Experimental tests of Law of Dulong & Petit:

\[ 3R = 24.9 \text{ J/k.mol} = 5.95 \text{ calories/k.mol} \]

The prediction is for \( C_{\text{mp}} \). We expect \( C_{\text{mp}} \) to be \( \sim 5\% \) larger.

Values at room temp:

<table>
<thead>
<tr>
<th>Element</th>
<th>( C_{\text{mp}} ) (J/k.mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>24.4</td>
</tr>
<tr>
<td>Sb</td>
<td>25.2</td>
</tr>
<tr>
<td>As</td>
<td>24.6</td>
</tr>
<tr>
<td>Be</td>
<td>16.4</td>
</tr>
<tr>
<td>Bi</td>
<td>25.7</td>
</tr>
<tr>
<td>Cu</td>
<td>24.5</td>
</tr>
</tbody>
</table>

\( C_{\text{mp}} \) for Ag as a function of \( T \)

(Recall prediction is 5.95 calories/k.mol)

\[ \text{Heat Capacity of Silver} \]

Notes:
1) At room temp, light elements have \( C_{\text{mp}} \) which is well below the prediction.
2) At low temps, the \( C_{\text{mp}} \) of all materials drops well below the prediction.

Why? Recall that equipartition theorem is only valid if \( k_B T \gg \text{quantum level spacing} \).

\[ \Rightarrow \text{At low } T, \text{ this will always be violated} \]

What about the light elements at room temp?

Quantum Mechanics: For a harmonic oscillator (our model for each atom in a solid), \( E_n = (n + \frac{1}{2}) h\omega \)

Where \( n = 0, 1, 2, ... \) is the quantum number.

\[ k = 1.05 \times 10^{-34} \text{ J.s} \text{ is Planck's constant} \]

\[ \omega = \sqrt{\frac{k_B T}{m}} \text{ is the angular freq. of the oscillator} \]

\[ \Rightarrow \text{level spacing } = \frac{h}{\omega} \]

\[ \Rightarrow \text{If } m \text{ is small (Be, C, etc.) and/or } k_B T \text{ is big (e.g. diamond) then } k_B T > h\omega \text{ even at room temp.} \]

For practical calculations, usually use \( c \)

\[ T_f \text{ when two objects are brought into contact is} \]

\[ T_f = \frac{T_1 c_1 m_1 + T_2 c_2 m_2}{c_1 m_1 + c_2 m_2} \text{ A weighted average of } T_1 \text{'s} \]

Weighted by \( C = mc \)