19 Nuclear reactions and radioactivity

Subject:

The description of nuclear transformations, the discussion of measuring and detection processes for nuclear radiation.

Radioactive substances can emit three types of radiation: α, β and γ radiation. Nuclear transformation processes can be subdivided into radioactive decay, nuclear fission and nuclear reaction.

Deficiencies:

Nuclear physics is a real quarry of obsolete concepts. This becomes obvious when comparing the description of nuclear transformations with that of chemical reactions. And here we are already with the first deficiency. The similarity between normal chemistry and nuclear chemistry, or between the physics of the atomic shell and the physics of the nucleus goes much farther than it appears in many textbooks. By taking profit of this analogy nuclear physics could be conceptually simplified and by emphasizing the analogy learning could be facilitated.

In nuclear physics, concepts that existed already in chemistry, are sometimes introduced with a new name: What in chemistry is a monomolecular reaction is called in nuclear physics a decay o a spontaneous fission. The autocatalytic reaction of chemistry is a chain reaction in nuclear physics. The reaction rate is measured in chemistry in mol/s. In nuclear physics it has another name, namely activity, and is measured in Becquerel.

One should expect that the relation between the two measures is

$1\ \text{mol/s} = 6{,}02 \cdot 10^{23}\ \text{Bq}.$

However, practice is different:

$1\ \text{mol/s} = 6{,}02 \cdot 10^{23}\ \text{Bq} \cdot \text{mol}.$

Reaction equations are written differently in chemistry and nuclear physics. For example the reaction of the nuclides ${}^{9}_{4}\text{Be}$ and ${}^{4}_{2}\text{He}$ into ${}^{12}_{6}\text{C}$ and ${}^{1}_{0}\text{n}$ is written in nuclear physics as

$${}^{9}_{4}\text{Be}\ (\alpha, n)\ {}^{12}_{6}\text{C}.$$

whereas in chemistry the notation would be

$${}^{9}_{4}\text{Be} + {}^{4}_{2}\text{He} \rightarrow {}^{12}_{6}\text{C} + {}^{1}_{0}\text{n}.$$

In addition the notation of nuclear physics has a further inconvenient: It emphasizes an asymmetry between the reactants ${}^{9}_{4}\text{Be}$ and ${}^{4}_{2}\text{He}$, as well as between the products ${}^{12}_{6}\text{C}$ and ${}^{1}_{0}\text{n}$ which is not essential: the difference of the masses of ${}^{9}_{4}\text{Be}$ and ${}^{12}_{6}\text{C}$ on the one hand, and ${}^{4}_{2}\text{He}$ and ${}^{1}_{0}\text{n}$ on the other. Moreover, this notation is applicable only when there are exactly two reactants and two products.

Sometimes the same word is used in chemistry and in nuclear physics in different meanings. In nuclear physics in a reaction must participate at least two reactants, in chemistry not.

Who wants to learn nuclear physics has to do with particularly many technical terms. It is common to make unnecessary and unessential distinctions. An example: One insists to distinguish between natural and artificial radioactivity, i.e. between decay process of nuclides found in nature and man-made nuclides. Of course, also chemists could distinguish between natural and artificial compounds and their spontaneous decomposition. Fortunately they don‘t do so, because this distinction would not reflect anything essential.

It is also dispensable to give to some decay products “radiation names” in addition to their normal names. Moreover, the denominations α-, β- and γ-radiation suggest that between the corresponding particles there should be a similarity or an analogy, which is not the case. On the other hand, the relationship between a γ process and a photochemical reaction is usually not made evident.

Origin:

How did it come that the description of radiations dominates so strongly nuclear physics? Where does the proliferation of technical terms come from? Why do we spent so much teaching time for the description of radiation measuring processes?

The first, and for a long time the only known transformations of nuclei were related to “radiations”. Only thanks to the radiation it was possible to get information about a nuclear process, i.e. only by the fact that one of the reaction products had a low mass and thus takes over almost the whole energy released in the process. At the beginning, one observed the radiation and one did not yet know the nature of it. It was natural to give it a proper name. Moreover, at the times of the beginnings of nuclear physics radiation was in fashion. Several times the discovery of a new radiation was rewarded with a Nobel prize. Only slowly the similarities between processes of the atomic shell and the nucleus became apparent. Only decades later nuclear reactions with reaction rates as high as those known from chemistry have been observed or realized. Only in the 1920 it was understood that the sun is a nuclear reactor, and the first man-made reactor began to operate in 1942.

Disposal:

The disposal is not simple. It requires a comprehensive restructuration of the contents of nuclear physics. When doing so it is best to take chemistry as a model.

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