

NUCLEAR RADIATION AND DISINTEGRATION

PETE STEWART

*Bearden High School
Knoxville*

All natural nuclear radiation consists of three types, alpha, beta, and gamma radiation. All radioactive elements emit either alpha or beta rays and either may be accompanied by gamma radiation, but a given element does not generally emit all three types of rays. Radium is a notable exception giving strong alpha radiation accompanied by weaker beta and gamma radiations.

Alpha radiation is actually made up of two neutrons and two protons. In fact an alpha particle is identical with the nucleus of the ordinary helium atom. Although the alpha particle has a speed of about ten Mev, it is easily stopped by a piece of paper.

Beta rays are actually fast moving electrons easily deflected in a magnetic field. They travel at .998C and are able to penetrate one mm. of lead.

The problem of beta origin had stumped physicists for years. A radioactive beta transition, like an alpha particle, must be accompanied by a definite energy change; and there is reason for believing that the disintegration of thorium C or Bi-212 is the maximum beta-particle energy, E-max. But often in atomic series the energy of the beta particle does not correspond with E-max. It was this discrepancy that had physicists tearing their hair. In 1931 a way out of this dilemma was seen by W. Pauli.

There is little doubt that the atomic nucleus does not contain free electrons but only neutrons and protons; hence the electrons which were emitted as beta rays from radio-active nuclei must result from the spontaneous conversion of a neutron into a proton and an electron. Pauli suggested that this process be accompanied by the emission of another particle, now called the neutrino; this was assumed to be electrically neutral and have a very small rest mass comparable to that of the electron. Since the E-max would have to be divided between the beta particle and the neutrino, the energy discrepancy would be accounted for.

Gamma rays are electromagnetic waves with a wavelength generally shorter than that of X-rays. They move at the speed of light and are able to penetrate twenty cm. of lead.

A very useful instrument for the study of alpha and beta radiation is the Wilson cloud chamber. The underlying principle is the fact that if the temperature of moist air is suddenly lowered, any ions present will act as centers around which the condensation of water begins. As the alpha and beta particles streak through the moist air, they collide with atoms present and ionize them. When the air is cooled, the water condenses

around these ions, leaving fog tracks where the particles once traveled.

In the Wilson cloud chamber alpha particles cause heavy straight "fog tracks" while beta tracks are lighter and less continuous in appearance and are usually quite crooked owing to more frequent deviations in direction caused by atoms and molecules in the path of the particles.

Einstein at the beginning of the century stated that mass and energy were the same thing and connected them with this equation; energy equals mass times the speed of light squared. If the mass is in grams and the speed of light in cm./sec., the energy will be in ergs.

Since the erg is too large a unit to use with nuclear quantities, a smaller measure is in order. This unit is 1.6×10^{-12} erg, and is called the electron volt (ev). For convenience two other energy units are used; one which is not often used, equal to a thousand electron volts, called the kilo-electron volt, is represented by Kev and the other, a million electron volts, is abbreviated Mev. By a series of substitutions of equivalents a new formula is arrived at. This is energy in Mev equals mass in amu times 931.

Looking at the alpha particle carefully creates what seems to be a paradox, for the weight of the particle is less than the sum of its parts (two neutrons and two protons). The weight loss is .0303 amu, and if applied to Einstein's equation, the mass turns into 28.8 Mev of energy. The energy released is referred to as binding energy and it takes that same large amount of energy to break up an alpha particle into its constituent nucleons. This is, of course, a simple use of the Einstein formula, but it serves to illustrate the stability of the alpha particle and also the relationship between mass and energy.

All radioactive disintegration involves two types of radiation, the alpha and beta particles. When an alpha particle is emitted from a nucleus, the particle will decrease the atomic number by two and the atomic mass by four. This is because there is a reduction of two protons and four particles from the nucleus. Since a beta particle is the result of a neutron changing into a proton and an electron, the emission of a beta particle will increase the atomic number by one but the mass of the electron released is not enough to affect the atomic mass.

Take for an example the disintegration of uranium I through two stages. Uranium I or U-238 emits an alpha particle. This will reduce the atomic number by two, changing it into the element two units lower on the atomic scale or thorium. Since its atomic mass has been reduced by four, the element may be written Th-234. This element in turn emits a beta particle. Since its atomic weight will remain unaffected, but its atomic number will climb one unit, the new element will be protactinium-234. As you may see by the chart the uranium series, as it is called, continues down to a stable form of lead, Pb-206.

In 1904 Rutherford suggested a constant for rate of decay called half life. It is the time necessary for a radio-element to decay to half its initial value. As seen by the graph, the radioactivity never ceases but continues, growing smaller by halves each period. The half life ranges from seconds as in radon (54.5 sec.) to years as in radium-226 (1620 years). Because of its importance in calculations, the half life appears on my charts of the atomic series.

Because the only time in a radioactive series that the atomic mass decreases is the time when an alpha particle is emitted, all atomic masses in a series may be expressed as multiples of four plus a constant integer. Thus the uranium series could be designated $4n$ plus 2 and those elements in the thorium series as $4n$. The only $4n$ plus 1 series is the artificial series of neptunium.

Just before the dawn of July 16, 1945, the first atomic bomb was set off. This marked man's first unleashing of the atom in an uncontrolled chain reaction. The next part of this talk will be devoted to the principles of nuclear fission.

Nuclear fission or atom smashing is produced artificially by bombarding the nucleus with some types of atomic particles. The problem then is to find a particle which would be able to penetrate the electromagnetic forces of the atom. Fast moving deuterons, tritons, or alpha particles are sometimes used; but since they would have to be moving at tremendous speed, for practical purposes they are out of the question. Since the proton and electron have a mass too small to penetrate the atom, there remains only the neutron.

Uranium can be split by either thermal neutrons of about .03 ev, or by fast neutrons with energy exceeding 1 Mev. It is the U-238 atom which suffers fission only in the latter case, but the neutrons of both types are effective for U-235. The fissioning of thorium requires fast neutrons, as also does protactinium. An example of a deuteron causing fission may be found in the splitting of uranium and thorium by 9 Mev deuterons.

Since it is the fissioning of U-235 which is used in the atom bomb, I shall elaborate on this subject. The isotopic weight of U-235 is 235.124 amu, and the mass of a neutron is 1.00897 making a total of 236.133 amu for the mass of the reacting particles. When it undergoes fission, a uranium nucleus splits in many different ways but the products which are obtained in the greatest yield have mass numbers of 95 and 139. These numbers add up to 234 instead of 236 because of some neutrons, assumed to be two in this case, are always liberated in the fission process. As in the alpha particle the uranium atom and the neutron used to start the reaction weigh somewhat more than its components produced in fission. This difference is translated into energy to the tune of 198 Mev.

Since the fissioned atom releases two neutrons, it is quite possible that they will go on to split more atoms. The newly fissioned atoms will in turn release more neutrons and split more atoms. This process builds up until many atoms are fissioning at a time. When this happens, it is called a chain reaction. For a chain reaction to take place, it is necessary to have a certain mass of the element present. The mass is called critical mass. When critical mass is obtained, the first fission is either spontaneous or set off by the cosmic particles around us.

This then is the principle behind the atom bomb. But although the military aspects of the atom have been more widely spread than have the peacetime uses, the atom can and is saving lives. Undoubtedly radioisotopes have saved lives directly in medicine, but they also make our world a safer place to live by making our industrial products safe. Many techniques have been developed for using the atom in industry, and the prospects for the future are very promising. Truly then if we resolve our international difficulties, the world is our oyster.

ANTIBODIES¹

NORMA AYERS

Powell High School

Powell Station, Tennessee

PURPOSE An attempt to overcome antibody reactions which reject skin transplants.

DEFINITION OF ANTIBODY

A specific protective substance produced by an animal in response to the introduction of an antigen.

DEFINITION OF ANTIGEN

A substance which, when introduced into an animal body, stimulates the production of specific entities (antibodies) that react or unite with the substance introduced (antigen).

TO DETERMINE A REJECTION DATE— THESE EXPERIMENTS WERE DONE

1. From the stomach to the back of a white mouse—seemed to be accepted.
2. From the back to the back of two white mice.
3. From the back of a white mouse to the back of a black mouse.

Experiments two and three were rejected in approximately one week.

ONE WEEK WAS THE ACCEPTED REJECTION DATE.

1. This project was a winner in the Southern Appalachian Science Fair in Knoxville, 1960.

I. YEAST INJECTIONS

- A. Why? The yeast injections were given in an attempt to inactivate the properdin system. Properdin is a natural body-defense chemical occurring in the blood. This system is composed of three things: properdin, magnesium ions (Mg^{++}), and complement. The parts of the complement are designated as C'1, C'2, C'3, and C'4. Zymosan, the insoluble cell wall of yeast, is thought to inactivate C'3 and therefore to inactivate the properdin system, or at least to lower the properdin level.
- B. How?
1. Regular yeast was mixed with tap water and was centrifuged with a hand centrifuge.
 2. Distilled water was added to the yeast cells until it became of a consistency easily drawn into a hypodermic needle.
 3. One cc in the first experiment and one-half cc in the second experiment was injected into each mouse under the skin of the stomach.
 4. After four days each mouse received a skin transplant upon the shoulder from a mouse of another strain to determine if the antibody reaction had been slowed or overcome by the inactivation of the properdin system.
- C. Observations
1. In the first experiment yeast was noticeable under the skin at the time of the transplant.
 2. In the second experiment the transplant showed no signs of rejection at the time of the death of the mouse.

RESULTS

	<i>First</i>	<i>Second</i>
Mice used —	Two white-took skin from black	One white and took skin from black
Deaths	One after yeast injection	One after second yeast injection
Duration of transplants	Injected March 13 March 17-30-13 days	Injected April 6—April 13 through injection — April 19 Died April 20—7 days

II. SKIN TRANSPLANTS FROM NEW BORN MICE

- A. Why? It is generally accepted that newborn mice do not have as many antibodies formed as the adult mouse.
- B. How?
1. Skin transplants were removed from mice two or three hours old.

2. These transplants were placed upon the shoulders of adult mice of another strain.

C. Observations

When in the second experiment the transplant was jerked off by a mouse the whole area bled, showing that there had been circulation of the blood through the transplant. There had been no signs of rejection.

D. Results

First

Mice used	Two white-took skin from black
Deaths	One from anesthetic
Duration of transplants	March 22-through April 4 — 13 days

III. SPLEEN INJECTIONS

- A. Why? Because of the following statement taken from an article by A. E. Billingham, L. Brent, and P. B. Medawar, F. R. S. found in *PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, Series B. Biological Science, No. 66, col., 239, March 15, 1956*: "Injection of newborn mice with homologous cells either confers tolerance or has no effect at all."

B. How?

1. Spleens were obtained

- a. A mouse was sacrificed: it was placed on its back, and an incision was made in the abdomen in the region of the spleen.
 - b. The spleen with its fatty mesentery and blood vessels was gently delivered through the incisions and was freed.
 - c. The spleen was homogenized by tearing it into bits with forceps and running it through 18 and 21 needles.
2. The homogenized spleen was injected into another strain under the skin of the head when the mouse was two or three hours of age.
 3. When the mice were older they were given skin transplants from the same strain of mouse as the spleen donor.

C. Observations

The white mouse's body swelled in the area around the transplants before it was rejected.

D. RESULTS	<i>First</i>	<i>Second</i>
Mice used	One white-took skin from the black	One black-took skin from the white
Deaths	None	None
Duration of transplants	Born Jan. 15 Feb. 18-23-6 days	Born Jan. 15 Feb. 18-March 2-13 days

IV. RADATION

A. Why? It has been proven that radiation kills antibodies.

B. How?

1. Bone marrow as prepared

a. Tyrode's solution was prepared.

b. Black mice were sacrificed; femur bones were removed and were cleaned of tissues.

c. The ends of the bones were snipped off with scissors.

d. A hypodermic needle containing a small amount of Tyrode's solution forced the bone marrow out.

e. The bone marrow was packed in ice.

f. Three hundred roentgens of X-ray radiation were administered at a hospital.

g. Approximately one hour after being irradiated, one cc of bone marrow was given to each mouse.

h. Transplants from the same strain as the bone marrow donors were given one week later upon the shoulder.

C. Observations

At a local science fair when the mice became excited, a transplant was ripped off and the whole area bled. This showed that there had been blood circulation through the transplant.

TECHNIQUES OF TRANSPLANTATION

1. Select the mouse to be used for the particular experiment.

2. Animal is anesthetized with one-half cc seconal.

3. The mouse is placed on its back; a small area shaved; a piece of skin is removed, and placed in saline solution.

4. This area is then replaced by skin from another mouse.

a. In some experiments the transplants were sutured onto the mouse. (Four stitches were used to hold the transplant in place.) A simple suture which is started on the outside of the lip of the wound on one side, carried across the under surface to the opposite side and brought through to the upper surface, is used. It is tied with a single square knot.

- b. In other experiments the transplants were kept in place by means of a solid antiseptic covering.
(Instruments)

A curved diamond needle was used because it has a double cutting edge. Scissors were used to make any incisions for the actions of the scissors closes most of blood vessels in the skin. All of the instruments were submerged in alcohol. The hair of the mouse was sponged with alcohol to prevent contamination of the surgical field with the animal hair.

EVALUATION

All methods with the exception of one seem to have successfully overcome antibody reactions for a short period of time as the normal rejection period is one week. The rejection of the one white mouse's transplant would seem to indicate that the transplant was not effected by the spleen injection while it conferred tolerance in the black mouse.

GENERAL INFORMATION

Types of antibodies:

1. antitoxins
2. agglutinins
3. precipitins
4. lysins
5. opsonins

UNITARIAN CONCEPT

That for a given microorganism there is only one antibody but that this antibody may be demonstrated in several different ways.

THEORIES OF ANTIBODY FORMATION

Side-chain theory

Antibodies are produced abundantly by an irreparably damaged cell.

Template theory

The antigen acts as a pattern for the synthesis of the antibody globulin capable of combining with the neutralizing-antigen of the type that initiated its production.

Burnet's enzyme theory

The body cells produce antibodies which are changed by the types of antigen introduced.

PURE PROTEIN ISOLATION

This was achieved by isolating a polysaccharide, adding it to antipneumococcus, which is rich in antibodies, washing resulting precipitate, dissolved dilute alkali,

stepping it through two more complex chemical processes at which time a new protein was obtained which was pure antibody.

WHEN ANTIBODIES ARE PRODUCED

As a result of contact with microorganisms or their products, active immunity results in cells or tissues of the host. That immunity might pass from generation to generation might explain racial resistance.

THOUGHT TO CONSIDER

Even with the immense amount of tireless work which has been done to learn more about antibodies, much more knowledge is necessary before we can possibly hope to solve the problems connected with them, or before we can hope to control antibodies.

PROPERDIN

The properdin system was discovered by the late Dr. Louis Pillemer in 1954, who recognized it by its ability to combine with zymosan.

The word *properdin* is a combination of two Latin words, *pro* meaning "to prepare" and *perdere* meaning "to destroy". Properdin, therefore, means "to prepare to destroy". It is well named, for it is a natural body-defense chemical occurring in the blood. More specifically, properdin is an antibody, a blood protein, a naturally occurring mechanism of humoral resistance.

The wide reactivity of properdin is one of the reasons for believing in a system separate from other systems involving distinct antibody. This system consists of three distinct components: Properdin, which naturally occurs in blood serum; magnesium ions (Mg^{++}); and a complement. The four parts of the complement are designated as C'1, C'2, C'3, and C'4. As the definition of complement suggests, all components are necessary for the proper operation of the properdin system.

Zymosan, the insoluble cell wall of yeast and a complex polysaccharide, may inactivate this system; however, the evidence is not conclusive; or a C'1 serum factor may be necessary for the inactivation of C'3 by the properdin-zymosan complex. Although all the components are necessary for the regular activities of the properdin system, only C'1 and C'4 and magnesium ions are required for the synthesizing of properdin within the cell walls of bacteria. Properdin can also be formed synthetically from mouse and cow sera.

Different methods may be used to control the properdin level. One such method would be to inject a variety of polysaccharides into the animal as previously mentioned, and depending on the type and dose of agent, the route by which it is given, and the time at which it is introduced, the properdin level will be changed. It is believed "the properdin levels may be controlled by

lymphocytes, a type of white blood cell produced by the lymph glands." Furthermore, it is maintained that "serum-properdin levels may be the result of stimulation or depletion of properdin by both bacterial and host products."

The properdin level is measured by the Phage Neutralization Techniques. Rats have often been found to be richest in properdin. Rise in the properdin titer accompanies increased resistance to infection. Blood serum from which properdin has been removed by means of zymosan shows no ability to kill bacteria; the serum recovers this ability when properdin is restored.

Through the work of Dr. Peter A. Herbert and William H. Kraemer, it has been proven that properdin slows the growth of cancer. Their experiments were conducted in this manner. Human cancer growths were transplanted in rats to test the effect of properdin on the rats' natural immunity. As previously stated, properdin is normally present in the blood serum, but it can be destroyed by irradiation.

The animals were divided into four groups, with one group left untreated to act as a control. Another group was given a heavy dose of radiation, and the other two groups received injections of zymosan.

Over one-half of the cancers transplanted in animals, given multiple doses of properdin reducing zymosan, continued to grow. Three-fourths of the group given irradiation were "takes", each of which was considered a breakdown of the rats' natural resistance. Only nineteen out of one hundred sixty were "takes" in the untreated group.

In experiments involving healthy prison volunteers at the Ohio State Penitentiary, the prisoners built up immunity to a second cancer transplant. Blood studies of both cancer patients and well volunteers showed that properdin was the only factor associated with immunity that cancer patients lacked and well volunteers had.

NEWS OF TENNESSEE SCIENCE

(Continued from page 263)

"The Effect of Postirradiation Storage on Seedling Height." While abroad, Dr. Wolff visited several European laboratories.

Gerald E. Cosgrove presented a series of lectures before the National Science Foundation-Atomic Energy Commission Summer Institute of Radiation Biology at Florida State University, Tallahassee, July 30-August 7.

Masashide Asano, under the sponsorship of the Japanese Atomic Energy Bureau, has joined the Pathology and Physiology Section. Dr. Asano received the M. D. degree from Shinshu University School of Medicine, Matsumoto, Japan, in 1952 and interned at Tokyo University Hospital. Since 1956 Dr. Asano has been with the National Institute of Health, Tokyo, Japan.

Gino Doria, a citizen of Italy, has joined the Mammalian Recovery Section. Dr. Doria received the M. D. degree from the University of Pavia in 1956, and worked at the Medical Clinic of the University for a year.