Chapter
26
Atomic and Nuclear Physics

Thomson's Atomic Model

J.J. Thomson gave the first idea regarding structure of atom. According to this model.

(1) An atom is a solid sphere in which entire and positive charge and it's mass is uniformly distributed and in which negative charge (*i.e.* electron) are embedded like seeds in watermelon.

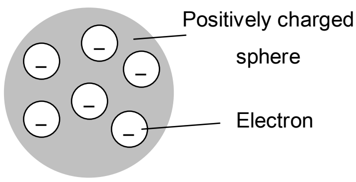


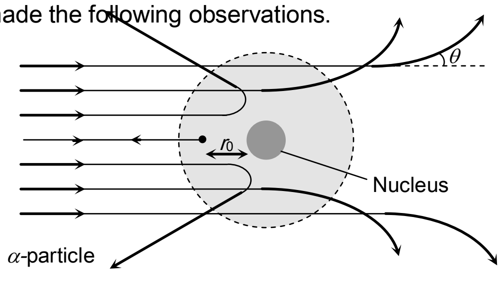
Fig. 26.1

(2) This model explained successfully the phenomenon of thermionic emission, photoelectric emission and ionization.

(3) The model fail to explain the scattering of α- particles and it cannot explain the origin of spectral lines observed in the spectrum of hydrogen and other atoms.

α-Scattering Experiment

'Geiger and Marsden (students of Rutherford) studied the scattering of α-particles by gold foil on the advice of Rutherford and made the following observations.



(1) Most of the α-particles pass through the foil straight away undeflected.

(2) Some of them are deflected through small angles.

(3) A few α-particles (1 in 1000) are deflected through the angle more than 90°.

(4) A few α-particles (very few) returned back *i.e.* deflected by 180°.

(5) Number of scattered particles : $N \propto \dfrac{1}{\sin^4(\theta/2)}$

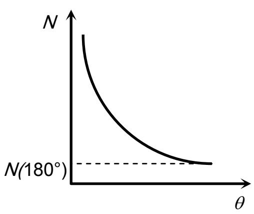


Fig. 26.3

(6) If t is the thickness of the foil and N is the number of α-particles scattered in a particular direction (*i.e.* θ = constant), it was observed that $\frac{N}{t} = \text{constant} \Rightarrow \frac{N_1}{N_2} = \frac{t_1}{t_2}$

(7) **Distance of closest approach** (Nuclear dimension) :

The minimum distance from the nucleus up to which the α-particle approach, is called the distance of closest approach (r_0). At this distance the entire initial kinetic energy has been converted into potential energy so

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}.\frac{(Ze)2e}{r_0} \Rightarrow r_0 = \frac{Ze^2}{mv^2\pi\varepsilon_0} = \frac{4kZe^2}{mv^2}$$

(8) **Impact parameter** (b) : The perpendicular distance of the velocity vector ($\vec{v}$) of the α-particle from the centre of the nucleus when it is far away from the nucleus is known as impact parameter. It is given as

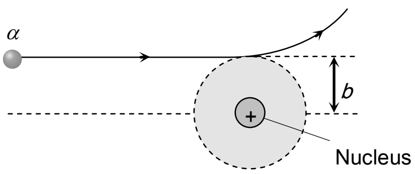


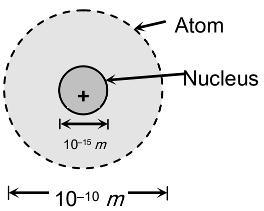
Fig. 26.4

$$b = \frac{Ze^2 \cot(\theta/2)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)} \Rightarrow b \propto \cot(\theta/2)$$

For large b, α particles will go undeviated and for small b the α-particle will suffer large scattering.

Rutherford's Atomic Model

After α-particles scattering experiment, following conclusions were made by Rutherford as regard as atomic structure :



Size of the nucleus = 1 *Fermi* = 10^{-15} *m*

Size of the atom 1 Å = 10^{-10} *m*

Fig. 26.5

(1) Most of the mass (at least 99.95%) and all of the charge of an atom concentrated in a very small region is called atomic nucleus.

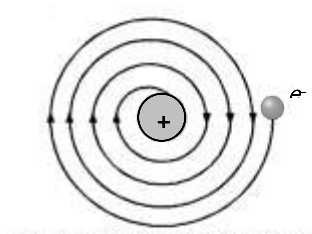
(2) Nucleus is positively charged and it's size is of the order of

10^{-15} *m* $\approx$ 1 *Fermi*. The nucleus occupies only about 10^{-12} of the total volume of the atom or less.

(3) In an atom there is maximum empty space and the electrons revolve around the nucleus in the same way as the planets revolve around the sun.

Failure of Rutherford's Model

(1) **Stability of atom :** It could not explain stability of atom because according to classical electrodynamics theory an accelerated charged particle should continuously radiate energy. Thus an electron moving in an circular path around the nucleus should ıove into smaller and smaller orb us and it should ultimately fall int



Instability of atom

Fig. 26.6

(2) According to this model the spectrum of atom must be continuous where as practically it is a line spectrum.

(3) It did not explain the distribution of electrons outside the nucleus.

Bohr's Atomic Model

Bohr proposed a model for hydrogen atom which is also applicable for some lighter atoms in which a single electron revolves around a stationary nucleus of positive charge Ze (called hydrogen like atom)

Bohr's model is based on the following postulates.

(1) He postulated that an electron in an atom can move around the nucleus in certain circular stable orbits without emitting radiations.

(2) Bohr found that the magnitude of the electron's

Angular momentum is quantized *i.e.* $L = mv_n r_n = n\left(\frac{h}{2\pi}\right)$

where n = 1, 2, 3, ... each value of n corresponds to a permitted value of the orbit radius.

r_n = Radius of n^{th} orbit, v_n = corresponding speed

(3) The radiation of energy occurs only when an electron jumps from one permitted orbit to another.

When electron jumps from higher energy orbit (E_2) to lower energy orbit (E_1) then difference of energies of these orbits *i.e.* $E_2 - E_1$ emits in the form of photon. But if electron goes from E_1 to E_2 it absorbs the same amount of energy.

Draw Backs of Bohr's Atomic Model

(1) It is valid only for one electron atoms, *e.g.* : H, He^+, Li^{+2}, Na^{+1} *etc.*

(2) Orbits were taken as circular but according to Sommerfield these are elliptical.

(3) Intensity of spectral lines could not be explained.

(4) Nucleus was taken as stationary but it also rotates on its own axis.

(5) It could not be explained the minute structure in spectrum line.

(6) This does not explain the Zeeman effect (splitting up of spectral lines in magnetic field) and Stark effect (splitting up in electric field)

(7) This does not explain the doublets in the spectrum of some of the atoms like sodium (5890 Å & 5896 Å)

Bohr's Orbits (for Hydrogen and H_2-like Atoms)

(1) **Radius of orbit :** For an electron around a stationary nucleus the electrostatics force of attraction provides the necessary centripetal force

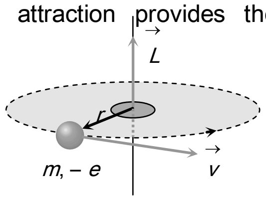


Fig. 26.7

i.e. $\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r^2} = \frac{mv^2}{r}$ …. (i)

also $mvr = \frac{nh}{2\pi}$ ….(ii)

From equation (i) and (ii) radius of n^{th} orbit

$$r_n = \frac{n^2h^2}{4\pi^2kZme^2} = \frac{n^2h^2\varepsilon_0}{\pi mZe^2} = 0.53\frac{n^2}{Z}\text{Å} \qquad \left(k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$\Rightarrow r_n \propto \frac{n^2}{Z}$$

(2) **Speed of electron :** From the above relations, speed of electron in n^{th} orbit can be calculated as

$$v_n = \frac{2\pi kZe^2}{nh} = \frac{Ze^2}{2\varepsilon_0 nh} = \left(\frac{c}{137}\right).\frac{Z}{n} = 2.2\times10^6\,\frac{Z}{n}\,m/sec$$

where (c = speed of light 3×10^8 *m/s*)

Table 26.1 : Some other quantities for revolution of electron in n^{th} orbit

Quantity	Formula	Dependency on n and Z
(1) Angular speed	$\omega_n = \frac{v_n}{r_n} = \frac{\pi mz^2e^4}{2\varepsilon_0^2n^3h^3}$	$\omega_n \propto \frac{Z^2}{n^3}$
(2) Frequency	$\nu_n = \frac{\omega_n}{2\pi} = \frac{mz^2e^4}{4\varepsilon_0^2n^3h^3}$	$\nu_n \propto \frac{Z^2}{n^3}$
(3) Time period	$T_n = \frac{1}{\nu_n} = \frac{4\varepsilon_0^2n^3h^3}{mz^2e^4}$	$T_n \propto \frac{n^3}{Z^2}$
(4) Angular momentum	$L_n = mv_nr_n = n\left(\frac{h}{2\pi}\right)$	$L_n \propto n$
(5) Corresponding current	$i_n = e\nu_n = \frac{mz^2e^5}{4\varepsilon_0^2n^3h^3}$	$i_n \propto \frac{Z^2}{n^3}$
(6) Magnetic moment	$M_n = i_nA = i_n(\pi r_n^2)$ (where $\mu_0 = \frac{eh}{4\pi m}$ = Bohr magneton)	$M_n \propto n$
(7) Magnetic field	$B = \frac{\mu_0 i_n}{2r_n} = \frac{\pi m^2z^3e^7\mu_0}{8\varepsilon_0^3n^5h^5}$	$B \propto \frac{Z^3}{n^5}$

Energy

(1) **Potential energy :** An electron possesses some potential energy because it is found in the field of nucleus potential energy of electron in n^{th} orbit of radius r_n is given by $U = k.\frac{(Ze)(-e)}{r_n} = -\frac{kZe^2}{r_n}$

(2) **Kinetic energy :** Electron posses kinetic energy because of it's motion. Closer orbits have greater kinetic energy than outer ones.

As we know $\frac{mv^2}{r_n} = \frac{k.(Ze)(e)}{r_n^2}$

$\Rightarrow$ Kinetic energy $K = \frac{kZe^2}{2r_n} = \frac{|U|}{2}$

(3) **Total energy :** Total energy (E) is the sum of potential energy and kinetic energy *i.e.* $E = K + U$

$\Rightarrow \quad E = -\frac{kZe^2}{2r_n}$ also $r_n = \frac{n^2h^2\varepsilon_0}{\pi mze^2}$.

Hence $E = -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right).\frac{z^2}{n^2} = -\left(\frac{me^4}{8\varepsilon_0^2ch^3}\right)ch\frac{z^2}{n^2}$

$$= -R\,ch\frac{Z^2}{n^2} = -13.6\frac{Z^2}{n^2}eV$$

where $R = \frac{me^4}{8\varepsilon_0^2ch^3}$ = Rydberg's constant = 1.09×10^7 *per m*.

(4) **Ionisation energy and potential :** The energy required to ionise an atom is called ionisation energy. It is the energy required to make the electron jump from the present orbit to the infinite orbit.

Hence $E_{ionisation} = E_\infty - E_n = 0 - \left(-13.6\frac{Z^2}{n^2}\right) = +\frac{13.6Z^2}{n^2}eV$

For H_2-atom in the ground state

$$E_{ionisation} = \frac{+13.6(1)^2}{n^2} = 13.6\,eV$$

The potential through which an electron need to be accelerated so that it acquires energy equal to the ionisation energy is called ionisation potential. $V_{ionisation} = \frac{E_{ionisation}}{e}$

(5) **Excitation energy and potential :** When energy is given to an electron from external source, it jumps to higher energy level. This phenomenon is called excitation.

The minimum energy required to excite an atom is called excitation energy of the particular excited state and corresponding potential is called exciting potential.

$E_{Excitation} = E_{Final} - E_{Initial}$ and $V_{Excitation} = \frac{E_{excitation}}{e}$

(6) **Binding energy (B.E.) :** Binding energy of a system is defined as the energy released when it's constituents are brought from infinity to form the system. It may also be defined as the energy needed to separate it's constituents to large distances. If an electron and a proton are initially at rest and brought from large distances to form a hydrogen atom, 13.6 *eV* energy will be released. The binding energy of a hydrogen atom is therefore 13.6 *eV*.

(7) **Energy level diagram :** The diagrammatic description of the energy of the electron in different orbits around the nucleus is called energy level diagram.

Table 26.2 : Energy level diagram of hydrogen/hydrogen like atom

	Principle quantum number	Orbit	Excited state	Energy for H_2 – atom
– – – – – –	$n = \infty$	Infinite	Infinite	0 *eV*
――――	$n = 4$	Fourth	Third	– 0.85 *eV*
――――	$n = 3$	Third	Second	– 1.51 *eV*
――――	$n = 2$	Second	First	– 3.4 *eV*
	$n = 1$	First	Ground	– 13.6 *eV*

Transition of Electron

When an electron makes transition from higher energy level having energy $E_2(n_2)$ to a lower energy level having energy E_1 (n_1) then a photon of frequency ν is emitted

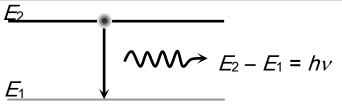


Fig. 26.8

(1) **Energy of emitted radiation**

$$\Delta E = E_2 - E_1 = \frac{-Rch\,Z^2}{n_2^2} - \left(-\frac{Rch\,Z^2}{n_1^2}\right)$$

$$= 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(2) **Frequency of emitted radiation**

$$\Delta E = h\nu \Rightarrow \nu = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h} = Rc\,Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(3) **Wave number/wavelength**

Wave number is the number of waves in unit length $\bar{\nu} = \frac{1}{\lambda} = \frac{\nu}{c} \Rightarrow \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{13.6Z^2}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

(4) **Number of spectral lines** : If an electron jumps from higher energy orbit to lower energy orbit it emits raidations with various spectral lines.

If electron falls from orbit n_2 to n_1 then the number of spectral lines emitted is given by

$$N_E = \frac{(n_2 - n_1 + 1)(n_2 - n_1)}{2}$$

If electron falls from n^{th} orbit to ground state (*i.e.* $n_2 = n$ and $n_1 = 1$) then number of spectral lines emitted $\boldsymbol{N_E = \frac{n\,(n-1)}{2}}$

(5) **Recoiling of an atom** : Due to the transition of electron, photon is emitted and the atom is recoiled

Recoil momentum of atom = momentum of photon $= \frac{h}{\lambda} = hRZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Also recoil energy of atom $= \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$ (where m = mass of recoil atom)

Hydrogen Spectrum and Spectral Series

When hydrogen atom is excited, it returns to its normal unexcited (or ground state) state by emitting the energy it had absorbed earlier. This energy is given out by the atom in the form of radiations of different wavelengths as the electron jumps down from a higher to a lower orbit. Transition from different orbits cause different wavelengths, these constitute spectral series which are characteristic of the atom emitting them. When observed through a spectroscope, these radiations are imaged as sharp and straight vertical lines of a single colour.

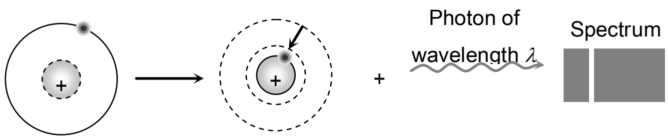


Fig. 26.9 : Emission spectra

The spectral lines arising from the transition of electron forms a spectra series.

(1) Mainly there are five series and each series is named after it's discover as Lymen series, Balmer series, Paschen series, Bracket series and Pfund series.

(2) According to the Bohr's theory the wavelength of the radiations emitted from hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \lambda = \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)R} = \frac{n_1^2}{\left(1 - \frac{n_1^2}{n_2^2}\right)R}$$

where n_2 = outer orbit (electron jumps from this orbit), n_1 = inner orbit (electron falls in this orbit)

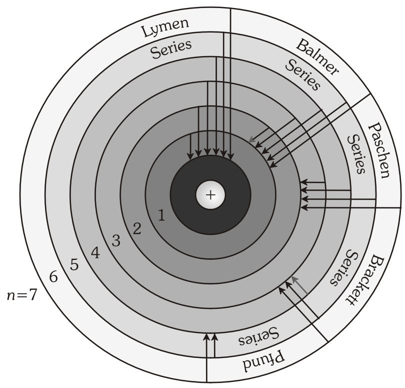


Fig. 26.10

(3) First line of the series is called first member, for this line wavelength is maximum (λ_{max})

For maximum wavelength if $n_1 = n$ then $n_2 = n + 1$

So $\lambda_{max} = \frac{n^2(n+1)^2}{(2n+1)R}$

(4) Last line of the series is called series limit, for this line wavelength is minimum (λ_{min})

For minimum wavelength $n_2 = \infty, n_1 = n$ So $\lambda_{min} = \frac{n^2}{R}$

(5) The ratio of first member and series limit can be calculated as $\frac{\lambda_{max}}{\lambda_{min}} = \frac{(n+1)^2}{(2n+1)}$

Table 26.3 : Different spectral series

Spectral series	Transition	λ_{max}	λ_{min}	$\frac{\lambda_{max}}{\lambda_{min}}$	Region
1. Lymen series	$n_2 = 2, 3, 4 \ldots\infty$ $n_1 = 1$	$\frac{4}{3R}$	$\frac{1}{R}$	$\frac{4}{3}$	Ultraviolet region
2.Balmer series	$n_2 = 3, 4, 5 \ldots\infty$ $n_1 = 2$	$\frac{36}{5R}$	$\frac{4}{R}$	$\frac{9}{5}$	Visible region
3. Paschen series	$n_2 = 4, 5, 6 \ldots\infty$ $n_1 = 3$	$\frac{144}{7R}$	$\frac{9}{R}$	$\frac{16}{7}$	Infrared region
4. Bracket series	$n_2 = 5, 6, 7 \ldots \infty$ $n_1 = 4$	$\frac{400}{9R}$	$\frac{16}{R}$	$\frac{25}{9}$	Infrared region
5. Pfund series	$n_2 = 6, 7, 8 \ldots \infty$ $n_1 = 5$	$\frac{900}{11R}$	$\frac{25}{R}$	$\frac{36}{11}$	Infrared region

Quantum Numbers

An atom contains large number of shells and subshells. These are distinguished from one another on the basis of their size, shape and orientation (direction) in space. The parameters are expressed in terms of different numbers called quantum number.

Quantum numbers may be defined as a set of four number with the help of which we can get complete information about all the electrons in an atom. It tells us the address of the electron *i.e.* location, energy, the type of orbital occupied and orientation of that orbital.

(1) **Principal Quantum number (*n*) :** This quantum number determines the main energy level or shell in which the electron is present. The average distance of the electron from the nucleus and the energy of the electron depends on it.

$E_n \propto \frac{1}{n^2}$ and $r_n \propto n^2$ (in *H*-atom)

The principal quantum number takes whole number values, $n = 1, 2, 3, 4, \ldots.. \infty$

(2) **Orbital quantum number (*l*) or azimuthal quantum number (*l*) :** This represents the number of subshells present in the main shell. These subsidiary orbits within a shell will be denoted as 1, 2, 3, 4 … or *s*, *p*, *d*, *f* … This tells the shape of the subshells.

The orbital angular momentum of the electron is given as $L = \sqrt{l(l+1)}\frac{h}{2\pi}$ (for a particular value of *n*).

For a given value of *n* the possible values of *l* are $l = 0, 1, 2, \ldots..$ upto $(n - 1)$

(3) **Magnetic quantum number (m_l) :** An electron due to it's angular motion around the nucleus generates an electric field. This electric field is expected to produce a magnetic field. Under the influence of external magnetic field, the electrons of a subshell can orient themselves in certain preferred regions of space around the nucleus called orbitals.

The magnetic quantum number determines the number of preferred orientations of the electron present in a subshell.

The angular momentum quantum number *m* can assume all integral value between $-l$ to $+l$ including zero. Thus m_l can be $-1, 0, +1$ for $l = 1$. Total values of m_l associated with a particular value of *l* is given by $(2l + 1)$.

(4) **Spin (magnetic) quantum number (m_s) :** An electron in atom not only revolves around the nucleus but also spins about its own axis. Since an electron can spin either in clockwise direction or in anticlockwise direction. Therefore for any particular value of magnetic quantum number, spin quantum number can have two values, *i.e.* $m_s = \frac{1}{2}$ (Spin up) or $m_s = -\frac{1}{2}$ (Spin down)

This quantum number helps to explain the magnetic properties of the substance.

Table 26.4 : Quantum states of the hydrogen atom

n	l	m_l	Spectroscopic notation	Shell
1	0	0	1 *s*	*K*
2	0	0	2 *s*	*L*
2	1	– 1, 0, 1	2 *p*	
3	0	0	3 *s*	
3	1	– 1, 0, 1	3 *p*	*M*
3	2	– 2, – 1, 0, 1, 2	3 *d*	
4	0	0	4 *s*	*N*

Electronic Configurations of Atoms

The distribution of electrons in different orbitals of an atom is called the electronic configuration of the atom. The filling of electrons in orbitals is governed by the following rules.

(1) **Pauli's exclusion principle :** "It states that no two electrons in an atom can have all the four quantum number (n, l, m_l and m_s) the same."

It means each quantum state of an electron must have a different set of quantum numbers n, l, m_l and m_s. This principle sets an upper limit on the number of electrons that can occupy a shell.

N_{max} in one shell = $2n^2$; Thus N_{max} in *K*, *L*, *M*, *N* …. shells are 2, 8, 18, 32,

(2) **Aufbau principle :** Electrons enter the orbitals of lowest energy first.

As a general rule, a new electron enters an empty orbital for which ($n + l$) is minimum. In case the value $(n+l)$ is equal for two orbitals, the one with lower value of n is filled first.

Thus the electrons are filled in subshells in the following order (memorize)

1*s*, 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, 6*s*, 4*f*, 5*d*, 6*p*, 7*s*, 5*f*, 6*d*, 7*p*, ……

(3) **Hund's Rule :** When electrons are added to a subshell where more than one orbital of the same energy is available, their spins remain parallel. They occupy different orbitals until each one of them has at least one electron. Pairing starts only when all orbitals are filled up.

Pairing takes place only after filling 3, 5 and 7 electrons in *p*, *d* and *f* orbitals, respectively.

Nucleus

(1) Rutherford's α-scattering experiment established that the mass of atom is concentrated with small positively charged region at the centre which is called 'nucleus'.

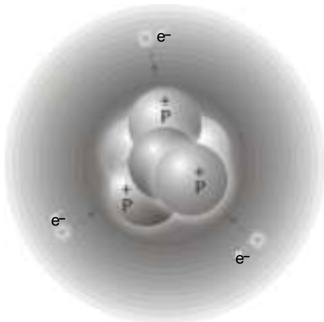


Fig. 26.11

(2) The stability or instability of a particular nucleus is determined by the competition between the attractive nuclear force among the protons and neutrons and the repulsive electrical interactions among the protons. Unstable nuclei *decay*, transforming themselves spontaneously into other structure by a variety of decay processes.

(3) We could not survive without the 3.90×10^{26} *watt* output of one near by fusion reactor, our sun.

(4) Nuclei are made up of proton and neutron. The number of protons in a nucleus (called the atomic number or proton number) is represented by the symbol *Z*. The number of neutrons (neutron number) is represented by *N*. The total number of neutrons and protons in a nucleus is called it's mass number *A* so $A = Z + N$.

(5) Neutrons and proton, when described collectively are called ***nucleons***. A single nuclear species having specific values of both *Z* and *N* is called a nuclide.

(6) Nuclides are represented as ${}_ZX^A$; where *X* denotes the chemical symbol of the element.

Neutron

Neutron is a fundamental particle which is essential constituent of all nuclei except that of hydrogen atom. It was discovered by Chadwick. A free neutron outside the nucleus is unstable and decays into proton and electron.

$${}_0n^1 \rightarrow \underset{\text{Proton}}{{}_1H^1} + \underset{\text{Electron}}{{}_{-1}\beta^0} + \underset{\text{Antinutrino}}{\bar{\nu}}$$

(1) The charge of neutron : It is neutral

(2) The mass of neutron : 1.6750×10^{-27} *kg*

(3) It's spin angular momentum : $\frac{1}{2} \times \left(\frac{h}{2\pi}\right) J\text{-}s$

(4) It's magnetic moment : 9.57×10^{-27} *J/Tesla*

(5) It's half life : 12 minutes

(6) Penetration power : High

(7) Types : Neutrons are of two types slow neutron and fast neutron, both are fully capable of penetrating a nucleus and causing artificial disintegration.

Thermal Neutrons

Fast neutrons can be converted into slow neutrons by certain materials called moderator's (Paraffin wax, heavy water, graphite) when fast moving neutrons pass through a moderator, they collide with the molecules of the moderator, as a result of this, the energy of moving neutron decreases while that of the molecules of the moderator increases. After sometime they both attains same energy. The neutrons are then in thermal equilibrium with the molecules of the moderator and are called thermal neutrons.

Energy of thermal neutron is about 0.025 *eV* and speed is about 2.2 *km/s*.

Types of Nuclei

The nuclei have been classified on the basis of the number of protons (atomic number) or the total number of nucleons (mass number) as follows

(1) **Isotopes :** The atoms of element having same atomic number but different mass number are called isotopes. All isotopes have the same chemical properties. The isotopes of some elements are the following

$${}_1H^1,\ {}_1H^2,\ {}_1H^3 \qquad {}_8O^{16},\ {}_8O^{17},\ {}_8O^{18} \qquad {}_2He^3,\ {}_2He^4$$
$${}_{17}Cl^{35},\ {}_{17}Cl^{37} \qquad {}_{92}U^{235},\ {}_{92}U^{238}$$

(2) **Isobars :** The nuclei which have the same mass number (*A*) but different atomic number (*Z*) are called isobars. Isobars occupy different positions in periodic table so all isobars have different chemical properties. Some of the examples of isobars are

$${}_1H^3 \text{ and } {}_2He^3,\quad {}_6C^{14} \text{ and } {}_7N^{14},\ {}_8O^{17} \text{ and } {}_9F^{17}$$

(3) **Isotones :** The nuclei having equal number of neutrons are called isotones. For them both the atomic number (*Z*) and mass number (*A*) are different, but the value of (*A* – *Z*) is same. Some examples are

$${}_4Be^9 \text{ and } {}_5B^{10},\ {}_6C^{13} \text{ and } {}_7N^{14},\ {}_8O^{18} \text{ and } {}_9F^{19}$$
$${}_3Li^7 \text{ and } {}_4Be^8,\ {}_1H^3 \text{ and } {}_2He^4$$

(4) **Mirror nuclei :** Nuclei having the same mass number *A* but with the proton number (*Z*) and neutron number (*A* – *Z*) interchanged (or whose atomic number differ by 1) are called mirror nuclei for example.

$_1H^3$ and $_2He^3$, $_3Li^7$ and $_4Be^7$

Size of Nucleus

(1) **Nuclear radius :** Experimental results indicates that the nuclear radius is proportional to $A^{1/3}$, where A is the mass number of nucleus *i.e.* $R \propto A^{1/3} \Rightarrow R = R_0 A^{1/3}$, where R_0 = $1.2 \times 10^{-15}\ m = 1.2\ fm$.

(2) **Nuclear volume :** The volume of nucleus is given by $V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A \Rightarrow V \propto A$

(3) **Nuclear density** : Mass per unit volume of a nucleus is called nuclear density.

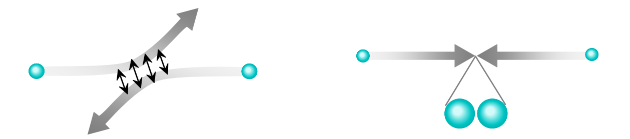
$$\text{Nuclear density}(\rho) = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$

where m = Average of mass of a nucleon (= mass of proton + mass of neutron = $1.66 \times 10^{-27}\ kg$) and mA = Mass of nucleus

$$\Rightarrow \rho = \frac{3m}{4\pi R_0^3} = 2.38 \times 10^{17}\ kg/m^3$$

Nuclear Force

Forces that keep the nucleons bound in the nucleus are called nuclear forces.



(A) At low speeds, electromagnetic repulsion

(B) At high speeds, nuclei come close enough for the strong

Fig. 26.12

(1) Nuclear forces are short range forces. These do not exist at large distances greater than $10^{-15}\ m$.

(2) Nuclear forces are the strongest forces in nature.

(3) These are attractive force and causes stability of the nucleus.

(4) These forces are charge independent.

(5) Nuclear forces are non-central force.

(6) **Nuclear forces are exchange forces :** According to scientist Yukawa the nuclear force between the two nucleons is the result of the exchange of particles called mesons between the nucleons.

π - mesons are of three types – Positive π meson (π^+), negative π meson (π^-), neutral π *meson* (π^0)

The force between neutron and proton is due to exchange of charged meson between them *i.e.*

$$p \to \pi^+ + n, \quad n \to p + \pi^-$$

The forces between a pair of neutrons or a pair of protons are the result of the exchange of neutral meson (π^0) between them *i.e.* $p \to p' + \pi^0$ and $n \to n' + \pi^0$

Thus exchange of π meson between nucleons keeps the nucleons bound together. It is responsible for the nuclear forces.

Dog-Bone analogy

The above interactions can be explained with the dog bone analogy according to which we consider the two interacting nucleons to be two dogs having a common bone clenched in between their teeth very firmly. Each one of these dogs wants to take the bone and hence they cannot be separated easily. They seem to be bound to each other with a strong attractive force (which is the bone) thc emselves are strong enemies. The meson pla of the common bone in between two nucleons

Fig. 26.13

Atomic Mass Unit (*amu*)

(1) In nuclear physics, a convenient unit of mass is the unified atomic mass unit abbreviated *u*.

(2) The *amu* is defined as $\frac{1}{12}th$ mass of a $_{B}C^{12}$ at on.

(3) 1 *amu* (or 1 *u*) = 1.6605402 × 10^{-27} *kg* .

(4) **Masses of electron, proton and neutrons :**

Mass of electron (m_e) = 9.1 × 10^{-31} *kg* = 0.0005486 *amu*, Mass of proton (m_p) = 1.6726 × 10^{-27} *kg* = 1.007276 *amu*

Mass of neutron (m_n) = 1.6750 × 10^{-27} *kg* = 1.00865 *amu*, Mass of hydrogen atom ($m_e + m_p$) = 1.6729 × 10^{-27} *kg* = 1.0078 *amu*

(5) The energy associated with a nuclear process is usually large, of the order of *MeV*.

(6) According to Einstein, mass and energy are inter convertible. The Einstein's mass energy relationship is given by $E = mc^2$

If *m* = 1 *amu*, *c* = 3 × 10^8 *m/sec* then *E* = 931 *MeV* *i.e.* 1 *amu* is equivalent to 931 *MeV* or **1 *amu* (or 1 *u*) = 931 *MeV***

(1 *u*) c^2 = 931 *MeV* ⇒ $1u = 931\frac{MeV}{c^2}$ or $c^2 = 931\frac{MeV}{u}$

Table 26.5 : Neutral atomic masses for some light nuclides

Element and isopore	Atomic mass (*u*)
Hydrogen (^1_1H)	1.007825
Deuterium (^2_1H)	2.014102
Tritium (^3_1H)	3.016049
Helium (^3_2He)	3.016029
Helium (^4_2He)	4.002603
Lithium (^7_3Li)	7.016004
Beryllium (^9_4Be)	9.012182
Carbon $(^{12}_6C)$	12.000000
Nitrogen $(^{14}_7N)$	14.003074
Oxygen $(^{16}_8O)$	15.994915

Pair Production and Pair-Annihilation

When an energetic γ-ray photon falls on a heavy substance. It is absorbed by some nucleus of the substance and an electron and a positron are produced. This phenomenon is called pair production and may be represented by the following equation

$$\underset{(\gamma-\text{photon})}{h\nu} = \underset{(\text{Positron})}{_{1}\beta^0} + \underset{(\text{Electron})}{_{-1}\beta^0}$$

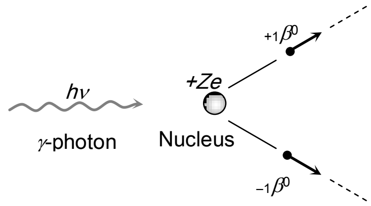


Fig. 26.14

The rest-mass energy of each of positron and electron is

$E_0 = m_0c^2$ = (9.1 × 10^{-31} *kg*) × (3.0 × 10^8 *m/s*)^2

= 8.2 × 10^{-14} *J* = **0.51 *MeV***

Hence, for pair-production it is essential that the energy of γ-photon must be at least 2 × 0.51 = 1.02 *MeV*. If the energy of γ-photon is less than this, it would cause photo-electric effect or Compton effect on striking the matter.

The converse phenomenon pair-annihilation is also possible. Whenever an electron and a positron come very close to each other, they annihilate each other by combining together and two γ-photons (energy) are produced. This phenomenon is called pair annihilation and is represented by the following equation.

$$\underset{(\text{Positron})}{_{+1}\beta^0} + \underset{(\text{Electron})}{_{-1}\beta^0} = \underset{(\gamma\text{-photon})}{h\nu} + \underset{(\gamma\text{-photon})}{h\nu}$$

Nuclear Stability

Among about 1500 known nuclides, less than 260 are stable. The others are unstable that decay to form other nuclides by emitting α, β-particles and γ - EM waves. (This process is called radioactivity). The stability of nucleus is determined by many factors. Few such factors are given below :

(1) **Neutron-proton ratio** $\left(\frac{N}{Z}\text{Ratio}\right)$: The chemical properties of an atom are governed entirely by the number of protons (*Z*) in the nucleus, the stability of an atom appears to

depend on both the number of protons and the number of neutrons.

(i) For lighter nuclei, the greatest stability is achieved when the number of protons and neutrons are approximately equal ($N \approx Z$) *i.e.* $\frac{N}{Z} = 1$

(ii) Heavy nuclei are stable only when they have more neutrons than protons. Thus heavy nuclei are neutron rich compared to lighter nuclei (for heavy nuclei, more is the number of protons in the nucleus, greater is the electrical repulsive force between them. Therefore more neutrons are added to provide the strong attractive forces necessary to keep the nucleus stable.)

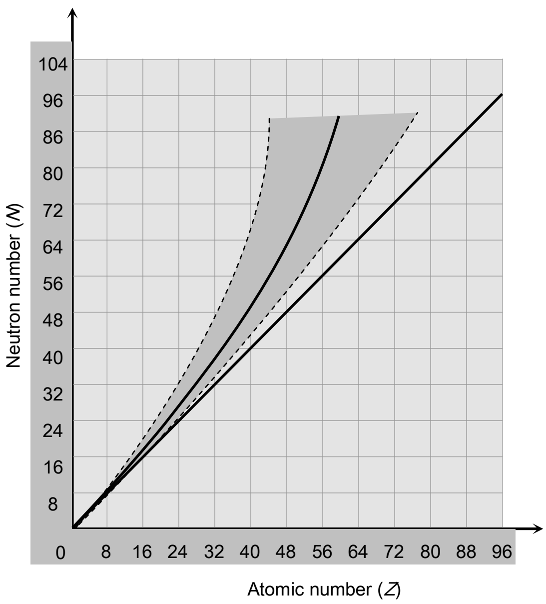


Fig. 26.15

(iii) Figure shows a plot of N verses Z for the stable nuclei. For mass number upto about A = 40. For larger value of Z the nuclear force is unable to hold the nucleus together against the electrical repulsion of the protons unless the number of neutrons exceeds the number of protons. At Bi (Z = 83, A = 209), the neutron excess in $N - Z$ = 43. There are no stable nuclides with Z > 83.

(2) **Even or odd numbers of Z or N :** The stability of a nuclide is also determined by the consideration whether it contains an even or odd number of protons and neutrons.

(i) It is found that an even-even nucleus (even Z and even N) is more stable (60% of stable nuclide have even Z and even N).

(ii) An even-odd nucleus (even Z and odd N) or odd-even nuclide (odd Z and even N) is found to be lesser sable while the odd-odd nucleus is found to be less stable.

(iii) Only five stable odd-odd nuclides are known : ${}_1H^2,\ {}_3Li^6,\ {}_5Be^{10},\ {}_7N^{14}$ and ${}_{75}Ta^{180}$

(3) **Binding energy per nucleon :** The stability of a nucleus is determined by value of it's binding energy per nucleon. In general higher the value of binding energy per nucleon, more stable the nucleus is

Mass Defect and Binding Energy

(1) **Mass defect (Δm) :** It is found that the mass of a nucleus is always less than the sum of masses of it's constituent nucleons in free state. This difference in masses is called mass defect. Hence mass defect

Δm = Sum of masses of nucleons – Mass of nucleus

$$= \{Zm_p + (A-Z)m_n\} - M = \{Zm_p + Zm_e + (A-Z)m_z\} - M'$$

where m_p = Mass of proton, m_n = Mass of each neutron, m_e = Mass of each electron

M = Mass of nucleus, Z = Atomic number, A = Mass number, M' = Mass of atom as a whole.

(2) **Packing fraction :** Mass defect per nucleon is called packing fraction

Packing fraction $(f) = \frac{\Delta m}{A} = \frac{M - A}{A}$ where M = Mass of nucleus, A = Mass number

Packing fraction measures the stability of a nucleus. Smaller the value of packing fraction, larger is the stability of the nucleus.

(i) Packing fraction may be of positive, negative or zero value.

(ii) At A = 16, $f \to$ Zero

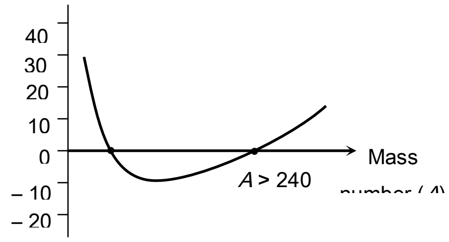


Fig. 26.16

(3) **Binding energy (B.E.) :** The neutrons and protons in a stable nucleus are held together by nuclear forces and energy is needed to pull them infinitely apart (or the same energy is released during the formation of the nucleus). This energy is called the binding energy of the nucleus.

or

The binding energy of a nucleus may be defined as the energy equivalent to the mass defect of the nucleus.

If Δm is mass defect then according to Einstein's mass energy relation

Binding energy = $\Delta m \cdot c^2 = [\{m_p Z + m_n(A - Z)\} - M] \cdot c^2$

(This binding energy is expressed in *joule*, because Δm is measured in *kg*)

If Δm is measured in *amu* then binding energy = Δm *amu* = $[\{m_p Z + m_n(A - Z)\} - M]$ *amu* = $\Delta m \times 931$ *MeV*

(4) **Binding energy per nucleon :** The average energy required to release a nucleon from the nucleus is called binding energy per nucleon.

Binding energy per nucleon

$$= \frac{\text{Total binding energy}}{\text{Mass number } (i.e. \text{ total number of nucleons})} = \frac{\Delta m \times 931}{A} \frac{MeV}{Nucleon}$$

Binding energy per nucleon $\propto$ Stability of nucleus

Binding Energy Curve

It is the graph between binding energy per nucleon and total number of nucleons (*i.e.* mass number *A*)

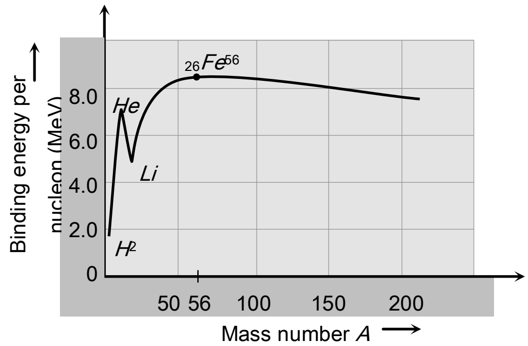


Fig. 26.17

(1) Some nuclei with mass number A < 20 have large binding energy per nucleon than their neighbour nuclei. For example $_2He^4$, $_4Be^8$, $_6C^{12}$, $_8O^{16}$ and $_{10}Ne^{20}$. These nuclei are more stable than their neighbours.

(2) The binding energy per nucleon is maximum for nuclei of mass number A = 56 ($_{26}Fe^{56}$). It's value is 8.8 *MeV* per nucleon.

(3) For nuclei having A > 56, binding energy per nucleon gradually decreases for uranium (A = 238), the value of binding energy per nucleon drops to 7.5 *MeV*.

Nuclear Reactions

The process by which the identity of a nucleus is changed when it is bombarded by an energetic particle is called nuclear reaction. The general expression for the nuclear reaction is as follows.

$$\underset{\text{(Parent nucleus)}}{X} + \underset{\text{(Incident particle)}}{a} \longrightarrow$$

$$\underset{\text{(Compound nucleus)}}{C} \longrightarrow \underset{\text{(Compound nucleus)}}{Y} + \underset{\text{(Product particles)}}{b} + \underset{\text{(Energy)}}{Q}$$

Here *X* and *a* are known as reactants and *Y* and *b* are known as products. This reaction is known as (*a*, *b*) reaction and can be represented as *X*(*a*, *b*) *Y*

(1) ***Q* value or energy of nuclear reaction :** The energy absorbed or released during nuclear reaction is known as *Q*-value of nuclear reaction.

Q-value = (Mass of reactants – mass of products)c^2 *Joules*

= (Mass of reactants – mass of products) *amu*

If $Q < 0$, The nuclear reaction is known as endothermic. (The energy is absorbed in the reaction)

If $Q > 0$, The nuclear reaction is known as exothermic (The energy is released in the reaction)

(2) **Law of conservation in nuclear reactions**

(i) Conservation of mass number and charge number : In the following nuclear reaction

$${}_2He^4 + {}_7N^{14} \rightarrow {}_8O^{17} + {}_1H^1$$

Mass number (*A*) $\rightarrow$ Before the reaction After the reaction

4 +14 = 18 17 + 1 = 18

Charge number (*Z*) $\rightarrow$ 2 + 7 = 9 8 + 1 = 9

(ii) Conservation of momentum : Linear momentum/angular momentum of particles before the reaction is equal to the linear/angular momentum of the particles after the reaction. That is $\Sigma p = 0$

(iii) Conservation of energy : Total energy before the reaction is equal to total energy after the reaction. Term *Q* is added to balance the total energy of the reaction.

(3) **Common nuclear reactions :** The nuclear reactions lead to artificial transmutation of nuclei. Rutherford was the first to carry out artificial transmutation of nitrogen to oxygen in the year 1919.

$${}_2He^4 + {}_7N^{14} \rightarrow {}_9F^{18} \rightarrow {}_8O^{17} + {}_1H^1$$

It is called (α, *p*) reaction. Some other nuclear reactions are given as follows.

(*p*, *n*) reaction $\Rightarrow$ ${}_1H^1 + {}_5B^{11} \rightarrow {}_6C^{12} \rightarrow {}_6C^{11} + {}_0n^1$

(*p*, α) reaction $\Rightarrow$ ${}_1H^1 + {}_3Li^{11} \rightarrow {}_4Be^8 \rightarrow {}_2He^4 + {}_2He^4$

(*p*, γ) reaction $\Rightarrow$ ${}_1H^1 + {}_6C^{12} \rightarrow {}_7N^{13} \rightarrow {}_7N^{13} + \gamma$

(*n*, *p*) reaction $\Rightarrow$ ${}_0n^1 + {}_7N^{14} \rightarrow {}_7N^{15} \rightarrow {}_6C^{14} + {}_1H^1$

(γ, *n*) reaction $\Rightarrow$ $\gamma + {}_1H^2 \rightarrow {}_1H^1 + {}_0n^1$

Nuclear Fission

(1) The process of splitting of a heavy nucleus into two lighter nuclei of comparable masses (after bombardment with a energetic particle) with liberation of energy is called nuclear fission.

(2) The phenomenon of nuclear fission was discovered by scientist Ottohann and F. Strassman and was explained by N. Bohr and J.A. Wheeler on the basis of liquid drop model of nucleus.

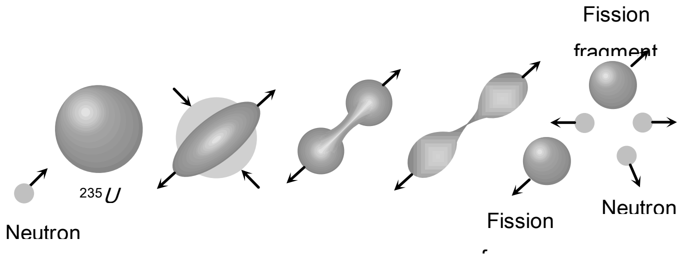


Fig. 26.18

(3) **Fission reaction of U^{235}**

$$_{92}U^{235} + {}_0n^1 \to \underset{\text{(unstable nucleus)}}{_{92}U^{236}} \to {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + Q$$

(4) The energy released in U^{235} fission is about 200 *MeV* or 0.8 *MeV* per nucleon.

(5) By fission of $_{92}U^{235}$, on an average 2.5 neutrons are liberated. These neutrons are called fast neutrons and their energy is about 2 *MeV* (for each). These fast neutrons can escape from the reaction so as to proceed the chain reaction they are need to slow down.

(6) Fission of U^{235} occurs by slow neutrons only (of energy about 1*eV*) or even by thermal neutrons (of energy about 0.025 *eV*).

(7) 50 *kg* of U^{235} on fission will release $\approx 4 \times 10^{15}$ *J* of energy. This is equivalence to 20,000 tones of *TNT* explosion. The nuclear bomb dropped at Hiroshima had this much explosion power.

(8) The mass of the compound nucleus must be greater than the sum of masses of fission products.

(9) The $\frac{\text{Binding energy}}{\text{A}}$ of compound nucleus must be less than that of the fission products.

(10) It may be pointed out that it is not necessary that in each fission of uranium, the two fragments $_{56}Ba$ and $_{36}Kr$ are formed but they may be any stable isotopes of middle weight atoms.

(11) Same other U^{235} fission reactions are

$$_{92}U^{235} + {}_0n^1 \to {}_{54}Xe^{140} + {}_{38}Sr^{94} + 2{}_0n^1$$

$$\to {}_{57}La^{148} + {}_{35}Br^{85} + 3\,{}_0n^1$$

$\to$ Many more

(12) The neutrons released during the fission process are called prompt neutrons.

(13) Most of energy released appears in the form of kinetic energy of fission fragments.

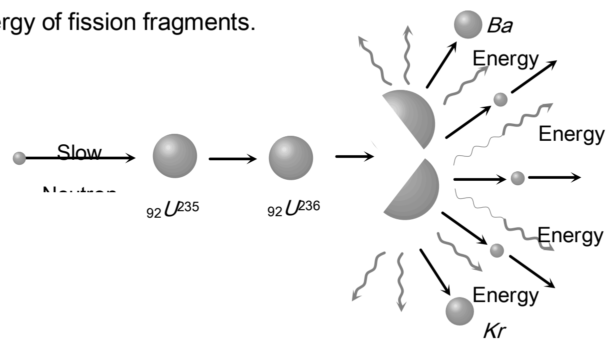


Fig. 26.19

Chain Reaction

In nuclear fission, three neutrons are produced along with the release of large energy. Under favourable conditions, these neutrons can cause further fission of other nuclei, producing large number of neutrons. Thus a chain of nuclear fissions is established which continues until the whole of the uranium is consumed.

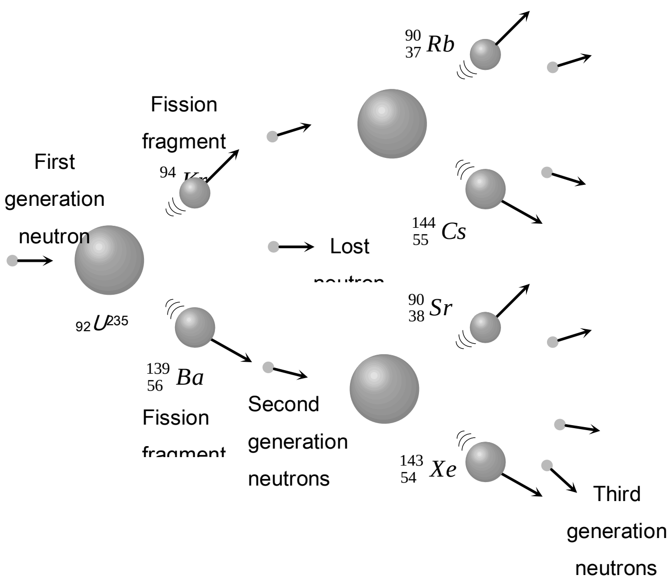


Fig. 26.20

In the chain reaction, the number of nuclei undergoing fission increases very fast. So, the energy produced takes a tremendous magnitude very soon.

Difficulties in Chain Reaction

In chain reaction following difficulties are observed

(1) **Absorption of neutrons by U^{238} :** the major part in natural uranium is the isotope U^{238} (99.3%), the isotope U^{235} is very little (0.7%). It is found that U^{238} is fissionable with fast neutrons, whereas U^{235} is fissionable with slow neutrons. Due to the large percentage of U^{238}, there is more possibility of collision of neutrons with U^{238}. It is found that the neutrons get slowed on coliding with U^{238}, as a result of it further fission of U^{238} is not possible (Because they are slow and they are absorbed by U^{238}). This stops the chain reaction.

Removal : (i) To sustain chain reaction $_{92}U^{235}$ is separated from the ordinary uranium. Uranium so obtained $\left({}_{92}U^{235}\right)$ is known as enriched uranium, which is fissionable with the fast and slow neutrons and hence chain reaction can be sustained.

(ii) If neutrons are slowed down by any method to an energy of about 0.3 *eV*, then the probability of their absorption by U^{238} becomes very low, while the probability of their fissioning U^{235} becomes high. This job is done by moderators. Which reduce the speed of neutron rapidly graphite and heavy water are the example of moderators.

(2) **Critical size :** The neutrons emitted during fission are very fast and they travel a large distance before being slowed down. If the size of the fissionable material is small, the neutrons emitted will escape the fissionable material before they are slowed down. Hence chain reaction cannot be sustained.

Removal : The size of the fissionable material should be large than a critical size.

The chain reaction once started will remain steady, accelerate or retard depending upon, a factor called neutron reproduction factor (*k*). It is defined as follows.

$$k = \frac{\text{Rate of production of neutrons}}{\text{Rate of loss of neutrons}}$$

If $k = 1$, the chain reaction will be steady. The size of the fissionable material used is said to be the critical size and it's mass, the critical mass.

If $k > 1$, the chain reaction accelerates, resulting in an explosion. The size of the material in this case is super critical. (Atom bomb)

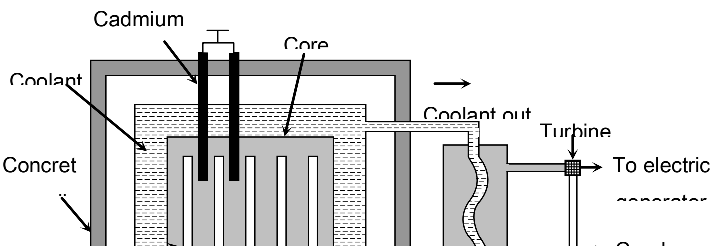
If $k < 1$, the chain reaction gradually comes to a halt. The size of the material used us said to be sub-critical.

Table 26.6 : Types of chain reaction

Controlled chain reaction	Uncontrolled chain reaction
Controlled by artificial method	No control over this type of nuclear reaction
All neurons are absorbed except one	More than one neutron takes part into reaction
It's rate is slow	Fast rate
Reproduction factor $k = 1$	Reproduction factor $k > 1$
Energy liberated in this type of reaction is always less than explosive energy	A large amount of energy is liberated in this type of reaction
Chain reaction is the principle of nuclear reactors	Uncontrolled chain reaction is the principle of atom bomb.

Nuclear Reactor

A nuclear reactor is a device in which nuclear fission can be carried out through a sustained and a controlled chain reaction. It is also called an atomic pile. It is thus a source of controlled energy which is utilised for many useful purposes.



(1) **Fissionable material (Fuel) :** The fissionable material used in the reactor is called the fuel of the reactor. Uranium isotope (U^{235}) Thorium isotope (Th^{232}) and Plutonium isotopes (Pu^{239}, Pu^{240} and Pu^{241}) are the most commonly used fuels in the reactor.

(2) **Moderator :** Moderator is used to slow down the fast moving neutrons. Most commonly used moderators are graphite and heavy water (D_2O).

(3) **Control Material :** Control material is used to control the chain reaction and to maintain a stable rate of reaction. This material controls the number of neutrons available for the fission. For example, cadmium rods are inserted into the core of the reactor because they can absorb the neutrons. The neutrons available for fission are controlled by moving the cadmium rods in or out of the core of the reactor.

(4) **Coolant :** Coolant is a cooling material which removes the heat generated due to fission in the reactor. Commonly used coolants are water, CO_2 nitrogen *etc.*

(5) **Protective shield :** A protective shield in the form a concrete thick wall surrounds the core of the reactor to save the persons working around the reactor from the hazardous radiations.

(6) **Uses of nuclear reactor**

(i) In electric power generation.

(ii) To produce radioactive isotopes for their use in medical science, agriculture and industry.

(iii) In manufacturing of Pu^{239} which is used in atom bomb.

(iv) They are used to produce neutron beam of high intensity which is used in the treatment of cancer and nuclear research.

Nuclear Fusion

(1) In nuclear fusion two or more than two lighter nuclei combine to form a single heavy nucleus. The mass of single nucleus so formed is less than the sum of the masses of parent nuclei. This difference in mass results in the release of tremendous amount of energy

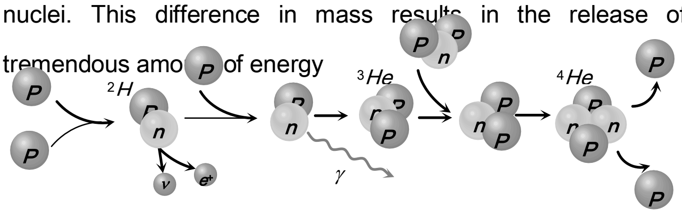


Fig. 26.22

(2) For fusion high pressure ($\approx 10^6$ *atm*) and high temperature (of the order of 10^7 *K* to 10^8 *K*) is required and so the reaction is called thermonuclear reaction.

(3) Here are three examples of energy-liberating fusion reactions, written in terms of the neutral atoms. Together the reactions make up the process called the proton-proton chain.

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + \beta^+ + \nu_e$$

$${}_1^2H + {}_1^1H \rightarrow {}_2^3He + \gamma$$

$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1H + {}_1^1H$$

$$4\ {}_1H^1 \rightarrow {}_2He^4 + 2\,\beta^+ + 2\gamma + 26.73\ MeV$$

(4) The proton-proton chain takes place in the interior of the sun and other stars. Each gram of the suns mass contains about 4.5×10^{23} protons. If all of these protons were fused into helium, the energy released would be about 130,000 *kWh*. If the sun were to continue to radiate at its present rate, it would take about $75 \times 10^{9}\ years$ to exhaust its supply of protons.

(5) For the same mass of the fuel, the energy released in fusion is much larger than in fission.

(6) **Plasma :** The temperature of the order of $10^8\ K$ required for thermonuclear reactions leads to the complete ionisation of the atom of light elements. The combination of base nuclei and electron cloud is called plasma. The enormous gravitational field of the sun confines the plasma in the interior of the sun.

The main problem to carryout nuclear fusion in the laboratory is to contain the plasma at a temperature of $10^8 K$. No solid container can tolerate this much temperature. If this problem of containing plasma is solved, then the large quantity of deuterium present in sea water would be able to serve as in-exhaustible source of energy.

Table 26.7 : Nuclear bomb (Based on uncontrolled nuclear reactions)

Atom bomb	Hydrogen bomb
Based on fission process it involves the fission of U^{235}	Based on fusion process. Mixture of deutron and tritium is used in it
In this critical size is important	There is no limit to critical size
Explosion is possible at normal temperature and pressure	High temperature and pressure are required
Less energy is released compared to hydrogen bomb	More energy is released as compared to atom bomb so it is more dangerous than atom bomb

Radioactivity

The phenomenon of spontaneous emission of radiatons by heavy elements is called radioactivity. The elements which shows this phenomenon are called radioactive elements.

(1) Radioactivity was discovered by Henery Becquerel in uranium salt in the year 1896.

(2) After the discovery of radioactivity in uranium, Piere Curie and Madame Curie discovered a new radioactive element called radium (which is 10^6 times more radioactive than uranium)

(3) Some examples of radio active substances are : Uranium, Radium, Thorium, Polonium, Neptunium *etc.*

(4) Radioactivity of a sample cannot be controlled by any physical (pressure, temperature, electric or magnetic field) or chemical changes.

(5) All the elements with atomic number (Z) > 82 are naturally radioactive.

(6) The conversion of lighter elements into radioactive elements by the bombardment of fast moving particles is called artificial or induced radioactivity.

(7) Radioactivity is a nuclear event and not atomic. Hence electronic configuration of atom don't have any relationship with radioactivity.

Nuclear Radiations

According to Rutherford's experiment when a sample of radioactive substance is put in a lead box and allow the emission of radiation through a small hole only. When the radiation enters into the external electric field, they splits into three parts (α-rays, β-rays and γ-rays)

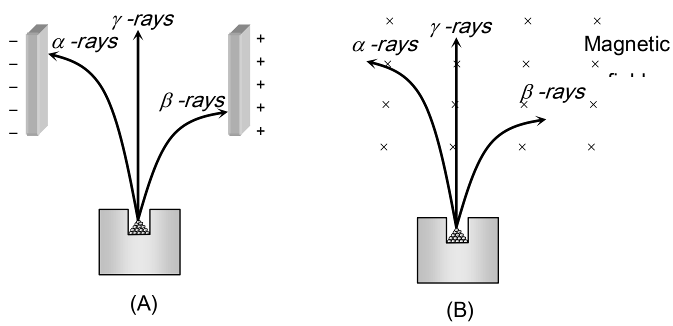


Fig. 26.23

(1) **α-decay** : Nearly 90% of the 2500 known nuclides are radioactive ; they are not stable but decay into other nuclides

(i) When unstable nuclides decay into different nuclides, they usually emit alpha (α) or beta (β) particles.

(ii) Alpha emission occurs principally with nuclei that are too large to be stable. When a nucleus emits an alpha particle, its *N* and *Z* values each decrease by two and *A* decreases by four.

(iii) Alpha decay is possible whenever the mass of the original neutral atom is greater than the sum of the masses of the final neutral atom and the neutral helium- atom.

(2) **β-decay** : There are different simple type of β-decay β^-, β^+ and electron capture.

(i) A beta minus particle (β^-) is an electron. Emission of β^- involves transformation of a neutron into a proton, an electron and a third particle called an antineutrino ($\bar{\nu}$).

(ii) β^- decay usually occurs with nuclides for which the neutron to proton ratio $\left(\frac{N}{Z} ratio\right)$ is too large for stability.

(iii) In β^- decay, *N* decreases by one, *Z* increases by one and *A* doesn't change.

(iv) β^- decay can occur whenever the neutral atomic mass of the original atom is larger than that of the final atom.

(v) Nuclides for which *N*/*Z* is too small for stability can emit a positron, the electron's antiparticle, which is identical to the electron but with positive charge. The basic process called beta plus β^+ decay

$p \rightarrow n + \beta^+ + \nu$ (ν = neutrino)

(vi) β^+ decay can occur whenever the neutral atomic mass of the original atom is at least two electron masses larger than that of the final atom

(vii) The mass of ν and $\bar{\nu}$ is zero. The spin of both is $\frac{1}{2}$ in units of $\frac{h}{2\pi}$. The charge on both is zero. The spin of neutrino is antiparallel to it's momentum while that of antineutrino is parallel to it's momentum.

(viii) There are a few nuclides for which β^+ emission is not energetically possible but in which an orbital electron (usually in the *k*-shell) can combine with a proton in the nucleus to form a neutron and a neutrino. The neutron remains in the nucleus and the neutrino is emitted.

$p + \beta^+ \rightarrow n + \nu$

(3) **γ-decay** : The energy of internal motion of a nucleus is quantized. A typical nucleus has a set of allowed energy levels, including a *ground state* (state of lowest energy) and several excited states. Because of the great strength of nuclear interactions, excitation energies of nuclei are typically of the order of the order of 1 *MeV*, compared with a few *eV* for atomic energy levels. In ordinary physical and chemical transformations the nucleus always remains in its ground state. When a nucleus is placed in an excited state, either by bombardment with high-energy particles or by a radioactive transformation, it can decay to the ground state by emission of one or more photons called gamma rays or gamma-ray photons, with typical energies of 10 *keV* to 5 *MeV*. This process is called gamma (γ) decay.

All the known conservation laws are obeyed in γ-decay.

The intensity of γ-decay after passing through *x* thickness of a material is given by $I = I_0 e^{-\mu x}$ (μ = absorption co-efficient)

Radioactive Disintegration

(1) **Law of radioactive disintegration :** According to Rutherford and Soddy law for radioactive decay is as follows.

"At any instant the rate of decay of radioactive atoms is proportional to the number of atoms present at that instant" *i.e.*

$-\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$. It can be proved that $N = N_0 e^{-\lambda t}$

In terms of mass $M = M_0 e^{-\lambda t}$

where *N* = Number of atoms remains undecayed after time *t*, N_0 = Number of atoms present initially (*i.e.* at *t* = 0), *M* = Mass of radioactive nuclei at time *t*, M_0 = Mass of radioactive nuclei at time *t* = 0, $N_0 - N$ = Number of disintegrated nucleus in time *t*

$\frac{dN}{dt}$ = rate of decay, λ = Decay constant or disintegration constant or radioactivity constant or Rutherford Soddy's constant or the probability of decay per unit time of a nucleus.

Table 26.8 : Properties of α, β and γ-rays

Features	α- particles	β - particles	γ - rays
1. Identity	Helium nucleus or doubly ionised helium atom ($_2He^4$)	Fast moving electron $(-\beta^0 \text{ or } \beta^-)$	Photons (E.M. waves)
2. Charge	+ 2*e*	– *e*	Zero
3. Mass 4 m_p (m_p = mass of proton = 1.87×10^{-27}	4 m_p	m_e	Massless
4. Speed	$\approx 10^7$ *m/s*	1% to 99% of speed of light	Speed of light
5. Range of kinetic energy	4 *MeV* to 9 *MeV*	All possible values between a minimum certain value to 1.2 *MeV*	Between a minimum value to 2.23 *MeV*
6. Penetration power (γ, β, α)	1 (Stopped by a paper)	100 (100 times of α)	10,000 (100 times of β upto 30 *cm* of iron (or *Pb*) sheet
7. Ionisation power ($\alpha > \beta > \gamma$)	10,000	100	1
8. Effect of electric or magnetic field	Deflected	Deflected	Not deflected
9. Energy spectrum	Line and discrete	Continuous	Line and discrete
10. Mutual interaction with matter	Produces heat	Produces heat	Produces, photo-electric effect, Compton effect, pair production
11. Equation of decay	$_ZX^A \xrightarrow{\alpha-decay}$ $_{Z-2}Y^{A-4} + {_2He^4}$ $_ZX^A \xrightarrow{n\alpha} {_{Z'}Y^{A'}}$ $\Rightarrow \boldsymbol{n_\alpha = \frac{A-A'}{4}}$	$_ZX^A \to {_{Z+1}Y^A} + {_{-1}e^0} + \bar{\nu}$ $_ZX^A \xrightarrow{n\beta} {_{Z'}X^A}$ $\Rightarrow \boldsymbol{n_\beta = (2n_\alpha - Z + Z')}$	$_ZX^A \to {_ZX^a} + \gamma$

(2) **Activity :** It is defined as the rate of disintegration (or count rate) of the substance (or the number of atoms of any material decaying per second) *i.e.*

$$A = -\frac{dN}{dt} = \lambda N = \lambda N_0 e^{-\lambda t} = A_0 e^{-\lambda t}$$

where A_0 = Activity of $t = 0$, A = Activity after time t

Units of activity (Radioactivity)

It's units are *Becqueral* (*Bq*), Curie (*Ci*) and Rutherford (*Rd*)

1 *Becquerel* = 1 *disintegration*/*sec*,

1 *Rutherford* = 10^6 *dis/sec*, 1 *Curie* = 3.7×10^{11} *dis/sec*

(3) **Half life ($T_{1/2}$)** : Time interval in which the mass of a radioactive substance or the number of it's atom reduces to half of it's initial value is called the half life of the substance.

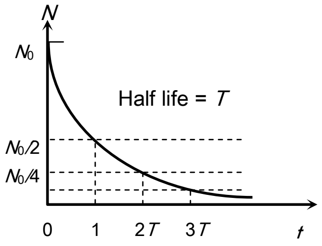


Fig. 26.24

i.e. if $N = \frac{N_0}{2}$

then $t = T_{1/2}$

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

$$\frac{N_0}{2} = N_0 e^{-\lambda (T_{1/2})} \Rightarrow T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{0.693}{\lambda}$$

Table 26.9 : Fraction of active/decayed atom at different time

Time (t)	Remaining fraction of active atoms (N/N_0) probability of survival	Fraction of atoms decayed $(N_0 - N)/N_0$ probability of decay
$t = 0$	1 (100%)	0
$t = T_{1/2}$	$\frac{1}{2}$ (50%)	$\frac{1}{2}$ (50%)
$t = 2(T_{1/2})$	$\frac{1}{4}$ (25%)	$\frac{3}{4}$ (75%)
$t = 3(T_{1/2})$	$\frac{1}{8}$ (12.5%)	$\frac{7}{8}$ (87.5%)
$t = 10\ (T_{1/2})$	$\left(\frac{1}{2}\right)^{10} \approx 0.1\%$	$\approx 99.9\%$
$t = n\ (N_{1/2})$	$\left(\frac{1}{2}\right)^n$	$\left\{1 - \left(\frac{1}{2}\right)^n\right\}$

(4) **Mean (or average) life (τ) :** The time for which a radioactive material remains active is defined as mean (average) life of that material.

(i) or it is defined as the sum of lives of all atoms divided by the total number of atoms

$$\text{i.e. } \tau = \frac{\text{Sum of the lives of all the atoms}}{\text{Total number of atoms}} = \frac{1}{\lambda}$$

(ii) From $N = N_0 e^{-\lambda t} \Rightarrow \frac{\ln \frac{N}{N_0}}{t} = -\lambda$ slope of the line shown in the graph *i.e.* the magnitude of inverse of slope of $\ln \frac{N}{N_0}$ *vs* t curve is known as mean life (τ).

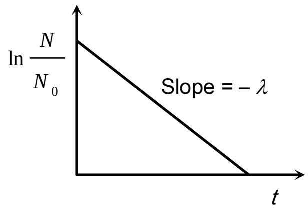


Fig. 26.25

(iii) From $N = N_0 e^{-\lambda t}$, if $t = \frac{1}{\lambda} = \tau$

$$\Rightarrow N = N_0 e^{-1} = N_0 \left(\frac{1}{e}\right) = 0.37 N_0 = 37\% \text{ of } N_0.$$

i.e. mean life is the time interval in which number of undecayed atoms (N) becomes $\frac{1}{e}$ times or 0.37 times or 37% of original number of atoms. or

It is the time in which number of decayed atoms ($N_0 - N$) becomes $\left(1 - \frac{1}{e}\right)$ times or 0.63 times or 63% of original number of atoms.

(iv) From $T_{1/2} = \frac{0.693}{\lambda} \Rightarrow \frac{1}{\lambda} = \tau = \frac{1}{0.693} . (t_{1/2}) = 1.44 (T_{1/2})$

i.e. mean life is about 44% more than that of half life. Which gives us $\tau > T_{(1/2)}$

Radioactive Series

(1) If the isotope that results from a radioactive decay is itself radioactive then it will also decay and so on.

(2) The sequence of decays is known as radioactive decay series. Most of the radio-nuclides found in nature are members of four radioactive series. These are as follows

Table 26.10 : Four radioactive series

Mass number	Series (Nature)	Parent	Stable end product	Integer n
$4n$	Thorium (natural)	${}_{90}Th^{232}$	${}_{82}Pb^{208}$	52
$4n + 1$	Neptunium	${}_{93}Np^{237}$	${}_{83}Bi^{209}$	52

	(Artificial)			
$4n + 2$	Uranium (Natural)	$_{92}U^{238}$	$_{82}Pb^{206}$	51
$4n + 3$	Actinium (Natural)	$_{89}Ac^{227}$	$_{82}Pb^{207}$	51

(3) The $4n + 1$ series starts from $_{94}Pu^{241}$ but commonly known as neptunium series because neptunium is the longest lived member of the series.

(4) The $4n + 3$ series actually starts from $_{92}U^{235}$.

Successive Disintegration and Radioactive Equilibrium

Suppose a radioactive element *A* disintegrates to form another radioactive element *B* which intern disintegrates to still another element *C*; such decays are called successive disintegration.

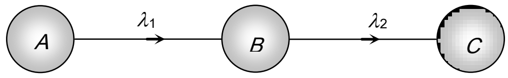


Fig. 26.26

Rate of disintegration of $A = \frac{dN_1}{dt} = -\lambda_1 N_1$ (which is also the rate of formation of *B*)

Rate of disintegration of $B = \frac{dN_2}{dt} = -\lambda_2 N_2$

$\therefore$ Net rate of formation of *B* = Rate of disintegration of *A* – Rate of disintegration of *B*

$$= \lambda_1 N_1 - \lambda_2 N_2$$

Equilibrium

In radioactive equilibrium, the rate of decay of any radioactive product is just equal to it's rate of production from the previous member.

i.e. $\lambda_1 N_1 = \lambda_2 N_2 \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{N_2}{N_2} = \frac{\tau_2}{\tau_1} = \frac{(T_{1/2})}{(T_{1/2})_1}$

Uses of Radioactive Isotopes

(1) **In medicine**

(i) For testing blood-chromium - 51

(ii) For testing blood circulation - *Na* - 24

(iii) For detecting brain tumor- Radio mercury - 203

(iv) For detecting fault in thyroid gland - Radio iodine - 131

(v) For cancer - cobalt - 60

(vi) For blood - Gold - 189

(vii) For skin diseases - Phospohorous - 31

(2) **In Archaeology**

(i) For determining age of archaeological sample (carbon dating) C^{14}

(ii) For determining age of meteorites - K^{40}

(iii) For determining age of earth-Lead isotopes

(3) **In agriculture**

(i) For protecting potato crop from earthworm- CO^{60}

(ii) For artificial rains - *AgI* (iii) As fertilizers - P^{32}

(4) **As tracers** - (Tracer) : Very small quantity of radioisotopes present in a mixture is known as tracer

(i) Tracer technique is used for studying biochemical reaction in tracer and animals.

(5) **In industries**

(i) For detecting leakage in oil or water pipe lines (ii) For determining the age of planets.

Tips & Tricks

✍ According to Bohr theory the momentum of an e^- revolving in second orbit of H_2 atom will be $\frac{h}{\pi}$

✍ For an electron in the n^{th} orbit of hydrogen atom in Bohr model, circumference of orbit $= n\lambda$; where λ = de-Broglie wavelength.

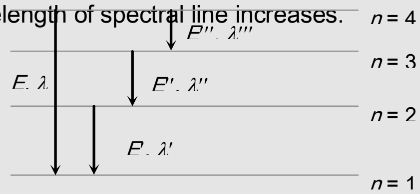
✍ *Rch* = Rydberg's energy $\simeq 2.17 \times 10^{-18}\, J \simeq 13.6\, eV$.

✍ For hydrogen atom principle quantum number $n = \sqrt{\frac{13.6}{(\text{B.E.})}}$.

✍ In an H_2 atom when e^- makes a transition from an excited state to the ground state it's kinetic energy increases while potential and total energy decreases.

✍ The maximum number of electrons in a subshell with orbital quantum number *l* is 2(2*l* + 1).

✍ With the increase in principal quantum number the energy difference between the two successive energy level decreases, while wavelength of spectral line increases.



$$E' > E'' > E'''$$

$$\lambda' < \lambda'' < \lambda'''$$

$$E = E' + E'' + E'''$$

$$\frac{1}{\lambda} = \frac{1}{\lambda'} + \frac{1}{\lambda''} + \frac{1}{\lambda'''}$$

✍ **Rydberg constant is different for different elements**

R(=1.09 × 10^7 m^{-1}) is the value of Rydberg constant when the nucleus is considered to be infinitely massive as compared to the revolving electron. In other words, the nucleus is considered to be stationary.

In case, the nucleus is not infinitely massive or stationary, then the value of Rydberg constant is given as $R' = \frac{R}{1 + \frac{m}{M}}$ where m is the mass of electron and *M* is the mass of nucleus.

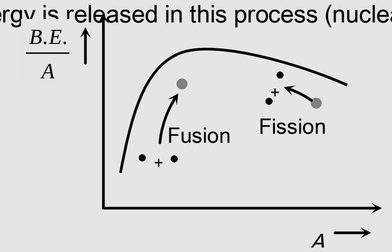
✍ **Atomic spectrum is a line spectrum**

Each atom has it's own characteristic allowed orbits depending upon the electronic configuration. Therefore photons emitted during transition of electrons from one allowed orbit to inner allowed orbit are of some definite energy only. They do not have a continuous graduation of energy. Therefore the spectrum of the emitted light has only some definite lines and therefore atomic spectrum is line spectrum.

✍ Just as dots of light of only three colours combine to form almost every conceivable colour on T.V. screen, only about 100 distinct kinds of atoms combine to form all the materials in the universe.

✍ Density of a nucleus is maximum at it's centre and decreases as we move outwards from the nucleus.

✍ When two very light nuclei combines to form a relatively heavy nucleus, then binding energy per nucleon increases. Thus, energy is released in this process (nuclear fusion).



✍ It may be noted that Plutonium is the best fuel as compared to other fissionable material. It is because fission in Plutonium can be initiated by both slow and fast neutrons. Moreover it can be obtained from U^{238}.

✍ Nuclear reactor is firstly devised by fermi.

✍ Apsara was the first Indian nuclear reactor.

✍ A type of reactor that can produce more fissile fuel than it consumes is the breeder reactor.

✍ To achieve fusion in laboratory a device is used to confine the plasma, called **Tokamak**.

✍ A test tube full of base nuclei will weight heavier than the earth.

✍ The nucleus of hydrogen contains only one proton. Therefore we may say that the proton is the nucleus of hydrogen atom.

✍ If the relative abundance of isotopes in an element has a ratio $n_1 : n_2$ whose atomic masses are m_1 and m_2 then atomic mass of the element is $M = \frac{n_1 m_1 + n_2 m_2}{n_1 + n_2}$

✍ No radioactive substance emits both α and β particles simultaneously. Also γ-rays are emitted after the emission of α or β-particles.

✍ β-particles are not orbital electrons they come from nucleus. The neutron in the nucleus decays into proton and an electron. This electron is emitted out of the nucleus in the form of β-rays.

✍ Activity per *gm* of a substance is known as specific activity. The specific activity of 1 *gm* of radium – 226 is 1 *Curie*.

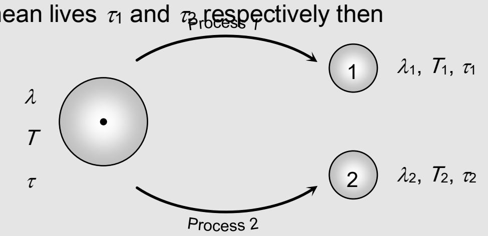
✍ 1 *millicurie* = 37 *Rutherford*

✍ The activity of a radioactive substance decreases as the number of undecayed nuclei decreases with time.

✍ $\text{Activity} \propto \frac{1}{\text{Half life}}$

✍ Half life and mean life of a substance doesn't change with time or with pressure, temperature *etc*.

✍ If a nuclide can decay simultaneously by two different process which have decay constant λ_1 and λ_2, half life T_1 and T_2 and mean lives τ_1 and τ_2 respectively then



$\Rightarrow \lambda = \lambda_1 + \lambda_2$ $\Rightarrow T = \frac{T_1 T_2}{T_1 + T_2}$

✍ There are at least three varieties of neutranas, each with it's corresponding antineutrino; one is associated with beta decay and the other two are associated with the decay of two unstable particles, the muon and the tau particles.

✍ Are all fusion reaction exoergic ?

Fusion reaction between sufficiently light nuclei are exoergic because the $\frac{B.E.}{A}$ increases. If the nuclei are too massive, however $\frac{B.E.}{A}$ decreases and fusion is endoergic (*i.e.* it takes in energy rather than releasing it)

✍ The Zeeman effect is the spliting of atomic energy levels and the associated spectrum lines when the atoms are placed in a magnetic field. This effect confirms experimentally the quantization of angular momentum.

Ordinary Thinking

Objective Questions

Atomic Structure

1. If in nature there may not be an element for which the principal quantum number $n > 4$, then the total possible number of elements will be [IIT 1983; MP PET 1999; RPMT 1999; RPET 2001]
   (a) 60 (b) 32
   (c) 4 (d) 64

2. In the Bohr's hydrogen atom model, the radius of the stationary orbit is directly proportional to (n = principle quantum number) [MNR 1988; SCRA 1994; CBSE PMT 1996; AIIMS 1999; DCE 2002]
   (a) n^{-1} (b) n
   (c) n^{-2} (d) n^2

3. In the n orbit, the energy of an electron $E_n = -\frac{13.6}{n^2} eV$ for hydrogen atom. The energy required to take the electron from first orbit to second orbit will be [MP PMT 1987; CPMT 1991, 97; RPMT 1999; DCE 2001; Kerala PMT 2004]
   (a) $10.2\ eV$ (b) $12.1\ eV$
   (c) $13.6\ eV$ (d) $3.4\ eV$

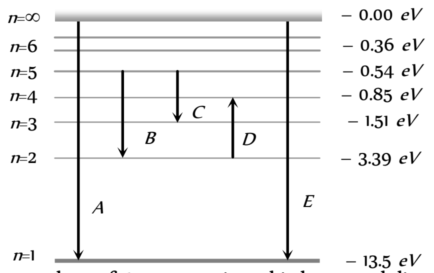
4. In the following atoms and moleculates for the transition from n= 2 to n = 1, the spectral line of minimum wavelength will be produced by [IIT 1983]
   (a) Hydrogen atom (b) Deuterium atom
   (c) Uni-ionized helium (d) di-ionized lithium

5. The Lyman series of hydrogen spectrum lies in the region [MNR 1993; MP PMT 1995; UPSEAT 2002]
   (a) Infrared (b) Visible
   (c) Ultraviolet (d) Of $X-$ rays

6. The size of an atom is of the order of [CPMT 1990; MP PMT 1984; KCET 1994]
   (a) $10^{-8} m$ (b) $10^{-10} m$
   (c) $10^{-12} m$ (d) $10^{-14} m$

7. Which one of the series of hydrogen spectrum is in the visible region [RPMT 1999;MP PET 1990; MP PMT 1994; AFMC 1998; CBSE PMT 1990; MH CET 2004]
   (a) Lyman series (b) Balmer series
   (c) Paschen series (d) Bracket series

8. The energy levels of the hydrogen spectrum is shown in figure. There are some transitions A, B, C, D and E. Transition A, B and C respectively represent [CPMT 1986, 88]



   (a) First member of Lyman series, third spectral line of Balmer series and the second spectral line of Paschen series
   (b) Ionization potential of hydrogen, second spectral line of Balmer series and third spectral line of Paschen series
   (c) Series limit of Lyman series, third spectral line of Balmer series and second spectral line of Paschen series
   (d) Series limit of Lyman series, second spectral line of Balmer series and third spectral line of Paschen series

9. In the above figure D and E respectively represent [CPMT 1986, 88]
   (a) Absorption line of Balmer series and the ionization potential of hydrogen
   (b) Absorption line of Balmer series and the wavelength lesser than lowest of the Lyman series
   (c) Spectral line of Balmer series and the maximum wavelength of Lyman series
   (d) Spectral line of Lyman series and the absorption of greater wavelength of limiting value of Paschen series

10. The Rutherford α-particle experiment shows that most of the α-particles pass through almost unscattered while some are scattered through large angles. What information does it give about the structure of the atom [AFMC 1997]
    (a) Atom is hollow
    (b) The whole mass of the atom is concentrated in a small centre called nucleus
    (c) Nucleus is positively charged
    (d) All the above

11. Which of the following is true [MP PET 1993]
    (a) Lyman series is a continuous spectrum
    (b) Paschen series is a line spectrum in the infrared
    (c) Balmer series is a line spectrum in the ultraviolet
    (d) The spectral series formula can be derived from the Rutherford model of the hydrogen atom

12. The energy required to knock out the electron in the third orbit of a hydrogen atom is equal to [DPMT 1987]
    (a) $13.6\ eV$ (b) $+\frac{13.6}{9} eV$
    (c) $-\frac{13.6}{3} eV$ (d) $-\frac{3}{13.6} eV$

13. An electron has a mass of $9.1 \times 10^{-31} kg$. It revolves round the nucleus in a circular orbit of radius $0.529 \times 10^{-10} metre$ at a speed of $2.2 \times 10^6 m/s$. The magnitude of its linear momentum in this motion is

[AFMC 1988]

(a) $1.1\times10^{-34}\,kg-m/s$ (b) $2.0\times10^{-24}\,kg-m/s$

(c) $4.0\times10^{-24}\,kg-m/s$ (d) $4.0\times10^{-31}\,kg-m/s$

14. In a beryllium atom, if a_0 be the radius of the first orbit, then the radius of the second orbit will be in general

[CBSE PMT 1992; Roorkee 1993; BHU 1998]

(a) na_0 (b) a_0

(c) n^2a_0 (d) $\frac{a_0}{n^2}$

15. The ionization potential for second *He* electron is

(a) 13.6 *eV* (b) 27.2 *eV*

(c) 54.4 *eV* (d) 100 *eV*

16. The energy required to remove an electron in a hydrogen atom from $n=10$ state is [MP PMT 1993]

(a) 13.6 *eV* (b) 1.36 *eV*

(c) 0.136 *eV* (d) 0.0136 *eV*

17. Every series of hydrogen spectrum has an upper and lower limit in wavelength. The spectral series which has an upper limit of wavelength equal to 18752 Å is [MP PMT 1993]

(a) Balmer series (b) Lyman series

(c) Paschen series (d) Pfund series

(Rydberg constant $R=1.097\times10^7$ *per metre*)

18. The kinetic energy of the electron in an orbit of radius *r* in hydrogen atom is (*e* = electronic charge) [MP PMT 1987]

(a) $\frac{e^2}{r^2}$ (b) $\frac{e^2}{2r}$

(c) $\frac{e^2}{r}$ (d) $\frac{e^2}{2r^2}$

19. Ionization potential of hydrogen atom is 13.6 *V*.

Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 *eV*. The spectral lines emitted by hydrogen atoms according to Bohr's theory will be

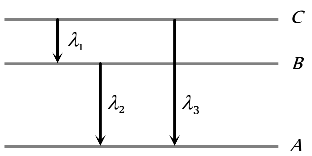
CBSE PMT 1996; MP PMT 1999; AMU (Med.) 2002]

(a) One (b) Two

(c) Three (d) Four

20. Energy levels A, B, C of a certain atom corresponding to increasing values of energy *i.e.* $E_A<E_B<E_C$. If $\lambda_1,\lambda_2,\lambda_3$ are the wavelengths of radiations corresponding to the transitions *C* to *B*, *B* to *A* and *C* to *A* respectively, which of the following statements is correct

[AIIMS 1995; CBSE PMT 1990, 2005]



(a) $\lambda_3=\lambda_1+\lambda_2$ (b) $\lambda_3=\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$

(c) $\lambda_1+\lambda_2+\lambda_3=0$ (d) $\lambda_3^2=\lambda_1^2+\lambda_2^2$

21. The angular momentum of electron in *n* orbit is given by

[Roorkee 1993]

(a) nh (b) $\frac{h}{2\pi n}$

(c) $n\frac{h}{2\pi}$ (d) $n^2\frac{h}{2\pi}$

22. The ratio of the energies of the hydrogen atom in its first to second excited state is [CPMT 1978]

(a) 1/ 4 (b) 4/9

(c) 9/ 4 (d) 4

23. An electron jumps from the 4^{th} orbit to the 2^{nd} orbit of hydrogen atom. Given the Rydberg's constant $R=10^5\,cm^{-1}$. The frequency in *Hz* of the emitted radiation will be

(a) $\frac{3}{16}\times10^5$ (b) $\frac{3}{16}\times10^{15}$

(c) $\frac{9}{16}\times10^{15}$ (d) $\frac{3}{4}\times10^{15}$

24. The ionisation potential of hydrogen atom is 13.6 *volt*. The energy required to remove an electron in the *n* = 2 state of the hydrogen atom is [NCERT 1983; MP PET 2005]

(a) 27.2 *eV* (b) 13.6 *eV*

(c) 6.8 *eV* (d) 3.4 *eV*

25. The ionisation energy of 10 times ionised sodium atom is

[DPMT 1991]

(a) 13.6 *eV* (b) $13.6\times11\,eV$

(c) $\frac{13.6}{11}eV$ (d) $13.6\times(11)^2\,eV$

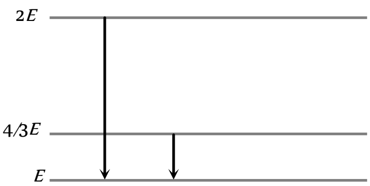
26. If the wavelength of the first line of the Balmer series of hydrogen is $6561\,Å$, the wavelength of the second line of the series should be [CPMT 1984; DPMT 2004]

(a) $13122\,Å$ (b) $3280\,Å$

(c) $4860\,Å$ (d) $2187\,Å$

27. The following diagram indicates the energy levels of a certain atom [CPMT 1996]
when the system moves from $2E$ level to *E*, a photon of wavelength λ is emitted. The wavelength of photon produced during its transition from $\frac{4E}{3}$ level to *E* is

[CPMT 1989]

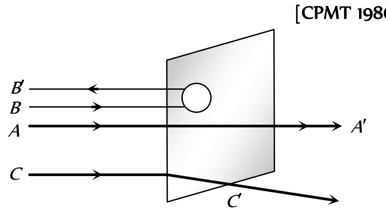


(a) $\lambda/3$ (b) $3\lambda/4$

(c) $4\lambda/3$ (d) 3λ

28. A beam of fast moving alpha particles were directed towards a thin film of gold. The parts A', B' and C' of the transmitted and reflected beams corresponding to the incident parts *A*, *B* and *C* of the beam, are shown in the adjoining diagram. The number of alpha particles in

[CPMT 1986, 88; RPET 2000]



(a) B' will be minimum and in C' maximum

(b) A' will be maximum and in B' minimum

(c) A' will be minimum and in B' maximum

(d) C' will be minimum and in B' maximum

29. According to Bohr's theory the radius of electron in an orbit described by principal quantum number n and atomic number Z is proportional to [CPMT 1988]

(a) Z^2n^2 (b) $\frac{Z^2}{n^2}$

(c) $\frac{Z^2}{n}$ (d) $\frac{n^2}{Z}$

30. The radius of electron's second stationary orbit in Bohr's atom is R. The radius of the third orbit will be

[EAMCET 1992; DPMT 1999]

(a) 3 R (b) 2.25 R

(c) 9 R (d) $\frac{R}{3}$

31. If m is mass of electron, v its velocity, r the radius of stationary circular orbit around a nucleus with charge Ze, then from Bohr's first postulate, the kinetic energy $K = \frac{1}{2}mv^2$ of the electron in *C.G.S.* system is equal to

[NCERT 1977]

(a) $\frac{1}{2}\frac{Ze^2}{r}$ (b) $\frac{1}{2}\frac{Ze^2}{r^2}$

(c) $\frac{Ze^2}{r}$ (d) $\frac{Ze}{r^2}$

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

(a) $(0.259)\,n\lambda$ (b) $\sqrt{n}\lambda$

(c) $(13.6)\,\lambda$ (d) $n\lambda$

33. In any Bohr orbit of the hydrogen atom, the ratio of kinetic energy to potential energy of the electron is [MP PET 1994]

(a) 1/2 (b) 2

(c) $-1/2$ (d) -2

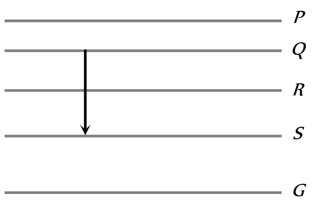
34. The spectral series of the hydrogen spectrum that lies in the ultraviolet region is the

[CPMT 1990; MP PET 1994; MP PMT 2000]

(a) Balmer series (b) Pfund series

(c) Paschen series (d) Lyman series

35. Figure shows the energy levels P, Q, R, S and G of an atom where G is the ground state. A red line in the emission spectrum of the atom can be obtained by an energy level change from Q to S. A blue line can be obtained by following energy level change



(a) P to Q (b) Q to R

(c) R to S (d) R to G

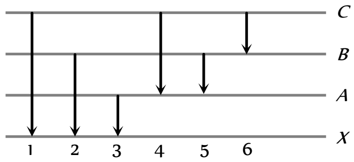
36. A hydrogen atom (ionisation potential 13.6 eV) makes a transition from third excited state to first excited state. The energy of the photon emitted in the process is [MNR 1995]

(a) 1.89 eV (b) 2.55 eV

(c) 12.09 eV (d) 12.75 eV

37. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (*e.g.* line no. 5 arises from the transition from level B to A). The following spectral lines will also occur in the absorption spectrum

[CBSE PMT 1995]



(a) 1, 4, 6 (b) 4, 5, 6

(c) 1, 2, 3 (d) 1, 2, 3, 4, 5, 6

38. When a hydrogen atom is raised from the ground state to an excited state [CBSE PMT 1995; AMU (Med.) 1999]

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

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

(c) Both kinetic energy and potential energy increase

(d) Both K.E. and P.E. decrease

39. An electron makes a transition from orbit $n = 4$ to the orbit $n = 2$ of a hydrogen atom. The wave number of the emitted radiations (R = Rydberg's constant) will be [CBSE PMT 1990]

[CBSE PMT 1995]

(a) $\frac{16}{3R}$ (b) $\frac{2R}{16}$

(c) $\frac{3R}{16}$ (d) $\frac{4R}{16}$

40. In Bohr model of the hydrogen atom, the lowest orbit corresponds to [Manipal MEE 1995]

(a) Infinite energy (b) The maximum energy

(c) The minimum energy (d) Zero energy

41. The ratio of the kinetic energy to the total energy of an electron in a Bohr orbit is [Roorkee 1995; BHU 2002]

(a) -1 (b) 2

(c) 1 : 2 (d) None of these

42. An electron in the $n = 1$ orbit of hydrogen atom is bound by 13.6 eV. If a hydrogen atom is in the $n = 3$ state, how much energy is required to ionize it [MP PMT 1995]

[MP PMT 1994]

(a) 13.6 eV (b) 4.53 eV

(c) 3.4 eV (d) 1.51 eV

43. Which of the following statements about the Bohr model of the hydrogen atom is false [MP PMT 1995]
(a) Acceleration of electron in $n = 2$ orbit is less than that in $n = 1$ orbit
(b) Angular momentum of electron in $n = 2$ orbit is more than that in $n = 1$ orbit
(c) Kinetic energy of electron in $n = 2$ orbit is less than that in $n = 1$ orbit
(d) Potential energy of electron in $n = 2$ orbit is less than that in $n = 1$ orbit

44. If an electron jumps from 1st orbital to 3rd orbital, then it will
(a) Absorb energy (b) Release energy
(c) No gain of energy (d) None of these

45. The ratio of the frequencies of the long wavelength limits of Lyman and Balmer series of hydrogen spectrum is [KCEE 1996]
(a) 27 : 5 (b) 5 : 27
(c) 4 : 1 (d) 1 : 4

46. Which of the following transitions in a hydrogen atom emits photon of the highest frequency [MP PET 1996; DPMT 2001]
(a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 1$
(c) $n = 2$ to $n = 6$ (d) $n = 6$ to $n = 2$

47. In terms of Rydberg's constant R, the wave number of the first Balmer line is [MP PMT 1996]
(a) R (b) $3R$
(c) $\frac{5R}{36}$ (d) $\frac{8R}{9}$

48. If the ionisation potential of helium atom is 24.6 *volt*, the energy required to ionise it will be [MP PMT 1996]
(a) 24.6 eV (b) 24.6 V
(c) 13.6 V (d) 13.6 eV

49. Which of the transitions in hydrogen atom emits a photon of lowest frequency (n = quantum number) [BHU 1999]
(a) $n = 2$ to $n = 1$ (b) $n = 4$ to $n = 3$
(c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 2$

50. According to Bohr's theory, the expressions for the kinetic and potential energy of an electron revolving in an orbit is given respectively by
(a) $+\frac{e^2}{8\pi\varepsilon_0 r}$ and $-\frac{e^2}{4\pi\varepsilon_0 r}$ (b) $+\frac{8\pi\varepsilon_0 e^2}{r}$ and $-\frac{4\pi\varepsilon_0 e^2}{r}$
(c) $-\frac{e^2}{8\pi\varepsilon_0 r}$ and $-\frac{e^2}{4\pi\varepsilon_0 r}$ (d) $+\frac{e^2}{8\pi\varepsilon_0 r}$ and $+\frac{e^2}{4\pi\varepsilon_0 r}$

51. In a hydrogen atom, which of the following electronic transitions would involve the maximum energy change [MP PET 1997]
(a) From $n = 2$ to $n = 1$ (b) From $n = 3$ to $n = 1$
(c) From $n = 4$ to $n = 2$ (d) From $n = 3$ to $n = 2$

52. In the lowest energy level of hydrogen atom, the electron has the angular momentum [MP PET 1997; BCECE 2003]
(a) π/h (b) h/π
(c) $h/2\pi$ (d) $2\pi/h$

53. The minimum energy required to excite a hydrogen atom from its ground state is [EAMCET (Engg.) 1995; MP PMT 1997; CPMT 1999; DCE 1999]
(a) 13.6 eV (b) $-13.6\ eV$
(c) 3.4 eV (d) 10.2 eV

54. Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is [AFMC 1996] [EAMCET (Engg.) 1995; MP PMT 1997]
(a) 1: 3 (b) 27 : 5
(c) 5 : 27 (d) 4 : 9

55. The Rydberg constant R for hydrogen is [MP PMT/PET 1998]
(a) $R = -\left(\frac{1}{4\pi\varepsilon_0}\right).\frac{2\pi^2 me^2}{ch^2}$ (b) $R = \left(\frac{1}{4\pi\varepsilon_0}\right).\frac{2\pi^2 me^4}{ch^2}$
(c) $R = \left(\frac{1}{4\pi\varepsilon_0}\right)^2.\frac{2\pi^2 me^4}{c^2h^2}$ (d) $R = \left(\frac{1}{4\pi\varepsilon_0}\right)^2.\frac{2\pi^2 me^4}{ch^3}$

56. The wavelength of the first line of Balmer series is $6563\ Å$. The Rydberg constant for hydrogen is about [MP PMT/PET 1998]
(a) $1.09 \times 10^7\ per\ m$ (b) $1.09 \times 10^8\ per\ m$
(c) $1.09 \times 10^9\ per\ m$ (d) $1.09 \times 10^5\ per\ m$

57. According to Bohr's theory the moment of momentum of an electron revolving in second orbit of hydrogen atom will be [MP PET 1999; KCET 2003]
(a) $2\pi h$ (b) πh
(c) $\frac{h}{\pi}$ (d) $\frac{2h}{\pi}$

58. The velocity of an electron in the second orbit of sodium atom (atomic number = 11) is v. The velocity of an electron in its fifth orbit will be [MP PET 1999]
(a) v (b) $\frac{22}{5}v$
(c) $\frac{5}{2}v$ (d) $\frac{2}{5}v$

59. The absorption transitions between the first and the fourth energy states of hydrogen atom are 3. The emission transitions between these states will be [MP PET 1999]
(a) 3 (b) 4
(c) 5 (d) 6

60. The ratio of longest wavelength and the shortest wavelength observed in the five spectral series of emission spectrum of hydrogen is [MP PET 1999]
(a) $\frac{4}{3}$ (b) $\frac{525}{376}$
(c) 25 (d) $\frac{900}{11}$

61. In the Bohr model of a hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass, e is the charge on the electron and ε_0 is the vacuum permittivity, the speed of the electron is [CBSE PMT 1998]

(a) 0 (b) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(c) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (d) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

62. The electron in a hydrogen atom makes a transition $n_1 \to n_2$, where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are [IIT 1998; KCET 2005]

(a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$

(c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

63. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom (Z = 3) is [IIT 1997 Re-Exam; MH CET 2000]

(a) 1.51 (b) 13.6

(c) 40.8 (d) 122.4

64. Which one of these is non-divisible [KCET 1994]

(a) Nucleus (b) Photon

(c) Proton (d) Atom

65. In Bohr's model of hydrogen atom, let PE represents potential energy and TE the total energy. In going to a higher level

(a) PE decreases, TE increases

(b) PE increases, TE increases

(c) PE decreases, TE decreases

(d) PE increases, TE decreases

66. According to Bohr's model, the radius of the second orbit of helium atom is [Bihar MEE 1995]

(a) 0.53 Å (b) 1.06 Å

(c) 2.12 Å (d) 0.265 Å

67. The fact that photons carry energy was established by [ISM Dhanbad 1994]

(a) Doppler's effect (b) Compton's effect

(c) Bohr's theory (d) Diffraction of light

68. An ionic atom equivalent to hydrogen atom has wavelength equal to 1/4 of the wavelengths of hydrogen lines. The ion will be

(a) He^+ (b) Li^{++}

(c) Ne^{9+} (d) Na^{10+}

69. The extreme wavelengths of Paschen series are [RPET 1997]

(a) $0.365\mu m$ and $0.565\mu m$ (b) $0.818\mu m$ and $1.89\mu m$

(c) $1.45\mu m$ and $4.04\mu m$ (d) $2.27\mu m$ and $7.43\mu m$

70. The third line of Balmer series of an ion equivalent to hydrogen atom has wavelength of 108.5 nm. The ground state energy of an electron of this ion will be [RPET 1997]

(a) 3.4 eV (b) 13.6 eV

(c) 54.4 eV (d) 122.4 eV

71. An electron in the n = 1 orbit of hydrogen atom is bound by 13.6 eV energy is required to ionize it is [MP PMT 2003]

(a) 13.6 eV (b) 6.53 eV

(c) 5.4 eV (d) 1.51 eV

72. Ionization energy of hydrogen is 13.6 eV. If $h = 6.6 \times 10^{-34}$ $J-sec$, the value of R will be of the order of [RPMT 1997]

(a) $10^{10} m^{-1}$ (b) $10^7 m^{-1}$

(c) $10^4 m^{-1}$ (d) $10^{-7} m^{-1}$

73. To explain his theory, Bohr used [CBSE PMT 1993; MP PET 2002]

(a) Conservation of linear momentum

(b) Conservation of angular momentum

(c) Conservation of quantum frequency

(d) Conservation of energy

74. The ionisation energy of hydrogen atom is 13.6 eV. Following Bohr's theory, the energy corresponding to a transition between the 3rd and the 4th orbit is [KCET 1994] [CBSE PMT 1992; DPMT 2000; RPMT 1999; AMU (Med.) 2001]

(a) 3.40 eV (b) 1.51 eV

(c) 0.85 eV (d) 0.66 eV

75. Hydrogen atoms are excited from ground state of the principal quantum number 4. Then the number of spectral lines observed will be [CBSE PMT 1993]

(a) 3 (b) 6

(c) 5 (d) 2

76. Hydrogen atom emits blue light when it changes from n = 4 energy level to the n = 2 level. Which colour of light would the atom emit when it changes from the n = 5 level to the n = 2 level

(a) Red (b) Yellow

(c) Green (d) Violet

77. In Rutherford scattering experiment, what will be the correct angle for α scattering for an impact parameter b = 0 [RPET 1997] [CBSE PMT 1994; JIPMER 2000]

(a) 90^o (b) 270^o

(c) 0^o (d) 180^o

78. The radius of hydrogen atom in its ground state is $5.3 \times 10^{-11} m$. After collision with an electron it is found to have a radius of

$21.2 \times 10^{-11} m$. What is the principal quantum number n of the final state of the atom

[CBSE PMT 1994; CPMT 2001; MH CET 2000]

(a) $n = 4$ (b) $n = 2$

(c) $n = 16$ (d) $n = 3$

79. The splitting of line into groups under the effect of electric or magnetic field is called [AFMC 1995]

(a) Zeeman's effect (b) Bohr's effect

(c) Heisenberg's effect (d) Magnetic effect

80. The energy of a hydrogen atom in its ground state is $-13.6\ eV$. The energy of the level corresponding to the quantum number $n = 2$ (first excited state) in the hydrogen atom is [CBSE PMT 1996; CBSE PMT 1997, 2001; MP PET 2000; AFMC 2000, 01, 02; BCECE 2003]

(a) – 2.72 eV (b) – 0.85 eV

(c) – 0.54 eV (d) – 3.4 eV

81. The first line of Balmer series has wavelength 6563 Å. What will be the wavelength of the first member of Lyman series

[RPMT 1996]

(a) 1215.4 Å (b) 2500 Å

(c) 7500 Å (d) 600 Å

82. The wavelength of Lyman series is [BHU 1997]

(a) $\frac{4}{3 \times 10967} cm$ (b) $\frac{3}{4 \times 10967} cm$

(c) $\frac{4 \times 10967}{3} cm$ (d) $\frac{3}{4} \times 10967\ cm$

83. When hydrogen atom is in its first excited level, its radius is .... its ground state radius [CBSE PMT 1997]

(a) Half (b) Same

(c) Twice (d) Four times

84. Hydrogen atom excites energy level from fundamental state to $n = 3$. Number of spectrum lines according to Bohr, is

[CPMT 1997]

(a) 4 (b) 3

(c) 1 (d) 2

85. Number of spectral lines in hydrogen atom is [CPMT 1997]

(a) 3 (b) 6

(c) 15 (d) Infinite

86. In Bohr's model, the atomic radius of the first orbit is r_0, then the radius of the third orbit is

[AIIMS 1997; CPMT 2001; KCET (Engg./Med.) 1999; Pb. PMT 2004]

(a) $\frac{r_0}{9}$ (b) r_0

(c) $9r_0$ (d) $3r_0$

87. The wavelength of the energy emitted when electron come from fourth orbit to second orbit in hydrogen is $20.397\ cm$. The wavelength of energy for the same transition in He^+ is

[AIIMS 1997; JIPMER 2000]

(a) $5.099\ cm^{-1}$ (b) $20.497\ cm^{-1}$

(c) $40.994\ cm^{-1}$ (d) $81.988\ cm^{-1}$

88. Minimum excitation potential of Bohr's first orbit in hydrogen atom is

[BHU 1998; JIPMER 2001, 02; Pb. PMT 2004]

(a) 13.6 V (b) 3.4 V

(c) 10.2 V (d) 3.6 V

89. 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 electrons 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 correct answer using the codes given below

Codes : [SCRA 1998]

(a) I and III (b) II and IV

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

90. The wavelength of radiation emitted is λ_0 when an electron jumps from the third to the second orbit of hydrogen atom. For the electron jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(a) $\frac{16}{25}\lambda_0$ (b) $\frac{20}{27}\lambda_0$

(c) $\frac{27}{20}\lambda_0$ (d) $\frac{25}{16}\lambda_0$

91. For electron moving in n orbit of H-atom the angular velocity is proportional to [RPET 1999]

(a) n (b) $1/n$

(c) n (d) $1/n$

92. The energy of electron in first excited state of H-atom is $-3.4\ eV$ its kinetic energy is

[RPET 1999; CBSE PMT 2005]

(a) – 3.4 eV (b) + 3.4 eV

(c) – 6.8 eV (d) 6.8 eV

93. The energy required to excite an electron from the ground state of hydrogen atom to the first excited state, is

[Pb. PMT 1999]

(a) $1.602 \times 10^{-14}\ J$ (b) $1.619 \times 10^{-16}\ J$

(c) $1.632 \times 10^{-18}\ J$ (d) $1.656 \times 10^{-20}\ J$

94. Which of the following phenomena suggests the presence of electron energy levels in atoms [JIPMER 1999]

(a) Radio active decay

(b) Isotopes

(c) Spectral lines

(d) α-particles scattering

95. Which of the following spectral series in hydrogen atom give spectral line of 4860 Å [Roorkee 1999]

(a) Lyman (b) Balmer

(c) Paschen (d) Brackett

96. If scattering particles are 56 for 90^o angle then this will be at 60^o angle [RPMT 2000]

(a) 224 (b) 256

(c) 98 (d) 108

97. When an electron in hydrogen atom is excited, from its 4^{th} to 5^{th} stationary orbit, the change in angular momentum of electron is (Planck's constant: $h = 6.6\times10^{-34}$ *J*- s) [AFMC 2000; Pb. PET 2001]

(a) 4.16×10^{-34} *J- s* (b) 3.32×10^{-34} *J-s*

(c) 1.05×10^{-34} *J-s* (d) 2.08×10^{-34} *J-s*

98. Energy of electron in a orbit of *H*-atom is [RPET 2000]

(a) Positive (b) Negative

(c) Zero (d) Nothing can be said

99. The concept of stationary orbits was proposed by [Pb. PMT 2000]

(a) Neil Bohr (b) J.J. Thomson

(c) Ruther ford (d) I. Newton

100. In a hydrogen atom, the distance between the electron and proton is $2.5\times10^{-11}\ m$. The electrical force of attraction between them will be [Pb. PMT 2000]

(a) $2.8\times10^{-7}\ N$ (b) $3.7\times10^{-7}\ N$

(c) $6.2\times10^{-7}\ N$ (d) $9.1\times10^{-7}\ N$

101. If λ_{max} is 6563 Å, then wave length of second line for Balmer series will be [RPMT 2000]

(a) $\lambda = \frac{16}{3R}$ (b) $\lambda = \frac{36}{5R}$

(c) $\lambda = \frac{4}{3R}$ (d) None of the above

102. What will be the angular momentum of a electron, if energy of this electron in *H*-atom is 1.5eV (in *J-sec*) [RPMT 2000]

(a) 1.05×10^{-34} (b) 2.1×10^{-34}

(c) 3.15×10^{-34} (d) -2.1×10^{-34}

103. Who discovered spin quantum number [RPMT 2000]

(a) Unlenbeck and Goudsmit

(b) Nell's Bohr

(c) Zeeman

(d) Sommerfield

104. The time of revolution of an electron around a nucleus of charge *Ze* in *n* Bohr orbit is directly proportional to [MP PET 2003]

(a) n (b) $\frac{n^3}{Z^2}$

(c) $\frac{n^2}{Z}$ (d) $\frac{Z}{n}$

105. In Bohr's model, if the atomic radius of the first orbit is r_0, then the radius of the fourth orbit is [CBSE PMT 2000]

(a) r_0 (b) $4r_0$

(c) $r_0/16$ (d) $16r_0$

106. If *R* is the Rydberg's constant for hydrogen the wave number of the first line in the Lyman series will be [KCET 2000]

(a) $\frac{R}{4}$ (b) $\frac{3R}{4}$

(c) $\frac{R}{2}$ (d) $2R$

107. In hydrogen atom, if the difference in the energy of the electron in $n = 2$ and $n = 3$ orbits is *E*, the ionization energy of hydrogen atom is [EAMCET (Med.) 2000]

(a) 13.2 *E* (b) 7.2 *E*

(c) 5.6 *E* (d) 3.2 *E*

108. The first member of the Paschen series in hydrogen spectrum is of wavelength 18,800 Å. The short wavelengths limit of Paschen series is [EAMCET (Med.) 2000]

(a) 1215 Å (b) 6560 Å

(c) 8225 Å (d) 12850 Å

109. The ratio of the largest to shortest wavelengths in Lyman series of hydrogen spectra is [EAMCET (Med.) 2000]

(a) $\frac{25}{9}$ (b) $\frac{17}{6}$

(c) $\frac{9}{5}$ (d) $\frac{4}{3}$

110. In Bohr model of hydrogen atom, the ratio of periods of revolution of an electron in $n = 2$ and $n = 1$ orbits is [EAMCET (Engg.) 2000]

(a) 2 : 1 (b) 4 : 1

(c) 8 : 1 (d) 16 : 1

111. The ratio of the longest to shortest wavelengths in Brackett series of hydrogen spectra is [EAMCET (Engg.) 2000]

(a) $\frac{25}{9}$ (b) $\frac{17}{6}$

(c) $\frac{9}{5}$ (d) $\frac{4}{3}$

112. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true

(a) Its kinetic energy increases and its potential and total energies decrease

(b) Its kinetic energy decreases, potential energy increases and its total energy remains the same

(c) Its kinetic and total energies decrease and its potential energy increases

(d) Its kinetic, potential and total energies decreases

113. The ratio of minimum to maximum wavelength in Balmer series is

(a) 5 : 9 (b) 5 : 36

(c) 1 : 4 (d) 3 : 4

114. The radius of the Bohr orbit in the ground state of hydrogen atom is 0.5 $\mathring{A}$. The radius of the orbit of the electron in the third excited state of He^+ will be **[MP PMT 2000]**

(a) 8 $\mathring{A}$ (b) 4 $\mathring{A}$

(c) 0.5 $\mathring{A}$ (d) 0.25 $\mathring{A}$

115. The ratio of the speed of the electron in the first Bohr orbit of hydrogen and the speed of light is equal to (where *e*, *h* and *c* have their usual meanings) **[MP PMT 2000]**

(a) $2\pi hc/e^2$ (b) $e^2h/2\pi c$

(c) $e^2c/2\pi h$ (d) $2\pi e^2/hc$

116. According to the Rutherford's atomic model, the electrons inside the atom are **[KCET (Med.) 2000]**

(a) Stationary (b) Not stationary

(c) Centralized (d) None of these

117. The energy of hydrogen atom in its ground state is – 13.6 *eV*. The energy of the level corresponding to the quantum number *n* is equal 5 is **[KCET (Engg./Med.) 2001]**

(a) – 5.40 *eV* (b) – 2.72 *eV*

(c) – 0.85 *eV* (d) – 0.54 *eV*

118. According to classical theory, the circular path of an electron in Rutherford atom is **[BHU 2001]**

(a) Spiral (b) Circular

(c) Parabolic (d) Straight line

119. Rutherford's α-particle experiment showed that the atoms have

(a) Proton (b) Nucleus

(c) Neutron (d) Electrons

120. Orbital acceleration of electron is **[RPET 2001]**

(a) $\frac{n^2h^2}{4\pi^2m^2r^3}$ (b) $\frac{n^2h^2}{2n^2r^3}$

(c) $\frac{4n^2h^2}{\pi^2m^2r^3}$ (d) $\frac{4n^2h^2}{4\pi^2m^2r^3}$

121. Which of the following is true for number of spectral lines in going form Layman series to Pfund series **[RPET 2001]**

(a) Increases

(b) Decreases

(c) Unchanged

(d) May decreases or increases

122. The wavelength of yellow line of sodium is 5896 $\mathring{A}$. Its wave number will be **[MP PET 2001]**

(a) 50883×10^{10} per *second*

(b) 16961 per *cm*

(c) 17581 per *cm*

(d) 50883 per *cm*

123. Radius of the first orbit of the electron in a hydrogen atom is 0.53 $\mathring{A}$. So, the radius of the third orbit will be **[MP PET 2000]** **[Kerala (Engg.) 2001]**

(a) 2.12 $\mathring{A}$ (b) 4.77 $\mathring{A}$

(c) 1.06 $\mathring{A}$ (d) 1.59 $\mathring{A}$

124. The first line in the Lyman series has wavelength λ. The wavelength of the first line in Balmer series is **[MH CET (Med.) 2001]**

(a) $\frac{2}{9}\lambda$ (b) $\frac{9}{2}\lambda$

(c) $\frac{5}{27}\lambda$ (d) $\frac{27}{5}\lambda$

125. In hydrogen atom which quantity is integral multiple of $\frac{h}{2\pi}$ **[DCE 2001]**

(a) Angular momentum (b) Angular velocity

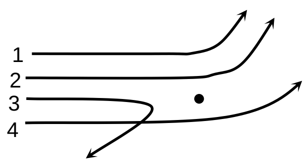
(c) Angular acceleration (d) Momentum

126. In the following transitions, which one has higher frequency **[UPSEAT 2001]**

(a) 3 – 2 (b) 4 – 3

(c) 4 – 2 (d) 3 – 1

127. The diagram shows the path of four α-particles of the same energy being scattered by the nucleus of an atom simultaneously. Which of these are/is not physically possible **[AMU (Med.) 2001]**



(a) 3 and 4 (b) 2 and 3

(c) 1 and 4 (d) 4 only

128. An electron jumps from 5th orbit to 4th orbit of hydrogen atom. **[AFMC 2001]** Taking the Rydberg constant as 10^7 *per metre*. What will be the frequency of radiation emitted **[Pb. PMT 2001]**

(a) $6.75 \times 10^{12}\ Hz$ (b) $6.75 \times 10^{14}\ Hz$

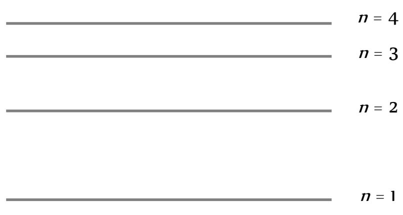
(c) $6.75 \times 10^{13}\ Hz$ (d) None of these

129. For principal quantum number $n = 3$, the possible values of orbital quantum number '*l*' are **[MP PET 2001; MP PMT 2001]**

(a) 1, 2, 3 (b) 0, 1, 2, 3

(c) 0, 1, 2 (d) –1, 0, +1

130. Four lowest energy levels of *H*-atom are shown in the figure. The number of possible emission lines would be **[MP PMT 2001]**



(a) 3 (b) 4

(c) 5 (d) 6

131. The order of the size of nucleus and Bohr radius of an atom respectively are [MP PET 2001; MP PMT 2001]

(a) $10^{-14}m, 10^{-10}m$ (b) $10^{-10}m, 10^{-8}m$

(c) $10^{-20}m, 10^{-16}m$ (d) $10^{-8}m, 10^{-6}m$

132. Energy of an electron in an excited hydrogen atom is – 3.4 *eV*. Its angular momentum will be: $h = 6.626\times10^{-34}J-s$

[UPSEAT 1999; Kerala PET 2002]

(a) $1.11\times10^{34}J$ sec (b) $1.51\times10^{-31}J$ sec

(c) $2.11\times10^{-34}J$ sec (d) $3.72\times10^{-34}J$ sec

133. The ratio of the wavelengths for $2\rightarrow1$ transition in *Li*, *He* and *H* is

(a) 1 : 2 : 3 (b) 1 : 4 : 9

(c) 4 : 9 : 36 (d) 3 : 2 : 1

134. The wavelength of light emitted from second orbit to first orbits in a hydrogen atom is [Pb. PMT 2002]

(a) $1.215\times10^{-7}m$ (b) $1.215\times10^{-5}m$

(c) $1.215\times10^{-4}m$ (d) $1.215\times10^{-3}m$

135. Energy of the electron in *n* orbit of hydrogen atom is given by $E_n = -\frac{13.6}{n^2}eV$. The amount of energy needed to transfer electron from first orbit to third orbit is

[MH CET 2002; Kerala PMT 2002]

(a) 13.6 *eV* (b) 3.4 *eV*

(c) 12.09 *eV* (d) 1.51 *eV*

136. The ratio of speed of an electron in ground state in Bohrs first orbit of hydrogen atom to velocity of light in air is

[MH CET 2002]

(a) $\frac{e^2}{2\varepsilon_0 hc}$ (b) $\frac{2e^2\varepsilon_0}{hc}$

(c) $\frac{e^3}{2\varepsilon_0 hc}$ (d) $\frac{2\varepsilon_0 hc}{e^2}$

137. Whenever a hydrogen atom emits a photon in the Balmer series [KCET 2002]

(a) It need not emit any more photon

(b) It may emit another photon in the Paschen series

(c) It must emit another photon in the Lyman series

(d) It may emit another photon in the Balmer series

138. The de-Broglie wavelength of an electron in the first Bohr orbit is

(a) Equal to one fourth the circumference of the first orbit

(b) Equal to half the circumference of the first orbit

(c) Equal to twice the circumference of the first orbit

(d) Equal to the circumference of the first orbit

139. In hydrogen atom, when electron jumps from second to first orbit, then energy emitted is [AIEEE 2002]

(a) – 13.6 *eV* (b) – 27.2 *eV*

(c) – 6.8 *eV* (d) None of these

140. Minimum energy required to takeout the only one electron from ground state of He^+ is [CPMT 2002]

(a) 13.6 *eV* (b) 54.4 *eV*

(c) 27.2 *eV* (d) 6.8 *eV*

141. The frequency of 1st line of Balmer series in H_2 atom is ν_0. The frequency of line emitted by singly ionised *He* atom is

[CPMT 2002]

(a) $2\nu_0$ (b) $4\nu_0$

(c) $\nu_0/2$ (d) $\nu_0/4$

142. When the electron in the hydrogen atom jumps from 2nd orbit to 1st orbit, the wavelength of radiation emitted is λ. When the electrons jump from 3rd orbit to 1st orbit, the wavelength of emitted radiation would be [UPSEAT 2003] [MP PMT 2002]

(a) $\frac{27}{32}\lambda$ (b) $\frac{32}{27}\lambda$

(c) $\frac{2}{3}\lambda$ (d) $\frac{3}{2}\lambda$

143. The possible quantum number for 3*d* electron are

[MP PMT 2002]

(a) $n=3, l=1, m_l=+1, m_s=-\frac{1}{2}$

(b) $n=3, l=2, m_l=+2, m_s=-\frac{1}{2}$

(c) $n=3, l=1, m_l=-1, m_s=+\frac{1}{2}$

(d) $n=3, l=0, m_l=+1, m_s=-\frac{1}{2}$

144. The radius of the first (lowest) orbit of the hydrogen atom is a_0. The radius of the second (next higher) orbit will be

[MP PET 2002; MP PMT 2004]

(a) $4a_0$ (b) $6a_0$

(c) $8a_0$ (d) $10a_0$

145. Which of the following transition will have highest emission wavelength [BHU 2003]

(a) $n=2$ to $n=1$ (b) $n=1$ to $n=2$

(c) $n=2$ to $n=5$ (d) $n=5$ to $n=2$

146. When the wave of hydrogen atom comes from infinity into the first orbit then the value of wave number is [RPET 2003]

(a) 109700 cm^{-1} (b) 1097 cm^{-1}

(c) 109 cm^{-1} (d) None of these

147. With the increase in principle quantum number, the energy difference between the two successive energy levels [KCET 2002]

[RPET 2003]

(a) Increases

(b) Decreases

(c) Remains constant

(d) Sometimes increases and sometimes decreases

148. In which of the following systems will the radius of the first orbit $(n=1)$ be minimum

[Kerala PET 2002; CBSE PMT 2003]

(a) Single ionized helium
(b) Deuterium atom
(c) Hydrogen atom
(d) Doubly ionized lithium

149. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is [AIEEE 2003]

(a) 122.4 eV (b) 30.6 eV
(c) 13.6 eV (d) 3.4 eV

150. Which of the following is quantised according to Bohr's theory of hydrogen atom [MP PMT 2004]

(a) Linear momentum of electron
(b) Angular momentum of electron
(c) Linear velocity of electron
(d) Angular velocity of electron

151. The shortest wavelength in the Lyman series of hydrogen spectrum is 912 $\mathring{A}$ corresponding to a photon energy of 13.6 eV. The shortest wavelength in the Balmer series is about

[MP PMT 2004]

(a) 3648 $\mathring{A}$ (b) 8208 $\mathring{A}$
(c) 1228 $\mathring{A}$ (d) 6566 $\mathring{A}$

152. Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2} eV$. The energy of a photon ejected when the electron jumps from $n = 3$ state to $n = 2$ state of hydrogen is approximately [CBSE PMT 2004]

(a) 1.5 eV (b) 0.85 eV
(c) 3.4 eV (d) 1.9 eV

153. The Bohr model of atoms [CBSE PMT 2004]

(a) Assumes that the angular momentum of electrons is quantized
(b) Uses Einstein's photo-electric equation
(c) Predicts continuous emission spectra for atoms
(d) Predicts the same emission spectra for all types of atoms

154. The colour of the second line of Balmer series is

[J & K CET 2004]

(a) Blue (b) Yellow
(c) Red (d) Violet

155. Which state of triply ionised Baryllium (Be^{+++}) has the same orbital radius as that of the ground state of hydrogen

[KCET 2004]

(a) $n = 4$ (b) $n = 3$
(c) $n = 2$ (d) $n = 1$

156. The ratio of areas within the electron orbits for the first excited state to the ground state for hydrogen atom is

[BCECE 2004]

(a) 16 : 1 (b) 18 : 1
(c) 4 : 1 (d) 2 : 1

157. The kinetic energy of an electron revolving around a nucleus will be

(a) Four times of P.E. (b) Double of P.E.
(c) Equal to P.E. (d) Half of its P.E.

158. Taking Rydberg's constant $R_H = 1.097 \times 10^7 m$ first and second wavelength of Balmer series in hydrogen spectrum is

[Pb. PMT 2004]

(a) 2000 $\mathring{A}$, 3000 $\mathring{A}$ (b) 1575 $\mathring{A}$, 2960 $\mathring{A}$
(c) 6529 $\mathring{A}$, 4280 $\mathring{A}$ (d) 6552 $\mathring{A}$, 4863 $\mathring{A}$

159. The kinetic energy of electron in the first Bohr orbit of the hydrogen atom is [Pb. PET 2000]

(a) – 6.5 eV (b) – 27.2 eV
(c) 13.6 eV (d) – 13.6 eV

160. In the spectrum of hydrogen atom, the ratio of the longest wavelength in Lyman series to the longest wavelength in the Balmer series is [UPSEAT 2004]

(a) 5/27 (b) 1/93
(c) 4/9 (d) 3/2

161. In Bohr's model of hydrogen atom, which of the following pairs of quantities are quantized [UPSEAT 2004]

(a) Energy and linear momentum
(b) Linear and angular momentum
(c) Energy and angular momentum
(d) None of the above

162. The energy of the highest energy photon of Balmer series of hydrogen spectrum is close to [UPSEAT 2004]

(a) 13.6 eV (b) 3.4 eV
(c) 1.5 eV (d) 0.85 eV

163. Energy of an electron in n orbit of hydrogen atom is $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $-\frac{2\pi^2 k^2 me^4}{n^2h^2}$ (b) $-\frac{4\pi^2 m ke^2}{n^2h^2}$
(c) $-\frac{n^2h^2}{2\pi k me^4}$ (d) $-\frac{n^2h^2}{4\pi^2 k me^2}$

164. Which one of the relation is correct between time period and number of orbits while an electron is revolving in a orbit

[DPMT 2003]

(a) n^2 (b) $\frac{1}{n^2}$
(c) n^3 (d) $\frac{1}{n}$

165. An electron changes its position from orbit $n = 4$ to the orbit $n = 2$ of an atom. The wavelength of the emitted radiation's is (R = Rydberg's constant) [BHU 2004]

(a) $\frac{16}{R}$ (b) $\frac{16}{3R}$
(c) $\frac{16}{5R}$ (d) $\frac{16}{7R}$

166. If the energy of a hydrogen atom in nth orbit is E_n, then energy in the nth orbit of a singley ionized helium atom will be [BCECE 2004]

(a) $4E_n$ (b) $E_n / 4$
(c) $2E_n$ (d) $E_n / 2$

167. What is the ratio of wavelength of radiations emitted when an electron in hydrogen atom jump from fourth orbit to second orbit and from third orbit to second orbit [MH CET 2004]

(a) 27 : 25 (b) 20 : 27
(c) 20 : 25 (d) 25 : 27

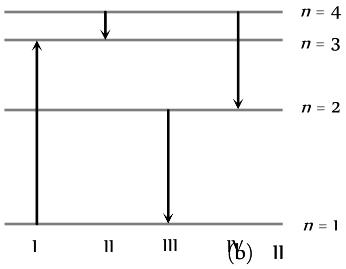
168. The energy of electron in the *n*th orbit of hydrogen atom is expressed as $E_n = \frac{-13.6}{n^2} eV$. The shortest and longest wavelength of Lyman series will be [Pb. PET 2003]

(a) 910 Å, 1213 Å (b) 5463 Å, 7858 Å
(c) 1315 Å, 1530 Å (d) None of these

169. The ground state energy of hydrogen atom is – 13.6 *eV*. What is the potential energy of the electron in this state [AIIMS 2005]

(a) 0 *eV* (b) – 27.2 *eV*
(c) 1 *eV* (d) 2 *eV*

170. The diagram shows-the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy [AIEEE 2005]



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

171. As the electron in Bohr orbit of Hydrogen atom passes from state $n = 2$ to $n = 1$, the kinetic energy *K* and potential energy *U* change as [MP PET 2005]

(a) *K* two-fold, *U* four-fold
(b) *K* four-fold, *U* two-fold
(c) *K* four-fold, *U* also four-fold
(d) *K* two-fold, *U* also two-fold

172. The magnetic moment (μ) of a revolving electron around the nucleus varies with principal quantum number *n* as [AIIMS 2005]

(a) $\mu \propto n$ (b) $\mu \propto 1/n$
(c) $\mu \propto n^2$ (d) $\mu \propto 1/n^2$

173. Bohr's atom model assumes [KCET 2005]

(a) The nucleus is of infinite mass and is at rest
(b) Electrons in a quantized orbit will not radiate energy
(c) Mass of electron remains constant
(d) All the above conditions

174. Radius of first Bohr orbit is *r*. What is the radius of 2nd Bohr orbit? [BHU 2005]

(a) 8*r* (b) 2*r*
(c) 4*r* (d) $2\sqrt{2r}$

Nucleus, Nuclear Reaction

1. Which of the following particles are constituents of the nucleus [CBSE PMT 199

(a) Protons and electrons (b) Protons and neutrons
(c) Neutrons and electrons (d) Neutrons and positrons

2. The particles which can be added to the nucleus of an atom without changing its chemical properties are called [NCERT 1979]

(a) Electrons (b) Protons
(c) Neutrons (d) None of the above

3. The neutron was discovered by [MP PMT 1992; RPMT 1996]

(a) Marie Curie (b) Pierre Curie
(c) James Chadwick (d) Rutherford

4. The mass number of a nucleus is [IIT 1986; ISM Dhanbad 1994; MP PMT 1997; CBSE PMT 2003; MH CET (Med.) 2001]

(a) Always less than its atomic number
(b) Always more than its atomic number
(c) Always equal to its atomic number
(d) Sometimes more than and sometimes equal to its atomic number

5. The energy equivalent of 1 *kilogram* of matter is about [MP PET/PMT 1988; MNR 1987]

(a) $10^{-15} J$ (b) 1 *J*
(c) $10^{-12} J$ (d) $10^{17} J$

6. Nuclear binding energy is equivalent to [MP PET/PMT 1988]

(a) Mass of proton (b) Mass of neutron
(c) Mass of nucleus (d) Mass defect of nucleus

7. If the binding energy of the deutrium is 2.23 *MeV*. The mass defect given in *a.m.u.* is [MP PET 1993]

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

8. Which of the following has the mass closest in value to that of the positron [AFMC 1993]

(a) Proton (b) Electron
(c) Photon (d) Neutrino

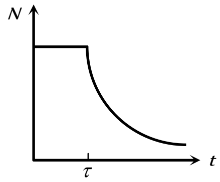
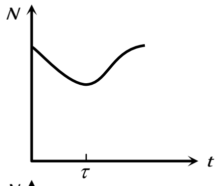
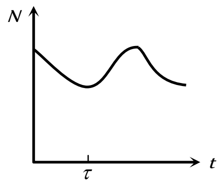
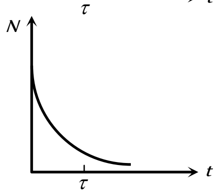
$(1\ a.m.u = 931\ MeV)$

9. Size of nucleus is of the order of [CPMT 1983; MP PET 2002, 03]

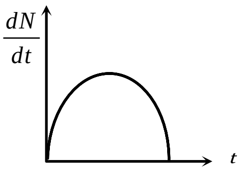
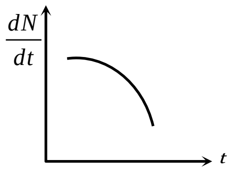
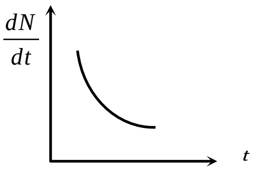
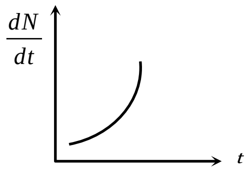
(a) $10^{-10} m$ (b) $10^{-15} m$
(c) $10^{-12} m$ (d) $10^{-19} m$

4. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean life time of one species is τ and that of the other is 5τ. The decay products in both cases are stable. A plot is made of the total number of radioactive nuclei as a function of time. Which of the following figures best represents the form of this plot

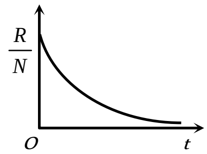
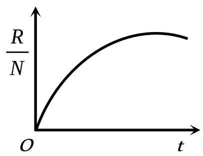
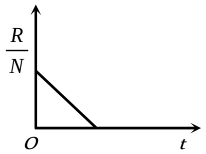
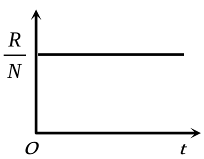
[IIT-JEE (Screening) 2001]

(a) 
(b) 
(c) 
(d) 

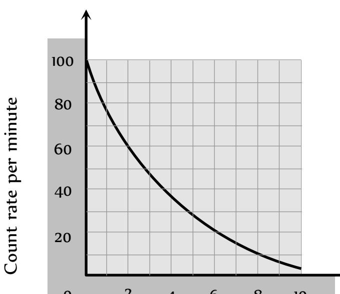
5. Radioactive element decays to form a stable nuclide, then the rate of decay of reactant $\left(\frac{dN}{dt}\right)$ will vary with time (t) as shown in figure

(a) 
(b) 
(c) 
(d) 

6. A radioactive sample has N_0 active atoms at $t = 0$. If the rate of disintegration at any time is R and the number of atoms is N, then the ratio R/N varies with time as

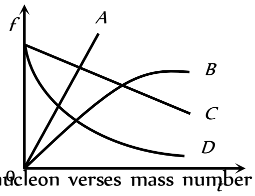
(a) 
(b) 
(c) 
(d) 

7. The count rate of 10g of radioactive material was measured at different times and this has been shown in the figure. The half life of material and the total counts (approximately) in the first half life period, respectively are [CPMT 1986]



(a) 4h, 9000 (b) 3h, 14000
(c) 3h, 235 (d) 3h, 50

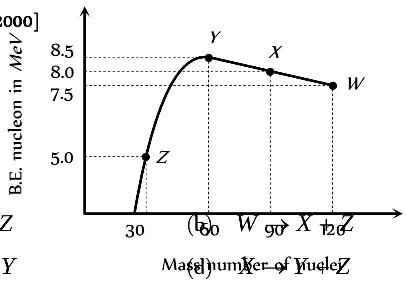
8. The fraction f of radioactive material that has decayed in time t, varies with time t. The correct variation is given by the curve



(a) A
(b) B
(c) C
(d) D

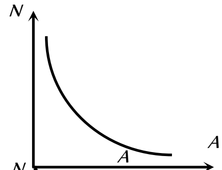
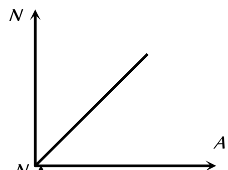
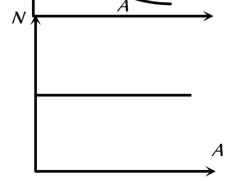
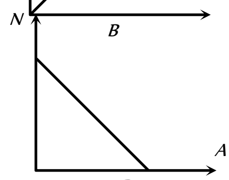
9. Binding energy per nucleon verses mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is

[DCE 2000]

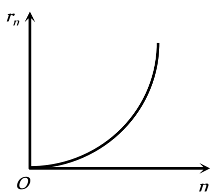
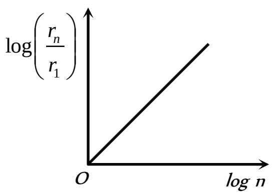
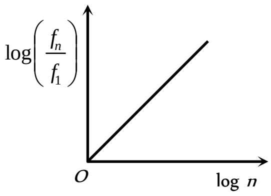


(a) $Y \rightarrow 2Z$ (b) $W \rightarrow X + Z$
(c) $W \rightarrow 2Y$ (d) $X \rightarrow Y + Z$

10. The plot of the number (N) of decayed atoms versus activity (A) of a radioactive substance is

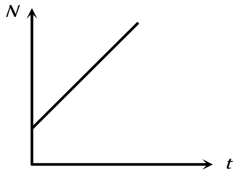
(a) 
(b) 
(c) 
(d) 

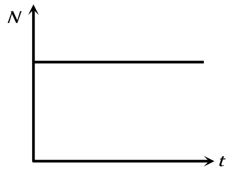
11. If in hydrogen atom, radius of n^{th} Bohr orbit is r_n, frequency of revolution of electron in n^{th} orbit is f_n choose the correct option

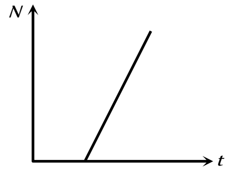
(a) 
(b) 
(c) 
(d) Both (a) and (b)

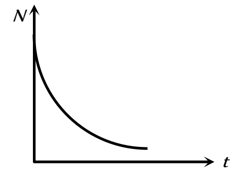
(c) (d)

12. The graph between the instantaneous concentration (N) of a radioactive element and time (t) is

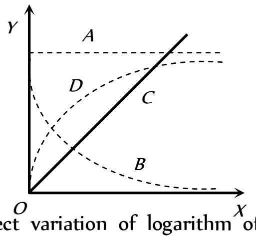
(a) 

(b) 

(c) 

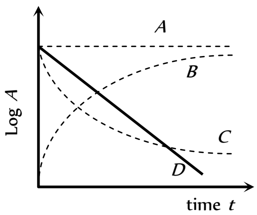
(d) 

13. In Fig. X represents time and Y represent activity of a radioactive sample. Then the activity of sample, varies with time according to the curve



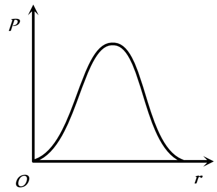
(a) A
(b) B
(c) C
(d) D

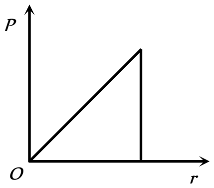
14. The graph which represents the correct variation of logarithm of activity (log A) versus time, in figure is

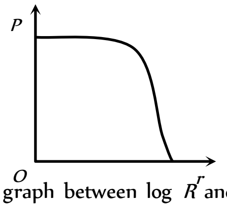


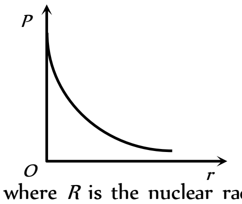
(a) A
(b) B
(c) C
(d) D

15. The charge density in a nucleus varies with distance from the centre of the nucleus according to the curve in Fig.

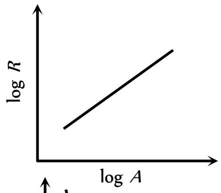
(a) 

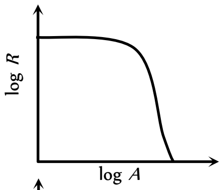
(b) 

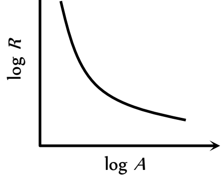
(c) 

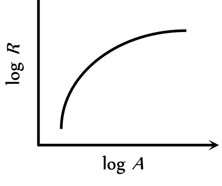
(d) 

16. The graph between log R and log A where R is the nuclear radius and A *is the mass number is*

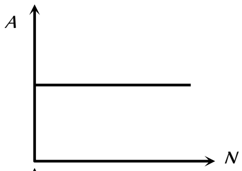
(a) 

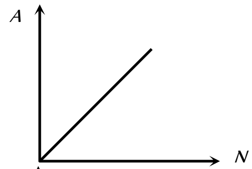
(b) 

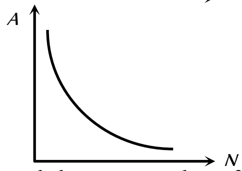


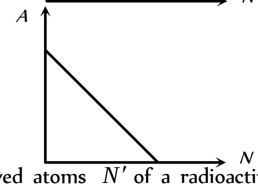


17. The curve between the activity A of a radioactive sample and the number of active atoms N is

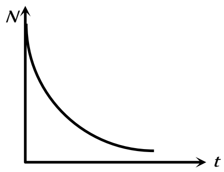
(a) 

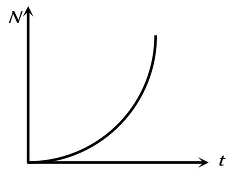
(b) 

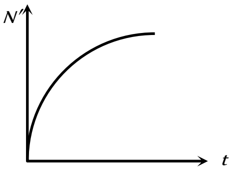
(c) 

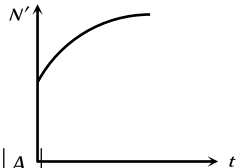
(d) 

18. The graph between number of decayed atoms N' of a radioactive element and time t is

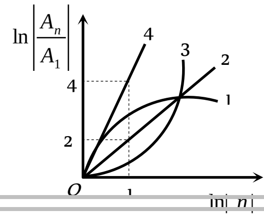
(a) 

(b) 

(c) 

(d) 

19. The figure shows a graph between $\ln\left|\frac{A_n}{A_1}\right|$ and $\ln|n|$, where A_n is the area enclosed by the nth orbit in a hydrogen like atom. The correct curve is



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

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : It is not possible to use ^{35}Cl as the fuel for fusion energy.

Reason : The binding energy of ^{35}Cl is too small.

[AIIMS 2005]

2. Assertion : ^{90}Sr from the radioactive fall out from a nuclear bomb ends up in the bones of human beings through the milk consumed by them. It causes impairment of the production of red blood cells.

Reason : The energetics β-particles emitted in the decay of ^{90}Sr damage the bone marrow. [AIIMS 2004]

3. Assertion : Neutrons penetrate matter more readily as compared to protons.

Reason : Neutrons are slightly more massive than protons. [AIIMS 2003]

4. Assertion : Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

Reason : According to classical physics all moving electrons radiate. [AIIMS 2003]

5. Assertion : Radioactive nuclei emit β^{-1} particles.

Reason : Electrons exist inside the nucleus. [AIIMS 2003]

6. Assertion : $_ZX^A$ undergoes $2\alpha -$ decays. $2\beta -$ decays and $2\gamma -$decays and the daughter product is $_{Z-2}Y^{A-8}$.

Reason : In α-decay the mass number decreases by 4 and atomic number decreases by 2. In β- decay the mass number remains unchanged, but atomic number increases by 1 only. [AIIMS 2001]

7. Assertion : Density of all the nuclei is same.

Reason : Radius of nucleus is directly proportional to the cube root of mass number. [AIIMS 2000]

8. Assertion : Isobars are the element having same mass number but different atomic number.

Reason : Neutrons and protons are present inside nucleus. [AIIMS 1997]

9. Assertion : The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.

Reason : Rutherford did α-particle scattering experiment.

10. Assertion : The positively charged nucleus of an atom has a radius of almost $10^{-15}m$.

Reason : In α-particle scattering experiment, the distance of closest approach for α-particles is $\simeq 10^{-15}m$.

11. Assertion : According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic.

Reason : According to electromagnetic theory an accelerated particle continuously emits radiation.

12. Assertion : Electrons in the atom are held due to coulomb forces.

Reason : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

13. Assertion : The electron in the hydrogen atom passes from energy level $n=4$ to the $n=1$ level. The maximum and minimum number of photon that can be emitted are six and one respectively.

Reason : The photons are emitted when electron make a transition from the higher energy state to the lower energy state.

14. Assertion : Hydrogen atom consists of only one electron but its emission spectrum has many lines.

Reason : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

15. Assertion : It is essential that all the lines available in the emission spectrum will also be available in the absorption spectrum.

Reason : The spectrum of hydrogen atom is only absorption spectrum.

16. Assertion : For the scattering of α-particles at a large angles, only the nucleus of the atom is responsible.

Reason : Nucleus is very heavy in comparison to electrons.

17. Assertion : All the radioactive elements are ultimately converted in lead.

Reason : All the elements above lead are unstable.

18. Assertion : Amongst alpha, beta and gamma rays, α-particle has maximum penetrating power.

Reason : The alpha particle is heavier than beta and gamma rays.

19. Assertion : The ionising power of β-particle is less compared to α-particles but their penetrating power is more.

Reason : The mass of β-particle is less than the mass of α-particle.

20. Assertion : The mass of β-particles when they are emitted is higher than the mass of electrons obtained by other means.

Reason : β-particle and electron, both are similar particles.

21. Assertion : Radioactivity of 10^8 undecayed radioactive nuclei of half life of 50 days is equal to that of 1.2×10^8 number of undecayed nuclei of some other material with half life of 60 days

Reason : Radioactivity is proportional to half-life.

22. Assertion : Fragments produced in the fission of U^{235} are radioactive.

Reason : The fragments have abnormally high proton to neutron ratio.

23. Assertion : Electron capture occurs more often than positron emission in heavy elements.

Reason : Heavy elements exhibit radioactivity.

24. Assertion : The mass of a nucleus can be either less than or more than the sum of the masses of nucleons present in it.

Reason : The whole mass of the atom is considered in the nucleus.

Answers

Atomic Structure

1	a	2	d	3	a	4	d	5	c
6	b	7	b	8	c	9	a	10	d
11	b	12	b	13	b	14	c	15	c
16	c	17	c	18	b	19	c	20	b
21	c	22	c	23	c	24	d	25	d
26	c	27	d	28	b	29	d	30	b
31	a	32	d	33	c	34	d	35	d
36	b	37	c	38	a	39	c	40	c
41	a	42	d	43	d	44	a	45	a
46	a	47	c	48	a	49	b	50	a
51	b	52	c	53	d	54	c	55	d
56	a	57	c	58	d	59	d	60	d
61	c	62	ad	63	d	64	b	65	b
66	b	67	c	68	a	69	b	70	c
71	a	72	b	73	b	74	d	75	b
76	d	77	d	78	b	79	a	80	d
81	a	82	a	83	b	84	b	85	d
86	c	87	a	88	c	89	a	90	b
91	d	92	b	93	c	94	c	95	b
96	a	97	c	98	b	99	a	100	b
101	a	102	c	103	a	104	b	105	d
106	b	107	b	108	c	109	d	110	c
111	a	112	a	113	a	114	b	115	d
116	b	117	d	118	a	119	b	120	a
121	b	122	b	123	b	124	d	125	a
126	d	127	d	128	c	129	c	130	d
131	a	132	c	133	c	134	a	135	c
136	a	137	c	138	d	139	d	140	b
141	b	142	a	143	b	144	a	145	d
146	a	147	b	148	d	149	b	150	b
151	a	152	d	153	a	154	a	155	c
156	d	157	d	158	d	159	c	160	a
161	c	162	b	163	a	164	c	165	b
166	a	167	b	168	a	169	b	170	c
171	c	172	a	173	d	174	c		

Nucleus, Nuclear Reaction

1	b	2	c	3	c	4	d	5	d
6	d	7	d	8	b	9	b	10	c
11	a	12	b	13	d	14	c	15	c
16	c	17	c	18	c	19	d	20	c
21	b	22	d	23	a	24	b	25	c
26	b	27	c	28	c	29	a	30	a
31	b	32	a	33	d	34	c	35	c
36	b	37	a	38	a	39	d	40	c
41	b	42	a	43	c	44	a	45	c
46	c	47	d	48	b	49	a	50	b
51	d	52	b	53	d	54	c	55	a
56	a	57	d	58	ad	59	c	60	a
61	c	62	b	63	a	64	a	65	d
66	c	67	a	68	b	69	b	70	d
71	b	72	d	73	bc	74	d	75	c
76	d	77	d	78	c	79	b	80	b
81	c	82	d	83	c	84	b	85	d
86	b	87	a	88	d	89	d	90	a
91	c	92	b	93	a	94	c	95	a
96	b	97	c	98	d	99	d	100	b
101	c	102	b	103	a	104	d	105	c
106	b	107	a	108	b	109	d	110	c
111	c	112	c	113	b	114	b	115	d
116	a	117	b	118	a	119	c	120	b
121	d	122	d	123	a	124	a	125	c
126	c	127	b	128	d	129	c	130	a
131	c	132	a	133	a	134	b	135	b
136	c	137	a	138	c	139	b	140	a
141	b	142	b	143	b	144	d	145	d
146	a	147	b	148	b	149	d	150	a
151	c	152	b	153	d	154	c	155	c
156	a	157	b	158	a	159	c	160	c
161	a	162	a	163	b	164	b	165	c
166	b	167	d	168	d	169	a	170	b
171	b	172	a	173	c	174	b	175	a
176	b	177	a	178	c	179	b		

Radioactivity

1	a	2	a	3	d	4	c	5	a
6	c	7	c	8	d	9	c	10	c
11	b	12	c	13	c	14	c	15	a
16	c	17	a	18	c	19	b	20	a
21	a	22	c	23	a	24	d	25	d
26	d	27	c	28	b	29	a	30	c
31	c	32	c	33	d	34	c	35	c
36	b	37	b	38	d	39	d	40	d
41	a	42	b	43	c	44	d	45	b
46	b	47	d	48	d	49	b	50	a
51	b	52	c	53	a	54	d	55	c
56	d	57	b	58	d	59	d	60	b
61	a	62	d	63	a	64	d	65	b
66	a	67	b	68	c	69	d	70	c
71	d	72	a	73	a	74	d	75	c
76	d	77	d	78	c	79	a	80	d
81	d	82	b	83	a	84	a	85	b

86	c	87	d	88	d	89	b	90	a
91	b	92	d	93	c	94	c	95	a
96	d	97	d	98	a	99	b	100	c
101	a	102	d	103	b	104	b	105	b
106	d	107	a	108	d	109	c	110	b
111	c	112	c	113	d	114	d	115	c
116	b	117	a	118	a	119	d	120	a
121	c	122	d	123	a	124	d	125	d
126	d	127	c	128	d	129	c	130	b
131	d	132	b	133	c	134	a	135	a
136	b	137	ac	138	b	139	c	140	c
141	d	142	c	143	a	144	d	145	c
146	b	147	d	148	b	149	b	150	c
151	c	152	a	153	b	154	b	155	d
156	b	157	c	158	c	159	d	160	c
161	a	162	d	163	c	164	c	165	d
166	d	167	c	168	c	169	b	170	d
171	b	172	c	173	b	174	a	175	c
176	d								

Critical Thinking Questions

1	c	2	c	3	b	4	a	5	a
6	a	7	a	8	d	9	b	10	d
11	a	12	a	13	a	14	d	15	c
16	d	17	c	18	d	19	c	20	d
21	b	22	c	23	d	24	a	25	d
26	d	27	c	28	c	29	cd	30	a
31	a	32	c	33	a	34	a	35	b
36	b	37	b	38	c	39	b	40	a
41	a	42	b	43	c	44	c	45	d
46	a	47	b	48	d	49	a	50	b
51	d	52	a	53	b	54	b	55	a
56	a	57	b	58	b	59	b	60	a
61	a	62	a	63	b	64	c	65	a

Graphical Questions

1	a	2	a	3	c	4	d	5	c
6	d	7	b	8	b	9	c	10	d
11	d	12	d	13	b	14	d	15	c
16	a	17	b	18	c	19	a		

Assertion and Reason

1	c	2	a	3	b	4	b	5	c
6	a	7	a	8	b	9	b	10	a
11	e	12	c	13	b	14	b	15	d
16	a	17	c	18	d	19	b	20	b
21	c	22	c	23	b	24	e		

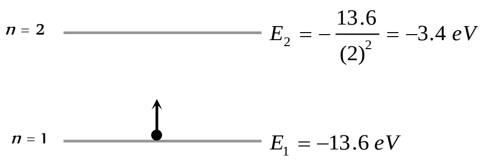
Answers and Solutions

Atomic Structure

1. (a) For n=1, maximum number of states $= 2n^2 = 2$ and for n = 2, 3, 4, maximum number of states would be 8, 18, 32 respectively, Hence number of possible elements = 2 + 8 + 18 + 32 = 60.

2. (d) Bohr radius $r = \frac{\varepsilon_0 n^2 h^2}{\pi Z m e^2}$; $\therefore r \propto n^2$

3. (a)



$E_{1\to 2} = -3.4 - (13.6) = +10.2\,eV$

4. (d) $\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

For di-ionised lithium the value of Z is maximum.

5. (c) Lyman series lies in the UV region.

6. (b) The size of the atom is of the order of 1Å = $10^{-10}\,m$.

7. (b) Balmer series lies in the visible region.

8. (c) Transition A ($n = \infty$ to 1) : Series limit of Lyman series

Transition B (n = 5 to n = 2) : Third spectral line of Balmer series

Transition C (n = 5 to n = 3) : Second spectral line of Paschen series

9. (a) D is excitation of electron from 2nd orbit corresponding to absorption line in Balmer series and E is the energy released to bring the electron from ∞ to ground state *i.e.* ionisation potential.

10. (d)

11. (b) Paschen series lies in the infrared region.

12. (b) Energy required to knock out the electron in the n^{th} orbit $= +\frac{13.6}{n^2}\,eV \Rightarrow E_3 = +\frac{13.6}{9}\,eV$.

13. (b) Linear momentum $= mv = 9.1\times 10^{-31} \times 2.2\times 10^6$

$= 2.0\times 10^{-24}\,kg - m/s$

14. (c) $r \propto n^2 \Rightarrow r_n = n^2 a_0$ $(\because r_1 = a_0)$

15. (c) For the ionization of second He electron. He^+ will act as hydrogen like atom.

Hence ionization potential

$= Z^2 \times 13.6\,volt = (2)^2 \times 13.6 = 54.4\,V$

16. (c) Energy required $= \frac{13.6}{n^2} = \frac{13.6}{10^2} = 0.136\,eV$

17. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{1}{R\lambda}$

$= \frac{1}{1.097\times 10^7 \times 18752\times 10^{-10}} = 0.0486 = \frac{7}{144}$. But

$\frac{1}{3^2} - \frac{1}{4^2} = \frac{7}{144} \Rightarrow n_1 = 3$ and $n_2 = 4$ (Paschen series)

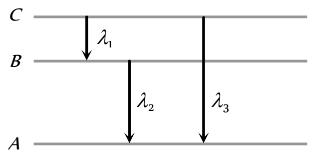
18. (b) Potential energy of electron in n^{th} orbit of radius r in H-atom

$U = -\frac{e^2}{r}$ (in CGS)

$\because$ K.E. $= \frac{1}{2}|\,P.E.| \Rightarrow K = \frac{e^2}{2r}$

19. (c) Final energy of electron $= -13.6 + 12.1 = -1.51\,eV$. which is corresponds to third level *i.e.* $n = 3$. Hence number of spectral lines emitted $= \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 3$

20. (b) Let the energy in A, B and C state be E_A, E_B and E_C, then from the figure



$(E_C - E_B) + (E_B - E_A) = (E_C - E_A)$ or $\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$

$\Rightarrow \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

21. (c) According to Bohr's second postulate.

22. (c) First excited state *i.e.* second orbit (n = 2)

Second excited state *i.e.* third orbit (n = 3)

$\because E = -\frac{13.6}{n^2} \Rightarrow \frac{E_2}{E_3} = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

23. (c) $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16} \Rightarrow \lambda = \frac{16}{3R} = \frac{16}{3}\times 10^{-5}\,cm$

Frequency $n = \frac{c}{\lambda} = \frac{3\times 10^{10}}{\frac{16}{3}\times 10^{-5}} = \frac{9}{16}\times 10^{15}\,Hz$

24. (d) Energy required to remove electron in the n = 2 state $= +\frac{13.6}{(2)^2} = +3.4\,eV$

25. (d) $(E)_Z = Z^2(E_{ion})_H = (11)^2 13.6\,eV$

26. (c) The wavelength of spectral line in Balmer series is given by $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

For first line of Balmer series, n = 3

$$\Rightarrow \frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$$; For second line $n = 4$.

$$\Rightarrow \frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{16}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{20}{27} \Rightarrow \lambda_1 = \frac{20}{27} \times 6561 = 4860\ Å$$

27. (d) $2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$

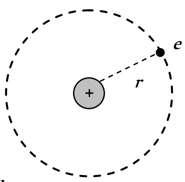
$$\frac{4E}{3} - E = \frac{hc}{\lambda'} \Rightarrow \frac{E}{3} = \frac{hc}{\lambda'} \ \therefore \frac{\lambda'}{\lambda} = 3 \Rightarrow \lambda' = 3\lambda$$

28. (b) Because atom is hollow and whole mass of atom is concentrated in a small centre called nucleus.

29. (d) $r = \frac{\varepsilon_0 n^2 h^2}{\pi Z m e^2}$; $\therefore r \propto \frac{n^2}{Z}$

30. (b) $r \propto n^2 \Rightarrow \frac{r_{(n=2)}}{r_{(n=3)}} = \frac{4}{9} \Rightarrow r_{(n=3)} = \frac{9}{4} R = 2.25\,R$

31. (a) In the revolution of electron, coulomb force provides the necessary centripetal force



$$\Rightarrow \frac{ze^2}{r^2} = \frac{mv^2}{r} \Rightarrow mv^2 = \frac{ze^2}{r}$$

$$\therefore \text{K.E.} = \frac{1}{2} mv^2 = \frac{ze^2}{2r}$$

32. (d) According to Bohr's theory $mvr = n\frac{h}{2\pi}$

$\Rightarrow$ Circumference $2\pi r = n\left(\frac{h}{mv}\right) = n\lambda$

33. (c) $K.E = \frac{kZe^2}{2r}$ and $P.E. = -\frac{kZe^2}{r}$; $\therefore \frac{K.E.}{P.E.} = -\frac{1}{2}$.

34. (d) Lyman series lies in the UV region.

35. (d) If E is the energy radiated in transition

then $E_{R\to G} > E_{Q\to S} > E_{R\to S} > E_{Q\to R} > E_{P\to Q}$

For getting blue line energy radiated should be maximum $\left(E \propto \frac{1}{\lambda}\right)$. Hence (d) is the correct option.

36. (b) Energy released $= 13.6\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = 2.55\,eV$

37. (c) The absorption lines are obtained when the electron jumps from ground state (n = 1) to the higher energy states. Thus only 1, 2 and 3 lines will be obtained.

38. (a) P.E. $\propto -\frac{1}{r}$ and K.E. $\propto \frac{1}{r}$

As r increases so K.E. decreases but P.E. increases.

39. (c) Wave number $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16}$

40. (c) In hydrogen atom, the lowest orbit (n = 1) corresponds to minimum energy (– 13.6 eV).

41. (a) K.E. = – (T.E.)

42. (d) Required energy $E_3 = \frac{+13.6}{3^2} = 1.51 eV$

43. (d) As n increases P.E. also increases.

44. (a) When an electron jumps from the orbit of lower energy (n=1) to the orbit of higher energy (n=3), energy is absorbed.

45. (a) For Lyman series

$$\nu_{\text{Lymen}} = \frac{c}{\lambda_{\max}} = Rc\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] = \frac{3RC}{4}$$

For Balmer series

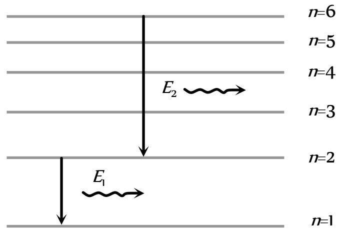
$$\nu_{\text{Balmer}} = \frac{c}{\lambda_{\max}} = Rc\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5RC}{36}$$

$$\therefore \frac{\nu_{\text{Lymen}}}{\nu_{\text{Balmer}}} = \frac{27}{5}$$

46. (a) $\because E_1 > E_2$

$\therefore \nu_1 > \nu_2$

i.e. photons of higher frequency will be emitted if transition takes place from n = 2 to 1.



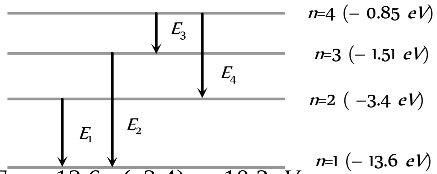
47. (c) Wave number $= \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first Balmer line n_1= 2, n_2=3

$$\therefore \text{Wave number} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{9-4}{9\times 4}\right) = \frac{5R}{36}$$

48. (a) Energy required to ionise helium atom = 24.6 eV

49. (b) From diagram



$$E_1 = -13.6 - (-3.4) = -10.2\,eV$$

$$E_2 = -13.6 - (-1.51) = -12.09\,eV$$

$$E_3 = -1.51 - (-0.85) = -0.66\,eV$$

$$E_4 = -3.4 - (-1.51) = -1.89\,eV$$

E_3 is least *i.e.* frequency is lowest.

50. (a) P.E. $= -\frac{ke^2}{r} = -\frac{e^2}{4\pi\varepsilon_0 r}$; K.E. $= -\frac{1}{2}(\text{P.E.}) = \frac{e^2}{8\pi\varepsilon_0 r}$

51. (b) Similar to Q. 49

52. (c) $mvr = \frac{nh}{2\pi}$, for n =1 it is $\frac{h}{2\pi}$

53. (d) Minimum energy required to excite from ground state

$$= 13.6\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 10.2\ eV$$

54. (c) $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first line of Lymen series $n_1 = 1$ and $n_2 = 2$
For first line of Balmer series $n_1 = 2$ and $n_2 = 3$

So, $\frac{\lambda_{Lymen}}{\lambda_{Balmer}} = \frac{5}{27}$

55. (d) $R = \frac{2\pi^2 k^2 e^4 m}{ch^3} = \left(\frac{1}{4\pi\varepsilon_0}\right)^2 \frac{2\pi^2 me^4}{ch^3}$

56. (a) $\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

$\therefore R = \frac{36}{5\lambda} = \frac{36}{5\times 6563\times 10^{-10}} = 1.09\times 10^7 m^{-1}$

57. (c) Angular momentum $L = n\left(\frac{h}{2\pi}\right)$

For this case n=2, hence $L = 2\times\frac{h}{2\pi} = \frac{h}{\pi}$

58. (d) $v \propto \frac{1}{n} \Rightarrow \frac{v_5}{v_2} = \frac{2}{5} \Rightarrow v_5 = \frac{2}{5}v_2 = \frac{2}{5}v$

59. (d) By using $N_E = \frac{n(n-1)}{2} \Rightarrow N_E = \frac{4(4-1)}{2} = 6$

60. (d) Shortest wavelength comes from $n_1 = \infty$ to $n_2 = 1$ and longest wavelength comes from $n_1 = 6$ to $n_2 = 5$ in the given case. Hence $\frac{1}{\lambda_{min}} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R$

$\frac{1}{\lambda_{max}} = R\left(\frac{1}{5^2} - \frac{1}{6^2}\right) = R\left(\frac{36-25}{25\times 36}\right) = \frac{11}{900}R$

$\therefore \frac{\lambda_{max}}{\lambda_{min}} = \frac{900}{11}$

61. (c) $\frac{mv^2}{a_0} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{a_0^2} \Rightarrow v = \frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$

62. (a,d) $T \propto n^3$. Given $T_{n_1} = 8\,T_{n_2}$, hence $n_1 = 2n_2$

Therefore, option (a) and (d) both are correct.

63. (d) $E = -Z^2 \times 13.6\ eV = -9\times 13.6\ eV = -122.4\ eV$

So ionisation energy = + 122.4 eV.

64. (b)

65. (b) As n increases P.E. increases and K.E. decreases.

66. (b) $r = \frac{n^2}{Z}(r_0)$; $\Rightarrow r_{(n=2)} = \frac{(2)^2}{2}\times 0.53 = 1.06\ Å$

67. (c)

68. (a) $\bar{v} \propto \frac{1}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant} \Rightarrow \lambda = \frac{\lambda}{4}Z^2 \Rightarrow Z = 2$

69. (b) In Paschen series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right]$

$\Rightarrow \lambda_{max} = \frac{144}{7R} = \frac{144}{7\times 1.1\times 10^7} = 1.89\times 10^{-6} m = 1.89\ \mu m$

Similarly $\lambda_{min} = \frac{9}{R} = \frac{9}{1.1\times 10^7} = 0.818\ \mu m$

70. (c) For third line of Balmer series $n_1 = 2$, $n_2 = 5$

$\therefore \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ gives $Z^2 = \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)\lambda R}$

On putting values $Z = 2$

From $E = -\frac{13.6Z^2}{n^2} = \frac{-13.6(2)^2}{(1)^2} = -54.4\ eV$

71. (a) Ionization energy = Binding energy.

72. (b) $E = -Rch \Rightarrow R = -\frac{E}{ch} = -\frac{13.6\times 1.6\times 10^{-19}}{3\times 10^8\times 6.6\times 10^{-34}}$

$= 1.098\times 10^7\ per\ m$

73. (b) Bohr postulated that the angular momentum of the electron is conserved.

74. (d) $E_3 = -\frac{13.6}{9} = -1.51\ eV$; $E_4 = -\frac{13.6}{16} = -0.85\ eV$

$\therefore E_4 - E_3 = 0.66\ eV$

75. (b) Number of spectral lines $N_E = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

76. (d) In the transition from orbit $5 \rightarrow 2$, more energy is liberated as compared to transition from $4 \rightarrow 2$.

77. (d) Impact parameter $b \propto \cot\frac{\theta}{2}$

Here $b = 0$, hence $\theta = 180^o$

78. (b) $r \propto n^2$ i.e. $\frac{r_f}{r_i} = \left(\frac{n_f}{n_i}\right)^2$

$\Rightarrow \frac{21.2\times 10^{-11}}{5.3\times 10^{-11}} = \left(\frac{n}{1}\right)^2 \Rightarrow n^2 = 4 \Rightarrow n = 2$

79. (a)

80. (d) $E_n = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4eV$

81. (a) $\frac{1}{\lambda_{Balmer}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$, $\frac{1}{\lambda_{Lyman}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$

$\therefore \lambda_{Lyman} = \lambda_{Balmer}\times\frac{5}{27} = 1215.4\ Å$

82. (a) $\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For Lyman series n_1=1 and n_2=2, 3, 4,

When n_2=2, we get $\lambda = \frac{4}{3R_H} = \frac{4}{3\times 10967}cm$

83. (b) $r \propto n^2$. For ground state n=1 and for first excited state n=2.

84. (b) No. of lines $N_E = \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 3$

85. (d) Infinitely large transitions are possible (in principle) for the hydrogen atom.

86. (c) $r_n \propto n^2$

87. (a) $E\left(=\frac{hc}{\lambda}\right) \propto \frac{Z^2}{n^2} \Rightarrow \lambda \propto \frac{1}{Z^2}$

Hence $\lambda_{He^+} = \frac{20.397}{4} = 5.099\,cm$

88. (c) Excitation potential $= \frac{\text{Excitation energy}}{\text{e}}$

Minimum excitation energy corresponds to excitation from $n = 1$ to $n = 2$

$\therefore$ Minimum excitation energy in hydrogen atom $= -3.4 - (-13.6) = +10.2\,eV$

so minimum excitation potential = 10.2 eV.

89. (a) Orbital speed varies inversely as the radius of the orbit. Energy increases with the increase in quantum number.

90. (b) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{\lambda_{3\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5R}{36}$

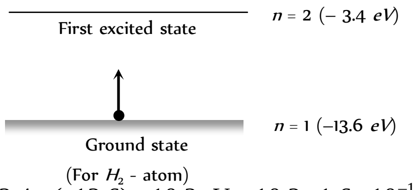
and $\frac{1}{\lambda_{4\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = \frac{3R}{16}$

$\therefore \frac{\lambda_{4\to 2}}{\lambda_{3\to 2}} = \frac{20}{27} \Rightarrow \lambda_{4\to 2} = \frac{20}{27}\lambda_0$

91. (d)

92. (b) Kinetic energy = |Total energy|

93. (c) Energy to excite the e^- from $n = 1$ to $n = 2$



$E = -3.4 - (-13.6) = 10.2\,eV = 10.2 \times 1.6 \times 10^{-19}$

$= 1.632 \times 10^{-18}\ J$

94. (c)

95. (b)

96. (a) According to scattering formula

$N \propto \frac{1}{\sin^4(\theta/2)} \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin(\theta_1/2)}{\sin(\theta_2/2)}\right]^4$

$\Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\frac{90^o}{2}}{\sin\frac{60^o}{2}}\right]^4 = \left[\frac{\sin 45^o}{\sin 30^o}\right]^4$

$\Rightarrow N_2 = (\sqrt{2})^4 \times N_1 = 4 \times 56 = 224$

97. (c) Change in the angular momentum

$\Delta L = L_2 - L_1 = \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} \Rightarrow \Delta L = \frac{h}{2\pi}(n_2 - n_1)$

$= \frac{6.6 \times 10^{-34}}{2 \times 3.14}(5 - 4) = 1.05 \times 10^{-34}\ J\text{-}S$

98. (b) $E_n = -\frac{13.6}{n^2}eV$

99. (a)

100. (b) $F = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(2.5 \times 10^{-11})^2} = 3.7 \times 10^{-7}\ N$

101. (a) For Balmer series $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where n = 3, 4, 5

For second line n = 4

So $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3}{16}R \Rightarrow \lambda = \frac{16}{3R}$

102. (c) Energy of electron in H atom $E_n = \frac{-13.6}{n^2}eV$

$\Rightarrow -1.5 = \frac{-13.6}{n^2} \Rightarrow n^2 = \frac{13.6}{1.5} = 3$

Now angular momentum

$p = n\frac{h}{2\pi} = \frac{3 \times 6.6 \times 10^{-34}}{2 \times 3.14} = 3.15 \times 10^{-34}\ J \times \sec$

103. (a)

104. (b) $T = \frac{2\pi r}{v}$; r = radius of n orbit $= \frac{n^2 h^2}{\pi m Z e^2}$

v = speed of e^- in n orbit $= \frac{ze^2}{2\varepsilon_0 nh}$

$\therefore T = \frac{4\varepsilon_0^2 n^3 h^3}{mZ^2 e^4} \Rightarrow T \propto \frac{n^3}{Z^2}$

105. (d) $r_n \propto n^2 \Rightarrow \frac{r_4}{r_1} = \left(\frac{4}{1}\right)^2 = \frac{16}{1} \Rightarrow r_4 = 16\,r_1 \Rightarrow r_4 = 16\,r_0$

106. (b) For Lyman series

$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ here n=2, 3, 4, 5.....

For first line

$\bar{v} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \bar{v} = R\left(1 - \frac{1}{4}\right) = \frac{3R}{4}$

107. (b) Energy $E = K\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ (K = constant)

n_1 = 2 and n_2 = 3, so $E = K\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = K\left[\frac{5}{36}\right]$

For removing an electron n_1 = 1 to $n_2 = \infty$

Energy $E_1 = K[1] = \frac{36}{5}E = 7.2\ E$

$\therefore$ Ionization energy = 7.2 E

108. (c) For Paschen series $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$; n=4, 5, 6....

For first member of Paschen series n = 4

$\frac{1}{\lambda_1} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right] \Rightarrow \frac{1}{\lambda_1} = \frac{7R}{144}$

$\Rightarrow R = \frac{144}{7\lambda_1} = \frac{144}{7 \times 18800 \times 10^{-10}} = 1.1 \times 10^{-7}$

For shortest wave length $n = \infty$

So $\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right] = \frac{R}{9}$

$\Rightarrow \lambda = \frac{9}{R} = \frac{9}{1.1 \times 10^{-7}} = 8.225 \times 10^{-7} m = 8225\,Å$

109. (d) For Lyman series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R$ and

$\frac{1}{\lambda_{min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = \frac{R}{1} \Rightarrow \frac{\lambda_{max}}{\lambda_{min}} = \frac{4}{3}$

110. (c) $T \propto n^3 \Rightarrow \frac{T_2}{T_1} = \frac{2^3}{1^3} = \frac{8}{1}$

111. (a) For Bracket series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{4^2} - \frac{1}{5^2}\right] = \frac{9}{25 \times 16}R$

and $\frac{1}{\lambda_{min}} = R\left[\frac{1}{4^2} - \frac{1}{\infty^2}\right] = \frac{R}{16} \Rightarrow \frac{\lambda_{max}}{\lambda_{min}} = \frac{25}{9}$

112. (a) For hydrogen and hydrogen like atoms $E_n = -13.6\frac{z^2}{n^2}eV$

$U_n = 2E_n = -27.2\frac{z^2}{n^2}eV$ and $K_n = |E_n| = 13.6\frac{z^2}{n^2}eV$

From these three relations we can see that as n decreases, K will increase but E and U will decreases.

113. (a) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{\lambda_{min}}{\lambda_{max}} = \frac{\left[\frac{1}{2^2} - \frac{1}{3^2}\right]}{\left[\frac{1}{2^2} - \frac{1}{\infty}\right]} = \frac{5}{9}$

114. (b) By using $r_n = r_0\frac{n^2}{Z}$; Where r_o = Radius of the Bohr orbit in the ground state atom . So for He^+ third excited state $n = 4,\ Z = 2,\ r_0 = 0.5Å \Rightarrow r_4 = 0.5 \times \frac{4^2}{2} = 4Å$

115. (d) Speed of electron in n orbit (in CGS) $v_n = \frac{2\pi Ze^2}{nh}$ $(k = 1)$

For first orbit H_2; $n = 1$ and $Z = 1$

So $v = \frac{2\pi e^2}{h} \Rightarrow \frac{v}{c} = \frac{2\pi e^2}{hc}$

116. (b)

117. (d) $E_n = -\frac{13.6}{n^2}eV \Rightarrow E_5 = \frac{-13.6}{5^2} = \frac{-13.6}{25} = -0.54\ eV$

118. (a)

119. (b)

120. (a) $mvr = \frac{nh}{2\pi} \Rightarrow v = \frac{nh}{2\pi mr} \Rightarrow \frac{v^2}{r} = \frac{n^2h^2}{4\pi^2m^2r^3}$.

121. (b) Maximum number of spectral lines are observed in Lymen series.

122. (b) Wave number $\bar{\nu} = \frac{1}{\lambda} = \frac{1}{5896 \times 10^{-8}} = 16961$ per cm

123. (b) $r_n \propto n^2 \Rightarrow \frac{r_3}{r_1} = \frac{3^2}{1} \Rightarrow r_3 = 9r_1 = 9 \times 0.53 = 4.77Å$

124. (d) For first line in Lyman series $\lambda_{L_1} = \frac{4}{3R}$ ..... (i)

For first line in Balmer series $\lambda_{B_1} = \frac{36}{5R}$ ..... (ii)

From equation (i) and (ii)

$\frac{\lambda_{B_1}}{\lambda_{L_1}} = \frac{27}{5} \Rightarrow \lambda_{B_1} = \frac{27}{5}\lambda_{L_1} \Rightarrow \lambda_{B_1} = \frac{27}{5}\lambda$

125. (a)

126. (d) 3 – 1 transition has higher energy so it has higher frequency $\left(\nu = \frac{E}{h}\right)$

127. (d) α-particles cannot be attracted by the nucleus.

128. (c) By using $\nu = RC\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\Rightarrow \nu = 10^7 \times (3 \times 10^8)\left[\frac{1}{4^2} - \frac{1}{5^2}\right] = 6.75 \times 10^{13}\ Hz$

129. (c) For M shell (n = 3), orbital quantum number l = 0, 1, 2.

130. (d) Number of possible emission lines $= \frac{n(n-1)}{2}$

Where n = 4; Number $= \frac{4(4-1)}{2} = 6$.

131. (a) Diameter of nucleus is of the order of $10^{-14} m$ and radius of first Bohr orbit of hydrogen atom $r = 0.53 \times 10^{-10} m$.

132. (c) The electron is in the second orbit (n=2)

Hence $L = \frac{nh}{2\pi} = \frac{2h}{2\pi} = \frac{6.6 \times 10^{-34}}{\pi} = 2.11 \times 10^{-34}\ J\text{-}sec$

133. (c) $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \lambda \propto \frac{1}{Z^2}$

$\lambda_{Li^{++}} : \lambda_{He^+} : \lambda_H = 4 : 9 : 36$

134. (a) Energy radiated $E = 10.2\,eV = 10.2 \times 1.6 \times 10^{-19}\ J$

$\Rightarrow E = \frac{hc}{\lambda} \Rightarrow \lambda = 1.215 \times 10^{-7} m$

135. (c) For $n = 1,\ E_1 = -\frac{13.6}{(1)^2} = -13.6\ eV$

and for n = 3, $E_3 = -\frac{13.6}{(3)^2} = -1.51\ eV$

So required energy

$= E_3 - E_1 = -1.51 - (-13.6) = 12.09\ eV$

136. (a) Similar to Q. 115

137. (c) Since in spectral series of hydrogen atom, Lymen series lies lower Balmer series.

138. (d) $mvr_n = \frac{nh}{2\pi} \Rightarrow pr_n = \frac{nh}{2\pi} \Rightarrow \frac{h}{\lambda} \times r_n = \frac{nh}{2\pi}$

$\Rightarrow \lambda = \frac{2\pi r_n}{n}$, for first orbit $n = 1$ so $\lambda = 2\pi r_1$

= circumference of first orbit

139. (d) $E_{n_1 \to n_2} = -13.6\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]; n_1 = 2\ \&\ n_2 = 1$

$\Rightarrow E_{II} \to E_I = -13.6 \times \frac{3}{4} = -10.2\ eV$

140. (b) $E_n = -\frac{13.6z^2}{n^2}eV \Rightarrow E_1 = -\frac{13.6 \times (2)^2}{(1)^2} = -54.4\ eV$

141. (b) $\nu \propto Z^2 \Rightarrow \frac{\nu_{H_2}}{\nu_{He}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4} \Rightarrow \nu_{He} = 4\nu_{H_2} = 4\nu$.

142. (a) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

First condition $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow R = \frac{4}{3\lambda}$

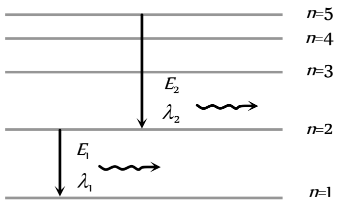
Second condition $\frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$

$\Rightarrow \lambda' = \frac{9}{8R} \Rightarrow \lambda' = \frac{9}{8 \times \frac{4}{3\lambda}} = \frac{27\lambda}{32}$

143. (b)

144. (a) $r_n \propto n^2$

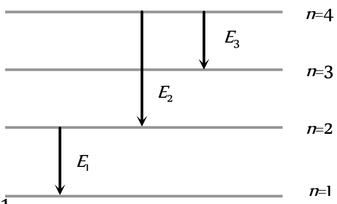
145. (d) $\because E_2 < E_1 \Rightarrow \lambda_2 > \lambda_1$



146. (a) Wave number $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]; n_2 = \infty$ and $n_1 = 1$

$\Rightarrow \bar{\nu} = R = 1.097 \times 10^7 m^{-1} = 109700\ cm^{-1}$

147. (b) $E_1 > E_2 > E_3$



148. (d) $r \propto \frac{1}{Z}$, for double ionized lithium $Z(=3)$ will be maximum. So r will be minimum

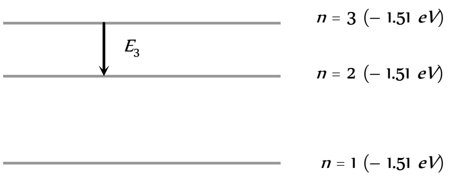
149. (b) $E_n = \frac{13.6}{n^2} \times Z^2$. For first excited state $n = 2$ and for $Li^{++}, z = 3 \Rightarrow E = \frac{13.6}{4} \times 9 = 30.6\ eV$

150. (b)

151. (a) In Lyman series $(\lambda_{\min})_L = \frac{1}{R}$ and $(\lambda_{\min})_B = \frac{4}{R}$

$\Rightarrow (\lambda_{\min})_B = 4 \times (\lambda_{\min})_L = 4 \times 912 = 3648\ \mathring{A}$

152. (d)



$E_{3\to2} = -3.4 - (-1.51) = -1.89\ eV \Rightarrow |E_{3\to2}| \approx 1.9\ eV$

153. (a)

154. (a)

155. (c) Radius of n orbit for any hydrogen like atom

$r_n = r_0\left(\frac{n^2}{Z}\right)$ (r_0 = radius of first orbit of H_2 -atom)

If $r_n = r_0 \Rightarrow n = \sqrt{Z}$. For Be, $Z = 4 \Rightarrow n = 2$.

156. (d) $r_n \propto n^4 \Rightarrow A_n \propto n^4 \Rightarrow \frac{A_1}{A_0} = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$

157. (d)

158. (d) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For first wavelength, $n_1 = 2$, $n_2 = 3$

$\Rightarrow \lambda_1 = 6563\ \mathring{A}$. For second wavelength, $n_1 = 2$, $n_2 = 4$

$\Rightarrow \lambda_2 = 4861\ \mathring{A}$

159. (c) K.E. = – (Total energy) = – (–13.6 eV) = + 13.6 eV

160. (a) In Lyman series $\lambda_{\max} = \frac{4}{3R}$

In Balmer series $\lambda_{\max} = \frac{36}{5R}$. So required ratio $= \frac{5}{27}$

161. (c)

162. (b) $E = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For highest energy in Balmer series

$n_1 = 2$ and $n_2 = \infty \Rightarrow E = 13.6\left[\frac{1}{(2)^2} - \frac{1}{(\infty)^2}\right] = 3.4\ eV$

163. (a)

164. (c) $T \propto n^3$

165. (b) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] \Rightarrow \lambda = \frac{16}{3R}$

166. (a) $E_n \propto Z^2 \Rightarrow \frac{(E_n)_{He}}{(E_n)_H} = \frac{Z_{He}^2}{Z_H^2} = 4 \Rightarrow (E_n)_{He} = 4 \times (E_n)_H$

167. (b) By using $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

168. (a) $\frac{1}{\lambda_{\max}} = R\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] \Rightarrow \lambda_{\max} = \frac{4}{3R} \approx 1213\ \mathring{A}$

and $\frac{1}{\lambda_{\min}} = R\left[\frac{1}{(1)^2} - \frac{1}{\infty}\right] \Rightarrow \lambda_{\min} = \frac{1}{R} \approx 910\ \mathring{A}$

169. (b) P.E. $= 2 \times$ Total energy $= 2 \times (-13.6) = -27.2$ eV

170. (c) Emitted energy $\Delta E = \frac{hc}{\lambda}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

171. (c) $U = 2E,\ K = -E$ and $E = -\frac{13.6}{n^2} = eV$.

172. (a)

173. (d)

174. (c) $r \propto n^2$

Nucleus, Nuclear Reaction

1. (b)

2. (c) Neutrons are neutral particles.

3. (c) James Chadwick discovered the neutron.

4. (d) In hydrogen, atomic number and mass number are equal.

5. (d) $E = mc^2 = 1 \times (3 \times 10^8)^2 = 9 \times 10^{16} \approx 10^{17}\ J$

6. (d) $B.E. = \Delta m\ \ amu = \Delta m \times 931\ MeV.$

7. (d) Mass defect $\Delta m = \dfrac{2.23}{931} = 0.0024.$

8. (b) Positron is the antiparticle of electron.

9. (b)

10. (c)

11. (a) B.E.$= \Delta mc = [2(1.0087 + 1.0073) - 4.0015] = 28.4\ MeV$

12. (b) $\dfrac{\text{Binding energy}}{\text{Nucleon}} = \dfrac{0.0303 \times 931}{4} \approx 7$

13. (d) Energy / day $= 200 \times 10^6 \times 24 \times 3600$

$= 2 \times 2.4 \times 3.6 \times 10^{12} = 1728 \times 10^{10}\ J$

14. (c) $E = \Delta mc^2 = 10^{-6} \times (3 \times 10^8)^2 = 9 \times 10^{10}\ J$

15. (c)

16. (c) Mass of ${}_1H^2 = 2.01478\ a.m.u.$

Mass of ${}_2He^4 = 4.00388\ a.m.u.$

Mass of two deuterium $= 2 \times 2.01478 = 4.02956$

Energy equivalent to $2\,{}_1H^2$

$= 4.02956 \times 1.112\ MeV = 4.48\ MeV$

Energy equivalent to ${}_2H^4$

$= 4.00388 \times 7.047\ MeV = 28.21\ MeV$

Energy released $= 28.21 - 4.48 = 23.73\ MeV = 24\ MeV$

17. (c) Energy released while forming a nucleus is known as binding energy (by definition).

18. (c) Nuclear force is stronger than coulomb force.

19. (d)

20. (c)

21. (b) $Q = 4\ (x_2 - x_1)$

22. (d)

23. (a) Rest energy of an electron $= m_e c^2$

Here $m_e = 9.1 \times 10^{-31} kg$ and c = velocity of light

$\therefore$ Rest energy $= 9.1 \times 10^{-31} \times (3 \times 10^8)^2\ joule$

$= \dfrac{9.1 \times 10^{-31} \times (3 \times 10^8)^2}{1.6 \times 10^{-19}} eV = 510\ keV$

24. (b) ${}_ZX^A = {}_{88}Ra^{226}$

Number of protons $= Z = 88$

Number of neutrons $= A - Z = 226 - 88 = 138$.

25. (c) Out side the Nucleus, neutron is unstable (life $\approx$ 932 *sec*).

26. (b) The order of magnitude of mass and volume of uranium nucleus will be

$m \simeq A(1.67 \times 10^{-27}\ kg)$ (A is atomic number)

$V = \dfrac{4}{3}\pi r^3 \simeq \dfrac{4}{3}\pi\,[(1.25 \times 10^{-15} m)A^{1/3}]^3$

$\simeq (8.2 \times 10^{-45} m^3)A$

Hence, $\rho = \dfrac{m}{V} = \dfrac{A(1.67 \times 10^{-27} kg)}{(8.2 \times 10^{-45} m^3)A}$

$\simeq 2.0 \times 10^{17} kg / m^3$.

27. (c) We have $r \propto A^{1/3} \Rightarrow \dfrac{r_2}{r_1} = \left(\dfrac{A_2}{A_1}\right)^{1/3} = \left(\dfrac{206}{4}\right)^{1/3}$

$\therefore r_2 = 3\left(\dfrac{206}{4}\right)^{1/3} = 11.6\ Fermi.$

28. (c) Nucleus does not contains electron.

29. (a) Let the percentage of B^{10} atoms be x, then Average atomic weight

$= \dfrac{10x + 11(100 - x)}{100} = 10.81 \Rightarrow x = 19 \quad \therefore \dfrac{N_{B^{10}}}{N_{B^{11}}} = \dfrac{19}{81}$

30. (a)

31. (b)

32. (a) Nuclear force is charge independent, it also acts between two neutrons.

33. (d) $p \to \pi^+ + n,\ \ n \to p + \pi^-$ and $n \to n' + \pi^0$

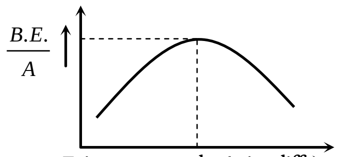
34. (c) Helium nucleus $\to {}_2He^4$.

Number of protons = Z = 2

Number of Neutrons = $A - Z$ = 2.

35. (c)

36. (b) Binding energy per nucleon increases with atomic number and is maximum for iron. After that it decrease.



37. (a) For isotopes Z is same and A is different. Therefore the number of neutrons $A - Z$ will also be different.

38. (a) This is due to mass defect because a part of mass is used in keeping the neutrons and protons bound as $\alpha -$ particle.

39. (d) B.E. of $Li^7 = 39.20\ MeV$ and $He^4 = 28.24\ MeV$

Hence binding energy of $2He^4 = 56.48\ MeV$

Energy of reaction $= 56.48 - 39.20 = 17.28\ MeV$.

40. (c) $r \propto (A)^{1/3}$

41. (b) $r \propto A^{1/3}$

42. (a) $E = mc^2 = (1 \times 10^{-3})(3 \times 10^8)^2 = 9 \times 10^{13}\ J$.

43. (c) $\Delta E = 8.5 \times 234 - 7.6 \times 236 = 195.4\ MeV = 200\ MeV$.

44. (a) $N = M - Z =$ Total no. of nucleons – no. of protons.

45. (c)

46. (c) Both coulomb and nuclear force act inside the nucleus.

47. (d) For stability in case of lighter nuclei $\dfrac{N}{Z} = 1$ and for heavier nuclei $\dfrac{N}{Z} > 1$.

48. (b) Nuclear forces are charge independent.

49. (a) Actual mass of the nucleus is always less than total mass of nucleons so

$M < (NM_n + Zm_p)$.

50. (b) Mass of H_2 nucleus =mass of proton =1 *amu* energy equivalent to 1 *amu* is 931 *MeV* so correct option is *(b)*.

51. (d) $R = R_0 A^{1/3} \Rightarrow R \propto A^{1/3}$.

52. (b)

53. (d) Number of neutrons $= A - Z = 23 - 11 = 12$.

54. (c) For ${}_6C^{12}$, $p = 6, e = 6, n = 6$

For ${}_6C^{14}$, $p = 6, e = 6, n = 8$

55. (a)

56. (a) The mass of nucleus formed is always less than the sum of the masses of the constituent protons and neutrons *i.e.* $m < (A - Z)m_n + zm_p$.

57. (d) $E = \Delta m.c^2 \Rightarrow E = \dfrac{0.3}{1000} \times (3 \times 10^8)^2 = 2.7 \times 10^{13}\, J$

$= \dfrac{2.7 \times 10^{13}}{3.6 \times 10^6} = 7.5 \times 10^6 kWh$.

58. (a, d)

59. (c) ${}_5B^{10} + {}_0n^1 \rightarrow {}_3Li^7 + {}_2He^4$.

60. (a)

61. (c) ${}_{92}U^{235}$ is normally fissionable.

62. (b)

63. (a)

64. (a) In atom bomb nuclear fission takes place with huge temperature.

65. (d) The given equation is ${}_2He^4 + {}_zX^A \rightarrow {}_{z+2}Y^{A+3} + A$

Applying charge and mass conservation

$4 + A = A + 3 + x \Rightarrow x = 1 \Rightarrow 2 + z = z + 2 + n \Rightarrow n = 0$

Hence *A* is a neutron.

66. (c) Energy of stars is due to the fusion of light hydrogen nuclei into *He*. In this process much energy is released.

67. (a) ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + 24\, MeV$.

68. (b) Energy $\propto c^2$; $\therefore$ Decrease in energy $\propto \dfrac{4}{9}$.

69. (b) Fusion reaction requires a very high temperature =(10^7 *K*).

70. (d) ${}_4Be^9 + {}_2He^4 \rightarrow {}_6C^{12} + {}_0n^1$.

71. (b)

72. (d)

73. (b, c)

74. (d)

75. (c) Cadmium rods absorb the neutrons so they are used to control the chain reaction process.

76. (d)

77. (d) No energy and mass enters or goes out of the system of the reaction and no external force is assumed to act.

78. (c)

79. (b)

80. (b) Energy of γ-ray photon $= 0.5 + 0.5 + 0.78 = 1.78\, MeV$.

81. (c)

82. (d)

83. (c) When fast moving neutrons pass through a moderator, they collide with the molecules of the moderator. As a result of this the neutrons are in thermal equilibrium with the surrounding molecules of moderator. These neutrons are called thermal neutrons.

84. (b) $E_b + E_c > E_a$

85. (d) Because sound waves require medium to travel through and there is no medium (air) on moon's surface.

86. (b) Heavy water is used as moderators in nuclear reactions to slow down the neutrons.

87. (a) $m = \dfrac{E}{c^2} = \dfrac{931 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2} = 1.66 \times 10^{-27} kg$.

88. (d) $E = \Delta mc^2, \Delta m = \dfrac{0.1}{100} = 10^{-3} kg$

$\therefore E = 10^{-3} \times (3 \times 10^8)^2 = 10^{-3} \times 9 \times 10^{16} = 9 \times 10^{13}\, J$.

89. (d) Energy released by $\gamma -$ rays for pair production must be greater than 1.02 *MeV*.

90. (a) ${}_8O^{18} + {}_1H^1 \rightarrow {}_9F^{18} + {}_on^1$

91. (c) Power $= 1000\, kW = 10^6\, J/s$

Rate of nuclear fission $= \dfrac{10^6}{200 \times 1.6 \times 10^{-13}} = 3.125 \times 10^{16}$.

92. (b) $A = 238 - 4 = 234$ and $Z = 92 - 2 = 90$.

93. (a) $P = n\left(\dfrac{E}{t}\right) \Rightarrow 1000 = \dfrac{n \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$\Rightarrow \dfrac{n}{t} = 3.125 \times 10^{13}$.

94. (c) Due to the production of neutrons, a chain of nuclear fission is established which continues until the whole of the source substance is consumed.

95. (a) ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{38}Sr^{90} + {}_{54}Xe^{143} + 3{}_0n^1$

96. (b) ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + Q$.

97. (c) Fast neutrons can escape from the reaction. So as to proceed the chain reaction. Slow neutrons are best.

98. (d) ${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + {}_1H^1$

99. (d)

100. (b) $\Delta m = 1 - 0.993 = 0.007\, gm$

$\therefore E = (\Delta m)c^2 = (0.007 \times 10^{-3})(3 \times 10^8)^2 = 63 \times 10^{10}\, J$.

101. (c) ${}_{85}X^{297} \rightarrow {}_{77}Y^{281} + 4\left({}_2He^4\right)$

102. (b) $x+1 = 24 + 4 \Rightarrow x = 27$.

103. (a)

104. (d) ${}_6C^{11} \rightarrow {}_5B^{11} + \beta^+ + \gamma$ because $\beta^+ = {}_1e^0$

105. (c)

106. (b) $\dfrac{\text{Energy}}{\text{Fission}} = 200\, MeV = 200 \times 10^6 \times 1.6 \times 10^{-19}\, J$

Fission rate $= \frac{5}{200\ MeV} = 1.56 \times 10^{11}$ fission/sec.

107. (a)

108. (b) Energy is released in the sun due to fusion.

109. (d)

110. (c) In nuclear fission, neutrons are released.

111. (c) ${}_1H^1 +_1 H^1 +_1 H^2 \to_2 He^4 +_{+1} e^0$ + energy.

112. (c)

113. (b) ${}_0n^1 =_1 p^1 +_{-1} e^0 + \bar{\nu}$

Antineutrino is required for conservation of spin.

114. (b)

115. (d) Fusion is the main process of energy production in the sun.

116. (a)

117. (b) Mass of proton = mass of antiproton

$= 1.67 \times 10^{-27}\ kg = 1 amu$

Energy equivalent to $1\ amu = 931\ MeV$

So energy equivalent to 2 *amu* $= 2 \times 931\ MeV$

$= 1862 \times 10^6 \times 1.6 \times 10^{-19} = 2.97 \times 10^{-10}\ J = 3 \times 10^{-10}\ J$.

118. (a) In fusion reaction, two lighter nuclei combines.

119. (c)

120. (b) Hydrogen bomb is based on nuclear fusion.

121. (d) ${}_{92}U^{235} +_0 n^1 \to_{92} U^{236}$ and

${}_{92}U^{236} \to_{56} Ba^{144} +_{36} Kr^{89} + 3_0n^1 + Q$.

122. (d) Fusion reaction of deuterium is

${}_1H^2 +_1 H^2 \to_2 He^3 +_0 n^1 + 3.27\ MeV$

So $E = \frac{6.02 \times 10^{23} \times 10^3 \times 3.27 \times 1.6 \times 10^{-13}}{2 \times 2} = 7.8 \times 10^{13}\ J$

$= 8 \times 10^{13}\ J$.

123. (a)

124. (a)

125. (c)

126. (c)

127. (b)

128. (d) Energy released in the fission of one nucleus = 200 *MeV*

$= 200 \times 10^6 \times 1.6 \times 10^{-19}\ J = 3.2 \times 10^{-11}\ J$

$P = 16 KW = 16 \times 10^3 Watt$

Now, number of nuclei required per *second*

$n = \frac{P}{E} = \frac{16 \times 10^3}{3.2 \times 10^{-11}} = 5 \times 10^{14}$.

129. (c)

130. (a) Number of fissions per second

$= \frac{\text{Power output}}{\text{Energy released per fission}}$

$= \frac{3.2 \times 10^6}{200 \times 10^6 \times 1.6 \times 10^{-19}} = 1 \times 10^{17}$

$\Rightarrow$ Number of fission per minute $= 60 \times 10^{17} = 6 \times 10^{18}$

131. (c)

132. (a) $X(n, \alpha)\ {}^7_3Li \Rightarrow_Z X^A +_0 n^1 \to 3Li^7 +_2 He^4$

$Z = 3 + 2 = 5$ and A= 7+4 – 1 =10

$\therefore {}_5 X^{10} =_5 B^{10}$

133. (a)

134. (b) Mass of electron = mass of positron = 9.1×10^{-31} *kg*

Energy released $E = (2m).c^2$

$= 2 \times 9.1 \times 10^{-31} \times (3 \times 10^8)^2 = 1.6 \times 10^{-13}$ *J*.

135. (b) ${}_1H^2 +_1 H^2 \to_2 He^4$ + energy

Binding energy of a $({}_1H^2)$ deuterium nuclei

$= 2 \times 1.1 = 2.2\ MeV$

Total binding energy of two deuterium nuclei

$= 2.2 \times 2 = 4.4\ MeV$

Binding energy of a $({}_2He^4)$ nuclei $= 4 \times 7 = 28\ MeV$

So, energy released in fusion $= 28 - 4.4 = 23.6\ MeV$

136. (c) Mass of a uranium nucleus

$= 92 \times 1.6725 \times 10^{-27} + 143 \times 1.6747 \times 10^{-27}$

$= 393.35 \times 10^{-27}\ kg$

Number of nuclei in the given mass

$= \frac{1}{393.35 \times 10^{-27}} = 2.542 \times 10^{24}$

Energy released $= 200 \times 2.542 \times 10^{24}\ MeV$

$= 5.08 \times 10^{26}\ MeV = 8.135 \times 10^{13}\ J = 8.2 \times 10^{13}\ J$

137. (a)

138. (c)

139. (b) In a material medium, when a positron meets an electron both the particles annihilate leading to the emission of two γ ray photons. This process forms the basis of an important diagnostic procedure called PET.

140. (a) Total mass of reactants

$= (2.0141) \times 2 = 4.0282\ amu$

Total mass of products $= 4.0024\ amu$

Mass defect $= 4.0282\ amu - 4.0024\ amu$

$= 0.0258\ amu$

$\therefore$ Energy released $E = 931 \times 0.0258 = 24\ MeV$

141. (b) ${}_7N^{14} + {}_2He^4 \to {}_8O^{17} + {}_1H^1$

142. (b)

143. (b)

144. (d) ${}_8O^{16} +_1 H^2 \to_7 N^{14} +_2 He^4$

145. (d)

146. (a)

147. (b) Nuclear fusion takes place in stars which results in joining of nuclei accompanied by release of tremendous amount of energy.

148. (b)

149. (d) *B.E.* per nucleon $\propto$ stability.

150. (a) Nuclei of different elements having the same mass number are called isotones *e.g.,* ${}_4Be^9$ and ${}_5B^{10}$

151. (c)

152. (b)

153. (d) Packing fraction $= \dfrac{M - A}{A}$

154. (c) $B = [Z M_p + N M_n - M(N, Z)]c^2$

$$\Rightarrow M(M, Z) = Z M_p + N M_n - B/c^2$$

155. (c)

156. (a) In nuclear reacter, nuclear fission can be carried out through a sustained and a controlled chain reaction.

157. (b) ${}_6C^{12} + {}_on^1 \rightarrow {}_7N^{13} + {}_{-1}\beta^o$

158. (a) ${}_on^1 + {}_{92}U^{235} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\ {}_on^1$

159. (c) The energy released in sun and hydrogen bomb are due to nuclear fusion.

160. (c)

161. (a)

162. (a) ${}_{84}Po^{210} \rightarrow {}_{82}X^{206} + {}_2He^4$

Using conservation of linear moments

$$206v' + 4v = 0 \Rightarrow v' = -\frac{4v}{(206)} \Rightarrow |v'| = \frac{4v}{206}$$

163. (b) Power $P = \dfrac{\text{Energy}}{\text{time}} = \dfrac{mc^2}{t}$, $= 1 \times 10^{-6} \times (3 \times 10^8)^2$

$= 9 \times 10^{10}\ W = 9 \times 10^7\ kW.$

164. (b)

165. (c)

166. (b) The elements high on the *B.E.* versus mass number plot are very tightly bound and hence, are stable. And the elements those are lower on this plot, are less tightly bound and hence, are unstable.

Since helium nucleus shows a peak on this plot so, it is very stable.

167. (d)

168. (d) $E = \Delta mc^2 = 1 \times (3 \times 10^8)^2 = 9 \times 10^{10}\ J$

$$\Rightarrow E = \frac{9 \times 10^{16}}{1.6 \times 10^{-19}} = 5.625 \times 10^{35}\ eV = 5.625 \times 10^{29}\ MeV.$$

169. (a) $E = \Delta mc^2 = 0.5 \times 10^{-3} \times (3 \times 10^8)^2 = 4.5 \times 10^{13}\ j$

$$\Rightarrow E = \frac{4.5 \times 10^{13}}{3.6 \times 10^6} = 1.25 \times 10^7\ kWH.$$

170. (b) ${}_0n^1 + {}_{92}U^{235} \rightarrow {}_{36}Kr^{94} + {}_{56}Ba^{139} + 3\ {}_0n^1$

171. (b)

172. (a) Number of protons = 2 + 2 + 6 + 2 + 6 = 18

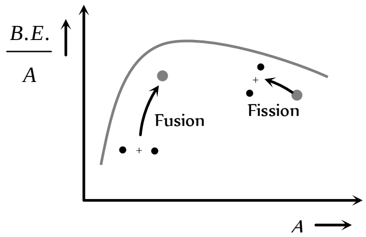
Number of neutrons = 40 – 18 = 22.

173. (c) Neutrons are unstable and having mean life time of 32 *sec,* decaying by emitting an electron and antineutrino to become proton.

174. (b) During fusion binding energy of daughter nucleus is always greater than the total energy of the parent nuclei so energy released = *c* – (*a* + *b*) = *c* – *a* – *b*

175. (a) These nuclei having different *Z* and *A* but equal (*A* – *Z*) are called isotones.

176. (b)



177. (a)

178. (c) $r \propto A^{1/3} \Rightarrow \dfrac{r_1}{r_2} = \left(\dfrac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{3.6}{r_2} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5} \Rightarrow r_2 = 6\ Fermi$$

179. (b)

Radioactivity

1. (a)

2. (a) By formula $N = N_0\left(\dfrac{1}{2}\right)^{t/T}$ or $10^4 = 8 \times 10^4 \left(\dfrac{1}{2}\right)^{t/3}$

or $\left(\dfrac{1}{8}\right) = \left(\dfrac{1}{2}\right)^{t/3}$ or $\left(\dfrac{1}{2}\right)^3 = \left(\dfrac{1}{2}\right)^{t/3} \Rightarrow 3 = \dfrac{t}{3}$

Hence t = 9 *years.*

3. (d) Fraction $= \dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^{\frac{6400}{1600}} = \left(\dfrac{1}{2}\right)^4 = \dfrac{1}{16}$

4. (c) Negative $\beta -$decay is expressed by the equation

$$n = p^+ + e^- + v^-$$

5. (a) No radioactive substance emit both α and β particles simultaneously. Some substances emit $\alpha -$ particles and some other emits $\beta -$particles. $\gamma -$ rays are emitted along with both α and $\beta -$particles.

6. (c) γ-rays are highly penetrating.

7. (c) Average life $\frac{1}{\lambda} = \frac{1600}{0.693} = 2308 \approx 2319$ years.

8. (d) Fraction of atoms remains after five half lives

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} = \left(\frac{1}{2}\right)^{5T/T} = \frac{1}{32}$$

$\Rightarrow$ Percentage atom remains $= \frac{1}{32} \times 100 = 3.125\%$

9. (c) β-rays emitted from nucleus and they carry negative charge.

10. (c)

11. (b) $_ZX^A \xrightarrow{_{-1}\beta^0} {}_{Z+1}Y^A \xrightarrow{2He^4(\alpha)}$

$${}_{Z-1}K^{A-4} \xrightarrow{_0\gamma^0} {}_{Z-1}K^{A-4}$$

12. (c) $N_t = N_0\left(\frac{1}{2}\right)^{t/T} = 50000\left(\frac{1}{2}\right)^{10/5} = 12500$

13. (c) $_ZX^A \xrightarrow{_{-1}\beta^0} {}_{Z+1}X^A$

14. (c) $N = N_0\left(\frac{1}{2}\right)^{t/T} \Rightarrow \frac{N_0}{64} = N_0\left(\frac{1}{2}\right)^{30/T} \Rightarrow T = \frac{30}{6} = 5 \text{ sec}$

15. (a)

16. (c)

17. (a) Average life $T = \frac{\text{Sum of all lives of all the atom}}{\text{Total number of atoms}} = \frac{1}{\lambda}$

$\Rightarrow T\lambda = 1$

18. (c) Fraction remains after n half lives $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{t/T}$

$$\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{T/2}{T}} = \left(\frac{1}{2}\right)^{1/2} = \frac{1}{\sqrt{2}}$$

19. (b)

20. (a) Penetration power of γ is 100 times of β, while that of β is 100 times of α.

21. (a) $\frac{N_0}{32} = N_0\left(\frac{1}{2}\right)^{60/T} \Rightarrow 5 = \frac{60}{T} \Rightarrow T = 12$ days

22. (c) By using $N = N_0\left(\frac{1}{2}\right)^{t/T}$; where $N = \left(1 - \frac{7}{8}\right)N_0 = \frac{1}{8}N_0$

So $\frac{1}{8}N_0 = N_0\left(\frac{1}{2}\right)^{t/T} \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/5} \Rightarrow t = 15$ *days.*

23. (a) $_{72}A^{180} \xrightarrow{\alpha} {}_{70}A_1^{176} \xrightarrow{\beta} {}_{71}A_2^{176} \xrightarrow{\alpha} {}_{69}A_3^{172}$

$$\xrightarrow{\gamma} {}_{69}A_4^{172}$$

24. (d)

25. (d) Half life of a substance doesn't depends upon Amount, temperature and pressure. It depends upon the nature of the substance.

26. (d) $T = \frac{0.6931 \times 1}{\lambda} = \frac{0.6931 \times 1}{4.28 \times 10^{-4}} \, year = 1620 \, years$

27. (c) In fusion two lighter nuclei combines, it is not the radioactive decay.

28. (b) $n_\alpha = \frac{A - A'}{4} = \frac{232 - 208}{4} = 6$

and $n_\beta = (2n_\alpha - Z + Z') = (2 \times 6 - 90 + 82) = 4$

29. (a) Remaining amount

$$= 16 \times \left(\frac{1}{2}\right)^{32/2} = 16 \times \left(\frac{1}{2}\right)^{16} = \left(\frac{1}{2}\right)^{12} < 1 \, mg$$

30. (c) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{15/5} = \frac{1}{8} \Rightarrow$ Decayed fraction $= 1 - \frac{1}{8} = \frac{7}{8}$

31. (c)

32. (c) By using $n_\alpha = \frac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

$\Rightarrow A' = A - 4n_\alpha = 236 - 4 \times 3 = 224$

and $Z' = (n_\beta - 2n_\alpha + Z) = (1 - 2 \times 3 + 88) = 83$

33. (d) Uncertain, because it is infinite. No radioactive element can be disintegrated fully.

34. (c) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/140} \Rightarrow \frac{1}{16} = \left(\frac{1}{2}\right)^{t/140}$.

$\Rightarrow \frac{t}{140} = 4 \Rightarrow t = 560 \, days$

35. (c) $\frac{C_{14}}{C_{12}} = \frac{1}{4} = \left(\frac{1}{2}\right)^{t/5700} \Rightarrow \frac{t}{5700} = 2 \Rightarrow t = 11400 \, years$

36. (b) Ionising property depends upon the charge and mass.

37. (b) $R = \frac{dN}{dt} \propto N \Rightarrow \frac{R_2}{R_1} = \frac{N_2}{N_1}$

But $\frac{N_2}{N_1} = \left(\frac{1}{2}\right)^{t_{1/2}} \Rightarrow \frac{25}{200} = \frac{1}{8} = \left(\frac{1}{2}\right)^3 \Rightarrow \frac{t}{t_{1/2}} = 3$

$\therefore t_{1/2} = \frac{t}{3} = \frac{3}{3} = 1 \, hour = 60 \, minutes$

38. (d) $t_{1/2} = \frac{0.6931}{0.01} = 69.31 \, seconds.$

39. (d) Because radioactivity is a spontaneous phenomenon.

40. (d) Undecayed isotope $= 1 - \frac{7}{8} = \frac{1}{8}$

$\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} \Rightarrow \left(\frac{1}{8}\right) = \left(\frac{1}{2}\right)^{t/15} \Rightarrow \frac{t}{15} = 3$

or $t = 45$ *hours*

41. (a) Mean life $= \frac{\text{Half life}}{0.6931} = \frac{10}{0.6931} = 14.4 \, hours$

42. (b) 20 *gm* substance reduces to 10 *gm* (*i.e.* becomes half in 4 min.

So $T_{1/2} = 4$ min . Again $M = M_0\left(\frac{1}{2}\right)^{t/T_{1/2}}$

$\Rightarrow 10 = 80\left(\frac{1}{2}\right)^{t/4} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/4} \Rightarrow t = 12$ *min.*

43. (c) $N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 1 = 16\left(\frac{1}{2}\right)^{\frac{2}{T_{1/2}}} \Rightarrow T_{1/2} = \frac{1}{2}\, hour$

44. (d)

45. (b) β – decay from nuclei based on this process only.

46. (b) $A = A_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 5 = A_0\left(\frac{1}{2}\right)^{\frac{2\times 60}{30}} = \frac{A_0}{16} \Rightarrow A_0 = 80\, sec^{-1}$

47. (d) $n_\alpha = \frac{A - A'}{4} = \frac{200-168}{4} = 8$

$n_\beta = 2n_a - Z + Z' = 2\times 8 - 90 + 80 = 6$

48. (d) Similar to Q. 47

49. (b) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$. Hence fraction of atoms decayed

$= 1 - \frac{N}{N_0} = 1 - \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = 1 - \left(\frac{1}{2}\right)^{\frac{3\times 60}{60}} = \frac{7}{8}$

In percentage it is $\frac{7}{8}\times 100 = 87.5\%$

50. (a) *C*-14 is carbon dating substance.

51. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} \Rightarrow \left(\frac{1}{16}\right) = \left(\frac{1}{2}\right)^{2/T} \Rightarrow \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{2/T}$

$\Rightarrow T = 0.5\, hour$ = 30 *minutes.*

52. (c) $\frac{dN}{dt} = -\lambda N \Rightarrow n = -\lambda N$ (Given $\frac{dN}{dt} = n$)

$\therefore \lambda = -\frac{n}{N}$ $\therefore$ Half life $= \frac{0.693}{\lambda} = \frac{0.693}{\lambda} = \frac{0.693\, N}{n}$ sec

53. (a) ${}_{92}X^{235} \xrightarrow{\alpha} {}_{90}X^{231} \xrightarrow{{}_{-1}e^0} {}_{91}Y^{231}$

54. (d) ${}_7N^{13} \rightarrow {}_6C^{13} + {}_{+1}e^0$

55. (c) $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 100 = 1600\left(\frac{1}{2}\right)^{\frac{8}{T_{1/2}}} \Rightarrow T_{1/2} = 2sec$

Again at t = 6 *sec*, $A = 1600\left(\frac{1}{2}\right)^{\frac{6}{2}} = 200$ *counts/sec*

56. (d) ${}_{92}U^{238} \rightarrow {}_{92}Th^{234} + {}_2He^4$

57. (b)

58. (d)

59. (d)

60. (b) By using $N = N_0e^{-\lambda t} \Rightarrow \frac{N_0}{2} = N_0e^{-\lambda T_{1/2}} \Rightarrow 2 = e^{\lambda T_{1/2}}$

By taking log both the side

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

61. (a) Number of half lives in 20 min = $n = \frac{20}{5} = 4$

Fraction of material remains after four half lives $= \frac{1}{16}$

Hence fraction that decays $= 1 - \frac{1}{16} = \frac{15}{16} = 93.75\%$

62. (d) In the given case, 12 days = 3 half lives Number of atoms left after 3 half lives.

$= 6.4\times 10^{10} \times \frac{1}{2^3} = 0.8\times 10^{10}$

63. (a) Decay constant remains unchanged in a chemical reaction.

64. (d) $n_\alpha = \frac{A - A'}{4} = \frac{238 - 206}{4} = 8$

65. (b) ${}_ZX^A \xrightarrow{\alpha} {}_{Z-2}Y^{A-4} \xrightarrow{2\beta} {}_ZX^{A-4}$

66. (a) Both the β-rays and the cathode rays are made up of electrons. γ-rays are EM waves, α-particles are doubly ionized helium atoms and protons and neutrons have approximately the same mass.

67. (b) ${}_{10}^{22}Ne \rightarrow {}_2^4He + {}_2^4He + {}_6^{14}X$; hence *X* is carbon.

68. (c) For 80 minutes, number of half lives of sample $A = n_A = \frac{80}{20} = 4$ and number of half lives of sample $B = n_B = \frac{80}{40} = 2$. Also by using $N = N_0\left(\frac{1}{2}\right)^n$

$\Rightarrow N \propto \frac{1}{2^n} \Rightarrow \frac{N_A}{N_B} = \frac{2^{n_B}}{2^{n_A}} = \frac{2^2}{2^4} = \frac{1}{4}$

69. (d) ${}_nX^m \xrightarrow{\alpha} {}_{n-2}X^{m-4} \xrightarrow{-\beta} {}_{n-1}X^{m-4}$

70. (c) Half-life $T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{1.07\times 10^{-4}} = 6476\, years$

71. (d) Number of nuclei decreases exponentially

$N = N_0e^{-\lambda t}$ and Rate of decay $\left(-\frac{dN}{dt}\right) = \lambda N$

Therefore, decay process losts up to $t = \infty$.

Therefore, a given nucleus may decay at any time after t = 0.

72. (a) To becomes $\frac{1}{4}$ *th*, it requires time of two half lives

i.e., $t = 2(T_{1/2}) = 2\times 5800 = 2\times 58$ *centuries*

73. (a) Carbon dating

74. (d) ${}_7X^{15} + {}_2He^4 \rightarrow {}_1P^1 + {}_8Y^{18}$

75. (c)

76. (d) ${}_{92}U^{238} \xrightarrow{\alpha} {}_{90}X^{234} \xrightarrow{\beta^-} {}_{91}Y^{234}$

77. (d)

78. (c) After three half lives (*i.e.*, 30 days) it remains $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$, so it will remain $\frac{1}{10}th$, approximately in 33 days.

79. (a) ${}_{92}U^{238} \xrightarrow{\alpha} {}_{90}Th^{234} \xrightarrow{\beta} {}_{91}Pa^{234} \xrightarrow{E({}_{-1}\beta^o)} {}_{92}U^{234}$

80. (d) By using $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{A}{A_0} = \left(\frac{1}{2}\right)^{9/3} = \frac{1}{8}$

81. (d) ${}_{48}Cd^{115} \xrightarrow{2({}_{-1}\beta^o)} {}_{50}Sn^{115}$

82. (b) In two half lives, the activity becomes one fourth.

83. (a) α decay decreases the mass number by 4 and atomic number by 2, β decay increases the atomic number by 1. Here atomic number of C is same as that of A.

84. (a) Number of half lives in two days four substance 1 and 2 respectively are $n_1 = \frac{2\times 24}{12} = 4$ and $n_2 = \frac{2\times 24}{1.6} = 3$

By using $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow \frac{N_1}{N_2} = \frac{(N_0)_1}{(N_0)_2} \times \frac{\left(\frac{1}{2}\right)^{n_1}}{\left(\frac{1}{2}\right)^{n_2}}$

$= \frac{2}{1} \times \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^3} = \frac{1}{1}$

85. (b)

86. (c) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{2.3} = 0.3$

87. (d) Number of $\alpha -$ particles emitted $= \frac{238-222}{4} = 4$

This decreases atomic number to $90 - 4\times 2 = 82$

Since atomic number of ${}_{83}Y^{222}$ is 83, this is possible if one $\beta -$ particle is emitted.

88. (d) Number of half lives in 150 years $n = \frac{150}{75} = 2$

Fraction of the atom of decayed $= 1 - \left(\frac{1}{2}\right)^n$

$= 1 - \left(\frac{1}{2}\right)^2 = \frac{3}{4} = 0.75 \Rightarrow$ Percentage decay = 75%

89. (b) $A = A_0 e^{-\lambda t} \Rightarrow 975 = 9750\, e^{-\lambda\times 5} \Rightarrow e^{5\lambda} = 10$

$\Rightarrow 5\lambda = \log_e 10 = 2.3026\log_{10} 10 = 2.3026$

$\Rightarrow \lambda = 0.461$

90. (a) Mass number decreases by $8\times 4 = 32$

Atomic number decreases by $8\times 2 - 5 = 11$

91. (b)

92. (d) $A = A_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 5\times 10^{-6} = 64\times 10^{-5}\left(\frac{1}{2}\right)^{t/3}$

$\Rightarrow \frac{1}{128} = \left(\frac{1}{2}\right)^{t/3} \Rightarrow t = 21$ *days*

93. (c) Decayed fraction $= \frac{3}{4}$, so undecayed fraction $= \frac{1}{4}$

Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n \Rightarrow n = 2$

$\Rightarrow t = n\times T_{1/2} = 2\times 3.8 = 7.6\ days$

94. (c) ${}_{84}X^{202} \xrightarrow{\alpha-\text{decay}} {}_{82}Y^{198} + {}_2He^4$ and

${}_{82}Y^{198} \xrightarrow{\beta-\text{decay}} {}_{83}Z^{198} + {}_{-1}\beta^0$

95. (a) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$

Now $t = n\times T_{1/2} = 3\times 3.8 = 11.4\ days$

96. (d) $n = \frac{72000}{24000} = 3$; Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \frac{1}{8}$

97. (d)

98. (a)

99. (b) $n_\alpha = \frac{A - A'}{4} = \frac{232-208}{4} = 6$

$n_\beta = 2n_\alpha - Z + Z' = 2\times 6 - 90 + 82 = 4$

100. (c)

101. (a) Number of half lives $n = \frac{5}{1} = 5$

Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^5 = \frac{1}{32}$

102. (d)

103. (b) Number of half lives $n = \frac{10}{5} = 2$, now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

Fraction decayed $= 1 - \frac{N}{N_0} = 1 - \frac{1}{4} = \frac{3}{4}$

$\Rightarrow$ In percentage $= \frac{3}{4}\times 100 = 75\%$

104. (b) Number of half lives $n = \frac{19}{3.8} = 5$; Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

$\Rightarrow \frac{N}{10.38} = \left(\frac{1}{2}\right)^5 \Rightarrow N = 10.38\times\left(\frac{1}{2}\right)^5 = 0.32gm$

105. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^5$

106. (d) $T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{2.303\log_{10} 2}{\lambda}$

107. (a) ${}_Z^AX \rightarrow {}_{Z-2}^{A-4}Y + {}_2^4He \rightarrow {}_{Z-3}^{A-4}Z + {}_1^0B$

108. (d) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n, n = 2 \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

So disintegrated part $= 1 - \frac{N}{N_0} = 1 - \frac{1}{4} = \frac{3}{4}$

109. (c) Number of half lives $n = \frac{10}{2.5} = 4$

$\Rightarrow \frac{A}{A_0} = \frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow A = 1.6 \times \left(\frac{1}{2}\right)^4 = 0.1\, curie$

110. (b) By using $N = N_0 e^{-\lambda t}$ and $t = \tau = \frac{1}{\lambda}$

Substance remains $= N = \frac{N_0}{e} = 0.37 N_0 \simeq \frac{N_0}{3}$

$\therefore$ Substance disintegrated $= N_0 - \frac{N_0}{3} = \frac{2N_0}{3}$

111. (c) $\frac{3}{4} th$ active decay takes place in time

$t = 2(T_{1/2}) \Rightarrow \frac{3}{4} = 2(T_{1/2}) \Rightarrow T_{1/2} = \frac{3}{8}\sec$

112. (c) By using $N = N_0 e^{-\lambda t}$ and average life time $t = \frac{1}{\lambda}$

So $N = N_0 e^{-\lambda \times 1/\lambda} = N_0 e^{-1} \Rightarrow \frac{N}{N_0} = e^{-1} = \frac{1}{e}$

Now disintegrated fraction $= 1 - \frac{N}{N_0} = 1 - \frac{1}{e} = \frac{e-1}{e}$

113. (d) Complete reaction will be as follows

${}_{92}X^{235} \rightarrow {}_{82}Y^{207} + 7\,{}_2He^4 + 4\,{}_{-1}e^0$

i.e., seven $\alpha -$ particles and four $\beta -$ particles will be emitted.

114. (d) $n_\alpha = \frac{A - A'}{4} = \frac{235 - 207}{4} = 7$

$n_\beta = (2n_\alpha - Z + Z') = (2 \times 7 - 92 + 82) = 4$

115. (c) During β-decay, a neutron is transformed into a proton and an electron.

116. (b) ${}_ZX^A \xrightarrow{\alpha} {}_{Z-2}X^{A-4}$

117. (a)

118. (a)

119. (d) After emitting β-particle $({}_{-1}e^0)$ mass of nucleus doesn't change.

120. (a) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{16} = \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n \Rightarrow n = 4.$

Also $n = \frac{t}{T_{1/2}} \Rightarrow T_{1/2} = \frac{40}{4} = 10\, days$

121. (c) As the $\gamma -$ particle has no charge and mass.

122. (d) With emission of an α particle $({}_2He^4)$ mass number decreases by 4 unit and atomic number decrease by 2 units and with emission of $2\beta^{-1}$ particle atomic number increases by 2 units. So Z will remain same and *N* will become $N - 4$.

123. (a) $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{100} = \left(\frac{1}{2}\right)^n \Rightarrow 2^n = 100$

n comes out in between 6 and 7.

124. (d) $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}}$

$\Rightarrow N = 1 \times \left(\frac{1}{2}\right)^{\frac{8.1}{2.7}} = \left(\frac{1}{2}\right)^3 = \frac{1}{8} \Rightarrow N = \frac{1}{8} mg = 0.125\, mg$

125. (d) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T}} \Rightarrow \frac{N_0}{4} = N_0\left(\frac{1}{2}\right)^{\frac{16}{T}} \Rightarrow T = 8$ days.

126. (d) ${}_{92}U^{238} \rightarrow {}_2He^4 + {}_{90}X^{234} \rightarrow {}_{-1}e^0 + {}_{91}U^{234}$

Hence, $A = 234$, $Z = 91$

127. (c) Mean life $= \frac{1}{\lambda} = 6.67 \times 10^8$ sec.

128. (d) $\frac{dN}{dt} = -\lambda N \Rightarrow \left|\frac{dN}{dt}\right| = \frac{0.693}{T_{1/2}} \times N$

$= \frac{0.693}{1.2 \times 10^7} \times 4 \times 10^{15} = 2.3 \times 10^8\, atoms/\sec$

129. (c) Remaining material $N = \frac{N_0}{2^{t/T}}$

$\Rightarrow N = \frac{10}{(2)^{20/15}} = \frac{10}{2.15} = 3.96\, gm$

So decayed material $= 10 - 3.96 = 6.04\, gm$

130. (b) Number of atoms remains undecayed $N = N_0 e^{-\lambda t}$

Number of atoms decayed $= N_0(1 - e^{-\lambda t})$

$= N_0\left(1 - e^{-\lambda \times \frac{1}{\lambda}}\right) = N_0\left(1 - \frac{1}{e}\right) = 0.63\, N_0 = 63\%$ of N_0.

131. (d)

132. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{16}\right) = \left(\frac{1}{2}\right)^n \Rightarrow n = 4$

also $n = \frac{t}{T_{1/2}} \Rightarrow T_{1/2} = \frac{120}{4} = 30\, days$

133. (c) $N = N_0 e^{-t/T_{1/2}} \Rightarrow \frac{1}{4} = e^{-t/10}$

$\Rightarrow \left(\frac{1}{2}\right)^2 = \frac{1}{e^{t/10}} \Rightarrow t = 20\, years$

134. (a) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = N_0\left(\frac{1}{2}\right)^{\frac{15}{5}} = \frac{N_0}{8}$

135. (a)

136. (b) $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{64} = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}}$

$$\Rightarrow \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}} \Rightarrow T_{1/2} = 10\,\text{sec}$$

137. (a, c)

138. (b) ${}_{(Z=92)}U^{(A=238)} \xrightarrow{(8\alpha, 6\beta)} {}_{Z'}X^{A'}$

so $A' = A - 4n_\alpha$ = 238 – 4 × 8 = 206

and $Z' = n_\beta - 2n_\alpha + z$ = 6 – 2 × 8 + 92 = 82.

139. (c) $A = A_0 e^{-\lambda t} = A_0 e^{-t/\tau}$; where τ = mean life

So $A_1 = A_0 e^{-t_1/T} \Rightarrow A_0 = \frac{A_1}{e^{-t_1/T}} = A_1 e^{t_1/T}$

$\therefore A_2 = A_0 e^{-t/T} = (A_1 e^{t_1/T}) e^{-t_2/T} \Rightarrow A_2 = A_1 e^{(t_1 - t_2)/T}$

140. (c)

141. (d) $n_\alpha = \frac{228 - 212}{4} = 4$ and $n_\beta = 2 \times 4 - 90 + 83 = 1$

142. (c) In a gamma decay process. There is no change in either A or Z.

143. (a) The radioactivity of a sample decays to $\frac{1}{16}th$ of its initial value in four half lives.

144. (d) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} \Rightarrow \frac{1}{16} = \left(\frac{1}{2}\right)^{t/48}$

$\Rightarrow \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{t/48} \Rightarrow t = 192\ hour.$

145. (c) If λ is the decay constant of a radioactive substance than average life = $\frac{1}{\lambda}$

Also half life $= \frac{0.693}{\lambda} = 0.693 \times (\text{Average life})$

in single average life, more than 63% of radioactive nuclei decay

146. (b)

147. (d) $M = M_0 e^{-\lambda t}$; given $t = 2\left(\frac{1}{\lambda}\right)$

$\Rightarrow M = 10 e^{-\lambda\left(\frac{2}{\lambda}\right)} = 10\left(\frac{1}{e}\right)^2 \Rightarrow M = 1.35\ gm$

148. (b)

149. (b) $\lambda = \frac{\log_e \frac{A_1}{A_2}}{t} = \frac{\log_e \frac{5000}{1250}}{5}$ = 0.4 *ln* 2

150. (c) $Z_{\text{Resuting nucleus}} = 92 - 8 \times 2 + 4 \times 1 - 2 \times 1 = 78$

151. (c) Radioactive nuclei that are injected into a patient collected at certain sites within it's body, undergoing radioactive decay and emitting electromagnetic radiation. These radiation can than be recorded by a detector. This procedure provides an important diagnostic tool called radio tracer technique.

152. (a) By using $n_\alpha = \frac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

153. (b) $N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

No of atoms at $t = 2hr$, $N_1 = 8 \times 10^{10} \left(\frac{1}{2}\right)^{\frac{2}{1}} = 2 \times 10^{10}$

No. of atoms at $t = 4hr$, $N_2 = 8 \times 10^{10} \left(\frac{1}{2}\right)^{\frac{4}{1}} = \frac{1}{2} \times 10^{10}$

$\therefore$ No. of atoms decayed in given duration

$= \left(2 - \frac{1}{2}\right) \times 10^{10} = 1.5 \times 10^{10}$

154. (b)

155. (d) $A = A_0 \left(\frac{1}{2}\right)^n \Rightarrow 30 = 240\left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$

$\therefore \frac{t}{T_{1/2}} = 3 \Rightarrow T_{1/2} = \frac{t}{3} = \frac{1}{3} hr$ = 20 *min.*

156. (b) $M = M_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 25 = 100\left(\frac{1}{2}\right)^{\frac{t}{1600}} \Rightarrow t$ = 3200 *years.*

157. (c) Activity $R = R_0 e^{-\lambda t}$

$\frac{R_0}{3} = R_0 e^{-\lambda \times 9} \Rightarrow e^{-9\lambda} = \frac{1}{3}$ ...(i)

After further 9 years $R' = R e^{-\lambda t} = \frac{R_0}{3} \times e^{-\lambda \times 9}$ ...(ii)

From equation (i) and (ii) $R' = \frac{R_0}{9}$.

158. (c) To reduce one fourth it takes time $t = 2(T_{1/2})$ = 2 × 40 = 80 *years.*

Decay constant $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{40} = 0.0173 years$

159. (d) $M = M_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = 20 \times \left(\frac{1}{2}\right)^{\frac{3.6}{3.6}} = 20 \times \left(\frac{1}{2}\right)^{10} = 0.019\, mg$

160. (c) $N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{30}{10}} = \frac{1}{8} = 0.125$.

161. (a) $\frac{7}{8}$ part decays *i.e.* remaining part is $\frac{1}{8}$

$N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^{\frac{15}{T_{1/2}}} \Rightarrow T_{1/2}$ = 5 *min.*

162. (d) $\frac{A}{A_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^{t/8} \Rightarrow t = 24\ years.$

163. (c) After $\beta^+ ({}_{+1}e^0)$ emission atomic number decreases by one and mass number remain unchanged. γ-emission, there will be no change on mass number and atomic number.

164. (c) New mass number $A' = A - 4n_\alpha = 232 - 4 \times 6 = 208$

atomic number $Z' = Z + n_\beta - 2n_\alpha = 90 + 4 - 2 \times 6 = 82$

165. (d)

166. (d) Using conservation of momentum $P_{daughter} = P_\alpha$

$$\Rightarrow \frac{E_d}{E_\alpha} = \frac{m_\alpha}{m_d} \Rightarrow E_d = \frac{E_\alpha \times m_\alpha}{m_d} = \frac{6.7 \times 4}{214} = 0.125\, MeV$$

167. (c)

168. (c)

169. (b) $N = N_0 \times \left(\frac{1}{2}\right)^{11400/5700} = N_0\left(\frac{1}{2}\right)^2 = 0.25 N_0$.

170. (d) Mean life $(T) = 1/\lambda$ = 100 *second*

Half-life = $\frac{0.693}{\lambda} = \frac{0.693 \times 100}{60}$ =1.155 *min.*

171. (b) By using $n_\alpha = \frac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

172. (c)

173. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{77} = 9 \times 10^{-3}\,/\,day$.

174. (a) By using $n_\alpha = \frac{A - A'}{4} = \frac{232 - 204}{4} = 7$.

175. (c) $\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} \left(\frac{1}{2}\right)^{1/2} = \frac{1}{\sqrt{2}}$.

176. (d)

Critical Thinking Questions

1. (c) At closest distance of approach

Kinetic energy = Potential energy

$$\Rightarrow 5 \times 10^6 \times 1.6 \times 10^{-19} = \frac{1}{4\pi\varepsilon_0} \times \frac{(ze)(2e)}{r}$$

For uranium z= 92, so $r = 5.3 \times 10^{-12}\, cm$

2. (c) Speed of electron in n orbit of hydrogen atom $v = \frac{e^2}{2\varepsilon_0 n h}$

In ground state $n = 1 \Rightarrow v = \frac{e^2}{2\varepsilon_0 h}$

$$\Rightarrow \frac{v}{c} = \frac{e^2}{2\varepsilon_0 ch} = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 3 \times 10^8 \times 6.6 \times 10^{-34}}$$

$$= \frac{1}{137}.$$

3. (b) Recoil momentum = momentum of photon $= \frac{h}{\lambda}$

$$= hR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{hR \times 15}{16} = 6.8 \times 10^{-27}\, N \times \sec$$

4. (a) The average time that the atom spends in this excited state is equal to Δt, so by using $\Delta E.\Delta t = \frac{h}{2\pi}$

$\Rightarrow$ Uncertainty in energy $= \frac{h/2\pi}{\Delta t}$

$$= \frac{6.6\times10^{-34}}{2\times3.14\times10^{-8}} = 1.05\times10^{-26}\,J = 6.56\times10^{-8}\,eV$$

5. (a) After the removal of first electron remaining atom will be hydrogen like atom.

So energy required to remove second electron from the atom

$$E = 13.6\times\frac{2^2}{1} = 54.4\,eV$$

$\therefore$ Total energy required = 24.6 + 54.4 = 79 eV.

6. (a) Electron after absorbing 10.2 eV energy goes to its first excited state (n=2) from ground state (n = 1).

$\therefore$ Increase in momentum $= \frac{h}{2\pi}$

$$= \frac{6.6\times10^{-34}}{6.28} = 1.05\times10^{-34}\,J\text{-}s.$$

7. (a) Using $\Delta E \propto Z^2$ ($\because$ n_1 and n_2 are same)

$$\Rightarrow \frac{hc}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant}$$

$$\Rightarrow \lambda_1 Z_1^2 = \lambda_2 Z_2^2 = \lambda_3 Z_3^2 = \lambda_4 Z_4^2$$

$$\Rightarrow \lambda_1\times1 = \lambda_2\times1^2 = \lambda_3\times2^2 = \lambda_4\times3^3$$

$$\Rightarrow \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4.$$

8. (d) $mvr = \frac{h}{2\pi}$ (for first orbit)

$$\Rightarrow m\omega r^2 = \frac{h}{2\pi} \Rightarrow m\times2\pi\nu\times r^2 = \frac{h}{2\pi} \Rightarrow \nu = \frac{h}{4\pi^2 mr^2}$$

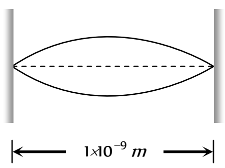
$$= \frac{6.6\times10^{-34}}{4(3.14)^2\times9.1\times10^{-31}\times(0.53\times10^{-10})^2} = 6.5\times10^{15}\,\frac{rev}{sec}$$

9. (b) It will form a stationary wave

$$\lambda = 2l = 2\times10^{-9}\,m$$

$$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}}$$

$$\Rightarrow E = \frac{h^2}{2m\lambda^2} = 6\times10^{-20}\,J$$



10. (d) Suppose closest distance is r, according to conservation of energy.

$$400\times10^3\times1.6\times10^{-19} = 9\times10^9\,\frac{(ze)(2e)}{r}$$

$$\Rightarrow 6.4\times10^{-14} = \frac{9\times10^9\times(82\times1.6\times10^{-19})\times(2\times1.6\times10^{-19})}{r}$$

$$\Rightarrow r = 5.9\times10^{-13}\,m = 0.59\,pm.$$

11. (a) Here radius of electron orbit $r \propto 1/m$ and energy $E \propto m$, where m is the mass of the electron.

Hence energy of hypothetical atom

$E_0 = 2\times(-13.6\,eV) = -27.2\,eV$ and radius $r_0 = \frac{a_0}{2}$

12. (a) Electronic configuration of iodine is 2, 8, 18, 18, 7,

Here $r_n = (0.053\times10^{-9}\,m)\frac{n^2}{Z}$

Here $n = 5$ and $Z = 53$, hence $r_n = 2.5\times10^{-11}\,m$.

13. (a) $N \propto \left[\frac{1}{\sin^4\theta/2}\right] \Rightarrow N_1 = 7\times\frac{1}{(\sin30^o)^4} = 112$

and $N_2 = 7\times\frac{1}{(\sin60^o)^4} = 12.5$.

14. (d) $E_n = -13.6\frac{Z^2}{n^2}eV$. Required energy for said transition

$$\Delta E = E_3 - E_1 = 13.6\,Z^2\left[\frac{1}{1^2}-\frac{1}{3^2}\right]$$

$$\Rightarrow \Delta E = 13.6\times3^2\left[\frac{8}{9}\right] = 108.8\,eV$$

$$\Rightarrow \Delta E = 108.8\times1.6\times10^{-19}\,J$$

Now $\Delta E = \frac{hc}{\lambda} = 108.8\times1.6\times10^{-19}$

$$\Rightarrow \lambda = \frac{6.6\times10^{-34}\times3\times10^8}{108.8\times1.6\times10^{-19}} = 0.11374\times10^{-7}\,m = 113.74\,Å$$

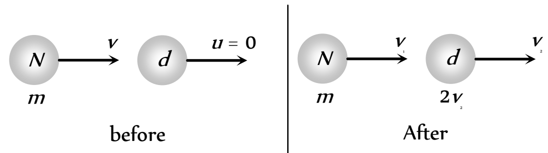
15. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

$$\Rightarrow \frac{1}{970.6\times10^{-10}} = 1.097\times10^7\left[\frac{1}{1^2}-\frac{1}{n_2^2}\right] \Rightarrow n_2 = 4$$

$\therefore$ Number of emission lines $N = \frac{n(n-1)}{2} = \frac{4\times3}{2} = 6$

16. (d) Neutron velocity = v, mass = m

Deuteron contains 1 neutron and 1 proton, mass = $2m$



In elastic collision both momentum and $K.E.$ are conserved $p_i = p_f$

$$mv = mv_1 + mv_2 \Rightarrow mv = mv_1 + 2mv_2 \quad \text{... (i)}$$

By conservation of kinetic energy

$$\frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(2m)v_2^2 \quad \text{... (ii)}$$

By solving (i) and (ii) we get

$$v_1 = \frac{m_1-m_2}{m_1+m_2}v + \frac{2m_2}{(m_1+m_2)}v \Rightarrow v_1 = \frac{m_1+2m}{3m} = -\frac{v}{3}$$

$$K_i = \frac{1}{2}mv^2,\; K_f = \frac{1}{2}mv_1^2 \Rightarrow \frac{K_i-K_f}{K_i} = 1-\frac{v_1^2}{v^2}$$

$= 1-\frac{1}{9} = \frac{8}{9}$ (Fractional change in $K.E.$)

17. (c) In hydrogen atom $E_n = -\frac{Rhc}{n^2}$

Also $E_n \propto m$; where m is the mass of the electron. Here the electron has been replaced by a particle whose mass is double of an electron. Therefore, for this hypothetical atom energy in n orbit will be given by $E_n = -\frac{2Rhc}{n^2}$

The longest wavelength λ_{max} (or minimum energy) photon will correspond to the transition of particle from $n = 3$ to $n = 2$

$$\Rightarrow \frac{hc}{\lambda_{max}} = E_3 - E_2 = Rhc\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

This gives $\lambda_{max} = \frac{18}{5R}$.

18. (d) As the transition $n = 4$ and $n = 3$, results in UV radiation and infrared radiation involves smaller amounts of energy UV. So we require a transition involving initial values of n greater than 4 *e.g.* $5 \to 4$.

19. (c) $\frac{hc}{\lambda} = E = eV$

$$\Rightarrow \lambda = \frac{hc}{eV} - \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 4.9} = 2525\,\overset{\circ}{A}$$

20. (d) Rydberg constant $R = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}$

Velocity $v = \frac{Ze^2}{2\varepsilon_0 nh}$ and energy $E = -\frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$

Now, it is clear from above expressions $R.v \propto n$

21. (b) In second excited state $n = 3$

So $l_H = l_{Li} = 3\left(\frac{h}{2\pi}\right)$

While $E \propto Z$ and $Z_H = 1$, $Z_{Li} = 3$

So $|E_{Li}| = 9|E_H|$ or $|E_H| < |E_{Li}|$

22. (c) Since the $^{133}_{55}Cs$ has larger size among the four atoms gives, thus the electrons present in the outermost orbit will be away from the nucleus and the electrostatic force experienced by electrons due to nucleus will be minimum. Therefore the energy required to liberate electron from outer will be minimum in the case of $^{133}_{55}Cs$.

23. (d)

24. (a) Potential energy $U = eV = eV_0 \ln\frac{r}{r_0}$

$\therefore$ Force $F = -\left|\frac{dU}{dr}\right| = \frac{eV_0}{r}$.

$\therefore$ The force will provide the necessary centripetal force. Hence $\frac{mv^2}{r} = \frac{eV_0}{r} \Rightarrow v = \sqrt{\frac{eV_0}{m}}$ .....(i)

and $mvr = \frac{nh}{2\pi}$ .....(ii)

From equation (i) and(ii) $mr = \left(\frac{nh}{2\pi}\right)\sqrt{\frac{m}{eV_0}}$ or $r \propto n$

25. (d) $(r_m) = \left(\frac{m^2}{Z}\right)(0.53Å) = (n \times 0.53Å) \Rightarrow \frac{m^2}{Z} = n$

$m = 5$ for $_{100}Fm^{257}$ (the outermost shell)

and $z = 100 \Rightarrow n = \frac{(5)^2}{100} = \frac{1}{4}$

26. (d) Energy radiated $= 1.4\ kW/m^2$

$$= 1.4\ kJ/\sec m^2 = \frac{1.4\ kJ}{\frac{1}{86400} day\, m^2} = \frac{1.4 \times 86400}{day\, m^2}$$

Total energy radiated/day

$$= \frac{4\pi \times (1.5 \times 10^{11})^2 \times 1.4 \times 86400}{1} \frac{kJ}{day} = E$$

$$\therefore E = mc^2 \Rightarrow m = \frac{E}{c^2}$$

$$= \frac{4\pi(1.5 \times 10^{11})^2 \times 1.4 \times 86400}{(3 \times 10^8)^2} = 3.8 \times 10^{14}\ kg.$$

27. (c) The equation is $O^{17} \to {}_0n^1 + O^{16}$

$\therefore$ Energy required = B.E. of O – B.E. of O

= 17 × 7.75 – 16 × 7.97 = 4.23 MeV

28. (c) $\Delta = mc^2 - m_0c^2 = \frac{m_0c^2}{\sqrt{1-(v^2/c^2)}} - m_0c^2$

$$= m_0c^2\left(\frac{1}{\sqrt{1-(v^2/c^2)}} - 1\right) = 0.511\left(\frac{1}{\sqrt{0.75}} - 1\right)$$

= 0.079 MeV

29. (c,d) Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less then the sum of masses of it's constituent particles $^{20}_{10}Ne$ is made up of 10 protons plus 10 neutrons. Therefore, mass of $^{20}_{10}Ne$ nucleus $M_1 < 10(m_p + m_n)$

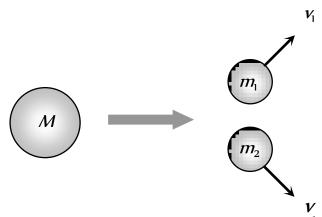
Also heavier the nucleus, more is he mass defect thus $20(m_n + m_p) - M_2 > 10(m_p + m_n) - M_1$

or $10(m_p + m_n) > M_2 - M_1$

$\Rightarrow M_2 < M_1 + 10(m_p + m_n) \Rightarrow M_2 < M_1 + M_1$

$\Rightarrow M_2 < 2M_1$.

30. (a)



By conservation of momentum $m_1v_1 = m_2v_2$

$\Rightarrow \frac{v_1}{v_2} = \frac{8}{1} = \frac{m_2}{m_1}$ ...... (i)

Also from $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$.

31. (a) Since nuclear density is constant hence mass $\propto$ volume.

32. (c) Mass defect $= 3 \times 2.014 - 4.001 - 1.007 - 1.008$

$= 0.026\ amu = 0.026 \times 931 \times 10^6 \times 1.6 \times 10^{-19}\ J$

$= 3.82 \times 10^{-12}\ J$

Power of star $=10^{16} W$

Number of deuterons used $=\frac{10^{16}}{\Delta M}=0.26\times 10^{28}$

Deuteron supply exhausts in $\frac{10^{40}}{0.26\times 10^{28}}=10^{12}\,s$.

33. (a) Since electron and positron annihilate

$$\lambda=\frac{hc}{E_{Total}}=\frac{6.6\times 10^{-34}\times 3\times 10^{8}}{(0.51+0.51)\times 10^{6}\times 1.6\times 10^{-19}}$$

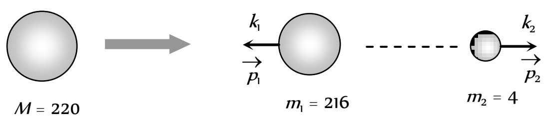
$=1.21\times 10^{-12}\,m=0.012\,Å$.

34. (a) Kinetic energy of the molecules of a gas at a temp. T is $\frac{3}{2}kT$

$\therefore$ To initiate the reaction $\frac{3}{2}kT=7.7\times 10^{-14}\,J$

$\Rightarrow \frac{3}{2}\times 1.38\times 10^{-23}\,T=7.7\times 10^{-14}\Rightarrow T=3.7\times 10^{9}\,K$.

35. (b)



Q-value of the reaction is 5.5 eV

i.e. $k_1+k_2=5.5\,MeV$ ......(i)

By conservation of linear momentum

$p_1=p_2\Rightarrow \sqrt{2(216)k_1}=\sqrt{2(4)k_2}$

$\Rightarrow k_2=54\,k_1$ ......(ii)

On solving equation (i) and (ii) we get k_2 = 5.4 MeV.

36. (b) By the formula $N=N_0e^{-\lambda t}$

Given $\frac{N}{N_0}=\frac{1}{20}$ and $\lambda=\frac{0.6931}{3.8}\Rightarrow 20=e^{\frac{0.6931\times t}{3.8}}$

Taking log of both sides

or log 20 $=\frac{0.6931\times t}{3.8}\log_{10}e$

or 1.3010 $=\frac{0.6931\times t\times 0.4343}{3.8}\Rightarrow t=16.5$ days.

37. (b) $N=N_0e^{-\lambda t}$

$\therefore 0.9N_0=N_0e^{-\lambda\times 5}\Rightarrow 5\lambda=\log_e\frac{1}{0.9}$ ...... (i)

and $xN_0=N_0e^{-\lambda\times 20}\Rightarrow 20\lambda=\log_e\left(\frac{1}{x}\right)$ ...... (ii)

Dividing (i) by (ii), we get

$$\frac{1}{4}=\frac{\log_e(1/0.9)}{\log_e(1/x)}=\frac{\log_{10}(1/0.9)}{\log_{10}(1/x)}=\frac{\log_{10}0.9}{\log_{10}x}$$

$\Rightarrow \log_{10}x=4\log_{10}0.9\Rightarrow x=0.658=65.8\%$

38. (c) If in the rock there is no Y element, then the time taken by element X to reduce to $\frac{1}{8}th$ the initial value will be equal to

$\frac{1}{8}=\left(\frac{1}{2}\right)^n$ or $n=3$

Therefore, from the beginning three half life time is spent. Hence the age of the rock is

$=3\times 1.37\times 10^{9}=4.11\times 10^{9}\,years$.

39. (b) $\frac{N}{N_0}=\left(\frac{1}{2}\right)^n\Rightarrow \frac{1}{64}=\left(\frac{1}{2}\right)^6=\left(\frac{1}{2}\right)^n\Rightarrow n=6.$

After 6 half lives intensity emitted will be safe.

$\therefore$ Total time taken $=6\times 2=12\,hrs$.

40. (a) $\frac{dN}{dt}=\lambda N;\ \lambda=\frac{0.6931}{t_{12}}=\frac{0.6931}{1620\times 365\times 24\times 60\times 60}$,

$N=\frac{6.023\times 10^{23}}{226}$

$\therefore \frac{dN}{dt}=\frac{0.6931\times 6.023\times 10^{23}}{1620\times 365\times 24\times 60\times 60\times 226}=3.61\times 10^{10}$

41. (a) $\lambda=\lambda_1+\lambda_2\Rightarrow \frac{1}{T}=\frac{1}{T_1}+\frac{1}{T_2}$

$\therefore T=\frac{T_1T_2}{T_1+T_2}=\frac{810\times 1620}{810+1620}=540\,years$

Hence $\frac{1}{4}th$ of material remain after 1080 *years*.

42. (b) Similar to Q. 40.

43. (c) $(T_{1/2})_x=(t_{\text{mean}})_y$

$\Rightarrow \frac{0.693}{\lambda_x}=\frac{1}{\lambda_y}\Rightarrow \lambda_x=0.693\,\lambda_y$ or $\lambda_x<\lambda_y$

Also rate of decay = λN

Initially number of atoms (N) of both are equal but since $\lambda_y>\lambda_x$, therefore, y will decay at a faster rate than x.

44. (c) $\lambda_\alpha=\frac{1}{1620}$ *per year* and $\lambda_\beta=\frac{1}{405}$ *per year* and it is given that the fraction of the remained activity $\frac{A}{A_0}=\frac{1}{4}$

Total decay constant

$\lambda=\lambda_\alpha+\lambda_\beta=\frac{1}{1620}+\frac{1}{405}=\frac{1}{324}\,per\,year$

We know that $A=A_0e^{-\lambda t}\Rightarrow t=\frac{1}{\lambda}\log_e\frac{A_0}{A}$

$\Rightarrow t=\frac{1}{\lambda}\log_e 4=\frac{2}{\lambda}\log_e 2$ = 324 × 2 × 0.693 = 449 *years*.

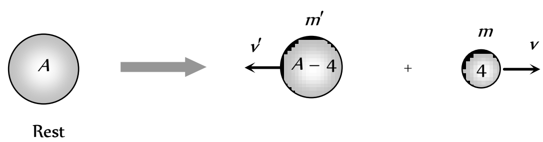
45. (d) $n=\frac{24}{24\times 138.6}=\frac{1}{138.6}$; Now $\frac{N}{N_0}=\left(\frac{1}{2}\right)^n=\left(\frac{1}{2}\right)^{1/138.6}$

$\Rightarrow N=10{,}00000\left(\frac{1}{2}\right)^{1/138.6}=995011$

So number of disintegration

$=1000000-995011=4989\approx 5000$.

46. (a)



According to conservation of momentum $4v=(A-4)v'\Rightarrow$

$v'=\frac{4v}{A-4}$.

47. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{20} = 0.03465$

Now time of decay $t = \frac{2.303}{\lambda}\log\frac{N_0}{N}$

$\Rightarrow t_1 = \frac{2.303}{0.03465}\log\frac{100}{67} = 11.6\,\text{min}\ min$

and $t_2 = \frac{2.303}{0.03465}\log\frac{100}{33} = 32 min$

Thus time difference between points of time

$= t_1 - t_2 = 32 - 11.6 = 20.4\ min \approx 20\ min.$

48. (d) $N_1 = N_0 e^{-10\lambda t}$ and $N_2 = N_0 e^{-\lambda t}$

$\Rightarrow \frac{N_1}{N_2} = \frac{1}{e} = e^{-1} = e^{(-10\lambda + \lambda)t} = e^{-9\lambda t} \Rightarrow t = \frac{1}{9\lambda}.$

49. (a) $N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow N_A = 10\left(\frac{1}{2}\right)^{t/1}$ and $N_B = 1\left(\frac{1}{2}\right)^{t/2}$

Given $N_A = N_B \Rightarrow 10\left(\frac{1}{2}\right)^{t} = \left(\frac{1}{2}\right)^{t/2}$

$\Rightarrow 10 = \left(\frac{1}{2}\right)^{-t/2} \Rightarrow 10 = 2^{t/2}$. Taking log both the sides.

$\log_{10} 10 = \frac{t}{2}\log_{10} 2 \Rightarrow 1 = \frac{t}{2} \times 0.3010 \Rightarrow t = 6.62$ years.

50. (b) Here $T_{1/2} = 20$ *minutes;* we know $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$

For 20% decay $\frac{N}{N_0} = \frac{80}{100} = \left(\frac{1}{2}\right)^{t_1/20}$ ..... (i)

For 80% decay $\frac{N}{N_0} = \frac{20}{100} = \left(\frac{1}{2}\right)^{t_2/20}$ ..... (ii)

Dividing (ii) by (i)

$\frac{1}{4} = \left(\frac{1}{2}\right)^{\frac{(t_2 - t_1)}{20}}$; on solving we get $t_2 - t_1 = 40$ *min.*

51. (d) Here the activity of the radioactive sample reduces to half in 140 days. Therefore, the half life of the sample is 140 days. 280 days is it's two half lives. So before two half lives it's activity was ($2^2 \times$ present activity).

$\therefore$ Initial activity = $2^2 \times 6000 = 24000\,dps.$

52. (a) Excitation energy $\Delta E = E_2 - E_1 = 13.6\ Z^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2.$

Now required energy to remove the electron from ground state

$= \frac{+13.6 Z^2}{(1)^2} = 13.6 (Z)^2 = 54.4\,eV.$

53. (b) Rate of disintegration $\frac{dN}{dt} = 10^{17}\,s^{-1}$

Half life $T_{1/2} = 1445$ year

$= 1445 \times 365 \times 24 \times 60 \times 60 = 4.55 \times 10^{10}$ *sec*

Now decay constant

$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{4.55 \times 10^{10}} = 1.5 \times 10^{-11}$ per sec

The rate of disintegration

$\frac{dN}{dt} = \lambda \times N_0 \Rightarrow 10^{17} = 1.5 \times 10^{-11} \times N_0$

$\Rightarrow N_0 = 6.6 \times 10^{27}.$

54. (b) $P = \frac{nE}{t} \Rightarrow 300 \times 10^6 = \frac{n \times 170 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$\therefore$ Number of atoms per sec $\frac{n}{t} = 1.102 \times 10^{19}$

Number of atoms per hour = $1.02 \times 10^{19} \times 3600$

$= 3.97 \times 10^{22}.$

55. (a) According to kinetic interpretation of temperature

$K.E. = \left(\frac{1}{2}mv^2\right) = \frac{3}{2}kT.$

$\Rightarrow 10.2 \times 1.6 \times 10^{-19} = \frac{3}{2} \times (1.38 \times 10^{-23})T$

$\Rightarrow T = 7.9 \times 10^4 K.$

56. (a) R_0 = Initial activity = 1 micro curie = 3.7×10^4 $d\,ps$

r = Activity in 1 cm^3 of blood at t = 5 *hrs*

$= \frac{296}{60} dps = 4.93\,dps$

R = Activity of whole blood at time t = 5 *hr,*

Total volume should be $V = \frac{R}{r} = \frac{R_0 e^{-\lambda t}}{r}$

$= \frac{3.7 \times 10^4 \times 0.7927}{4.93} = 5.94 \times 10^3\ cm^3 = 5.94$ *Litre.*

57. (b) Let ground state energy (in *eV*) be E_1

Then from the given condition

$E_{2n} - E_1 = 204\,eV$ or $\frac{E_1}{4n^2} - E_1 = 204\,eV$

$\Rightarrow E_1\left(\frac{1}{4n^2} - 1\right) = 204\,eV$ .....(i)

and $E_{2n} - E_n = 40.8\,eV$

$\Rightarrow \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8\,eV$ .....(ii)

From equation (i) and (ii), $\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$

58. (b) Here $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/3}$

where n = Number of half lives $= \frac{1}{3}$

$\Rightarrow \frac{N}{N_0} = \frac{1}{1.26} \Rightarrow \frac{N_U}{N_{Pb} + N_U} = \frac{1}{1.26}$

$\Rightarrow N_{Pb} = 0.26\,N_U \Rightarrow \frac{N_{Pb}}{N_U} = 0.26$

59. (b) For K_α X-ray line

$$\frac{1}{\lambda_\alpha} = R(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}(Z-1)^2$$

On putting the given values

$$\frac{1}{0.76\times10^{-10}} = \frac{3}{4}\times1.09\times10^7(Z-1)^2$$

$$\Rightarrow (Z-1)^2 \approx 1600 \Rightarrow Z-1 = 40 \Rightarrow Z = 41$$

60. (a) Maximum energy is liberated for transition $E_n \to 1$ and minimum energy for $E_n \to E_{n-1}$

Hence $\frac{E_1}{n^2} - E_1 = 52.224\, eV$ ......(i)

and $\frac{E_1}{n^2} - \frac{E_1}{(n-1)^2} = 1.224\, eV$ .....(ii)

Solving equations (i) and (ii) we get

$E_1 = -54.4\, eV$ and $n = 5$

Now $E_1 = -\frac{13.6\, Z^2}{1^2} = -54.4\, eV$. Hence $Z = 2$

61. (a) Activity of substance that has 2000 disintegration/sec

$$= \frac{2000}{3.7\times10^{10}} = 0.054\times10^{-6} ci = 0.054\, \mu ci$$

The number of radioactive nuclei having activity A

$$N = \frac{A}{\lambda} = \frac{2000\times T_{1/2}}{\log_e 2}$$

$$= \frac{2000\times138.6\times24\times3600}{0.693} = 3.45\times10^{10}$$

62. (a) Maximum number of nuclei will be present when rate of decay = rate of formation $\Rightarrow \lambda N = \alpha \Rightarrow N = \frac{\alpha}{\lambda}$

63. (b) $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{3}{5} = \left(\frac{27}{A}\right)^{1/3} \Rightarrow \frac{27}{125} = \frac{27}{A} \Rightarrow A = 125$$

Number of nuclei in atom $X = A - 52 = 125 - 52 = 73$.

64. (c) 1 week ≈ 7 days $\simeq$ $7\times24 hrs \simeq 14$ half lives

Number of atoms left $= \frac{No}{(2)^{14}}$, Activity = $N\lambda$

$\therefore$ Activity left is $\frac{1}{(2)^{14}}$ times the initial

$$\Rightarrow \frac{1}{(2)^{14}}\times1 \text{ curie} = \frac{1}{16384}\times1 \text{ curie} \cong 61\times10^{-6} \text{ curie}$$

$\approx 60\mu$ *curie.*

65. (a) $m_0c^2 = 0.54\, MeV$ and K.E. = $mc^2 - m_0c^2$

Also $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1-(0.8)^2}} = \frac{m_0}{0.6}$

$$\therefore E = mc^2 = \frac{m_0}{0.6}c^2 = \frac{m_0c}{0.6} = \frac{0.5\,H}{0.6} = 0.9\, MeV$$

$\therefore$ K.E.= (0.9 – 0.54) = 0.36 *MeV.*

Graphical Questions

1. (a) B.E. per nucleon is maximum for Fe^{56}. For further detail refer theory.

2. (a) $\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = 2\pi c\bar{\nu} \Rightarrow \omega \propto \bar{\nu}$.

3. (c)

4. (d) The total number of atoms neither remains constant (as in option (a) nor can ever increase (as in option (b) and (c)). They will continuously decrease with time. Therefore option (d) is correct.

5. (c) $N = N_0e^{-\lambda t} \Rightarrow \frac{dN}{dt} = -N_0\lambda e^{-\lambda t}$

i.e. Rate of decay $\left(\frac{dN}{dt}\right)$ varies exponentially with time (t).

6. (d) Rate $R = -\frac{dN}{dt} = \lambda N_0e^{-\lambda t} = \lambda N \Rightarrow \frac{R}{N} = \lambda$ (constant)

i.e. graph between $\frac{R}{N}$ and t, be a straight line parallel to the time axis.

7. (b) Read time for 50 count rate, it gives half life period of 3 *hrs*, one small square gives 600 counts (10 × 60). The number of small squares between graph and time axis are approx 24

Hence count rate = $24\times600 = 14400$

8. (b) Number of atoms undecayed $N = N_0e^{-\lambda t}$

Number of atoms decayed $= N_0 - N = N_0(1-e^{-\lambda t})$

$\Rightarrow$ Decayed fraction $f = \frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$

i.e. fraction will rise up to 1, following exponential path as shown in graph (B).

9. (c) Energy is released in a process when total Binding energy (B.E.) of the nucleus is increased or we can say when total *B.E.* of products is more than the reactants. By calculation we can see that only in case of option (c), this happens.

Given $W \to 2Y$

B.E. of reactants = 120 × 75 = 900 *MeV*

and *B.E.* of products = $2\times(60\times85) = 1020\, MeV$

i.e. B.E. of products > *B.E.* of reactants.

10. (d) $N = N_0e^{-\lambda t}$ and $A = A_0e^{-\lambda t} = \lambda N_0e^{-\lambda t}$

$\therefore N_{decayed} = N_0 - N = N_0 - N_0 e^{\lambda t} \Rightarrow N_{decayed} = N_0 - \dfrac{A}{\lambda}$

This is equation of straight line with negative slope.

11. (d) Radius of n^{th} orbit $r_n \propto n^2$, graph between r_n and n is a parabola. Also, $\dfrac{r_n}{r_1} = \left(\dfrac{n}{1}\right)^2 \Rightarrow \log_e\left(\dfrac{r_n}{r_1}\right) = 2\log_e(n)$

Comparing this equation with $y = mx + c$,

Graph between $\log_e\left(\dfrac{r_n}{r_1}\right)$ and $\log_e(n)$ will be a straight line, passing from origin.

Similarly it can be proved that graph between $\log_e\left(\dfrac{f_n}{f_1}\right)$ and $\log_e n$ is not a straight line.

12. (d) By using $N = N_0 e^{-\lambda t}$ and $\dfrac{dN}{dt} = -\lambda N.$

It shows that N decreases exponentially with time.

13. (b) Activity $= -\dfrac{dN}{dt} = \lambda N = \lambda\, N_0 e^{-\lambda t}$

i.e., graph between activity and t, be exponential having negative slope.

14. (d) Activity $A = \lambda\, N_0 e^{-\lambda t} \Rightarrow \log_e A = \log_e \lambda N_0 + \log_e e^{-\lambda t}$

$\Rightarrow \log_e A = \log_e C - \lambda t$ (Take $\lambda N_0 = C$)

$\Rightarrow \log_e A = -\lambda t + \log_e C$

This is the equation of a straight line having negative slope (= $-\lambda$) and positive intercept on $\log_e A$ axis.

15. (c) Charge density is uniform inside and then falls rapidly near the surface of the nucleus.

16. (a) $R = R_0 A^{1/3}$; where $R_0 = 1.2 \times 10^{-15} m.$

$\Rightarrow \log_e R = \log_e R_0 + \dfrac{1}{3}\log_e A$

This is the equation of a straight line with positive slope.

17. (b) $\left|\dfrac{dN}{dt}\right| = \lambda N \Rightarrow \left|\dfrac{dN}{dt}\right| \propto N$

18. (c) Number of atom decayed $N' = N_0(1 - e^{-\lambda t})$

N' will increase with time (t) exponentially.

19. (a) $A_n = \pi r_n^2 \Rightarrow \dfrac{A_n}{A_1} = \left(\dfrac{r_n}{r_1}\right)^2 = \left(\dfrac{n}{1}\right)^4$ $(\because r_n \propto n^2)$

Taking $\log_e$ both the side $\log_e \dfrac{A_n}{A_1} = 4\log_e(n)$

Comparing it with $y = mx + c$, graph (4) is correct.

Assertion and Reason

1. (c) In fusion, lighter nuclei are used so, fusion is not possible with ^{35}Cl. Also binding energy of ^{35}Cl is not too small.

2. (a) $^{90}_{38}Sr$ decays to $^{90}_{39}Y$ by the emission of $\beta-$rays. Sr gets absorbed in bones along with calcium.

Reason is also true. $^{90}Sr \xrightarrow{\beta} {}^{90}Y$ which emits $\beta-$rays of very high energy. Sr does not emit $\gamma-$rays. The damage is by the $\beta-$rays only.

3. (b) Neutron is about 0.1 more massive than proton. But the unique thing about the neutron is that while it is heavy, it has no charge (it is neutral). This lack of charge gives it the ability to penetrate matter without interacting as quickly as the beta particles or alpha particles.

4. (b) Bohr postulated that electrons in stationary orbits around the nucleus do not radiate.

This is the one of Bohr's postulate. According to this the moving electrons radiate only when they go from one orbit to the next lower orbit.

5. (c) Nuclear stability depends upon the ratio of neutron to proton. If the n/p ratio is more than the critical value, then a neutron gets converted into a proton forming a β^- particle in the process. $n \rightarrow p + e^-$

The β^- particle (e^-) is emitted from the nucleus in some radioactive transformation. So electrons do not exist in the nucleus but they result in some nuclear transformation.

6. (a) ${}_ZX^A \rightarrow 2({}_2He^4) + 2({}_{-1}e^0) + 2\gamma + {}_{Z-2}X^{A-8}$

7. (a) Experimentally, it is found that the average radius of a nucleus is given by

$R = R_0 A^{1/3}$ where $R_0 = 1.1 \times 10^{-15} m = 1.1\, fm$

and $A =$ mass number

8. (b)

9. (b) Rutherford confirmed the repulsive force on α-particle due to nucleus varies with distance according to inverse square law and that the positive charges are concentrated at the centre and not distributed throughout the atom.

10. (a) In α-particle scattering experiment, Rutherford found a small number of α-particles which were scattered back through an angle approaching to $180°$. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom.

11. (e) According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence they will be losing their energy continuously and the orbital radius will go on decreasing and form spiral and finally the electron will fall on the nucleus.

12. (c) According to postulates of Bohr's atom model, the electron revolve round the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbits it does not radiate any energy.

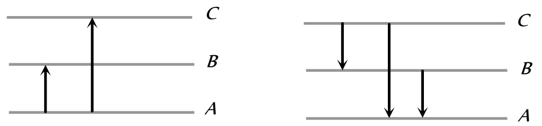
13. (b) Maximum number of photon is given by all the transitions possible $= {}^4C_2 = 6$

Minimum number of transition = 1,

that is directly jump from 4 to 1.

14. (b) When the atom gets appropriate energy from outside, then this electron rises to some higher energy level. Now it can return either directly to the lower energy level or come to the lowest energy level after passing through other lower energy lends, hence all possible transitions take place in the source and many lines are seen in the spectrum.

15. (d) Emission transitions can take place between any higher energy level and any energy level below it while absorption transitions start from the lowest energy level only and may end at any higher energy level. Hence number of absorptions transitions between two given energy levels is always less than the number of emission transitions between same two levels.



Absorption　　　　Emission

16. (a) We knows that an electron is very light particle as compared to an α-particle. Hence electron cannot scatter the α-particle at large angles, according to law of conservation of momentum. On the other hand, mass of nucleus is comparable with the mass of α-particle, hence only the nucleus of atom is responsible for scattering of α-particles.

17. (c) All those elements which are heavier than lead are radioactive. This is because in the nuclei of heavy atoms, besides the nuclear attractive forces, repulsive forces between the protons are also effective and these forces reduce the stability of the nucleus. Hence, the nuclei of heavier elements are being converted into lighter and lighter elements by emission of radioactive radiation. When they are converted into lead, the emission is stopped because the nucleus of lead is stable (or lead is most stable elements in radioactive series).

18. (d) The penetrating power is maximum in case of gamma rays because gamma rays are an electromagnetic radiation of very small wavelength.

19. (b) β-particles, being emitted with very high speed compared to α-particles, pass very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

20. (b) β-particles are emitted with very high velocity (up to 0.99 c). So, according to Einstein's theory of relatively, the mass of a β-particle is much higher compared to is` its rest mass (m_0). The velocity of electrons obtained by other means is very small compared to c (Velocity of light). So its mass remains nearly m_0. But β-particle and electron both are similar particles.

21. (c) Radioactivity $=-\dfrac{dN}{dt}=\lambda N=\dfrac{0.693N}{T}$

$$=\frac{0.693\times10^8}{50}=\frac{0.693\times1.2\times10^8}{60}=0.693\times2\times10^6.$$

Radioactivity is proportional to $1/T_{1/2}$, and not to $T_{1/2}$.

22. (c) Fragments produced in the fission of U^{235} are radioactive. When uranium undergoes fission, barium and krypton are not the only products. Over 100 different isotopes of more than 20 different elements have been detected among fission products. All of these atoms are, however, in the middle of the periodic table, with atomic numbers ranging from 34 to 58. Because the neutron-proton ratio needed for stability in this range is much smaller than that of the original uranium nucleus, the residual nuclei called fission fragments, always have too many neutrons for stability. A few free neutrons are liberated during fission and the fission fragments undergo a series of beta decays (each of which increases Z by one and decreases N by one) until a stable nucleus is reached. During decay of the fission fragments, an average of 15 MeV of additional energy is liberated.

23. (b) Electron capture occurs more often than positron emission in heavy elements. This is because if position emission is energetically allowed, electron capture is necessarily allowed, but the reverse is not true *i.e.* when electron capture is energetically allowed, positron emission is not necessarily allowed.

24. (e) The whole mass of the atom is concentrated at nucleus and $M_{nucleus}$ < (Sum of the masses of nucleous) because, when nucleous combines, some energy is wasted.

Atomic and Nuclear Physics

SET Self Evaluation Test -26

1. In Bohr model of hydrogen atom, the force on the electron depends on the principal quantum number as

(a) $F \propto 1/n^3$ (b) $F \propto 1/n^4$

(c) $F \propto 1/n^5$ (d) Does not depend on n

2. A nucleus X emits 9α-particles and $5p$ particle. The ratio of total protons and neutrons in the final nucleus is

(a) $\frac{Z-13}{(A-Z-23)}$ (b) $\frac{(Z-18)}{(A-36)}$

(c) $\frac{(Z-13)}{(A-36)}$ (d) $\frac{(Z-13)}{(A-Z-13)}$

3. If $t_{1/2}$ is the half life of a substance then $t_{3/4}$ is the time in which substance

(a) Decays $\frac{3}{4}th$ (b) Remains $\frac{3}{4}th$

(c) Decays $\frac{1}{2}$ (d) Remains $\frac{1}{2}$

4. The energy level diagram for an hydrogen like atom is shown in the figure. The radius of its first Bohr orbit is

(a) 0.265 Å (b) 0.53 Å

(c) 0.132 Å (d) None of these

5. How much work must be done to pull apart the electron and the proton that make up the Hydrogen atom, if the atom is initially in the state with $n = 2$

(a) $13.6 \times 1.6 \times 10^{-19} J$ (b) $3.4 \times 1.6 \times 10^{-19} J$

(c) $1.51 \times 1.6 \times 10^{-19} J$ (d) 0

6. The nuclide ^{131}I is radioactive, with a half-life of 8.04 days. At noon on January 1, the activity of a certain sample is 60089. The activity at noon on January 24 will be

(a) 75 *Bq* (b) Less than 75 *Bq*

(c) More than 75 *Bq* (d) 150 *Bq*

7. U^{238} decays into Th^{234} by the emission of an $\alpha-$particle. There follows a chain of further radioactive decays, either by $\alpha-$decay or by β- decay. Eventually a stable nuclide is reached and after that, no further radioactive decay is possible. Which of the following stable nuclides is the and product of the U^{238} radioactive decay chain

(a) Pb^{206} (b) Pb^{207}

(c) Pb^{208} (d) Pb^{209}

8. If the mass of a radioactive sample is doubled, the activity of the sample and the disintegration constant of the sample are respectively

(a) Increases, remains the same

(b) Decreases, increases

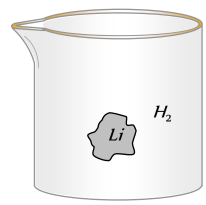
(c) Decreases, remains same

(d) Increases, decreases

9. When a sample of solid lithium is placed in a flask of hydrogen gas then following reaction happened

$^1_1H + {}_3Li^7 \rightarrow {}_2He^4 + {}_2He^4$

This statement is



(a) True

(b) False

(c) May be true at a particular pressure

(d) None of these

10. Consider an initially pure *M gm* sample of *X*, an isotope that has a half life of *T* hour, what is it's initial decay rate (N_A = Avogrado No.)

(a) $\frac{M N_A}{T}$ (b) $\frac{0.693 M N_A}{T}$

(c) $\frac{0.693 M N_A}{AT}$ (d) $\frac{2.303 M N_A}{AT}$

11. At a given instant there are 25% undecayed radioactive nuclei in a same. After 10 *sec* the number of undecayed nuclei reduces to 6.25%, the mean life of the nuclei is

(a) 14.43 *sec* (b) 7.21 *sec*

(c) 5 *sec* (d) 10 *sec*

12. Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of nucleus to that of Helium nucleus is $14^{1/3}$. The atomic number of nucleus will be

(a) 25 (b) 26

(c) 56 (d) 30

13. The ratio of ionization energy of Bohr's hydrogen atom and Bohr's hydrogen like lithium atom is

(a) 1 : 1 (b) 1 : 3

(c) 1 : 9 (d) None of these

14. What is the angular momentum of an electron in Bohr's hydrogen atom whose energy is – 0.544 eV.

(a) $\frac{h}{\pi}$ (b) $\frac{2h}{\pi}$

(c) $\frac{5h}{2\pi}$ (d) $\frac{7h}{2\pi}$

15. Consider a hypothetical annihilation of a stationary electron with a stationary positron. What is the wavelength of resulting radiation.

(a) $\frac{h}{2m_0c}$ (b) $\frac{h}{m_0c}$

(c) $\frac{2h}{m_0c}$ (d) $\frac{h}{m_0c^2}$

(h = Plank's constant, c = speed of light, m_o = rest mass)

16. Nuclear reactions are given as

(i) □ $(n, p)_{15}p^{32}$ □ $(p, \alpha)_8O^{16}$ (iii) $_7$□^{14} (p) $_6C^{14}$

missing particle or nuclide (in box □) in these reactions are respectively

(a) S, F, $_0n^1$ (b) F, S, $_0n^1$

(c) Be, F, $_0n^1$ (d) None of these

17. In a sample of hydrogen like atoms all of which are in ground state, a photon beam containing photons of various energies is passed. In absorption spectrum, five dark lines, are observed. The number of bright lines in the emission spectrum will be (assume that all transitions takes place).

(a) 5 (b) 10

(c) 15 (d) None of these

18. A hydrogen atom emits a photon corresponding to an electron transition from n = 5 to n = 1. The recoil speed of hydrogen atom is almost (mass of proton ≈ 1.6×10^{-27} kg).

(a) 10 ms (b) 2×10^{-2} ms

(c) 4 ms (d) 8×10^{-2} ms

19. Number of nuclei of a radioactive substance at time t = 0 are 1000 and 900 at time t = 2 s. Then number of nuclei at time t = 4 s will be

(a) 800 (b) 810

(c) 790 (d) 700

20. The ratio between total acceleration of the electron in singly ionized helium atom and hydrogen atom (both in ground state) is

(a) 1 (b) 8

(c) 4 (d) 16

21. If the series limit of Lymen series for Hydrogen atom is equal to the series limit of Balmer series for a hydrogen like atom, then atomic number o this hydrogen like atom will be

(a) 1 (b) 2

(c) 3 (d) 4

22. Which sample contains greater number of nuclei :

a 5.00- μCi sample of ^{240}Pu (half-life 6560y) or a 4.45-μCi sample of ^{243}Am (half-life 7370 y)

(a) ^{240}Pu (b) ^{243}Am

(c) Equal in both (d) None of these

23. The fission of ^{235}U can be triggered by the absorption of a slow neutrons by a nucleus. Similarly a slow proton can also be used. This statement is

(a) Correct (b) Wrong

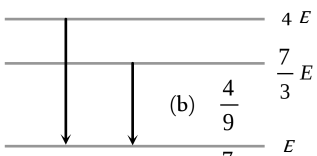
(c) Information is insufficient (d) None of these

24. The radioactivity of a given sample of whisky due to tritium (half life 12.3 years) was found to be only 3% of that measured in a recently purchased bottle marked "7 years old". The sample must have been prepared about

(a) 220 years back (b) 300 years back

(c) 400 years back (d) 70 years back

25. The following diagram indicates the energy levels of a certain atom when the system moves from $4E$ level to E. A photon of wavelength λ_1 is emitted. The wavelength of photon produced during it's transition from $\frac{7}{3}E$ level to E is λ_2. The ratio $\frac{\lambda_1}{\lambda_2}$ will be



(a) $\frac{9}{4}$ (b) $\frac{4}{9}$

(c) $\frac{3}{2}$ (d) $\frac{7}{3}$

Answers and Solutions

(SET -26)

1. (b) $F \propto \frac{v^2}{r}$ also $v \propto \frac{1}{n}$ and $r \propto n^2 \Rightarrow F \propto \frac{1}{n^4}$

2. (a) $_ZX^A \xrightarrow{9\alpha,} {}_{Z-18}X^{A-36} \xrightarrow{5\beta} {}_{Z-13}X^{A-36}$

Number of protons = (Z = 13)

Number of neutrons = (A – 36) – (Z – 13) = (A – Z – 23)

$\therefore \frac{P}{N} = \frac{(Z-13)}{(A-Z-23)}$

3. (a) You must remember that $t_{1/2}$ is time in which substance decays half. Hence in $t_{3/4}$ time substance decays $\frac{3}{4}th$.

4. (a) We know that $E_n = -13.6\frac{Z^2}{n^2}eV$ and $r_n = 0.53\frac{n^2}{Z}(\mathring{A})$

Here for $n = 1$, $E_1 = -54.4\ eV$

Therefore $-54.4 = -13.6\frac{Z^2}{1^1} \Rightarrow Z = 2$

Hence radius of first Bohr orbit $r = \frac{0.53(1)^2}{2} = 0.265\ \mathring{A}$

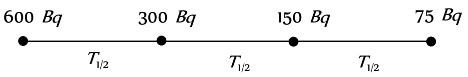
5. (b) The electrostatic *P.E.* is zero when the electron and proton are far apart from each other. Work done in pulling electron and proton far away from each other

$$W = E_f - E_i = 0 - E_i = -\left(-\frac{13.6}{n^2}eV\right)$$

$$\Rightarrow W = \frac{13.6}{(2)^2}\times 1.6\times 10^{-19}\ J = 3.4\times 1.6\times 10^{-19}\ J.$$

6. (c) Number of days from January 1st to January 24th = 23 days.

Number of half lives $n = \frac{23}{8.04} = 2.86(<3)$



In three half lives activity becomes 75 *Bq*, but the given number of half lives are lesser than 3 so activity becomes greater than 75 *Bq*.

7. (a) (4*n*+2) series starts from U^{238} and it's stable end product is Pb^{206}.

8. (a) Activity depends upon mass, but λ doesn't change.

9. (b) The given reaction is a nuclear reaction, which can take place only if a proton (a hydrogen nucleus) comes into contact with a lithium nucleus. If the hydrogen is in the atomic from, the interaction between it's electron cloud and the electron cloud of a lithium atom keeps the two nuclei from getting close to each other. Even if isolated protons are used, they must be fired at the *Li* atom with enough kinetic energy to over come the electric repulsion between the proton and *Li* atom.

10. (c) $N = N_0e^{-\lambda t} \Rightarrow \left|\frac{dN}{dt}\right| = N_0\lambda e^{-\lambda t}$

Initially at $t = 0$, $\left|\frac{dN}{dt}\right|_{t=0} = N_0\lambda$

where N_0 = Initial number of undecayed atoms

$$= \frac{\text{Mass of the sample}}{\text{Mass of a single atom of X}} = \frac{M}{A/N_A} = \frac{MN_A}{A}$$

$$\therefore \left|\frac{dN}{dt}\right|_{t=0} = \frac{MN_A\lambda}{A} = \frac{0.693\,MN_A}{AT}$$

11. (b) In 10 *sec*, number of nuclei has been reduced to one fourth (25% to 6.25%).

Therefore it's half life is $T_{1/2} = 5\ sec.$

$\therefore$ Mean life $T = \frac{T_{1/2}}{0.693} = \frac{5}{0.693} = 7.21\ sec.$

12. (b) By using $R = R_0\,A^{1/3} \Rightarrow \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{R}{R_{He}} = \left(\frac{A}{4}\right)^{1/3} \Rightarrow (14)^{1/3} = \left(\frac{A}{4}\right)^{1/3}$$

$\Rightarrow A = 56$ so $Z = 56 - 30 = 26$.

13. (c) Energy of an electron in ground state of an atom (Bohr's hydrogen like atom) is given as

$E = -13.6\,Z^2 eV$ (Z = atomic number of the atom)

$\Rightarrow E_{ionization} = 13.6\ Z$

$$\Rightarrow \frac{(E_{ion})_H}{(E_{ion})_{Li}} = \left(\frac{Z_H}{Z_{Li}}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$$

14. (c) By using $E = -\frac{13.6}{n^2}eV$ (for H_2 atom)

$$\Rightarrow -0.544 = -\frac{13.6}{n^2} \Rightarrow n = 25 \Rightarrow n = 5$$

$\therefore$ Angular momentum $= n\frac{h}{2\pi} = \frac{5h}{2\pi}$.

15. (b) From conservation of momentum, two identical photons must travel in opposite directions with equal magnitude of momentum and energy $\frac{hc}{\lambda}$

from conservation of energy $\frac{hc}{\lambda} + \frac{hc}{\lambda} = m_0c^2 + m_0c^2$

$$\Rightarrow \lambda = \frac{h}{m_0c}.$$

16. (a) (i) ${}_{16}S^{32} + {}_0n^1 \rightarrow {}_{15}p^{32} + {}_1H^1$

(ii) ${}_9F^{19} + {}_1H^1 \rightarrow {}_2He^4 + {}_8O^{16}$

(iii) ${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$

17. (c) Number of lines in absorption spectrum = (*n*–1)

$\Rightarrow 5 = n - 1 \Rightarrow n = 6$

$\therefore$ Number of bright lines in the emission spectrum

$$= \frac{n(n-1)}{2} = \frac{6(6-1)}{2} = 15.$$

18. (c) The Hydrogen atom before the transition was at rest. Therefore from conservation of momentum.

$$p_{H-\text{atom}} = p_{\text{photon}} = \frac{E_{\text{radiated}}}{c} = \frac{13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)eV}{c}$$

$$1.6\times 10^{-27}\times v = \frac{13.6\left(\frac{1}{1^2} - \frac{1}{5^2}\right)\times 1.6\times 10^{-19}}{3\times 10^8}$$

$\Rightarrow v = 4.352\ m/s \approx 4\ m/sec.$

19. (b) In 2 *sec* only 90% nuclei are left behind. Thus in next two second 90% of 900 or 810 nuclei will be left.

20. (b) Acceleration $a \propto \frac{v^2}{r}$

where $v \propto \frac{Z}{n}$ and $r \propto \frac{n^2}{Z} \Rightarrow a \propto \frac{Z^3}{n^4}$

Since both are in ground state *i.e.*, $n = 1$

so $a \propto Z \Rightarrow \frac{a_{He^+}}{a_H} = \left(\frac{Z_{He^+}}{Z_H}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$.

21. (b) By using $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For Hydrogen atom $\frac{1}{(\lambda_{\min})_H} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] = R$

$\Rightarrow (\lambda_{\min})_H = \frac{1}{R}$ .....(i)

For hydrogen like atom $\left(\frac{1}{\lambda_{\min}}\right)_{\text{atom}} = RZ^2\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$

$\Rightarrow (\lambda_{\min})_{\text{atom}} = \frac{4}{RZ^2}$ ....(ii)

From equation (i) and (ii) $\frac{1}{R} = \frac{4}{RZ^2} \Rightarrow Z = 2$.

22. (c) The activity $\left(-\frac{dN}{dt}\right) = \lambda N \Rightarrow N = \left(-\frac{dN}{dt}\right)\left(\frac{T_{1/2}}{\log_e 2}\right)$

Taking the ratio of this expression for ^{240}Pu to this same expression for ^{243}Am,

$$\frac{N_{Pu}}{N_{Am}} = \frac{\left(-\frac{dN_{Pu}}{dt}\right)(T_{1/2})_{Pu}}{\left(-\frac{dN_{Am}}{dt}\right)(T_{1/2})_{Am}} = \frac{(5\mu ci)\times(6560y)}{(4.45\mu ci)\times(7370y)} = 1$$

i.e. the two samples contains equal number of nuclei.

23. (b) Because the neutron has no electric charge, it experience no electric repulsion from a U^{235} nucleus. Hence a slow moving neutron can approach and enter a U^{235} nucleus, thereby providing the excitation needed to trigger fission. By contrast a slow moving proton feels a strong repulsion from a U^{235} nucleus. It never get's close to the nucleus, so it cannot trigger fission.

24. (d) After one half life period, the activity of Tritium becomes 50%.

After 2 half life period 25%

After 3 half life period 12.5%

After 4 half life period 6.25%

After 5 half life period 3.12% ≈ 3%

It is 5 × 12.5 years + 7 years *i.e.* approximately 70 years only .

25. (b) Transition from $4E$ to E

$(4E - E) = \frac{hc}{\lambda_1} \Rightarrow \lambda_1 = \frac{hc}{3E}$ ...... (i)

Transition from $\frac{7}{3}E$ to E

$\left(\frac{7}{3}E - E\right) = \frac{hc}{\lambda_2} \Rightarrow \lambda_2 = \frac{3hc}{4E}$ ...... (i)

From equation (i) and (ii) $\frac{\lambda_1}{\lambda_2} = \frac{4}{9}$

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