

Indian Institute of Technology Kanpur

Thermodynamics (ESO201A)

Semester: 2022-23-I

Mid-Semester Examination

Closed Notes, Closed Book

Time Limit: 2 hours

Full Marks: 30

Note: Show all steps and calculations.  $1 \text{ Pa} = 1 \text{ N/m}^2$ .

1. It is desired to compress isothermally two kmol of ammonia from the initial state of  $30 \text{ m}^3/\text{kmol}$  and  $300 \text{ K}$  to the final state of  $5 \text{ m}^3/\text{kmol}$  and  $300 \text{ K}$ . It is known that ammonia obeys the following relations.

$$\left( P + \frac{a}{v^2} \right) \left( \frac{1}{v} - b \right) = R_u T \text{ and } d\bar{u} = \bar{c}_v dT + \frac{a}{v^2} d\bar{v}$$

where,  $a = 423.3 \text{ kPa} (\text{m}^3/\text{kmol})^2$ ;  $b = 0.0373 \text{ m}^3/\text{kmol}$ ;  $R_u = 8.315 \text{ kJ/kmol K}$  and  $\bar{c}_v = 27.2376 \text{ kJ/kmol K}$ . Note that  $P$  is in kPa,  $v$  is in  $\text{m}^3/\text{kmol}$  and  $T$  is in kelvin.

Calculate (correct to two decimal places) (i) work done (in kJ); (b) change in the internal energy from the initial to the final state (in kJ); and (iii) energy transferred as heat (in kJ).

(5+3+2 = 10)

2. Air is compressed in a variable-load piston-cylinder device equipped with a paddle wheel. Initially, air is at  $500 \text{ kPa}$  and  $27^\circ\text{C}$ . The paddle wheel is now turned by an external electric motor until  $50 \text{ kJ/kg}$  of work has been transferred to air. During this process, heat is transferred to maintain a constant air temperature while allowing the gas volume to triple. Calculate the required amount of heat transfer, in  $\text{kJ/kg}$  (correct to one decimal place). Treat the air as an ideal gas (justify the assumption). For air,  $R = 0.287 \text{ kJ/kg K}$ ,  $P_{cr} = 3.77 \text{ MPa}$ ,  $T_{cr} = 132.5 \text{ K}$ .

(1 + 7 = 8)

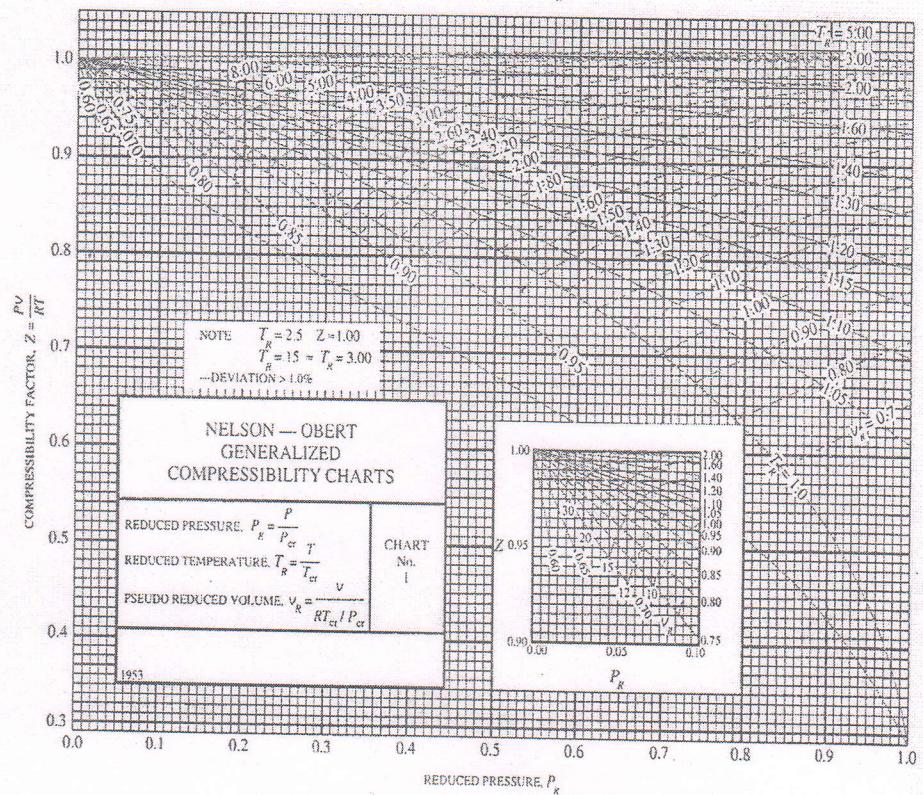
3. Methane at  $8 \text{ MPa}$  and  $300 \text{ K}$  is heated at constant pressure until its volume has increased by 50 percent. Determine the final temperature in kelvin (correct to one decimal place) of the gas using the compressibility factor chart on the reverse of this page. Show on a small diagram how you have obtained the required values from the chart. For methane,  $R = 0.5182 \text{ kJ/kg K}$ ,  $T_{cr} = 191.1 \text{ K}$ ,  $P_{cr} = 4.64 \text{ MPa}$ .

(6)

4. A rigid tank contains water vapour at  $250^\circ\text{C}$  and at an unknown pressure. When the tank is cooled to  $124^\circ\text{C}$ , the vapour starts condensing. Estimate the initial pressure of the water vapour in MPa (correct to one decimal place) in the tank. Show the process on a  $T-v$  plot along with the liquid-vapour mixture dome. See the relevant steam tables (printed on the front and back of the page) enclosed with the question paper.

(5+1 = 6)

(a) Low pressures,  $0 < P_R < 1.0$



(b) Intermediate pressures,  $0 < P_R < 7$

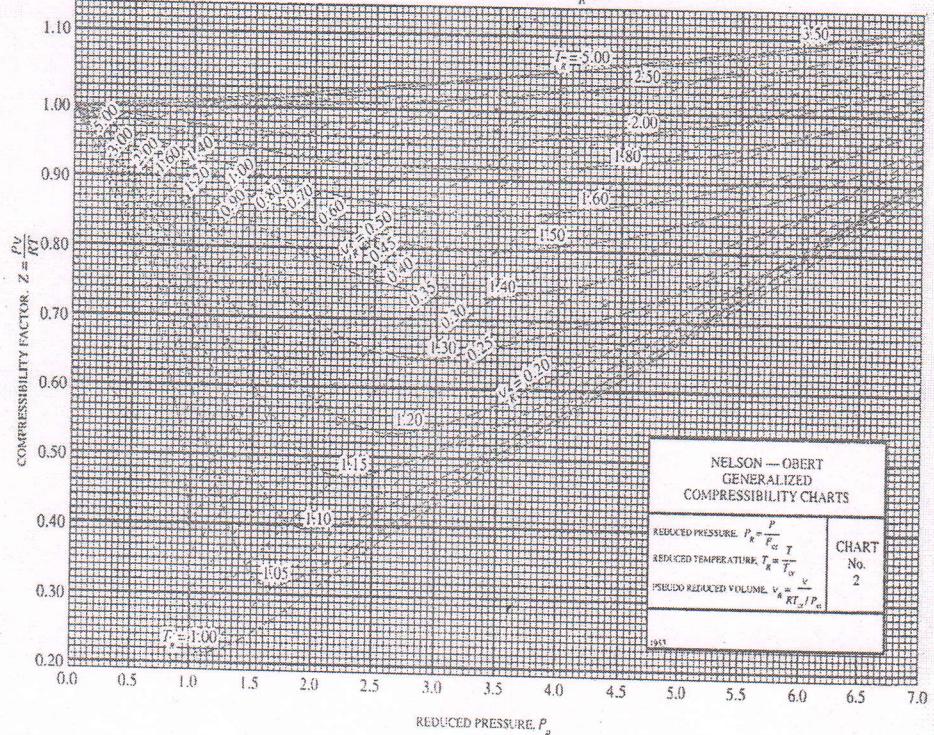


FIGURE A-15

Nelson-Obert generalized compressibility chart.

Used with permission of Dr. Edward E. Obert, University of Wisconsin.

TABLE A-4

Saturated water—Temperature table

| Temp.,<br><i>T</i> °C | Sat. press.,<br><i>P<sub>sat</sub></i> kPa | Specific volume,<br>m <sup>3</sup> /kg |                                     |                                      | Internal energy,<br>kJ/kg            |                                     |                                      | Enthalpy,<br>kJ/kg                   |                                     |                                      | Entropy,<br>kJ/kg·K                  |                                     |  |
|-----------------------|--|--|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|--|
|                       |  | Sat. liquid,<br><i>v<sub>f</sub></i>   | Sat. vapor,<br><i>v<sub>g</sub></i> | Sat. liquid,<br><i>u<sub>f</sub></i> | Sat. vapor,<br><i>u<sub>fg</sub></i> | Sat. vapor,<br><i>u<sub>g</sub></i> | Sat. liquid,<br><i>h<sub>f</sub></i> | Sat. vapor,<br><i>h<sub>fg</sub></i> | Sat. vapor,<br><i>h<sub>g</sub></i> | Sat. liquid,<br><i>s<sub>f</sub></i> | Sat. vapor,<br><i>s<sub>fg</sub></i> | Sat. vapor,<br><i>s<sub>g</sub></i> |  |
| 0.01                  | 0.6117                                     | 0.001000                               | 206.00                              | 0.000                                | 2374.9                               | 2374.9                              | 0.001                                | 2500.9                               | 2500.9                              | 0.0000                               | 9.1556                               | 9.1556                              |  |
| 5                     | 0.8725                                     | 0.001000                               | 147.03                              | 21.019                               | 2360.8                               | 2381.8                              | 21.020                               | 2489.1                               | 2510.1                              | 0.0763                               | 8.9487                               | 9.0249                              |  |
| 10                    | 1.2281                                     | 0.001000                               | 106.32                              | 42.020                               | 2346.6                               | 2388.7                              | 42.022                               | 2477.2                               | 2519.2                              | 0.1511                               | 8.7488                               | 8.8999                              |  |
| 15                    | 1.7057                                     | 0.001001                               | 77.885                              | 62.980                               | 2332.5                               | 2395.5                              | 62.982                               | 2465.4                               | 2528.3                              | 0.2245                               | 8.5559                               | 8.7803                              |  |
| 20                    | 2.3392                                     | 0.001002                               | 57.762                              | 83.913                               | 2318.4                               | 2402.3                              | 83.915                               | 2453.5                               | 2537.4                              | 0.2965                               | 8.3696                               | 8.6661                              |  |
| 25                    | 3.1698                                     | 0.001003                               | 43.340                              | 104.83                               | 2304.3                               | 2409.1                              | 104.83                               | 2441.7                               | 2546.5                              | 0.3672                               | 8.1895                               | 8.5567                              |  |
| 30                    | 4.2469                                     | 0.001004                               | 32.879                              | 125.73                               | 2290.2                               | 2415.9                              | 125.74                               | 2429.8                               | 2555.6                              | 0.4368                               | 8.0152                               | 8.4520                              |  |
| 35                    | 5.6291                                     | 0.001006                               | 25.205                              | 146.63                               | 2276.0                               | 2422.7                              | 146.64                               | 2417.9                               | 2564.6                              | 0.5051                               | 7.8466                               | 8.3517                              |  |
| 40                    | 7.3851                                     | 0.001008                               | 19.515                              | 167.53                               | 2261.9                               | 2429.4                              | 167.53                               | 2406.0                               | 2573.5                              | 0.5724                               | 7.6832                               | 8.2556                              |  |
| 45                    | 9.5953                                     | 0.001010                               | 15.251                              | 188.43                               | 2247.7                               | 2436.1                              | 188.44                               | 2394.0                               | 2582.4                              | 0.6386                               | 7.5247                               | 8.1633                              |  |
| 50                    | 12.352                                     | 0.001012                               | 12.026                              | 209.33                               | 2233.4                               | 2442.7                              | 209.34                               | 2382.0                               | 2591.3                              | 0.7038                               | 7.3710                               | 8.0748                              |  |
| 55                    | 15.763                                     | 0.001015                               | 9.5639                              | 230.24                               | 2219.1                               | 2449.3                              | 230.26                               | 2369.8                               | 2600.1                              | 0.7680                               | 7.2218                               | 7.9898                              |  |
| 60                    | 19.947                                     | 0.001017                               | 7.6670                              | 251.16                               | 2204.7                               | 2455.9                              | 251.18                               | 2357.7                               | 2608.8                              | 0.8313                               | 7.0769                               | 7.9082                              |  |
| 65                    | 25.043                                     | 0.001020                               | 6.1935                              | 272.09                               | 2190.3                               | 2462.4                              | 272.12                               | 2345.4                               | 2617.5                              | 0.8937                               | 6.9360                               | 7.8296                              |  |
| 70                    | 31.202                                     | 0.001023                               | 5.0396                              | 293.04                               | 2175.8                               | 2468.9                              | 293.07                               | 2333.0                               | 2626.1                              | 0.9551                               | 6.7989                               | 7.7540                              |  |
| 75                    | 38.597                                     | 0.001026                               | 4.1291                              | 313.99                               | 2161.3                               | 2475.3                              | 314.03                               | 2320.6                               | 2634.6                              | 1.0158                               | 6.6655                               | 7.6812                              |  |
| 80                    | 47.416                                     | 0.001029                               | 3.4053                              | 334.97                               | 2146.6                               | 2481.6                              | 335.02                               | 2308.0                               | 2643.0                              | 1.0756                               | 6.5355                               | 7.6111                              |  |
| 85                    | 57.868                                     | 0.001032                               | 2.8261                              | 355.96                               | 2131.9                               | 2487.8                              | 356.02                               | 2295.3                               | 2651.4                              | 1.1346                               | 6.4089                               | 7.5435                              |  |
| 90                    | 70.183                                     | 0.001036                               | 2.3593                              | 376.97                               | 2117.0                               | 2494.0                              | 377.04                               | 2282.5                               | 2659.6                              | 1.1929                               | 6.2853                               | 7.4782                              |  |
| 95                    | 84.609                                     | 0.001040                               | 1.9808                              | 398.00                               | 2102.0                               | 2500.1                              | 398.09                               | 2269.6                               | 2667.6                              | 1.2504                               | 6.1647                               | 7.4151                              |  |
| 100                   | 101.42                                     | 0.001043                               | 1.6720                              | 419.06                               | 2087.0                               | 2506.0                              | 419.17                               | 2256.4                               | 2675.6                              | 1.3072                               | 6.0470                               | 7.3542                              |  |
| 105                   | 120.90                                     | 0.001047                               | 1.4186                              | 440.15                               | 2071.8                               | 2511.9                              | 440.28                               | 2243.1                               | 2683.4                              | 1.3634                               | 5.9319                               | 7.2952                              |  |
| 110                   | 143.38                                     | 0.001052                               | 1.2094                              | 461.27                               | 2056.4                               | 2517.7                              | 461.42                               | 2229.7                               | 2691.1                              | 1.4188                               | 5.8193                               | 7.2382                              |  |
| 115                   | 169.18                                     | 0.001056                               | 1.0360                              | 482.42                               | 2040.9                               | 2523.3                              | 482.59                               | 2216.0                               | 2698.6                              | 1.4737                               | 5.7092                               | 7.1829                              |  |
| 120                   | 198.67                                     | 0.001060                               | 0.89133                             | 503.60                               | 2025.3                               | 2528.9                              | 503.81                               | 2202.1                               | 2706.0                              | 1.5279                               | 5.6013                               | 7.1292                              |  |
| 125                   | 232.23                                     | 0.001065                               | 0.77012                             | 524.83                               | 2009.5                               | 2534.3                              | 525.07                               | 2188.1                               | 2713.1                              | 1.5816                               | 5.4956                               | 7.0771                              |  |
| 130                   | 270.28                                     | 0.001070                               | 0.66808                             | 546.10                               | 1993.4                               | 2539.5                              | 546.38                               | 2173.7                               | 2720.1                              | 1.6346                               | 5.3919                               | 7.0265                              |  |
| 135                   | 313.22                                     | 0.001075                               | 0.58179                             | 567.41                               | 1977.3                               | 2544.7                              | 567.75                               | 2159.1                               | 2726.9                              | 1.6872                               | 5.2901                               | 6.9773                              |  |
| 140                   | 361.53                                     | 0.001080                               | 0.50850                             | 588.77                               | 1960.9                               | 2549.6                              | 589.16                               | 2144.3                               | 2733.5                              | 1.7392                               | 5.1901                               | 6.9294                              |  |
| 145                   | 415.68                                     | 0.001085                               | 0.44600                             | 610.19                               | 1944.2                               | 2554.4                              | 610.64                               | 2129.2                               | 2739.8                              | 1.7908                               | 5.0919                               | 6.8827                              |  |
| 150                   | 476.16                                     | 0.001091                               | 0.39248                             | 631.66                               | 1927.4                               | 2559.1                              | 632.18                               | 2113.8                               | 2745.9                              | 1.8418                               | 4.9953                               | 6.8371                              |  |
| 155                   | 543.49                                     | 0.001096                               | 0.34648                             | 653.19                               | 1910.3                               | 2563.5                              | 653.79                               | 2098.0                               | 2751.8                              | 1.8924                               | 4.9002                               | 6.7927                              |  |
| 160                   | 618.23                                     | 0.001102                               | 0.30680                             | 674.79                               | 1893.0                               | 2567.8                              | 675.47                               | 2082.0                               | 2757.5                              | 1.9426                               | 4.8066                               | 6.7492                              |  |
| 165                   | 700.93                                     | 0.001108                               | 0.27244                             | 696.46                               | 1875.4                               | 2571.9                              | 697.24                               | 2065.6                               | 2762.8                              | 1.9923                               | 4.7143                               | 6.7067                              |  |
| 170                   | 792.18                                     | 0.001114                               | 0.24260                             | 718.20                               | 1857.5                               | 2575.7                              | 719.08                               | 2048.8                               | 2767.9                              | 2.0417                               | 4.6233                               | 6.6650                              |  |
| 175                   | 892.60                                     | 0.001121                               | 0.21659                             | 740.02                               | 1839.4                               | 2579.4                              | 741.02                               | 2031.7                               | 2772.7                              | 2.0906                               | 4.5335                               | 6.6242                              |  |
| 180                   | 1002.8                                     | 0.001127                               | 0.19384                             | 761.92                               | 1820.9                               | 2582.8                              | 763.05                               | 2014.2                               | 2777.2                              | 2.1392                               | 4.4448                               | 6.5841                              |  |
| 185                   | 1123.5                                     | 0.001134                               | 0.17390                             | 783.91                               | 1802.1                               | 2586.0                              | 785.19                               | 1996.2                               | 2781.4                              | 2.1875                               | 4.3572                               | 6.5447                              |  |
| 190                   | 1255.2                                     | 0.001141                               | 0.15636                             | 806.00                               | 1783.0                               | 2589.0                              | 807.43                               | 1977.9                               | 2785.3                              | 2.2355                               | 4.2705                               | 6.5059                              |  |
| 195                   | 1398.8                                     | 0.001149                               | 0.14089                             | 828.18                               | 1763.6                               | 2591.7                              | 829.78                               | 1959.0                               | 2788.8                              | 2.2831                               | 4.1847                               | 6.4678                              |  |
| 200                   | 1554.9                                     | 0.001157                               | 0.12721                             | 850.46                               | 1743.7                               | 2594.2                              | 852.26                               | 1939.8                               | 2792.0                              | 2.3305                               | 4.0997                               | 6.4302                              |  |

TABLE A-6

Superheated water

| T<br>°C                        | v<br>m <sup>3</sup> /kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/kg·K | v<br>m <sup>3</sup> /kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/kg·K | v<br>m <sup>3</sup> /kg | u<br>kJ/kg | h<br>kJ/kg | s<br>kJ/kg·K |
|--------------------------------|-------------------------|------------|------------|--------------|-------------------------|------------|------------|--------------|-------------------------|------------|------------|--------------|
| <i>P</i> = 0.01 MPa (45.81°C)* |                         |            |            |              |                         |            |            |              |                         |            |            |              |
| Sat. <sup>†</sup>              | 14.670                  | 2437.2     | 2583.9     | 8.1488       | 3.2403                  | 2483.2     | 2645.2     | 7.5931       | 1.6941                  | 2505.6     | 2675.0     | 7.3589       |
| 50                             | 14.867                  | 2443.3     | 2592.0     | 8.1741       |                         |            |            |              |                         |            |            |              |
| 100                            | 17.196                  | 2515.5     | 2687.5     | 8.4489       | 3.4187                  | 2511.5     | 2682.4     | 7.6953       | 1.6959                  | 2506.2     | 2675.8     | 7.3611       |
| 150                            | 19.513                  | 2587.9     | 2783.0     | 8.6893       | 3.8897                  | 2585.7     | 2780.2     | 7.9413       | 1.9367                  | 2582.9     | 2776.6     | 7.6148       |
| 200                            | 21.826                  | 2661.4     | 2879.6     | 8.9049       | 4.3562                  | 2660.0     | 2877.8     | 8.1592       | 2.1724                  | 2658.2     | 2875.5     | 7.8356       |
| 250                            | 24.136                  | 2736.1     | 2977.5     | 9.1015       | 4.8206                  | 2735.1     | 2976.2     | 8.3568       | 2.4062                  | 2733.9     | 2974.5     | 8.0346       |
| 300                            | 26.446                  | 2812.3     | 3076.7     | 9.2827       | 5.2841                  | 2811.6     | 3075.8     | 8.5387       | 2.6389                  | 2810.7     | 3074.5     | 8.2172       |
| 400                            | 31.063                  | 2969.3     | 3280.0     | 9.6094       | 6.2094                  | 2968.9     | 3279.3     | 8.8659       | 3.1027                  | 2968.3     | 3278.6     | 8.5452       |
| 500                            | 35.680                  | 3132.9     | 3489.7     | 9.8998       | 7.1338                  | 3132.6     | 3489.3     | 9.1566       | 3.5655                  | 3132.2     | 3488.7     | 8.8362       |
| 600                            | 40.296                  | 3303.3     | 3706.3     | 10.1631      | 8.0577                  | 3303.1     | 3706.0     | 9.4201       | 4.0279                  | 3302.8     | 3705.6     | 9.0999       |
| 700                            | 44.911                  | 3480.8     | 3929.9     | 10.4056      | 8.9813                  | 3480.6     | 3929.7     | 9.6626       | 4.4900                  | 3480.4     | 3929.4     | 9.3424       |
| 800                            | 49.527                  | 3665.4     | 4160.6     | 10.6312      | 9.9047                  | 3665.2     | 4160.4     | 9.8883       | 4.9519                  | 3665.0     | 4160.2     | 9.5682       |
| 900                            | 54.143                  | 3856.9     | 4398.3     | 10.8429      | 10.8280                 | 3856.8     | 4398.2     | 10.1000      | 5.4137                  | 3856.7     | 4398.0     | 9.7800       |
| 1000                           | 58.758                  | 4055.3     | 4642.8     | 11.0429      | 11.7513                 | 4055.2     | 4642.7     | 10.3000      | 5.8755                  | 4055.0     | 4642.6     | 9.9800       |
| 1100                           | 63.373                  | 4260.0     | 4893.8     | 11.2326      | 12.6745                 | 4259.9     | 4893.7     | 10.4897      | 6.3372                  | 4259.8     | 4893.6     | 10.1698      |
| 1200                           | 67.989                  | 4470.9     | 5150.8     | 11.4132      | 13.5977                 | 4470.8     | 5150.7     | 10.6704      | 6.7988                  | 4470.7     | 5150.6     | 10.3504      |
| 1300                           | 72.604                  | 4687.4     | 5413.4     | 11.5857      | 14.5209                 | 4687.3     | 5413.3     | 10.8429      | 7.2605                  | 4687.2     | 5413.3     | 10.5229      |
| <i>P</i> = 0.20 MPa (120.21°C) |                         |            |            |              |                         |            |            |              |                         |            |            |              |
| Sat.                           | 0.88578                 | 2529.1     | 2706.3     | 7.1270       |                         |            |            |              |                         |            |            |              |
| 150                            | 0.95986                 | 2577.1     | 2769.1     | 7.2810       | 0.60582                 | 2543.2     | 2724.9     | 6.9917       | 0.46242                 | 2553.1     | 2738.1     | 6.8955       |
| 200                            | 1.08049                 | 2654.6     | 2870.7     | 7.5081       | 0.63402                 | 2571.0     | 2761.2     | 7.0792       | 0.47088                 | 2564.4     | 2752.8     | 6.9306       |
| 250                            | 1.19890                 | 2731.4     | 2971.2     | 7.7100       | 0.71643                 | 2651.0     | 2865.9     | 7.3132       | 0.53434                 | 2647.2     | 2860.9     | 7.1723       |
| 300                            | 1.31623                 | 2808.8     | 3072.1     | 7.8941       | 0.79645                 | 2728.9     | 2967.9     | 7.5180       | 0.59520                 | 2726.4     | 2964.5     | 7.3804       |
| 400                            | 1.54934                 | 2967.2     | 3277.0     | 8.2236       | 0.87535                 | 2807.0     | 3069.6     | 7.7037       | 0.65489                 | 2805.1     | 3067.1     | 7.5677       |
| 500                            | 1.78142                 | 3131.4     | 3487.7     | 8.5153       | 1.03155                 | 2966.0     | 3275.5     | 8.0347       | 0.77265                 | 2964.9     | 3273.9     | 7.9003       |
| 600                            | 2.01302                 | 3302.2     | 3704.8     | 8.7793       | 1.18672                 | 3130.6     | 3486.6     | 8.3271       | 0.88936                 | 3129.8     | 3485.5     | 8.1933       |
| 700                            | 2.24434                 | 3479.9     | 3928.8     | 9.0221       | 1.34139                 | 3301.6     | 3704.0     | 8.5915       | 1.00558                 | 3301.0     | 3703.3     | 8.4580       |
| 800                            | 2.47550                 | 3664.7     | 4159.8     | 9.2479       | 1.49580                 | 3479.5     | 3928.2     | 8.8345       | 1.12152                 | 3479.0     | 3927.6     | 8.7012       |
| 900                            | 2.70656                 | 3856.3     | 4397.7     | 9.4598       | 1.65004                 | 3664.3     | 4159.3     | 9.0605       | 1.23730                 | 3663.9     | 4158.9     | 8.9274       |
| 1000                           | 2.93755                 | 4054.8     | 4642.3     | 9.6599       | 1.80417                 | 3856.0     | 4397.3     | 9.2725       | 1.35298                 | 3855.7     | 4396.9     | 9.1394       |
| 1100                           | 3.16848                 | 4259.6     | 4893.3     | 9.8497       | 1.95824                 | 4054.5     | 4642.0     | 9.4726       | 1.46859                 | 4054.3     | 4641.7     | 9.3396       |
| 1200                           | 3.39938                 | 4470.5     | 5150.4     | 10.0304      | 2.11226                 | 4259.4     | 4893.1     | 9.6624       | 1.58414                 | 4259.2     | 4892.9     | 9.5295       |
| 1300                           | 3.63026                 | 4687.1     | 5413.1     | 10.2029      | 2.26624                 | 4470.3     | 5150.2     | 9.8431       | 1.69966                 | 4470.2     | 5150.0     | 9.7102       |
| <i>P</i> = 0.50 MPa (151.83°C) |                         |            |            |              |                         |            |            |              |                         |            |            |              |
| Sat.                           | 0.37483                 | 2560.7     | 2748.1     | 6.8207       |                         |            |            |              |                         |            |            |              |
| 200                            | 0.42503                 | 2643.3     | 2855.8     | 7.0610       | 0.31560                 | 2566.8     | 2756.2     | 6.7593       | 0.24035                 | 2576.0     | 2768.3     | 6.6616       |
| 250                            | 0.47443                 | 2723.8     | 2961.0     | 7.2725       | 0.35212                 | 2639.4     | 2850.6     | 6.9683       | 0.26088                 | 2631.1     | 2839.8     | 6.8177       |
| 300                            | 0.52261                 | 2803.3     | 3064.6     | 7.4614       | 0.39390                 | 2721.2     | 2957.6     | 7.1833       | 0.29321                 | 2715.9     | 2950.4     | 7.0402       |
| 350                            | 0.57015                 | 2883.0     | 3168.1     | 7.6346       | 0.43442                 | 2801.4     | 3062.0     | 7.3740       | 0.32416                 | 2797.5     | 3056.9     | 7.2345       |
| 400                            | 0.61731                 | 2963.7     | 3272.4     | 7.7956       | 0.47428                 | 2881.6     | 3166.1     | 7.5481       | 0.35442                 | 2878.6     | 3162.2     | 7.4107       |
| 500                            | 0.71095                 | 3129.0     | 3484.5     | 8.0893       | 0.51374                 | 2962.5     | 3270.8     | 7.7097       | 0.38429                 | 2960.2     | 3267.7     | 7.5735       |
| 600                            | 0.80409                 | 3300.4     | 3702.5     | 8.3544       | 0.59200                 | 3128.2     | 3483.4     | 8.0041       | 0.44332                 | 3126.6     | 3481.3     | 7.8692       |
| 700                            | 0.89696                 | 3478.6     | 3927.0     | 8.5978       | 0.66976                 | 3299.8     | 3701.7     | 8.2695       | 0.50186                 | 3298.7     | 3700.1     | 8.1354       |
| 800                            | 0.98966                 | 3663.6     | 4158.4     | 8.8240       | 0.74725                 | 3478.1     | 3926.4     | 8.5132       | 0.56011                 | 3477.2     | 3925.3     | 8.3794       |
| 900                            | 1.08227                 | 3855.4     | 4396.6     | 9.0362       | 0.82457                 | 3663.2     | 4157.9     | 8.7395       | 0.61820                 | 3662.5     | 4157.0     | 8.6061       |
| 1000                           | 1.17480                 | 4054.0     | 4641.4     | 9.2364       | 0.90179                 | 3855.1     | 4396.2     | 8.9518       | 0.67619                 | 3854.5     | 4395.5     | 8.8185       |
| 1100                           | 1.26728                 | 4259.0     | 4892.6     | 9.4263       | 0.97893                 | 4053.8     | 4641.1     | 9.1521       | 0.73411                 | 4053.3     | 4640.5     | 9.0189       |
| 1200                           | 1.35972                 | 4470.0     | 5149.8     | 9.6071       | 1.05603                 | 4258.8     | 4892.4     | 9.3420       | 0.79197                 | 4258.3     | 4891.9     | 9.2090       |
| 1300                           | 1.45214                 | 4686.6     | 5412.6     | 9.7797       | 1.13309                 | 4469.8     | 5149.6     | 9.5229       | 0.84980                 | 4469.4     | 5149.3     | 9.3898       |
|                                |                         |            |            |              | 1.21012                 | 4686.4     | 5412.5     | 9.6955       | 0.90761                 | 4686.1     | 5412.2     | 9.5625       |

\*The temperature in parentheses is the saturation temperature at the specified pressure.

† Properties of saturated vapor at the specified pressure.