1. Determine the entropy change for air as it goes from 285 K and 150 kPa to 1850 K and 1000 kPa.

**Solution:**
Our entropy change will be given by

\[ s_2 - s_1 = \varphi_2 - \varphi_1 - R \ln\left(\frac{P_2}{P_1}\right) \]

so we go to the air table (A.3SI) and fill in our table below

<table>
<thead>
<tr>
<th>Substance Type: Ideal Gas (air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process: Unknown</td>
</tr>
<tr>
<td>State 1</td>
</tr>
<tr>
<td>T₁ = 285 K</td>
</tr>
<tr>
<td>P₁ = 150 kPa</td>
</tr>
<tr>
<td>( \varphi_1 = 6.66705 \text{ kJ/(kg·K)} )</td>
</tr>
</tbody>
</table>

*Italicized* values read from air tables or calculated from ideal gas equation.

Now calculating

\[ s_2 - s_1 = \varphi_2 - \varphi_1 - R \ln\left(\frac{P_2}{P_1}\right) = 8.7255 - 6.66705 - (0.287)\ln(1000/150) \]

\[ = 1.5140 \text{ kJ/(kg·K)} \]

2. Determine the internal energy change for air as it undergoes an isometric process from 320 K and 72 kPa to 720 kPa.

**Solution:**
Our internal energy change will be given by, \( u_2 - u_1 \), where the \( u \)’s come form the tables

So we go to the air table (A.3SI) and fill in our table below

<table>
<thead>
<tr>
<th>Substance Type: Ideal Gas (air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process: Unknown</td>
</tr>
<tr>
<td>State 1</td>
</tr>
<tr>
<td>T₁ = 320 K</td>
</tr>
<tr>
<td>P₁ = 72 kPa</td>
</tr>
<tr>
<td>( u_1 = 15.902 \text{ kJ/kg} )</td>
</tr>
</tbody>
</table>

*Italicized* values read from air tables.

*Bold* values are calculated.

We note that our second state is not fixed (we only know the pressure), but we know the process, so that

\[ v_2 = v_1 \]

From our ideal gas law we have

\[ v_1 = \frac{RT_1}{P_1} = \frac{(0.287)(320)}{72} = 1.2756 \text{ m}^3/\text{kg} \]

and

\[ v_2 = 1.2756 \text{ m}^3/\text{kg} \]
We have now fixed our second state and can calculate the temperature using the ideal gas law

\[ T_2 = \frac{P_2 v_2}{R} = \frac{(720)(1.2756)}{0.287} = 3211 \text{ K} \]

We can now go to the air table and use interpolation to find

\[ u_2 = 2678.44 \text{ kJ/kg} \]

Then

\[ \Delta u = 2678.44 - 15.90 = 2662.54 \text{ kJ/kg} \]

3. Determine the enthalpy change (in kJ/kg) for OH as it goes from 2400 K and 1300 kPa to 1600 K and 700 kPa.

**Solution:**

Our enthalpy change will be given by, \( h_2 - h_1 \). However, we find that we do not have ideal gas tables for OH. Hence, we will have to use the constant \( c_p \) approach, where the \( c_p,\text{avg} \) comes from the tables.

So we go to the Table A.2SI.

<p>| Substance Type: Ideal Gas (air) |</p>
<table>
<thead>
<tr>
<th>Process: Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State 1</strong></td>
</tr>
<tr>
<td>( T_1 = 2400 \text{ K} )</td>
</tr>
<tr>
<td>( P_1 = 1300 \text{ kPa} )</td>
</tr>
</tbody>
</table>

Our average temperature is

\[ T_{\text{avg}} = \frac{(T_1+T_2)}{2} = \frac{(2400+1600)}{2} = 2000 \text{ K} \]

which from our table gives

\( c_p,\text{avg} = 2.0354 \text{ kJ/(kg} \cdot \text{K}) \)

Then our change in enthalpy is

\[ \Delta h = c_{p,\text{avg}}(T_2-T_1) = (2.0354)(1600-2400) = -1628.32 \text{ kJ/kg} \]

4. Determine the internal energy change (in kJ/kg) for OH as it undergoes an isentropic process from 3200 K and 7.2 MPa to 720 kPa.

**Solution:**

Our internal energy change will be given by, \( u_2 - u_1 \). Again we will use the constant specific heat approach where \( c_v,\text{avg} \) will come from Table A.2SI.

<p>| Substance Type: Ideal Gas (air) |</p>
<table>
<thead>
<tr>
<th>Process: Isentropic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State 1</strong></td>
</tr>
<tr>
<td>( T_1 = 3200 \text{ K} )</td>
</tr>
<tr>
<td>( P_1 = 7200 \text{ kPa} )</td>
</tr>
</tbody>
</table>

We note that our second state is not fixed (we only know the pressure), but we know the process, so that

\[ s_2 - s_1 = c_{p,\text{avg}} \cdot \ln(T_2 / T_1) - R \ln(P_2 / P_1) = 0 \]

We know everything in this equation, except for \( T_2 \), which we can solve for

\[ T_2 = T_1 \exp \left[ \frac{R \ln(P_2 / P_1)}{c_{p,\text{avg}}} \right] \]

The problem here is that we do not know \( c_{p,\text{avg}} \), which requires \( T_2 \) to determine. This is a classic iteration problem. What we will do is guess a value for \( c_{p,\text{avg}} \) (normally at \( T_1 \)), then solve for \( T_2 \).
Use that $T_2$ to recalculate $c_p, \text{avg}$, recalculate $T_2$, and continue until $T_2$ becomes a constant. At 3200 K we have:

$$c_p = 2.1679 \text{ kJ/(kg-K)}$$

so that

$$T_2 = (3200) \exp\left\{ \frac{(8.314/17)n(720/7200)}{2.1679} \right\} = 2455 \text{ K}$$

Now calculating $T_{\text{avg}}$

$$T_{\text{avg}} = \frac{T_1 + T_2}{2} = \frac{3200 + 2455}{2} = 2877 \text{ K}$$

Reevaluating $c_p$

$$c_p = 2.1447 \text{ kJ/(kg-K)}$$

Recalculating $T_2$

$$T_2 = 2548 \text{ K}$$

which we will take as good enough. Then

$$T_{\text{avg}} = 2874 \text{ K}$$

with

$$c_{v,\text{avg}} = 1.6573 \text{ kJ/(kg-K)}$$

Then (finally)

$$\Delta u = c_{v,\text{avg}}(T_2 - T_1) = (1.6573)(2548 - 3400) = -1081.38 \text{ kJ/kg}$$