# Introduction to Nuclear and Particle Physics

## Nuclear structure

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# He scattering

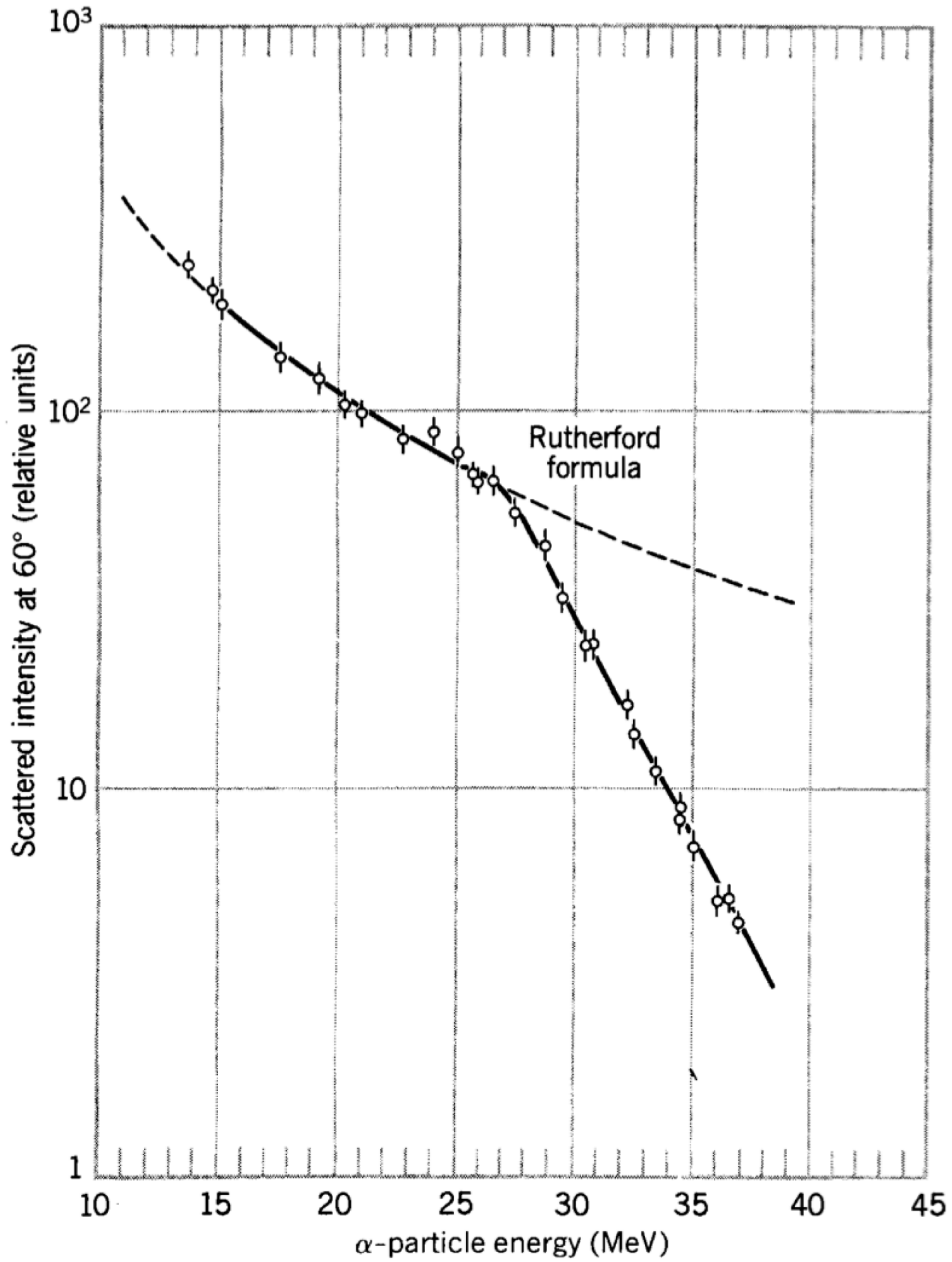



**Figure 3.11** The breakdown of the Rutherford scattering formula. When the incident $\alpha$ particle gets close enough to the target Pb nucleus so that they can interact through the nuclear force (in addition to the Coulomb force that acts when they are far apart) the Rutherford formula no longer holds. The point at which this breakdown occurs gives a measure of the size of the nucleus. Adapted from a review of $\alpha$ particle scattering by R. M. Eisberg and C. E. Porter, *Rev. Mod. Phys.* **33**, 190 (1961).

# Mass spectrograph

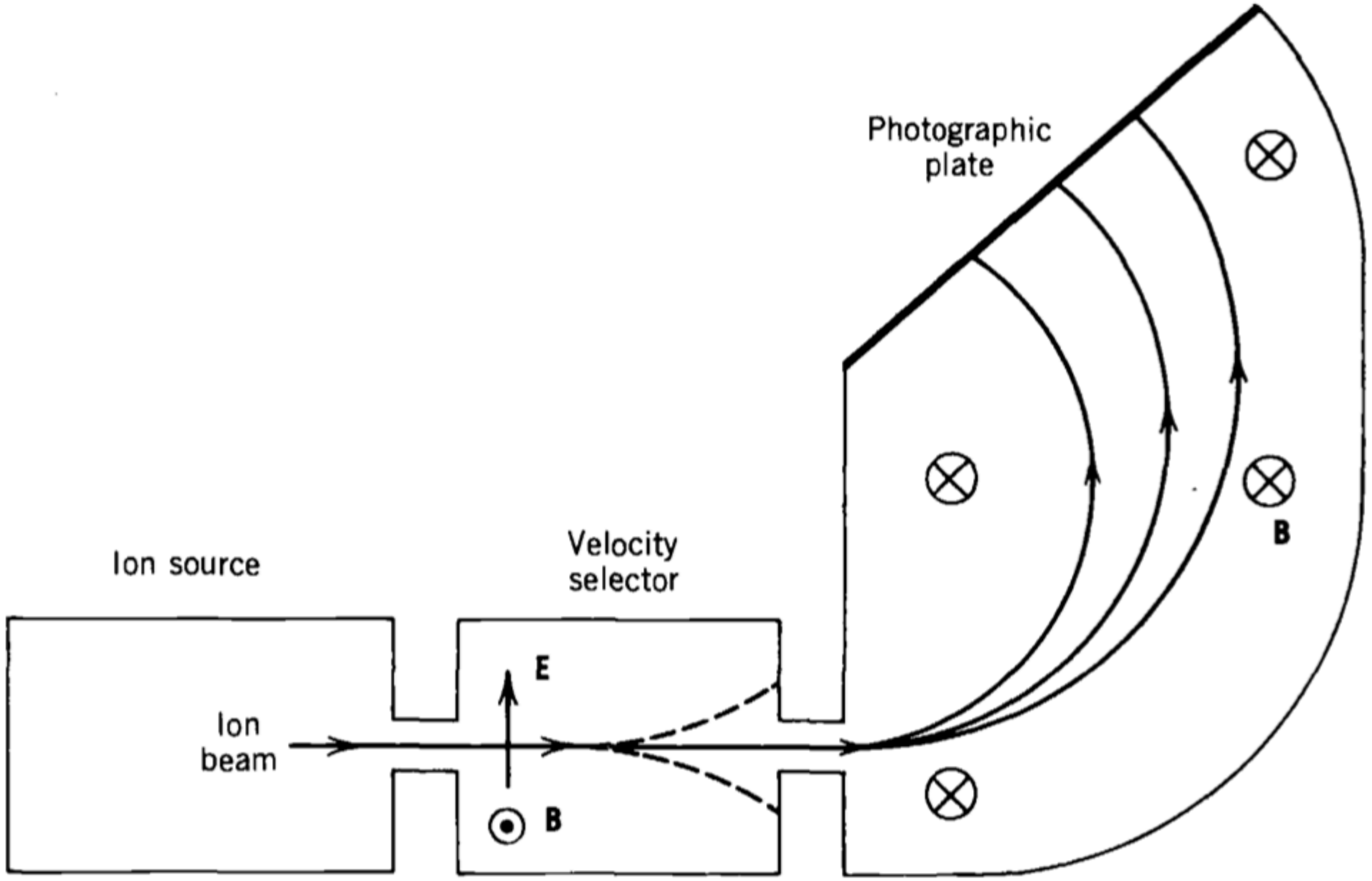
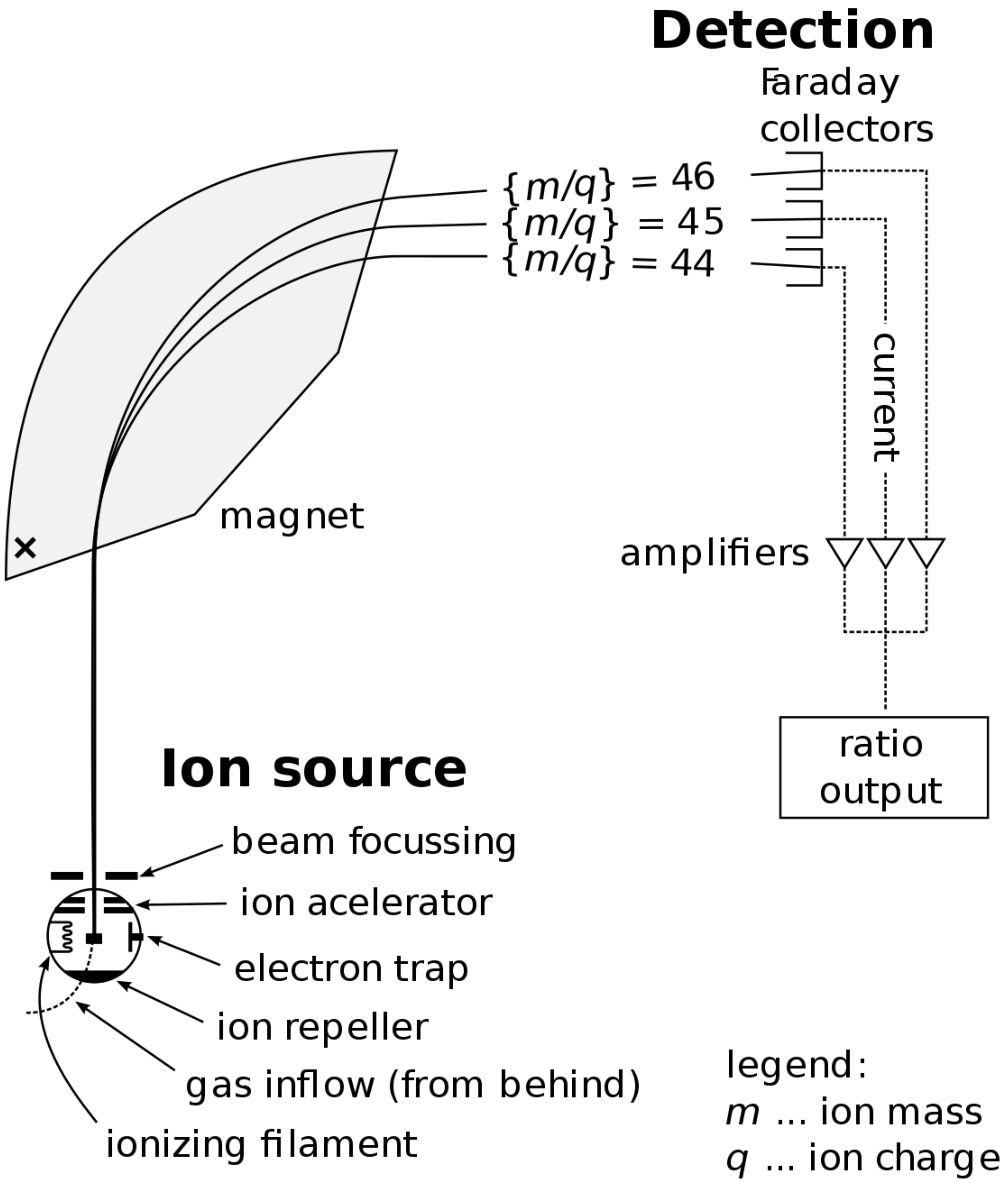



**Figure 3.13** Schematic diagram of mass spectrograph. An ion source produces a beam with a thermal distribution of velocities. A velocity selector passes only those ions with a particular velocity (others being deflected as shown), and momentum selection by a uniform magnetic field permits identification of individual masses.

# Mass spectrometer




https://en.wikipedia.org/wiki/Mass_spectrometry

# Mass-spectrum

| | | | |
|---|---|---|---|
| $^{78}$Kr | 0.356% | $^{83}$Kr | 11.5% |
| $^{80}$Kr | 2.27% | $^{84}$Kr | 57.0% |
| $^{82}$Kr | 11.6% | $^{86}$Kr | 17.3% |

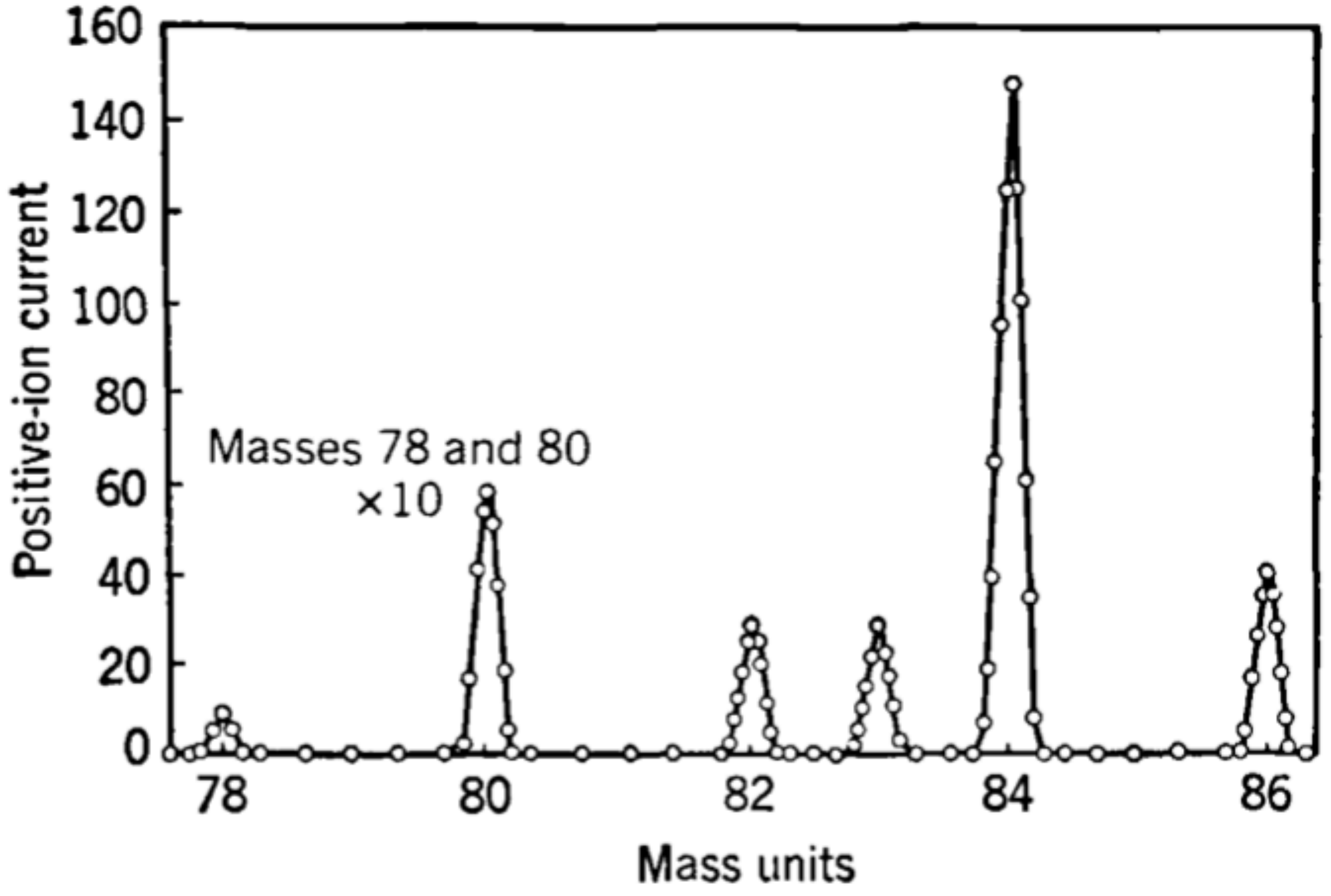



**Figure 3.14** A mass-spectrum analysis of krypton. The ordinates for the peaks at mass positions 78 and 80 should be divided by 10 to show these peaks in their true relation to the others.

# Leser Isotop separation

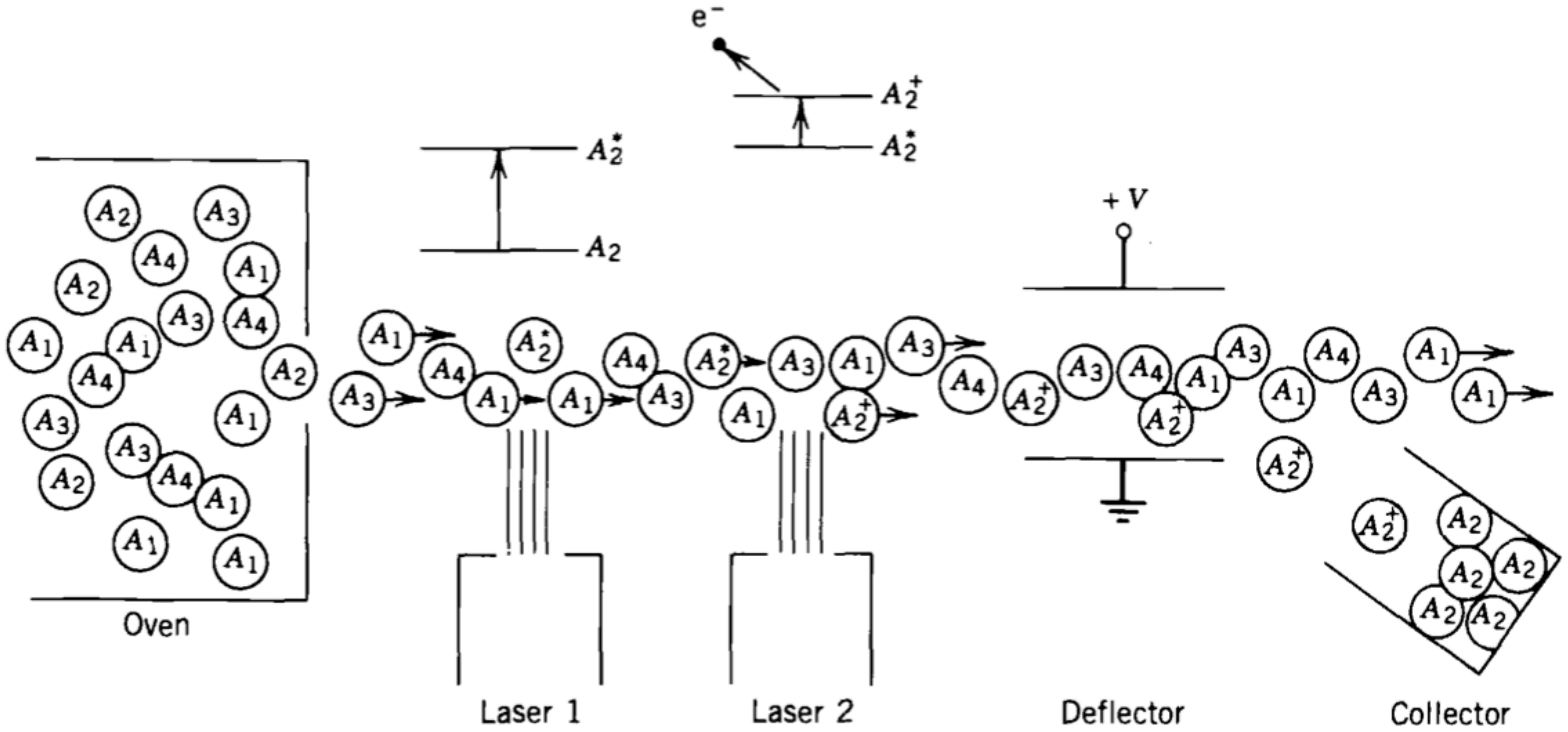



**Figure 3.15** Laser isotope separation. The beam of neutral atoms from the oven is a mixture of four isotopes $A_1$, $A_2$, $A_3$, and $A_4$. The first laser is tuned to the transition corresponding to the resonant excitation of isotope $A_2$ to a certain excited state; because of the sharpness of the laser energy and the isotope shift that gives that particular transition a different energy in the other isotopes, only $A_2$ is excited. The second laser has a broad energy profile, so that many free-electron states can be reached in the ionization of the atoms; but because only the $A_2$ isotopes are in the excited state, only the $A_2$ atoms are ionized. The $A_2$ ions are then deflected and collected.

# Nuclear binding energy

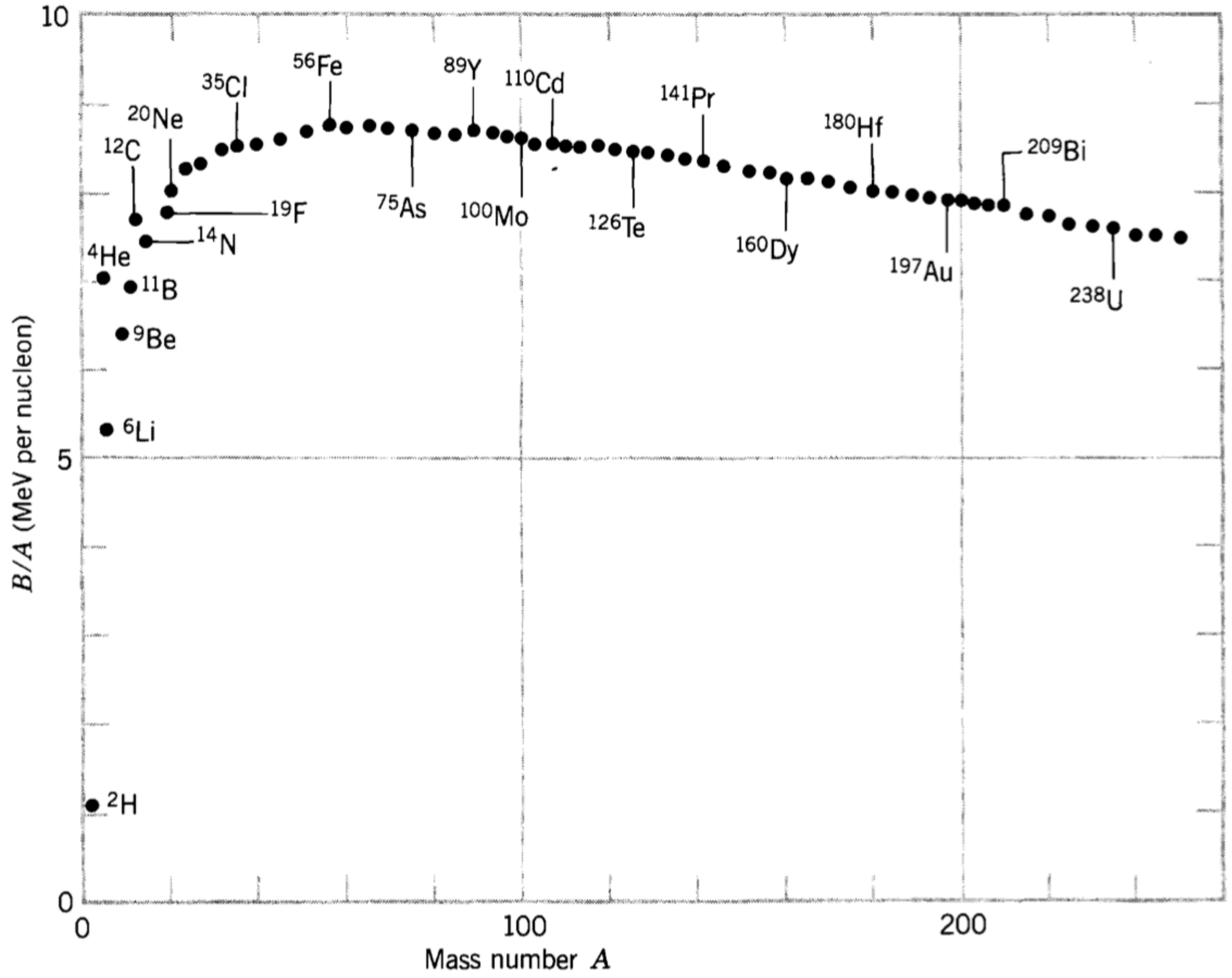



**Figure 3.16** The binding energy per nucleon.

# Nuclear binding energy

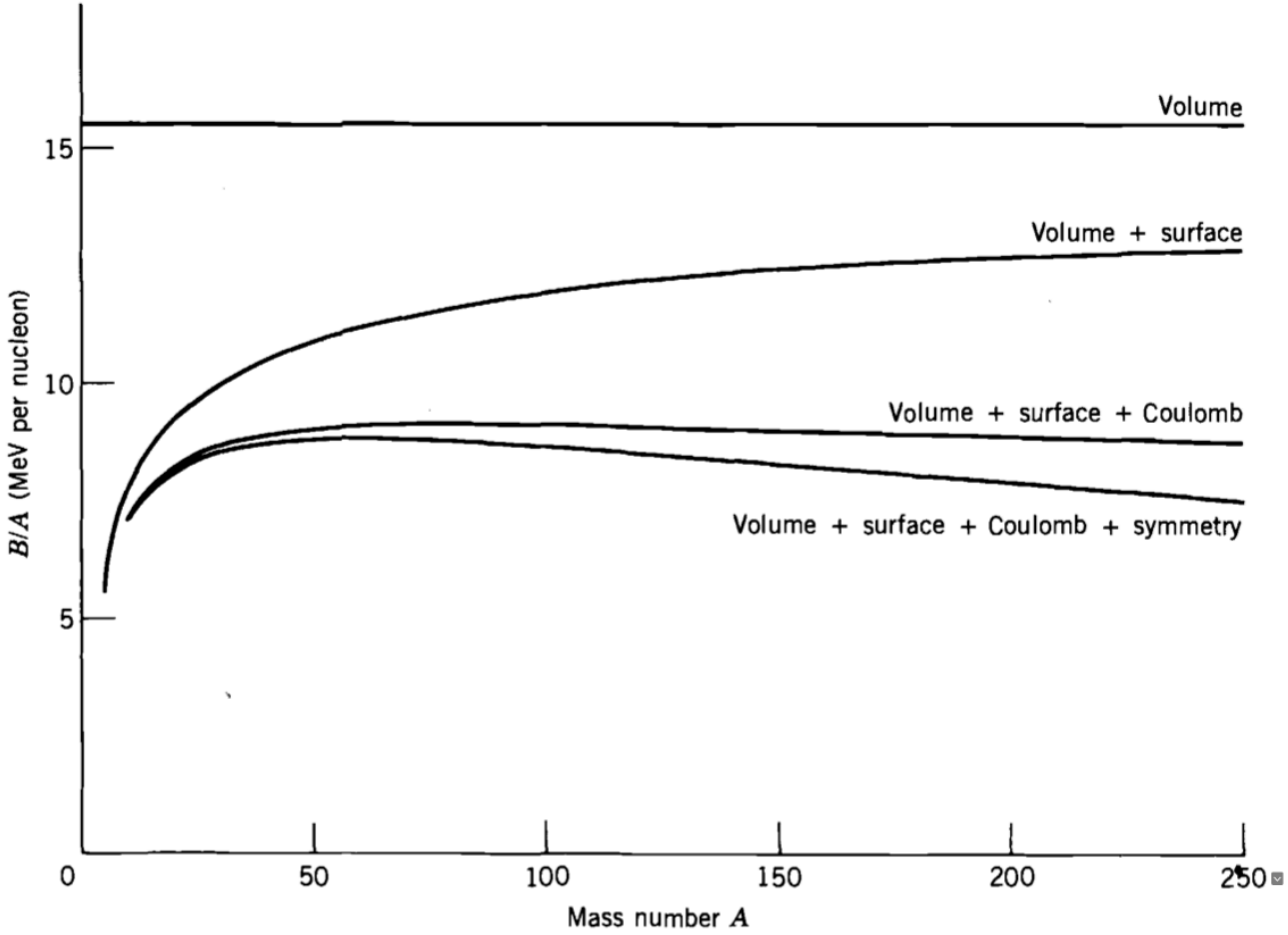



**Figure 3.17** The contributions of the various terms in the semiempirical mass formula to the binding energy per nucleon.

# Nuclear binding energy

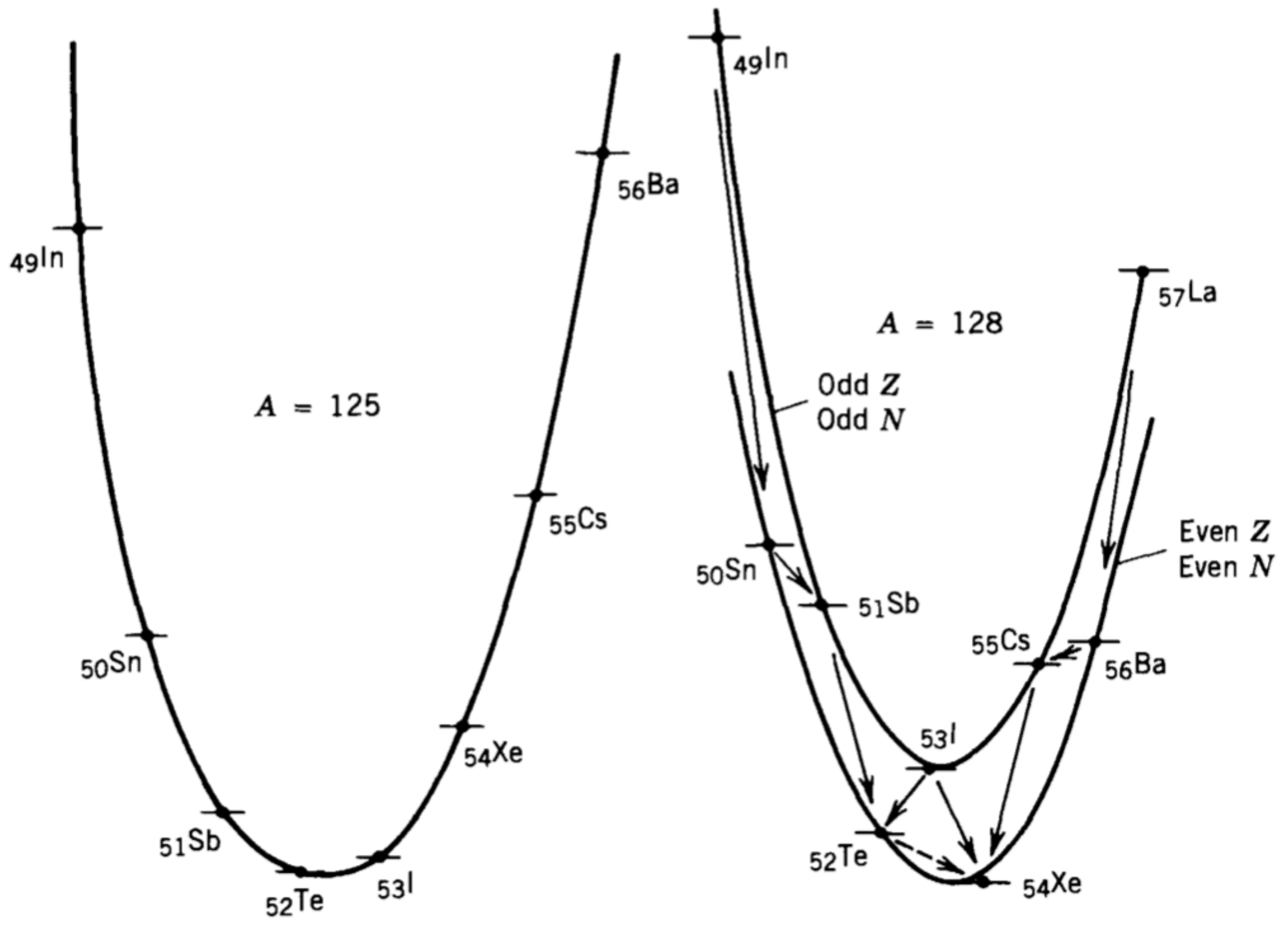



**Figure 3.18** Mass chains for $A = 125$ and $A = 128$. For $A = 125$, note how the energy differences between neighboring isotopes increase as we go further from the stable member at the energy minimum. For $A = 128$, note the effect of the pairing term; in particular, $^{128}$I can decay in either direction, and it is energetically possible for $^{128}$Te to decay directly to $^{128}$Xe by the process known as double $\beta$ decay.