放射医学专业英语

Radiation Medical English

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原子能出版社

放射医学专业英语

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内容简介

本书选材注重知识性、科学性、时代性，较全面、系统地介绍了放射医学专业各方面的知识，包括放射物理、辐射剂量、放射化学、放射生物、放射毒理、放射临床损伤和放射卫生防护等内容。考虑到学生的实际需要，本书的选材以放射生物、放射临床损伤和放射卫生防护文献居多。全书共有二十六个单元，每个单元又分 A，B 两个部分，每个部分在阅读课文前提出指导性的问题，并在课文后配有专业词汇、词组、难句分析并附参考译文、正误判断及简答问题等内容，书后附有核科学大事记及总词汇表。

本书为吉林大学“十五”规划教材，可作为高等院校放射医学专业学生英语教材，亦可作为从事放射医学与卫生防护及其他相关学科的科技工作者学习放射医学专业英语的工具书。

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前　言

近年来，随着科学与技术的迅猛发展，我国高等教育中专业外语教学越来越受到重视，各种专业的外语教材纷纷问世，但是，由于各种原因，目前尚无适合放射医学专业英语的教材，致使放射医学专业英语教学的展开出现困难局面。为解决这一迫切需要，我们编写了这部《放射医学专业英语》，并被列入吉林大学“十五”规划教材。

我们编写《放射医学专业英语》的宗旨是，培养学生阅读本专业文献的能力，加深对所学专业知识的理解，扩大专业词汇量。在编写本书的过程中，我们通过各种途径从国外收集近期出版的书刊，从中选取有关放射医学专业领域的文献，对篇幅过长的文章做了适当的删节。在选材上，我们注意把握实用性、知识性、系统性和科学性，以期达到培养学生熟练掌握本专业英语并在实际工作中运用自如的目的。

本书较全面、系统地介绍了放射医学专业领域里的研究内容，其中包括放射物理、辐射剂量、放射化学、放射生物、放射毒理、放射临床损伤和放射卫生防护等。考虑到学生的实际需要，本书的选材以放射生物、放射临床损伤和放射卫生防护文献居多。

全书共有二十六个单元，每个单元又分为A，B两部分，每个部分在课文前设阅读指导问题（Guided Questions），并在课文后配有专业词汇（New Words）、词组（Phrases and Expressions）、难句分析（Sentence Analysis）并附参考译文、正误判断（True or False Questions）及简答问题（Short Answer Questions）等内容，书后附有核科学大事记（Milestones in the Radiation Sciences）及总词汇表（Glossary）。本书作为高等院校放射医学专业本科生用英语教材，亦可作为从事放射医学与卫生防护及其他相关学科的科技工作者学习放射医学专业英语的工具书。

本书特别感谢蔡露博士、罗灿博士和赵勇博士在国外收集的大

量材料，感谢赵红光和王志成两位在读博士生在编写后期所做的工作，感谢吉林大学教务处和公共卫生学院及放射生物学教研室对本书的编写所给予的热情鼓励和大力支持。

参加本书的编写人员，除吉林大学公共外语教育学院英语教授孙萍外，均为在放射医学领域卓有建树的博士和正在攻读学位的博士研究生，他们中不乏在国外深造多年后学成归来的专家或正在国外从事本领域研究的学者，这为本书的编写提供了质量上的保证。但由于编写时间较为仓促，编写专业外语教材的经验不足，书中的缺点和疏漏在所难免，恳请读者批评、指正。

主　编

二〇〇五年十二月

目　录

Unit 1

Section A
Radioactivity and Radiation (1)

Before You Read
Guided Questions

1. Do you know something about the discovery of X-rays?
2. What are alpha, beta and gamma radiations?
3. What is the mechanism of radioactive decay?

In 1895 the German physicist Wilhelm Conrad Röentgen discovered "a new kind of ray", emitted by a gas discharge tube, that could blacken photographic film contained in light-tight containers. He called these rays X-rays in his first announcement in December 1895 — the X representing the unknown. In demonstrating the properties of X-rays at a public lecture, Röentgen asked Rudolf Albert van Kölliker, a prominent Swiss professor of anatomy, to put his hand in the beam and so produced the first radiograph. The first medical use of X-rays was reported in the *Lancet* of January 23, 1896. In this report, X-rays were used to locate a piece of a knife in the backbone of a drunken sailor, who was paralyzed until the fragment was removed following its localization. The new technology spread rapidly through Europe and the United States, and the field of diagnostic radiology was born. There is some debate about who first used X-rays therapeutically, but by 1897, Wilhelm Alexander Freud, a German surgeon, demonstrated before the Vienna Medical Society the disappearance of a hairy mole following treatment with X-rays. Antoine Henri Becquerel discovered radioactivity in 1898, and radium was isolated by Pierre and Marie Curie in the same year.

The first recorded experiment in radiobiology was performed by Becquerel when he inadvertently left a radium container in his vest pocket. He subsequently described the skin erythema that appeared 2 weeks later and the ulceration that developed and required several weeks to heal. It is said that Pierre Curie repeated the experiment in 1901 by deliberately producing a radium "burn" on his own forearm. From these early beginnings, just before the turn of the century, the study of radiobiology began.

Alpha, Beta and Gamma Radiations

Alpha radiation (α) was shown by Rutherford and Royds to consist of helium nuclei which consist of two protons and two neutrons. These four particles are bound together so tightly that the alpha particle behaves in many situations as if it were a fundmental particle. An α-particle has a mass of 4 U and carries two units of positive charge.

Beta radiation (β) consists of high speed electrons which originate in the nucleus. These "nuclear electrons" have identical properties to the atomic electrons, that is they have a mass of 1/1 840 U and carry one unit of negative charge. Another type of beta radiation was discovered by C. D. Anderson in 1932. This radiation consists of particles of the same mass as the electron but having one unit of positive charge, and is known as positron radiation. Although less important from a radiation protection viewpoint than negative β-particles, a knowledge of positrons is necessary in order to understand certain radioactive decay mechanisms. Beta radiation is signified β^- (electrons) or β^+ (positrons). In everyday use the term beta radiation normally refers to the negative type.

Gamma radiation (γ) belongs to a class known as electromagnetic radiation. This type of radiation consists of quanta or packets of energy transmitted in the form of a wave motion. Other well-known members of this class of radiation are radio waves and visible light. The amount of energy in each quantum is related to the wavelength of the radiation. It is found from experiment that $E \propto 1/\lambda$ where E is the energy of the quantum or photon of electromagnetic radiation and λ is its wavelength.

The wavelength of electromagnetic radiation varies enormously. All electromagnetic radiations travel through free space with the same velocity of 3×10^8 m/s (186 000 miles/s). Their velocity decreases in dense media but for air the decrease is negligible.

Another class of electromagnetic radiation which is in most respects identical to γ-radiation is known as X-radiation. The essential difference between the two types of radiation lies in their origin. Whereas γ-rays result from changes in the nucleus, X-rays are emitted when atomic electrons undergo a change in orbit.

For example: in the cathode ray tube of a television receiver, electrons are accelerated from the electron gun to the screen through an electrical potential of about 10 000 volts. The electrons therefore have energy of 10 000 eV when they strike the screen. The electronvolt is a very small unit so radiation energies are usually expressed in kilo electronvolt (1 keV = 1 000 eV) or mega electronvolt (1 MeV = 1 000 000 eV).

Even if the radiation being considered is not beta (electron) radiation, it is still possible to use the electronvolt as a unit of energy. The energy of a particle depends on its mass and speed, e.g. a particle of mass m travelling with velocity v, much smaller than the velocity of light, has kinetic energy (E_K)

$$E_K = 1/2\, mv^2$$

(a correction is necessary for particles having velocities approaching the velocity of light). A small particle such as an electron requires a much higher velocity than, say, an α-particle to have the same kinetic energy.

In the case of electromagnetic radiation, the energy is inversely proportional to the wavelength of the radiation. Thus radiations with short wavelengths have higher energies than radiations with longer wavelengths.

The Mechanism of Radioactive Decay

The nuclei of the heavier elements found in nature are so large that they are slightly unstable. For example, the isotope uranium-238 has 92 protons and 146 neutrons. In order to achieve greater stability the nucleus may emit an α-particle, so reducing its number of protons and neutrons to 90 and 144, respectively. This means that the nucleus now has an atomic number (*Z*) of 90 instead of 92 and so is no longer a uranium nucleus. It is now an isotope of the element thorium (Th) with atomic number 90 and mass number 234, namely thorium-234. Another example of this process is the decay of polonium-218 (^{218}Po) by alpha emission to lead-214 (^{214}Pb).

There are more neutrons than protons in heavy nuclei. Alpha emission reduces the number of each by 2 but the proportionate reduction is considerably less for neutrons than for protons. In the ^{238}U decay process, the number of protons is reduced by 2 out of 92 whereas the number of neutrons is reduced by 2 out of 146, which is significantly less. The effect of Alpha emission is therefore to produce neutron-rich nuclei which are still unstable. The nucleus does not simply eject a neutron (or neutrons) to correct this instability. Instead, one of the neutrons in the nucleus changes into a proton by emitting a beta particle, i.e. a high speed electron. This phenomenon is known as beta emission. In the case of ^{234}Th, formed by the α-decay of ^{238}U, the nucleus further decays by β-emission to protactinium-234 (^{234}Pa). Considering again polonium-218, the complete decay is bismuth-214 (^{214}Bi) which is also unstable and so further α- and β-decay processes occur until a stable atom is produced.

Electrons emitted during β-decay have a continuous distribution in energy, ranging from zero to a maximum energy E_{max} which is characteristic of the particular nucleus. It is found from experiment that the most probable beta energy is about 1/3 E_{max}. In most cases, after the emission of an α- or a β-particle, the nucleus re-arranges itself slightly, releasing energy in the form of gamma emission.

Two other decay processes should also be mentioned, namely positron emission and electron capture. In position emission, a proton in the nucleus ejects a positive electron (β^+) and so becomes a neutron. For example, sodium-22 (^{22}Na) by position emission is neon-22 (^{22}Ne). Electron capture is a process in which an electron from an inner orbit is captured by the nucleus resulting in the conversion of a proton to a neutron. A re-arrangement of atomic electrons then causes the emission of X-rays.

Natural Radioactive Series

Apart from ^{22}Na, the above examples of radioactive decay are all naturally-occurring radioactive substances and belong to the so-called natural radioactive series. There are three natural radioactive series, called the thorium, uranium-radium and actinium series. In addition, the neptunium series does not occur in nature because the half-life of its longest-lived member is only 2.2×10^6 years which is much smaller than the age of the Universe (3×10^9 years). These four series are called the heavy disintegration series.

Induced Radioactivity

Lighter elements may be made radioactive by bombarding them with nuclear particles. One example of this is the bombardment of a stable nucleus of an element by neutrons in a nuclear reactor. If a neutron strikes a nucleus it may be absorbed and a gamma photon emitted. Such a process is known as a neutron, gamma (n, γ) reaction. The resulting atom is normally unstable because of the excess neutron and will eventually decay by β-emission.

Thus if the stable isotope cobalt-59 is bombarded or irradiated with neutrons, atoms of the radioactive isotope cobalt-60 are produced. These atoms will eventually undergo β-decay and become atoms of the stable isotope nickel-60.

New Words

1. physicist ['fizisist] *n.* expert in or student of physics 物理学家，唯物论者
2. ray [rei] *n.* narrow beam or line of light or other radiation 射线，光线，闪现
3. radiograph ['reidiəugra:f] *n.* 放射照相，放射照相仪；*v.* 拍射线照片；radiography *n.* 放射（X 光线）照相术，放射线摄影
4. *Lancet* ['la:nsit] *n.* (英国) 柳叶刀杂志
5. paralyze ['pærəlaiz] *v.* affect (sb) with paralysis 使瘫痪，使麻痹
6. diagnostic [ˌdaiəg'nɔstik] *a.* used in diagnosis 诊断的，辨别的
7. radiology [ˌreidi'ɔlədʒi] *n.* 放射线学，放射医学
8. therapeutically [ˌθerə'pju:tikəli] *a.* 治疗性地，在治疗上
9. surgeon ['sə:dʒən] *n.* 外科医生（医师）
10. mole [məul] *n.* small permanent dark spot on the human skin 黑痣，摩尔；hairy ~ 毛痣
11. radioactivity ['reidiəuæk'tiviti] *n.* spontaneous emission of radiation, either directly from unstable atomic nuclei or as a consequence of a nuclear reaction 放射性，放射现象，放射能力，放射性活度
12. radium ['reidjəm] *n.* a rare, brilliant white, luminescent, highly radioactive metallic element [化] 镭 (Ra), 88 号元素
13. radiobiology ['reidiəubai'ɔlədʒi] *n.* 放射（辐射）生物学
14. cobalt [kəu'bɔ:lt] *n.* a trace element, atomic symbol Co, atomic number 27, and relative atomic mass 58.93 钴
15. inadvertently ['inəd'və:təntli] *ad.* by accident; unintentionally 偶然地，不故意地
16. erythema [ˌeri'θi:mə] *n.* abnormal redness of the skin due to capillary congestion 红斑
17. ulceration [ˌʌlsə'reiʃən] *n.* open sore containing poisonous matter on the outside of the body or on the surface of an internal organ 溃疡（形成）
18. forearm ['fɔ:ra:m] *n.* 前臂
19. radiation [ˌreidi'eiʃən] *n.* 辐射，放射
20. helium ['hi:ljəm] *n.* a noble gas with the atomic symbol He, atomic number 2, and relative atomic mass 4.003 氦
21. nucleus ['nju:kliəs] *n.* 原子核，晶核，胞核；*pl.* nuclei
22. positron ['pɔzitrɔn] *n.* a positively charged particle having the same mass and magnitude of charge as the electron and constituting the antiparticle of the electron 正电子
23. neutron ['nju:trɔn] *n.* an electrically neutral subatomic particle in the baryon family, having a mass 1 839 times that of the electron, stable when bound in an atomic nucleus, and having a mean lifetime of approximately 1.0×10 seconds as a free particle 中子
24. particle ['pa:tikl] *n.* 粒子，微粒，点，极小量

25. atomic [ə'tɔmik] *a.* 原子的，原子能的

26. charge [tʃa:dʒ] *n.* 电荷，负荷，充电，负荷，负载; negative ~ 负电荷，阴电荷; positive ~ 正电荷，阳电荷

27. quantum ['kwɔntəm] *n.* 量子，数量; *pl.* quanta.

28. radioactive ['reidiəu'æktiv] *a.* exhibiting radioactivity 放射性的，有辐射能的

29. decay [di'kei] *v.* to break down into component parts, rot 腐烂，衰减，衰变; radioactive ~ 放射性衰变

30. electromagnetic [ilektrəu'mægnitik] *a.* 电磁的

31. wavelength ['weivleŋθ] *n.* 波长

32. photon ['fəutɔn] *n.* 光子

33. velocity [vi'lɔsiti] *n.* 速度

34. emit [i'mit] *v.* give or send (sth) out, discharge 发出，放射

35. orbit ['ɔ:bit] *n.* 轨道，环形，眶，眼窝

36. cathode ['kæθəud] *n.* negative electrode 阴极，负极

37. volt [vəult] *n.* 伏[特]

38. electronvolt (eV) [i'lektrɔnvəult] *n.* 电子伏; kiloelectronvolt (1 keV = 1 000 eV) 千电子伏; megaelectronvolt (1 MeV = 1 000 000 eV) 兆千电子伏

39. mass [mæs] *n.* 质量

40. isotope ['aisətəup] *n.* one of two or more forms of a chemical element with different relative atomic mass and different nuclear properties but the same chemical properties 同位素

41. uranium [juə'reinjəm] *n.* a silvery heavy radioactive polyvalent metallic element 铀 (U), 92 号元素

42. *Z* [zed, zi:] *n.* atomic number 原子序数

43. thorium ['θɔ:riəm] *n.* a radioactive metallic element that occurs combined in minerals and is usually associated with rare earths 钍 (Th), 90 号元素

44. polonium [pə'ləuniəm] *n.* a radioactive element, atomic symbol Po, atomic number 84, and relative atomic mass of the isotope with the longest half-life (^{209}Po) is 208.98 钋

45. lead [li:d] *n.* a metallic element, atomic symbol Pb, atomic number 82, and relative atomic mass 207.2 铅

46. protactinium [ˌprəutæk'tiniəm] *n.* a radioactive element, atomic symbol Pa, atomic number 91, and relative atomic mass 231 镤

47. bismuth ['bizməθ] *n.* a metallic element, atomic symbol Bi, atomic number 83, and relative atomic mass 208.98 铋

48. emission [i'miʃən] *n.* sending out or giving off 发出，放射，散布，发布; positron ~ 正 (阳) 电子发射

49. neon ['ni:ən] *n.* a noble gas with the atomic symbol Ne, atomic number 10, and relative atomic mass 20.18 氖

50. actinium [æk'tiniəm] *n.* a radioactive element, atomic symbol Ac, atomic number 89, and relative atomic mass 227.0278 锕

51. neptunium [nep'tju:niəm] *n.* a radioactive element, atomic symbol Np, atomic number 93, and relative atomic mass 237 镎

52. disintegration [disˌinti'greiʃən] *n.* breaking into small parts or pieces 裂解，瓦解，崩解，蜕变，裂变

53. bombard [bɔm'ba:d] *v.* attack (a place) with bombs or shells, (physics) direct a stream of high-speed

particles at (an atom, etc.) 轰击; bombardment *n.*

54. irradiate [i'reidieit] *v.* send rays of light upon sth 照射，照耀

55. nickel ['nikl] *n.* a trace element, atomic symbol Ni, atomic number 28, and relative atomic mass 58.69 镍

Phrases and Expressions

1. Wilhelm Conrad Röentgen (1845 – 1923): German physicist, a recipient of the first Nobel Prize for Physics, in 1901, for his discovery of X rays, which heralded the age of modern physics and revolutionized diagnostic medicine
2. Antoine-Henri Becquerel (1852 – 1908): discovered natural radioactivity, awarded (with Pierre Curie and Marie Curie) 1903 Nobel prize for physics
3. Marie Curie (1867 – 1934): Polish-born French chemist, distinguished types of radiation in radioactivity (a term she coined in 1898), discovered (1898) polonium and radium, awarded 1911 Nobel prize for chemistry for this discovery and for isolation of pure radium; Pierre Curie (1859 – 1906): husband of Marie, French chemist, conducted research on various forms of magnetism; awarded (with Marie Curie and A. H. Becquerel) 1903 Nobel prize for physics for work on radioactivity
4. Ernest Rutherford (1871 – 1937): 1st Baron Rutherford of Nelson, British physicist, awarded 1908 Nobel prize for chemistry for discovering that radioactive elements change into other elements
5. Carl David Anderson (1905 – 1991): American physicist, awarded (with Victor Hess) 1936 Nobel prize for physics for discovering the positron; confirmed existence of mesons
6. gas discharge tube 气体放电管
7. photographic film 照相胶片，照相软片
8. light-tight 不漏光，防光，不透光的
9. Vienna Medical Society 维也纳医学会
10. wave motion 波动
11. radio waves 无线电波
12. visible light 可见光 (线)，可视光线
13. television receiver 电视接收机 (器)
14. electrical potential 电势，电位
15. kinetic energy (E_K) 动能
16. natural radioactive series 天然放射系 (列)
17. half-life 半衰期，半寿期，半存留期
18. nuclear reactor 核反应堆，核反应器
19. electron capture 电子俘获
20. identical to, similar in every detail, exactly alike 等同于…

Sentence Analysis

1. In this report, X-rays were used to locate a piece of a knife in the backbone of a drunken sailor, who was paralyzed until the fragment was removed following its localization.
   此句中的 who 引导定语从句，修饰 a drunken sailor。

参考译文：在这个报道中，一名喝醉的水手被麻醉后，医生应用 X 射线定位脊柱内的一块刀片并将其取出。

2. A small particle such as an electron requires a much higher velocity than, say, an α-particle to have the same kinetic energy.

句中的 say作“比如说”解。

参考译文：像电子这样质量小的粒子要具有与α-粒子相同的动能，就必须比 α-粒子速度快得多。

3. Alpha emission reduces the number of each by 2 but the proportionate reduction is considerably less for neutrons than for protons.

连词 but 连接两个分句，后一个分句的表语是形容词比较级。

参考译文：α 发射使核内中子和质子的数量各减少 2 个，但相对来说中子数的减少比例明显低于质子数。

4. In the ^{238}U decay process, the number of protons is reduced by 2 out of 92 whereas the number of neutrons is reduced by 2 out of 146 which is significantly less.

连词 Whereas作“而，却，反之”解，引导状语从句。

参考译文：^{238}U 在衰变过程中，其质子数从 92 个减少了 2 个，而中子数从 146 个减少了 2 个，中子数的减少比例明显低于质子数。

After You Read

Comprehension Check

True or False Questions

1. Electromagnetic radiations with long wavelengths have higher energies than radiations with shorter wavelengths.
2. The effect of alpha emission is to produce neutron-rich nuclei which are still unstable, so the nucleus eject a neutron (or neutrons) to correct this instability.
3. There are more neutrons than protons in heavy nuclei.
4. Alpha particles lose their energy very rapidly and only travel very short distances in dense media.
5. X-rays are emitted when atomic electrons undergo a change in orbit.

Short Answer Questions

1. What does Beta radiation consist of?
2. What is the essential difference between the two types of radiation: X-rays and γ-rays?
3. What phenomenon is known as α- and β-decay?
4. What process is known as neutron and gamma (n, γ) reactions?

Section B
Radioactivity and Radiation (2)

Before You Read

Guided Questions

1. Do you know something about the unit of radioactivity?
2. Do you know something about how X- and γ-radiation interact with matter?
3. What is the mechanism of charged particles interacting with absorbing medium?

The Unit of Radioactivity

The decay of a radioactive sample is statistical in nature and it is impossible to predict when any particular atom will disintegrate. The result of this uncertainty regarding the behaviour of any particular atom is that the radioactive decay law is exponential in nature, and is expressed mathematically as:

$$N = N_0 e^{-\lambda t}$$

where N_0 is the number of nuclei present initially, N is the number of nuclei present at time t and λ is the radioactive decay constant.

The half-life ($T_{1/2}$) of a radioactive species is the time required for one half of the nuclei in a sample to decay. It is obtained by putting $N = N_0/2$ in the above equation:

$$N_0 = N_0 e^{-\lambda T1/2}$$

and so

$$T_{1/2} = \log_e 2/\lambda = 0.693/\lambda$$

Since the disintegration rate, or activity of the sample is proportional to the number of unstable nuclei, this also varies exponentially with time, namely

$$A = A_0 e^{-\lambda t}$$

In one half-life the activity decays to 1/2 A_0, in two half-lives to 1/4 A_0, and so on. The half-life of a particular radioactive isotope is constant and its measurement assists in the identification of radioactive samples of unknown composition. This method can only be applied to isotopes whose disintegration rates change appreciably over reasonable counting periods. At the other end of the scale, the isotope must have a long enough half-life to allow some measurements to be made before it all disintegrates. Measured half-lives range from about 10^{-14} years (^{212}Po) to about 10^{17} years (^{209}Bi) which represents a factor of 10^{31}. To determine extremely short and extremely long half-lives, more elaborate means must be used.

Until quite recently the unit of radioactivity was the curie (Ci), along with its various submultiples. The curie was originally related to the activity of one gram of radium but the definition was later standardized as 3.7×10^{10} nuclear disintegrations (dis) per second, which is almost the same: 1 Ci = 3.7×10^{10}dis/s or 2.22×10^{12} dis/min.

A disintegration usually involves the emission of one or more charged particles (α or β).

These may be accompanied, though not always, by one or more gamma emissions. Some nuclides emit only X- or gamma radiation.

The SI unit of activity is the becquerel (Bq) which is defined as 1 nuclear disintegration per second. Compared with the curie the becquerel is a very small unit. In practice it is often convenient to adopt the usual multiplying prefixes, for example: 1 becquerel (Bq) = 1 dis/s.

For simplicity, in this text only Bq, MBq (10^6 Bq) and TBq (10^{12} Bq) have been used. The relationship between the old unit and the SI unit is illustrated as follows:

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$$

Similarly

$$1 \text{ Bq} \approx 2.7 \times 10^{-11} \text{ Ci}$$

The Nuclide Chart

A vast amount of information has been collected regarding the behaviour of stable and unstable nuclei. This information has been published in a form which enables the characteristics of any nucleus to be read off immediately. The compilation is known as the nuclide chart.

In this chart, each nuclide occupies a square and relevant information regarding the nuclide is printed inside the square. Stable, naturally radioactive and artificial nuclides are differentiated by the use of different colours or shading of the squares. In each case the symbol and mass number are shown as well as the natural abundance of the isotope, if it is stable. For radioactive isotopes the half-life, the mode or modes of decay, and the energies of the emitted particles or gamma rays are shown. All the nuclides on the same horizontal line have the same atomic number while all nuclides with the same mass number lie on a 45° diagonal line, running from upper left to lower right.

The nuclide chart can be used to obtain rapid information on the products of various nuclear reactions. For instance, a (n, γ) reaction on sodium-23 (^{23}Na) produces sodium-24 (^{24}Na). ^{24}Na decays with a half-life of 15.0 h by emitting β^--particles of energy 1.39 MeV and γ-rays of 2.75 MeV and 1.37 MeV. The nucleus resulting from the decay of ^{24}Na is magnesium-24 (^{24}Mg) which is stable. It is obvious that, the nuclide chart is an extremely valuable source of information on the properties of both stable and unstable nuclides.

Interaction of Radiation with Matter

1. Charged particles

Alpha and beta particles lose energy mainly through interactions with atomic electrons in the absorbing medium. The energy transferred to the electrons causes them either to be excited to a higher energy level (excitation) or separated entirely from the parent atom (ionization). Another important effect is that when charged particles are slowed down very rapidly they emit energy in the form of X-rays. This is known as bremsstrahlung (braking radiation) and is only of practical importance in the case of beta radiation.

2. X- and γ-radiations

X- and γ-radiations interact with matter through a variety of alternative mechanisms, the three most important of which are the photoelectric effect, Compton scattering and pair-production. In the photoelectric effect all the energy of an X- or γ-photon is transferred to an atomic electron which is ejected from its parent atom. The photon is, in this case, completely absorbed. On the other hand Compton scattering occurs when only part of the energy of the photon is transferred to an atomic electron. The photon is therefore scattered with a reduced energy.

In the intense electric field close to a charged particle, usually a nucleus, an energetic γ-photon may be converted into a positron-electron pair. This is pair-production and the two particles share the available energy. Thus all three interactions result in the photon energy being transferred to atomic electrons which subsequently lose energy.

3. Neutrons

Neutrons are uncharged and cannot cause ionization directly. As with γ-radiation, neutrons ultimately transfer their energy to charged particles. In addition a neutron may be captured by a nucleus usually resulting in γ-emission.

Penetrating powers of nuclear radiations

The alpha particle is a massive particle (by nuclear standards) and travels relatively slowly through matter. It thus has a high chance of interacting with atoms along its path and it will give up some of its energy during each of these interactions. As a consequence, alpha particles lose their energy very rapidly and only travel very short distances in dense media.

Beta particles are very much smaller than alpha particles and travel much faster. Thus they undergo fewer interactions per unit length of track and so give up their energy more slowly than alpha particles. This means that beta particles travel further in dense media than alphas.

Gamma radiation loses its energy mainly by interacting with atomic electrons. It travels very large distances in dense media and is very difficult to be absorbed completely.

Neutrons give up their energy through a variety of interactions, the relative importance of which are very dependent on the neutron energy. For this reason it is common practice to divide neutrons into at least three energy groups: fast, intermediate and thermal. Neutrons are very penetrating and will travel large distances in dense media.

New Words

1. statistical [stə'tistikəl] *a.* of or shown by statistics 统计的，统计学的
2. predict [pri'dikt] *v.* say in advance that sth will happen, forecast 预言，预示，预报
3. exponential [ˌekspəu'nenʃəl] *n.*, *a.* expressed in terms of a designated power of e, the base of natural logarithms [数] 指数（的），幂（的）; exponentially *ad.*
4. curie (Ci) ['kjuəri] *n.* 居里
5. submultiple ['sʌb'mʌltipl] *n.* 约数，因数
6. initial [i'niʃəl] *a.* of or at the beginning, first 最初的，开始的，原始的，字首的
7. elaborate [i'læbərət] *a.* very detailed and complicated, carefully prepared and finished 精心制作的，详尽阐述的
8. definition [ˌdefi'niʃən] *n.* statement that gives the exact meaning (of words, etc.) 定义，解说，精确度，清晰度