7.1 Periodic Table as a Powerful Tool for Radiation Education

放射線教育に対する周期表使用の有効性

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Abstract

The periodic tables ordinarily start with an element of atomic number 1, hydrogen. Hydrogen atoms, however, are derived from neutrons by way of β decay. Consequently, neutron should be located at a zero position of atomic number, which corresponds to the left side and above helium. A periodic table, especially with the zero position for neutron, is essential from present view of matter and serves as a powerful tool for radiation education.

要旨

周期表は原子番号１の水素から始まる。しかしながら、水素原子核（陽子）は中性子のβ崩壊によって生成される。したがって、中性子は原子番号０（陽電荷０、電子０）の位置に置かれるのが合理的である。そしてこの位置は当然水素の左側で且つヘリウムの上に対応する。このような中性子を０の位置に持つ周期表を使用すると、放射線教育、特に初心者に対する教育に極めて効果的であることが示され、物質に関する現代的知見から見ても本質的である。

なお、このような試みは、JCO における中性子臨界事故をきっかけになされたという経緯があるが、フランスでは 1946 年に武谷光男によって、それぞれ核化学および核物理学の教科書に掲載されていることが示された。

Introduction

Neutral particles in a nucleus have long remained unknown until Chadwick discovered a neutron (1932), although J.J. Thomson and Aston had suggested existence of anything neutral (1912) through recognizing light neon and heavy one by means of anode ray analysis, Rutherford and other scientists

independently predicted that anything neutral (1920) should exist in the nucleus. What was a cause of the difficulty in the history of discovery of neutron ?

A neutron criticality accident happened at the Tokai facilities of JCO, a nuclear fuel maker, on Sept. 30, 1999, and was discussed in various contexts domestically, and in a severe tone, especially at abroad /1/. A background survey of the environmental neutrons has not been performed at any nuclear facilities concerning fission in the country. Neutron monitor which detected and recorded the neutrons from the JCO criticality accident was what had been equipped for fusion research facilities fairly distant from the JCO, but not for facilities of nuclear fuel treatment. Radiation education on neutron has not been made in both school and social education. In this country, textbooks of this field have been entirely unchanged these 100 years, "We have three kinds of radiations, α, β and γ rays". That is all. It is meant that description on neutron was not seen in the textbooks. From this reason, scientists in basic fields and science educationists also must be said to have been responsible

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for the neutron criticality accident through making light of fundamental aspects of radiation education and nuclear technology without revision of the old textbooks during 100 years.

Experimental (Social practice as Public Acceptance, hereafter PA, activities)

Just after the JCO accident, some lectures on properties of neutron were requested from the public in the vicinity of Rokkasho nuclear site in order to they may be become familiar with neutron and be free from anxiety on it. We, on demand, made lectures with a clear educational intention that an entire ignorance of neutron should be conquered for the public in the Peninsula Shimokita (Mutsu and Rokkasho), Chiba and Aomori. Focus is introduction of some explanation for understanding occurrence and properties of neutron. The explanation on properties of neutron was made as follows:

1) Neutrons come to the earth from the sun and stars, and are falling on us as rain or shower both day and night. This radiation which comes from the sky was called cosmic ray.
2) Secondary neutrons are derived from spallation (crashing into smaller parts) of nitrogen and oxygen atoms in the atmosphere due to the cosmic rays, spontaneous and induced fissions of uranium and transuranium elements, and neutron-producing nuclear reactions of light elements.
3) Neutron is beta-emitting nuclide with half-life of 10.6 min to decay into hydrogen, atomic number of which is one.
4) Neutron is a source matter of hydrogen in the universe.
5) Neutron should be regarded as an element with atomic number of zero.
6) Neutron is located before hydrogen in the table of isotopes as well as in the chart of nuclides.
7) Neutron should be listed up on the periodic table, and location of it should be before hydrogen, that is, left side of hydrogen, and above helium. The upper part of the left side of this newly arranged periodic table /2/ will serve for understanding as 'fusion corner'.

8) Neutron gives its kinetic energy to hydrogen in the maximum efficiency. From this reason, hydrogen-containing materials (as well as human body) serve as effective shields of neutron.
9) Neutron is neutral in charge, and is not affected by both positive and negative charges of atom, so easily goes into matter without resistance. In other words, it has a great penetrating power against matter.
10) Slow neutron easily gets close to nucleus and is caught by it. The nucleus which has caught it will act as beta-emitting nucleus in most cases. So neutron will make radioactive matter, that is, activate other matter.
11) We are not able to detect or count particles without charge such as neutron using electric or electronic devices.
12) We must convert neutron without charge to any charged particle for detecting and counting.
13) Neutron reacts with boron to give alpha particle with the highest probability. This nuclear reaction is employed for detecting and counting neutrons.
14) This same nuclear reaction is made use of protecting human body against neutrons with the highest probability as well. Boron converts neutron (with the longest range of naturally occurred radiations) into alpha particle (with the shortest range of them).

A Series of these explanations are arranged in a historical sequence and logically natural order. It will be helpful for basic understanding of dynamical aspect of atoms. It, however, does not mean that we always come to the last explanation. In one case we have stopped at the eighth explanation, and in other case we have stepped to the twelfth one. A principle for selection is faces of audiences. Faces of audiences serve as an indicator for selection of the proper steps to meet the situation.

Results

In Mutsu City, the meeting was organized by the Peninsula Shimokita Activation Society /3/. There are some fireman and head of fire department among the audience. In the accident of Tokai, the members of fire brigade were carelessly exposed to the neutrons in th criticality. So, they might have attended the meting of their own will for the purpose of understanding a radiation of neutron. The audiences in most cases understood the above-mentioned explanations, especially protection for human bodies using nuclear reaction with boron.

In Rokkasho Village, the Conference of Health Collaborators organized the meeting for understanding a shield against neutrons. They are responsible for helping medical doctors, nurses, and health nurses against the safety of the public. They wanted to understand how to protect human body against neutrons. Accordingly we proceeded to the last explanation in this case, and they learned about neutron enough. In the course of meeting, they showed a deep sympathy to the villagers of Tokai who were greatly disturbed by the accident.

In Chiba City, the members of the Society of Japanese Women Scientists organized the meeting at the Nati0nal Institute for Radiological Sciences. The targets were pupils of elementary schools, those of

junior and senior high schools, and citizens containing house wives. This meeting was accompanied by a science experiment class for radiation measurements by audience themselves. Counters of alpha, beta and gamma rays were ready for measuring samples, and a course of self-made cloud chambers and measurements of environmental radiations using them were recommended. We, for the first time, mentioned the new periodic table containing zero position of atomic number for neutron. After finishing of the course of measurements, one of the middle-aged house wives came to us and told that the periodic table with zero position of atomic number for neutron was very nice for her to make clear the meaning of periodic table itself and to know relation between atoms and neutrons, and remembered her of the school days. This comment by a citizen was the most encouraging for us to employ it for explanation of understanding neutron.

In Aomori City, members of the Rotary Club organized the meetings, and members of Aoimori Science BBL /4/ organized meetings periodically twelve times during these two years. As a theme of the learning, topics of cosmic science were rather preferred to nuclear science. Universal occurrence of neutrons in the cosmos, their change into hydrogen and reverse change under gravitation in neutron stars and supernovae are reasonably understand using the periodic table containing neutron.

Discussion

1) Historical phase of the periodic table in relation with the discovery of radioactivity /Appendices 1/.

J.L. Meyer of Germany tried to classify elements using atomic weights obtained by S. Cannizzaro (1862, 1868). D.I. Mendelejeff announced his first periodic table of elements (1869). The next periodic table Mendelejeff proposed (1906) was a short period table similar as well as nowadays in use. On the other hand, Werner- Pfeiffer preferred along period table. There were some vacant positions for eka-elements that had not been discovered at that time. The word, eka, is a numeral of Sanskrit, one, and means an element that should contact in vertical direction in the table, or in a more concrete sense, an element that should locate just below in the table, because lighter elements were already known in most cases. In the case of neutron, it, however, was of a lighter case, or of the lightest case of unknown substances.

2) Possible effectivity for searching for any light particle.

When radioactive substances were discovered, they were recognized also to emit some light particles in addition to electromagnetic wave similar with X-ray, and first of all, a beta ray was recognized by Becqurel to be an electron with high velocity (1900), and an alpha ray by Rutherford to be positively charged helium with high velocity (1909). During This period /5-8/ , if any lighter material particles (apart from charge) than helium were supposed to be emitted in a phenomenon of the radioactivity and were searched consciously, a situation in relation to the discovery of neutron might have been so much different from the history. Before the discovery of neutron, a framework of human beings for observing and thinking natural phenomena was so deeply affected from negativity/positivity dualism /Appendices 2/ as a general principle that it seemed to be very difficult for human beings to think of a neutral particle, and it took much longer than thirty years for them to discover neutron after discovery

electron. It may be possible for us to call a lighter particle (than helium) emitted from decay of radioactive substances or nuclear reactions as eka-helium /Appendices 3/, because it ought to exist in an atom and to compose atoms as well as helium nucleus (alpha particle).

3) Effectivity for understanding relation between neutron and matter.

In some stage of classifying various kinds of atoms, there was clear step where hydrogen was regarded as a component of atoms, because of atomic weight of each atom seemed to be integer times of that of hydrogen. This hunch was not to be entirely a mistake when neutron was not yet discovered, and was thought to rather contain implicitly possible existence of a particle with nearly equal atomic 'weight'. At this stage, the position with atomic weight of one and atomic number of one may regarded to be in degeneracy with atomic number of zero. The discovery of neutron splits the degeneracy into the different two states, neutron and proton, and the latter is written in atomic expression as hydrogen, but the former itself is neutral to be located at the zero position of atomic number.

The house wife among the audience of the meeting at Chiba City told that, though she learned atoms in the ordinary periodic table and neutron in her high school days, she was able to understand a total image of substance and relation between neutron and matter under a sweep of eyes by our explanation using the periodic table with zero position. This testimony given in the meeting for the public seemed to be very important as that from non-specialist of science, and gave us the first chance inspiring us so much that we employed with confidence the periodic table with zero position of atomic number.

4) Effectivity for understanding nuclear fusion reaction.

The upper part of the left side of the periodic table is effective for explanation of nuclear fusion reaction, which takes place from four hydrogen atoms to give one atom of helium (and two neutrinos) in the sun and stars, and from one deuterium atom and one tritium atom to gives one helium atom (and two neutrinos) and one neutron in a fusion reactor on the earth.

5) The periodic table with zero position in relation to TABLE OF ISOTOPES and CHART OF NUCLIDES.

We have various kinds of TABLE OF ISOTOPES /9/, in which the zero position of atomic number, of course, has been established for neutron. Isotopes are one-dimensionally arranged versus atomic number with internal order in mass number. If we make isotopes degenerate in mass number in the table of isotopes, and make element degenerate periodicity in the periodic table with zero position for neutron, resulting two one-dimensional series are entirely in agreement with each other. On the other hand, in various kinds of CHART OF NUCLIDES /10/ published, the zero position of atomic number for neutron is reasonably reserved rather as a starting point. Nuclides are expanded two-dimensionally versus atomic number and neutron number with equal mass line with 90 degree against a line on which atomic number is equal to neutron number. If we make the chart degenerate in neutron number, a resulting one-dimensional series as well become the same as above mentioned two one-dimensional series. The periodic table with zero position of atomic number for neutron, the table of isotopes, and the chart of nuclides, irrespective of difference in appearance, are entirely equivalent from viewpoint of a scientific recognition on matter.

Conclusions

It has been made clear through our practice in the public acceptance activities that the periodic table with zero position for neutron functions effective for radiation education to the public, especially to beginners. It promotes understanding of dynamical aspect of atoms, namely, change of radioactive elements with atomic number N (containing zero) emitting beta ray (electron) into elements adjacent to the rightside with atomic number N+1, relation between neutron and matter, for example, neutron capture (activation of matter by neutron), following decomposition (nuclear fission), and nuclear fusion reaction.

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Appendix

Appendices1. From atom to nucleus.

The word, atom, was originally introduced by ancient materialists as an ultimate particle of which the universe is composed. The word, atom means not to be divided into any parts. At beginning of the 19th century this philosophical concept, however, has been changed by

Avogadro into a scientific concept that shows what is actually countable one by one. At the very short time from the end of the 19th century to the beginning of 20th century, it came to be thought that atom should have any internal structure according to a series of discoveries of X-ray, electron, radiations from uranium minerals, and polonium and radium as the first group of radioactive elements. At this stage, the definition that atom is what is not to be divided was no longer valid. Although atom has become something to be divided, it has remained yet unknown how atom should be divided. In other words, nucleus was not yet known, and consequently was not defined. It was in those days that the short period periodic table of elements was introduced by Medelejeff. Discovery of nucleus could not be earlier than recognition of alpha ray to be helium without electron (1909) by Rutherford group. And, nucleus, was ultimately discovered (1911) through experiment of alpha ray scattering with gold plate by Rutherford. Accordingly, about 10 years or more after J.J. Thomson discovered electron (1897) may be said to be a creative twilight through which the scientists roamed about a concept of nucleus /5-8/. At this stage, negativity/positivity dualism functioned still effective. At the next stage, however, the dualism did not work well, and twenty years passed till discovery of neutron (1932). Discovery of neutron may be said to liberation from the old framework of thinking like the negativity/poitivity dualism common to human beings irrespective east or west.

Appendices 2. The theory of negativity/positivity five elements (yin-yang wu xing theory) in ancient China.

Ancient Chinese philosophers developed the theory of negativity/positivity five elements. The theory is regarded to originate fro a shade/shine dualism. The terminology suggests that this theory of southern origin, because it may be possible only in the subtropical region that a shade protects living things from sunshine, and make them feel comfortable under shade of trees. In an early stage, theory of shade and shine, and theory of five elements were independently proposed, and the former was developed to more concrete negativity/positivity dualism, which combined with the latter to form one theory.

Here, five elements mean wood, fire, soil, metal, and water. The order of the five elements should be written in this way, because it has a meaning or an interpretation. Each of elements was composed from rarest gaseous material, qi. It seems to be similar to ether that was thought by ancient Greek philosophers to be the rarest and noblest element prevailing only in the universe above the moon and named the fifth elements in addition to four elements (fire, air, water, and soil) in the universe below the moon, namely on the earth. Both the qi and the ether were neutral in nature. The qi, however, later split into twi phases, negativity (yin) and positivity (yang). At this stage, wood was thought to be composed of less negativity and more positivity, fire was of positivity only (this is similar to phlogiston in alchemy), soil was of half negativity and half positivity, metal was of more negativity and less positivity, and water was of negativity only. This was a main pont of the theory of negativity/positivity five elements.

By the way, what does this order of the five elements mean? It seems to us curious logically. An

ecological or historical viewpoint, however, leads us to an idea that order may be the sequence of materials or phenomena necessary for muman beings or recognized or encountered by them at early stage on the earth:

1) they lived in woods, or strictly speaking, they evolved from a higher kind of monkey in woods, found themselves to be in woods,
2) they learned or found making fire from wood,
3) they learned or found making ash as a kind of soil by burning wood,
4) they learned or found metal by digging soil, and
5) they learned or found water (lake, river, and sea) by going out of woods.

The stage 1) to 3) correspond to times of earthenware, the stage 4) corresponds to times of metalware, and the stage 5) corresponds to recognition of total environment as life-sphere.

The negativity/positivity five elements theory was applied widely for understanding and explaining the nature and the human phenomenon, and during a very long time functioned a framework of thinking. This theory was introduced to ancient Japan, and had a great influence on thinking, especially about human phenomenon here, which would be said to continue even nowadays, because you would find or the system to be alive in various kinds of antique style calendars, for example, the author is classified to be as wood in element and to be as green in color according to the year of the birth. It should be emphasized that negativity or positivity is a continuum in nature, but not a particle as well as an atom. They related to only quality of element, but not to quantity or size. From this reason the theory has not lead us to any internal structure of matter.

Appendices 3. Atomic science (scientist) and nuclear science (scientist).

The category of nuclear scientist is very new. A well-known nuclear physicist, Prof. Shin'ichiro Tomonaga, for example, told himself to be an atomic scientist, and his field of science was called atomic physics even at the times after the a world war II. At an early stage of research of this field, the word, radioactivity, was exclusively used among new sciences at the beginning of the 20^{th} century. Nuclear science and scientists that come into existence in the latter half of the 20^{th} century for the first time and reveal themselves suddenly in the presence of the public from the secret world of military research for development of atomic bombs in the desert of Los Alamos. Even nowadays, the word, atom, is used to the extent unreasonably expanded. Atomic bomb is a nuclear bomb in nature, and atomic energy is nuclear energy in nature. Nowadays, atomic physics or atomic science, however, is no longer nuclear physics or nuclear science. This kind of terminology might have any mental origin or basis. Apart from specialists, this kind of terminology will lead the public to ambiguity between atom and nucleus, and obscurity of scientific topics in general.