

# Re: Energy and Mass

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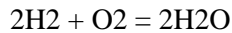
*Source:* <http://sci.tech-archive.net/Archive/sci.physics/2007-02/msg01919.html>

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- *From:* "Keith P Walsh" <[keith.p.walsh@xxxxxxxxxxxxxxxx](mailto:keith.p.walsh@xxxxxxxxxxxxxxxx)>
  - *Date:* 11 Feb 2007 09:53:54 -0800
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On 11 Feb, 15:31, "Jon Slaughter" <[Jon\\_Slaugh...@xxxxxxxxxxxxx](mailto:Jon_Slaugh...@xxxxxxxxxxxxx)> wrote:

One more example is say the forming of water



By measuring the masses of 2H<sub>2</sub> and O<sub>2</sub> inividually one would get X and then 2H<sub>2</sub>O should way X, but does it? is it even close?– Hide quoted text –

John,

All matter consists of an arrangement of energy.

More directly, all matter IS energy.

This idea was first proposed by Albert Einstein when he introduced the equation:

$$E=mc^2$$

What this equation means is that the total amount of energy, E, comprising any amount of matter with mass m is equal to the mass multiplied by the speed of light squared.

To give a random example, the pencil on my desk has a mass of 5g. If I convert this quantity of mass (0.005kg) into a quantity of energy using  $E=mc^2$  with an approximate value of  $3 \times 10^8 \text{m/s}$  for the speed of light, I get an approximate (but pretty accurate) value for the total energy of the pencil of:

$$4.5 \times 10^{13} \text{ Joules (or } 4.5 \times 10^{10} \text{kJ)}$$

My pencil isn't moving at a very high speed or anything. (At least not relative to me it isn't).

It's just sitting there on my desk.

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Now that's a lot of energy. But I would have difficulty converting any significant proportion of this energy into any other useful form such as heat or light. That's because the great majority of that energy goes into making up the atoms of carbon, hydrogen, oxygen and whatever other atoms go into making up my pencil, and I have no practical means of converting these atoms into heat and light.

Having said that, I could convert a tiny portion of this total energy into small amounts of heat and light by burning the wooden part of the pencil. And in order for the conservation equation for this combustion to balance I would have to conclude that the products of the combustion (including any ash, water vapour, carbon dioxide, etc.) would, in total, have a mass which is slightly less than my pencil originally had, by an amount equivalent to the energy given off – according to  $E=mc^2$ .

Consider your equation for the combustion of hydrogen:



From the point of view of mass/energy conservation this equation is

not complete. It does not balance. The reaction it describes is an EXOTHERMIC reaction; that is, a net amount of energy is released and dissipated to the surroundings. This amount of energy contributed to the mass of the  $2\text{H}_2$  and/or  $\text{O}_2$  before combustion, but does not contribute to the mass of the  $\text{H}_2\text{O}$  afterwards.

Assuming that the equation represents molar masses, a chemistry textbook will give the amount of energy derived from this reaction as 572kJ.

This is equivalent to a mass of  $572000/c^2 = 6.355 \times 10^{-13}$ , an extremely small mass. Nevertheless the rest mass of the products of the reaction (just water) must be less than the total of the rest masses of the reactants (hydrogen and oxygen) by this amount.

Be careful. In my experience some people don't believe this. In fact, it appears that some "scientists" are convinced that the equation  $E=mc^2$  has nothing to do with chemical reactions.

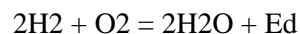
They are wrong.

Others may argue that the difference in mass is so small that it can be ignored. Well, for practical purposes (for example in the design of chemical processing plant) this may be true. But from the point of view of understanding the nature of chemical reactions it is a fundamental truth that the mass of the products of an exothermic reaction must be less than the mass of the reactants by an amount

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which is equivalent to the amount of energy released, according to the relationship  $E=mc^2$ . And, conversely, it is a fundamental truth that the mass of the products of an endothermic reaction must be greater than the mass of the reactants by an amount which is equivalent to the amount of energy absorbed, according to the relationship  $E=mc^2$ .

For the combustion of hydrogen, the correct equation of conservation is:



Where  $E_d$  is the amount of energy released and dissipated to the surroundings by the reaction. The quantities may be expressed in terms of energy or mass.

Best regards,

Keith P Walsh

PS, I've just noticed that André Michaud got his answer in before I posted mine. I think André's response is consistent with mine. I'd be interested to hear if he agrees with me.