1. As 1 eV = $1.602 \times 10^{-19}$ J, the kinetic energy $= T = 100\text{eV} = 1.602 \times 10^{-17}$ 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:

$$v = \frac{p}{m_e} = \frac{(5.402 \times 10^{-24} \text{ kg m s}^{-1})}{(9.109 \times 10^{-31} \text{ kg})} = 5.93 \times 10^6 \text{ m s}^{-1}$$

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 $\nu = c / \lambda$:

<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 $\nu = 1.32 \times 10^{18}$ Hz. Using $\lambda = c / \nu$ gives $\lambda = 0.227 \text{ nm}$
3. The energy levels get closer and closer together as \( n \) increases so the \textit{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. Radial part:

\[
\begin{align*}
0 & \quad r \\
\text{node} & \quad r
\end{align*}
\]

5. Orbital & \( n \) & \( l \) & \( m_l \) \\
\hline
4d & 4 & 2 & -2, -1, 0, 1, 2 \\
1s & 1 & 0 & 0 \\
3p & 3 & 1 & -1, 0, 1 \\
5d & 5 & 2 & -2, -1, 0, 1, 2 \\

5. \( 2p \): 

\[
\text{nodal plane}
\]

\( 3p \):

\[
\text{nodal plane}, \quad \text{spherical node}
\]
6. (a) O \quad [\text{He}]^2s^22p^4 \quad [\text{He}] \quad \uparrow\downarrow \quad \uparrow\uparrow\uparrow

(b) Ga \quad [\text{Ar}]^4s^23d^{10}4p^1 \quad [\text{Ar}] \quad \uparrow\downarrow \quad \uparrow\uparrow\uparrow\uparrow\uparrow\uparrow \quad \uparrow

(c) Fr \quad [\text{Rn}]^7s^1 \quad [\text{Rn}] \quad \uparrow

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.