# Topic 26 Nuclear physics

## Summary

- The mass defect of a nucleus is the difference between the total mass of the separate nucleons and the mass of the nucleus.
- Einstein's mass–energy equivalence relation $E = mc^2$
- The binding energy of a nucleus is the energy needed to separate completely all its constituent nucleons.
- The binding energy per nucleon is a measure of the stability of a nucleus. A high binding energy per nucleon means the nucleus is stable.
- Nuclear fusion is the joining together of light nuclei to form a larger, heavier nucleus.
- Nuclear fission is the splitting of a heavy nucleus into two smaller, lighter nuclei of approximately equal mass.
- Radioactive decay is a spontaneous, random process.
- The half-life $t_{1/2}$ of a radioactive nuclide is the time taken for the number of undecayed nuclei to be reduced to half the original number.
- The activity of a radioactive source is the number of nuclei that decay per unit time. The unit of activity is the becquerel (Bq). 1 becquerel $= 1\mathrm{s}^{-1}$.
- The activity $-\mathrm{d}N/\mathrm{d}t$ of a source is related to the number $N$ of undecayed nuclei by the equation $\mathrm{d}N/\mathrm{d}t = -\lambda N$ where $\lambda$ is the decay constant.
- The decay constant is defined as the probability of decay per unit time of a nucleus.
- The number $N$ of undecayed nuclei in a radioactive sample at time $t$ is given by the equation:
  $N = N_0\, e^{-\lambda t}$
  where $N_0$ is the number of undecayed nuclei at time $t = 0$.
- The half-life $t_{1/2}$ and the decay constant $\lambda$ are related by the equation $\ln 2 = \lambda t_{1/2}$ or $t_{1/2} = 0.693/\lambda$.

# Definitions and formulae

- $E = mc^2$ (energy–mass equivalence)
- Mass defect of a nucleus is the difference between the total mass of the separate nucleons and the combined mass of the nucleus.
- Binding energy is the energy equivalent of the mass defect of a nucleus. It is the energy required to separate to infinity all the nucleons of a nucleus.
- Nuclear fission is the splitting of a heavy nucleus into two lighter nuclei of approximately the same mass.
- Nuclear fusion is the joining together of two light nuclei to produce a heavier nucleus with the release of energy.
- Random decay means that it is not possible to predict which nucleus in a sample will decay next.
- Spontaneous decay is a process that is not affected by any external factors such as temperature and pressure.
- Activity = number of nuclei (disintegrations) per unit time.
- $A = -(\Delta N/\Delta t)$
- Unit of activity of $A$: $s^{-1}$ or Bq
- $(\Delta N/\Delta t) = A = -\lambda N$
- Decay constant $\lambda = A/N$ = activity/number of nuclei; unit of $\lambda$ is $s^{-1}$
- The decay constant $\lambda$ is defined as the probability per unit time that a nucleus will undergo decay.
- $x = x_0 e^{-\lambda t}$ for $x = A$ or $N$
- Half life $t_{1/2}$ is the time for half the number of nuclei of a particular sample to decay, or the time for the activity of a particular sample of a nuclide to halve.
- $\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$