Exam 3
C&PE 211
Monday December 3, 2012
Closed Book - Closed Notes

Name:

1. Please do not turn the page until you are instructed to do so.
2. Please write your name in the space provided and if you separate the pages, put your initials on all of the pages.
3. Please read each question carefully and work those that you know first. Do not spend too much time on one problem. If you get stuck move on to the next question. Partial credit is given so working through a problem as much as you can is to your benefit.
4. Do all of the work on the sheets provided. Write clearly and organized. If I cannot read your writing or follow the solution, no credit will be given.
5. Only a small amount of credit is given for the answer to the problem. The majority of the credit is given for the formulas and the work you use to solve the problem. If you do not show all of your work you will not receive full credit for the problem.
6. Cheating on this exam will result in no credit for the exam. Two instances of cheating will result in failure of the course.
7. If a box is provided please put your answers in the box. If a box is not provided, please box your final answers. All work will be checked, but the answer in the box will be considered to be the final answer.

Please remember:
Don't panic! Panicking can cause silly errors.
Good Luck!

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Due to his grammar mistake, Wilbur found a position. It just wasn't the one he wanted.
1. (2 points each - no partial credit for each part)
   Define sensible heat and latent heat.

   sensible heat: Heat that causes the raising/lowering of the temperature of a substance, e.g., from 25°C to 75°C.

   latent heat: Heat that causes a change in phase of a substance, e.g., from liquid to a vapor.

2. (3 points - no partial credit)
   Discuss why reference states are so important and how they are used.

   Since $\Delta H$ or $\Delta U$ are not a definitive value, one must know a reference state in order to calculate $\Delta H$ or $\Delta U$. Both of these are state properties, which means it depends on the state of the system and not on how the system reaches that state. Reference states are used to calculate process changes in order to determine $\Delta H/\Delta U$.

   Example: Water at 50°C to vapor at 110°C.

   Water at 50°C

   $\Delta H$ or $\Delta U$ for vapor

   Water at 110°C

   Reference states are also used to know how the value is taken, such as $H = U + PV$. The energy change is considered.
3. (2 points each – no partial credit for each part.) Define what reference state you would use in the following cases.

a. Solving a problem using the steam tables in the back of the book?
   
   Saturated Steam is referenced at the triple point of water. ✓

b. Using the heat of reaction method?
   
   Reference is usually at a stream's temperature, pressure, and prime of an non-reactive species in order to simplify calculations.

c. Using the heat of formation method?
   
   Reference states are the elements that make up the products and reactants at 25°C and 1 atm. ✓

4. (4 points - no partial credit)
   
   The heat of reaction for the following reaction at 25°C and 1 atm is:

   \[ 4 \text{NH}_3(g) + 5 \text{O}_2(g) \rightarrow 4 \text{NO}(g) + 6 \text{H}_2\text{O}(g) \]

   a) -1084.76 kJ/mol  b) -904.74 kJ/mol  c) -820.7 kJ/mol  d) -1165.68 kJ/mol

   \[ \Delta H_R = \sum \text{Products} - \sum \text{Reactants} = \left[ \begin{array}{c} 4 \text{H}(1.38 \frac{\text{kcal}}{\text{mol} \cdot \text{K}}) \\
-2 \text{H}_2\text{O}(1.83 \frac{\text{kcal}}{\text{mol} \cdot \text{K}}) \\
\end{array} \right] - \left[ \begin{array}{c} 4 \text{N}(1.38 \frac{\text{kcal}}{\text{mol} \cdot \text{K}}) \\
6 \text{O}_2(1.61 \frac{\text{kcal}}{\text{mol} \cdot \text{K}}) \\
\end{array} \right] \]

   \[ = -904.74 \frac{\text{kcal}}{\text{mol}} \]
5. (43 points)
10,000 moles/hr of liquid methanol (CH₃OH) enters a furnace at 25°C where it is burned with 100% excess air. The air enters the furnace as a separate stream at 200°C. Only complete combustion products are formed and all species exiting the furnace are in the vapor phase.

\[
\begin{array}{c|c|c|c}
& \text{CH}_3\text{OH} & \text{O}_2 & \text{Water} \\
\hline
\text{Input} & 10,000 & 0 & 0 \\
\text{Output} & 0 & 0 & 0 \\
\text{Total} & 10,000 & 0 & 0 \\
\hline
\text{Reactant} & 1 & 2 & 3 \\
\text{Product} & 0 & 0 & 0 \\
\end{array}
\]

Possible Unnamed: \((5, \text{w} + 11) \cdot \text{Br}_\text{meth} + (100) \cdot \text{air}

Known: 12

\[\text{PS: \# \text{unknown}} = 5 \text{ (excess)}
\]

\[\text{Sum (3s) 1 not solvable}\]

a. Write the balanced reaction for the complete combustion of liquid methanol. You must show the phase of each species to receive full credit.

\[2 \text{CH}_3\text{OH}(l) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 4 \text{H}_2\text{O}(g)\]

b. The furnace is being cooled by a cooling jacket with flowing water to help remove some of the heat generated. Assuming that the only heat removed from the reactor is through the cooling jacket, find the heat removed from the reactor (kJ/hr) if the inlet to the cooling jacket is 1250 kg/hr of water at 75°C and 1 bar and the outlet of the cooling jacket is steam at 1 bar and 350°C.

Heat removed from reactor (kJ/hr) = 3,577,500 \frac{kJ}{hr
c. If the outlet temperature of the reactor is 400°C, using the heat removed from the reactor that you calculated in part b, solve for the fractional conversion of methanol. You must clearly show all reference states and any assumptions you make for simplifying the general energy balance. **You can assume that you only need to use the first term in the heat capacities.** If you could not solve for the heat on part b, you can assume that the heat removed from the reactor is 4x10^6 kJ/hr. **If you assume this you will automatically lose at least 5 points.**

\[
\text{Fractional Conversion} = 73.8\% \quad \checkmark
\]

\[\Delta H = \Delta H^\text{reaction} + \Delta H^\text{heat} = Q - \frac{dQ}{dT} \quad \Rightarrow \quad \Delta H = Q = \Delta H^\text{heat} = Q - \Delta H^\text{reaction}
\]

**Reference:** 25°C, latent of the elements that make reactants / products

**Method:** Heat of formation.

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<tr>
<th>C</th>
<th>H</th>
<th>O</th>
<th>( \Delta H )</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
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<td>( \Delta H_1 )</td>
</tr>
<tr>
<td>( \text{CH}_3\text{OH} )</td>
<td>O</td>
<td>0</td>
<td>( \Delta H_2 )</td>
</tr>
<tr>
<td>( \text{H}_2\text{O} )</td>
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<td>1</td>
<td>( \Delta H_3 )</td>
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<td>( \text{H}_2\text{CO} )</td>
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<td>1</td>
<td>( \Delta H_4 )</td>
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<tr>
<td>( \text{H}_2\text{O} )</td>
<td>0</td>
<td>1</td>
<td>( \Delta H_5 )</td>
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<tr>
<td>( \text{Vapor} )</td>
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<td>Vapor</td>
<td>Vapor</td>
</tr>
<tr>
<td>25°C</td>
<td>200°C</td>
<td>4100°C</td>
<td></td>
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</table>

\[\Delta H_1 = -236.6 \text{ kJ/mol} \quad \text{(no need to raise temperature)}
\]

\[\Delta H_2 = \left( \frac{dH}{dT} \right)_{25^\circ C} = \left( \frac{29 \times 10^{-3} \text{ kJ}}{\text{mol} \cdot \text{K}} \right) \Rightarrow 5.08 \text{ kJ/mol}
\]

\[\Delta H_3 = \left( \frac{dH}{dT} \right)_{200^\circ C} = \left( \frac{29.1 \times 10^{-3} \text{ kJ}}{\text{mol} \cdot \text{K}} \right) \Rightarrow 5.04 \text{ kJ/mol}
\]
\[ H_t = -201.42 + \int_{25}^{42.93 \times 10^{-3}} \frac{d}{dt} \]

\[ H_s = 0 \frac{15}{\text{mol}} + \int_{25}^{24.1 \times 10^{-3}} \frac{d}{dt} \]

\[ H_b = 0 \frac{15}{\text{mol}} + \int_{25}^{24.1 \times 10^{-3}} \frac{d}{dt} \]

\[ H_C = -393.5 \frac{15}{\text{mol}} + \int_{25}^{36.11 \times 10^{-3}} \frac{d}{dt} \]

\[ H_H = -241.93 \frac{15}{\text{mol}} + \int_{25}^{33.416 \times 10^{-3}} \frac{d}{dt} \]

<table>
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<th>x</th>
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<th>2</th>
<th>3</th>
</tr>
</thead>
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<td>( N_2 )</td>
<td>238.6</td>
<td>-</td>
<td>-185.10</td>
</tr>
<tr>
<td>( N_2 )</td>
<td>5.08</td>
<td>10.9</td>
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</tr>
<tr>
<td>( O_2 )</td>
<td>5.09</td>
<td>10.9</td>
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<td>( O_2 )</td>
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<td>( H_2O )</td>
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<td>Phase</td>
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<td>Vapour</td>
<td>Vapour</td>
</tr>
<tr>
<td>Temp</td>
<td>25°C</td>
<td>200°C</td>
<td>400°C</td>
</tr>
</tbody>
</table>
Problem 3

Using \( P = \) \( \frac{3}{2} \) \((10000) \)

\[ 0.21 \text{ S}_2 - \frac{3}{2} (10000) \] \( \implies \text{S}_2 = 142857.1 \text{ moles} \)

\[ \frac{3}{2} (10000) \]

\[ 0.79 \text{ S}_2 \text{ (N}_2) = 142857.1 \text{ moles} \]

\[ 0.21 \text{ S}_2 \text{ (O}_2) = 30,000 \text{ moles} \]

Since heat removal (from \( P = 31577.500 \text{ kJ} \))

and \( DH = Q \implies \Delta \text{H}_{\text{mol}} = \Delta \text{H}_{\text{mol}} = Q \)

Use Molar Equations and \( S_1 \), \( S_2 \), and \( S_3 \) for moles

Values (Question 2 page)

Combine these two equations to get \( \Delta H \)

\[ -185.10 \frac{\text{kJ}}{\text{mol}} (10000 - 2 \text{S}_1) + 10.9 \frac{\text{kJ}}{\text{mol}} (112857.1 \text{ mol}) + \\
10.6 \frac{\text{kJ}}{\text{mol}} (30000 - 3 \text{S}_1) + -380.0 \frac{\text{kJ}}{\text{mol}} (2 \text{S}_1) + -229.3 (4 \text{S}_1) \]

\[ = -578.6 \frac{\text{kJ}}{\text{mol}} (10000 \text{ mol}) + 5.06 \frac{\text{kJ}}{\text{mol}} (112857.1 \text{ mol}) \]

\[ + 5.06 \frac{\text{kJ}}{\text{mol}} (30000 \text{ mol}) \]

\[ = -3577,500 \text{ kJ mol}^{-1} \]

Heat simplifies to:

\[ -1339.7 \text{E} - 293857.61 \text{ kJ} \]

\[ Q = 3,577,500 \text{ kJ} \]

\[ -1339.7 \text{E} - 293857.61 \text{ kJ} = -1659485.932 \]

\[ = 3577,500 \text{ kJ} \]

\[ \text{Since } Q \text{ is being used, the reaction } \]

\[ \text{calorimetric value from } \Delta H = Q \text{ in this case} \]
\[ -1339.7 \, \xi_1 = -4943.628.322 \]
\[ \xi_1 = 3640.1 \]

\[ n_{13} = 10,000 - 2(3640.1) \]
\[ = 2619.8 \text{ moles} \]

\[
\text{Conversion} = \frac{\text{amount reacted}}{\text{amount fed}}
\]

\[ = \frac{2 \xi_1}{10,000} = \frac{2(3640.1)}{10,000} = 0.728 \]

\[ \text{or 73.8\% conversion} \]
6. (40 points)

An equimolar vapor stream containing methanol and water at 150°C is fed to a continuous condenser at a rate of 100 mol/s. Some of the vapor stream condenses and both the liquid and the vapor streams leaving the condenser contain methanol and water. The liquid contains 27.5 mole% methanol and 72.5 mole% water. The ratio of the total vapor to total liquid leaving the condenser is 2.5. Using the information given, solve the material balance to the nearest mole{s} around the condenser and fill in the material and enthalpy table below.

![Diagram with arrows and equations]

<table>
<thead>
<tr>
<th>Stream 1</th>
<th>Stream 2</th>
<th>Stream 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>50</td>
<td>29</td>
</tr>
<tr>
<td>CH₃OH</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>71</td>
</tr>
<tr>
<td>Moles</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>Phase</td>
<td>Vapor</td>
<td>Vapor</td>
</tr>
<tr>
<td>Temp.</td>
<td>150°C</td>
<td>?</td>
</tr>
</tbody>
</table>

**Material balance and enthalpy table for the system.**

\[
\begin{align*}
\text{Total} & = n_{CH₃OH} + 2 n_{H₂O} \\
2.5 & = \frac{n_{CH₃OH} + 2 n_{H₂O}}{n_{H₂O}} \\
2.5 & = 2.5 \\
\Rightarrow \quad n_{H₂O} &= 2.5 \quad \text{mol}
\end{align*}
\]
\[ S_2 = 2.5 \Rightarrow S_2 = 2.5S_3 \]

\[ S_2 = n_1 + 0.275S_3 \]
\[ S_2 = n_2 + 0.725S_3 \]

\[ L = n_1 + n_2 + S_3 \Rightarrow LW = 3.5S_3 \]

\[ S_3 = \frac{28.57}{50 \text{ ml}} \]
\[ S_3 = 0.57 \text{ ml} \]

\[ 0.275S_3 = 3 \text{ ml} \]
\[ 0.725S_3 = 24 \text{ ml} \]

\[ S_2 = n_1 + 8 \text{ ml} \Rightarrow n_1 = \frac{41}{9} \text{ ml} \]
\[ S_2 = n_2 + 21 \text{ ml} \Rightarrow n_2 = 29 \text{ ml} \]

\[ n_1 + n_2 = 71 \text{ ml} \]
b) If you know that 1335 kW of heat is removed from the process, calculate the temperature of the streams exiting the condenser. You must clearly show all reference states and any assumptions you make for simplifying the general energy balance. You can assume that you only need to use the first term in the heat capacities.

\[ \Delta H + \Delta \text{KE} = \Delta \text{EE} = \Delta H = Q \]

Reference state: 25°C, liquid at the elements

Heat of formation:

Forming table on Question (6a): are at the same temperature

\[
\begin{align*}
\hat{H}_1 &= -201.2 \, \text{kJ/mol} + \int_{25°C}^{T} 42.93 \times 10^{-3} \, dT \\
&= \left[ -195.8 \, \text{kJ/mol} \right] \\
\hat{H}_2 &= -241.83 \, \text{kJ/mol} + \int_{25°C}^{T} 33.46 \times 10^{-3} \, dT \\
&= \left[ -237.6 \, \text{kJ/mol} \right] \\
\hat{H}_3 &= -201.2 \, \text{kJ/mol} + \int_{25°C}^{T} 42.93 \times 10^{-3} \, dT \\
&= \left[ -0.6324 \, \text{kJ/mol} - 201.2 \, \text{kJ/mol} \right] \\
\hat{H}_4 &= -241.83 \, \text{kJ/mol} + \int_{25°C}^{T} 33.46 \times 10^{-3} \, dT \\
&= \left[ -0.03346 \, T - 236.811 \, \text{kJ/mol} \right] \\
\hat{H}_5 + \hat{H}_6
\end{align*}
\]
\[ A_5 = -238.6 \frac{\text{kJ}}{\text{mol}} + \int \frac{75.86 \times 10^{-3}}{\text{kJ}} \, \text{d}T \]
\[ = \left[ 0.07586 \, \text{T} - 240.4965 \frac{\text{kJ}}{\text{mol}} \right] \]

\[ A_6 = -285.84 \frac{\text{kJ}}{\text{mol}} + \int \frac{75.41 \times 10^{-3}}{\text{kJ}} \, \text{d}T \]
\[ = \left[ 0.07541 \, \text{T} - 287.725 \frac{\text{kJ}}{\text{mol}} \right] \]

Given energy balance, 
\[ \Delta H = Q \quad \text{or} \quad \Delta H_{\text{in}} - \Delta H_{\text{out}} = 0 \]

\[ \Delta H_{\text{in}} = \sqrt{42 \, \text{m}^3/\text{s} \left( 0.04293 \, \text{T} - 202.27 \frac{\text{kJ}}{\text{mol}} \right) + 24 \, \text{mol/s} \cdot \left( -0.03346 \, \text{T} - 235.811 \right) - \}
\[ + 8 \, \text{mol/s} \left( 0.07586 \, \text{T} - 240.4965 \frac{\text{kJ}}{\text{mol}} \right) + 21 \, \text{mol/s} \cdot \left( 0.07541 \, \text{T} - 287.725 \right) } \]
\[ = 3.023 \, \text{T} - 23329.056 \, \text{kJ} \]

\[ \Delta H_{\text{out}} = \frac{\sqrt{50 \, \text{mol/s} \left( -195.8 \frac{\text{kJ}}{\text{mol}} \right) + 50 \, \text{mol/s} \cdot \left( -237.6 \frac{\text{kJ}}{\text{mol}} \right) } } {5} \]
\[ = 21670 \, \text{kJ} \]

\[ Q = -1335 \, \text{kJ} \]

\[ \left[ 3.023 \, \text{T} - 23329.056 \, \text{kJ} \right] - \left[ -21670 \, \text{kJ} \right] = -1335 \, \text{kJ} \]

\[ 3.023 \, \text{T} = 3241.056 \]

\[ \text{[10°C]} = 1107.2 \, ^\circ \text{C} \]

\[ \check{\text{Mark}} \]

(C)
Extra Credit:

Knowing that condensation is a fast process and thus, the vapor and liquid streams exiting the condenser can be assumed to be in equilibrium with each other, show that if the condenser in problem 6 is operating at atmospheric pressure, show that the temperature you calculated in 6b is reasonable.

If the vapor and the liquid streams are in equilibrium, then we can assume that Raoult's law can be applied to the system.

Raoult's Law: \( P_{\text{vapor}} y_i = P^* x_i \)

Using Antoine's Equation:

\[ \log (P^*) = A - \frac{B}{T + C} \quad \text{where } T = \text{oC} \]

Using 107.2°C as temperature:

Water: \( 8.10765 \times \frac{1750.28}{(107.2 + 235.68)} = 983.66 \text{ mmHg} \)

\( P^* = 10 \)

Methanol: \( 3.06049 \times \frac{1582.771}{(107.2 + 234.726)} = 3374.627 \text{ mmHg} \)

\( P^* \text{ (vap)} = 10 \)

Given that the sum of all partial pressures of the vapor stream is equal to 1, that is, \( \Sigma y_i = 1 \)

Raoult's law can be simplified down to:

\( P_{\text{vapor}} = c \times x_i = \frac{P_{\text{vapor}}}{P^*} \times x_i \)

If \( P_{\text{vapor}} = 1 \text{ atm or } 760 \text{ mmHg} \), then...
\[ X_{\text{water}} = \left( \frac{760 \text{ mmHg}}{983.66 \text{ mmHg}} \right) = 0.77 = 77\% \]

\[ X_{\text{CH}_3\text{OH}} = \left( \frac{760 \text{ mmHg}}{3379.625 \text{ mmHg}} \right) = 0.23 = 23\% \]

These values are close to the original values of 72.5% mole of water and 27.5% mole of methanol.

The reason why these values are still equal is the following reasoning:

- Actual pressure of the system is not attainable.
- Rounding error due to rounding to the nearest whole mole.
- Rounding error in calculating enthalpies.
- Rounding errors in solving for other multiplicity enthalpy values with the mole守恒定律.

\[ \sim 107.2^\circ\text{C} \] was a reasonable temperature for the condenser.
<table>
<thead>
<tr>
<th>Species</th>
<th>phase</th>
<th>MW</th>
<th>SG</th>
<th>Tb (°C)</th>
<th>Δ Hvap (Tb) KJ/mol</th>
<th>Δ Hp KJ/mol</th>
<th>a x 10^3</th>
<th>A</th>
<th>B</th>
<th>C</th>
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</table>

1 kW = 1 kJ/s
### Table B.7 Properties of Superheated Steam

| p (bar) | H | — | S at 1 bar | S at 400°C | T (°C) | 50 | 70 | 90 | 110 | 130 | 150 | 170 | 190 | 210 | 230 | 250 | 270 | 290 | 310 | 330 | 350 |
|---------|---|---|-----------|-----------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.1     | H | 191.8 | 258.4 | 259.9 | 288.0 | 298.8 | 297.8 | 297.2 | 297.6 | 297.7 | 297.6 | 297.7 | 297.6 |
|         | S | 191.8 | 258.4 | 259.9 | 288.0 | 298.8 | 297.8 | 297.2 | 297.6 | 297.7 | 297.6 | 297.7 | 297.6 |
| 0.4     | H | 306.0 | 286.0 | 298.4 | 320.6 | 328.0 | 326.6 | 326.0 | 325.8 | 325.7 | 325.6 | 325.7 | 325.7 |
|         | S | 306.0 | 286.0 | 298.4 | 320.6 | 328.0 | 326.6 | 326.0 | 325.8 | 325.7 | 325.6 | 325.7 | 325.7 |
| 0.8     | H | 538.2 | 420.7 | 488.4 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 |
|         | S | 538.2 | 420.7 | 488.4 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 | 538.2 |
| 1.2     | H | 837.5 | 625.3 | 788.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 |
|         | S | 837.5 | 625.3 | 788.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 | 837.5 |
| 1.6     | H | 1162.2 | 825.2 | 1093.7 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 |
|         | S | 1162.2 | 825.2 | 1093.7 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 | 1162.2 |
| 2.0     | H | 1486.5 | 1082.0 | 1413.2 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 |
|         | S | 1486.5 | 1082.0 | 1413.2 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 | 1486.5 |
| 2.4     | H | 1810.8 | 1330.4 | 1752.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 |
|         | S | 1810.8 | 1330.4 | 1752.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 | 1810.8 |
| 2.8     | H | 2135.1 | 1579.1 | 2112.0 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 |
|         | S | 2135.1 | 1579.1 | 2112.0 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 | 2135.1 |
| 3.2     | H | 2460.4 | 1827.1 | 2436.6 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 |
|         | S | 2460.4 | 1827.1 | 2436.6 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 | 2460.4 |
| 3.6     | H | 2786.0 | 2074.5 | 2753.6 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 |
|         | S | 2786.0 | 2074.5 | 2753.6 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 | 2786.0 |
| 4.0     | H | 3101.4 | 2321.6 | 3069.9 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 |
|         | S | 3101.4 | 2321.6 | 3069.9 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 | 3101.4 |
| 4.4     | H | 3417.0 | 2568.6 | 3403.6 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 |
|         | S | 3417.0 | 2568.6 | 3403.6 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 | 3417.0 |

*Adapted from R. W. Haywood, *Thermodynamic Tables in SI (Metric) Units*, Cambridge University Press, London, 1968. Water is a liquid in the enclosed region between 30°C and 380°C. H = specific enthalpy (kJ/kg), S = specific entropy (kJ/kg), V = specific volume (m³/kg). Note: kJ/kg × 0.4305 = Btu/lb. (continued)