

How Missing Mass Becomes Nuclear Energy

Understanding Mass-Energy Equivalence, Mass Defect, and Nuclear Binding

Mass-Energy Equivalence

$$E = m c^2$$

The universal relationship stating that mass and energy are interchangeable forms of the same thing. A small amount of mass can be converted into an immense amount of energy.

✓ **Key Takeaway:** Matter itself is a concentrated form of energy.

Mass Defect

$$\Delta m = Zm_p + (A-Z)m_n - m_{\text{nucleus}}$$

The difference between the mass of the constituent nucleons (protons and neutrons) and the actual mass of the nucleus. This "missing" mass is converted into binding energy.

✓ **Key Takeaway:** The mass of the nucleus is always less than the sum of its parts.

Nuclear Binding Energy (B.E.)

$$\text{B.E.} = \Delta m c^2$$

The energy released when a nucleus is formed from its nucleons, or the energy required to break a nucleus apart. It is a measure of nuclear stability.

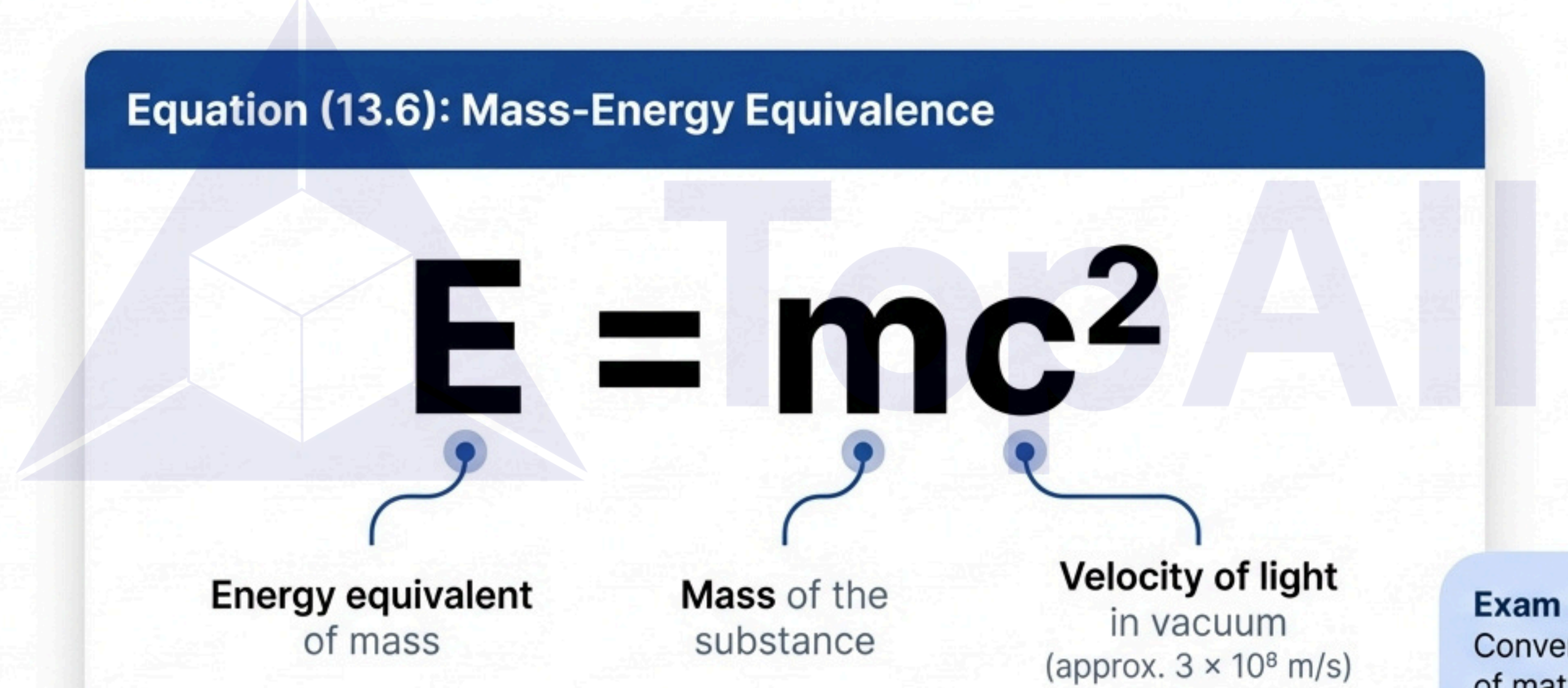
✓ **Key Takeaway:** Higher B.E. per nucleon indicates greater nuclear stability.



Mass and Energy are Interconvertible

Before Einstein's special theory of relativity, mass and energy were believed to be conserved separately. Einstein proved that mass is actually another form of energy.

Equation (13.6): Mass-Energy Equivalence

The diagram shows the equation $E = mc^2$ in large black font. To the left of the equation is a faint, large watermark of the TopAll logo. Three blue lines with circular endpoints point from labels below to the variables in the equation: one from 'Energy equivalent of mass' to 'E', one from 'Mass of the substance' to 'm', and one from 'Velocity of light in vacuum (approx. 3 x 10^8 m/s)' to 'c^2'.
$$E = mc^2$$

Energy equivalent
of mass

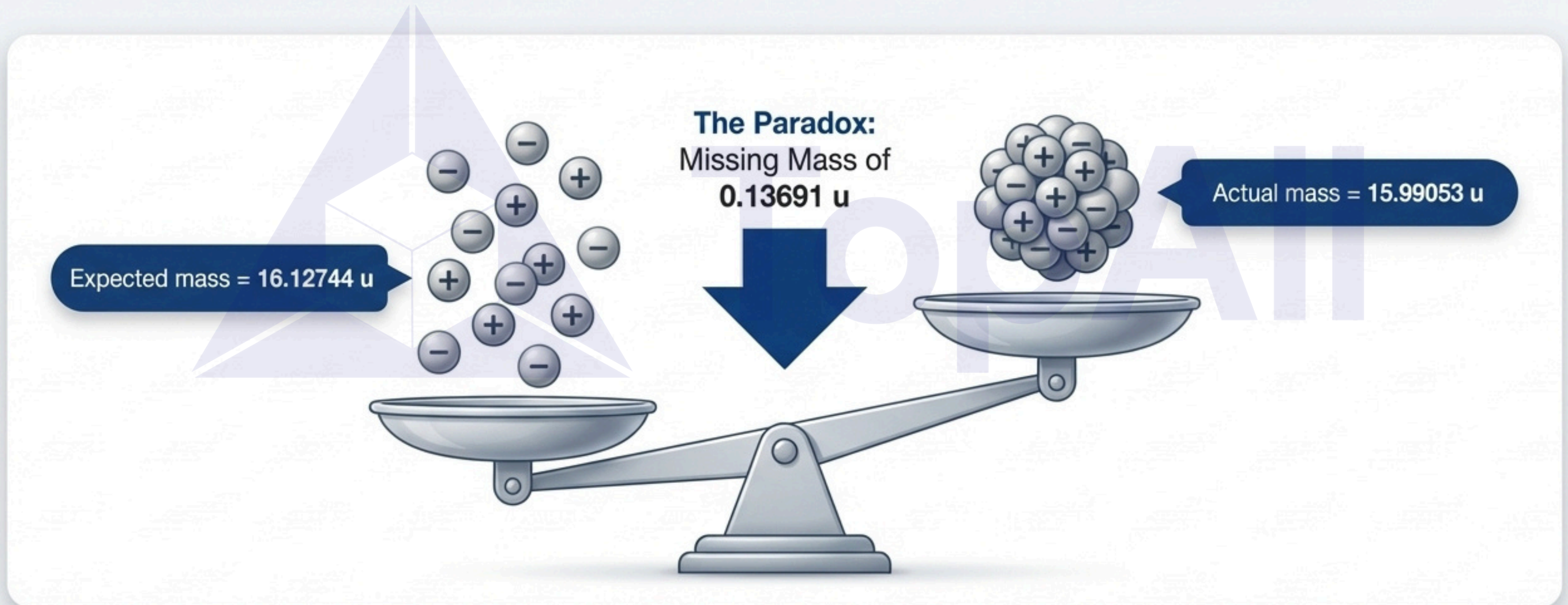
Mass of the
substance

Velocity of light
in vacuum
(approx. 3×10^8 m/s)

Exam Example:
Converting just 1 gram
of matter releases an
enormous 9×10^{13}
Joules of energy.

The Whole is Less Than the Sum of its Parts

When protons and neutrons bind to form a nucleus, the final mass is surprisingly less than the total mass of the individual, unbound nucleons.





You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



Turn theory into marks with **unlimited MCQs, smart analysis, and focused revision.**

Practice Now



At prep.topall.app

Key Highlights

- » Free Study Material, Videos & Infographics
- » Push Your Limits with Level-Based Challenges
- » Climb the Leaderboard Among Fellow Aspirants
- » Practice Unlimited MCQs for NEET & JEE
- » Get Clear Explanations, Not Just Marks
- » Track Your Performance Smarter



Defining the Mass Defect (ΔM)

The exact difference in mass between the individual constituents and the assembled nucleus is formally known as the mass defect.

Equation (13.7): The Mass Defect

$$\Delta M = [Z m_p + (A - Z)m_n] - M$$

Z = Atomic number (number of protons)

(A-Z) = Neutron number (number of neutrons)

m_p = Mass of a single proton

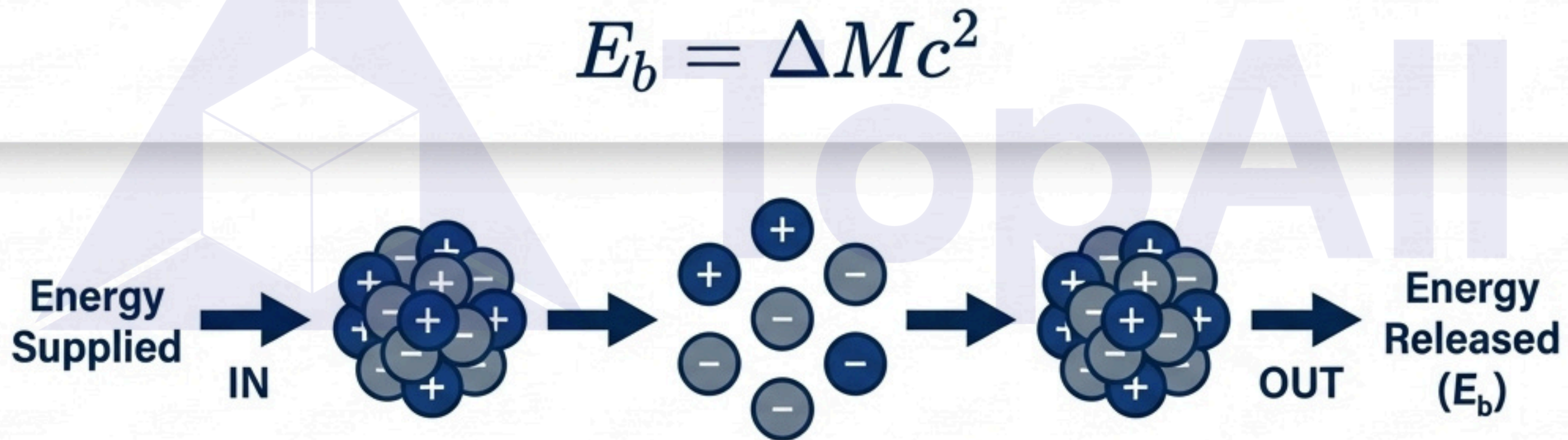
m_n = Mass of a single neutron

M = Actual measured mass of the bound nucleus

Mass Defect Becomes Binding Energy (E_b)

To break a nucleus apart, you must supply energy. When nucleons bind together, that exact same amount of energy is released. This energy is the mass defect converted via $E = mc^2$.

Equation (13.8): Nuclear Binding Energy



For Oxygen-16, the ΔM of 0.13691 u equals a Binding Energy of 127.5 MeV.

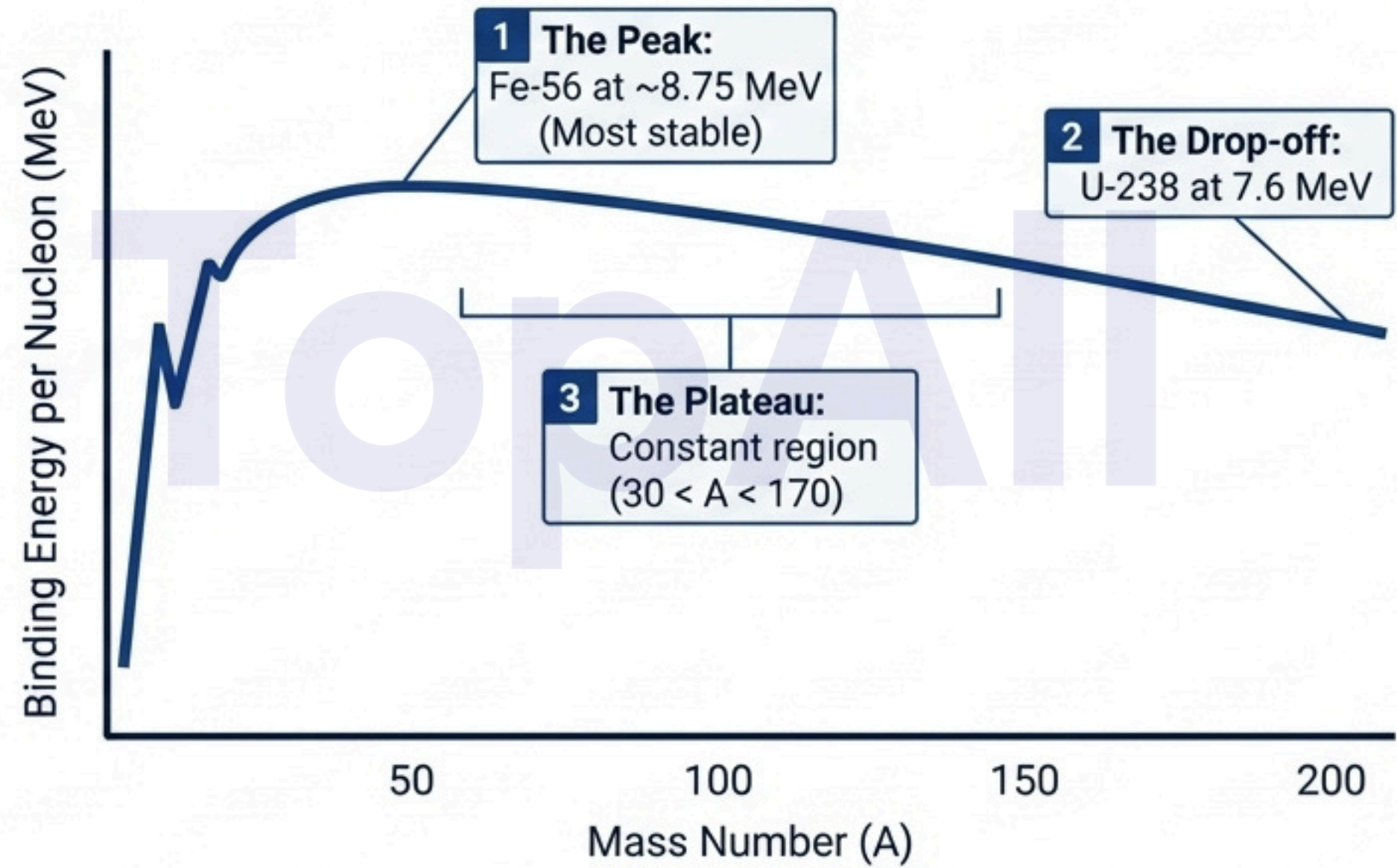
Binding Energy per Nucleon (E_{bn})

Equation (13.9)

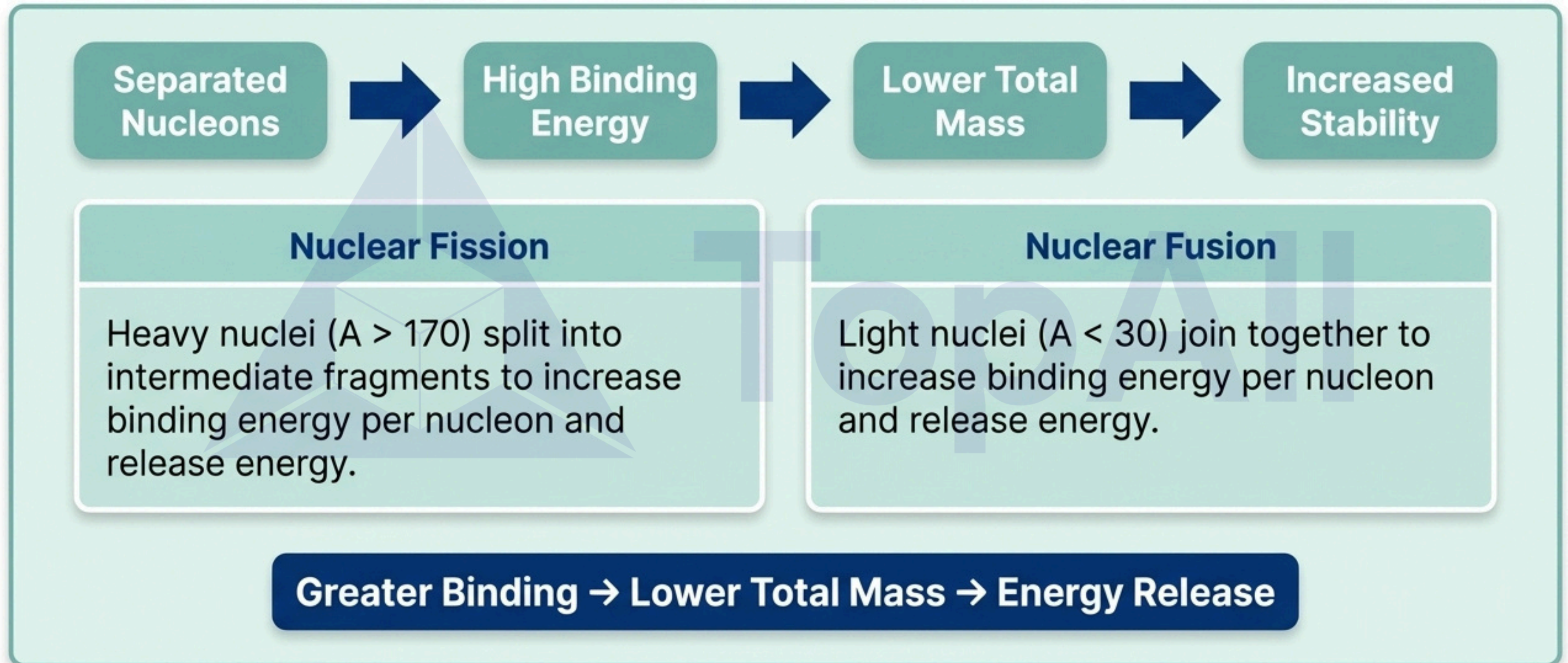
$$E_{bn} = \frac{E_b}{A}$$

Think of this as the average energy needed to extract a single nucleon.

Higher E_{bn} = Greater Stability.



The Golden Rule of Nuclear Stability





You've Learned the Theory.

Now Let's Test It.

Reading notes gets you knowledge.

Practicing MCQs gets you marks.

That's exactly what TopAll Pro is built for.

Try TopAll Pro Now

What TopAll Pro Does Differently

-  **Stuck? Snap it. Solve it. — Doubts AI**
Photo → step-by-step solution in seconds, 24/7
-  **Your AI Coach finds your blind spots**
Concept-level weakness detection — not just chapter-level
-  **4.5 Lakh+ questions. Never run out.**
13× more content than any other prep app in India
-  **Build your own test in 60 seconds**
Pick a chapter, set difficulty — AI does the rest instantly.
-  **AI Recommendation that helps you improve**
AI Recommendation Analysis your Tests and tell you where you need to improve.



Practice the moment you finish studying
Jump in while the concept is still fresh in your head

4.5L+
MCQs

1.5L+
Students

AI Powered
In-Depth Analysis