1) **P1.1.** Estimate the average speed (mph) of hydrogen molecules at 200 K and 3 bars.

- $H_2$ is 2.02 g/mole
- $R = 8.314 \text{ J/(K mole)}$
- Joule = $\text{kg m}^2/\text{s}^2$
- 2.24 mph/(m/s)

You can assume you know the temperature and pressure to 10% accuracy or you can make some other assumption concerning the accuracy of these values (state your assumption).

2) **1.12.** The gas phase reaction $A \rightarrow 2R$ is conducted in a 0.1 m$^3$ spherical tank. The initial temperature and pressure in the tank are 0.05 MPa and 400 K. After species A is 50% reacted, the temperature has fallen to 350 K. What is the pressure in the vessel?

- $R = 8.314 \text{ cm}^3 \text{ MPa/(K mole)}$

3) **1.17.** Determine the temperature, volume, and quality for one kg water under the following conditions:

- a. $U = 3000 \text{ kJ/kg}$, $P = 0.3 \text{ MPa}$
- c. $U = 2500 \text{ kJ/kg}$, $P = 0.3 \text{ MPa}$

See tables below.
### E.9. Properties of Water

#### I. Saturation Temperature

| \( T \) (°C) | \( P \) (MPa) | \( v^l \) (m³/kg) | \( v^g \) (m³/kg) | \( u^l \) (kJ/kg) | \( u^g \) (kJ/kg) | \( h^l \) (kJ/kg) | \( h^g \) (kJ/kg) | \( \Delta u^l_{

#### Properties

- **Pressure (\( P \))**: Measures the force per unit area, typically expressed in MPa.
- **Volume at saturation (\( v \))**: Represents the volume of liquid or gas at saturation conditions.
- **Internal Energy at saturation (\( u \))**: The energy content of the substance at saturation.
- **Enthalpy at saturation (\( h \))**: The total energy of the substance, including both internal and kinetic energy.

#### Units

- **Temperature (\( T \))**: Measured in °C.
- **Pressure (\( P \))**: Measured in MPa.
- **Volume (\( v \))**: Measured in m³/kg.
- **Internal Energy (\( u \))**: Measured in kJ/kg.
- **Enthalpy (\( h \))**: Measured in kJ/kg.

#### Analysis

The table provides a comprehensive list of properties for water at various temperatures, indicating how these properties change with temperature. This information is crucial for various applications, including thermodynamics, chemical engineering, and environmental science.
### III. Superheated Steam

<table>
<thead>
<tr>
<th>$P = 0.01$MPa</th>
<th>$P = 0.05$MPa</th>
<th>$P = 0.10$MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T(\degree C)$</td>
<td>$V(m^3/kg)$</td>
<td>$U(kJ/kg)$</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>45.8</td>
<td>14.6701</td>
<td>2432.2</td>
</tr>
<tr>
<td>50.0</td>
<td>14.9159</td>
<td>2443.3</td>
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<td>55.0</td>
<td>15.1774</td>
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<td>15.4790</td>
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</tr>
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<td>65.0</td>
<td>15.7967</td>
<td>2593.4</td>
</tr>
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<td>70.0</td>
<td>16.1286</td>
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<tr>
<td>85.0</td>
<td>17.2112</td>
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<tr>
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<tr>
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<td>3218.4</td>
</tr>
<tr>
<td>120</td>
<td>20.0284</td>
<td>3283.5</td>
</tr>
</tbody>
</table>

**Note:** The table continues with similar entries for different pressures and temperatures.
ANSWERS: Chemical Engineering Thermodynamics
Quiz 1 January 14, 2016

1)  

**P1.1. Estimate the average speed (mph) of hydrogen molecules at 200 K and 3 bars.**

\[ \text{H}_2 \text{ is } 2.02 \text{ g/mole} \]
\[ \text{R } = 8.314 \text{ J/(K mole)} \]
\[ \text{Joule } = \text{ kg} \text{ m}^2/\text{s}^2 \]
\[ 2.24 \text{ mph}/(\text{m/s}) \]

You can assume you know the temperature and pressure to 10% accuracy or you can make some other assumption concerning the accuracy of these values (state your assumption).

Energy = \( \frac{3}{2} kT = \frac{1}{2} mv^2 \)

So \( v \sim (3RT/M_w)^{1/2} = 3500 \text{ mph} \) if you assume 10% accuracy in the temperature and you assume an ideal gas. The ideal gas assumption is probably not very good at 3 bar. You don’t need the pressure if you assume an ideal gas. The book answer seems to be wrong.

2)  

**1.12. The gas phase reaction \( A \rightarrow 2R \) is conducted in a 0.1 m\(^3\) spherical tank. The initial temperature and pressure in the tank are 0.05 MPa and 400 K. After species A is 50% reacted, the temperature has fallen to 350 K. What is the pressure in the vessel?**

\[ \text{R } = 8.314 \text{ cm}^3 \text{ MPa/(K mole)} \]

Initially assume you are at pure “A”

Use the ideal gas law you can get the initial moles of “A”

\[ n_{A,i} = \frac{PV}{RT} = 0.05 \text{ MPa} \times 0.1 \times 10^6 \text{ cm}^3/(8.314 \text{ (cm}^3 \text{ MPa/(K mole)) 400K}) \]

= 1.5 moles of A initially

Then 50% reacts so you have 0.75 moles of A and 1.50 moles of R so you have 2.25 moles total. Again assume an ideal gas (doesn’t matter the type of atom for an ideal gas)

\[ P = \frac{n_{\text{total}}RT}{V} = 2.25 \text{ moles} \times 8.314 \text{ (cm}^3 \text{ MPa/(K mole)) 400K/0.1 \times 10^6 \text{ cm}^3 = 0.075 MPa} \]

assuming 10% accuracy in the initial values. He gets 0.065 in the book answer after a bit more complicated calculation.

3)  

**1.17. Determine the temperature, volume, and quality for one kg water under the following conditions:**

- **a.** \( U = 3000\text{ kJ/kg, P} = 0.3 \text{ MPa} \)
- **c.** \( U = 2500\text{ kJ/kg, P} = 0.3 \text{ MPa} \)
Assume 10% accuracy in the P and U values so you have 1.1 m³/kg (you can make other assumptions concerning the accuracy but need to state that.) It asks for one kg of water so the answer is 1.1 m³ and 420°C.

Again, assume 10% accuracy in values he specifies for U and P so, T = 130°C, q = 0.98, and it is for 1 kg so 0.59 m³.