Generally useful constants (MKS):

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>amu</td>
<td>$1.6605 \times 10^{-27}$ kg</td>
</tr>
<tr>
<td>NA</td>
<td>$6.02221 \times 10^{23}$ mol</td>
</tr>
<tr>
<td>k</td>
<td>$1.38066 \times 10^{-23}$ J/K</td>
</tr>
<tr>
<td>me</td>
<td>$9.1094 \times 10^{-31}$ kg</td>
</tr>
<tr>
<td>h</td>
<td>$6.62608 \times 10^{-34}$ J s</td>
</tr>
<tr>
<td>q</td>
<td>$1.6022 \times 10^{-19}$ C</td>
</tr>
<tr>
<td>c</td>
<td>$2.9979 \times 10^{8}$ m/s</td>
</tr>
</tbody>
</table>

Problem 1.3 (Engel)

A. Using the rms speed, $v_{rms} = \sqrt{\frac{3kT}{m}}$, calculate gas temperatures of He & Ar for which $\lambda = 0.20$ nm (a wavelength value needed to resolve diffraction from the surface of a metal crystal).

B. Explain why Ar atomic beams are not suitable for atomic diffraction experiments.

Solution to Part A

**Strategy.** Part A asks for temperatures, $T$, which we can obtain if we know $v_{rms}$ and $m$.

$$T = \frac{mv_{rms}^2}{3k}$$

The velocities can be obtained from the momenta, $p$
\[ v_{\text{rms}} = \frac{p}{m} \]

And the momenta can be obtained from the de Broglie wavelengths, \( \lambda \).

\[ p = \frac{h}{\lambda} \]

**Execution.** Calculate momenta for \( \lambda = 0.20 \text{ nm} \) (but first convert nm to m).

\[ \lambda = (0.20 \text{ nm}) \left( \frac{m}{10^{-9} \text{ nm}} \right) \]

\[ 2 \times 10^{-10} \text{ m} \]

\[ p = \frac{h}{\lambda} \]

\[ 3.31304 \times 10^{-24} \text{ J s} \frac{m}{\text{ m}} \]

Calculate atomic masses of He and Ar as a list variable

\[ \text{mass} = \{ 4.003, 39.95 \} \text{ amu} \]

\[ \{ 6.64698 \times 10^{-27} \text{ kg}, 6.6337 \times 10^{-26} \text{ kg} \} \]

Calculate velocities

\[ v = \frac{p}{\text{mass}} \]

\[ \{ \frac{498.428 \text{ J s}}{\text{ kg m}}, \frac{49.9426 \text{ J s}}{\text{ kg m}} \} \]

Calculate temperatures

\[ T = \frac{\text{mass} \times v^2}{3k} \]

\[ \{ \frac{39.8677 \text{ J K} \text{ s}^2}{\text{ kg m}^2}, \frac{3.99475 \text{ J K} \text{ s}^2}{\text{ kg m}^2} \} \]

My units look terribly complicated. Simplify by recognizing that \( J = \text{kg m}^2 \text{ s}^{-2} \)
Solution to Part B

Why are Ar beams unsuitable? Possibility #1 - 4 K is unreachable? No, this is a feasible lab temperature, although it takes a little doing. Possibility #2 - Something happens to Ar at 4 K? This is correct. Ar is a gas down to -186 C (87 K). It solidifies at -199 C (74 K). So an "atomic beam" of 4 K Ar is physically impossible unless the beam is made so diffuse as to make measurements impractical.

\[ T \times \frac{kg \cdot m^2}{J \cdot s^2} \]

(39.8677 K, 3.99475 K)