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Can we "convert" mass into energy or vice versa?

A consideration by Dr. Manfred Pohl

Very often specialist colleagues expressed the opinion about the possibility to "convert" energy into mass or vice versa. On closer analysis, however, we can see that such a physical process cannot exist. A young physicist once argued in response to my objection the conversion of mass into energy and vice versa was confirmed "billions of times". Well, the uncommented assertion with strong expressions like “billions of times” cannot suffice as evidence. Billions of times is not even necessary. A single proof would be enough, but it has so far failed to materialize. The present paper aims to show that mass **cannot** converted into energy. The reverse process is also not possible. The reason for this view should be submitted for public discussion.

When dealing with this question, it is often assumed that there is a so-called *pure*, i.e. *massless*, energy that can be generated from a mass. In my opinion, that is exactly where the mistake lies: There is no energy without mass. A science journalist operated on me with the argument that mass does not play a role in the tension energy of a spring and summed up: “Right now so, there is energy without mass.”

Well, I gave him the calculation bases for determining the tension energy of a spring according to Hooke's law. But first I asked him to give a very popular scientific consideration. He should compare the tension energy of two springs. The first is the spiral spring from the chassis of an electric locomotive, a spring that cannot be lifted without the help of a second person. The second is the spiral spring from a ballpoint pen, a spring that leaps away if you touch it clumsily, so that you will hardly find it again. Can the tension energy of these two springs be assessed without taking into account their mass? Another logical thought: If the mass of the spring does not play a role, we could also try to assess the tension energy of a spring whose mass is zero, i.e. a spring that does not even exist. We can certainly see without difficulty that these are all mental games that contain insurmountable logical deficits and have no physical meaning.

I see the cause of this and other wrong attitudes in an inadequate conception of matter. In many places in the specialist literature one finds the representation that energy does not belong to the matter. It is removed from matter and contrasted to it. For example, a well-known encyclopedia writes that physics is concerned with the study of *matter and energy,* as if energy were something other than matter. This ultimately leads to the view one can convert into the other.

To clarify the problem of so-called *pure*, i.e. *massless* energy, you can, for example, use the energy equation of mechanical energy:

$$E_{ges} = E_{kin} + E_{pot} = \frac{m \cdot v^2}{2} + m \cdot g \cdot h$$

v, g, and *h* are non-zero values in this equation, *g* is the acceleration due to gravity. The equation shows that the energy is always zero when the mass is zero. That means, there is no energy without mass. And therefore there cannot be mass without energy.

The same statement can be obtained from the analysis of Einstein's equation of mass-energy equivalence:

$$E = m \cdot c^2$$

Here *c* is a natural constant, the speed of light in the vacuum. Here can one see too, that the energy is zero when the mass is zero and vice versa. However, if the mass is different from zero, then there is also an equivalent energy to it.

If you could "convert" mass into energy, that would mean by canceling of one to obtain another appearance of matter, and here it would mean, mass disappears but energy arises from it (which contains no mass!), in the opposite case energy disappears and mass arises from it (which is free of energy!).

The following consideration shows the questionability of such a process.

The starting point is the law of conservation of energy: In a closed system, the total energy is constant if energy is not removed from the system to outside or if energy is not supplied to the system from outside:

$$E_{ges} = const\,. \tag{1}$$

If you divide this total energy of the system into any two parts, for example

$$E_{ges} = E + E_1\,, \tag{2}$$

so is consequently in this closed system because of (1)

$$E + E_1 = const\,. \tag{3}$$

I will now follow the assumed claim that energy can to convert into mass: The energy component E_1 converts into the mass *m*:

$$E_1 \Rightarrow m \tag{4}$$

Under this assumption, the energy component E_1 would no longer exist, it would have been canceled, and the mass *m* has arisen in its place. If we now uses assumption (4) in equation (3), we are obtaining as a direct consequence

$$E + m = const\,. \tag{5}$$

If you look at equation (5), you can see that the units of measure already cause problems. In general, sizes with different units of measurement cannot be added or subtracted from one another. Therefore, you cannot summarize *J* and *kg* either. Otherwise, you would have to be able to summarize a meter and a second. Nevertheless, all of this is complete nonsense.

I now want temporarily to overlook this deficiency and still hold on to the claim that such a conversion can carried out. Then, as shows equation (5), the sum of energy and mass would be constant. This means a larger mass contains a smaller energy and a smaller mass contains a larger one.

According to the mass-energy equivalence, however, a completely different statement results with a completely different result.

The mass-energy equivalence is

$$E = m \cdot c^2 . \tag{6}$$

Here *c* is the natural constant of the speed of light in the vacuum. This relationship was theoretically derived by Albert Einstein in 1905 and subsequently proven in practice by a large number of experimental investigations. There are no doubts about this statement.

So that means that is

$$\frac{E}{m} = c^2 = const \tag{7}$$

However, that means **the ratio of energy to mass is constant** (**not the sum!**). So to increase the mass leads to an increase of the energy and vice versa. However, this is a completely different statement than in equation (5), in which the sum $E + m = const$ is supposed to be constant, in which a larger mass should even result a smaller energy.

However, since expressions (1), (2) and (3) in the above derivation are undeniably correct, the error must be in expression (4), in which the “conversion” of energy into mass was postulated. This step is not possible. There is no such process in the nature. It is impossible to “convert” one into the other, meaning to cancel the one in favor of the other. You just can't convert *J* into *kg* or vice versa, just as you can't "convert", for example, *kWh* into m^2. Physically, it is nonsense. Therefore we can obviously say:

The result of equation (5) is wrong.

Let us now return to the units of measurement that we temporarily disregarded above and analyze them in more detail.

Mass and energy cannot be added. There are two essentially different entities, of which, as already stated above, one cannot exist without the other, which emerged from equation (6): If the mass $m = 0$, so is $E = 0$. However, if $E \neq 0$, then is $m \neq 0$, that means, there is no mass without energy and no energy without mass.

These two entities have different units of measurement. The unit of measurement for mass is the kilogram (*kg*):

$$[m] = kg$$

The unit of measurement for energy is the joule ($m \cdot kg^2/s^2$):

$$[E] = \frac{kg \cdot m^2}{s^2}$$

Physical categories with different units of measurement cannot be added up. What would be the addition of a kilogram with a joule? We would have to write

$$1kg + 1\frac{kg \cdot m^2}{s^2} = ?$$

This “sum” cannot be explained. If, on the other hand, the units of measurement are inserted into the mass-energy equivalence, we are obtaining

$$\left[E = m \cdot c^2\right];\ \frac{kg \cdot m^2}{s^2} = kg \cdot \frac{m^2}{s^2}\ .$$

As we can see, this is a correct result.

Let's look at another example from electrical engineering: the ratio of voltage to current is resistance. The units of measurement of the quantities are the volt, the ampere and the ohm:

$$\left[\frac{U}{I} = R\right];\frac{V}{A} = \Omega\ .$$

Nobody in the profession would think about summate voltage and current (*U + I =?*), because it would to be senseless.

When inserting the measurement units from the MKSA system into the equation

$$\left[\frac{U}{I} = R\right];1V = 1\frac{kg \cdot m^2}{A \cdot s^3};1\Omega = 1\frac{kg \cdot m^2}{A^2 \cdot s^3}$$

we also get a completely correct result, but the sum

$$1\frac{kg \cdot m^2}{A \cdot s^3} + 1\ A = ?$$

has no some physical content.

It is the same with mass and energy. Different physical categories can only be related to one another in a way that corresponds to their natural properties. If we violate this principle, we will get no or useless results.

Conclusion:

It is impossible to “convert” energy into mass. The reverse process cannot physically carried out too. Both entities are two mutually equivalent manifestations of the same reality, the matter. One cannot occur without the other. Where there is energy there is also mass, and where there is mass there is also energy. That is a basic statement of the mass-energy equivalence.

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