群馬大学

’12

受験 番号	

後期日程

医学部医学科小論文問題

注　意　事　項

1. 試験開始の合図があるまで問題冊子を開いてはいけません。
2. この問題冊子のページ数は 11 ページです。問題冊子，答案用紙及び下書き用紙に落丁，乱丁，印刷不鮮明などの箇所がある場合は申し出てください。
3. 解答は指定の答案用紙に記入してください。
   - (1) 文字はわかりやすく，横書きで，はっきりと記入してください。
   - (2) 解答の字数に制限がある場合には，それを守ってください。
   - (3) 訂正，挿入の語句は余白に記入してください。
   - (4) ローマ字，数字を使用するときは，ます目にとらわれなくてもかまいません。
4. 試験時間は 90 分です。
5. 答案用紙は持ち帰ってはいけません。
6. 問題冊子と下書き用紙は持ち帰ってください。

◇M27(370—181)

次の文章を読んで，設問A～Jに答えなさい。文末に，＊印のついた単語の訳注があります。

In 1895, the German physicist Wilhelm Conrad Röntgen 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, Röntgen asked Rudolf Albert von Kölliker, a prominent Swiss professor of anatomy*, to put his hand in the beam and so produced the first publicly taken 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 location. 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 1896, Leopold Freund, an Austrian surgeon, demonstrated before the Vienna* Medical Society the disappearance of a hairy mole* following treatment with x-rays. Antoine-Henri Becquerel discovered radioactivity emitted by uranium* compounds in 1896, and two years later, Pierre and Marie Curie isolated the radioactive elements polonium* and radium*. Within a few years, radium was used for the treatment of cancer.

The first recorded biologic effect of radiation was due to Becquerel, who inadvertently* left a radium container in his vest pocket. He subsequently described the skin erythema* that appeared two weeks later and the ulceration* that developed and required several weeks to heal. It is said that Pierre Curie repeated this experience in 1901 by deliberately producing a radium "burn" on his own forearm*. From these early beginnings, at the turn of the century, the study of radiobiology* began.

The absorption of energy from radiation in biologic material may lead to excitation* or to ionization*. The raising of an electron in an atom or molecule to a higher energy level without actual ejection of the electron is called excitation. If the radiation has sufficient energy to eject one or more orbital* electrons from the atom or molecule, the process is called ionization, and that radiation is said to be ionizing radiation. The important characteristic of ionizing radiation is the localized release of large amounts of energy. The energy dissipated* per ionizing event is about 33 eV, which is more than enough to break a strong chemical bond; for example, the energy associated with a C=C bond is 4.9 eV. For convenience, it is usual to classify ionizing radiations as either electromagnetic* or particulate*.

(A) Most experiments with biologic systems have involved x- or γ-rays, two forms of electromagnetic radiation. X- and γ-rays do not differ in nature or in properties; the designation* of x- or γ-rays reflects the ways they are produced. X-rays are produced extranuclearly; γ-rays are produced intranuclearly. In practical terms, this means that x-rays are produced in an electrical device that accelerates electrons to high energy and then stops them abruptly in a target, usually made of tungsten or gold. Part of the kinetic energy* (the energy of motion) of the electrons is converted to x-rays. On the other hand, γ-rays are emitted by radioactive isotopes*; they represent excess energy that is given off as the unstable nucleus breaks up and decays in its efforts to reach a stable form. Natural background radiation from rocks in the earth also includes γ-rays. Everything that is stated about x-rays in this chapter applies equally well to γ-rays.

X-rays may be considered from (B) two different standpoints. First, they may be thought of as waves of electrical and magnetic energy. The magnetic and electrical fields, in planes at right angles to each other, vary with time, so that the wave moves forward in much the same way as ripples* move over the surface of a pond if a stone is dropped into the water. The wave moves with a velocity, c, which in a vacuum has a value of 3×10^{10} cm/s. The distance between successive peaks of the wave, λ, is known as the wavelength. The number of waves passing a fixed point per second is the frequency, ν. The product of frequency times wavelength gives the velocity of the wave; that is, $\lambda\nu=c$.

A helpful, if trivial, analogy is to liken the wavelength to the length of a person's stride when walking; the number of strides per minute is the frequency. The product of the length of stride times the number of strides per minute gives the speed, or velocity, of the walker.

Like x-rays, radio waves, radar*, radiant heat*, and visible light are forms of electromagnetic radiation. They all have the same velocity, c, but they have different wavelengths and therefore different frequencies. To extend the previous analogy, different radiations may be likened to a group of people, some tall, some short, walking together at the same speed. The tall walkers take long measured strides but make few strides per minute; to keep up, the short walkers compensate for the shortness of their strides by increasing the frequencies of their strides. A radio wave may have a distance between successive peaks (i.e., wavelength) of 300 m; for a wave of visible light, the corresponding distance is about 5×10^{-5} cm. The wavelength for x-rays may be 10^{-8} cm. X- and γ-rays, then, occupy the short-wavelength end of the electromagnetic spectrum.

Alternatively, x-rays may be thought of as streams of photons*, or "packets" of energy. Each energy packet contains an amount of energy equal to $h\nu$, where h is known as Planck's constant and ν is the frequency. If a radiation has a long wavelength, it has a small frequency, and so the energy per photon is small. Conversely, if a given radiation has a short wavelength, the frequency is large and the energy per photon is large. There is a simple numeric relationship between the photon energy, E, (in kiloelectron volts, keV*) and the wavelength, λ, (in angstroms, Å*):

(C) $$\underline{\lambda\ (\text{Å})=12.4/E\ (\text{keV})}$$

The concept of x-rays being composed of photons is very important in radiobiology. If x-rays are absorbed in living material, energy is deposited in the tissues and cells. This energy is deposited unevenly in discrete packets. The energy in a beam of x-rays is quantized* into large individual packets, each of which is big enough to break a chemical bond and initiate the chain of events that culminates in* a biologic change. The critical difference between nonionizing and (D) ionizing* radiations is the size of the individual packets of energy, not the total energy involved. A simple calculation illustrates this point. It is shown that a total-body dose of about 4 Gy* of x-rays given to a human is lethal in about half of the individuals exposed. This dose represents an absorption of energy of only about 280 J, assuming the person to be a "standard man" weighing 70 kg. The smallness of the amount of energy involved can be illustrated in many ways. Converted to heat, it would represent a temperature rise of 0. 002 ℃, which would do no harm at all; the same amount of energy in the form of heat is absorbed in drinking one sip of warm coffee. Alternatively, the energy inherent in a lethal dose of x-rays may be compared with mechanical energy or work: It would correspond to the work done in lifting a person weighting 70 kg about $\boxed{\text{E}}$ cm from the ground.

Energy in the form of heat or mechanical energy is absorbed uniformly and evenly, and much greater quantities of energy in these forms are required to produce damage in living things. The potency of x-rays, then, is a function not so much of the total energy absorbed as of the size of the individual energy packets. In their biologic effects, electromagnetic radiations are usually considered ionizing if they have a photon energy in excess of 124 eV, which corresponds to a wavelength shorter than about 10^{-6} cm.

Radiation may be classified as directly or indirectly ionizing. All of the charged particles such as electrons, protons, and α-particles are directly ionizing; that is, provided the individual particles have sufficient kinetic energy, they can disrupt the atomic structure of the absorber through which they pass directly and produce chemical and biologic changes. Electromagnetic radiations (x- and γ-rays) are indirectly ionizing (F). They do not produce chemical and biologic damage themselves, but when they are absorbed in the material through which they pass, they give up their energy to produce fast-moving charged particles that in turn are able to produce damage.

The process by which x-ray photons are absorbed depends on the energy of the photons concerned and the chemical composition of the absorbing material. At high energies, characteristic of a cobalt-60* unit or a linear accelerator used for radiotherapy*, the Compton process* (G) dominates. In this process, the photon interacts with what is usually referred to as a "free" electron, an electron whose binding energy is negligibly small compared with the photon energy. Part of the energy of the photon is given to the electron as kinetic energy; the photon, with whatever energy remains, continues on its way, deflected* from its original path Figure 1 in page 9. In place of the incident photon, there is a fast electron and a photon of reduced energy, which may go on to take part in further interactions. In any given case, the photon may lose a little energy or a lot; in fact, the fraction lost may vary from 0 to 80 %. In practice, if an x-ray beam is absorbed by tissue, a vast number of photons interact with a vast number of atoms, and on a statistical* basis, all possible energy losses occur. The net result is the production of a large number of fast electrons, many of which can ionize other atoms of the absorber, break vital chemical bonds, and initiate the change of events that ultimately is expressed as biologic damage.

For photon energies characteristic of diagnostic radiology, both Compton and photoelectric absorption processes* occur, the former dominating at the higher end of the energy range and the latter being most important at lower energies. In the photoelectric absorption process, the x-ray photon interacts with a bound electron in, for example, the K, L, or M shell of an atom of the absorbing material. The photon gives up all of its energy to the electron; some is used to overcome the binding energy of the electron and release it from its orbit; the remainder is given to the electron as kinetic energy of motion. The kinetic energy (KE) of the ejected electron is therefore given by the expression

$$\mathrm{KE} = h\nu - E_B$$

in which $h\nu$ is the energy of the incident photon and E_B is the binding energy of the electron in its orbit. The vacancy left in the atomic shell as a result of the ejection of an electron then must be filled by another electron falling in from an outer shell of the same atom or by a conduction electron from outside the atom. The movement of an electron from one shell to another represents a change of energy states. Because the electron is negatively charged, its movement from a loosely bound to a tightly bound shell represents a decrease of potential energy; this energy change is balanced by the emission of a photon of "characteristic" electromagnetic radiation. In soft tissue, this characteristic radiation has a low energy, typically 0.5 kV, and is of little biologic consequence.

The Compton and photoelectric absorption processes differ in several respects that are vital in (I) the application of x-rays to diagnosis* and therapy*. The mass absorption coefficient* for the Compton process is independent of the atomic number of the absorbing material. By contrast, the mass absorption coefficient for photoelectric absorption process varies rapidly with atomic number (Z) and is, in fact, about proportional to Z^3.

For diagnostic radiology, photons are used in the energy range in which photoelectric absorption process is as important as the Compton process. Because the mass absorption coefficient varies critically with Z, the x-rays are absorbed to a greater extent by bone because bone contains elements with high atomic numbers, such as calcium. This differential absorption in materials of high Z is one reason for the familiar appearance of the radiograph. For radiotherapy, however, high-energy photons in the megavoltage range are preferred because the Compton process is overwhelmingly* important. As a consequence, the absorbed dose is about the same in soft tissue, muscle, and bone, so that differential absorption in bone, which posed a problem in the early days when lower-energy photons were used for therapy, is avoided.

Although the differences among the various absorption processes are of practical importance in radiology, the consequences for radiobiology are minimal. Whether the absorption process is the photoelectric or the Compton process, much of the energy of the absorbed photon is converted to the kinetic energy of a fast electron.

Eric J. Hall and Amato J. Giaccia 著　"Radiobiology for the radiologist" Lippincott Williams & Wilkins 社より，一部改変

*訳　注

emit：放つ
anatomy：解剖学
radiograph：エックス線写真
Lancet：学術雑誌の名称
backbone：背骨
paralyzed：まひした
diagnostic radiology：診断放射線学
therapeutically：治療法として
Vienna：ウィーン
hairy mole：有毛母斑(あざの一種)
uranium：ウラン
polonium：ポロニウム
radium：ラジウム
inadvertently：不注意にも
erythema：紅斑(皮膚が炎症をおこして赤くなった状態)
ulceration：かいよう(皮膚表面または粘膜表面上の組織欠損による病変)形成

forearm：前腕
radiobiology：放射線生物学
excitation：励起
ionization：イオン化
orbital：軌道の
dissipate：散らす
electromagnetic：電磁気の
particulate：微粒子からなる
designation：名称
kinetic energy：運動エネルギー
radioactive isotope：放射性同位体
ripple：さざ波
radar：レーダー
radiant heat：放射熱
photon：光子
kiloelectron volt, keV：エネルギーの単位。 1 keVは電子を1000 Vで加速した時に得られるエネルギー値
angstrome, Å：長さの単位。 1 Åは 10^{-8} cm
quantize：量子化する
culminate in：結果的に・・・になる
ionize：イオン化する
Gy：グレイ，放射線の吸収線量の単位
cobalt-60：コバルト60
radiotherapy：放射線治療
Compton process：コンプトン過程
deflect：それる，ゆがむ
statistical：統計上の
photoelectric absorption process：光電吸収過程
diagnosis：診断
therapy：治療
mass absorption coefficient：質量吸収係数
overwhelmingly：圧倒的に

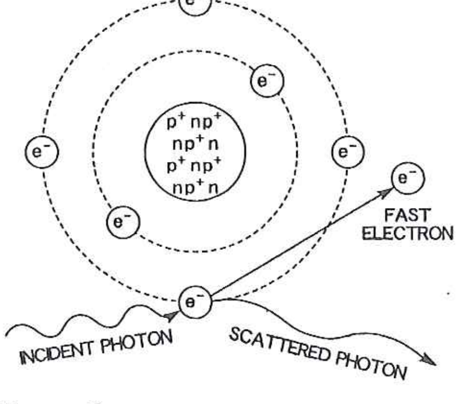

Figure 1

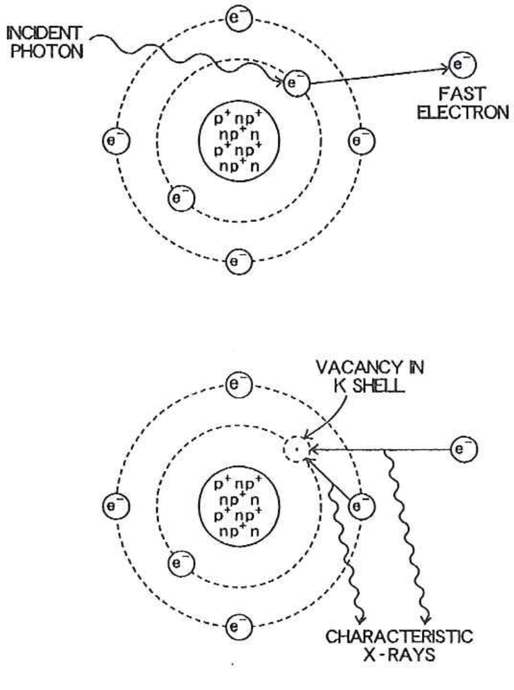

Figure 2

設　問

A．下線部(A)の記述に関して，本文中で述べられているエックス線とガンマ線の発生様式の違いを，答案用紙 $\boxed{1-1}$ のA欄に日本語100字以内（句読点を含めて）で説明しなさい。

B．下線部(B)の two different standpoints について，答案用紙 $\boxed{1-1}$ のB欄に日本語50字以内（句読点を含めて）で説明しなさい。

C．下線部(C)の式を用いて，波長が0.1Åのエックス線がもつ光子のエネルギーを求め，単位も含めて答案用紙 $\boxed{1-1}$ のC欄に記入しなさい。

D．下線部(D)の ionizing radiation であるためには，最低どのくらいの光子エネルギーが必要であると本文中で述べられているか，数値を単位も含めて答案用紙 $\boxed{1-1}$ のD欄に記入しなさい。

E．空欄 $\boxed{\quad E \quad}$ に当てはまる数値を計算し，答案用紙 $\boxed{1-1}$ のE欄に計算式とあわせて記入しなさい。ただし，重力加速度を $9.8\ \mathrm{m/s^2}$ とする。

F．下線部(F) indirectly ionizing とはどのようなことか，答案用紙 $\boxed{1-2}$ のF欄に日本語100字以内（句読点を含めて）で説明しなさい。

G．下線部(G) Compton process とはどのようなものか，答案用紙 $\boxed{1-2}$ のG欄に日本語50字以内（句読点を含めて）で説明しなさい。

H．9ページの Figure 1 の FAST ELECTRON はどのような作用を及ぼし得ると本文中で述べられているか，答案用紙 $\boxed{1-2}$ のH欄に日本語50字以内（句読点を含めて）で説明しなさい。

I．下線部(I)の記述に関して，放射線診断に用いられるエックス線と放射線治療に用いられるエックス線ではエネルギーの点で違いがある。その相違について本文中ではどのように述べられているか，エックス線を使い分ける理由を含めて，答案用紙 $\boxed{1-2}$ のＩ欄に日本語110字以内（句読点を含めて）で説明しなさい。

J．9ページのFigure 2は本文中のある部分を説明するFigureである。Figure 2に以下の英文表題をつける場合，空欄 $\boxed{\text{J}}$ を埋めるのに適切な語を本文中から選び，答案用紙 $\boxed{1-2}$ のＪ欄に記入しなさい。

Absorption of a photon of x- or γ-rays by the $\boxed{\text{J}}$ process.