

Solid-state, nuclear and particle models

GRE · GRE Subject Test · GRE Physics

A semiconductor's conductivity depends on available states and carriers, not merely on the number of electrons in the material.

Prerequisites: 25, 45, 46.

- Use band and carrier descriptions
- Apply radioactive decay and binding-energy ideas
- Check conservation laws in particle reactions

Choose the system and model

Filled bands cannot carry ordinary current without accessible nearby states. Metals have partially filled or overlapping bands; semiconductors have a small band gap . Donor and acceptor doping change carrier populations.

Use the governing relation

Fermi–Dirac occupancy is $1/[\exp((E-\mu)/(kT))+1]$. At zero temperature it becomes a step at the Fermi energy; thermal broadening does not make every state half occupied.

Apply the conditions

Radioactive populations obey $N=N_0e^{(-\lambda t)}$, activity λN and half-life $\ln 2/\lambda$. Binding energy comes from a mass deficit multiplied by c^2 ; compare binding energy per nucleon when discussing stability.

Check the conclusion

Nuclear and particle processes must conserve charge, energy, momentum and the applicable quantum numbers. Beta decay includes a neutrino or antineutrino; a two-body electron-only story cannot explain its continuous energy spectrum.

Worked method

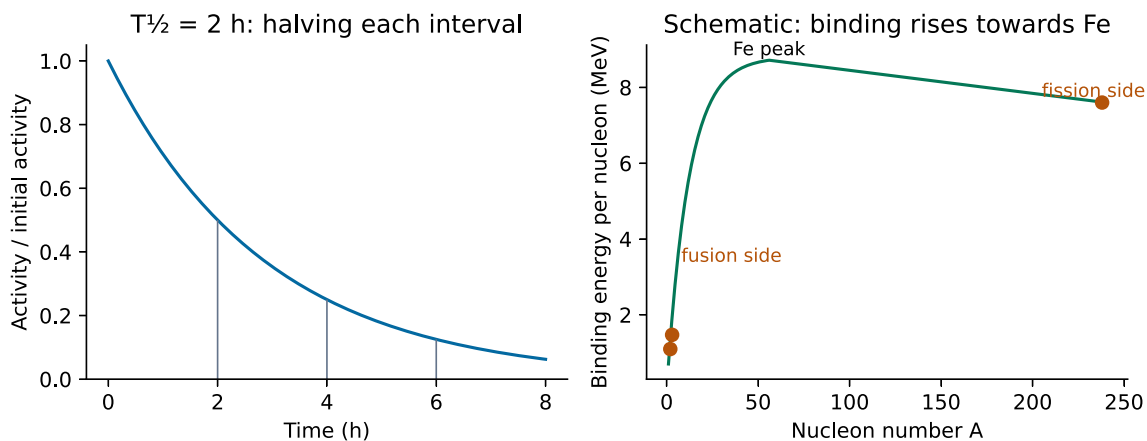
Binding energy is the positive energy required to separate a nucleus into free nucleons. For a reaction use total initial and final rest masses, with a consistent mass convention.

$$Q = (M_i - M_f)c^2.$$

A mass decrease of 0.0040 atomic mass units gives

$$Q = \Delta Mc^2 = (0.0040 \text{ u})(931.5 \text{ MeV/u}) = 3.73 \text{ MeV}.$$

Positive Q means energy release. Charge, nucleon number, energy and momentum must still balance; Q alone does not establish a reaction rate.



Solid-state, nuclear and particle models: original GRE teaching diagram.

Check conditions and vocabulary

Activity and surviving population both decay, but their units differ: activity is transitions per second.

band gap: An energy interval with no allowed bulk electronic states in the band model.

half-life: Time for a radioactive population to halve.