1. A vessel contains R-134a at 100 °C and 3.00 MPa.

(a) From the given property table, find the specific volume. (10 %)

(b) Use the ideal-gas model to calculate the specific volume. Compare the result with that you find in (a) and comment on the relative magnitudes. [The molar mass is 102.03 kg/kmol.] (10%)

(c) Use the given property table to calculate the Helmholtz free energy and the Gibbs free energy. (5 %)

*Superheated R-134a*

| Temp. (°C) | $v$ (m³/kg) | $u$ (kJ/kg) | $h$ (kJ/kg) | $s$ (kJ/kg-K) | $v$ (m³/kg) | $u$ (kJ/kg) | $h$ (kJ/kg) | $s$ (kJ/kg-K) |
|---|---|---|---|---|---|---|---|---|
| | 1600 kPa (57.90 °C) | | | | 2000 kPa (67.48 °C) | | | |
| Sat. | 0.01215 | 407.11 | 426.54 | 1.7051 | 0.00930 | 410.15 | 428.75 | 1.6991 |
| 60 | 0.01239 | 409.49 | 429.32 | 1.7135 | — | — | — | — |
| 70 | 0.01345 | 420.37 | 441.89 | 1.7507 | 0.00958 | 413.37 | 432.53 | 1.7101 |
| 80 | 0.01438 | 430.72 | 453.72 | 1.7847 | 0.01055 | 425.20 | 446.30 | 1.7497 |
| 90 | 0.01522 | 440.79 | 465.15 | 1.8166 | 0.01137 | 436.20 | 458.95 | 1.7850 |
| 100 | 0.01601 | 450.71 | 476.33 | 1.8469 | 0.01211 | 446.78 | 471.00 | 1.8177 |
| 110 | 0.01676 | 460.57 | 487.39 | 1.8762 | 0.01279 | 457.12 | 482.69 | 1.8487 |
| 120 | 0.01748 | 470.42 | 498.39 | 1.9045 | 0.01342 | 467.34 | 494.19 | 1.8783 |
| 130 | 0.01817 | 480.30 | 509.37 | 1.9321 | 0.01403 | 477.51 | 505.57 | 1.9069 |
| 140 | 0.01884 | 490.23 | 520.38 | 1.9591 | 0.01461 | 487.68 | 516.90 | 1.9346 |
| 150 | 0.01949 | 500.24 | 531.43 | 1.9855 | 0.01517 | 497.89 | 528.22 | 1.9617 |
| 160 | 0.02013 | 510.33 | 542.54 | 2.0115 | 0.01571 | 508.15 | 539.57 | 1.9882 |
| 170 | 0.02076 | 520.52 | 553.73 | 2.0370 | 0.01624 | 518.48 | 550.96 | 2.0142 |
| 180 | 0.02138 | 530.81 | 565.02 | 2.0622 | 0.01676 | 528.89 | 562.42 | 2.0398 |
| | 3000 kPa (86.20 °C) | | | | 4000 kPa (100.33 °C) | | | |
| Sat. | 0.00528 | 411.83 | 427.67 | 1.6759 | 0.00252 | 394.86 | 404.94 | 1.6036 |
| 90 | 0.00575 | 418.93 | 436.19 | 1.6995 | — | — | — | — |
| 100 | 0.00665 | 433.77 | 453.73 | 1.7472 | — | — | — | — |
| 110 | 0.00734 | 446.48 | 468.50 | 1.7862 | 0.00428 | 429.74 | 446.84 | 1.7148 |
| 120 | 0.00792 | 458.27 | 482.04 | 1.8211 | 0.00500 | 445.97 | 465.99 | 1.7642 |
| 130 | 0.00845 | 469.58 | 494.91 | 1.8535 | 0.00556 | 459.63 | 481.87 | 1.8040 |
| 140 | 0.00893 | 480.61 | 507.39 | 1.8840 | 0.00603 | 472.19 | 496.29 | 1.8394 |
| 150 | 0.00937 | 491.49 | 519.62 | 1.9133 | 0.00644 | 484.15 | 509.92 | 1.8720 |
| 160 | 0.00980 | 502.30 | 531.70 | 1.9415 | 0.00683 | 495.77 | 523.07 | 1.9027 |
| 170 | 0.01021 | 513.09 | 543.71 | 1.9689 | 0.00718 | 507.19 | 535.92 | 1.9320 |
| 180 | 0.01060 | 523.89 | 555.69 | 1.9956 | 0.00752 | 518.51 | 548.57 | 1.9603 |

2. Heat engines are cyclic devices where the working fluid returns to its initial state at the end of each cycle.

(a) Describe the four processes in a Carnot cycle and draw the corresponding P-v (pressure-volume) curves. (10 %)

(b) Using the ideal-gas model for the working fluid, calculate the work, the heat transfer, and the thermal efficiency for a Carnot cycle. (10 %)

(c) Calculate the net entropy change for a Carnot cycle and comment on the relation of your result with the second law of thermodynamics. (5 %)

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3. Air at the rate of 30 kg/min is compressed in a centrifugal air compressor from 1 bar to 3 bar. The temperature increases from 20℃ to 100℃ during compression. Neglect the heat interaction between the compressor and surroundings and changes in potential and kinetic energy. The surrounding air temperature is 20℃.

Take for air, Cp =1.005kJ/kg K, R = 0.287 kJ/kg K

Determine (a) actual power (10%) and (b) minimum power required to run the compressor. (10 %)

4. Calculate the decrease in available energy when 10 kg of water at 70℃ mixes with 20 kg of water at 20℃, the pressure being taken as constant and the temperature of the surroundings being 10℃. (15%)

Take Cp of water as 4.18 kJ/kg K

5. A heat pump working on a reversed Carnot cycle takes in energy from a reservoir maintained at 5°C and delivers it to another reservoir where temperature is 77°C. The heat pump derives power for its operation from a reversible engine operating within the higher and lower temperatures of 1077°C and 77°C. For 100 kJ/kg of energy supplied to reservoir at 77°C, estimate the energy taken from the reservoir at 1077°C. (15 %)

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