The Missing Mass

Use fusion data to calculate the energy released in a star.

ESS.1.d "Analyze and interpret data to quantify the energy produced in stars, using Einstein's theory of general relativity by applying E=mc2 to show that the small amount of mass produced during hydrogen fusion produces a large amount of energy."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Circle the two masses and the sample count in the table, underline c^2, and number the four calculation steps in the passage in order. These marks will help you trace how mass data become an energy estimate.

How the Sun Turns Mass into Energy

1. Inside the Sun, hydrogen nuclei combine through several steps to form helium. To track mass, scientists compare four neutral hydrogen atoms before the process with one neutral helium atom afterward. Other particles, including neutrinos, escape. When accounting for their energy, the helium atom's smaller mass reveals how much mass became energy.

2. The table reports rounded masses for one completed set of fusion reactions and a count for a much larger sample. Subtract the final atom's mass from the starting atoms' mass to find the mass converted. Divide that difference by the starting mass to find the fraction converted. Keep track of powers of ten when using the data.

ROUNDED DATA FOR HYDROGEN FUSION

Quantity	Value	Unit
Mass of four hydrogen atoms	6.692×10^{-27}	kg
Mass of one helium atom	6.646×10^{-27}	kg
c^2	9.0×10^{16}	m^2/s^2
Fusion sets in sample	1.0×10^{25}	sets

3. Einstein's equation $E = mc^2$ converts missing mass m into released energy E. Here, c^2 is listed in units that turn kilograms into joules. Multiply the mass converted per set by c^2 to find its energy, then scale up using the number of sets. Not all that energy warms the Sun, since neutrinos carry some away.

2 ANSWER WITH EVIDENCE

Use the passage

1. How much mass is converted into energy in one fusion set? Show the subtraction.

2. What percentage of the starting mass is converted into energy? Round to two decimal places.

3. Use $E = mc^2$ to calculate the energy released by one fusion set.

4. For the number of fusion sets in the table, how much total mass is converted, and how much energy is released?

3 YOUR TURN

Your own words

Choose a new count from 2.0×10^{25} to 5.0×10^{25} fusion sets. Calculate the total mass converted and energy released, then explain in two or three sentences how a small mass loss can release so much energy.

The Missing Mass

PART 1 · READ AND MARK

Circle the two masses and the sample count in the table, underline c^2, and number the four calculation steps in the passage in order. These marks will help you trace how mass data become an energy estimate. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	How much mass is converted into energy in one fusion set? Show the subtraction.	**$(6.692 - 6.646) \times 10^{-27}$ kg = 4.6×10^{-29} kg.**
2	What percentage of the starting mass is converted into energy? Round to two decimal places.	**$(0.046 \div 6.692) \times 100 \approx 0.69\%$.**
3	Use $E = mc^2$ to calculate the energy released by one fusion set.	**$(4.6 \times 10^{-29}$ kg$)(9.0 \times 10^{16}$ m^2/s$^2) = 4.14 \times 10^{-12}$ J.**
4	For the number of fusion sets in the table, how much total mass is converted, and how much energy is released?	**Total mass converted is 4.6×10^{-4} kg. Energy released is 4.14×10^{13} J.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I chose 3.0×10^{25} fusion sets, which convert $(3.0 \times 10^{25})(4.6 \times 10^{-29}$ kg$) = 1.38 \times 10^{-3}$ kg of mass. The energy released is $(1.38 \times 10^{-3}$ kg$)(9.0 \times 10^{16}$ m^2/s$^2) = 1.242 \times 10^{14}$ J. Even this small mass loss releases substantial energy because c^2 is very large.

Accept answers with reasonable rounding and consistent units. The calculated energy includes energy carried away by neutrinos, so it is not all energy that warms the Sun.