1. As 1 eV = 1.602 × 10^{-19} J, the kinetic energy = \( T = 100 \text{eV} = 1.602 \times 10^{-17} \text{ J} \). Rearranging the equation for the kinetic energy in terms of the momentum and substituting in the value of the electron mass, \( m_e \), gives:

\[
p = \sqrt{2m_e \times T}
\]

\[
= \sqrt{2 \times (9.109 \times 10^{-31} \text{ kg}) \times (1.602 \times 10^{-17} \text{ J})} = 5.402 \times 10^{-24} \text{ kg m s}^{-1}
\]

As the momentum \( p = mv \), the electron velocity is:

\[
v = \frac{p}{m_e} = \frac{(5.402 \times 10^{-24} \text{ kg ms}^{-1})}{(9.109 \times 10^{-31} \text{ kg})} = 5.93 \times 10^6 \text{ ms}^{-1}
\]

From de Broglie’s relationship, the wavelength associated with a particle of momentum \( p \) is:

\[
\lambda = \frac{h}{p} = \frac{(6.626 \times 10^{-34} \text{ J s})}{(5.402 \times 10^{-24} \text{ kg m s}^{-1})} = 1.23 \times 10^{-10} \text{ m} = 1.23 \text{ angstroms}
\]

2. Moseley found empirically that a plot of \( \sqrt{\nu} \) vs. atomic number \( Z \) gives a straight line. The wavelengths first need to be converted into frequencies using \( \nu = \frac{c}{\lambda} \):

<table>
<thead>
<tr>
<th>element</th>
<th>( ^{20}\text{Ca} )</th>
<th>( ^{22}\text{Ti} )</th>
<th>( ^{23}\text{V} )</th>
<th>( ^{25}\text{Mn} )</th>
<th>( ^{26}\text{Fe} )</th>
<th>( ^{28}\text{Ni} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency (Hz)</td>
<td>( 8.92 \times 10^{17} )</td>
<td>( 1.09 \times 10^{18} )</td>
<td>( 1.20 \times 10^{18} )</td>
<td>( 1.42 \times 10^{18} )</td>
<td>( 1.55 \times 10^{18} )</td>
<td>( 1.81 \times 10^{18} )</td>
</tr>
</tbody>
</table>

A plot of \( \sqrt{\nu} \) vs \( Z \) is shown below and is indeed a straight line. For \( Z = 24 \) (Cr), the value of \( \sqrt{\nu} = 1.15 \times 10^{9} \) so \( \nu = 1.32 \times 10^{18} \text{ Hz} \). Using \( \lambda = \frac{c}{\nu} \) gives \( \lambda = 0.227 \text{ nm} \).
3. The energy levels get closer and closer together as \( n \) increases so the biggest gap is between the \( n = 1 \) and \( n = 2 \) levels.

Helium has \( Z = 2 \). The energy of the \( n = 1 \) and \( n = 2 \) levels are:

\[
E_1 = \frac{-E_R(2)^2}{(1)^2} = -4E_R \quad \text{and} \quad E_2 = \frac{-E_R(2)^2}{(2)^2} = -E_R
\]

The energy separation is \( 3E_R = 3 \times (2.18 \times 10^{-18} \text{ J}) = 6.54 \times 10^{-18} \text{ J} \)

4. 

5. 

<table>
<thead>
<tr>
<th>Orbital</th>
<th>( n )</th>
<th>( l )</th>
<th>( m_l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>4(d)</td>
<td>4</td>
<td>2</td>
<td>-2, -1, 0, 1, 2</td>
</tr>
<tr>
<td>1(s)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3(p)</td>
<td>3</td>
<td>1</td>
<td>-1, 0, 1</td>
</tr>
<tr>
<td>5(d)</td>
<td>5</td>
<td>2</td>
<td>-2, -1, 0, 1, 2</td>
</tr>
</tbody>
</table>

5.

2\(p\): 3\(p\):
Optional question.

The s-electrons in mercury must travel at high speeds due to their closeness to the large \((Z = 80)\) nuclear charge. As a consequence, their masses are relativistically increased. This causes a reduction in the size of s-orbitals and this, in turn, increases the attraction to the nucleus. As a result, the \(6s^2\) electrons are unexpectedly inert and reluctant to get involved in metallic type bonding. The weak interaction between Hg atoms causes it to be a liquid at room temperature.

Calculations in which relativity is ignored indicate that in a hypothetical universe in which relativistic effects are zero (i.e. one in which the speed of light is infinite), mercury would be a metallic solid like zinc and cadmium.