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QUESTION ONE

(1)

Q1 a(i). Every body continues in its state of rest or uniform motion in a straight line unless acted on by an external force.

- The rate of change of momentum is directly proportional to the applied force and acts in the direction of the force.

- To every action there is an equal and opposite reaction.

(ii) Change in momentum = $mu - (-mu) = 2mu$

Time between Collisions $= \frac{2L}{u}$

force $= \frac{\text{change in momentum}}{\text{time}} = \frac{2mu}{\frac{2L}{u}} = \frac{mu^2}{L}$ 04

(b)(i). Linear momentum is the product of mass and its velocity.

- The law of Conservation of linear momentum:

If the resultant force on a system of interacting bodies is zero, total linear momentum is conserved. 02

(ii) Initial total momentum $= m_1u + m_2(0) = m_1u$

Final total momentum $= (m_1+m_2)V$.

By conservation of linear momentum,

$m_1u = (m_1+m_2)V$, $\Rightarrow V = \frac{m_1u}{(m_1+m_2)}$ 04

(c) By conservation of linear momentum,

$\frac{10}{1000} \times 300 + \frac{290}{1000} \times 0 = \frac{(10+290)V}{1000}$, $\Rightarrow V = 10ms^{-1}$

from $V^2 = u^2 + 2as$, $\Rightarrow 0 = 10^2 + 2a \times 15$, $\therefore a = -3.33ms^{-2}$.

Retarding force = frictional force $= ma = \frac{300}{1000} \times \frac{10}{3} = 1N$.

But force $F = \mu R = \mu mg$, $\Rightarrow \mu = \frac{F}{mg} = \frac{1}{\frac{300}{1000} \times g} = 0.34$ 07

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OR: from work-energy theorem, $\frac{1}{2} \times 0.3 \times 10^2 = F \times 15$, $\Rightarrow F = 1N$.
(note $F = \mu R = \mu mg$), $\Rightarrow \frac{1}{2}mv^2 = \mu mgs$).

OR from retarding force = frictional force

$\Rightarrow ma = \mu R = \mu mg$, $\Rightarrow \mu = a/g = \frac{3.33}{9.81} = 0.34$.

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Question Two. (2)

(a) - Planets describe ellipses about the sun as one focus.
- The imaginary line joining the sun and a planet sweeps out equal areas in equal time intervals.
- The squares of the periodic time of revolution of the planets about the sun are proportional to the cubes of their mean distances from the sun. 03

(b) $F = \frac{GMm}{r^2}$ $\Rightarrow [G] = \frac{[F][r^2]}{[M][m]} = \frac{MLT^{-2}L^2}{M^2} = M^{-1}L^3T^{-2}$ 03

(c)(i) $m(r_e+h)\omega^2 = \frac{GM_em}{(r_e+h)^2}$, but $\omega = \frac{2\pi}{T}$

$\Rightarrow \frac{4\pi^2}{T^2} = \frac{GM_e}{(r_e+h)^3}$, also $GM_e = gr_e^2$

$\Rightarrow \frac{4\pi^2}{T^2} = \frac{gr_e^2}{(r_e+h)^3}$, $\Rightarrow g = \frac{4\pi^2(r_e+h)^3}{T^2 r_e^2}$ 06

(ii) Parking orbit - path of a satellite that it appears to be stationary to an observer on the earth's surface. The period of revolution of the satellite is equal to the period of rotation of the earth ($T = 24$ hours). 02

(d)(i) $V = \sqrt{\frac{gr_e^2}{R}} = \sqrt{\frac{9.81 \times (6.4\times10^6)^2}{(6.4\times10^6 + 6\times10^5)}} = 7.5764\times10^3 ms^{-1}$ 03

OR $V = \sqrt{\frac{GM}{R}}$ $= 7.542\times10^3 ms^{-1}$

(ii) $T = \frac{2\pi(r_e+h)}{V} = \frac{2\pi(6.4\times10^6 + 6\times10^5)}{7.5764\times10^3} = 5805.2s$ 03

OR $T = \frac{2\pi}{r_e}\sqrt{\frac{(r_e+h)^3}{g}} = \frac{2\pi}{6.4\times10^6}\sqrt{\frac{(6.4\times10^6+6\times10^5)^3}{9.81}} = 5802.2s$

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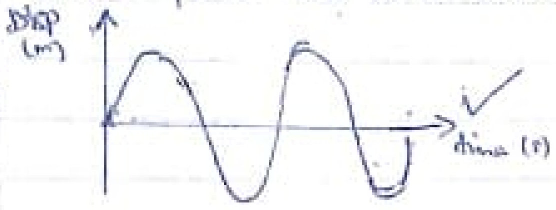
QUESTION THREE (3)

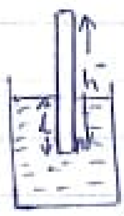
13(a)(i) SHM is a periodic motion of a body whose acceleration is directly proportional to the displacement of the body from a fixed point and it is directed towards the fixed point. ✓ 01

(ii)



01

b) (i)



- Let A be the cross-sectional area of the rod and density of the liquid be ρ.
- Weight of liquid displaced = upthrust ✓
- Volume of liquid displaced = Al ✓, ∴ upthrust $U = Al\rho g$ ✓
- If the rod is slightly displaced through a distance, x, the new upthrust, $U' = A(l+x)\rho g$ ✓ 06
- Resultant force $F = Al\rho g - A(l+x)\rho g = -A\rho g x$ ✓
- But $F = ma$, ⇒ $ma = -A\rho g x$ ✓, ∴ $a = -\frac{A\rho g x}{m}$
- Since $\frac{A\rho}{m}$ is constant, ⇒ $a \propto x$, hence the rod performs SHM.

ii) $m = Ah\sigma$ ✓, σ is the density of the rod.

$\therefore \omega^2 = \frac{A\rho g}{m}$, ⇒ $\omega^2 = \frac{A\rho g}{Ah\sigma} = \frac{\rho g}{\sigma h}$ ✓ (for ω^2)

$\omega = 2\pi f$, ⇒ $f = \sqrt{\frac{\rho g}{\sigma h} \times \frac{1}{4\pi^2}} = \sqrt{\frac{1000 \times 9.81}{920 \times 0.16 \times 4\pi^2}}$ ✓ $= 1.299\ Hz$ ✓ 04

iii) $V = \omega\sqrt{r^2 - x^2}$ ✓ $= 2\pi f\sqrt{r^2 - x^2} = 2\pi \times 1.299\sqrt{0.007^2 - 0.005^2}$ ✓

∴ $V = 0.03997\ ms^{-1}$ or $3.998 \times 10^{-2}\ ms^{-1}$ ✓ 03

c) It is energy possessed by a body by the virtue of its position or state. ✓ 01

b) (i) Chemical energy → K.E → K.E + P.E → P.E → K.E + P.E → K.E → sound + heat. 03

(ii) Electrical → K.E (M.E) → sound. 01

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(4)

Q4 a(i) Elastic deformation is when a material is deformed and it regains its original shape and size when the deforming force is removed ✓

- Plastic deformation is when a force is applied and the material doesnot regain its original shape and size when the force is removed. ✓ 02

(ii) Work hardening is the strengthening of a material by repeatedly deforming it. ✓ Atomic planes slide over each other ✓ and this increases plane dislocations which prevents ✓ further sliding of atomic planes. 02

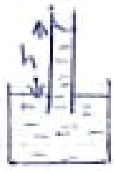
(b) (i)

(03)

(ii) Rubber doesnot obey Hooke's law ✓ except for very small loads. This is because rubber contains coiled molecules which uncoil when stretched. ✓ 03

· When fully uncoiled rubber becomes stiff. ✓

(c)

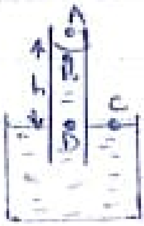


· A liquid in the tube in contact with glass is acted on by the surface tension force given by $F_\gamma = 2\pi r\gamma$. ✓

· The weight of the liquid supported by column h is $W = h\rho g A$ 04

$\Rightarrow W = \pi r^2 h\rho g$ ✓ $\because \pi r^2 h\rho g = 2\pi r\gamma$ ✓ $\therefore h = \frac{2\gamma}{\rho g r}$. ✓

OR



· $P_A - P_B = \frac{2\gamma}{r}$ ✓ But $P_A = P_C$ = Atmospheric and $P_C = P_D$ (same level).

· $P_D = h\rho g + P_B$ ✓, $\Rightarrow P_D - P_B = h\rho g$

$\Rightarrow$ or $P_A - P_B = h\rho g$, $\Rightarrow h\rho g = \frac{2\gamma}{r}$ ✓ $\therefore h = \frac{2\gamma}{\rho g r}$. ✓

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(5)

(d) Surface area of a drop $= 4\pi r^2$

Area of a big drop $= 4\pi(2.0\times10^{-3})^2 = 5.03\times10^{-5}m^2$ ✓

Area of a small drop $= 4\pi(0.5\times10^{-3})^2 = 3.14\times10^{-6}m^2$.

Area of two drops $= 2\times3.14\times10^{-6} = 6.28\times10^{-6}m^2$ ✓

change in surface area $= 5.03\times10^{-5} - 6.28\times10^{-6}$

$= 4.402\times10^{-5}m^2$. ✓

change in surface energy = change in area × γ ✓ 05

$= 4.402\times10^{-5}\times0.52$

$= 2.289\times10^{-5}$ J. ✓

(e) Increase in temperature lowers surface tension ✓ (01)

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(6)

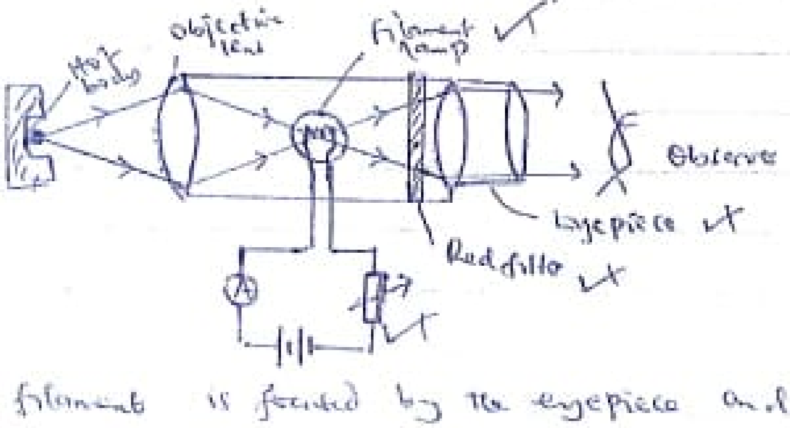
Q5 (a) (i) The property used is pressure of a fixed mass of a gas at constant volume. ✓ 01

(ii) - Property should vary linearly with change in temperature. ✓
- Property should vary continuously with temperature. ✓ Any 02 — 02
- Property should be sensitive to temperature change
- Property should be accurately measurable with simple apparatus.
- Property should vary over a wide range.

(b) (i) Place the bulb in pure melting ice ✓ and the length l_0 ✓ of the mercury column is recorded. Place the bulb in steam from water boiling ✓ at standard pressure and l_{100} ✓ is noted. Place the bulb in contact with the body at unknown temperature θ ✓ and note l_θ ✓; $\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100°C$ ✓ 04

(ii) - It is not very sensitive ✓, it is delicate (can easily break) ✓, It cannot measure rapidly changing temperature ✓. Any two 02
It is not accurate ✓, It measures a small range of temperature, It cannot measure the temperature at a point.

(c)



Any four 0 1/2

The filament is focused by the eyepiece and the objective focuses the object so that the image of the object lies in the same plane as the filament. ✓ 06
Light from the hot body and the filament is passed through the red filter ✓ and viewed by the eyepiece. Current is adjusted ✓ until the filament and the Object are equally bright. ✓
The temp. of the hot body is then read from Ammeter calibrated ✓ in Kelvins (or °C).

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(7)

(d) $PV = nRT$ ✓

$n_1 = \frac{P_1 V}{RT_1} = \frac{21.4 \times 10^5 \times 50 \times 10^{-3}}{8.31 \times 303} = 42.5$ moles ✓

$n_2 = \frac{7.8 \times 10^5 \times 50 \times 10^{-3}}{8.31 \times 283} = 16.6$ moles ✓

$\Delta m = (n_1 - n_2) M_R$ ✓ $= (42.5 - 16.6) \times 32 = 828.8g$ ✓

OR $\Delta m = (42.5 - 16.6) M_R = 25.9 M_R$ g.

05

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Q6(a)(i) The boiling point of a liquid is the temperature at which its saturated vapour pressure equals the external pressure. ✓ (01)

(ii) When a liquid boils, vapour bubbles are formed at the bottom and rise to the surface and burst. ✓ When extra pressure is applied the pressure inside the bubble becomes less than that exerted at the liquid surface. ✓ This extra pressure prevents bubbles from rising to the surface. ✓ Increasing the temperature increases the pressure inside the bubbles to enable them to rise to the surface ✓, hence boiling point is raised. (04)

ALT.

A liquid boils when its SVP = external pressure ✓ and SVP increases with increasing temperature. ✓ When external pressure is raised, a liquid will boil at a higher SVP ✓ which occurs at higher temperatures. ✓ (04)

b(i) • By reducing the volume ✓ occupied by a gas, the molecules take less time to move between the walls of the container ✓ as the distance is reduced. The number of collisions per unit time per unit area increases, hence pressure increases at constant temperature. (03)

• By heating the gas, ✓ the molecules gained more K.E. ✓ The molecules will bombard the walls many times per unit time per unit area. The total rate of change ✓ of momentum will increase. Hence pressure will increase. (03)

(c)(i)

(02)

(ii) In region AB there is unsaturated vapour which fairly obeys Boyle's law. ✓
In region BC vapour is saturated ✓ the pressure therefore remains constant ✓ as volume reduces.

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In region CD all the vapour turns into liquid. Therefore there is very small change in volume for large pressure increase.

ALTERNATIVE

For the curve above critical temperature, ①, the real gas above critical temperature T_c, as the gas is being compressed, the pressure increases in accordance with Boyle's law ($PV = k$). However high the pressure, there will be no change of state.

At critical temperature T_c, curve ②, in the region GH there is unsaturated vapour which fairly obeys Boyle's law. F is the critical volume and pressure. Along EF the gas fairly obeys Boyle's law.

d) 1st STROKE:

$P_1V_1 = P_2V_2$, but $V_2 = 225 + 25 = 250\,cm^3$

$\therefore 75 \times 225 = P_2 \times 250$; $\therefore P_2 = 67.5\,cmHg$

or

2ND STROKE

$P_2V_2 = P_3V_3$

$\therefore 67.5 \times 225 = P_3 \times 250$, $\Rightarrow P_3 = 60.8\,cmHg$

ALTERNATIVELY

$$P_1 = \left(\frac{V_2}{V_1 + V_2}\right)^n P = \left(\frac{225}{225+25}\right)^2 \times 75 = 60.75\,cmHg,$$ n = no. of strokes.

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7.(a)(i) Thermal conductivity is the rate of heat flow per unit cross-sectional area per unit temperature gradient ✓ 01

(ii) When a fluid is heated from underneath, it expands ✓ and becomes less dense ✓ than the fluid above. The warm less dense fluid rises to the top ✓ and the cooler more dense fluid from above moves downwards ✓ to take its place. This process continues and a circulating current ✓ of fluid is established until the whole fluid is heated up ✓ 03

(b) (i) It states that the rate of loss of heat is proportional to excess temperature between the body and surroundings under forced convections or steady draught. ✓ 01

(ii) Hot water in a calorimeter is placed near an open window ✓ Temperature of water is recorded at a suitable time intervals. ✓ A graph of temperature against time is plotted. ✓ Slope of the graph is obtained at tempt. θ_1. ✓ More values of slope are got at different temperatures θ_2, θ_3, --- θ_4. ✓ For each temperature, excess temperature $(\theta - \theta_R)$ ✓ is calculated, where θ_R is room temperature. ✓ A graph of the slopes against excess temperature is plotted. ✓ A straight line graph through the origin verifies Newton's law. ✓ 05

(c)(i) No heat is lost to the surroundings as it flows from the inner ~~...~~ and outer surfaces. ✓ The temperature gradient across the composite wall is constant. ✓ 02

(ii) from $Q/t = \frac{KA(\theta_2 - \theta_1)}{L}$ ✓

$\Rightarrow \frac{0.4A(29-\theta)}{12\times10^{-2}} = \frac{0.8A(\theta-21)}{12\times10^{-2}}$ ✓, $\therefore \theta = 23.7^{\circ}C$ ✓ 04

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(11)

(d) The short wavelength radiation from the sun penetrates the atmosphere and is absorbed by the earth's surface. This absorbed energy warms up the earth which then re-radiates long wavelength radiations (eg infrared radiation).
Some of this radiated energy is absorbed (or trapped) by the atmosphere. This leads to increased temperatures of the earth with time. OL

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Q8(a)(i) Radioactivity is the spontaneous disintegration of a radioactive nuclide (or atom) accompanied by the emission of radiations. ✓ 01

(ii) Isotopes are atoms of the same element that have the same atomic number but different mass number. ✓ 01

(b)(i) Mass defect is the difference in mass of the constituent nucleons and the nucleus of an atom ✓ 01

(ii) A heavy nucleus is unstable if there are too many ✓ neutrons or too many protons 01

(iii) The large number of protons increases the electrostatic repulsion between themselves ✓ This force may not be counterbalanced by the nuclear force. Thus nucleus becomes unstable. ✓ 02

(c)(i) $E = mc^2$ ✓ $= 0.0053 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2 = 7.92 \times 10^{-13}$ J ✓ 03

(or $E = 4.77 \times 10^{-14}$ uJ).

OR $E = m \times 931$. ✓

$= 0.0053 \times 931 \times 1.6 \times 10^{-13}$ ✓ $= 7.90 \times 10^{-13}$ J ✓

(or 7.9×10^{-13} J, $e = 1.6 \times 10^{-19}$)

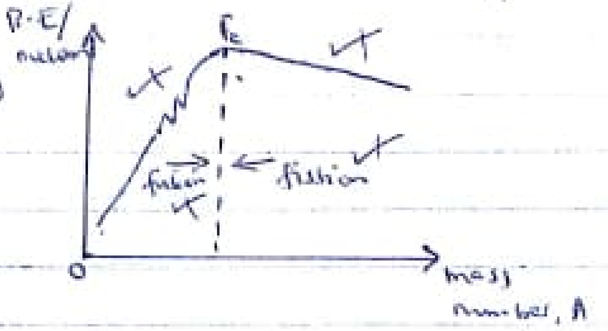
(ii) 4.60 MeV $= 4.60 \times 10^6 \times 1.6 \times 10^{-19}$ ✓ $= 7.36 \times 10^{-13}$ J ✓

Energy of photon of γ-rays $= 7.92 \times 10^{-13} - 7.36 \times 10^{-13}$

$= 0.56 \times 10^{-13}$ J. ✓ 04

From $E = hf$, $f = \frac{E}{h}$ ✓ $= \frac{0.56 \times 10^{-13}}{6.6 \times 10^{-34}}$ ✓ $= 8.5 \times 10^{19}$ Hz ✓

(d)(i)



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(13)

d) (ii) For nuclei whose A<56, two small nuclei combined to form a heavier nucleus of smaller mass but greater binding energy per nucleon; mass difference accounts for energy released.
For nuclei whose A>56, a heavy nucleus splits to form two lighter nuclei of greater binding energy per nucleon, mass difference accounts for energy released. 03

e) (i) Uses of radio isotopes
- Treatment of cancer
- Production of energy in nuclear reactors 01
- Detection of leaks in pipes
- Carbon dating.

(ii) Health hazards:
- Cause genetic mutation 01
- Destroy eye sight
- Cause cancer
- Cause deep seated-wounds in humans.

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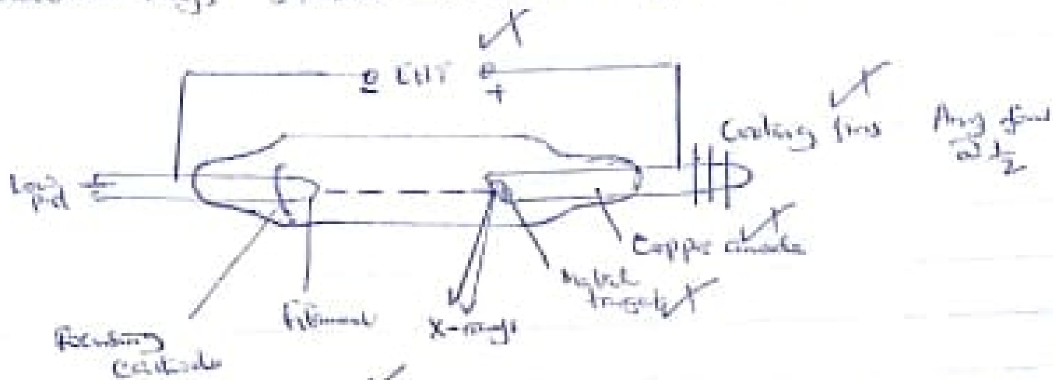
9(a) X-rays are electromagnetic radiations of very high frequency (short wavelength) produced when cathode rays strike metal target. ✓ 01

b) (i)



The filament is heated by current from the low p.d. It emits electrons by thermionic emission. The electrons are accelerated by the EHT between the cathode and anode. On striking the metal target, electrons lose their energy as heat and x-rays. The heat is conducted by the copper rod and dissipated to the surroundings by the cooling fins. 05

(ii) Electrical energy (by EHT) → K.E → Heat + X-rays. 02

(c) (i) $eV = \frac{1}{2}m_e v^2$, $\Rightarrow V = \frac{1}{2}\frac{m_e v^2}{e}$

$\therefore V = \frac{1}{2} \times \frac{9.11\times10^{-31} \times (3.75\times10^{7})^2}{1.6\times10^{-19}} = 4003\,V$ 02

or $(4.003\times10^{3}\,V)$.

(ii) $I = ne$, $\Rightarrow 10\times10^{-3} = n\times1.6\times10^{-19}$, $\therefore n = 6.25\times10^{16}$ electrons 02

(iii) Acceleration of electrons $= \frac{eE}{m} = \frac{Ve}{dm}$

$\therefore a = \frac{4003}{5\times10^{-2}} \times \frac{1.6\times10^{-19}}{9.11\times10^{-31}} = 1.41\times10^{16}\,ms^{-2}$.

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(15)

Using $s = ut + \frac{1}{2}at^2$

$\therefore 5 \times 10^{-2} = \frac{1}{2} \times 1.41 \times 10^{16} t^2$

$\therefore t = 2.66 \times 10^{-9} s$

$\therefore$ Number of electrons striking target in time $2.66 \times 10^{-9} s$ is $2.66 \times 10^{-9} \times 6.25 \times 10^{16} = 1.66 \times 10^{8}$

These electrons occupy 5.0cm.

$\therefore$ Electrons in a space of 1cm $= \frac{1.66 \times 10^8}{5}$

$= 3.33 \times 10^7$ electrons

(d) In location of a fractured bone. X-rays are directed to the area of the body with suspected bone fracture. The shadow of the bone is formed on a photographic film placed on the opposite side of the body. 03

OR In destroying cancer cells. X-rays are directed to the area of the body with suspected cancer cells. The cells are then destroyed or killed.

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(16)

Q10 (a) Electrons revolve in allowed orbits and when in these orbits they do not emit radiation. 1

When an electron jumps from an orbit of higher energy to one of lower energy an electromagnetic radiation of definite frequency is emitted (given by $E_2 - E_1 = hf$) 1 03

The angular momentum of an electron in orbit is an integral multiple of $\frac{h}{2\pi}$, ie $mvr = \frac{nh}{2\pi}$.

(b) When a gas is heated electrons shift to higher energy levels making the atom excited. Electron transition from higher energy level to lower energy level occurs which causes radiation of definite wavelength to be emitted. Bright lines are formed against a dark back ground. This constitutes the emission line spectra. 03 3

An atom can absorb energy from a photon displacing an electron to one of the higher energy levels. The photon will be absorbed. This reduces the intensity of the radiation that contained the photon. A dark line is observed on a bright back ground whose wavelength is equal to that of the absorbed photon. This is the absorption line spectrum. 03 4

(c) - Most alpha particles passed through undeflected because the atom has empty space in it.

- The few alpha particles were scattered through small angles because of the presence of a positive charge that repelled the alpha particles. 06

- Very few alpha particles were scattered through large angles because the positive charge is located in a very small portion of the atom making the chance of a head-on collision very small.

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d) (i) K.E = P.E

$\Rightarrow \frac{1}{2}mv^2 = \frac{Q_1Q_2}{4\pi\varepsilon_0 R}$ ✓

$\therefore 3.5\times10^6\times1.6\times10^{-19} = \frac{2e\times79e}{4\pi\varepsilon_0 R}$ ✓ for conversion

$\therefore R = \frac{2\times79\times1.6\times10^{-19}\times9.0\times10^9}{3.5\times10^6}$ ✓ subst

$\therefore R = 6.50\times10^{-14}$ m. ✓

04

(ii) The least distance of approach is an estimate of of the radius of the gold atom ✓

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-END-