23 Mass-energy equivalence – Part 1

Name: ____________ Class: ________ Date: __________

Vocabulary 词汇

Write each word three times. 把每个单词抄写三遍。

English	中文	Write it 3 times (English)		
Mass-energy equivalence	质能等价			
nuclear reaction	核反应			
nucleon number	核子数			

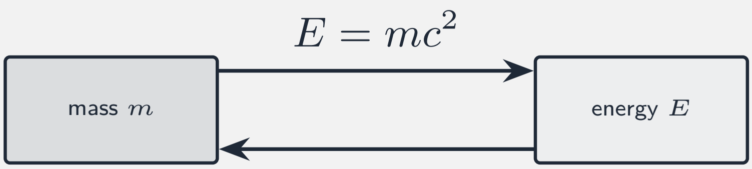
Recall

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 质能等价: $E = mc^2$. 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

$$^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \;\rightarrow\; {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

top: $14 + 4 = 17 + 1$ bottom: $7 + 2 = 8 + 1$

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

Worked example. In $^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + X$: 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, $^{1}_{1}\mathrm{H}$.

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 $^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{A}_{Z}\mathrm{H}$, 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]