Modern Physics

MODERN PHYSICS

C1A Electromagnetic waves :

Properties of electromagnetic waves :

1. These are transverse waves such that the electric field, the magnetic fields and direction of propogation of the wave are mutually perpendicular to each other.

2. In vacuum the speed of an e.m. wave is given by $\mathbf{c = \frac{1}{\sqrt{\mu_0 \in_0}} = 3 \times 10^8 m/s}$.

3. The direction of propagation is along the vector $\mathbf{S = \frac{1}{\mu_0}(\vec{E} \times \vec{B})}$. $\vec{S}$ is called the Poynting vector. Its S.I. unit is W/m^2.

4. The electric and magnetic fields are related as E = cB.

Classification of Electromagnetic Waves

Name	**Approximate wavelength range**	**Energy**
Gamma Rays	6×10^{-13} m – 10^{-10} m	MeV
X-Rays	10^{-12} m – 10^{-9} m	keV
U.V. Rays	10^{-9} m – 10^{-7} m	4eV to 100 eV
Visible Light	4×10^{-7} m – 7.5×10^{-7} m	2eV to 3eV
Infrared	8×10^{-7} m – 10^{-3} m	mili eV
Microwaves	10^{-3} m – 0.3 m	very less energy
Radiowaves	0.3 m – 10^4 m	very-very small energy

Practice Problems :

1. If $\vec{E}$ and $\vec{B}$ be the electric and magnetic field of electromagnetic waves, then the direction of propagation of e.m. wave is along the direction of

(a) $\vec{E}$ (b) $\vec{B}$ (c) $\vec{E} \times \vec{B}$ (d) None of these

2. The electromagnetic radiations are in descending order of wavelength in the following sequence

(a) infra-red waves, radio waves, X-rays, visible light rays

(b) Radio-waves, infra-red waves, visible light, X-rays

(c) Radio waves, visible light, infra-red waves, X-rays

(d) X-rays, visible light, infra-red wave, radiowaves

3. Consider an electric charge oscillating with a frequency of 10 MHz. The radiation emitted will have a wavelength equal to

(a) 20 m (b) 30 m (c) 40 m (d) 10 m

[Answers : (1) c (2) b (3) b]

C1B Photons :

An electromagnetic wave (light) is quantized, and its quanta are called photons.

Important point for Photons :

1. It is energy carrying particle where energy, E = hν $\Rightarrow E = \frac{hc}{\lambda}$, where λ is the wavelength of photon and c is the velocity of photons (3×10^8 m/s). The above relation is converted in wavelength λ (Å) of a photon of energy E (eV), is given by $\mathbf{\lambda = \frac{12400}{E(eV)} Å}$.

2. Momentum of photon : $\mathbf{p = \frac{E}{c} = \frac{h}{\lambda}}$.

3. If a packet will contain n photons of frequency ν then its energy equals to nhν.

4. Number of photons emitted by a source of power P per unit time is given by $\mathbf{\frac{P}{h\nu}}$.

5. The rest mass of the photon is zero whereas relativistic mass equals to $\mathbf{\frac{E}{c^2}}$, where E is the energy carried by the photons.

6. Photons are chargeless and spinless particle and they are not affected in the presence of electric or magnetic field.

Practice Problems :

1. The momentum of a photon of an electromagnetic radiation is 3.3×10^{-29} kg m/s. The frequency of the associated waves is (h = 6.6×10^{-34} Js, c = 3×10^8 m/s)

(a) 3.0×10^3 Hz (b) 6.0×10^3 Hz (c) 7.5×10^{12} Hz (d) 1.5×10^{13} Hz

2. Which one of the following statements about photons is incorrect ?

(a) Rest mass of a photon is zero

(b) Momentum of a photon of frequency *v* is hv/c

(c) Energy of a photon of frequency *v* is *hv*

(d) Photons exert no pressure

3. An X-ray has a wavelength of 0.010 Å. Its momentum in kg m/s and energy in joule is given by respectively

(a) 2.126×10^{-23}, 4.98×10^{-13} J (b) 3.313×10^{-22}, 3.98×10^{-13} J

(c) 3.456×10^{-25}, 2.98×10^{-13} J (d) 6.626×10^{-22}, 1.98×10^{-13} J

4. Radio waves received by a radio telescope from distant starts may have a wavelength of about 0.20 m. If the speed of the wave is 3×10^8 km/s, then frequency of the wave will be

(a) 6.7×10^{-10} Hz (b) 6.7×10^{-9} Hz

(c) 1.5×10^4 Hz (d) 1.5×10^9 Hz

5. A radio transmitter operates at a frequency of 880 kHz and power of 10 kW. The number of photons per second emitted are

(a) 1.7×10^{31} (b) 1327×10^{34} (c) 13.27×10^{34} (d) 0.075×10^{34}

[Answers : (1) d (2) d (3) d (4) d (5) a]

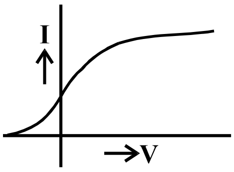
C2 Photoelectric Effect :

The emission of electrons from a metallic surface when irradiated by electromagnetic radiation is called the phenomenon of photoelectric effect. The emitted electrons are called as photoelectrons.

The governing relation is $h\nu = K_{max} + \phi$, in which hν is the photon energy, K_{max} is the kinetic energy of the most energetic emitted electrons, and φ is the work function of the target material – that is, the minimum energy an electron must have if it is to emerge from the surface of the target. If hν is less than φ, the photoelectric effect does not occur.

Effect of Potential Difference

When the frequency and intensity of radiation are kept constant and the positive potential of collector plate is gradually increased, then the photoelectric current i increases with the potential difference V. At some value of the potential difference, when all the emitted photoelectrons are collected then the photoelectric will have the maximum value known as saturation current. On further increasing the potential difference, their is no effect on the current. If the collector plate will make negative and its potential will increase then photo-electric current will decrease. At a certain negative potential the photoelectric current will become zero, this potential is known as stopping potential and the relation between k_{max} and stopping potential V_s is given by $k_{max} = ½mv^2_{max} = eV_s$. The variation of photoelectric current with the potential as shown in the graph :



Effect of frequency

For a given intensity of radiation, if frequency of radiation will increase then maximum kinetic energy of ejected photo electrons will increase and hence the stopping potential will increase.

Effect of intensity

If the frequency remains constant and intensity will increase then photoelectric current at the saturation stage will increase.

Effect of work function

Work function depends on the metallic surface. On changing the metallic surface, for the same frequency of incident radiation, k_{max} will change.

<u>Practice Problems :</u>

1. **The work function of a metal is 4 eV. Which of the following wavelength is not capable to eject the photoelectron or does not give any photoelectric current ?**

   (a) 1700 Å (b) 2700 Å (c) 3100 Å (d) 5900 Å

2. **The work function of a metallic surface is 5.00 eV. Photoelectrons are emitted when light of wavelength 2000 Å falls on it. Choose the correct statement from the following**

   (a) The maximum kinetic energy of the emitted photoelectron is 1.2 eV

   (b) The stopping potential is 1.2 V

   (c) The kinetic energy of the emitted photoelectron is from 0 to 1.2 eV

   (d) All the above statements are correct

3. **The photoelectric threshold wavelength for a metal surface is 6600 Å. The work function for the metal is**

   (a) 1.87 V (b) 1.87 eV (c) 18.7 eV (d) 0.18 eV

4. **The threshold wavelength for photoelectric emission from a material is 5200 Å. Photoelectrons will be emitted when this material is illuminated with monochromatic radiation from a**

   (a) 50 watt infrared lamp (b) 1 watt ultraviolet lamp

   (c) 50 watt ultraviolet lamp (d) both (b) and (c) are correct

5. **If Planck's constant is denoted by h, the electronic charge by e and work function of metallic surface is ϕ then, experiments on photoelectric effect allow the determination of**

   (a) only h (b) only h/e

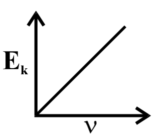
   (c) both h and h/e (d) h, h/e and ϕ

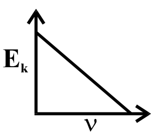
6. **In photoelectric emission the number of electrons ejected per second is proportional to the**

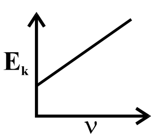
   (a) intensity of light (b) wavelength of light

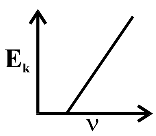
   (c) frequency of light (d) work function of the material

7. **The maximum kinetic energy (E_k) of photoelectrons varies with the frequency (ν) of the incident radiation as**

   (a) 

   (b) 

   (c) 

   (d) 

8. **In photoelectric effect, the photoelectric current**
   - (a) **does not depend on the photon frequency, but only on the intensity of the incident beam**
   - (b) **depends both on the intensity and the frequency of the incident beam**
   - (c) **increases when the frequency of the incident photon increases**
   - (d) **decreases when the frequency of the incident photon increases.**

9. **Stopping potential or maximum kinetic energy of photoelectrons**
   - (a) **does not depend on the frequency of the incident light**
   - (b) **does not depend on the nature of cathode material**
   - (c) **depends on both the frequency of the incident light and the nature of the cathode material**
   - (d) **depends on the intensity of the incident light**

10. **Photons of energy 5 eV, incident on a metalsurface, liberate electrons which are stopped by a negative potential of 3.5 V. The work function of the metal is**
    - (a) **5 eV** (b) **1.5 eV** (c) **7 eV** (d) **17.4 eV**

11. **In a photo-emissive cell, with exciting wavelengths λ, the fastest electron has speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be**
    - (a) $v\,(3/4)^{1/2}$ (b) $v\,(4/3)^{1/2}$
    - (c) less than $v\,(4/3)^{1/2}$ (d) greater than $v\,(4/3)^{1/2}$

[Answers : (1) d (2) d (3) b (4) d (5) d (6) a (7) d (8) a (9) c (10) b (11) d]

C3 de-Broglie Waves

The wavelength of the wave associated with a moving particle is equal to Planck's quantum constant divided by the momentum of the particle and given by $\lambda = \frac{h}{mv}$, where v is the speed of the particle of mass 'm'.

Practice Problems :

1. **Photons of energy 5 eV, incident on a metal surface of work function 4 eV. The minimum de-broglie wavelength of the ejected photoelectron is**
   - (a) **12.27 Å** (b) **1.227 Å** (c) **0.1227 Å** (d) **none**

2. **The kinetic energy of electrons is 10^{-20} J and the photons also have the same energy. The wavelengths associated with these particles are λ_e and λ_{ph} respectively. These wavelengths are related in the following way**
   - (a) $\lambda_{ph} = \lambda_e$ (b) $\lambda_{ph} < \lambda_e$
   - (c) λ_e/λ_{ph} = c (velocity of light) (d) $\lambda_{ph} > \lambda_e$

3. **An electron of mass m, when accelerated through a potential V, has de-Broglie wavelength λ. The de-Broglie wavelength associated with a proton of mass M accelerated through the same potential difference will be**
   - (a) $\lambda\sqrt{\left(\frac{M}{m}\right)}$ (b) $\lambda\sqrt{\left(\frac{m}{M}\right)}$ (c) $\lambda\left(\frac{M}{m}\right)$ (d) $\lambda\left(\frac{m}{M}\right)$

[Answers : (1) a (2) d (3) b]

C4 Atomic Model

In 1911 Ernest Rutherford proposed that the positive charge of the atom is densely concentrated at the center of the atom, forming its nucleus, and that, furthermore, the nucleus is responsible for most of the mass of the atom. Rutherford proposal was based on the results of α-particle scattering experiment.

In 1913, Bohr proposed a model of the hydrogen atom (one electron system) based on a clever combination of classical and early quantum concepts. His basic assumption - that atoms exist in discrete quantum states of well-defined energy for which the magnitude of angular momentum of the electron in such orbits is quantised given by $\mathbf{L = mvr = n\frac{h}{2\pi}} = \mathbf{n}\hbar$ where v is the speed of the electron in the orbit, r is the radius of the orbit, n is the principle quantum number.

The energies of atom are quantized; that is, the atom have only certain specific values of energy associated with different quantum series. Atom can make transitions between different quantum states by emitting or absorbing a photon; the frequency f associated with that light is given by $h\nu = E_{high} - E_{low}$,

where E_{high} is the higher energy and E_{low} is the lower energy of the pair of quantum states involved in the transition. Atoms also have quantized angular momenta and magnetic dipole moments.

Important Points for Bohr Atom

1. Radius of nth orbit : $\mathbf{r = \frac{\epsilon_0 n^2 h^2}{\pi Z e^2 m} = 0.53\frac{n^2}{Z}}$ **Å**

2. Velocity of the electron in the nth orbit : $\mathbf{v = \frac{Ze^2}{2\epsilon_0 nh} = \frac{Z}{n}\left(\frac{c}{137}\right)}$

3. Total Energy of the Electron in the nth orbit : $\mathbf{E_n = \frac{-Z^2e^4m}{8\epsilon_0^2 n^2h^2}}$

   Kinetic energy of the electron in the nth orbit : $K_n = |E_n| = -E_n$

   Potential energy of the electron in the nth orbit : $U_n = -2E_n$

4. Wavelength of photon emitted for a transition from n_2 to n_1

$$\mathbf{\frac{1}{\lambda} = R_\infty Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$$

where $R_\infty = 1.096 \times 10^7\ m^{-1}$ (for a stationary nucleus) is known as Rydberg Constant

If nucleus is not considered to be stationary then $\mathbf{R = \frac{R_\infty}{1+\frac{m}{M}}}$, where m is the mass of electron (revolving particle) and M is the mass of nucleus.

<u>**Practice Problems :**</u>

1. The wavelength of the energy emitted when electron come from fourth orbit to second orbit in hydrogen is 20,397 cm^{-1}. The wavelength of the energy for the same transition in He$^+$ is

(a) 5,099 cm^{-1} (b) 20,497 cm^{-1} (c) 40,994 cm^{-1} (d) 81,988 cm^{-1}

2. When the electron jumps from a level n = 4 to n = 1, momentum of the recoiled hydrogen atom will be

(a) 6.8×10^{-27} kg × m/s (b) 12.75×10^{-19} kg × m/s

(c) 13.6×10^{-19} kg × m/s (d) zero

3. If the series limit wavelength of Lyman series for the hydrogen atom is 912 Å, then the series limit wavelength for the Balmer series of hydrogen atom is

(a) 912 Å (b) 912 × 2 Å (c) 912 × 4 Å (d) (912/2) Å

4. Which of the following statements are true regarding Bohr's model of hydrogen atom ?

I. Orbiting speed of electron decreases as it shifts to discrete orbits away from the nucleus

II. Radii of allowed orbits of electron are proportional to the principal quantum number

III. Frequency with which electron orbits around the nucleus in discrete orbits is inversely proportional to the principal quantum number

IV. Binding force with which the electron is bound to the nucleus increases as it shifts to outer orbits

Select the correct answer using the codes given below :

Codes

(a) I and III (b) II and IV (c) I, II and III (d) II, III and IV

5. If the potential energy of the electron in the first allowed orbit in hydrogen atom is E, its

(a) ionisation potentials is –E/2 (b) kinetic energy is –E/2

(c) total energy is E/2 (d) all of the above statements are true

6. In hydrogen atom H_α-line arise due to transition of electron from 3rd orbit to 2nd orbit. In the spectrum of singly ionised helium there is a line having almost the same wavelength as that of H_α line, this is due to transition of electron between the orbits

(a) 3 to 2 (b) 1 to 2 (c) 5 to 3 (d) 6 to 4

7. The ratio of the frequencies of the long wavelength limits of the Lyman and Balmer series of hydrogen is

(a) 27 : 5 (b) 5 : 27 (c) 4 : 1 (d) 1 : 4

8. E_n and J_n denote the total energy magnitude and the angular momentum of an electron in the nth allowed orbit of a Bohr atom. Then

(a) $E_n \propto J_n$ (b) $E_n \propto 1/J_n$ (c) $E_n \propto J_n^2$ (d) $E_n \propto 1/J_n^2$

9. Consider an electron in the nth orbit of a hydrogen atom in the Bohr model. The circumference of the orbit can be expressed in terms of de-Broglie wavelength λ of that electron as

(a) (0.529) n λ (b) $\sqrt{n}\,\lambda$ (c) (13.6) λ (d) n λ

10. In Bohr model of hydrogen atom, choose the incorrect statement from the following :

(a) the radius of nth orbit is proportional to n^2

(b) the total energy of electron in nth orbit is proportional to n

(c) the angular momentum of the electron in an orbit is an integral multiple of h/2 π

(d) the magnitude of the potential energy of an electron in any orbit is greater than its kinetic energy

11. When a hydrogen atom is raised from the ground state an excited state, then

(a) both K.E. and P.E. decrease

(b) P.E. increases and K.E. decreases

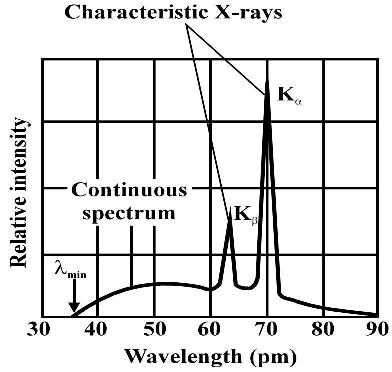
(c) P.E. decreases and K.E. increases

(d) both kinetic energy (K.E.) and potential energy (P.E.) increase

[Answers : (1) a (2) a (3) c (4) a (5) d (6) d (7) b (8) d (9) d (10) b (11) b]

C5 X-rays : X-rays are electromagnetic waves having energy in KeV. When a solid target, such as solid copper or tungsten, is bombarded with electrons whose kinetic energies are in the kiloelectron-volt range, electromagnetic radiation called **X rays** is emitted.

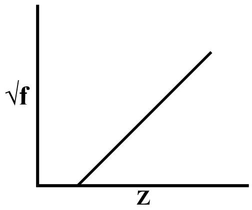
Figure shows the wavelength spectrum of the x rays produced when a beam of 35 KeV electrons falls on a molybdenum target, We see a broad, continuous spectrum of radiation on which are superimposed two peaks of sharply defined wavelengths.



A continuous spectrum x-rays is emitted when high-energy electrons lose some of their energy in a collision with atomic nuclei. The cutoff wavelength λ_{min} is the wavelength emitted when such electrons lose all their initial energy in a single such encounter and is $\lambda_{min} = \frac{hc}{K_0}$, in which K_0 is the initial kinetic energy of the electrons that strike the target.

The characteristic x-ray spectrum arises when high-energy electrons eject electrons from deep within the atom; when a resulting "hole" is filled by an electron from farther out in the atom, a photon of the characteristic x-ray spectrum is generated.

In 1913 British physicist H.G.J. Moseley measured the frequencies of the characteristic x rays from a number of elements. He noted that when the square root of the frequency is plotted against the position of the element in the periodic table, a straight line results, as in the Moseley plot of figure.



This allowed Moseley to conclude that the property that determines the position of an element in the periodic table is not its atomic mass but its atomic number Z - that is, the number of protons in its nucleus. He found that relation between $\sqrt{f}$ and Z, given by $\sqrt{f} = a(Z - b)$, where a and b are constant.

Practice Problems :

1. An X-ray tube is operating at 40 kV, which of the following wavelength will be absent in the X-ray spectrum ?

(a) 0.2 Å (b) 0.4 Å (c) 0.6 Å (d) 100 Å

[Answers : (1) a]

C6 Radioactivity

Most known nuclides are radioactive; they spontaneously decay at a rate R (= – dN/dt) that isproportional to the number N of radioactive atoms present, the proportionally constant being the disintegration constant. This leads to the law of exponential decay : $N = N_0e^{-\lambda t}$, $R = \lambda N = R_0e^{-\lambda t}$

The half-life $T_{1/2} = (\ln 2)/\lambda$ of a radioactive nuclide is the time required for the decay rate R (or the number N) in a sample to drop to half its initial value.

Units of Activity

1 becauerel (Bq) = 1 disintegration per second (dps)

1 curie = 3.7×10^{10} dps

1 rutherford = 10^6 dps

Mean life of a radioactive sample is defined as the average of the lives of all nucleus.

$$T_{av} = \frac{\int_0^\infty N_0e^{-\lambda t}dt}{N_0} = \frac{1}{\lambda} = \frac{T}{0.693}$$

Practice Problems :

1. The decay constant of a radioactive sample is λ. The half life and mean life of the sample are respectively given by

(a) 1/λ and (ln2)/λ (b) (ln2)/λ and 1/λ

(c) λ(ln2) and 1/λ (d) λ/(ln2) and 1/λ

2. **Plutonium decays with a half life of 24000 years. If plutonium is stored for 72000 years, the fraction of it has remains is**

(a) 1/2 (b) 1/3 (c) 1/4 (d) 1/8

3. **The half life of Bi^{210} is 5 days. If we start with 50,000 atoms of this isotope, the number of atoms left over after 10 days is**

(a) 5,000 (b) 25,000 (c) 12,500 (d) 20,000

4. **A radioactive isotope X with a half-life of 1.37×10^9 years decays to Y which is stable. A sample of rocks from the moon was found to contain both the elements X and Y which were in the ratio 1 : 7. The age of the rocks is**

(a) 1.96×10^8 years (b) 3.85×10^9 years

(c) 4.11×10^9 years (d) 9.59×10^9 years

5. **The radioactivity of a sample is R_1 at a time T_1 and R_2 at a time T_2. If the half-life of the specimen is T, the number of atoms that have disintegrated in the time $(T_2 - T_1)$ is proportional to**

(a) $(R_1T_1 - R_2T_2)$ (b) $(R_1 - R_2)$ (c) $(R_1 - R_2)/T$ (d) $(R_1 - R_2)T$

6. **The decay constant for the radioactive isotope ^{57}Co is $3 \times 10^{-8}\ s^{-1}$. The number of disintegrations taking place in a milligram of pure ^{57}Co per second is**

(a) 10^{16} (b) 3×10^{11} (c) 3×10^6 (d) 3×10^7

7. **The half life of radium is 1620 years and its atomic weight is 226 kg per kilomol. The number of atoms that will decay from its 1 g sample per second will be**

(a) 3.61×10^{10} (b) 3.61×10^{12} (c) 3.11×10^{15} (d) 3.11×10^{16}

8. **A freshly prepared radioactive source of half life 2 hr. emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is**

(a) 6 hr (b) 12 hr (c) 24 hr (d) 128 hr

9. **Which of the following statement is true ?**

I. All radioactive elements decay exponentially with time.

II. Half life time of a radioactive element is the time required for one half of the radioactive atoms to disintegrate.

III. Age of the earth can be determined by radioactive dating

IV. Half-life time of a radioactive element is fifty per cent its average life period

Select the correct answer using the codes given below :

(a) I and II (b) I, III and IV (c) I, II and III (d) II and III

10. **What percentage of original radio active atoms is left after five half lives**

(a) 20% (b) 10% (c) 5% (d) 3.125%

11. The count-rate of Geiger Muller counter for the radiation of the α**-radioactive material of half-life of 30 minutes decrease to 5 $second^{-1}$ after 2 hours. The initial count rate was**

(a) 20 $second^{-1}$ (b) 25 $second^{-1}$ (c) 80 $second^{-1}$ (d) 625 $second^{-1}$

[Answers : (1) b (2) d (3) c (4) c (5) d (6) b (7) a (8) b (9) c (10) d (11) c]

C7 Mass-Energy Equivalence

An object of mass m and the energy equivalent E of that mass are related by $E = mc^2$. The energy equivalent of one amu is 931.5 MeV.

C8 About the Nucleus

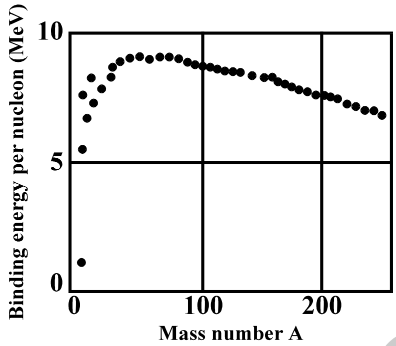
1. Nuclei have a mean radius r given by $r = r_0A^{1/3}$ where $r_0 = 1.2$ fm and A is the mass number.
2. The density of the nucleus is of the order of $10^{17}\ kg/m^3$.
3. Nuclei in the nucleus are held together by an attractive force (known as nuclear force) acting among the mucleous. It is thought to be a secondary effect of the strong force acting between the quarks that make up the nucleons. Nuclear force is the strongest force in nature.

4. The mass M of a nucleus is less than the total mass $\sum \mathbf{m}$ of its individual protons and neutrons. That means that the mass energy Mc^2 of a nucleus is less than the total mass energy $\sum(\mathbf{mc^2})$ of its individual protons and neutrons. The difference between these two energies is called the binding energy of the neucleus $\Delta E_{be} = \sum(\mathbf{mc^2}) - \mathbf{Mc^2}$.

   Binding energy per neucleon ΔE_{ben}, which is the ratio of the binding energy ΔE_{be} of a nucleus to the number A of nucleons in that nucleus : $\mathbf{\Delta E_{ben} = \frac{\Delta E_{be}}{A}}$.

5. The average binding energy per nucleon is about 8.8 MeV/nucleon.

6. The variation of average binding energy per nucleon with mass number A is as shown in figure



The nucleons in a nucleus on the right side of the plot would be more tightly bound if that nucleus were to split into two nuclei that lie near the top of the plot. Such a process, called fission, occurs naturally with large (high mass number A) nuclei such as uranium, which can undergo fission spontaneously (that is, without an external cause of source of energy). The process can also occur in nuclear weapons in which many uranium or plutonium nuclei are made to fission all at once, to create an explosion.

The nucleons in any pair of nuclei on the left side of the plot would be more tightly bound if the pair were to combine to form a single nucleus that lies near the top of the plot. Such a process, called fusion, occurs naturally in stars. Were this not true, the Sun would not shine and thus life could not exist on Earth.

7. **Decay Process**

   Alpha decay $\quad {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

   Beta decay (β^-) $\quad {}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + e^- + \bar{\nu}$

   Beta decay (β^+) $\quad {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + e^+ + \nu$

   Electron capture $\quad {}^{A}_{Z}X + e^- \longrightarrow {}^{A}_{Z-1}Y + \nu$ + x-ray

   Gamma decay $\quad {}^{A}_{Z}X^* \longrightarrow {}^{A}_{Z}X + \gamma$

8. **Nuclear reactions** can occur when a target nucleus X is bombarded by a particle a, resulting in a nucleus Y and an outgoing particle b :

   $a + X \rightarrow Y + b$ or X(a, b)Y

   The rest energy transformed to kinetic energy in such a reaction, called the reaction energy Q, is $Q = (M_a + M_X - M_Y - M_b)c^2$

A reaction for which Q is positive is called exothermic. A reaction for which Q is negative is called endothermic. The minimum kinetic energy of the incoming particle necessary for such a reaction to occur is called the threshold energy.

Practice Problems :

1. The volume of a nucleus directly proportional to A^x where A is mass number of the nucleus. The value of x is

(a) 1 (b) 2 (c) 3 (d) 4

2. Which of the following is incorrect for nuclear force ?

(a) short range force (b) charge independent force

(c) strongly attractive force (d) all are incorrect

3. In positive beta decay, which of the following particles will be emmited ?

(a) positron and neutrino (b) electron and antineutrino

(c) positron and antineutrino (d) electron and neutrino

4. During a negative beta decay

(a) an atomic electron is ejected

(b) an electron which is already present within the nucleus is ejected

(c) a neutron in the nucleus decays emitting an electron

(d) a part of the binding energy of the nucleus is converted into an electron

5. The radioactive nuclide $^{228}_{88}Ra$ decays by the emission of three α-particles and one β^- particle. The nuclide X finally formed is

(a) $^{220}_{84}X$ (b) $^{222}_{86}X$ (c) $^{216}_{83}X$ (d) $^{215}_{88}X$

6. In the transformation sequence represented by $^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y \rightarrow ^{A-4}_{Z-2}Y \rightarrow ^{A-4}_{Z-1}K$ the decays are in the order

(a) α, β, γ (b) β, γ, β (c) γ, α, β (d) α, γ, β

7. A nucleus ruptures into two nuclear parts which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear size (nuclear radius) ?

(a) $2^{1/3} : 1$ (b) $1 : 2^{1/3}$ (c) $3^{1/2} : 1$ (d) $1 : 3^{1/2}$

8. In a β-decay

(a) the parent and the daughter nuclei have the same number of protons

(b) the daughter nucleus has one proton less than the parent nucleus

(c) the daughter nucleus has one proton more than the parent nucleus

(d) the daughter nucleus has one neutron more than the parent nucleus

9. If the binding energy of deutron is 2.23 MeV, its mass defect in atomic mass unit is

(a) –0.0012 (b) 0.0012 (c) 0.0024 (d) –0.0024

10. Which of the following is a fusion reaction ?

(a) $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$ (b) $^{1}_{0}n + ^{14}_{7}N \rightarrow ^{14}_{6}C + ^{1}_{1}H$

(c) $^{1}_{0}n + ^{238}_{92}U \rightarrow ^{239}_{93}Np + \beta^- + \gamma$ (d) $^{3}_{1}H \rightarrow ^{3}_{2}He + \beta^- + \gamma$

11. If the total binding energies of $^{2}_{1}H$, $^{4}_{2}He$, $^{56}_{26}Fe$ and $^{235}_{92}U$ nuclei are 2.22, 28.3, 492 and 1786 MeV respectively, identify the most stable nucleus out of the following

(a) $^{56}_{26}Fe$ (b) $^{2}_{1}H$ (c) $^{235}_{92}U$ (d) $^{4}_{2}He$

12. When $^{235}_{92}U$ undergoes fission, 0.1% of its original mass is changed into energy. How much energy is released if 1 kg of $^{235}_{92}U$ undergoes fission ?

(a) 9×10^{10} J (b) 9×10^{11} J (c) 9×10^{12} J (d) 9×10^{13} J

13. **Choose the correct statement for nuclear fission :**

(a) **In this process the neutrons split the uranium nuclei into two fragments of about the same size (barium & krypton) and several neutrons.**

(b) **The energy released per fission of ^{235}U is 200 MeV**

(c) **Nuclear reactor is based on controlled nuclear fission**

(d) **All are correct**

14. **Choose the correct statement for the nuclear fusion :**

(a) **This process takes place at very high temperature**

(b) **The link of this process are protons**

(c) **The source of energy at sun is nuclear fusion**

(d) **All are correct**

15. **Choose the correct statement :**

(a) **The binding energy per nucleon is maximum for Fe**

(b) **The average binding energy per nucleon is of the order of 7.5 MeV**

(c) **Both (a) & (b) are correct**

(d) **None of these**

16. **In nuclear reactions we have conservation of**

(a) **mass only** **(b)** **momentum only**

(c) **energy only** **(d)** **mass, energy and momentum**

17. **The ratio of the radii of the nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$ is approximately**

(a) **6 : 10** **(b)** **13 : 52** **(c)** **40 : 177** **(d)** **14 : 73**

[Answers : (1) a (2) d (3) a (4) c (5) c (6) d (7) b (8) c (9) c (10) a (11) a (12) d (13) d (14) d (15) c (16) b (17) a]