UNIT ONE

Summary of the Atom and the Nucleus

1-Over View

a-Target Population

The students of third class in the environmental and pollution department in Basrah technical college in radiation pollution subject.

b-Rationale

The information about nucleus and atom structures are very important to study and understanding the radiation pollution

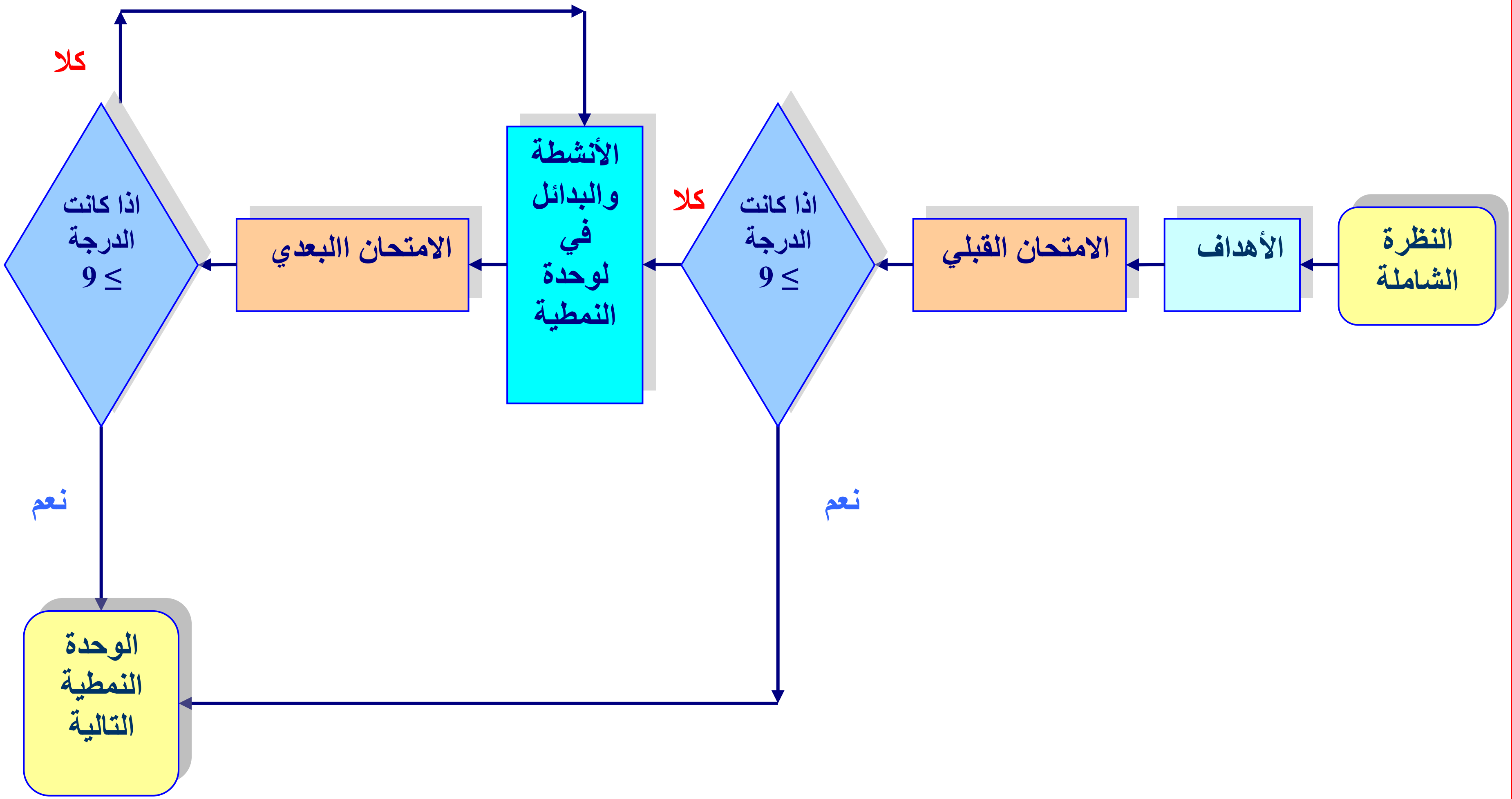
c-Central Ideas

1-the atomic number
2-the mass number
3-nucleus binding energy
4-size and mass of nucleus

d-Objectives

After going through this unit, you will be able to
1-describe the structure of the atom
2- describe the structure of the nucleus
3- calculate the binding energy per nucleon based on semi-empirical mass formula
4-calculat the size and mass of nucleus

E-Streamline scheme



2-Pre-Test

3-Unit Presentation

Summary of the Atom and the Nucleus

1-1: The Nucleus

*Atoms consist of a nucleus and an electron shell.

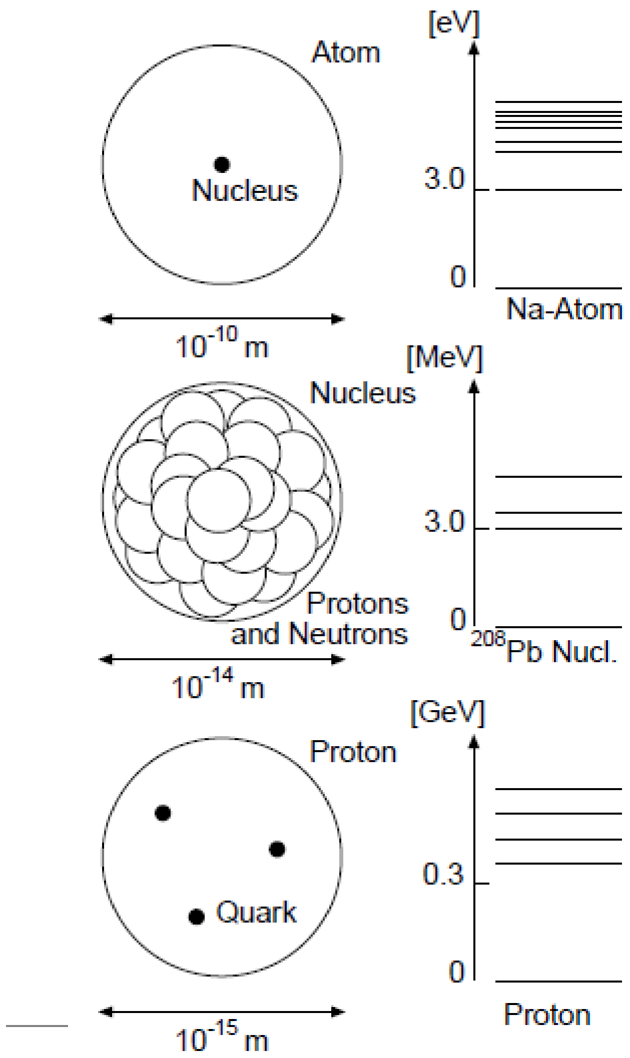
*A nucleus consists of nucleons: protons and neutrons. As the mass of a nucleon is about 2000 times the mass of an electron the nucleus carries practically all the mass of an atom.

*A nucleon consists of 3 quarks .

*1 fm (femtometer, Fermi) = 10^{-15} m

is the typical length scale of nuclear physics

*1 MeV (Mega-electron volt) =1.602 10^{-13} J is the typical energy scale of nuclear physics



1-2: Nuclides

*A nuclides is a specific combination of a number of protons and neutrons.
* $^{A}_{Z}X_{N}$ is the complete symbol for a nuclide, but the information is redundant and ^{A}X is sufficient.
*X is the chemical symbol of the element
*Z is the atomic number, giving the number of protons in the nucleus (and electrons in the shell)
*N is the number of neutrons
*A = Z + N is the mass number
Nuclides with the same atomic number Z are called isotopes, same A isobars, same N isotones .

1-3: The Atomic Mass Unit

*The mass reference is not the proton or the hydrogen atom, but the isotope ^{12}C . Carbon and it's many compounds are always present in a spectrometer and are well suited for a mass calibration.
*An atomic mass unit (amu) is therefore defined as 1/12 of the mass of the ^{12}C nuclide:

$$1u = \frac{1}{12} M_{^{12}C} = 931.481 MeV/c^2 = 1.66043 \cdot 10^{-27} kg$$

*For comparison, the proton mass is 938.272 MeV/c^2

1-4: The Size and the Mass of the Nucleus:

The radii of most nuclei is given by the equation:

$$R = R_0 \, A^{1/3}$$

R: radius of the nucleus, A: mass number, $R_0 = 1.2 \times 10^{-15}$ m

The mass of a nucleus is given by:

$$m = A \, u$$

$u = 1.66\ldots \times 10^{-27}$ kg

1-5: The Nucleus Binding Energy

*The binding energy B of a nucleus is the difference in mass energy between a nucleus $^{A}_{Z}X_{N}$ and it's constituent Z protons and N neutrons:

$$B = (Zm_p + Nm_n - [m(^{A}X) - Zm_e])c^2$$

where

$m(^{A}X)$ is the atomic mass of ^{A}X . The binding energy is determined from atomic masses, since they can be measured much more precisely than nuclear masses.

*Grouping the Z proton and electron masses into Z neutral hydrogen atoms, we can re-write this as:

$$B = (Zm(^{1}H) + Nm_n - m(^{A}X))c^2$$

*With the masses generally given in atomic mass units, it is convenient to include the conversion factor in c, thus c^2= 931.481 MeV/u.

4-Post-Test

5-Keys of Answers

References

UNIT TWO

Radioactivity and Radiation

1-Over View

a-Target Population

The students of third class in the environmental and pollution department in Basrah technical college in radiation pollution subject.

b-Rationale

because of the importance of radiation pollution the understanding of the radioactivity and radiation is very important to study the radiation pollution

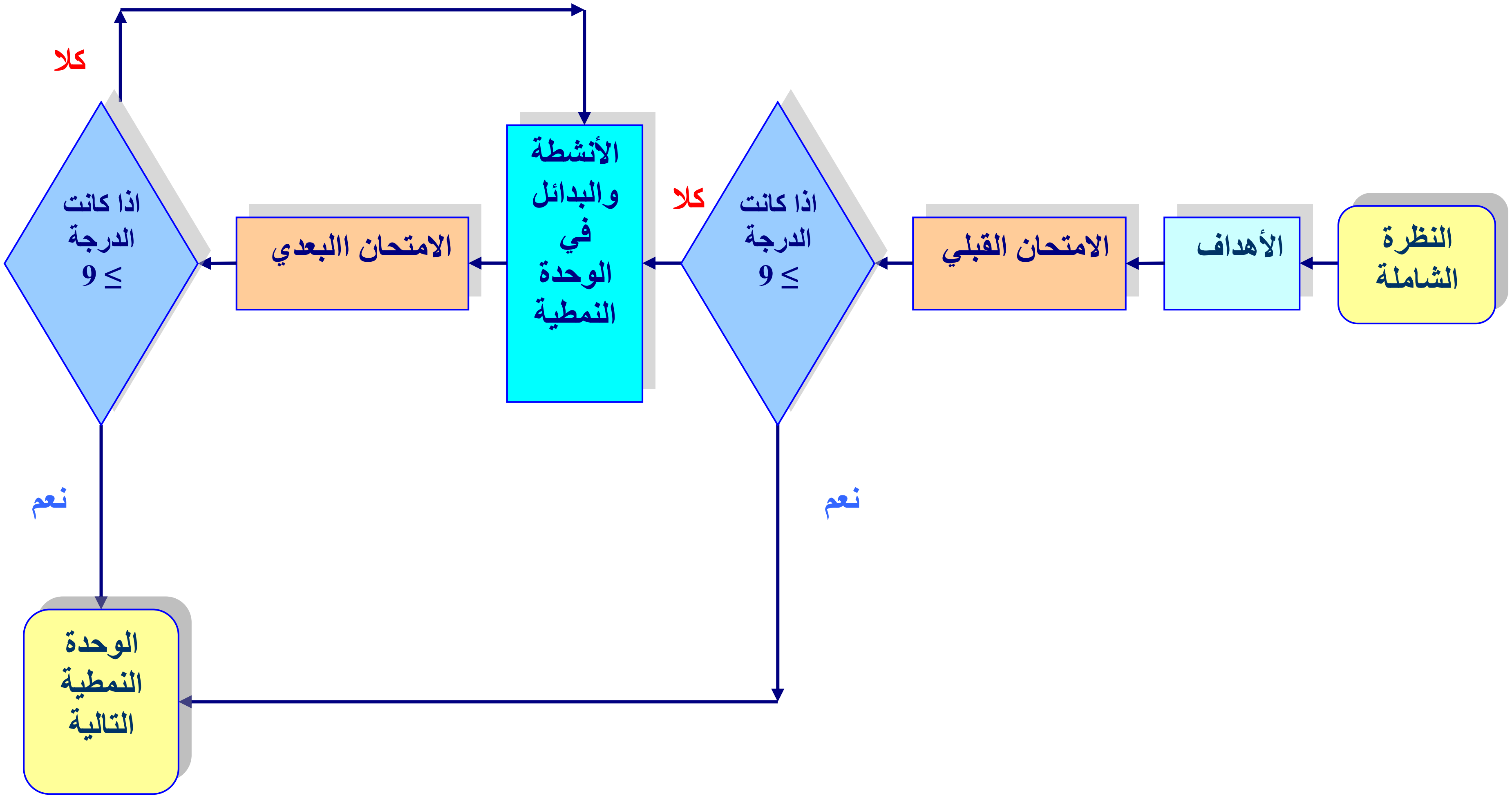
c-Central Ideas

1- the radiation series
2-the types of radiation
3- The radioactive decay law
4- Nuclear Stability

d-Objectives

After going through this unit, you will be able to:
1-understanding the laws and figure for stabilities for the nucleus
2-understanding the all manner which produced the types of radiation
3-knwing the law of radioactivity and half-life and mean –life
4-knwing the types and energies of all radiation

E-Streamline scheme

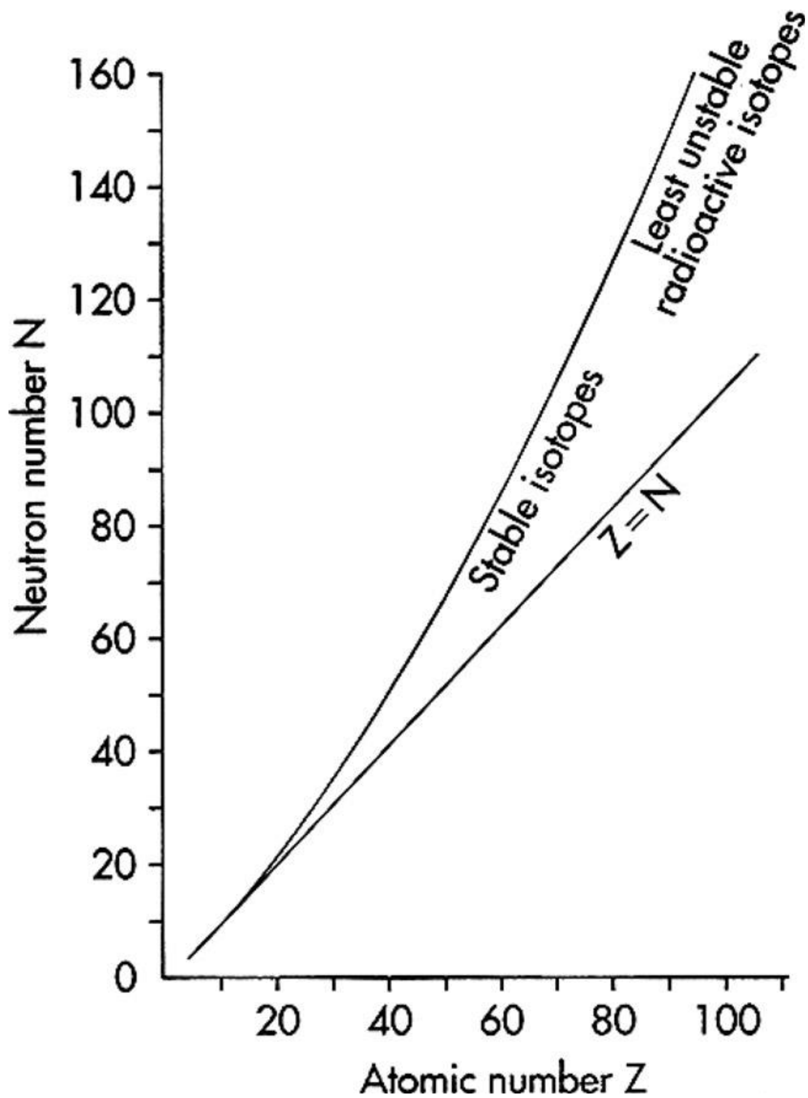


2-Pre-Test
3-Unit Presentation

2-1: Nuclear Stability

The nuclei of many atoms are stable. In general, it is these atoms that constitute ordinary matter. In stable nuclei of lighter atoms, the number of neutrons is about equal to the number of protons. A high level of symmetry exists in the placement of protons and neutrons into nuclear energy levels similar to the electron shells constituting the extra nuclear structure of the atom. The assignment of nucleons to energy levels in the nucleus is referred to as the "shell model" of the nucleus. For heavier stable atoms, the number of neutrons increases faster than the number of protons, suggesting that the higher energy levels are spaced more closely for neutrons than for protons. The number of neutrons (i.e., the neutron number) in nuclei of stable atoms is plotted in Figure (2-1) as a function of the number of protons (i.e., the atomic number). Above Z = 83, no stable forms of the elements exist, and the plot depicts the neutron/proton (N/Z) ratio for the least unstable forms of the elements (i.e., isotopes that exist for relatively long periods before changing).

Nuclei that have an imbalance in the N/Z ratio are positioned away from the stability curve depicted in Figure(2-1). These unstable nuclei tend to undergo changes within the nucleus to achieve more stable configurations of neutrons and protons. The changes are accompanied by the emission of particles and electromagnetic radiation (photons) from the nucleus, together with the release of substantial amounts of energy related to an increase in binding energy of the nucleons in their final nuclear configuration. These changes are referred to as *radioactive decay* of the nucleus, and the process is described as *radioactivity*. If the number of protons is different between the initial and final nuclear configurations, Z is changed and the nucleus is transmuted from one elemental form to another. The various processes of radioactive decay are summarized in Table (2-1).



FIGURE(2-1): Number of neutrons (N) in stable (or least unstable) nuclei as a function of the number of protons (atomic number Z).

2-2: Radioactive Decay

Radioactivity can be described mathematically without reference to the specific mode of decay of a sample of radioactive atoms. The rate of decay (the number of atoms decaying per unit time) is directly proportional to the number of radioactive atoms N present in the sample:

$$\Delta N / \Delta t = -\lambda N \qquad \text{………………………} \quad \textbf{(2-1)}$$

where $\Delta N / \Delta t$ is the rate of decay. The constant λ is the *decay constant* of the particular species of atoms in the sample, and the negative sign reveals that the number of radioactive atoms in the sample is diminishing as the sample decays. The decay constant can be expressed as $-(\Delta N / \Delta t) / N$ revealing that it represents the fractional rate of decay of the atoms. The value of λ is characteristic of the type of atoms in the sample and changes from one nuclide to the next. Units of λ are $(\text{time})^{-1}$. Larger values of λ characterize more unstable nuclides that decay more rapidly.

The rate of decay of a sample of atoms is termed the *activity* A of the sample (i.e., $A = \Delta N / \Delta t$). A rate of decay of 1 atom per second is termed an *activity* of *1 becquerel (Bq)*. That is,

1Bq = 1 disintegration per second (dps)

TABLE(2-1): Radioactive Decay Processes

Type of Decay	*A′*	*Z′*	*N′*	*Comments*
Negatron ($\beta-$)	A	$Z+1$	$N-1$	$E_{\beta\text{-mean}} \cong \frac{E_{max}}{3}$
Positron (β^+)	A	$Z-1$	$N+1$	$E_{\beta\text{-mean}} \cong \frac{E_{max}}{3}$
Electron capture	A	$Z-1$	$N+1$	Characteristic + auger electrons
Isomeric transition gamma (γ) emission	A	Z	N	Metastable if $T_{1/2} > 10^{-6}$ sec
Internal conversion (IC)	A	Z	N	IC electrons: characteristic + auger electrons
Alpha (α)	$A-4$	$Z-2$	$N-2$	

A common unit of activity is the megabecquerel (MBq), where

1 MBq = 10^6 dps.

An earlier unit of activity, the curie (Ci) is defined as

1Ci = 3.7×10^{10} dps

Multiples of the curie are the picocurie (10^{-12} Ci), nanocurie (10^{-9} Ci), microcurie (10^{-6} Ci), millicurie (10^{-3} Ci), kilocurie (10^3 Ci), and megacurie (10^6 Ci). The becquerel and the curie are related by 1 Bq = 1 dps = 2.7×10^{-11} Ci. The activity of a radioactive sample per unit mass (e.g., MBq/mg) is known as the *specific activity* of the sample.

Example (2-1)

A : ${}^{60}_{27}Co$ has a decay constant of 0.131 y−1. Find the activity in MBq of a sample containing 10^{15} atoms.

$$A = \lambda N = \frac{(0.131\ y^{-1})(10^{15}\ atoms)}{31.54\times 10^{6}\ \frac{sec}{y}}$$

= 4.2×10^6 atoms/s = 4.2×10^6 Bq

= 4.2 MBq

B. What is the specific activity of the sample in MBq/g? The number of atomic mass units of ^{60}Co is 59.9338.

$$Sample\ mass = \frac{10^{15} \times 59.9338\ amu}{6.023 \times 10^{23}\ \frac{amu}{g}}$$

= 9.95×10^{-8} g

Specific activity = (4.2 MBq)/(9.95×10^{-8} g)

= 42×10^{6} MBq/g

2-3: The radioactive decay law

Through the process of mathematical integration of equation (2-1), an expression for the number N of radioactive atoms remaining in a sample after a time t has elapsed can be shown to equal:

$$N = N_0\ e^{-\lambda t} \qquad \text{………… (2-2)}$$

where N_0 is the number of atoms present at time $t = 0$. This equation(2-2) called the ***Law of Radioactive Decay*** . The number of radioactive atoms N^* that have decayed after time t is $N_0 - N$ or

$$N^* = N_0\ \ (1 - e^{-\lambda t}) \qquad \text{…………….(2-3)}$$

The probability that a particular atom will not decay during time t is N/N_0 or $e^{-\lambda t}$, and the probability that the atom will decay during time t is $1 - N/N_0$ or $1 - e^{-\lambda t}$. For small values of λt, the probability of decay

$(1 - e^{-\lambda t})$ can be approximated as λt or, expressed as the probability of decay per unit time, p(decay per unit time) ~ λ.

2-4: The sample activity

$A(t) = dN(t) / dt$

$= \lambda N_0 e^{-\lambda t} = \lambda N(t)$ ....**(2-4)**

$A_0 = \lambda N_0$

$A = A_0 \; e^{-\lambda t}$ ……………….. **(2-5)**

where A is the activity of the sample at time t, and A_0 is the activity at time $t = 0$.

2-5: The half-life and mean-life

The physical half-life $T_{1/2}$ of a radioactive sample is the time required for half of the atoms in the sample to decay. The half-life is related to the decay constant of the sample through the expression:

$$T_{1/2} = (\ln 2)/\lambda = 0.693/\lambda$$

where ln 2 is the natural (naperian) logarithm of 2 (logarithm to the base *e*), and 0.693 is the value of this logarithm. The average life t_{avg} of a radioactive sample, sometimes referred to as the mean life, is the average time for decay of atoms in the sample. The average life is

$$t_{avg} = 1/\lambda = 1.44\,(T_{1/2})$$

Example 2-2

What are the half-life and average life of the sample of $^{60}_{27}Co$ described in Example 2-1?

$T_{1/2} = 0.693/\lambda = 0.693/0.131\ y^{-1}$

$= 5.3$ y

$T_{avg} = 1.44(T_{1/2}) = 1.44(5.3$ y$)$

$= 7.63$ y

Example 2-3

The physical half-life of ^{131}I is 8.0 days.

A.: A sample of ^{131}I has a mass of 100 μg. How many ^{131}I atoms are present in the sample when the number of amu for one atom is 131?

Number of atoms N = (Number of grams) (Number of amu /g) /(Number of amu/atom)

$= (100 \times 10^{-6} g)(6.02 \times 10^{23}\text{amu/g})/(131\ \text{amu/atom})$

$= 4.6 \times 10^{17}$ atoms

B: How many ^{131}I atoms remain after 20 days have elapsed?

$N = N_0\ e^{-(0.693\ t/T1/2)}$

$= (4.6 \times 10^{17}\ \text{atoms})\ e^{-(0.693/8\ d)(20\ d)}$

$= 8.1 \times 10^{16}$ atoms

C: What is the activity of the sample after 20 days?

$A = \lambda N$

$= (0.693/8.0 \text{ d})(1/86, 400 \text{ s/d})(8.1 \times 10^{16} \text{ atoms})$

$= 8.2 \times 10^{10}$ atoms/sec

$= 8.2 \times 10^{4}$ MBq

D: What is the specific activity of the ^{131}I sample?

SA $= 8.2 \times 10^{4}$ MBq/0.1mg

$= 8.2 \times 10^{5}$ MBq/mg

E: What activity should be ordered at 8 AM Monday to provide an activity of 8.2×10^{4} MBq at 8 AM on the following Friday?

Elapsed time = 4 days

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

$8.2 \times 10^{4} \text{ MBq} = N_0\, e^{-(0.693/8\text{d})(4\text{d})}$

$8.2 \times 10^{4} \text{ MBq} = N_0\,(0.7072)$

$N_0 = 11.6 \times 10^{4}$ MBq must be ordered

2-6: Types of Radioactive Decay

The process of radioactive decay often is described by a decay scheme in which energy is depicted on the vertical (y) axis and atomic number is shown on the horizontal (x) axis. A generic decay scheme is illustrated in Figure 2-2. The original nuclide (or "parent") is depicted as $^{A}_{Z}X$, and the product nuclide (or "progeny") is denoted as element P , Q, R, or S depending on the decay path. In the path from X to P , the nuclide gains stability by emitting an alpha (α) particle, two neutrons and two protons ejected from the nucleus as a single particle. In this case, the progeny nucleus has an atomic number of $Z - 2$ and a mass number of A−4 and is positioned at reduced elevation in the decay scheme to demonstrate that energy is released as the nucleus gains stability through radioactive decay. The released energy is referred to as the *transition energy*. In the path from X to Q, the nucleus gains stability through the process in which a proton in the nucleus changes to a neutron. This process can be either positron decay or electron capture and yields an atomic number of Z –1 and an unchanged mass number *A*. The path from X to R represents negatron decay in which a neutron is transformed into a proton, leaving the progeny with an atomic number of $Z + 1$ and an unchanged mass number A. In the path from *R* to *S*, the constant *Z* and constant A signify that no change occurs in nuclear composition. This pathway is termed an isomeric transition between nuclear isomers and results only in the release of energy from the nucleus through the processes of gamma emission and internal conversion.

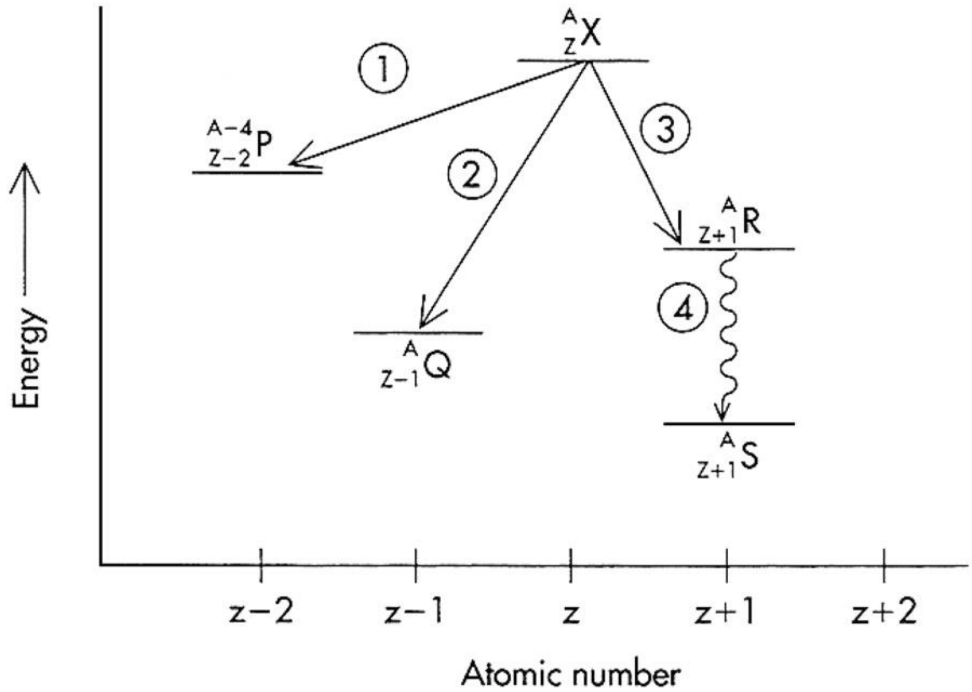


FIGURE 2-2: Symbolic radioactive decay scheme.

2-6-1: Alpha Decay

Alpha decay is a decay process in which greater nuclear stability is achieved by emission of 2 protons and 2 neutrons as a single alpha (α) particle (a nucleus of helium) from the nucleus. Alpha emission is confined to relatively heavy nuclei such as ^{226}Ra:

$$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$$

Where $^{4}_{2}He$ represents the alpha particle. The sum of mass numbers and the sum of atomic numbers after the transition equal the mass and atomic numbers of the parent before the transition. In α-decay, energy is released as kinetic energy of the α particle, and is sometimes followed by energy released during an isomeric transition resulting in emission of a γ ray or conversion electron. Alpha particles are always ejected with energy characteristic of the particular nuclear transition. in which the parent ^{226}Ra decays directly to the final energy state (ground state) of the progeny ^{222}Rn in 94% of all transitions. In 6% of the transitions, ^{226}Ra decays to an intermediate higher energy state of ^{222}Rn, which then decays to the ground state by isomeric transition. For each of the transition pathways, the transition energy between parent and ground state of the progeny is constant. In the example of ^{226}Ra, the transition energy is 4.78 MeV.

2-6-2: Beta Decay

Nuclei with an N/Z ratio that is above the line of stability tend to decay by a form of beta (β) decay known as negatron emission. In this mode of decay, a neutron is transformed into a proton, and the Z of the nucleus is increased by 1 with no change in A. In this manner, the N/Z ratio is reduced, and the product nucleus is nearer the line of stability. Simultaneously an electron (termed a negative beta particle or negatron) is ejected from the nucleus together with a neutral massless particle, termed a neutrino (actually an “antineutrino” in negatron decay), that carries away the remainder of the released energy that is not accounted for by the negatron. The neutrino (or antineutrino) seldom interacts with matter and is not important to applications of radioactivity in medicine.

The process of negatron emission may be written:

$$ {}_{0}^{1}n \rightarrow {}_{1}^{1}p + {}_{-1}^{0}e + \bar{\nu} $$

$$ \rightarrow {}_{1}^{1}p + {}_{-1}^{0}\beta + \bar{\nu} $$

Where ${}_{-1}^{0}e$ depicts the ejected negatron (negative beta particle) and ${}_{-1}^{0}\beta$ reflects the nuclear origin of the negatron. The symbol $\bar{\nu}$ represents the antineutrino. An example of negatron emission is beta decay of ^{60}Co:

$$ {}_{27}^{60}Co \rightarrow {}_{28}^{60}N + {}_{-1}^{0}\beta + \bar{\nu} + \text{ isomeric transition} $$

with the isomeric transition often accomplished by release of cascading gamma rays of 1.17 and 1.33 MeV. The transition energy for decay of ^{60}Co is 2.81 MeV. A discrete amount of energy is released when a negatron is emitted from the nucleus. This energy is depicted as the maximum energy E_{max} of the negatron. Negatrons, however, usually are emitted with some fraction of this energy, and the remainder is carried from the nucleus by the antineutrino. The mean energy of the negatron is $E_{max}/3$. An energy spectrum of 0.31 MeV E_{max} negatrons emitted from ^{60}Co is shown

in Figure 2–3. Negatron energy spectra are specific for each negatron transition in every nuclide by this mode of nuclear transformation.

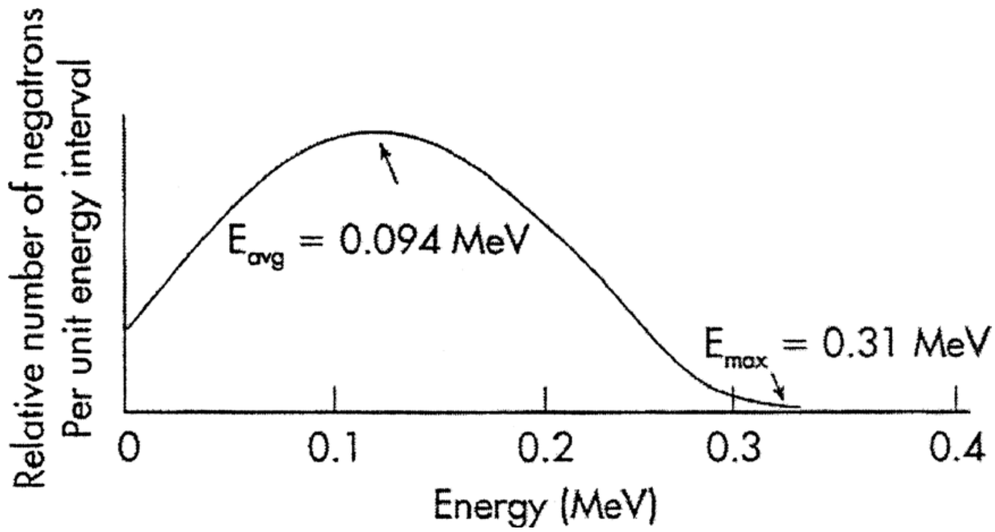


FIGURE 2-3: Energy spectrum of negatrons from ${}^{60}_{27}Co$.

Example 2-4

Determine the transition energy and the E_{max} of negatrons released during the decay of ${}^{60}_{27}Co$ (atomic mass 59.933814 amu) to ${}^{60}_{28}Ni$ (atomic mass 59.930787 amu).

$$\text{Transition:}\quad {}^{60}_{27}\text{Co}\left[+\,{}^{0}_{-1}\text{e}\right] \rightarrow {}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta + \bar{\nu} + \text{isomeric transmission}$$

where the ${}^{0}_{-1}e$ on the left side of the transition must be added from outside the atom to balance the additional positive nuclear charge of ^{60}Ni compared with ^{60}Co.

$$\begin{aligned} \text{Mass difference} &= \text{mass}\left({}^{60}_{27}\text{Co} + {}^{0}_{-1}e\right) - \text{mass}\left({}^{60}_{28}\text{Ni} + {}^{0}_{-1}\beta\right) \\ &= (59.933814 + 0.00055)\,\text{amu} - (59.930787 + 0.00055)\,\text{amu} \\ &= 0.003027\,\text{amu} \\ \text{Transition energy} &= (0.003027\,\text{amu})\,(931\,\text{MeV/amu}) \\ &= 2.81\,\text{MeV} \end{aligned}$$

The isomeric transition in ^{60}Co accounts for (1.17 + 1.33) = 2.50 MeV . Hence the negatron *E*max is 2.81 − 2.50 = 0.31 MeV.

Nuclei below the line of stability are unstable because they have too few neutrons for the number of protons in the nucleus. These nuclei tend to gain stability by a decay process in which a proton is transformed into a neutron, resulting in a unit decrease in *Z* with no change in *A*. One possibility for this transformation is positron decay:

$$\begin{aligned} {}^{1}_{1}p &\rightarrow {}^{1}_{0}\text{n} + {}^{0}_{+1}\text{e} + \nu \\ &\rightarrow {}^{1}_{0}\text{n} + {}^{0}_{+1}\beta + \nu \end{aligned}$$

Where ${}^{0}_{-1}\beta$ represents the nuclear origin of the emitted positive electron (positron). A representative positron transition is

$${}^{18}_{9}\text{F} \rightarrow {}^{18}_{8}\text{O} + {}^{0}_{+1}\beta + \nu$$

where ν represents the release of a neutrino, a noninteractive particle similar to an antineutrino except with opposite axial spin. In positron decay, the atomic mass of the decay products exceeds the atomic mass of the atom before decay. This difference in mass must be supplied by energy released during decay according to the relationship E = mc^2. The energy requirement is 1.02 MeV. Hence, nuclei with a transition energy less than 1.02 MeV cannot undergo positron decay. For nuclei with transition energy greater than 1.02 MeV, the energy in excess of 1.02 MeV is shared among the kinetic energy of the positron, the energy of the neutrino, and the energy released during isomeric transitions. Decay of ^{18}F is depicted in the margin, in which the vertical component of the positron decay pathway represents the 1.02 MeV of energy that is expressed as increased mass of the products of the decay process.

An alternate pathway to positron decay is electron capture, in which an electron from an extra nuclear shell, usually the K shell, is captured by the nucleus and combined with a proton to transform it into a neutron. The process is represented as

$$ {}^{1}_{1}p + {}^{0}_{1}\mathrm{e} \rightarrow {}^{0}_{1}\mathrm{n} + \nu $$

Electron capture does not yield a mass imbalance before and after the transformation. Hence, there is no transition energy prerequisite for electron capture. Low *N/Z* nuclei with transition energy less than 1.02 MeV can decay only by electron capture. Low *N/Z* nuclei with transition energy greater than 1.02 MeV can decay by both positron decay and electron capture. For these nuclei, the electron capture branching ratio describes the probability of electron capture, and (1-branching ratio) depicts the probability of positron decay. Usually, positron decay occurs more frequently than electron capture for nuclei that decay by either process. The branching ratio for electron capture of ^{18}F is 3%.

Example 2-5

Determine the transition energy and E_{max} of positrons released during the transformation of ${}^{18}_{9}F$ (atomic mass = 18.000937 amu) to ${}^{18}_{8}O$ (atomic mass = 17.999160 amu). There are no isomeric transitions in this decay process.

$$\text{Transition:} \quad {}^{18}_{9}\mathrm{F} \rightarrow {}^{18}_{8}\mathrm{O} + {}^{0}_{1}\beta + \nu + {}^{0}_{1}\mathrm{e}$$

where the ${}^{0}_{-1}e$ on the right side of the transition must be released from the atom to balance the reduced positive nuclear charge of ^{18}O compared with ^{18}F.

$$\begin{aligned}\text{Mass difference} &= \text{mass}\left({}^{18}_{9}\mathrm{F}\right) - \text{mass}\left({}^{18}_{8}\mathrm{O} + {}^{0}_{+1}\beta + {}^{0}_{+1}\mathrm{e}\right)\\ &= (18.000937)\,\text{amu} - (17.999160 + 2(0.00055)\,\text{amu}\\ &= 0.000677\,\text{amu}\\ \text{Energy available as } E_{max} &= (0.000677\,\text{amu})(931\,\text{MeV/amu})\\ &= 0.630\,\text{MeV}\end{aligned}$$

The energy equivalent to the mass of the ${}^{0}_{+1}\beta$ and ${}^{0}_{+1}e$ is 2(0.00055 amu) (931 MeV/amu) = 1.02 MeV. Hence the total transition energy is (0.63 + 1.02) MeV = 1.65 MeV.

2-6-3: Gamma Emission and Internal Conversion

Frequently during radioactive decay, a product nucleus is formed in an “excited” energy state above the ground energy level. Usually the excited state decays instantly to a lower energy state, often the ground energy level. Occasionally, however, the excited state persists with a finite half-life. An excited energy state that exists for a finite time before decaying is termed a *metastable* energy state and denoted by an m following the mass number (e.g., 99mTc, which has a half-life of 6 hours). The transition

from an excited energy state to one nearer the ground state, or to the ground state itself, is termed an *isomeric transition* because the transition occurs between isomers with no change in Z, N, or A. An isomeric transition can occur by either of two processes: gamma emission or internal co Gamma rays are high-energy electromagnetic radiation that differ from x rays only in their origin: Gamma rays are emitted during transitions between isomeric energy states of the nucleus, whereas x rays are emitted during electron transitions outside the nucleus. Gamma rays and other electromagnetic radiation are described by their energy E and frequency ν, two properties that are related by the expression

$E = h\nu$, where h = Planck's constant (h = 6.62 × 10^{-34} J-sec). The frequency ν and wavelength λ of electromagnetic radiation are related by the expression $\nu = c/\lambda$, where c is the speed of light in a vacuum. No radioactive nuclide decays solely by gamma emission; an isomeric transition is always preceded by a radioactive decay process, such as electron capture or emission of an alpha particle, negatron, or positron. Isomeric transitions for ^{60}Co yield gamma rays of 1.17 and 1.33 MeV with a frequency of more than 99%. Gamma rays are frequently used in medicine for detection and diagnosis of a variety of ailments, as well as for treatment of cancer. Internal conversion is a competing process to gamma emission for an isomeric transition between energy states of a nucleus. In a nuclear transition by internal conversion, the released energy is transferred from the nucleus to an inner electron, which is ejected with a kinetic energy equal to the transferred energy reduced by the binding energy of the electron. Internal conversion is accompanied by emission of x rays and Auger electrons as the electron structure of the atom resumes a stable configuration following ejection of the conversion electron. The *internal conversion coefficient* is the fraction of conversion electrons divided by the number of gamma rays emitted during a particular isomeric transition. The conversion coefficient can be expressed in terms of specific electron shells denoting the origin of the conversion electron. The probability of internal conversion increases with Z and the lifetime of the excited state of the nucleus.

4-Post-Test

5-Keys of Answers

References

UNIT THREE

Interaction of Radiation with Matter

1-Over View

a-Target Population

The students of third class in the environmental and pollution department in Basrah technical college in radiation pollution subject.

b-Rationale

the interaction between any type of radiation with matter there are a great change happen in matter therefore the study of the manner which the radiation interact with matter is very important.

c-Central Ideas

1-interaction of heavy charged particles with matter.

2-interaction of electrons with matter.

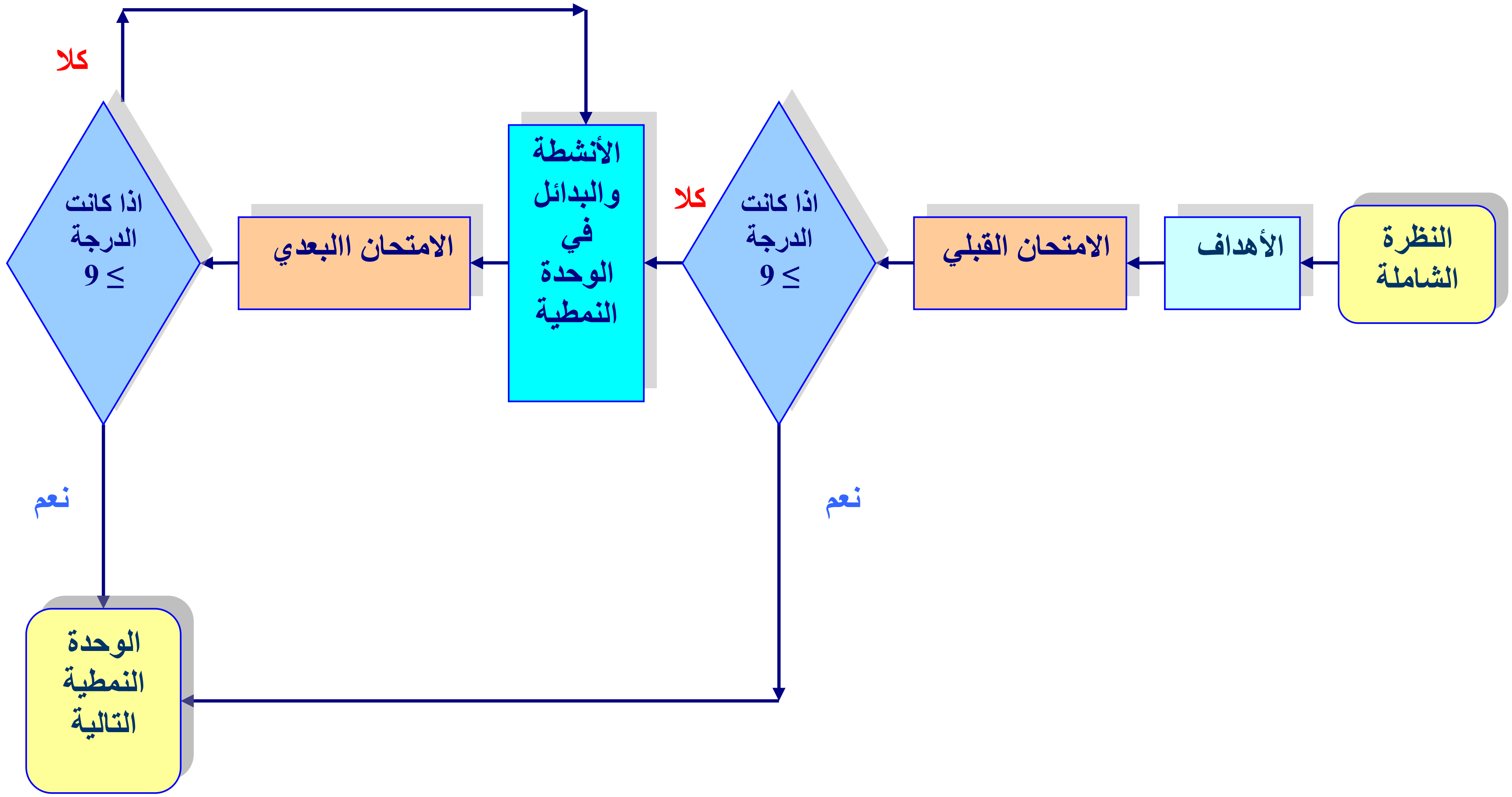
3-interaction of gamma radiation with matter.

4-interaction of neutrons with matter.

d-Objectives

After going through this unit, you will be able to:
1-describ the manner of interact the radiation with matter
2-understand the difference in the interaction between the radiation and matter according to the type of rays and particles
3-understanding the basic theory for the interaction
4-understanding of energy loss mechanism
5- calculate the stopping power
6-shielding of radiation.

E-Streamline scheme



2-Pre-Test

3-Unit Presentation

Interaction of Radiation with Matter

3-1: Introduction

The interaction of radiation with matter is including the following kinds:

1-interaction of heavy charged particles with matter.

2-interaction of electrons with matter.

3-interaction of gamma radiation with matter.

4-interaction of neutrons with matter.

3-2: interaction of heavy charged particles with matter

3-2-1: the energy transfer

When the heavy charged particles like alpha particles, deuterons and protons are collided on the matter the energy of the particles transfer from particles to matter successively until the particles are stopped.

- **Energy-Loss Mechanisms**

-The basic mechanism for the slowing down of a moving charged particle is **Coulombic interactions** between the particle and electrons in the medium. This is common to all charged particles

- A heavy charged particle traversing matter loses energy primarily through the **ionization** and **excitation** of atoms.

- The moving charged particle exerts **electromagnetic forces** on atomic electrons and imparts energy to them. The energy transferred may be sufficient to pull out of electrons from its orbits an electron out of an atom and thus **ionize** it, or it may leave the atom in an **excited, nonionized state**.

- The heavy charged particles when incident on the matter its collided with electron of the atoms of matter and not with the nucleus of the atom there for All heavy charged particles travel essentially **straight paths** in matter.. .
- A heavy charged particle can transfer only a **small fraction** of its energy in a single electronic collision. Its **deflection in the collision is negligible**.

3-2-2:W is the energy required to cause an ionization

The heavy charged particle ionized the atoms of the matter therefore consist electron-ion pairs .

When n represent the number of electron-ion pairs which result from the primary and secondary ionization.

$$\overline{W} = \frac{E}{n}$$

Where $\overline{W}$ represent the mean value of energy required to consist a one pair of electron-ion. The value of $\overline{W}$ is depend on the type of matter and not depend on the incident particles, for example the value of $\overline{W}$ for air in the standard conditions of temperature and pressure equal 35 volt.

3-2-3: The stopping power

It is a mean of loss for the energy of a particle when it pass one millimeter through the matter. The stopping power is given by the following:

$$\frac{-dE}{dx} = \overline{W} .\ S$$

Where S is called the specific ionization and defined as a number of pairs of electron-ion which consist in one millimeter of air in temperature 15^{O} and pressure 760 millimeter mercury.

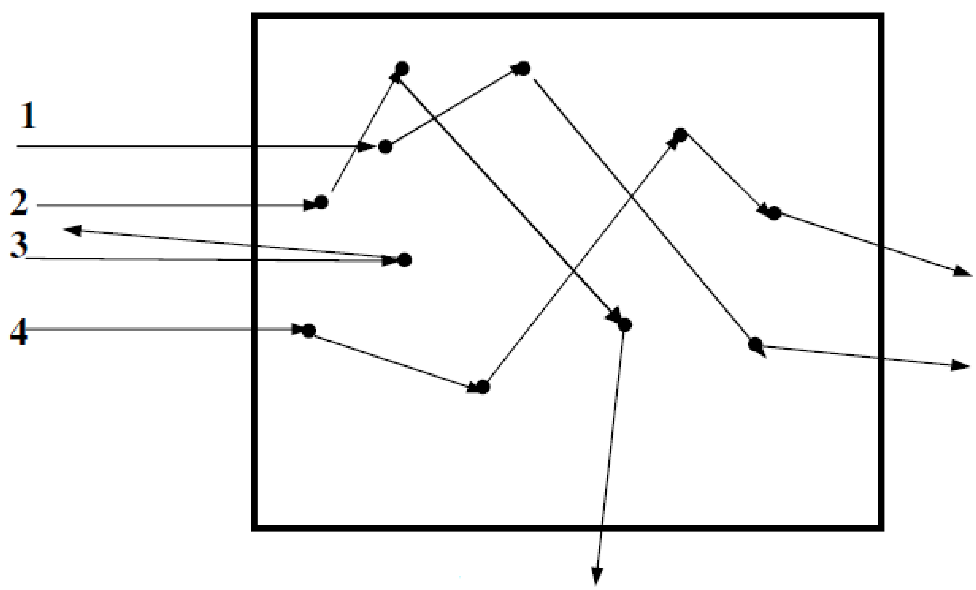
3-3: Interaction of electrons with matter

3-3-1: Energy transfer from electron to matter

-The electron missing its energy when collided with matter by transfer the energy from incident electron to the electrons of atoms of the matter and caused exited it.

- the energy which transfer to the atom electron is equal approximately to the half of energy of incident electron.

- because of the mass of electron is very small therefore the track (pass) electron is not a straight line ,it is a broken line as shown in figure(3-1) .



Figure(3-1) : The track of electron in matter.

- The positron missing its energy with a same manner of electron but the positron in the last of track is disappear, when positron is collided with final electron the positron and this electron are disappear and two gamma photon are emitted , this phenomenon is called annihilation.

- From figure(3-1) we noted many of electron have a high energy may be transmitted from the matter (electrons 1 and 4), and the other electrons are back scattering (electron number3) or dispersion in the matter (electron 2).

3-3-2: The law of absorption of electron

The absorption of beta rays in the matter take an exponential shape:

$$N = N_o \, e^{-\mu \, x} \qquad \text{..............(3-1)}$$

Where

N_o=the number of beta particles which collided on the matter.

N=the number of beta particles which pass through the thickness (x) of the matter.

μ =is known a linear absorption coefficient and it is dependent on the kind of the absorption matter, its unit is cm^{-1}

3-4: Gamma Interaction with matter

A photon can interact with matter by a number of competing mechanisms. The interaction can be with the entire atom, as in the photoelectric effect, or with one electron in the atom, as in the Compton effect, or with the atomic nucleus (as in pair production). The probability for each of these competing independent processes can be expressed as a collision cross section per atom, per electron, or per nucleus in the absorber. The sum of all these cross sections, normalized to a per atom basis, is then the probability that the incident photon will have an interaction of some kind while passing through a very thin absorber which contains one atom per cm2 of area normal to the path of the incident photon. The total collision cross section, σ , per atom when multiplied by the number, n, of atoms per cm^3 of absorber is then the linear attenuation coefficient, μ_0 per centimeter of travel in the absorber. The fraction of incident photons which can pass through a thickness x of absorber without having an interaction of any kind is given by

$$I_0 = e^{-\mu_0 x} = e^{-\sigma n x}$$

We sometimes wish to express the absorption in terms of the equivalent matter traversed, namely $\xi = \mathrm{gm/cm^2}$. Then the thickness of the material can be expressed by $d\xi$ where:

$$d\xi = \rho dx.$$

.

The mass absorption coefficient is defined by:

$$\mu_m = \frac{\mu_0}{\rho},$$

so that the fraction of the beam not absorbed is:

$$\frac{I}{I_0} = e^{-\mu_m \xi} \quad .$$

In this experiment we will measure the mass absorption coefficient of materials of different Z for gamma rays of a large range of energies. We will try to understand these results in terms of what we know about the interactions of gamma rays with matter. As mentioned above, there are three mechanisms of interaction which are important at the gamma ray energies we are interested in: photoelectric effect, pair production, and Compton effect. These are described briefly below.

• Photoelectric Effect

In this interaction the photon ejects an electron from an atom (generally from the K or L shells). The photon is completely absorbed and all its energy is transferred to the atomic electron. The atom then emits characteristic X–rays and Auger electrons as it returns to normal.

• Pair Production

In pair production a photon of sufficiently high energy is annihilated and an electron–positron pair is created. For a free photon conservation of energy and momentum would not be possible, so pair production must take place in the field of a nucleus (or of another electron) which will take up the balance of momentum. The energy threshold for this process is 1.02 MeV.

• Compton Effect

In the Compton effect the gamma ray scatters off of a loosely bound electron and loses only part of its energy. The electron recoils in one direction and the gamma goes off in another direction with a reduced energy. The following figure (3-2) provides a guide to the relative importance of these three principal interactions over a wide range of energy, $h\nu$, of the incident photons and atomic numbers, Z of the attenuating material. Knowledge of these interactions will also be important in understanding the detection of gammas with a scintillation detector.

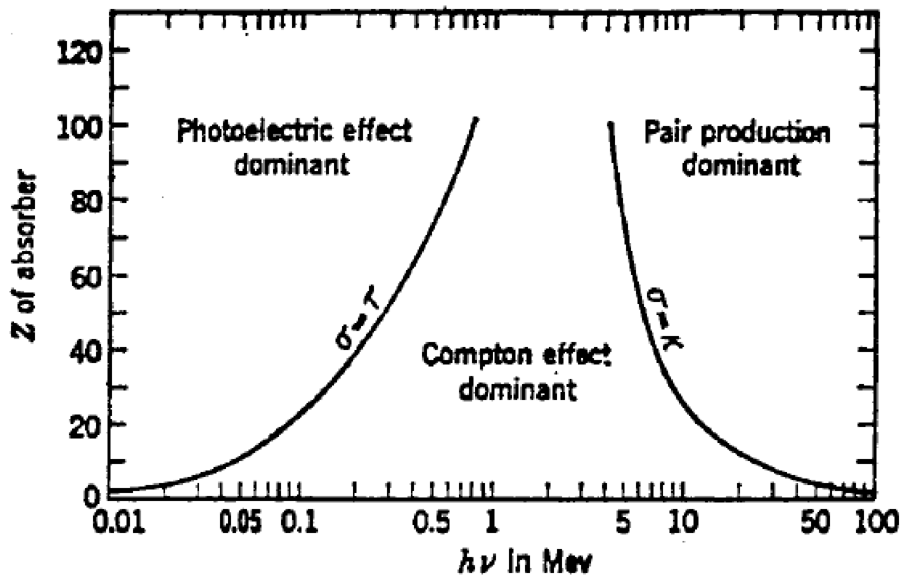


Figure (3-2): Relative importance of the three major types of Gamma ray interaction. The lines show the values of Z and $h\nu$ for which the two neighboring effects are just equal

.3-5: Shielding

The goal of shielding is confinement, with eventual conversion of radioactive energy to heat which can be dissipated by cooling (air, water, etc.). As we will see, the primary radioactivity particle may sometimes induce secondary energetic particles by basic interaction processes, and they in turn produce tertiary particles etc. It is necessary to study the dependence of various fundamental interaction processes on particle energy and on absorber atomic number Z, to understand these cascade processes in a quantitative way. Depending on primary energy and type, various shielding methods illustrated schematically above will be appropriate. Sometimes a combination is employed, layered to deal with the successive cascade particles.

Different radiations have different properties, as summarized below

Radiation	***Type of Radiation***	***Mass (AMU)***	***Charge***	***Shielding material***
Alpha	Particle	4	+2	Paper, skin, clothes
Beta	Particle	1/1836	±1	Plastic, glass, light metals
Gamma	Electromagnetic Wave	0	0	Dense metal, concrete, Earth
Neutrons	Particle	1	0	Water,concrete, polyethylene, oil

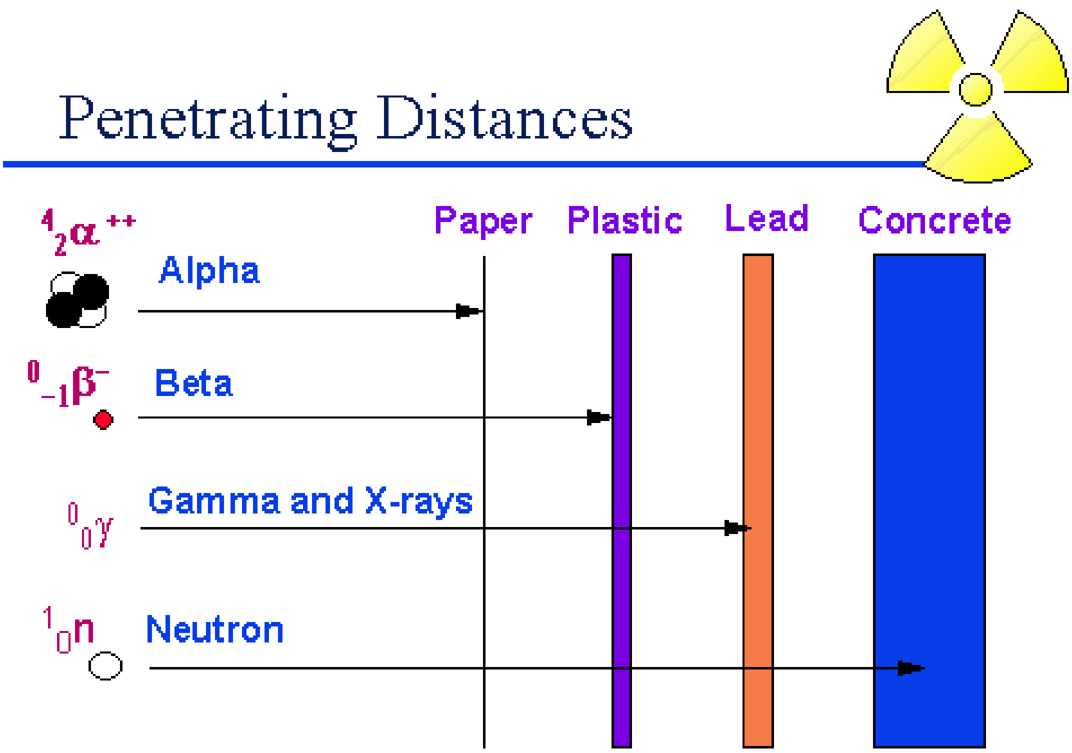


Figure (3-3): Effective Shielding Materials for Various Radiation Types

3-5: Interaction of neutrons with matter

3-5-1: What is neutron:

Neutron is a neutral charged particle have a mass 1.0866 a.m.u.

Because of the neutron have not charged therefore can not be accelerated.

The neutron have not any ionized and electrostatic interactions with atom and electrons.

The neutrons interact with nucleus only when it pass through the matter. In the case when neutrons have not nuclear interaction the matter is consider a space ,therefore neutron can be able to penetrate the matter easly.

When neutron emitted from nucleus it decay spontaneously into proton, negative beta particle and antineutrino :

$$^{o}n \longrightarrow P^{+} + \beta^{-} + \acute{\upsilon}$$

The half-life of neutron is 15 minute.

3-5-2: The kinds of neutrons:

The neutrons classified in order to its energy into five kinds:

1-thermal neutrons , have kinetic energy less than 1eV.

2- slow neutrons, have energy between (1eV-0.1 keV).

3-mid energy neutrons, have energy between (0.1 keV-20 keV).

4- fast neutrons, have energy between (0.2 MeV-10MeV).

5- very fast neutrons, have energy greater than 10MeV.

3-5-3:Mecanisem of interact the neutron with nucleus:

The neutrons disperse its energy by two kind of scattering:

1-The neutron elastic scattering:

When the neutron with energy E_o is collided on nucleus with atomic number **A** ,it is scatter from its pass, in this interaction when the internal energy of nucleus don't change (i.e. the nucleus don't transfer from the ground state to exited state) and the kinetic energy for nucleus just change , the scattering is called elastic.

By using energy-momentum conservation law, the neutron energy is written as:

$$E = E_0 (A^2 + 2A \cos \phi +1) / (A + 1)^2$$

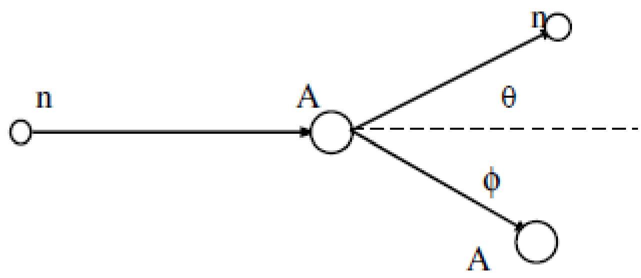
Where

E=the neutron energy after interaction.

Φ = the scattering angle.

When the value of A is small E became smaller. Therefore, hydrogen is the best to cool down the neutrons.

When the value of Φ is large until 180^o E became smaller.



2- The neutron inelastic scattering:

When the neutron is collided on nucleus with atomic number **A** ,it is scatter from its pass, in this interaction when the internal energy of nucleus change (i.e. the nucleus transfer from the ground state to exited state), the scattering is called inelastic and the neutron energy don't change in great amount, therefore , the neutron inelastic scattering cant cool down the neutrons.

4-Post-Test
5-Keys of Answers
References

UNIT FOUR

THE NUCLEAR DETECTORS

1-Over View

a-Target Population

The students of third class in the environmental and pollution department in Basrah technical college.

b-Rationale

the radiation doses exist in lab and any work place therefore the apparatus and detectors to determine this doses is very important.

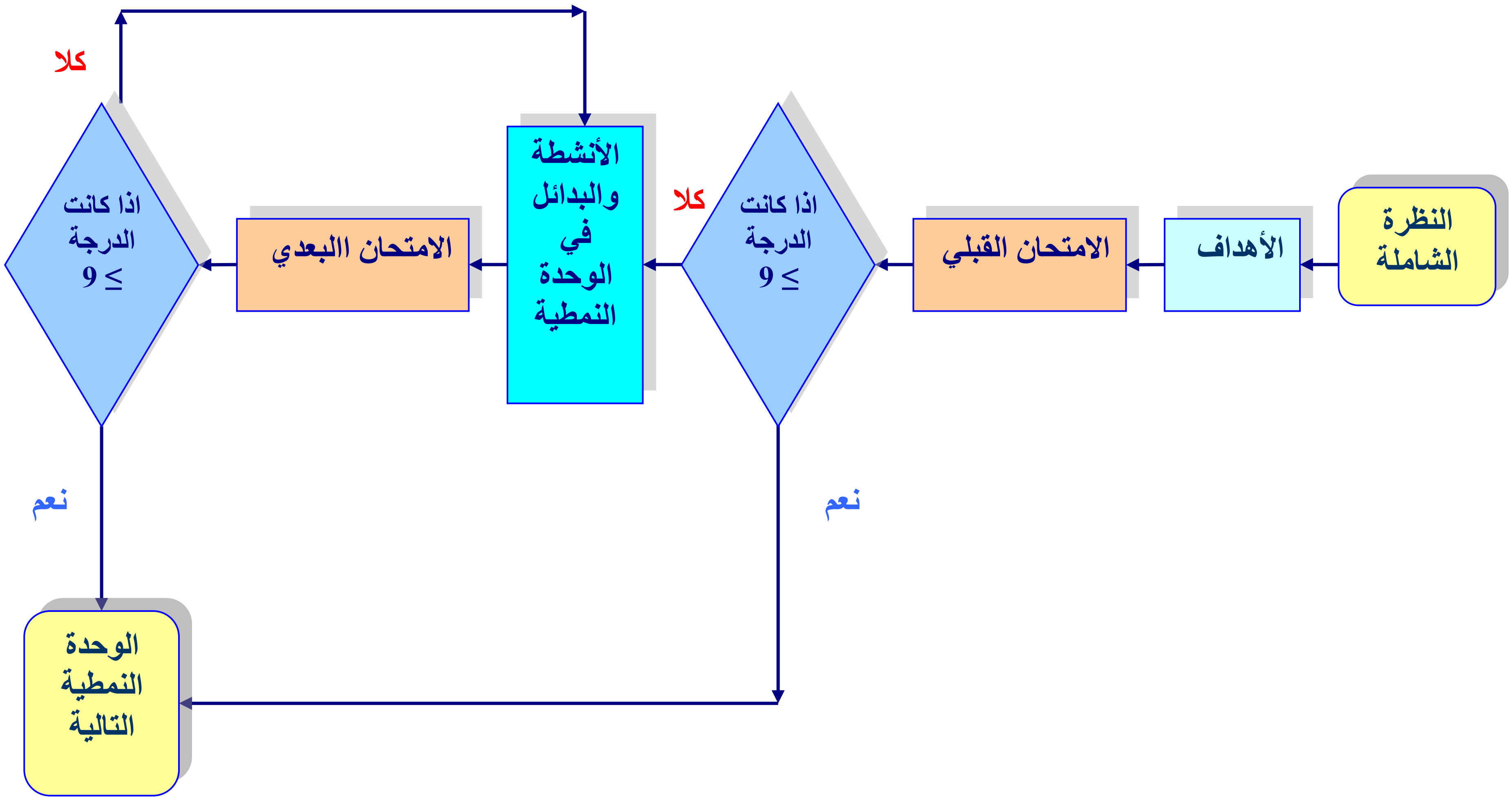
c-Central Ideas

1-ionized radiation
2-types of detectors
3-ionized gas detectors

d-Objectives

After going through this unit, you will be able to
1-knowing the types of radiation detectors
2- understand the method of operation of any type of detector
3- understand all theoretical basic for operation of detectors

E-Streamline scheme



2-Pre-Test
3-Unit Presentation

THE NUCLEAR DETECTORS

4-1: INTRODUCTION

In all aspects of radiological control, a knowledge of the characteristic and magnitude of the radiation field is essential in evaluating the degree of radiological hazard present. Radiation itself can not be detected directly. Because of this, radiation detection is accomplished by analysis of the effects produced by the radiation as it interacts in a material. Numerous different methods of accomplishing this analysis have been developed and implemented with varying degrees of success. Several of these have found extensive application in radiological control.

-Why do we need radiation detectors?

•Personal safety

•Cannot see radiation

•Survey work areas

•Measure exposure

•Measure patient doses

•Diagnostic counting/imaging

And we must know about radiation

–How much?

–Energy?

–Position?

4-2:Radiation we trying to detect?

•X-rays

•High energy photons(gamma)

•Beta particles

•Alpha particles

In the detector, the incident radiation interacts with the detector material to produce an observable effect, be it a chemical change or creation of an electrical signal.

4-3: Detectors type

1-Ionization Detectors

In ionization detectors, the incident radiation creates ion pairs in the detector. The ionization media can be either gas (most common) or solid (semi-conductors). Gas filled chambers can be operated as either ion chambers, proportional counters, or Geiger Mueller (GM) tubes. A typical solid ionization detector is a GeLi detector used in a multi channel analyzer.

2-Excitation Detectors

In excitation detectors, the incident radiation excites the atoms of the detector material. The atoms give off the excess energy in the form of visible light. Thermoluminescent dosimeters (TLD) and scintillation detectors fall in this category.

3-Chemical Detectors

In chemical detectors, the incident radiation causes ionization or excitation of the detector media thereby causing chemical changes which can be analyzed. Film badges are an example of a chemical detector.

4-Other Detectors

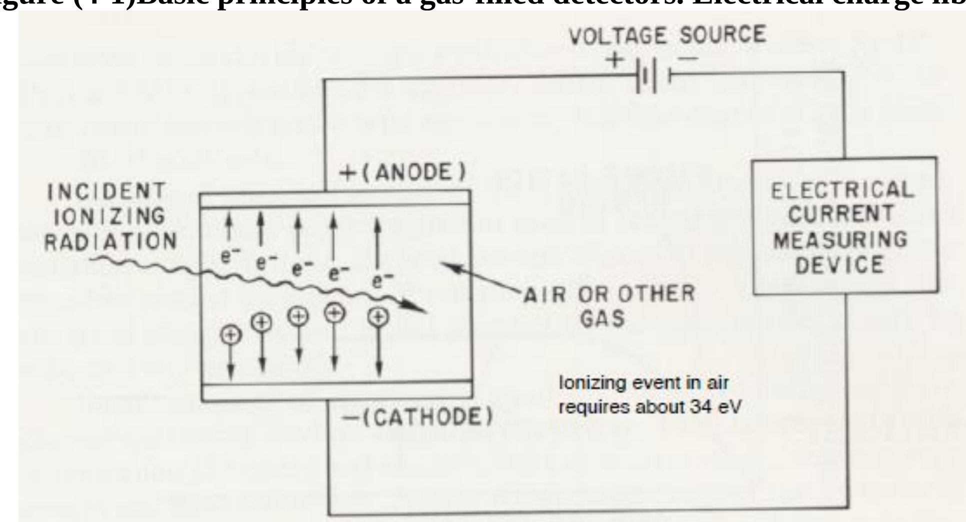
There are a number of detectors that don't use ionization, excitation, or chemical changes. Examples are Cerenkov detectors, Activation foils, and Biological detectors.

4-3-1:**Ionization Detectors**

4-3-1-1:Gas filled detectors|

Basic Construction

Figure (4-1)Basic principles of a gas-filled detectors. Electrical charge liberated



by ionizing radiation is collected by positive and negative electrodes.

Any contained gas volume that has a pair of electrodes can serve as a gas filled ionization detector. The detector can be almost any shape or size but is usually cylindrical. It should be noted that the size, shape, and configuration is a function of the desired detector characteristics. The gas used in the detector can be almost any gaseous mixture that will ionize, including air. Some ionization detectors, particularly ionization chambers use only air, while other detectors use gas mixtures that ionize more readily to obtain the desired detector response.

Basic Theory

A gaseous mixture in a normal undisturbed state has positive and negative charges which are balanced such that no net charge is observed. When a particle or ray interacts with the gas atoms or molecules (and in some gases, the detector materials), energy is added to the gas and one or more electrons may be split off of the parent atom or molecule. The most common process results in a single negatively charged electron, leaving behind a positively charged atom. Together the negative electron and positive atom (minus one electron) are called an *ion-pair*. If left undisturbed, the negative ions can be collected by a positive ion and return to a neutral state. If a voltage potential is established across the two electrodes, electric fields are set up in the gas volume between the electrons. In most detectors, the center electrode is positively charged, and the shell of the detector is negatively charged. If an ion pair is created between the electrodes, the electron will be attracted to the center electrode, while the positively charged ion will be attracted to the detector shell. When either ion reaches the electrode, electric currents are set up. Because of mass differences, the electron reaches the electrode first. It takes up to 1,000 times longer for the positive ion to reach the side. The amount of current flow is representative of the energy and number of radiation events that caused ionization. The readout circuitry analyzes this current and provides an indication of the amount of radiation that has been detected.

Ion Pair Production

For a gas filled ionization detector to be of value for radiological control purposes, the manner in which the response varies as a function of the energy, quantity, and type of radiation must be known. ***Factors such as the size and shape of the detector, the pressure and composition of the gas, the size of the voltage potential across the electrodes, the material of construction, the type of radiation, the quantity of radiation, and the energy of the radiation can all affect the response of the detector.*** Detectors for a special purpose are designed to incorporate the optimum characteristics necessary to obtain the desired response.

Type of Radiation

Each type of radiation has a specific probability of interaction with the detector media. This probability varies with the energy of the incident radiation and the characteristics of the detector gas. The probability of interaction is expressed in terms of specific ionization with units of ion pairs per centimeter. A radiation with a high specific ionization, such as alpha, will produce more ion pairs in each centimeter that it travels than will a radiation with a low specific ionization such as gamma. In Table 1, note the magnitude of the difference between the specific ionization for the three types of radiation.

Table 1. Specific Ionization In Air at STP.

Radiation	Energy	Ion pairs/cm
Alpha	3 MeV 6 MeV	55,000 40,000
Beta	0.5 MeV 1 MeV 3 MeV	110 92 77
Gamma	0.5 MeV 1 MeV 3 MeV	0.6 1.1 2.5

Energy of the Radiation

Review of the data in Table 1 will reveal that, generally, the probability of interaction between the incident particle radiation and the detector gas (and therefore the production of ions) decreases with increasing radiation energy. In photon interactions, the overall probability of interaction increases because of the increasing contribution of the pair production reactions. As the energy of the particle radiation decreases, the probability of interaction increases, not only in the gas, but also in the materials of construction. Low energy radiations may be attenuated by the walls of the detector and not reach the gas volume. Obviously, this must be accounted for in the design of the detector.

Quantity of Radiation

As the number of radiation events striking a detector increases, the overall probability of an interaction occurring with the formation of an ion pair increases. In addition, the number of ion pairs created increases and therefore detector response increases.

Detector Size

The probability of an interaction occurring between the incident radiation and a gas atom increases as the number of atoms present increases. A larger detector volume offers more "targets" for the incident radiation, resulting in a larger number of ion pairs. Since, each radiation has a specific ionization in terms of ion pairs per centimeter, increasing the detector size also increases the length of the path that the radiation traverses through the detector. The longer the path, the larger the number of ion pairs.

Type of Detector Gas

The amount of energy expended in the creation of an ion pair is a function of the type of radiation, the energy of the radiation, and the characteristics of the absorber (in this case, the gas). This energy is referred to as the ionization potential, or W-Value, and is expressed in units of electron volts per ion pair. Typical gases have W-Values of 25-50 eV, with an average of about 34 eV per ion pair.

Detector Gas Pressure

In the section on detector size, it was shown the probability of interaction increases with detector size. In many cases, there is a practical limit to detector size. Instead of increasing detector size to increase the number of "target" atoms, increasing the pressure of the gas will accomplish the same goal. Gas under pressure has a higher density (more atoms per cm^3) than a gas not under pressure, and therefore offers more targets, a higher probability of interaction, and greater ion pair production. For example, increasing the pressure of a typical gas to 100 psi increases the density by about 7 times.

Voltage Potential Across the Electrodes

Once the ion pair is created, it must be collected in order to produce an output pulse or current flow from the detector. If left undisturbed, the ion pairs will recombine, and not be collected. If a voltage potential is applied across the electrodes, a field is created in the detectors, and the ion pairs will be accelerated towards the electrodes. The stronger the field, the stronger the acceleration. As the velocity of the electron increases, the electron may cause one or more ionizations on its own. This process is known as secondary ionization. The secondary ion pairs are accelerated towards the electrode and collected, resulting in a stronger pulse than would have been created by the ions from primary ionization.

Effect of Voltage Potential on the Detector Process

If the applied voltage potential is varied from 0 to a high value, and the pulse size recorded, a response curve will be observed. For the purposes of discussion, this curve is broken into six regions. The ion chamber region, the proportional region, and the Geiger-Mueller region are useful for detector designs used in radiological control. Other regions are not useful. In the recombination region, the applied voltage is insufficient to collect all of the ion pairs before some of them recombine. In the limited proportional region, neither the output current nor the number of output pulses are proportional to the radiation level. Calibration is impossible. In the continuous discharge region, the voltage is sufficient to cause arcing and breakdown of the detector gas.

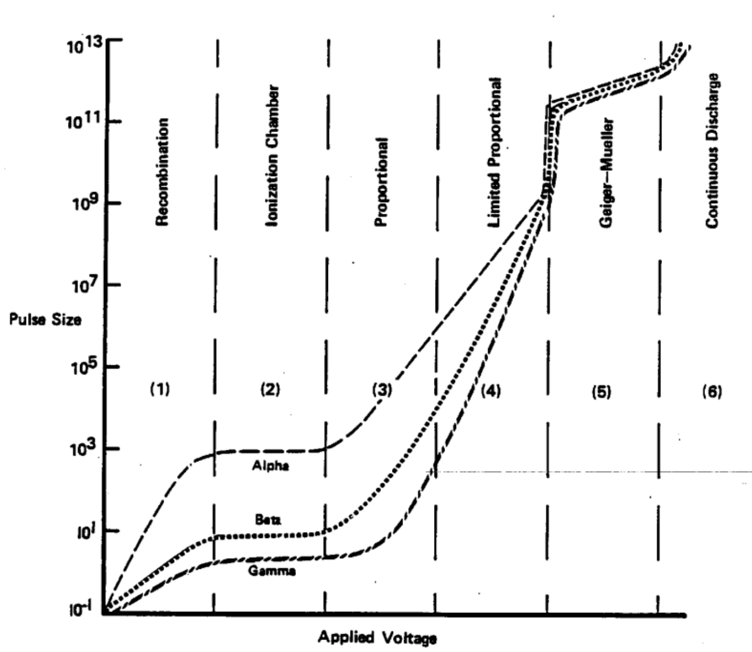


Figure 3. Six-region Curve for Gas-filled Detectors

Geiger-Mueller Detectors

As the voltage on the detector is increased beyond the proportional region, the detector enters the limited proportional region. As mentioned before, this region is unusable for radiological control purposes. In this region the small individual avalanches which occur within the tube start to interfere with each other. This interference is unpredictable and reduces the overall output signal.

As the voltage is increased further, the secondary ions are also accelerated to very high velocities and gain sufficient energy to cause ionization themselves. These tertiary ionizations spread rapidly throughout the tube causing an avalanche. The avalanche, caused by a single ionization, results in a single very large pulse. The avalanche continues until the fields created by the produced ions interfere with the field created by the high voltage potential across the detector. When this occurs, the amount of acceleration decreases preventing further secondary ionization and halting the avalanche. The output pulse size is a function of the gas amplification which occurs. In a GM tube, the gas amplification can range upwards from about 1 E8. Since the number of ions eventually produced and collected have no relation to the initial incident ionizing event, the pulse size is independent of radiation energy or specific ionization (a 0.1 MeV gamma creates the same size pulse as a 0.5 MeV gamma). For this reason, GM tubes cannot discriminate against different radiation types or radiation energies. Any radiation event with sufficient energy to create the first ion pair can create a large pulse. For this reason, the GM detector is more sensitive than the ion chamber or proportional counter.

A GM detector can also be avalanched by the small amount of energy released by a positive ion when it is neutralized at the cathode. To prevent this undesirable occurrence, a quenching gas is added to the counting gas. Thus, instead of causing ionization, this excess energy is expended in dissociating the quenching gas molecules.

The following sequence of events should help to explain the processes involved in GM detection.

• At time zero, the voltage potential across the detector is maximum. An incident radiation causes ionization, resulting in an ion pair.

• These ion pairs are accelerated towards the center electrode, thereby gaining energy.

• The primary ion pairs cause secondary ionization. The ion pairs created by the secondary ionization begin to accelerate towards the center electrode, thereby gaining energy. Since the potential is greatest near the center electrode, the bulk of the ionization occurs near the center electrode.

• The secondary ion pairs cause additional ionization and ion pairs. These ion pairs are accelerated and begin to cause ionization of their own. This process continues and an avalanche occurs.

• The negative ions (electrons) are collected by the center electrode and form a pulse. The positive ions form a cloud surrounding the center electrode. This ion cloud reduces the voltage potential across the detector. With a reduced voltage potential the gas amplification factor decreases such that secondary ionization stops, thereby halting the avalanche. The events described above occur very rapidly, in the range of a fraction of microsecond. During this period the positive ion cloud is relatively stationary. The positive ion cloud is the cause of both the dead time and recovery time.

• The positive ion cloud starts to drift towards the shell of the detector.

• As the cloud drifts, the voltage potential starts to increase.

• After about a microsecond (typically) the voltage potential is high enough to collect the electrons from another ionization should they occur. This is the end of the dead time. If another event does occur, the pulse will be very small and probably not measurable as the detector voltage is in the ion chamber region.

• As the ion cloud continues to drift, the voltage potential continues to increase and gas amplification starts to occur. The detector is now in the proportional region. An event which occurs now will result in a large pulse. Whether or not this pulse is measured is a function of the input sensitivity of the electronic package.

• Eventually the gas amplification factor will increase to the point where an avalanche can occur when the positive ions reach the detector shell and are neutralized. At this point the detector has recovered and is ready for another radiation event. This time is about 100-300 sec in typical detectors.

• During neutralization, the positive ions may release photons which in themselves could cause an avalanche if no quenching gas was present. Instead, the photons react with the molecules of the quenching gas, thereby dissipating their energy.

The effect of the long resolving time in a GM detector is to reduce the ability of the detector to measure high dose rates accurately. For example, with a 200 sec resolving time, a count rate of 10,000 cpm will be measured as 9,700 cpm, an error of 3%. At 100,000 cpm, the measured count rate will be 75,000, an error of 25%.

There is another effect in GM detectors that is related to resolving time. If the incident radiation events occur at an extremely high rate, a string of small pulses will occur. These pulses prevent the GM detector from completely recovering. Since a full size pulse does not occur, the electronics will not indicate that any radiation is present.

GM Detector Construction

Although there is no technical reason why GM detectors cannot be operated as gas flow detectors, this is not commonly done. Almost all GM detectors which are encountered in radiological control work are cylindrical in construction.

Advantages of GM Detectors

• GM detectors are relatively independent of the pressure and temperature effects which affect ion chamber detectors. This is because of the magnitude of the output pulse.

• GM detectors require less highly regulated power supplies. This is because the pulse repetition rate is measured and not the pulse height.

• GM detectors are generally more sensitive to low energy and low intensity radiations than are proportional or ion chamber detectors.
(There are exceptions.)

• GM detectors can be used with simpler electronics packages. The input sensitivity of a typical GM survey instrument is 300-800 millvolt, while the input sensitivity of a typical proportional survey instrument is 2 millivolt. Disadvantages of GM Detectors

• GM detector response is not related to the energy deposited; therefore GM detectors can not be used to directly measure true dose, as can be done with an ion chamber instrument.

• GM detectors have a typically large recovery time. This limits their use in extremely high radiation fields. Dead time in a GM detector can be reduced by reducing the physical size of the detector. However, the smaller the detector, the lower the sensitivity. For this reason, wide range GM survey instruments, such as the Teletector or the E520, commonly have two GM detectors - one for the low ranges, one for the high ranges.

• GM detectors can not discriminate against different types of radiation . nor against various radiation energies. This is because the size of the GM avalanche is independent of the primary ionization which created it.

Typical Applications

GM detectors are widely used in portable survey instruments at nuclear power facilities due to their ruggedness and the simplicity of the associated electronics. GM detectors are also used for personal monitoring for contamination (friskers), for process monitoring, and for area radiation monitoring. In addition, GM detectors are often used for laboratory counting when just a gross count is desired.

Comparison of the Various Radiation Detectors. When comparing the various detectors, one should keep in mind that exceptions are possible, (e.g. a large, pressurized ion chamber may be more sensitive than a small GM detector, even though, as a class, GM detectors are more sensitive than ion chambers.

4-Post-Test
5-Keys of Answers
References

UNIT FIVE
RADIATION HAZARD

1-Over View

a-Target Population

The students of third class in the environmental and pollution department in Basrah technical college.

b-Rationale

the effects which came from the ionized radiation are caused the cancer therefore the study of the radiation hazard is very important to the people life.

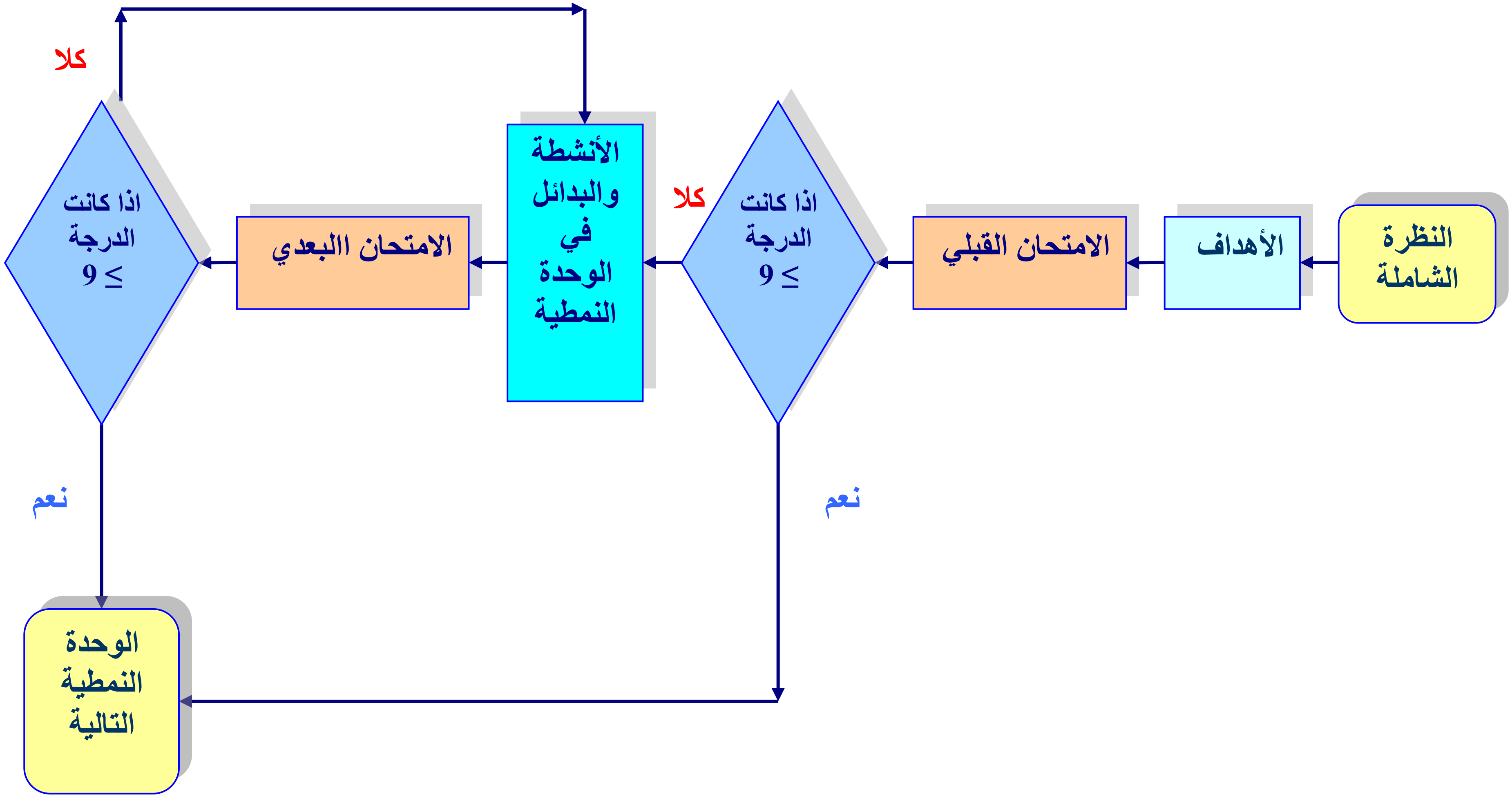
c-Central Ideas

1- BIOLOGICAL EFFECTS OF RADIATION HAZARDS
2- VIDEO IMAGING MODALITIES
3- NUCLEAR MEDICINE DEPARTMENT

d-Objectives

After going through this unit, you should be able to:
1- enlist the biological effects of Radiation Hazards
2-describe the radiation protective and safety measures in designing of diagnostic x-ray
3-Magnetic Resonance Imaging, Nuclear Medicine Services
4-discuss various aspects requiring attention in planning of Radiation Therapy with particular reference to design and protection of personnel and materials
6-describe the procedure for radio waste collection and disposal relating to Nuclear Medicine, Tele Therapy and Brachy Therapy.

E-Streamline scheme



2-Pre-Test

3-Unit Presentation

RADIATION HAZARD

3.1 . INTRODUCTION

3.2 BIOLOGICAL EFFECTS OF RADIATION HAZARDS

Radiation protection and safety in all imaging techniques are of great concern to safeguard radiation hazards. Radiation protection facilities and disposal of radioactive waste are of paramount importance in radio-therapy centers. Failure t observe the safeguard procedures invariably leads to harmful biological effects. Radiation injuries can arise from various sources, viz. Gamma, Beta, Alpha and Neutrons.

The effects of radiation depend on type of cells of body affected, dose and source of radiation to which individual is exposed. The effects can be acute and chromic.

Acute radiation effect is called as acute radiation syndrome (ARS). This is combination of syndromes occurring in stages during a period of hours to week after exposure, as injury

to various organs is expressed. It occurs in three successive phases: Prodromal Appearing within a first few hours, lasting for n day or more. Latent period : Lasting for days and weeks. I Manifest phase : Where recovery or death occurs within 6 weeks of exposure. I Chromic or Delayed Effects occur months to years after radiation exposure and include a variety of effects on almost all tissues and organs. Some of the possible delayed effects are:

a) Shortening of life span.

b) Cataract formation.

c) Chronic radio dermatitis.

d) Leukemia.

e) Cancer.

f) Decreased fertility.

g) Genetic mutation.

h) Depilation (falling of hair).

3.3 DIAGNOSTIC IMAGIYG

In this section you will learn about diagnostic imaging which includes radiography, fluoroscopy, mammography, and other similar techniques. Radiography is 4 device of making pictorial records by means of x-ray on sensitized film, fluoroscopy is direct visualization through medium of x-ray, where as mammography is a screening technique, for determining the presence of breast turn ours. Most imaging requires radiation protection. shielded control alcove. This area shall be provided with a view window designed to provide full view of the examination table and the patient at all times, including full view of the patient when the table is in a tilt position or the chest x-ray is being utilized. For mammography machines with built in shielding for the operator. Mammography room should be designed to appeal to women. X-ray room in which remote control is to be used, it is essential to have a lead glass window to protect the radiologist who is in line with x-ray table at floor level, so that the operator can see and communicate with the patient. The lower edge of the protective screen should be about 115 cm for use in the erect position. 'The television monitor should be placed so that it can be easily seen through the lead glass window. Simultaneously the patient should be kept in view. The control panel should be close to the x-ray table so that the patient showing any signs of distress could be quickly reached. Door opening should be at least 130 cm wide. All artificial lighting in the screening room should be wall mounted. 'The ceiling has to be free from air ducts, pipes etc., and should be weight bearing in all directions for the installation of ceiling mounting equipments.

An examination room suites for general examinations including chest, abdomen, skull, extremities, spine and IVP; a suite for special procedures including cardiovascular, neurological and urological procedures, and suites for routine fluoroscopy, and for rapid chest examinations could be envisaged.

The x-ray film processing devices have until very recently been concentrated to dark rooms, which in a sense have been the central point of the department. The size of the darkroom depends on the number of working in it. Citrus fruit color and pastel shades are suitable for the walls and ceiling of the dark room. Dark color, above all black should be avoided. Ten air changes per hour are recommended. Since automatic processors have largely taken over from manual systems, there have been changes in the dark room planning. Medical x-ray films can be cassette loaded, exposed, unloaded and processed entirely in daylight. About 90% of all x-ray examinations could be performed without access to a dark room. The automatic system reduces the physical workload of carrying the cassettes by the radiographer.

3.3.1 Radiation Protection and Safety

In general, the amount of radiation in a small basic radiological facility is so little that radiation protection is not a major problem. In larger set ups it assumes a greater proportion and requires urgent attention.

The recommendation for wall thickness for radiation protection which follow is based on a minimum x-ray room size. Calculate the desired thickness of material on the basis of total radiation exposure of 150 mA-minutes a week at 100 kv. The number of milli-Amperes used for each exposure multiplied by number of seconds provides the milli-Ampere seconds (mA-s) for each exposure; the milli-Ampere-minutes per day can be calculated by multiplying the number of exposures per day by the average exposure used.

In basic radiology facility it is, therefore, permissible to utilize a wall thickness design figure of 1 mrn of lead equivalent. This incorporates a sizeable safety factor and will be satisfactory until at least 30 patients are examined daily.

Radiation Hazards

A standard poured concrete wall of about 8-12 cm thickness would be required to provide a lead equivalent of 1 mm. If cinder blocks or bricks are used, a thickness of about 12-15 cm

will be required depending upon the density of the material actually used i.e.,

(thickness of concrete) x (2.35 gm/cm3) = thickness x density (of similar material).

Within the x-ray room, there are two specific high-risk areas; the wall behind chest stand and the wall of the dark room. Provided the x-ray unit is properly positioned, the wall of the dark room will need no special protection if it is constructed of at least 10 cm of concrete. At no time should the main x-ray beam ever be pointed at the wall of the dark room, to prevent radiation fogging the stored films.

There are two ways to over come; increased protection as part of the chest x-ray cassette stand or increased protection on the wall itself behind the chest stand. For the farmer chest cassette holder must carry 2 mm of lead equivalent, whereas in the later way; an area, 2 m in height and 1 m wide, centered immediately behind the chest stand must have the Services shielding of 2 rnm of lead equivalent. This can be obtained by increasing the thickness of

the concrete wall to 20 cm, It is worth remembering that simple plate glass of 1cm thickness is equivalent to lm of lead and provides a very satisfactory radiation barrier.

It should be re-emphasized that these calculations provide for more of a margin of safety than is likely to be necessary in a basic radiological facility. However any change in room

dimensions, a more powerful generator oi a large increase in the number of patients will alter these requirements. Normal one brick wall thickness up to 250 mm is considered adequate.

The x-ray control (console) must be designed in such a way that the switch is an integral part of the unit and protection should be incorporated in the design of control panel. There should be a shield of 1 mrn lead equivalent, at least 75 cm wide in front of the control panel and extending 50 cm on either side. It should be 2 m in height and should have a lead glass window with at least 1 mm lead equivalent (25 cm x 25 cm in size) situated in the central panel at eye level, so that operator can see clearly through it. Should there be a requirement for patient to be held then lead protective clothing must be worn.

Standard glass windows do not provide much radiation protection. However there is no radiation hazard provided people do not loiter within 1 m of the window of standard size of x-ray room. If patients wait outside the room, the window should be at least 1.5 m above 1 the floor finish inside. Windows are desirable for both light and ventilation

3.3.2 Radiation Safety Monitoring

It is internationally accepted practice that all personnel who work with ionizing radiation be I continuously monitored to record the dosage received during their work. In diagnostic x-ray department, this is usually done by requiring each operator to wear while at work a small film badge of standard design. A written record must be kept for each wearer. Such a film badge service can only be organized and controlled on a central basis and report must be examined on monthly basis by a radiologist or radiation safety officer.

Other personal methods of protection include the routine use of radiation proof apron (lead j equivalent 2.5 rnrn). These are usually double sided, and racks to support them should be provided in the x-ray room, preferably near the control panel. Protective gloves (lead equivalent 0.3 mm) must also be worn whenever a patient needs to be held by a nurse or aide who will be in the x-ray beam during the exposure.

4-Post-Test

5-Keys of Answers

References