870 | 5.2907 | 6.9777 |
| 140 | 0.3613 | 0.001 080 | 0.5089 | 588.74 | 1961.3 | 2550.0 | 589.13 | 2144.7 | 2733.9 | 1.7391 | 5.1908 | 6.9299 |
| 145 | 0.4154 | 0.001 085 | 0.4463 | 610.18 | 1944.7 | 2554.9 | 610.63 | 2129.6 | 2740.3 | 1.7907 | 5.0926 | 6.8833 |
| 150 | 0.4758 | 0.001 091 | 0.3928 | 631.68 | 1927.9 | 2559.5 | 632.20 | 2114.3 | 2746.5 | 1.8418 | 4.9960 | 6.8379 |
| 155 | 0.5431 | 0.001 096 | 0.3468 | 653.24 | 1910.8 | 2564.1 | 653.84 | 2098.6 | 2752.4 | 1.8925 | 4.9010 | 6.7935 |
| 160 | 0.6178 | 0.001 102 | 0.3071 | 674.87 | 1893.5 | 2568.4 | 675.55 | 2082.6 | 2758.1 | 1.9427 | 4.8075 | 6.7502 |
| 165 | 0.7005 | 0.001 108 | 0.2727 | 696.56 | 1876.0 | 2572.5 | 697.34 | 2066.2 | 2763.5 | 1.9925 | 4.7153 | 6.7078 |
| 170 | 0.7917 | 0.001 114 | 0.2428 | 718.33 | 1858.1 | 2576.5 | 719.21 | 2049.5 | 2768.7 | 2.0419 | 4.6244 | 6.6663 |
| 175 | 0.8920 | 0.001 121 | 0.2168 | 740.17 | 1840.0 | 2580.2 | 741.17 | 2032.4 | 2773.6 | 2.0909 | 4.5347 | 6.6256 |
| 180 | 1.0021 | 0.001 127 | 0.194 05 | 762.09 | 1821.6 | 2583.7 | 763.22 | 2015.0 | 2778.2 | 2.1396 | 4.4461 | 6.5857 |
| 185 | 1.1227 | 0.001 134 | 0.174 09 | 784.10 | 1802.9 | 2587.0 | 785.37 | 1997.1 | 2782.4 | 2.1879 | 4.3586 | 6.5465 |
| 190 | 1.2544 | 0.001 141 | 0.156 54 | 806.19 | 1783.8 | 2590.0 | 807.62 | 1978.8 | 2786.4 | 2.2359 | 4.2720 | 6.5079 |
| 195 | 1.3978 | 0.001 149 | 0.141 05 | 828.37 | 1764.4 | 2592.8 | 829.98 | 1960.0 | 2790.0 | 2.2835 | 4.1863 | 6.4698 |
| 200 | 1.5538 | 0.001 157 | 0.127 36 | 850.65 | 1744.7 | 2595.3 | 852.45 | 1940.7 | 2793.2 | 2.3309 | 4.1014 | 6.4323 |
| 205 | 1.7230 | 0.001 164 | 0.115 21 | 873.04 | 1724.5 | 2597.5 | 875.04 | 1921.0 | 2796.0 | 2.3780 | 4.0172 | 6.3952 |
| 210 | 1.9062 | 0.001 173 | 0.104 41 | 895.53 | 1703.9 | 2599.5 | 897.76 | 1900.7 | 2798.5 | 2.4248 | 3.9337 | 6.3585 |

(1)

TABLE A.1.1SI (Continued) Saturated Steam: Temperature Table (SI Units)

| Temp. °C <i>T</i> | Press. MPa <i>P</i> | Specific Volume m ³ /kg | | Internal Energy kJ/kg | | | Enthalpy kJ/kg | | | Entropy kJ/kg K | | |
|-------------------------|---------------------------|--|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|
| | | Sat. Liquid <i>v_f</i> | Sat. Vapor <i>v_g</i> | Sat. Liquid <i>u_f</i> | Evap. <i>u_{fg}</i> | Sat. Vapor <i>u_g</i> | Sat. Liquid <i>h_f</i> | Evap. <i>h_{fg}</i> | Sat. Vapor <i>h_g</i> | Sat. Liquid <i>s_f</i> | Evap. <i>s_{fg}</i> | Sat. Vapor <i>s_g</i> |
| 215 | 2.104 | 0.001 181 | 0.094 79 | 918.14 | 1682.9 | 2601.1 | 920.62 | 1879.9 | 2800.5 | 2.4714 | 3.8507 | 6.3221 |
| 220 | 2.318 | 0.001 190 | 0.086 19 | 940.87 | 1661.5 | 2602.4 | 943.62 | 1858.5 | 2802.1 | 2.5178 | 3.7683 | 6.2861 |
| 225 | 2.548 | 0.001 199 | 0.078 49 | 963.73 | 1639.6 | 2603.3 | 966.78 | 1836.5 | 2803.3 | 2.5639 | 3.6863 | 6.2503 |
| 230 | 2.795 | 0.001 209 | 0.071 58 | 986.74 | 1617.2 | 2603.9 | 990.12 | 1813.8 | 2804.0 | 2.6099 | 3.6047 | 6.2146 |
| 235 | 3.060 | 0.001 219 | 0.065 37 | 1009.89 | 1594.2 | 2604.1 | 1013.62 | 1790.5 | 2804.2 | 2.6558 | 3.5233 | 6.1791 |
| 240 | 3.344 | 0.001 229 | 0.059 76 | 1033.21 | 1570.8 | 2604.0 | 1037.32 | 1766.5 | 2803.8 | 2.7015 | 3.4422 | 6.1437 |
| 245 | 3.648 | 0.001 240 | 0.054 71 | 1056.71 | 1546.7 | 2603.4 | 1061.23 | 1741.7 | 2803.0 | 2.7472 | 3.3612 | 6.1083 |
| 250 | 3.973 | 0.001 251 | 0.050 13 | 1080.39 | 1522.0 | 2602.4 | 1085.36 | 1716.2 | 2801.5 | 2.7927 | 3.2802 | 6.0730 |
| 255 | 4.319 | 0.001 263 | 0.045 98 | 1104.28 | 1496.7 | 2600.9 | 1109.73 | 1689.8 | 2799.5 | 2.8383 | 3.1992 | 6.0375 |
| 260 | 4.688 | 0.001 276 | 0.042 21 | 1128.39 | 1470.6 | 2599.0 | 1134.37 | 1662.5 | 2796.9 | 2.8838 | 3.1181 | 6.0019 |
| 265 | 5.081 | 0.001 289 | 0.038 77 | 1152.74 | 1443.9 | 2596.6 | 1159.28 | 1634.4 | 2793.6 | 2.9294 | 3.0368 | 5.9662 |
| 270 | 5.499 | 0.001 302 | 0.035 64 | 1177.36 | 1416.3 | 2593.7 | 1184.51 | 1605.2 | 2789.7 | 2.9751 | 2.9551 | 5.9301 |
| 275 | 5.942 | 0.001 317 | 0.032 79 | 1202.25 | 1387.9 | 2590.2 | 1210.07 | 1574.9 | 2785.0 | 3.0208 | 2.8730 | 5.8938 |
| 280 | 6.412 | 0.001 332 | 0.030 17 | 1227.46 | 1358.7 | 2586.1 | 1235.99 | 1543.6 | 2779.6 | 3.0668 | 2.7903 | 5.8571 |
| 285 | 6.909 | 0.001 348 | 0.027 77 | 1253.00 | 1328.4 | 2581.4 | 1262.31 | 1511.0 | 2773.3 | 3.1130 | 2.7070 | 5.8199 |
| 290 | 7.436 | 0.001 366 | 0.025 57 | 1278.92 | 1297.1 | 2576.0 | 1289.07 | 1477.1 | 2766.2 | 3.1594 | 2.6227 | 5.7821 |
| 295 | 7.993 | 0.001 384 | 0.023 54 | 1305.2 | 1264.7 | 2569.9 | 1316.3 | 1441.8 | 2758.1 | 3.2062 | 2.5375 | 5.7437 |
| 300 | 8.581 | 0.001 404 | 0.021 67 | 1332.0 | 1231.0 | 2563.0 | 1344.0 | 1404.9 | 2749.0 | 3.2534 | 2.4511 | 5.7045 |
| 305 | 9.202 | 0.001 425 | 0.019 948 | 1359.3 | 1195.9 | 2555.2 | 1372.4 | 1366.4 | 2738.7 | 3.3010 | 2.3633 | 5.6643 |
| 310 | 9.856 | 0.001 447 | 0.018 350 | 1387.1 | 1159.4 | 2546.4 | 1401.3 | 1326.0 | 2727.3 | 3.3493 | 2.2737 | 5.6230 |
| 315 | 10.547 | 0.001 472 | 0.016 867 | 1415.5 | 1121.1 | 2536.6 | 1431.0 | 1283.5 | 2714.5 | 3.3982 | 2.1821 | 5.5804 |
| 320 | 11.274 | 0.001 499 | 0.015 488 | 1444.6 | 1080.9 | 2525.5 | 1461.5 | 1238.6 | 2700.1 | 3.4480 | 2.0882 | 5.5362 |
| 330 | 12.845 | 0.001 561 | 0.012 996 | 1505.3 | 993.7 | 2498.9 | 1525.3 | 1140.6 | 2665.9 | 3.5507 | 1.8909 | 5.4417 |
| 340 | 14.586 | 0.001 638 | 0.010 797 | 1570.3 | 894.3 | 2464.6 | 1594.2 | 1027.9 | 2622.0 | 3.6594 | 1.6763 | 5.3357 |
| 350 | 16.513 | 0.001 740 | 0.008 813 | 1641.9 | 776.6 | 2418.4 | 1670.6 | 893.4 | 2563.9 | 3.7777 | 1.4335 | 5.2112 |
| 360 | 18.651 | 0.001 893 | 0.006 945 | 1725.2 | 626.3 | 2351.5 | 1760.5 | 720.5 | 2481.0 | 3.9147 | 1.1379 | 5.0526 |
| 370 | 21.03 | 0.002 213 | 0.004 925 | 1844.0 | 384.5 | 2228.5 | 1890.5 | 441.6 | 2332.1 | 4.1106 | .6865 | 4.7971 |
| 374.14 | 22.09 | 0.003 155 | 0.003 155 | 2029.6 | 0 | 2029.6 | 2099.3 | 0 | 2099.3 | 4.4298 | 0 | 4.4298 |

(2)

TABLE A.1.2SI Saturated Steam: Pressure Table (SI Units)

| Press. kPa P | Temp. °C T | Specific Volume | | Internal Energy | | | Enthalpy | | | Entropy | | |
|--------------------|------------------|-------------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|-------------------|------------------------|-------------------------|-------------------|------------------------|
| | | Sat. Liquid v_f | Sat. Vapor v_g | Sat. Liquid u_f | Evap. u_{fg} | Sat. Vapor u_g | Sat. Liquid h_f | Evap. h_{fg} | Sat. Vapor h_g | Sat. Liquid s_f | Evap. s_{fg} | Sat. Vapor s_g |
| 0.6113 | 0.01 | 0.001 000 | 206.14 | .00 | 2375.3 | 2375.3 | .01 | 2501.3 | 2501.4 | .0000 | 9.1562 | 9.1562 |
| 1.0 | 6.98 | 0.001 000 | 129.21 | 29.30 | 2355.7 | 2385.0 | 29.30 | 2484.9 | 2514.2 | .1059 | 8.8697 | 8.9756 |
| 1.5 | 13.03 | 0.001 001 | 87.98 | 54.71 | 2338.6 | 2393.3 | 54.71 | 2470.6 | 2525.3 | .1957 | 8.6322 | 8.8279 |
| 2.0 | 17.50 | 0.001 001 | 67.00 | 73.48 | 2326.0 | 2399.5 | 73.48 | 2460.0 | 2533.5 | .2607 | 8.4629 | 8.7237 |
| 2.5 | 21.08 | 0.001 002 | 54.25 | 88.48 | 2315.9 | 2404.4 | 88.49 | 2451.6 | 2540.0 | .3120 | 8.3311 | 8.6432 |
| 3.0 | 24.08 | 0.001 003 | 45.67 | 101.04 | 2307.5 | 2408.5 | 101.05 | 2444.5 | 2545.5 | .3545 | 8.2231 | 8.5776 |
| 4.0 | 28.96 | 0.001 004 | 34.80 | 121.45 | 2293.7 | 2415.2 | 121.46 | 2432.9 | 2554.4 | .4226 | 8.0520 | 8.4746 |
| 5.0 | 32.88 | 0.001 005 | 28.19 | 137.81 | 2282.7 | 2420.5 | 137.82 | 2423.7 | 2561.5 | .4764 | 7.9187 | 8.3951 |
| 7.5 | 40.29 | 0.001 008 | 19.24 | 168.78 | 2261.7 | 2430.5 | 168.79 | 2406.0 | 2574.8 | .5764 | 7.6750 | 8.2515 |
| 10 | 45.81 | 0.001 010 | 14.67 | 191.82 | 2246.1 | 2437.9 | 191.83 | 2392.8 | 2584.7 | .6493 | 7.5009 | 8.1502 |
| 15 | 53.97 | 0.001 014 | 10.02 | 225.92 | 2222.8 | 2448.7 | 225.94 | 2373.1 | 2599.1 | .7549 | 7.2536 | 8.0085 |
| 20 | 60.06 | 0.001 017 | 7.649 | 251.38 | 2205.4 | 2456.7 | 251.40 | 2358.3 | 2609.7 | .8320 | 7.0766 | 7.9085 |
| 25 | 64.97 | 0.001 020 | 6.204 | 271.90 | 2191.2 | 2463.1 | 271.93 | 2346.3 | 2618.2 | .8931 | 6.9383 | 7.8314 |
| 30 | 69.10 | 0.001 022 | 5.229 | 289.20 | 2179.2 | 2468.4 | 289.23 | 2336.1 | 2625.3 | .9439 | 6.8247 | 7.7686 |
| 40 | 75.87 | 0.001 027 | 3.993 | 317.53 | 2159.5 | 2477.0 | 317.58 | 2319.2 | 2636.8 | 1.0259 | 6.6441 | 7.6700 |
| 50 | 81.33 | 0.001 030 | 3.240 | 340.44 | 2143.4 | 2483.9 | 340.49 | 2305.4 | 2645.9 | 1.0910 | 6.5029 | 7.5939 |
| 75 | 91.78 | 0.001 037 | 2.217 | 384.31 | 2112.4 | 2496.7 | 384.39 | 2278.6 | 2663.0 | 1.2130 | 6.2434 | 7.4564 |
| MPa | | | | | | | | | | | | |
| 0.100 | 99.63 | 0.001 043 | 1.6940 | 417.36 | 2088.7 | 2506.1 | 417.46 | 2258.0 | 2675.5 | 1.3026 | 6.0568 | 7.3594 |
| 0.125 | 105.99 | 0.001 048 | 1.3749 | 444.19 | 2069.3 | 2513.5 | 444.32 | 2241.0 | 2685.4 | 1.3740 | 5.9104 | 7.2844 |
| 0.150 | 111.37 | 0.001 053 | 1.1593 | 466.94 | 2052.7 | 2519.7 | 467.11 | 2226.5 | 2693.6 | 1.4336 | 5.7897 | 7.2233 |
| 0.175 | 116.06 | 0.001 057 | 1.0036 | 486.80 | 2038.1 | 2524.9 | 486.99 | 2213.6 | 2700.6 | 1.4849 | 5.6868 | 7.1717 |
| 0.200 | 120.23 | 0.001 061 | 0.8857 | 504.49 | 2025.0 | 2529.5 | 504.70 | 2201.9 | 2706.7 | 1.5301 | 5.5970 | 7.1271 |
| 0.225 | 124.00 | 0.001 064 | 0.7933 | 520.47 | 2013.1 | 2533.6 | 520.72 | 2191.3 | 2712.1 | 1.5706 | 5.5173 | 7.0878 |
| 0.250 | 127.44 | 0.001 067 | 0.7187 | 535.10 | 2002.1 | 2537.2 | 535.37 | 2181.5 | 2716.9 | 1.6072 | 5.4455 | 7.0527 |
| 0.275 | 130.60 | 0.001 070 | 0.6573 | 548.59 | 1991.9 | 2540.5 | 548.89 | 2172.4 | 2721.3 | 1.6408 | 5.3801 | 7.0209 |
| 0.300 | 133.55 | 0.001 073 | 0.6058 | 561.15 | 1982.4 | 2543.6 | 561.47 | 2163.8 | 2725.3 | 1.6718 | 5.3201 | 6.9919 |
| 0.325 | 136.30 | 0.001 076 | 0.5620 | 572.90 | 1973.5 | 2546.4 | 573.25 | 2155.8 | 2729.0 | 1.7006 | 5.2646 | 6.9652 |
| 0.350 | 138.88 | 0.001 079 | 0.5243 | 583.95 | 1965.0 | 2548.9 | 584.33 | 2148.1 | 2732.4 | 1.7275 | 5.2130 | 6.9405 |
| 0.375 | 141.32 | 0.001 081 | 0.4914 | 594.40 | 1956.9 | 2551.3 | 594.81 | 2140.8 | 2735.6 | 1.7528 | 5.1647 | 6.9175 |
| 0.40 | 143.63 | 0.001 084 | 0.4625 | 604.31 | 1949.3 | 2553.6 | 604.74 | 2133.8 | 2738.6 | 1.7766 | 5.1193 | 6.8959 |
| 0.45 | 147.93 | 0.001 088 | 0.4140 | 622.77 | 1934.9 | 2557.6 | 623.25 | 2120.7 | 2743.9 | 1.8207 | 5.0359 | 6.8565 |
| 0.50 | 151.86 | 0.001 093 | 0.3749 | 639.68 | 1921.6 | 2561.2 | 640.23 | 2108.5 | 2748.7 | 1.8607 | 4.9606 | 6.8213 |
| 0.55 | 155.48 | 0.001 097 | 0.3427 | 655.32 | 1909.2 | 2564.5 | 655.93 | 2097.0 | 2753.0 | 1.8973 | 4.8920 | 6.7893 |
| 0.60 | 158.85 | 0.001 101 | 0.3157 | 669.90 | 1897.5 | 2567.4 | 670.56 | 2086.3 | 2756.8 | 1.9312 | 4.8288 | 6.7600 |
| 0.65 | 162.01 | 0.001 104 | 0.2927 | 683.56 | 1886.5 | 2570.1 | 684.28 | 2076.0 | 2760.3 | 1.9627 | 4.7703 | 6.7331 |
| 0.70 | 164.97 | 0.001 108 | 0.2729 | 696.44 | 1876.1 | 2572.5 | 697.22 | 2066.3 | 2763.5 | 1.9922 | 4.7158 | 6.7080 |
| 0.75 | 167.78 | 0.001 112 | 0.2556 | 708.64 | 1866.1 | 2574.7 | 709.47 | 2057.0 | 2766.4 | 2.0200 | 4.6647 | 6.6847 |
| 0.80 | 170.43 | 0.001 115 | 0.2404 | 720.22 | 1856.6 | 2576.8 | 721.11 | 2048.0 | 2769.1 | 2.0462 | 4.6166 | 6.6628 |
| 0.85 | 172.96 | 0.001 118 | 0.2270 | 731.27 | 1847.4 | 2578.7 | 732.22 | 2039.4 | 2771.6 | 2.0710 | 4.5711 | 6.6421 |
| 0.90 | 175.38 | 0.001 121 | 0.2150 | 741.83 | 1838.6 | 2580.5 | 742.83 | 2031.1 | 2773.9 | 2.0946 | 4.5280 | 6.6226 |
| 0.95 | 177.69 | 0.001 124 | 0.2042 | 751.95 | 1830.2 | 2582.1 | 753.02 | 2023.1 | 2776.1 | 2.1172 | 4.4869 | 6.6041 |
| 1.00 | 179.91 | 0.001 127 | 0.194 44 | 761.68 | 1822.0 | 2583.6 | 762.81 | 2015.3 | 2778.1 | 2.1387 | 4.4478 | 6.5865 |
| 1.10 | 184.09 | 0.001 133 | 0.177 53 | 780.09 | 1806.3 | 2586.4 | 781.34 | 2000.4 | 2781.7 | 2.1792 | 4.3744 | 6.5536 |
| 1.20 | 187.99 | 0.001 139 | 0.163 33 | 797.29 | 1791.5 | 2588.8 | 798.65 | 1986.2 | 2784.8 | 2.2166 | 4.3067 | 6.5233 |
| 1.30 | 191.64 | 0.001 144 | 0.151 25 | 813.44 | 1777.5 | 2591.0 | 814.93 | 1972.7 | 2787.6 | 2.2515 | 4.2438 | 6.4953 |
| 1.40 | 195.07 | 0.001 149 | 0.140 84 | 828.70 | 1764.1 | 2592.8 | 830.30 | 1959.7 | 2790.0 | 2.2842 | 4.1850 | 6.4693 |
| 1.50 | 198.32 | 0.001 154 | 0.131 77 | 843.16 | 1751.3 | 2594.5 | 844.89 | 1947.3 | 2792.2 | 2.3150 | 4.1298 | 6.4448 |
| 1.75 | 205.76 | 0.001 166 | 0.113 49 | 876.46 | 1721.4 | 2597.8 | 878.50 | 1917.9 | 2796.4 | 2.3851 | 4.0044 | 6.3896 |
| 2.00 | 212.42 | 0.001 177 | 0.099 63 | 906.44 | 1693.8 | 2600.3 | 908.79 | 1890.7 | 2799.5 | 2.4474 | 3.8935 | 6.3409 |
| 2.25 | 218.45 | 0.001 187 | 0.088 75 | 933.83 | 1668.2 | 2602.0 | 936.49 | 1865.2 | 2801.7 | 2.5035 | 3.7937 | 6.2972 |
| 2.5 | 223.99 | 0.001 197 | 0.079 98 | 959.11 | 1644.0 | 2603.1 | 962.11 | 1841.0 | 2803.1 | 2.5547 | 3.7028 | 6.2575 |
| 3.0 | 233.90 | 0.001 217 | 0.066 68 | 1004.78 | 1599.3 | 2604.1 | 1008.42 | 1795.7 | 2804.2 | 2.6457 | 3.5412 | 6.1869 |

(Continued)

(3)

TABLE A.1.2SI (Continued) Saturated Steam: Pressure Table (SI Units)

| Press. MPa <i>P</i> | Temp. °C <i>T</i> | Specific Volume | | Internal Energy | | | Enthalpy | | | Entropy | | |
|---------------------------|-------------------------|--|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|--|--------------------------------|---------------------------------------|
| | | Sat. Liquid <i>v_f</i> | Sat. Vapor <i>v_g</i> | Sat. Liquid <i>u_f</i> | Evap. <i>u_{fg}</i> | Sat. Vapor <i>u_g</i> | Sat. Liquid <i>h_f</i> | Evap. <i>h_{fg}</i> | Sat. Vapor <i>h_g</i> | Sat. Liquid <i>s_f</i> | Evap. <i>s_{fg}</i> | Sat. Vapor <i>s_g</i> |
| 3.5 | 242.60 | 0.001 235 | 0.057 07 | 1045.43 | 1558.3 | 2603.7 | 1049.75 | 1753.7 | 2803.4 | 2.7253 | 3.4000 | 6.1253 |
| 4 | 250.40 | 0.001 252 | 0.049 78 | 1082.31 | 1520.0 | 2602.3 | 1087.31 | 1714.1 | 2801.4 | 2.7964 | 3.2737 | 6.0701 |
| 5 | 263.99 | 0.001 286 | 0.039 44 | 1147.81 | 1449.3 | 2597.1 | 1154.23 | 1640.1 | 2794.3 | 2.9202 | 3.0532 | 5.9734 |
| 6 | 275.64 | 0.001 319 | 0.032 44 | 1205.44 | 1384.3 | 2589.7 | 1213.35 | 1571.0 | 2784.3 | 3.0267 | 2.8625 | 5.8892 |
| 7 | 285.88 | 0.001 351 | 0.027 37 | 1257.55 | 1323.0 | 2580.5 | 1267.00 | 1505.1 | 2772.1 | 3.1211 | 2.6922 | 5.8133 |
| 8 | 295.06 | 0.001 384 | 0.023 52 | 1305.57 | 1264.2 | 2569.8 | 1316.64 | 1441.3 | 2758.0 | 3.2068 | 2.5364 | 5.7432 |
| 9 | 303.40 | 0.001 418 | 0.020 48 | 1350.51 | 1207.3 | 2557.8 | 1363.26 | 1378.9 | 2742.1 | 3.2858 | 2.3915 | 5.6772 |
| 10 | 311.06 | 0.001 452 | 0.018 026 | 1393.04 | 1151.4 | 2544.4 | 1407.56 | 1317.1 | 2724.7 | 3.3596 | 2.2544 | 5.6141 |
| 11 | 318.15 | 0.001 489 | 0.015 987 | 1433.7 | 1096.0 | 2529.8 | 1450.1 | 1255.5 | 2705.6 | 3.4295 | 2.1233 | 5.5527 |
| 12 | 324.75 | 0.001 527 | 0.014 263 | 1473.0 | 1040.7 | 2513.7 | 1491.3 | 1193.6 | 2684.9 | 3.4962 | 1.9962 | 5.4924 |
| 13 | 330.93 | 0.001 567 | 0.012 780 | 1511.1 | 985.0 | 2496.1 | 1531.5 | 1130.7 | 2662.2 | 3.5606 | 1.8718 | 5.4323 |
| 14 | 336.75 | 0.001 611 | 0.011 485 | 1548.6 | 928.2 | 2476.8 | 1571.1 | 1066.5 | 2637.6 | 3.6232 | 1.7485 | 5.3717 |
| 15 | 342.24 | 0.001 658 | 0.010 337 | 1585.6 | 869.8 | 2455.5 | 1610.5 | 1000.0 | 2610.5 | 3.6848 | 1.6249 | 5.3098 |
| 16 | 347.44 | 0.001 711 | 0.009 306 | 1622.7 | 809.0 | 2431.7 | 1650.1 | 930.6 | 2580.6 | 3.7461 | 1.4994 | 5.2455 |
| 17 | 352.37 | 0.001 770 | 0.008 364 | 1660.2 | 744.8 | 2405.0 | 1690.3 | 856.9 | 2547.2 | 3.8079 | 1.3698 | 5.1777 |
| 18 | 357.06 | 0.001 840 | 0.007 489 | 1698.9 | 675.4 | 2374.3 | 1732.0 | 777.1 | 2509.1 | 3.8715 | 1.2329 | 5.1044 |
| 19 | 361.54 | 0.001 924 | 0.006 657 | 1739.9 | 598.1 | 2338.1 | 1776.5 | 688.0 | 2464.5 | 3.9388 | 1.0839 | 5.0228 |
| 20 | 365.81 | 0.002 036 | 0.005 834 | 1785.6 | 507.5 | 2293.0 | 1826.3 | 583.4 | 2409.7 | 4.0139 | .9130 | 4.9269 |
| 21 | 369.89 | 0.002 207 | 0.004 952 | 1842.1 | 388.5 | 2230.6 | 1888.4 | 446.2 | 2334.6 | 4.1075 | .6938 | 4.8013 |
| 22 | 373.80 | 0.002 742 | 0.003 568 | 1961.9 | 125.2 | 2087.1 | 2022.2 | 143.4 | 2165.6 | 4.3110 | .2216 | 4.5327 |
| 22.09 | 374.14 | 0.003 155 | 0.003 155 | 2029.6 | 0 | 2029.6 | 2099.3 | 0 | 2099.3 | 4.4298 | 0 | 4.4298 |

(4)

TABLE A.1.3SI Superheated Vapor (SI Units)

| T | P = .010 MPa (45.81) | | | | P = .050 MPa (81.33) | | | | P = .10 MPa (99.63) | | | |
|----------------------|----------------------|--------|--------|---------|----------------------|--------|--------|---------|---------------------|--------|--------|---------|
| | v | u | h | s | v | u | h | s | v | u | h | s |
| Sat. | 14.674 | 2437.9 | 2584.7 | 8.1502 | 3.240 | 2483.9 | 2645.9 | 7.5939 | 1.6940 | 2506.1 | 2675.5 | 7.3594 |
| 50 | 14.869 | 2443.9 | 2592.6 | 8.1749 | | | | | | | | |
| 100 | 17.196 | 2515.5 | 2687.5 | 8.4479 | 3.418 | 2511.6 | 2682.5 | 7.6947 | 1.6958 | 2506.7 | 2676.2 | 7.3614 |
| 150 | 19.512 | 2587.9 | 2783.0 | 8.6882 | 3.889 | 2585.6 | 2780.1 | 7.9401 | 1.9364 | 2582.8 | 2776.4 | 7.6134 |
| 200 | 21.825 | 2661.3 | 2879.5 | 8.9038 | 4.356 | 2659.9 | 2877.7 | 8.1580 | 2.172 | 2658.1 | 2875.3 | 7.8344 |
| 250 | 24.136 | 2736.0 | 2977.3 | 9.1002 | 4.820 | 2735.0 | 2976.0 | 8.3556 | 2.406 | 2733.7 | 2974.3 | 8.0334 |
| 300 | 26.445 | 2812.1 | 3076.5 | 9.2813 | 5.284 | 2811.3 | 3075.5 | 8.5373 | 2.639 | 2810.4 | 3074.3 | 8.2158 |
| 400 | 31.063 | 2968.9 | 3279.6 | 9.6077 | 6.209 | 2968.5 | 3278.9 | 8.8642 | 3.103 | 2967.9 | 3278.2 | 8.5434 |
| 500 | 35.679 | 3132.3 | 3489.1 | 9.8978 | 7.134 | 3132.0 | 3488.7 | 9.1546 | 3.565 | 3131.6 | 3488.1 | 8.8344 |
| 600 | 40.295 | 3302.5 | 3705.4 | 10.1608 | 8.057 | 3302.2 | 3705.1 | 9.4178 | 4.028 | 3301.9 | 3704.7 | 9.0976 |
| 700 | 44.911 | 3479.6 | 3928.7 | 10.4028 | 8.981 | 3479.4 | 3928.5 | 9.6599 | 4.490 | 3479.2 | 3928.2 | 9.3398 |
| 800 | 49.526 | 3663.8 | 4159.0 | 10.6281 | 9.904 | 3663.6 | 4158.9 | 9.8852 | 4.952 | 3663.5 | 4158.6 | 9.5654 |
| 900 | 54.141 | 3855.0 | 4396.4 | 10.8396 | 10.828 | 3854.9 | 4396.3 | 10.0967 | 5.414 | 3854.8 | 4396.1 | 9.7764 |
| 1000 | 58.757 | 4053.0 | 4640.6 | 11.0393 | 11.751 | 4052.9 | 4640.5 | 10.2964 | 5.875 | 4052.8 | 4640.3 | 9.9764 |
| 1100 | 63.372 | 4257.5 | 4891.2 | 11.2287 | 12.674 | 4257.4 | 4891.1 | 10.4859 | 6.337 | 4257.3 | 4891.0 | 10.1659 |
| 1200 | 67.987 | 4467.9 | 5147.8 | 11.4091 | 13.597 | 4467.8 | 5147.7 | 10.6662 | 6.799 | 4467.7 | 5147.6 | 10.3463 |
| 1300 | 72.602 | 4683.7 | 5409.7 | 11.5811 | 14.521 | 4683.6 | 5409.6 | 10.8382 | 7.260 | 4683.5 | 5409.5 | 10.5183 |
| P = .20 MPa (120.23) | | | | | | | | | | | | |
| Sat. | .8857 | 2529.5 | 2706.7 | 7.1272 | .6058 | 2543.6 | 2725.3 | 6.9919 | .4625 | 2553.6 | 2738.6 | 6.8959 |
| 150 | .9596 | 2576.9 | 2768.8 | 7.2795 | .6339 | 2570.8 | 2761.0 | 7.0778 | .4708 | 2564.5 | 2752.8 | 6.9299 |
| 200 | 1.0803 | 2654.4 | 2870.5 | 7.5066 | .7163 | 2650.7 | 2865.6 | 7.3115 | .5342 | 2646.8 | 2860.5 | 7.1706 |
| 250 | 1.1988 | 2731.2 | 2971.0 | 7.7086 | .7964 | 2728.7 | 2967.6 | 7.5166 | .5951 | 2726.1 | 2964.2 | 7.3789 |
| 300 | 1.3162 | 2808.6 | 3071.8 | 7.8926 | .8753 | 2806.7 | 3069.3 | 7.7022 | .6548 | 2804.8 | 3066.8 | 7.5662 |
| 400 | 1.5493 | 2966.7 | 3276.6 | 8.2218 | 1.0315 | 2965.6 | 3275.0 | 8.0330 | .7726 | 2964.4 | 3273.4 | 7.8985 |
| 500 | 1.7814 | 3130.8 | 3487.1 | 8.5133 | 1.1867 | 3130.0 | 3486.0 | 8.3251 | .8893 | 3129.2 | 3484.9 | 8.1911 |
| 600 | 2.013 | 3301.4 | 3704.0 | 8.7770 | 1.3414 | 3300.8 | 3703.2 | 8.5892 | 1.0055 | 3300.2 | 3702.4 | 8.4554 |
| 700 | 2.244 | 3478.8 | 3927.6 | 9.0194 | 1.4957 | 3478.4 | 3927.1 | 8.8319 | 1.1215 | 3477.9 | 3926.5 | 8.6988 |
| 800 | 2.475 | 3663.1 | 4158.2 | 9.2449 | 1.6499 | 3662.9 | 4157.8 | 9.0576 | 1.2372 | 3662.4 | 4157.3 | 8.9244 |
| 900 | 2.706 | 3854.5 | 4395.8 | 9.4566 | 1.8041 | 3854.2 | 4395.4 | 9.2692 | 1.3529 | 3853.9 | 4395.1 | 9.1364 |
| 1000 | 2.937 | 4052.5 | 4640.0 | 9.6563 | 1.9581 | 4052.3 | 4639.7 | 9.4690 | 1.4685 | 4052.0 | 4639.4 | 9.3364 |
| 1100 | 3.168 | 4257.0 | 4890.7 | 9.8458 | 2.1121 | 4256.8 | 4890.4 | 9.6585 | 1.5840 | 4256.5 | 4890.2 | 9.5254 |
| 1200 | 3.399 | 4467.5 | 5147.3 | 10.0262 | 2.2661 | 4467.2 | 5147.1 | 9.8389 | 1.6996 | 4467.0 | 5146.8 | 9.7064 |
| 1300 | 3.630 | 4683.2 | 5409.3 | 10.1982 | 2.4201 | 4683.0 | 5409.0 | 10.0110 | 1.8151 | 4682.8 | 5408.8 | 9.8784 |
| P = .30 MPa (133.55) | | | | | | | | | | | | |
| Sat. | .6058 | 2543.6 | 2725.3 | 6.9919 | .4625 | 2553.6 | 2738.6 | 6.8959 | .4625 | 2553.6 | 2738.6 | 6.8959 |
| 150 | .6339 | 2570.8 | 2761.0 | 7.0778 | .4708 | 2564.5 | 2752.8 | 6.9299 | .4708 | 2564.5 | 2752.8 | 6.9299 |
| 200 | .7163 | 2650.7 | 2865.6 | 7.3115 | .5342 | 2646.8 | 2860.5 | 7.1706 | .5342 | 2646.8 | 2860.5 | 7.1706 |
| 250 | .7964 | 2728.7 | 2967.6 | 7.5166 | .5951 | 2726.1 | 2964.2 | 7.3789 | .5951 | 2726.1 | 2964.2 | 7.3789 |
| 300 | .8753 | 2806.7 | 3069.3 | 7.7022 | .6548 | 2804.8 | 3066.8 | 7.5662 | .6548 | 2804.8 | 3066.8 | 7.5662 |
| 400 | 1.0315 | 2965.6 | 3275.0 | 8.0330 | .7726 | 2964.4 | 3273.4 | 7.8985 | .7726 | 2964.4 | 3273.4 | 7.8985 |
| 500 | 1.1867 | 3130.0 | 3486.0 | 8.3251 | .8893 | 3129.2 | 3484.9 | 8.1911 | .8893 | 3129.2 | 3484.9 | 8.1911 |
| 600 | 1.3414 | 3300.8 | 3703.2 | 8.5892 | 1.0055 | 3300.2 | 3702.4 | 8.4554 | 1.0055 | 3300.2 | 3702.4 | 8.4554 |
| 700 | 1.4957 | 3478.4 | 3927.1 | 8.8319 | 1.1215 | 3477.9 | 3926.5 | 8.6988 | 1.1215 | 3477.9 | 3926.5 | 8.6988 |
| 800 | 1.6499 | 3662.9 | 4157.8 | 9.0576 | 1.2372 | 3662.4 | 4157.3 | 8.9244 | 1.2372 | 3662.4 | 4157.3 | 8.9244 |
| 900 | 1.8041 | 3854.2 | 4395.4 | 9.2692 | 1.3529 | 3853.9 | 4395.1 | 9.1364 | 1.3529 | 3853.9 | 4395.1 | 9.1364 |
| 1000 | 1.9581 | 4052.3 | 4639.7 | 9.4690 | 1.4685 | 4052.0 | 4639.4 | 9.3364 | 1.4685 | 4052.0 | 4639.4 | 9.3364 |
| 1100 | 2.1121 | 4256.8 | 4890.4 | 9.6585 | 1.5840 | 4256.5 | 4890.2 | 9.5254 | 1.5840 | 4256.5 | 4890.2 | 9.5254 |
| 1200 | 2.2661 | 4467.2 | 5147.1 | 9.8389 | 1.6996 | 4467.0 | 5146.8 | 9.7064 | 1.6996 | 4467.0 | 5146.8 | 9.7064 |
| 1300 | 2.4201 | 4683.0 | 5409.0 | 10.0110 | 1.8151 | 4682.8 | 5408.8 | 9.8784 | 1.8151 | 4682.8 | 5408.8 | 9.8784 |
| P = .40 MPa (143.63) | | | | | | | | | | | | |
| Sat. | .4625 | 2553.6 | 2738.6 | 6.8959 | .4625 | 2553.6 | 2738.6 | 6.8959 | .4625 | 2553.6 | 2738.6 | 6.8959 |
| 150 | .4708 | 2564.5 | 2752.8 | 6.9299 | .4708 | 2564.5 | 2752.8 | 6.9299 | .4708 | 2564.5 | 2752.8 | 6.9299 |
| 200 | .5342 | 2646.8 | 2860.5 | 7.1706 | .5342 | 2646.8 | 2860.5 | 7.1706 | .5342 | 2646.8 | 2860.5 | 7.1706 |
| 250 | .5951 | 2726.1 | 2964.2 | 7.3789 | .5951 | 2726.1 | 2964.2 | 7.3789 | .5951 | 2726.1 | 2964.2 | 7.3789 |
| 300 | .6548 | 2804.8 | 3066.8 | 7.5662 | .6548 | 2804.8 | 3066.8 | 7.5662 | .6548 | 2804.8 | 3066.8 | 7.5662 |
| 400 | .7726 | 2964.4 | 3273.4 | 7.8985 | .7726 | 2964.4 | 3273.4 | 7.8985 | .7726 | 2964.4 | 3273.4 | 7.8985 |
| 500 | .8893 | 3129.2 | 3484.9 | 8.1911 | .8893 | 3129.2 | 3484.9 | 8.1911 | .8893 | 3129.2 | 3484.9 | 8.1911 |
| 600 | 1.0055 | 3300.2 | 3702.4 | 8.4554 | 1.0055 | 3300.2 | 3702.4 | 8.4554 | 1.0055 | 3300.2 | 3702.4 | 8.4554 |
| 700 | 1.1215 | 3477.9 | 3926.5 | 8.6988 | 1.1215 | 3477.9 | 3926.5 | 8.6988 | 1.1215 | 3477.9 | 3926.5 | 8.6988 |
| 800 | 1.2372 | 3662.4 | 4157.3 | 8.9244 | 1.2372 | 3662.4 | 4157.3 | 8.9244 | 1.2372 | 3662.4 | 4157.3 | 8.9244 |
| 900 | 1.3529 | 3853.9 | 4395.1 | 9.1364 | 1.3529 | 3853.9 | 4395.1 | 9.1364 | 1.3529 | 3853.9 | 4395.1 | 9.1364 |
| 1000 | 1.4685 | 4052.0 | 4639.4 | 9.3364 | 1.4685 | 4052.0 | 4639.4 | 9.3364 | 1.4685 | 4052.0 | 4639.4 | 9.3364 |
| 1100 | 1.5840 | 4256.5 | 4890.2 | 9.5254 | 1.5840 | 4256.5 | 4890.2 | 9.5254 | 1.5840 | 4256.5 | 4890.2 | 9.5254 |
| 1200 | 1.6996 | 4467.0 | 5146.8 | 9.7064 | 1.6996 | 4467.0 | 5146.8 | 9.7064 | 1.6996 | 4467.0 | 5146.8 | 9.7064 |
| 1300 | 1.8151 | 4682.8 | 5408.8 | 9.8784 | 1.8151 | 4682.8 | 5408.8 | 9.8784 | 1.8151 | 4682.8 | 5408.8 | 9.8784 |
| P = .50 MPa (151.86) | | | | | | | | | | | | |
| Sat. | .3749 | 2561.2 | 2748.7 | 6.8213 | .3749 | 2561.2 | 2748.7 | 6.8213 | .3749 | 2561.2 | 2748.7 | 6.8213 |
| 200 | .4249 | 2642.9 | 2855.4 | 7.0592 | .4249 | 2642.9 | 2855.4 | 7.0592 | .4249 | 2642.9 | 2855.4 | 7.0592 |
| 250 | .4744 | 2723.5 | 2960.7 | 7.2709 | .4744 | 2723.5 | 2960.7 | 7.2709 | .4744 | 2723.5 | 2960.7 | 7.2709 |
| 300 | .5226 | 2802.9 | 3064.2 | 7.4599 | .5226 | 2802.9 | 3064.2 | 7.4599 | .5226 | 2802.9 | 3064.2 | 7.4599 |
| 350 | .5701 | 2882.6 | 3167.7 | 7.6329 | .5701 | 2882.6 | 3167.7 | 7.6329 | .5701 | 2882.6 | 3167.7 | 7.6329 |
| 400 | .6173 | 2963.2 | 3271.9 | 7.7938 | .6173 | 2963.2 | 3271.9 | 7.7938 | .6173 | 2963.2 | 3271.9 | 7.7938 |
| 500 | .7109 | 3128.4 | 3483.9 | 8.0873 | .7109 | 3128.4 | 3483.9 | 8.0873 | .7109 | 3128.4 | 3483.9 | 8.0873 |
| 600 | .8041 | 3299.6 | 3701.7 | 8.3522 | .8041 | 3299.6 | 3701.7 | 8.3522 | .8041 | 3299.6 | 3701.7 | 8.3522 |
| 700 | .8969 | 3477.5 | 3925.9 | 8.5952 | .8969 | 3477.5 | 3925.9 | 8.5952 | .8969 | 3477.5 | 3925.9 | 8.5952 |
| 800 | .9896 | 3662.1 | 4156.9 | 8.8211 | .9896 | 3662.1 | 4156.9 | 8.8211 | .9896 | 3662.1 | 4156.9 | 8.8211 |
| 900 | 1.0822 | 3853.6 | 4394.7 | 9.0329 | 1.0822 | 3853.6 | 4394.7 | 9.0329 | 1.0822 | 3853.6 | 4394.7 | 9.0329 |
| 1000 | 1.1747 | 4051.8 | 4639.1 | 9.2328 | 1.1747 | 4051.8 | 4639.1 | 9.2328 | 1.1747 | 4051.8 | 4639.1 | 9.2328 |
| 1100 | 1.2672 | 4256.3 | 4889.9 | 9.4224 | 1.2672 | 4256.3 | 4889.9 | 9.4224 | 1.2672 | 4256.3 | 4889.9 | 9.4224 |
| 1200 | 1.3596 | 4466.8 | 5146.6 | 9.6029 | 1.3596 | 4466.8 | 5146.6 | 9.6029 | 1.3596 | 4466.8 | 5146.6 | 9.6029 |
| 1300 | 1.4521 | 4682.5 | | | | | | | | | | |

TABLE A.1.3SI (Continued) Superheated Vapor (SI Units)

| T | v | u | h | s | v | u | h | s | v | u | h | s |
|------------------------------|---------|--------|--------|------------------------------|---------|--------|--------|------------------------------|---------|--------|--------|--------|
| P = 1.00 MPa (179.91) | | | | P = 1.20 MPa (187.99) | | | | P = 1.40 MPa (195.07) | | | | |
| Sat. | .194 44 | 2583.6 | 2778.1 | 6.5865 | .163 33 | 2588.8 | 2784.8 | 6.5233 | .140 84 | 2592.8 | 2790.0 | 6.4693 |
| 200 | .2060 | 2621.9 | 2827.9 | 6.6940 | .169 30 | 2612.8 | 2815.9 | 6.5898 | .143 02 | 2603.1 | 2803.3 | 6.4975 |
| 250 | .2327 | 2709.9 | 2942.6 | 6.9247 | .192 34 | 2704.2 | 2935.0 | 6.8294 | .163 50 | 2698.3 | 2927.2 | 6.7467 |
| 300 | .2579 | 2793.2 | 3051.2 | 7.1229 | .2138 | 2789.2 | 3045.8 | 7.0317 | .182 28 | 2785.2 | 3040.4 | 6.9534 |
| 350 | .2825 | 2875.2 | 3157.7 | 7.3011 | .2345 | 2872.2 | 3153.6 | 7.2121 | .2003 | 2869.2 | 3149.5 | 7.1360 |
| 400 | .3066 | 2957.3 | 3263.9 | 7.4651 | .2548 | 2954.9 | 3260.7 | 7.3774 | .2178 | 2952.5 | 3257.5 | 7.3026 |
| 500 | .3541 | 3124.4 | 3478.5 | 7.7622 | .2946 | 3122.8 | 3476.3 | 7.6759 | .2521 | 3121.1 | 3474.1 | 7.6027 |
| 600 | .4011 | 3296.8 | 3697.9 | 8.0290 | .3339 | 3295.6 | 3696.3 | 7.9435 | .2860 | 3294.4 | 3694.8 | 7.8710 |
| 700 | .4478 | 3475.3 | 3923.1 | 8.2731 | .3729 | 3474.4 | 3922.0 | 8.1881 | .3195 | 3473.6 | 3920.8 | 8.1160 |
| 800 | .4943 | 3660.4 | 4154.7 | 8.4996 | .4118 | 3659.7 | 4153.8 | 8.4148 | .3528 | 3659.0 | 4153.0 | 8.3431 |
| 900 | .5407 | 3852.2 | 4392.9 | 8.7118 | .4505 | 3851.6 | 4392.2 | 8.6272 | .3861 | 3851.1 | 4391.5 | 8.5556 |
| 1000 | .5871 | 4050.5 | 4637.6 | 8.9119 | .4892 | 4050.0 | 4637.0 | 8.8274 | .4192 | 4049.5 | 4636.4 | 8.7559 |
| 1100 | .6335 | 4255.1 | 4888.6 | 9.1017 | .5278 | 4254.6 | 4888.0 | 9.0172 | .4524 | 4254.1 | 4887.5 | 8.9457 |
| 1200 | .6798 | 4465.6 | 5145.4 | 9.2822 | .5665 | 4465.1 | 5144.9 | 9.1977 | .4855 | 4464.7 | 5144.4 | 9.1262 |
| 1300 | .7261 | 4681.3 | 5407.4 | 9.4543 | .6051 | 4680.9 | 5407.0 | 9.3698 | .5186 | 4680.4 | 5406.5 | 9.2984 |
| P = 1.60 MPa (201.41) | | | | P = 1.80 MPa (207.15) | | | | P = 2.00 MPa (212.42) | | | | |
| Sat. | .123 80 | 2596.0 | 2794.0 | 6.4218 | .110 42 | 2598.4 | 2797.1 | 6.3794 | .099 63 | 2600.3 | 2799.5 | 6.3409 |
| 225 | .132 87 | 2644.7 | 2857.3 | 6.5518 | .116 73 | 2636.6 | 2846.7 | 6.4808 | .103 77 | 2628.3 | 2835.8 | 6.4147 |
| 250 | .141 84 | 2692.3 | 2919.2 | 6.6732 | .124 97 | 2686.0 | 2911.0 | 6.6066 | .111 44 | 2679.6 | 2902.5 | 6.5453 |
| 300 | .158 62 | 2781.1 | 3034.8 | 6.8844 | .140 21 | 2776.9 | 3029.2 | 6.8226 | .125 47 | 2772.6 | 3023.5 | 6.7664 |
| 350 | .174 56 | 2866.1 | 3145.4 | 7.0694 | .154 57 | 2863.0 | 3141.2 | 7.0100 | .138 57 | 2859.8 | 3137.0 | 6.9563 |
| 400 | .190 05 | 2950.1 | 3254.2 | 7.2374 | .168 47 | 2947.7 | 3250.9 | 7.1794 | .151 20 | 2945.2 | 3247.6 | 7.1271 |
| 500 | .2203 | 3119.5 | 3472.0 | 7.5390 | .195 50 | 3117.9 | 3469.8 | 7.4825 | .175 68 | 3116.2 | 3467.6 | 7.4317 |
| 600 | .2500 | 3293.3 | 3693.2 | 7.8080 | .2220 | 3292.1 | 3691.7 | 7.7523 | .199 60 | 3290.9 | 3690.1 | 7.7024 |
| 700 | .2794 | 3472.7 | 3919.7 | 8.0535 | .2482 | 3471.8 | 3918.5 | 7.9983 | .2232 | 3470.9 | 3917.4 | 7.9487 |
| 800 | .3086 | 3658.3 | 4152.1 | 8.2808 | .2742 | 3657.6 | 4151.2 | 8.2258 | .2467 | 3657.0 | 4150.3 | 8.1765 |
| 900 | .3377 | 3850.5 | 4390.8 | 8.4935 | .3001 | 3849.9 | 4390.1 | 8.4386 | .2700 | 3849.3 | 4389.4 | 8.3895 |
| 1000 | .3668 | 4049.0 | 4635.8 | 8.6938 | .3260 | 4048.5 | 4635.2 | 8.6391 | .2933 | 4048.0 | 4634.6 | 8.5901 |
| 1100 | .3958 | 4253.7 | 4887.0 | 8.8837 | .3518 | 4253.2 | 4886.4 | 8.8290 | .3166 | 4252.7 | 4885.9 | 8.7800 |
| 1200 | .4248 | 4464.2 | 5143.9 | 9.0643 | .3776 | 4463.7 | 5143.4 | 9.0096 | .3398 | 4463.3 | 5142.9 | 8.9607 |
| 1300 | .4538 | 4679.9 | 5406.0 | 9.2364 | .4034 | 4679.5 | 5405.6 | 9.1818 | .3631 | 4679.0 | 5405.1 | 9.1329 |
| P = 2.50 MPa (223.99) | | | | P = 3.00 MPa (233.90) | | | | P = 3.50 MPa (242.60) | | | | |
| Sat. | .079 98 | 2603.1 | 2803.1 | 6.2575 | .066 68 | 2604.1 | 2804.2 | 6.1869 | .057 07 | 2603.7 | 2803.4 | 6.1253 |
| 225 | .080 27 | 2605.6 | 2806.3 | 6.2639 | .070 58 | 2644.0 | 2855.8 | 6.2872 | .058 72 | 2623.7 | 2829.2 | 6.1749 |
| 250 | .087 00 | 2662.6 | 2880.1 | 6.4085 | .081 14 | 2750.1 | 2993.5 | 6.5390 | .068 42 | 2738.0 | 2977.5 | 6.4461 |
| 300 | .098 90 | 2761.6 | 3008.8 | 6.6438 | .090 53 | 2843.7 | 3115.3 | 6.7428 | .076 78 | 2835.3 | 3104.0 | 6.6579 |
| 350 | .109 76 | 2851.9 | 3126.3 | 6.8403 | .099 36 | 2932.8 | 3230.9 | 6.9212 | .084 53 | 2926.4 | 3222.3 | 6.8405 |
| 400 | .120 10 | 2939.1 | 3239.3 | 7.0148 | .107 87 | 3020.4 | 3344.0 | 7.0834 | .091 96 | 3015.3 | 3337.2 | 7.0052 |
| 450 | .130 14 | 3025.5 | 3350.8 | 7.1746 | .116 19 | 3108.0 | 3456.5 | 7.2338 | .099 18 | 3103.0 | 3450.9 | 7.1572 |
| 500 | .139 98 | 3112.1 | 3462.1 | 7.3234 | .124 43 | 3285.0 | 3682.3 | 7.5085 | .113 24 | 3282.1 | 3678.4 | 7.4339 |
| 600 | .159 30 | 3288.0 | 3686.3 | 7.5960 | .148 38 | 3466.5 | 3911.7 | 7.7571 | .126 99 | 3464.3 | 3908.8 | 7.6837 |
| 700 | .178 32 | 3468.7 | 3914.5 | 7.8435 | .164 14 | 3653.5 | 4145.9 | 7.9862 | .140 56 | 3651.8 | 4143.7 | 7.9134 |
| 800 | .197 16 | 3655.3 | 4148.2 | 8.0720 | .179 80 | 3846.5 | 4385.9 | 8.1999 | .154 02 | 3845.0 | 4384.1 | 8.1276 |
| 900 | .215 90 | 3847.9 | 4387.6 | 8.2853 | .195 41 | 4045.4 | 4631.6 | 8.4009 | .167 43 | 4044.1 | 4630.1 | 8.3288 |
| 1000 | .2346 | 4046.7 | 4633.1 | 8.4861 | .210 98 | 4250.3 | 4883.3 | 8.5912 | .180 80 | 4249.2 | 4881.9 | 8.5192 |
| 1100 | .2532 | 4251.5 | 4884.6 | 8.6762 | .226 52 | 4460.9 | 5140.5 | 8.7720 | .194 15 | 4459.8 | 5139.3 | 8.7000 |
| 1200 | .2718 | 4462.1 | 5141.7 | 8.8569 | .242 06 | 4676.6 | 5402.8 | 8.9442 | .207 49 | 4675.5 | 5401.7 | 8.8723 |
| 1300 | .2905 | 4677.8 | 5404.0 | 9.0291 | | | | | | | | |

(6)

UNIVERSITI SAINS MALAYSIA
Pusat Pengajian Sains Kimia

Pemalar Asas dalam Kimia Fizik

| <u>Simbol</u> | <u>Keterangan</u> | <u>Nilai</u> |
|----------------------|-------------------|--|
| N_A | Nombor Avogadro | $6.022 \times 10^{23} \text{ mol}^{-1}$ |
| F | Pemalar Faraday | 96,500 C mol ⁻¹ , atau coulomb per mol, elektron |
| e | Cas elektron | 4.80×10^{-10} esu 1.60×10^{-19} C atau coulomb |
| m_e | Jisim elektron | 9.11×10^{-28} g 9.11×10^{-31} kg |
| m_p | Jisim proton | 1.67×10^{-24} g 1.67×10^{-27} kg |
| h | Pemalar Planck | 6.626×10^{-27} erg s 6.626×10^{-34} J s |
| c | Halaju cahaya | 3.0×10^{10} cm s ⁻¹ 3.0×10^8 m s ⁻¹ |
| R | Pemalar gas | 8.314×10^7 erg K ⁻¹ mol ⁻¹ 8.314 J K ⁻¹ mol ⁻¹ 0.082 l atm K ⁻¹ mol ⁻¹ 1.987 cal K ⁻¹ mol ⁻¹ |
| k | Pemalar Boltzmann | 1.380×10^{-16} erg K ⁻¹ molekul ⁻¹ 1.380×10^{-23} J K ⁻¹ molekul ⁻¹ |
| g | | 981 cm s ⁻² 9.81 m s ⁻² |
| 1 atm | | 76 cmHg 1.013×10^6 dyne cm ⁻² 101,325 N m ⁻² |
| $2.303 \frac{RT}{F}$ | | 0.0591 V, atau volt, pada 25 °C |

Berat Atom yang Berguna

| | | | | |
|------------|------------|------------|------------|------------|
| H = 1.0 | C = 12.0 | I = 126.9 | Fe = 55.8 | As = 74.9 |
| Br = 79.9 | Cl = 35.5 | Ag = 107.9 | Pb = 207.0 | Xe = 131.1 |
| Na = 23.0 | K = 39.1 | N = 14.0 | Cu = 63.5 | F = 19.0 |
| O = 16.0 | S = 32.0 | P = 31.0 | Ca = 40.1 | Mg = 24.0 |
| Sn = 118.7 | Cs = 132.9 | W = 183.85 | | |