

25.1 Nuclear binding, particle families and Hall carriers

Name: _____ Class: _____ Date: _____

Total: 10 marks**KEY WORDS** binding energy per nucleon

• Hall coefficient

Objective

Compare binding energy per nucleon and reaction energy; Distinguish leptons, mesons and baryons with conservation constraints; Infer dominant carrier sign from the one-carrier Hall model. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Binding B is the nucleon mass deficit times c^2 ; compare B/A across mass numbers. Its broad maximum lies near iron/nickel. Light fusion or heavy fission can release energy by increasing total binding. Reaction $Q = (\text{initial} - \text{final rest mass})c^2$ requires the specified isotopes/products, not just element names.

Leptons include electrons, muons and neutrinos without constituent quarks. A negative muon shares electron charge $-e$ and spin $1/2$ but differs in mass/flavour. Ordinary mesons contain quark–antiquark pairs; baryons contain three quarks, antibaryons three antiquarks.

Check charge, energy, momentum, baryon and relevant lepton numbers. Proton uud has charge $+e$; neutron udd is neutral. Beta-minus decay $n \rightarrow p + e^- + \bar{\nu}_e$ includes the antineutrino for lepton balance and kinematics. Mass alone does not classify a particle.

For a one-carrier Hall model with stated directions/convention, $R_H = 1/(nq)$. Its sign follows charge: electron-like negative, hole-like positive. Resistivity alone does not identify carrier sign. Two-carrier semiconductors need mobility-weighted contributions; raw voltage polarity requires fixed leads and field direction.

■ Worked method

In a one-carrier Hall effect model, use $R_H = 1/(nq)$ with a fixed lead convention. For electrons, $q = -e$, $n = 5.0 \times 10^{22}$ per cubic metre,

$$R_H = -\frac{1}{ne} = -\frac{1}{(5.0 \times 10^{22} \text{ m}^{-3})(1.60 \times 10^{-19} \text{ C})} = -1.25 \times 10^{-4} \text{ m}^3/\text{C}.$$

Negative coefficient indicates electron-like carriers under this model, not a negative density. Raw voltage polarity is meaningful only with declared field and lead directions.

Particle families in the ordinary constituent model

Examples	Ordinary constituent model	Family
Electron / muon	None	Lepton
Pion / kaon	Quark + antiquark	Meson
Proton / neutron	Three quarks	Baryon

2 Practice

2.1 Choose one answer. Which ordinary constituent description is correct? [1]

- **A** Lepton: one quark; baryon: one antiquark
- **B** Lepton: no constituent quarks; baryon: three quarks
- **C** Lepton: three quarks; meson: none
- **D** Muon: quark–antiquark pair
- **E** Baryon: always one quark and one antiquark

2.2 Choose one answer. Under $R_H = 1/(nq)$ for a single carrier, a negative coefficient identifies: [1]

- **A** Positive holes
- **B** Zero carrier density
- **C** Electron-like negative charge
- **D** No magnetic force
- **E** A neutral carrier with $q=0$

2.3 A nucleus has binding energy 72 MeV and mass number 9. B/A is _____ MeV. Show your relation and units. [2]

Solutions

2.1 B Leptons are not constituent-quark composites; ordinary baryons contain three quarks.

Compare the rejected options: Lepton: one quark; baryon: one antiquark; Lepton: three quarks; meson: none; Muon: quark–antiquark pair; Baryon: always one quark and one antiquark. Use the stated model and conditions.

2.2 C Density is positive, so coefficient sign follows charge sign.

Compare the rejected options: Positive holes; Zero carrier density; No magnetic force; A neutral carrier with $q=0$. Use the stated model and conditions.

2.3 8. Divide total binding by nucleon count: $72/9=8$.

2.4 False. A muon is a charged lepton; names do not establish quark composition.

3.1 Charge: $0 = 1 - 1 + 0$. Baryon number: $1 = 1 + 0 + 0$. Electron-lepton number: $0 = 0 + 1 - 1$. Omitting the antineutrino violates the latter balance and leaves incorrect two-body kinematics. Three final bodies share available energy in different proportions while conserving total energy/momentum in each event. Award each conservation check and spectrum/omission explanation.