1. Explain the meaning of the term "Bremsstrahlung".

a) Bremsstrahlung or “braking” radiation is emitted when an electron is decelerated by collisions with a metal target. The emission is a broad spectrum but with a well-defined maximum energy (minimum wavelength).

2. Briefly explain why the atomic radius increases abruptly from neon to sodium.

Neon has all its electrons in \( n = 2 \) orbitals, and a filled-shell configuration. Increasing nuclear charge by one to form sodium contracts these orbitals, but the additional electron must go into a higher energy (3s) orbital, which extends further from the nucleus.

3. Calculate the shortest wavelength in the continuous x-ray spectrum emitted from a metal target being struck by 30 keV electrons.

\[
30,000 \text{ eV} = 30,000 \times 1.602 \times 10^{-19} = 4.802 \times 10^{-15} \text{ J.}
\]

Stopping electrons in one collision corresponds to a \( \Delta E \) of \( 4.802 \times 10^{-15} \text{ J.} \)

The minimum wavelength corresponds to this maximum energy. i.e.

\[
\lambda = \frac{hc}{\Delta E} = \frac{6.626 \times 10^{-34} \text{ J s} \times 3.00 \times 10^8 \text{ m s}^{-1}}{4.802 \times 10^{-15} \text{ J}}
\]

\[
= 4.14 \times 10^{-11} \text{ m} = 0.0414 \text{ nm} = 0.414 \text{ Å}
\]

4. The wavelength of \( K_{\alpha} \) x-ray emission for molybdenum is \( \lambda = 0.7107 \text{ Å.} \) Ignoring electron spin effects, estimate the energy of the 1s state of Mo.

1. Estimated using the hydrogen-like atom. This should be ok for the 1s state.

The energy of the 1s state is given by:

\[
E_1 = -Z^2E_R = -42^2 \times 2.18 \times 10^{-18} = 3.84 \times 10^{-15} \text{ J} = 24.0 \text{ keV}
\]

2. Estimated from the transition wavelength.

\( K_{\alpha} \) x-ray emission corresponds to a \( 2p \rightarrow 1s \), or more simply the \( n = 2 \rightarrow n = 1 \) transition, for which:

\[
\Delta E = h\frac{c}{\lambda} = -Z^2E_R(\frac{1}{4} - 1) = \frac{3}{4}E_1 \quad \text{since} \quad E_1 = -Z^2E_R
\]

So \( E_1 = 4h\frac{c}{3\lambda} = 3.73 \times 10^{-15} \text{ J} \) or 23.3 keV

Both answers are acceptable, although it’s preferable to use the experimental results provided (i.e. Method 2.)

5. The emission spectrum of the star Vega is shown at right. Estimate its temperature from its maximum emission at around 4100 Å.

\[
4.5k_B T = \frac{hc}{\lambda}
\]

\[
\Rightarrow \quad T = \frac{6.626 \times 10^{-34} \text{ J s} \times 3.00 \times 10^8 \text{ m s}^{-1}}{4.5 \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times 4100 \times 10^{-10} \text{ m}}
\]

\[
= 7800 \text{ K}
\]