- Describe how one of the following pieces of experimental evidence contributed to the development of quantum mechanics.

*photoelectric effect* OR *visible spectrum of hydrogen*

**Marks 3**

***Photoelectric effect:***
**Certain aspects of the photoelectric effect could only be explained by considering light as particulate - a steam of photons. The energy of the photons was proportional to the frequency (not intensity) of the light. This explained the facts that there was a minimum threshold energy and that there was no time lag.**

***Visible spectrum of hydrogen*:**
**The visible spectrum of hydrogen showed distinct bands at certain wavelengths only. This showed that energy was quantised (ie not continuous) and that only certain energy levels were allowed.**

- K-shell x-ray emission ($2p \rightarrow 1s$) from an unknown element is of the same wavelength as the shortest x-rays observed as *Bremsstrahlung* when electrons are accelerated by 52.9 keV into a copper target. What is the name of the unknown element?

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**As the emission is to the 1s core level, it can be treated with the hydrogen-like orbital energy equation**

$$E_n = \frac{-E_R Z^2}{n^2} \quad \text{where } E_R = 2.18\times10^{-18}\ \text{J}$$

**For $n$ = 1 (1s) and $n$ = 2 (2p), the energies are:**

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

**respectively. The separation, $E_1 - E_2$ is**

**separation = ¾ $E_R Z^2$ = ¾ × (2.18 × $10^{-18}$ J) $Z^2$ = 1.64 × $10^{-18}$ $Z^2$ J.**

**The energy 52.9 keV corresponds to (52.9×$10^3$) × (1.602 × $10^{-19}$) J = 8.47 × $10^{-15}$ J.**

**If 1.64 × $10^{-18}$ $Z^2$ J = 8.47 × $10^{-15}$ J then $Z^2$ = 5183 so $Z$ = 72. This is the atomic number of hafnium.**

ANSWER: **Hafnium**