

23 Mass-energy equivalence – Part 1

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English	Write it 3 times (English)
Mass-energy equivalence	_____
nuclear reaction	_____
nucleon number	_____

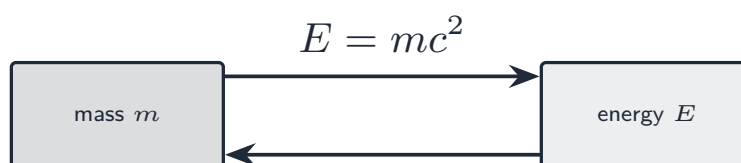
Recall

Einstein showed that mass and energy are two forms of the same thing – a tiny amount of mass can become a huge amount of energy.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

■ 1 Mass-energy equivalence



Mass-energy equivalence : $E = mc^2$. A small mass change Δm matches a large energy $\Delta E = c^2 \Delta m$, because c^2 is huge.

Worked example. Convert $\Delta m = 1.0 \times 10^{-3}$ kg (one gram) completely to energy: $\Delta E = c^2 \Delta m = (3.0 \times 10^8)^2 (1.0 \times 10^{-3}) = 9.0 \times 10^{13}$ J – far more than burning a gram of any fuel.

■ 2 Balancing a nuclear reaction



$$\text{top: } 14 + 4 = 17 + 1 \quad \text{bottom: } 7 + 2 = 8 + 1$$

In a **nuclear reaction** , the top numbers (the **nucleon number**) balance, and so do the bottom numbers (the charge).

Worked example. In ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + X$: the top numbers give $14 + 4 = 17 + A$, so $A = 1$; the bottom give $7 + 2 = 8 + Z$, so $Z = 1$. So X is a proton, ${}^1_1\text{H}$.

Watch out: $c^2 \approx 9 \times 10^{16}$, so even a mass change too small to weigh releases an enormous energy. Always work in SI units (kg, m s⁻¹).

Practice

Try these in order.

23.1 Write the *mass-energy* equation. [1]

23.2 Why does a small mass change give a large energy? [1]

23.3 In a nuclear reaction, what must the top numbers do? [1]

23.4 What do the *bottom* numbers represent? [1]

23.5 In ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + {}^A_Z\text{H}$, find A . [1]

23.6 A mass of 2.0×10^{-3} kg is converted entirely to energy. Find the energy released ($c = 3.0 \times 10^8$ m s⁻¹). [2]

23.7 Challenge. Burning coal and nuclear fission both release energy, but fission releases far more per kilogram. Explain why, using $E = mc^2$. [2]