Problem of the week

Atomic Physics (SL&HL)

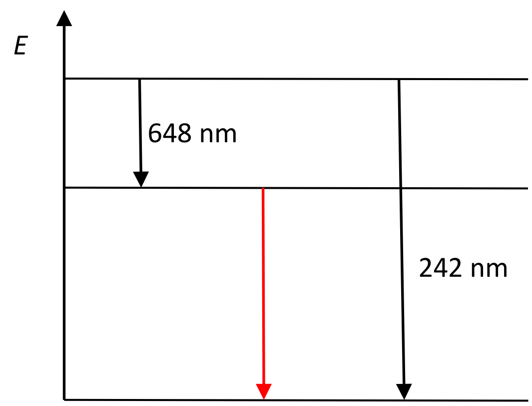
(a)

(i) What do you understand by the statement that the *energy of electrons in atoms is discrete*?

(ii) Outline the experimental evidence for energy levels in atoms.

(iii) Describe how an absorption spectrum is formed.

(b) The diagram shows three transitions in a hypothetical atom. The wavelengths of the photons emitted in two of the transitions are given.



Calculate the wavelength of the photon emitted in the transition indicated by the red arrow.

(c) For the Rutherford-Marsden-Geiger experiment,

(i) state the force responsible for deflecting the alpha particles,

(ii) explain the large angle deflections of the alpha particles,

(iii) suggest **two** reasons why the gold foil was made very thin.

(d) For the neutral atom of ${}^{238}_{94}\mathrm{Pu}$ state the number of

(i) electrons,

(ii) neutrons in the nucleus.

(e) State what is meant by isotopes.

Answers

(a)

(i) The energy of the electrons takes specific, distinct values.

(ii) The existence of emission and absorption spectra. In emission spectra, for example, the photons emitted have specific wavelengths and hence specific energies that correspond to differences in energy between energy levels.

(iii) Light is passed through a gas at low pressure. Photons whose energy corresponds to energy difference between level in the atoms of the gas are absorbed by electrons which then make transitions to higher energy states. The electrons re-emit these photons as they make transitions to lower states but they do so in random directions so these photons are missing in the transmitted beam through the gas leading to dark lines in the transmitted spectrum.

(b) The energy of the 648 nm photon is $E=\frac{hc}{\lambda}=\frac{1.24\times 10^{-6}}{648\times 10^{-9}}=1.91\ \text{eV}$. That of the 242 nm photon is $E=\frac{hc}{\lambda}=\frac{1.24\times 10^{-6}}{242\times 10^{-9}}=5.12\ \text{eV}$. The energy of the third transition is $5.12-1.91=3.21\ \text{eV}$ and hence $\lambda=\frac{hc}{E}=\frac{1.24\times 10^{-6}}{3.21}=3.86\times 10^{-7}\ \text{m}=386\ \text{nm}$.

OR

$\frac{hc}{\lambda}=\frac{hc}{\lambda_1}-\frac{hc}{\lambda_2}$ hence $\lambda=\frac{\lambda_1\lambda_2}{\lambda_1-\lambda_2}=\frac{648\times 242}{648-242}=386\ \text{nm}$.

(c)

(i) The electric force.

(ii) The alpha particles get very close to the tiny nucleus and so experience a very large electric deflecting force.

(iii) To avoid (1) absorption of the alpha particles and (2) multiple scatterings.

(d)

(i) 94

(ii) 238 – 94 = 144

(e) Atoms of the same element hence having the same number of protons in the nucleus but with different number of neutrons.