**มหาวิทยาลัยสงขลานครินทร์**

**คณะวิศวกรรมศาสตร์**

การสอบปลายภาค ประจำภาคการศึกษาที่ 1 ปีการศึกษา 2554

วันที่ 9 ตุลาคม 2554 เวลา 09.00-12.00 น.

วิชา 216-332 Engineering Thermodynamics II ห้อง S102 และ A403 , S817

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<u>คำสั่ง</u>

1. ข้อสอบมี 16 แผ่นรวมปก ประกอบด้วยปัญหา 5 ข้อ อ่านโจทย์ให้เข้าใจแล้ว**แสดงวิธีทำทุกข้อในข้อสอบ**
2. อนุญาตให้นำเครื่องคิดเลขเข้าห้องสอบได้
3. อนุญาตให้นำกระดาษ A4 ที่จดด้วยลายมือ (ห้ามถ่ายเอกสาร) จำนวน 1 แผ่น เข้าห้องสอบได้
4. ไม่อนุญาตให้นำเอกสาร หนังสือ Dictionary หรือตำราอื่นใดเข้าห้องสอบ ยกเว้นที่อนุญาตตามข้อ 3.
5. ค่าคงที่ต่างๆ ที่กำหนดให้แต่ละข้อ ให้ใช้เฉพาะข้อนั้นๆ เท่านั้น ห้ามนำไปใช้กับข้ออื่นๆ

**ชื่อ-สกุล**.................................................................................................. **รหัส**..................................

| ปัญหา | คะแนนเต็ม | คะแนนที่ได้ |
|---|---|---|
| ข้อที่ 1. | 20 | |
| ข้อที่ 2. | 15 | |
| ข้อที่ 3. | 20 | |
| ข้อที่ 4. | 25 | |
| ข้อที่ 5. | 20 | |
| **คะแนนรวม (100)** | | |

รศ.กำพล ประทีปชัยกูร

อ.สราวุธ โกนสร้าง

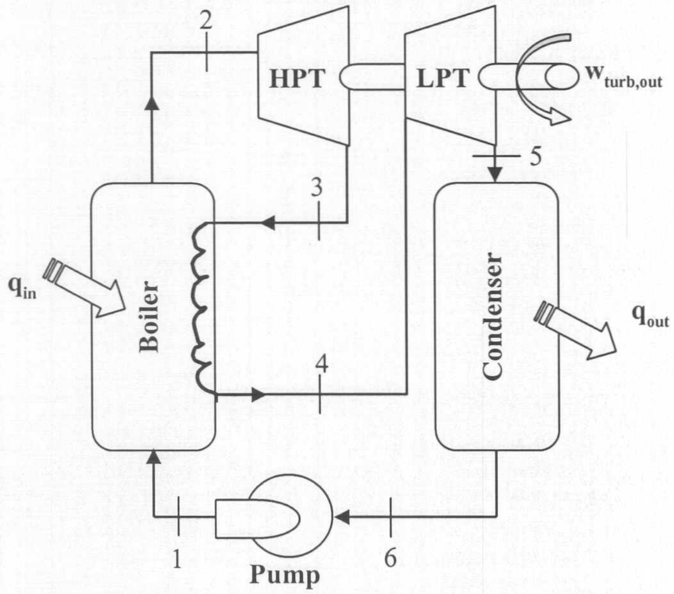
ผู้ออกข้อสอบ

**ทุจริตในการสอบ โทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา**

ชื่อ-สกุล.................................................................................................... รหัส...................................

1. A steam power plant operates on the ideal reheat Rankine cycle. Steam enters the high-pressure turbine at 6 MPa and 400°C and leaves at 2 MPa. Steam is then reheated at constant pressure to the same temperature before it expands to 20 kPa in the low-pressure turbine. Determine:
    a. the turbine work output, in kJ/kg,
    b. the thermal efficiency of the cycle, and
    c. the thermal efficiency of the cycle in case both turbines have an isentropic efficiency of 88%.

    Show the cycle on a T-s diagram with respect to saturation line. (20 scores)



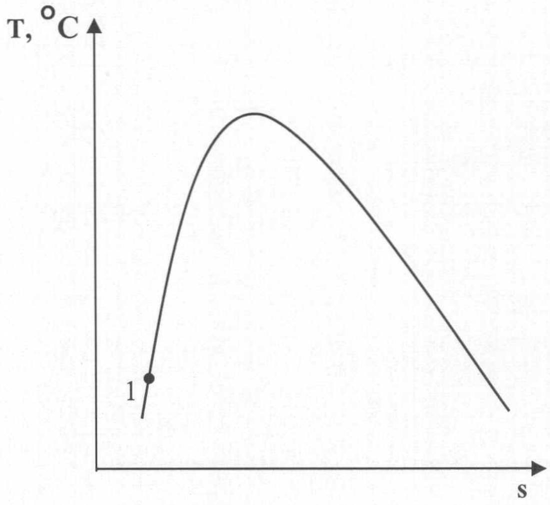




**Table of Properties (in case of ideal cycle)**

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **P** (kPa) | | | | | | |
| **T** (°C) | | | | | | |
| **h** (kJ/kg) | | | | | | |
| **v** ($m^3$/kg) | | | | | | |
| **s** (kJ/kg-K) | | | | | | |

ชื่อ-สกุล................................................................................................ รหัส.................................

**Answers:**

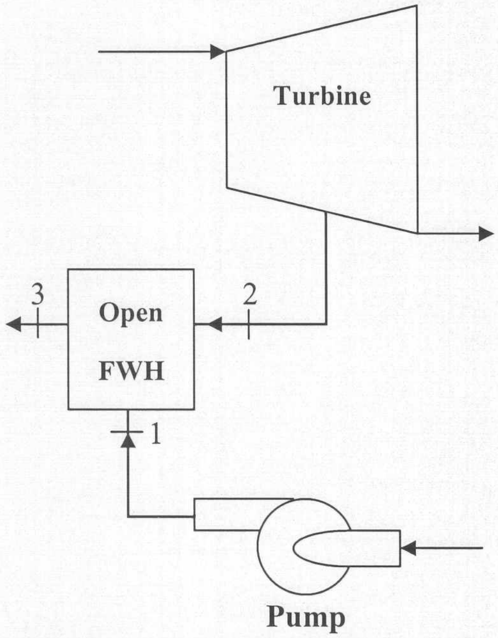
(a) The turbine work output is ______________________________ kJ/kg.

(b) The thermal efficiency of the cycle is ____________________%.

(c) In case both turbines have an isentropic efficiency of 88%, The thermal efficiency of the cycle reduces to ______________________%.

ชื่อ-สกุล.................................................................................................. รหัส..................................

2. Turbine bleed steam enters an open feed water heater of a regenerative Rankine cycle at 200 kPa and 150°C while the cold feedwater enters at 40°C. Determine the ratio of the bleed steam mass flow rate to the inlet feedwater mass flow rate required to heat the feedwater to 110°C. Draw the described process on T-s diagram with respect to saturated curve. (15 scores)



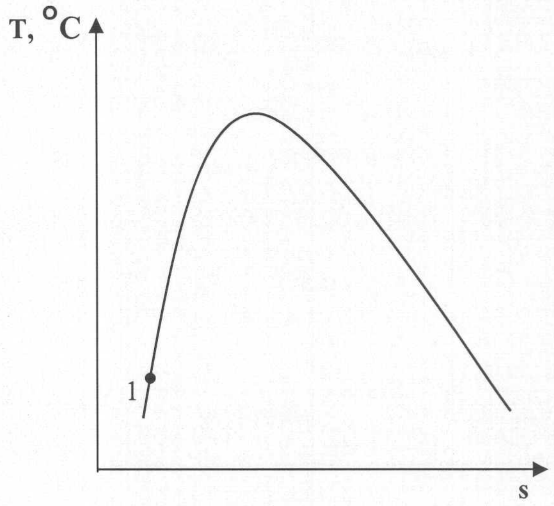




**Table of Properties**

| | 1 | 2 | 3 |
|---|---|---|---|
| **P** (kPa) | | 200 | |
| **T** (°C) | 40 | 150 | 110 |
| **h** (kJ/kg) | | | |

**ชื่อ-สกุล..................................................................................... รหัส.................................**

**Answer:**

The ratio of the bleed steam mass flow rate to the inlet feedwater mass flow rate required is _

___________________________.

ชื่อ-สกุล.......................................................................................... รหัส.................................

3. $O_2$-rich air, which consists of 63 percent $O_2$ and 37 percent $N_2$ by mole numbers, is compressed isothermally at 220 K from 10 to 17 MPa in a steady-flow device. The compression process is internally reversible, and the mass flow rate of air is 1.75 kg/s. Determine:

   (a) the power input to the compressor and

   (b) the rate of heat rejection by treating the as an ideal gas.

(Given:

| | M (kg/kmol) | $c_P$ (kJ/kg-K) | $c_V$ (kJ/kg-K) |
|---|---|---|---|
| Oxygen | 31.999 | 0.918 | 0.658 |
| Nitrogen | 28.013 | 1.039 | 0.743 |

) (20 scores)

$M_{air}$ = ______________________ kg/kmol $\quad \overline{c}_{P,air}$ = ______________________ kJ/kmol-K

$\overline{c}_{V,air}$ = ______________________ kJ/kmol-K $\quad k_{air}$ = ______________________

$\dot{N}_{air}$ = ______________________ kmol/s

ชื่อ-สกุล.................................................................................... รหัส...............................

**Answers:**

(a) The power input to the compressor is ____________________and

(b) The rate of heat rejection is ______________ by treating the mixture **as an ideal gas**.

ชื่อ-สกุล.......................................................................................... รหัส..................................

4. Air enters a cooling section at 1 atm, 32 °C and 70% relative humidity at a rate of 300 g/s. The air is cooled and dehumidified by passing it over a cooling coil though which cold water flows. The water experiences a temperature rise to 10 °C. The air leaves the cooling section and enters heating section as saturated air with absolute humidity of 10 g/kg dry air. The cooled-&-dehumidified air is then heated up to 22 °C and relative humidity reduces to 60%. Determine:

1) the rate of heat transfer to cold water,
2) the mass flow rate of the cold water,
3) the mass flow rate of the condensed water at cooling section, in kg/kg dry air, and
4) the rate of heat gained by air at heating section.

(Given: $C_{p,water}$ = 4.18 kj/kg-°C) (25 scores)

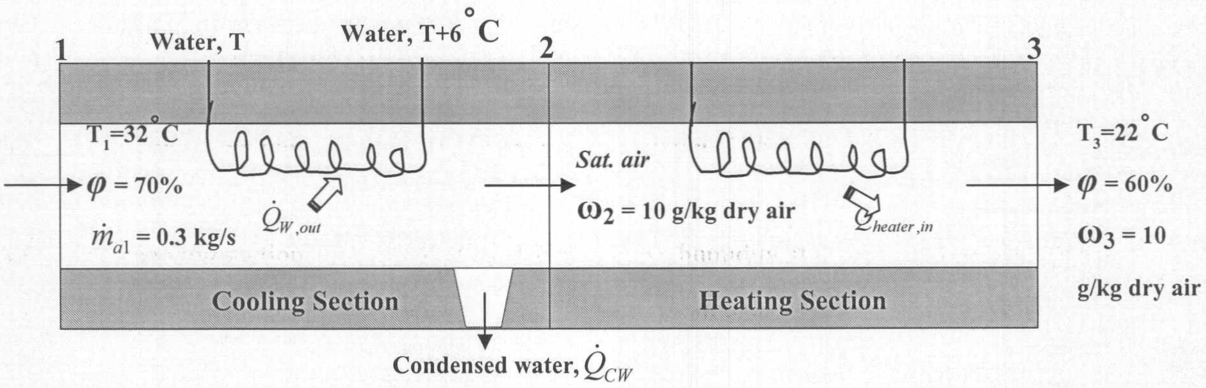



**Table of properties**

| Section | $h$ (kJ/kg dry air) | $\omega$ (kg $H_2O$/kg dry air) | $\dot{m}_a$ ($m^3$/kg dry air) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

**ชื่อ-สกุล**........................................................................................ **รหัส**.................................

**Answers:**

a) The rate of heat transfer to the cold water is ________________kW.

b) The mass flow rate of the cold water is _____________kg/s.

c) The mass flow rate of the condensed water at cooling section is _____________kg/s.

d) The rate of heat gained by air at heating section is __________________kW.

ชื่อ-สกุล.................................................................................................. รหัส.................................

5. The n-Octane gas ($C_8H_{18}$) is burned with 100 percent excess air in a constant pressure burner. The reactants have a temperature of 25°C at 1 atm. The air and fuel enter this burner steadily at standard conditions and the products of combustion leave at 267°C. Calculate the heat transfer, in kJ/kg fuel, during this combustion.

(Given: $M_{m,C8H18}$ = 114 kg/kmol) (20 scores)

**The complete chemical equation**

$C_8H_{18}$+ _____($O_2$ + 3.76$N_2$) → ______$H_2O$ + ______$CO_2$ + ______$N_2$

**The combustion equation with 100% excess air is**

$C_8H_{18}$+ _____($O_2$ + 3.76$N_2$) → ______$H_2O$ + ______$CO_2$ + ______$N_2$+ ________$O_2$

ชื่อ-สกุล.................................................................................... รหัส.................................

**Answer:**

The heat transfer during this combustion is __________ kJ/kg fuel.

ชื่อ-สกุล........................................................................................ รหัส...............................

Saturated water—Temperature table

| | | *Specific volume,* m³/kg | | *Internal energy,* kJ/kg | | | *Enthalpy,* kJ/kg | | | *Entropy,* kJ/kg·K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp., $T$ °C | Sat. press., $P_{sat}$ kPa | 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, $s_g$ |
| 0.01 | 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 |

ชื่อ-สกุล.............................................................................................. รหัส...............................

Saturated water—Pressure table

| | | Specific volume, m$^3$/kg | | Internal energy, kJ/kg | | | Enthalpy, kJ/kg | | | Entropy, kJ/kg·K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Press., $P$ kPa | Sat. temp., $T_{sat}$ °C | 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, $s_g$ |
| 1.0 | 6.97 | 0.001000 | 129.19 | 29.302 | 2355.2 | 2384.5 | 29.303 | 2484.4 | 2513.7 | 0.1059 | 8.8690 | 8.9749 |
| 1.5 | 13.02 | 0.001001 | 87.964 | 54.686 | 2338.1 | 2392.8 | 54.688 | 2470.1 | 2524.7 | 0.1956 | 8.6314 | 8.8270 |
| 2.0 | 17.50 | 0.001001 | 66.990 | 73.431 | 2325.5 | 2398.9 | 73.433 | 2459.5 | 2532.9 | 0.2606 | 8.4621 | 8.7227 |
| 2.5 | 21.08 | 0.001002 | 54.242 | 88.422 | 2315.4 | 2403.8 | 88.424 | 2451.0 | 2539.4 | 0.3118 | 8.3302 | 8.6421 |
| 3.0 | 24.08 | 0.001003 | 45.654 | 100.98 | 2306.9 | 2407.9 | 100.98 | 2443.9 | 2544.8 | 0.3543 | 8.2222 | 8.5765 |
| 4.0 | 28.96 | 0.001004 | 34.791 | 121.39 | 2293.1 | 2414.5 | 121.39 | 2432.3 | 2553.7 | 0.4224 | 8.0510 | 8.4734 |
| 5.0 | 32.87 | 0.001005 | 28.185 | 137.75 | 2282.1 | 2419.8 | 137.75 | 2423.0 | 2560.7 | 0.4762 | 7.9176 | 8.3938 |
| 7.5 | 40.29 | 0.001008 | 19.233 | 168.74 | 2261.1 | 2429.8 | 168.75 | 2405.3 | 2574.0 | 0.5763 | 7.6738 | 8.2501 |
| 10 | 45.81 | 0.001010 | 14.670 | 191.79 | 2245.4 | 2437.2 | 191.81 | 2392.1 | 2583.9 | 0.6492 | 7.4996 | 8.1488 |
| 15 | 53.97 | 0.001014 | 10.020 | 225.93 | 2222.1 | 2448.0 | 225.94 | 2372.3 | 2598.3 | 0.7549 | 7.2522 | 8.0071 |
| 20 | 60.06 | 0.001017 | 7.6481 | 251.40 | 2204.6 | 2456.0 | 251.42 | 2357.5 | 2608.9 | 0.8320 | 7.0752 | 7.9073 |
| 25 | 64.96 | 0.001020 | 6.2034 | 271.93 | 2190.4 | 2462.4 | 271.96 | 2345.5 | 2617.5 | 0.8932 | 6.9370 | 7.8302 |
| 30 | 69.09 | 0.001022 | 5.2287 | 289.24 | 2178.5 | 2467.7 | 289.27 | 2335.3 | 2624.6 | 0.9441 | 6.8234 | 7.7675 |
| 40 | 75.86 | 0.001026 | 3.9933 | 317.58 | 2158.8 | 2476.3 | 317.62 | 2318.4 | 2636.1 | 1.0261 | 6.6430 | 7.6691 |
| 50 | 81.32 | 0.001030 | 3.2403 | 340.49 | 2142.7 | 2483.2 | 340.54 | 2304.7 | 2645.2 | 1.0912 | 6.5019 | 7.5931 |
| 75 | 91.76 | 0.001037 | 2.2172 | 384.36 | 2111.8 | 2496.1 | 384.44 | 2278.0 | 2662.4 | 1.2132 | 6.2426 | 7.4558 |
| 100 | 99.61 | 0.001043 | 1.6941 | 417.40 | 2088.2 | 2505.6 | 417.51 | 2257.5 | 2675.0 | 1.3028 | 6.0562 | 7.3589 |
| 101.325 | 99.97 | 0.001043 | 1.6734 | 418.95 | 2087.0 | 2506.0 | 419.06 | 2256.5 | 2675.6 | 1.3069 | 6.0476 | 7.3545 |
| 125 | 105.97 | 0.001048 | 1.3750 | 444.23 | 2068.8 | 2513.0 | 444.36 | 2240.6 | 2684.9 | 1.3741 | 5.9100 | 7.2841 |
| 150 | 111.35 | 0.001053 | 1.1594 | 466.97 | 2052.3 | 2519.2 | 467.13 | 2226.0 | 2693.1 | 1.4337 | 5.7894 | 7.2231 |
| 175 | 116.04 | 0.001057 | 1.0037 | 486.82 | 2037.7 | 2524.5 | 487.01 | 2213.1 | 2700.2 | 1.4850 | 5.6865 | 7.1716 |
| 200 | 120.21 | 0.001061 | 0.88578 | 504.50 | 2024.6 | 2529.1 | 504.71 | 2201.6 | 2706.3 | 1.5302 | 5.5968 | 7.1270 |
| 225 | 123.97 | 0.001064 | 0.79329 | 520.47 | 2012.7 | 2533.2 | 520.71 | 2191.0 | 2711.7 | 1.5706 | 5.5171 | 7.0877 |
| 250 | 127.41 | 0.001067 | 0.71873 | 535.08 | 2001.8 | 2536.8 | 535.35 | 2181.2 | 2716.5 | 1.6072 | 5.4453 | 7.0525 |
| 275 | 130.58 | 0.001070 | 0.65732 | 548.57 | 1991.6 | 2540.1 | 548.86 | 2172.0 | 2720.9 | 1.6408 | 5.3800 | 7.0207 |
| 300 | 133.52 | 0.001073 | 0.60582 | 561.11 | 1982.1 | 2543.2 | 561.43 | 2163.5 | 2724.9 | 1.6717 | 5.3200 | 6.9917 |
| 325 | 136.27 | 0.001076 | 0.56199 | 572.84 | 1973.1 | 2545.9 | 573.19 | 2155.4 | 2728.6 | 1.7005 | 5.2645 | 6.9650 |
| 350 | 138.86 | 0.001079 | 0.52422 | 583.89 | 1964.6 | 2548.5 | 584.26 | 2147.7 | 2732.0 | 1.7274 | 5.2128 | 6.9402 |
| 375 | 141.30 | 0.001081 | 0.49133 | 594.32 | 1956.6 | 2550.9 | 594.73 | 2140.4 | 2735.1 | 1.7526 | 5.1645 | 6.9171 |
| 400 | 143.61 | 0.001084 | 0.46242 | 604.22 | 1948.9 | 2553.1 | 604.66 | 2133.4 | 2738.1 | 1.7765 | 5.1191 | 6.8955 |
| 450 | 147.90 | 0.001088 | 0.41392 | 622.65 | 1934.5 | 2557.1 | 623.14 | 2120.3 | 2743.4 | 1.8205 | 5.0356 | 6.8561 |
| 500 | 151.83 | 0.001093 | 0.37483 | 639.54 | 1921.2 | 2560.7 | 640.09 | 2108.0 | 2748.1 | 1.8604 | 4.9603 | 6.8207 |
| 550 | 155.46 | 0.001097 | 0.34261 | 655.16 | 1908.8 | 2563.9 | 655.77 | 2096.6 | 2752.4 | 1.8970 | 4.8916 | 6.7886 |
| 600 | 158.83 | 0.001101 | 0.31560 | 669.72 | 1897.1 | 2566.8 | 670.38 | 2085.8 | 2756.2 | 1.9308 | 4.8285 | 6.7593 |
| 650 | 161.98 | 0.001104 | 0.29260 | 683.37 | 1886.1 | 2569.4 | 684.08 | 2075.5 | 2759.6 | 1.9623 | 4.7699 | 6.7322 |
| 700 | 164.95 | 0.001108 | 0.27278 | 696.23 | 1875.6 | 2571.8 | 697.00 | 2065.8 | 2762.8 | 1.9918 | 4.7153 | 6.7071 |
| 750 | 167.75 | 0.001111 | 0.25552 | 708.40 | 1865.6 | 2574.0 | 709.24 | 2056.4 | 2765.7 | 2.0195 | 4.6642 | 6.6837 |

Superheated water

$P$ = 0.20 MPa (120.21°C)

| $T$ °C | $v$ m$^3$/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg·K |
|---|---|---|---|---|
| Sat. | 0.88578 | 2529.1 | 2706.3 | 7.1270 |
| 150 | 0.95986 | 2577.1 | 2769.1 | 7.2810 |
| 200 | 1.08049 | 2654.6 | 2870.7 | 7.5081 |
| 250 | 1.19890 | 2731.4 | 2971.2 | 7.7100 |
| 300 | 1.31623 | 2808.8 | 3072.1 | 7.8941 |
| 400 | 1.54934 | 2967.2 | 3277.0 | 8.2236 |
| 500 | 1.78142 | 3131.4 | 3487.7 | 8.5153 |
| 600 | 2.01302 | 3302.2 | 3704.8 | 8.7793 |
| 700 | 2.24434 | 3479.9 | 3928.8 | 9.0221 |
| 800 | 2.47550 | 3664.7 | 4159.8 | 9.2479 |
| 900 | 2.70656 | 3856.3 | 4397.7 | 9.4598 |
| 1000 | 2.93755 | 4054.8 | 4642.3 | 9.6599 |
| 1100 | 3.16848 | 4259.6 | 4893.3 | 9.8497 |
| 1200 | 3.39938 | 4470.5 | 5150.4 | 10.0304 |
| 1300 | 3.63026 | 4687.1 | 5413.1 | 10.2029 |

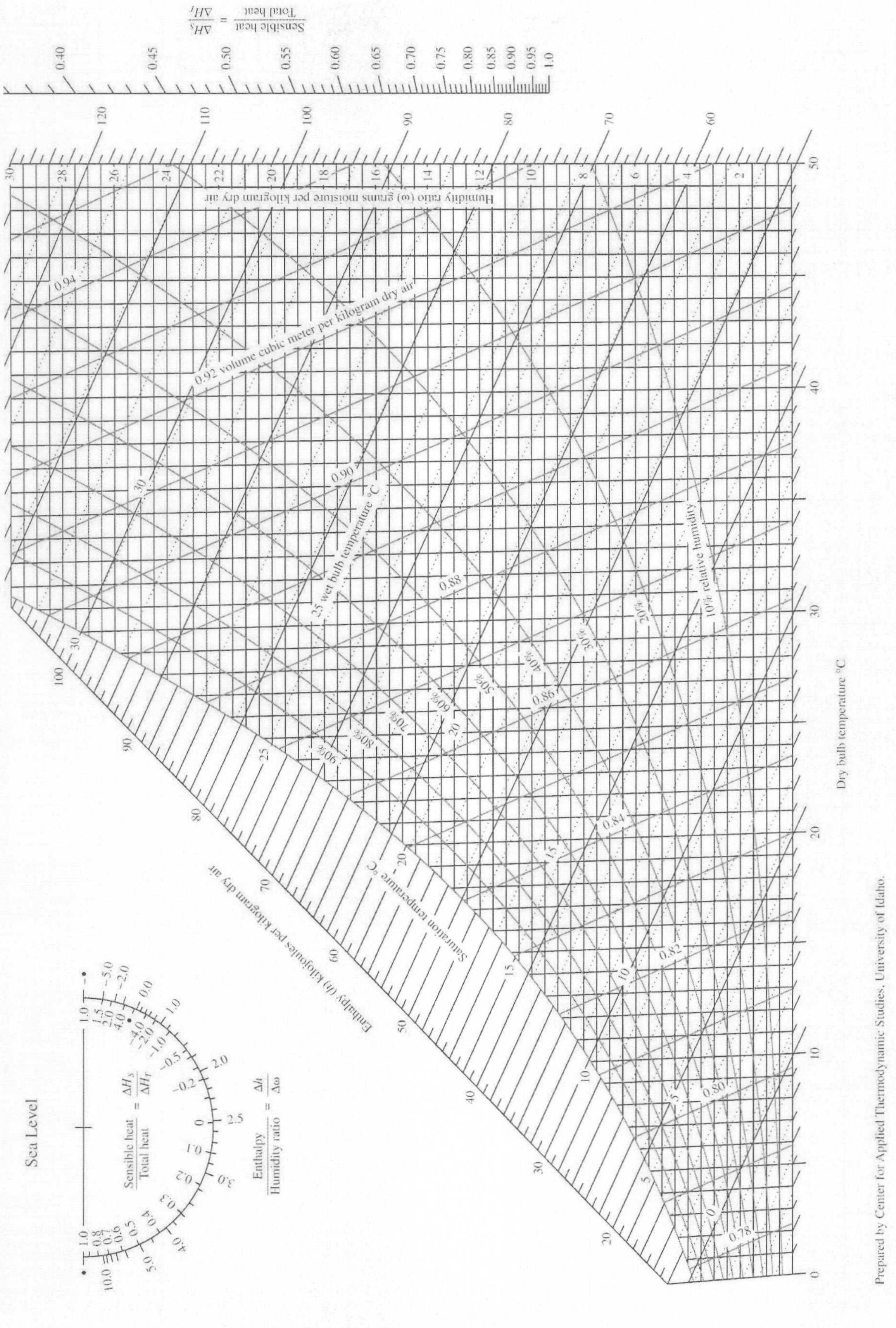
$P$ = 2.00 MPa (212.38°C)

| $T$ °C | $v$ m$^3$/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg·K |
|---|---|---|---|---|
| Sat. | 0.09959 | 2599.1 | 2798.3 | 6.3390 |
| 225 | 0.10381 | 2628.5 | 2836.1 | 6.4160 |
| 250 | 0.11150 | 2680.3 | 2903.3 | 6.5475 |
| 300 | 0.12551 | 2773.2 | 3024.2 | 6.7684 |
| 350 | 0.13860 | 2860.5 | 3137.7 | 6.9583 |
| 400 | 0.15122 | 2945.9 | 3248.4 | 7.1292 |
| 500 | 0.17568 | 3116.9 | 3468.3 | 7.4337 |
| 600 | 0.19962 | 3291.5 | 3690.7 | 7.7043 |
| 700 | 0.22326 | 3471.7 | 3918.2 | 7.9509 |
| 800 | 0.24674 | 3658.0 | 4151.5 | 8.1791 |
| 900 | 0.27012 | 3850.9 | 4391.1 | 8.3925 |
| 1000 | 0.29342 | 4050.2 | 4637.1 | 8.5936 |
| 1100 | 0.31667 | 4255.7 | 4889.1 | 8.7842 |
| 1200 | 0.33989 | 4467.2 | 5147.0 | 8.9654 |
| 1300 | 0.36308 | 4684.2 | 5410.3 | 9.1384 |

$P$ = 6.0 MPa (275.59°C)

| $T$ °C | $v$ m$^3$/kg | $u$ kJ/kg | $h$ kJ/kg | $s$ kJ/kg·K |
|---|---|---|---|---|
| Sat. | 0.03245 | 2589.9 | 2784.6 | 5.8902 |
| 300 | 0.03619 | 2668.4 | 2885.6 | 6.0703 |
| 350 | 0.04225 | 2790.4 | 3043.9 | 6.3357 |
| 400 | 0.04742 | 2893.7 | 3178.3 | 6.5432 |
| 450 | 0.05217 | 2989.9 | 3302.9 | 6.7219 |
| 500 | 0.05667 | 3083.1 | 3423.1 | 6.8826 |
| 550 | 0.06102 | 3175.2 | 3541.3 | 7.0308 |
| 600 | 0.06527 | 3267.2 | 3658.8 | 7.1693 |
| 700 | 0.07355 | 3453.0 | 3894.3 | 7.4247 |
| 800 | 0.08165 | 3643.2 | 4133.1 | 7.6582 |
| 900 | 0.08964 | 3838.8 | 4376.6 | 7.8751 |
| 1000 | 0.09756 | 4040.1 | 4625.4 | 8.0786 |
| 1100 | 0.10543 | 4247.1 | 4879.7 | 8.2709 |
| 1200 | 0.11326 | 4459.8 | 5139.4 | 8.4534 |
| 1300 | 0.12107 | 4677.7 | 5404.1 | 8.6273 |

**ชื่อ-สกุล.............................................................................................. รหัส..................................**


Sea Level
Sensible heat / Total heat = ΔH_S / ΔH_T
Enthalpy / Humidity ratio = Δh / Δω
Humidity ratio (ω) grams moisture per kilogram dry air
0.92 volume cubic meter per kilogram dry air
25 wet bulb temperature °C
10% relative humidity
Saturation temperature °C
Enthalpy (h) kilojoules per kilogram dry air
Dry bulb temperature °C
Prepared by Center for Applied Thermodynamic Studies, University of Idaho.

ชื่อ-สกุล........................................................................................ รหัส................................

Enthalpy of formation, Gibbs function of formation, and absolute entropy at 25°C, 1 atm

| Substance | Formula | $\bar{h}_f^\circ$ kJ/kmol | $\bar{g}_f^\circ$ kJ/kmol | $\bar{s}^\circ$ kJ/kmol·K |
|---|---|---|---|---|
| Carbon | $C(s)$ | 0 | 0 | 5.74 |
| Hydrogen | $H_2(g)$ | 0 | 0 | 130.68 |
| Nitrogen | $N_2(g)$ | 0 | 0 | 191.61 |
| Oxygen | $O_2(g)$ | 0 | 0 | 205.04 |
| Carbon monoxide | $CO(g)$ | −110,530 | −137,150 | 197.65 |
| Carbon dioxide | $CO_2(g)$ | −393,520 | −394,360 | 213.80 |
| Water vapor | $H_2O(g)$ | −241,820 | −228,590 | 188.83 |
| Water | $H_2O(\ell)$ | −285,830 | −237,180 | 69.92 |
| Hydrogen peroxide | $H_2O_2(g)$ | −136,310 | −105,600 | 232.63 |
| Ammonia | $NH_3(g)$ | −46,190 | −16,590 | 192.33 |
| Methane | $CH_4(g)$ | −74,850 | −50,790 | 186.16 |
| Acetylene | $C_2H_2(g)$ | +226,730 | +209,170 | 200.85 |
| Ethylene | $C_2H_4(g)$ | +52,280 | +68,120 | 219.83 |
| Ethane | $C_2H_6(g)$ | −84,680 | −32,890 | 229.49 |
| Propylene | $C_3H_6(g)$ | +20,410 | +62,720 | 266.94 |
| Propane | $C_3H_8(g)$ | −103,850 | −23,490 | 269.91 |
| *n*-Butane | $C_4H_{10}(g)$ | −126,150 | −15,710 | 310.12 |
| *n*-Octane | $C_8H_{18}(g)$ | −208,450 | +16,530 | 466.73 |
| *n*-Octane | $C_8H_{18}(\ell)$ | −249,950 | +6,610 | 360.79 |
| *n*-Dodecane | $C_{12}H_{26}(g)$ | −291,010 | +50,150 | 622.83 |
| Benzene | $C_6H_6(g)$ | +82,930 | +129,660 | 269.20 |
| Methyl alcohol | $CH_3OH(g)$ | −200,670 | −162,000 | 239.70 |
| Methyl alcohol | $CH_3OH(\ell)$ | −238,660 | −166,360 | 126.80 |
| Ethyl alcohol | $C_2H_5OH(g)$ | −235,310 | −168,570 | 282.59 |
| Ethyl alcohol | $C_2H_5OH(\ell)$ | −277,690 | −174,890 | 160.70 |
| Oxygen | $O(g)$ | +249,190 | +231,770 | 161.06 |
| Hydrogen | $H(g)$ | +218,000 | +203,290 | 114.72 |
| Nitrogen | $N(g)$ | +472,650 | +455,510 | 153.30 |
| Hydroxyl | $OH(g)$ | +39,460 | +34,280 | 183.70 |

*Source:* From JANAF, *Thermochemical Tables* (Midland, MI: Dow Chemical Co., 1971); *Selected Values of Chemical Thermodynamic Properties,* NBS Technical Note 270-3, 1968; and *API Research Project 44* (Carnegie Press, 1953).

Ideal-gas properties of nitrogen, $N_2$

| $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^\circ$ kJ/kmol·K | $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^\circ$ kJ/kmol·K |
|---|---|---|---|---|---|---|---|
| 260 | 7,558 | 5,396 | 187.514 | 650 | 19,075 | 13,671 | 214.489 |
| 270 | 7,849 | 5,604 | 188.614 | 660 | 19,380 | 13,892 | 214.954 |
| 280 | 8,141 | 5,813 | 189.673 | 670 | 19,685 | 14,114 | 215.413 |
| 290 | 8,432 | 6,021 | 190.695 | 680 | 19,991 | 14,337 | 215.866 |
| 298 | 8,669 | 6,190 | 191.502 | 690 | 20,297 | 14,560 | 216.314 |
| 500 | 14,581 | 10,423 | 206.630 | 900 | 26,890 | 19,407 | 224.647 |
| 510 | 14,876 | 10,635 | 207.216 | 910 | 27,210 | 19,644 | 225.002 |
| 520 | 15,172 | 10,848 | 207.792 | 920 | 27,532 | 19,883 | 225.353 |
| 530 | 15,469 | 11,062 | 208.358 | 930 | 27,854 | 20,122 | 225.701 |
| 540 | 15,766 | 11,277 | 208.914 | 940 | 28,178 | 20,362 | 226.047 |

ชื่อ-สกุล.................................................................................... รหัส...............................

Ideal-gas properties of oxygen, $O_2$

| $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K | $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K |
|---|---|---|---|---|---|---|---|
| 260 | 7,566 | 5,405 | 201.027 | 650 | 19,544 | 14,140 | 228.932 |
| 270 | 7,858 | 5,613 | 202.128 | 660 | 19,870 | 14,383 | 229.430 |
| 280 | 8,150 | 5,822 | 203.191 | 670 | 20,197 | 14,626 | 229.920 |
| 290 | 8,443 | 6,032 | 204.218 | 680 | 20,524 | 14,871 | 230.405 |
| 298 | 8,682 | 6,203 | 205.033 | 690 | 20,854 | 15,116 | 230.885 |
| 500 | 14,770 | 10,614 | 220.589 | 900 | 27,928 | 20,445 | 239.823 |
| 510 | 15,082 | 10,842 | 221.206 | 910 | 28,272 | 20,706 | 240.203 |
| 520 | 15,395 | 11,071 | 221.812 | 920 | 28,616 | 20,967 | 240.580 |
| 530 | 15,708 | 11,301 | 222.409 | 930 | 28,960 | 21,228 | 240.953 |
| 540 | 16,022 | 11,533 | 222.997 | 940 | 29,306 | 21,491 | 241.323 |

Ideal-gas properties of carbon dioxide, $CO_2$

| $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K | $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K |
|---|---|---|---|---|---|---|---|
| 260 | 7,979 | 5,817 | 208.717 | 650 | 24,674 | 19,270 | 247.032 |
| 270 | 8,335 | 6,091 | 210.062 | 660 | 25,160 | 19,672 | 247.773 |
| 280 | 8,697 | 6,369 | 211.376 | 670 | 25,648 | 20,078 | 248.507 |
| 290 | 9,063 | 6,651 | 212.660 | 680 | 26,138 | 20,484 | 249.233 |
| 298 | 9,364 | 6,885 | 213.685 | 690 | 26,631 | 20,894 | 249.952 |
| 500 | 17,678 | 13,521 | 234.814 | 900 | 37,405 | 29,922 | 263.559 |
| 510 | 18,126 | 13,885 | 235.700 | 910 | 37,935 | 30,369 | 264.146 |
| 520 | 18,576 | 14,253 | 236.575 | 920 | 38,467 | 30,818 | 264.728 |
| 530 | 19,029 | 14,622 | 237.439 | 930 | 39,000 | 31,268 | 265.304 |
| 540 | 19,485 | 14,996 | 238.292 | 940 | 39,535 | 31,719 | 265.877 |

Ideal-gas properties of water vapor, $H_2O$

| $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K | $T$ K | $\bar{h}$ kJ/kmol | $\bar{u}$ kJ/kmol | $\bar{s}^{\circ}$ kJ/kmol·K |
|---|---|---|---|---|---|---|---|
| 260 | 8,627 | 6,466 | 184.139 | 650 | 22,230 | 16,826 | 215.856 |
| 270 | 8,961 | 6,716 | 185.399 | 660 | 22,600 | 17,112 | 216.419 |
| 280 | 9,296 | 6,968 | 186.616 | 670 | 22,970 | 17,399 | 216.976 |
| 290 | 9,631 | 7,219 | 187.791 | 680 | 23,342 | 17,688 | 217.527 |
| 298 | 9,904 | 7,425 | 188.720 | 690 | 23,714 | 17,978 | 218.071 |
| 500 | 16,828 | 12,671 | 206.413 | 900 | 31,828 | 24,345 | 228.321 |
| 510 | 17,181 | 12,940 | 207.112 | 910 | 32,228 | 24,662 | 228.763 |
| 520 | 17,534 | 13,211 | 207.799 | 920 | 32,629 | 24,980 | 229.202 |
| 530 | 17,889 | 13,482 | 208.475 | 930 | 33,032 | 25,300 | 229.637 |
| 540 | 18,245 | 13,755 | 209.139 | 940 | 33,436 | 25,621 | 230.070 |