Conservation of Mass and Energy in Nuclear Reactions

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Learning Objectives

- Explain the meaning of Einstein’s famous equation, $E = mc^2$.
- Relate Einstein’s equation to the conservation of mass and energy in nuclear reactions.

It’s so simple that a baby can understand it! Well, not really, but Einstein’s famous equation is pretty simple: $E = mc^2$. Do you know what it means and why it’s so famous?

Einstein’s Equation

Einstein’s equation is possibly the best-known equation of all time. There’s reason for that. The equation is incredibly important. It changed how scientists view energy and matter, which are two of the most basic concepts in all of science. The equation shows that energy and matter are two forms of the same thing. This new idea turned science upside down when Einstein introduced it in the early 1900s. Amazingly, the idea has withstood the test of time as more and more evidence has been gathered to support it.

You can learn more about Einstein’s equation in the video below.
Q: What do the letters in Einstein’s equation stand for?
A: E stands for energy, m stands for mass, and c stands for the speed of light.

The speed of light is 300,000 kilometers (186,000 miles) per second, so \( c^2 \) is a very big number. Therefore, the amount of energy in even a small mass of matter is tremendous. Suppose, for example, that you have 1 gram of matter. That’s about the mass of a paperclip. Multiplying this mass by \( c^2 \) would yield enough energy to power 3,600 homes for a year!

**Mass and Energy in Nuclear Reactions**

Einstein’s equation helps scientists understand what happens in nuclear reactions and why they produce so much energy. When the nucleus of a radioisotope undergoes fission or fusion in a nuclear reaction, it loses a tiny amount of mass. What happens to the lost mass? It isn’t really lost at all. It is converted to energy. How much energy? \( E = mc^2 \). The change in mass is tiny, but it results in a great deal of energy.

Q: In a nuclear reaction, mass decreases and energy increases. What about the laws of conservation of mass and conservation of energy? Are mass and energy not conserved in nuclear reactions? Do we need to throw out these laws when it comes to nuclear reactions?
A: No, the laws still apply. However, it’s more correct to say that the sum of mass and energy is always conserved in a nuclear reaction. Mass changes to energy, but the total amount of mass and energy combined remains the same.

**Summary**

- Einstein’s equation, \( E = mc^2 \), shows that matter and energy are two forms of the same thing. It also shows that there is a tremendous amount of energy (E) in a small mass (m) of matter.
- In nuclear reactions, matter changes to energy, but the total amount of mass and energy together does not change.

**Review**

1. Describe in words the meaning of Einstein’s equation, \( E = mc^2 \).
2. Why is this equation so important?
3. How does Einstein’s equation relate to the conservation of mass and energy in nuclear reactions?