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Special Relativity and the Half-Life of a Radioactive Element

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According to the time dilation of Special relativity, the time interval measured by the observer on the moving object is always larger than that measured by the observer on the Earth. The equation of this theory that describes this dilation is given by

$$\Delta t = \Delta t_0/\sqrt{(1 - \upsilon^2/c^2)} \ldots (1)$$

where Δt is the time interval measured by the observer on the object moving at a speed υ relative to the Earth, Δt_0 is the time interval measured by the Earth's observer and c ($\approx 3\times10^8$ m sec^{-1}) is the speed of light. The term $1/\sqrt{(1 - \upsilon^2/c^2)}$ is the Lorentz-Einstein or the time dilation factor γ.

The law of radioactive decay predicts how the number of the non-decayed atoms of a given radioactive substance decreases with time. This law for a radioactive element can be expressed with the following equation

$$N = N_0 2^{-0.693t/T} \quad \ldots (2)$$

where N is the number of its radioactive atoms at a time t, N_0 is their initial number at a time t = 0 and T is the so-called half-life of this element.[1] In this communication, we will use a hypothetical sample of the radioactive element sodium-22 (Na-22). Its half-life is T = 2.6 years.[2]

We will perform the following thought experiment: the Na-22 sample is placed in a spaceship that travels around the Milky Way galaxy at a speed $\upsilon = 0.866c$ relative to the Earth. The half-life of a radioactive element on the Earth T_0 is related to its half-live T when traveling at speed υ by

$$T = T_0/\sqrt{(1 - \upsilon^2/c^2)} \ldots (3)$$

Hence, the γ factor of the Na-22 sample in the spaceship is $1/\sqrt{(1 - \upsilon^2/c^2)} = 1'\sqrt{(1 - 0.866^2)} = 2$.

The spaceship's observer (Marie) radiochemically determined that about 50 % of the Na-22 atoms have been disintegrated. Her measurement is following eqn. (2).

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[1] Just to remind the reader: the half-life T is the time required to decay one-half of the initial radioactive element. Hence, at the moment T, we have $N = N_0/2$.

[2] Na-22 is a man-made isotope. It decays emitting a positron (β^+ decay) into a stable neon-22. Na-22 is used in nuclear medicine imaging for positron emission tomography.

Using eqn. (3), the Earth's observer (Pierre) would calculate that the half-life of her Na-22 atoms $T_0 = T \times \sqrt{(1 - \upsilon^2/c^2)} = 2.6$ years $\times \sqrt{(1 - 0.866^2)} = 1.3$ years. Using eqn. (2), he would also estimate that only about 39 % of Marie's Na-22 atoms have been disintegrated and *vice versa*. Marie would estimate, using eqn. (2), that only 39 % of Pierre's Na-22 atoms have been disintegrated.

Since there is one single sample, the question now is which of these two results would be radiochemically confirmed by Marie and Pierre after the spaceship's return? The author, as an experimental scientist, strongly believes that these afterward radiochemical measurements would confirm Marie's result. If so, there seems to be only one reasonable explanation: the time dilation of Special relativity is not adequate in this case. If, on the other hand, the Pierre calculation is confirmed by these measurements then this dilation needs an alternative explanation outside the theory of Special relativity.[3]

Reference

[1] R. G. Ziefle, *Einstein's special relativity violates the constancy of the velocity c of light under one-way conditions and thus contradicts the behavior of electromagnetic radiation*. Physics Essays 34, 275-279 (2021).

[3]In another context, Ziefle [1] concludes that an alternative theory is needed to explain the relativistic effects and constancy of the speed of light measured on Earth.