

# A Trip to Pluto

When Albert Einstein wrote a three-page paper in 1905 outlining his theory that  $E=mc^2$ , there were no references to anyone else's work or ideas. Einstein could reason in words and mathematics why energy and mass are simply two forms of the same thing, but he could not confirm it. Confirmation in science comes in the form of the verification and validation of a testable statement—not just once but thousands of times by different groups of scientists.  $E=mc^2$  was dramatically confirmed following the 1938 generation of fission by German scientists Otto Hahn and Fritz Strassmann, and the realization by Lise Meitner and Otto Robert Frisch that mass was being converted to energy. Since then, the fact that energy can be converted to mass, and that mass can be converted to energy, has been shown countless times. In fact, every single nuclear reaction is testimony to Einstein's theory.

You may know that, in chemical reactions, mass is always conserved. The atoms that make up the molecules on one side of a reaction (the reactants) recombine to form different molecules on the other side of a reaction (the products). The outermost electrons of atoms interact to form these new molecules. Energy is absorbed or given off in a chemical reaction.

In nuclear reactions, mass is never conserved—some mass is exchanged for energy and energy for mass. Nuclear reactions take place in an atom's nucleus. In a spontaneous nuclear reaction, such as radioactive decay, mass is “lost” and appears as energy in the form of particles or gamma rays. However, the total mass and energy is always conserved. One simple method of accounting used by nuclear scientists and elementary particle physicists is to express all mass in energy units. The total energy (mass and energy) is the same before and after any nuclear reaction.

Once energetic particles are produced in a nuclear reaction, they interact with surrounding matter. As they zing along, their energy is shared through collisions with many other atoms and heat is generated. In a nuclear reactor, the rate of reaction is controlled. The energetic fission fragments heat the surrounding water, which is used to create steam and run electric generators. In a nuclear bomb, the energy released is sudden and uncontrolled. Massive destruction is caused by the tremendous heat and radiation released all at once.

In this activity, you will go on a hypothetical trip to the planet Pluto. Your task is to examine the possible fuel sources for your rocket engine and compute how much of each fuel you will need for the trip. You will compare wood and fossil fuels (chemical reactions) with fission and fusion (nuclear reactions). You will also consider the fuel efficiency of a hypothetical photon drive. Use your “Planning Your Trip” handout to get started.

