PHYSICS

BOOKS - DHANPAT RAI & CO PHYSICS (HINGLISH)

ATOMS, NUCLEI AND MOLECULES

Example

1. In a head on collision between an alpha particle and gold nucleus, the minimum distance of approach is $4 \times 10^{-14} m$. Calculate the energy of of α-particle. Take Z=79 for gold.

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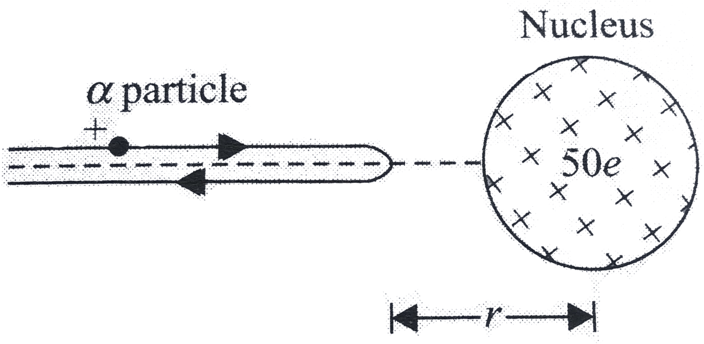
2. An alpha particle with kinetic energy $10 MeV$ is heading toward a stationary tin nuclcus of atomic number 50. Calculate the distance of closest approach (Fig . 3.23).



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3. A beam of α-particle of velocity $2.1 \times 10^7 m/s$ is scattered by a gold foil (Z=79). Find the distance of closest approach of α- particle to the gold nucleus. for α-particle, $2e/m = 4.8 \times 10^7 kg^{-1}$.

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4. An α-particle after passing through a potential difference of $2 \times 10^6 V$ falls on a silver foil. The atomic number of silver is 47. Calculaye (i) the kinetic energy of the α-particle at the time of falling on the foil (ii) the kinetic energy of the α-particle at a distance of 5×10^{-14} m from the nucleus and (iii) the shortest distance from the nucleus of silver to which the α-particle reaches.

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5. The number of alpha particles scattered at 60° is 100 per minute in an alpha particle scattering experiment. Calculate the number of alpha particles scattered per minute at 90°.

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6. Calculate the impact parameter of a 5 MeV particle scattered by 90°, when it approach a gold nucleus (Z=79).

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7. A projectile of mass m, charge Z', initial speed v and impact parameter b is scattered by a heavy nucleus of charge Z. Use angular momentum and energy conservation to obtain a formula connecting the minimum distance (s) of the projectile form the nucleus to these parameters .show that for b=0, s reduces to the closest distance of approach r_0.

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8. for scattering by an inverse square law field (such as that produced by a charged nucleus in Rutherford's model), the relation between impact parameter b and the scattering angle θ is given by

$$b = \frac{Ze^2 \cot \theta / 2}{4\pi \in_0 \left(\frac{1}{2}mv^2\right)}$$

(a) What is the scattering angle for b=0?

(b) for given impact parameter, b, does the angle of deflection increase or decrease with increase in energy?

(c) What is the impact parameter at which the scattering angle is 90° for Z=79 and initial energy=10MeV?

(d) Why is it that the mass of the nucleus does not enter the formula above, but its charge does?

(e) for a given energy of the projectile, does the scattering angle increase or decrease with decrease in impact parameter?

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9. Evalute Rydberg constant by putting the value of the fundamental constants in its expression

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10. Calculate the value of 'fine structure constant'

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11. What is the angular momentum of an electon in the third orbit of an atom ?

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12. Write down the expression for the radii of orbits of hydrogen atom. Calculate the radius of the smallest orbit

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13. Calculate the velocity of electron in Bohr's first orbit of hydrogen atom. How many times does the electron go in Bohr's first orbit in one second ?

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14. Determine the speed of the electron in $n = 3$ orbit of He^{+} ion.

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15. Show that the speed of an electron in the innermost orbit of H-atom is 1/137 times the speed of light in vaccum.

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16. Calculate the period of revolution of an electron revolving in the first orbit of hydrogen atom. Given radius of first orbit $= 0.53 \text{Å}$ and $c = 3 \times 10^8 \text{ ms}^{-1}$

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17. The energy of an electron in the nth orbit is given by $E_n = -13.6 / n^2 eV$. Calculate the energy required to excite an electron from ground state to the second excited state.

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18. The total energy of an electron in the first excited state of hydrogen atom is -3.4 eV.

(a) What is kinetic energy of electron in this state?

(ii) What is potential energy of electron in this state?

(c) Which of the answers above would change if the choice of zero of potential energy is changed?

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19. The electron, in a given Bohr orbit has a total energy of $-1.5eV$. Calculate its (i) kinetic energy, (ii) potential energy and (iii) the wavelength of light emitted, when the electron makes a transition to the ground state. Ground state energy $= -13.6eV$

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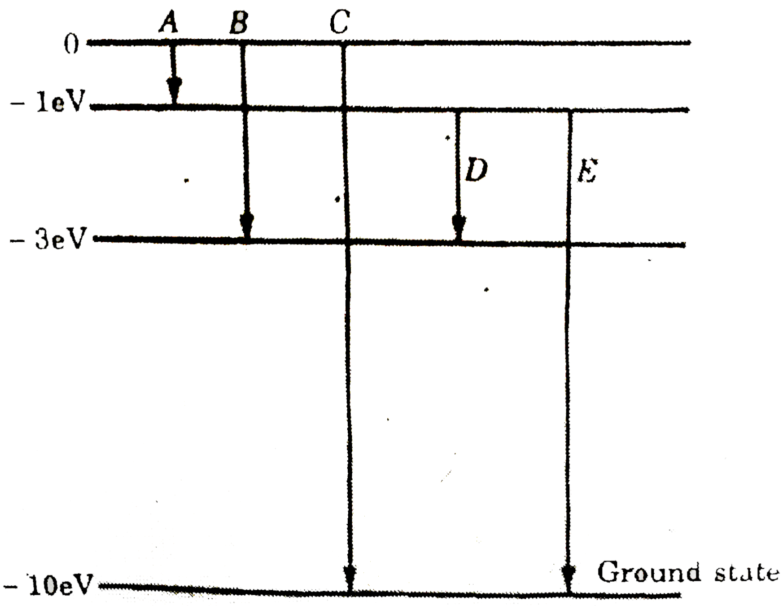
20. The energy levels of an atom of element X are shown in Fig. 20.2. Which one of the level transitions will result in the emission of photons of wavelength 620 nm ? Support your answer with mathematical calculations.



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21. Using the Rydberg formula, calculate the wavelength of the first four spectral lines in the Lyman series of the hydrogen spectrum.

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22. Calculate the shortest and the longest wavelength of Lyman series. Given Ryberg's constant, $R = 10967700 \text{ m}^{-1}$.

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23. The wavelength of H_{α}, line of the Balmer series is 6553Å. Calculate the value of Ryberg constant.

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24. The seond line of Balmer series has wavelength 4861Å The wavelength o fthe first line Balmer series is

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25. The energy of an electron in an excited hydrogen atom is $-3.4eV$. Calculate the angular momentum . Given : Rydbrg's

$R = 1.09737 \times 10^{-7} m^{-1}$. Plank's constant $h = 6.626176 \times 10^{-34} J - s$, speed of light`c = 3 xx 10^(8) m s^(-1).

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26. Which state of triply ionised Beryllium (Be^{+++}) the same orbital radius as that of the ground state hydrogen ?

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27. Which level of the doubly ionized lithium has the same energy as the ground state energy of the hydrogen atom? Compare the orbital radii of the two levels.

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28. Obtain the first Bohr radius and the ground state energy of a muonic hydrogen atom (i.e., an atom in which a negatively charged muon (μ) of mass about $207m_e$ revolves around a proton).

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29. Using Bohr's formula for energy quantization, determine (i) the longest wavelength in Lyman series of hydrogen atom spectrum. (ii) the excitation energy of the n=3 level of He^{+} atom. (iii) the ionization potential of the ground state of Li^{++} atom.

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30. Obtain an expression for the frequency of radiations emitted when a hydrogen atom de-excites from level n to level (n-1). for larger n, show that the frequency equals the classical frequency of revolution of the electron in the orbit.

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31. A free electron of energy $1.4eV$ collides with a H^+ ions. As a result of collision, a hydrogen atom in the ground state is formed and a photon is released. What is the wavelength of the emitted radiation ? In which part of the electromagnetic spectrum does this spectrum lie ? Give ionisation potential of hydrogen $= 13.6eV$

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32. Express 16 mg mass into equivalent energy in eV.

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33. How many electron- volt make one joule?

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34. Express 1 joule in eV. Taking 1a.m.u. $= 931 MeV$, calculate the mass of $._6 C^{12}$.

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35. The three stable isotopes of neon $._{10} Ne^{20}$, $._{10} Ne^{21}$ and $._{10} Ne^{22}$ have respective abundances of 90.51%, 0.27% and 9.22%. The atomic masses of the three isotopes are $19.99u$, $20.99u$ and $21.99u$ respectively. Obtain the average atomic mass of neon.

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36. The natural boron is composed of two isotopes $._5 B^{10}$ and $._5 B^{11}$ having masses $10.003u$ and $11.009u$ resp. Find the relative abundance of each isotope in the natural boron if atomic mass of natural boron is 10.81u.

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37. Compare the radii of two nuclei with mass number 1 and 27 respectively.

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38. Obtain approximately the ratio of the nuclear radii of the gold isotope $._{79}Au^{197}$ and the silver isotope $._{47}Ag^{107}$. What is the approximate ratio of their nuclear mass densities ?

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39. The nuclear mass of $._{26}F^{56}$ is 55.85u. Calculate its nuclear density.

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40. Why is nuclear density same for all nuclei?

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41. Assuming that protons and neutrons have equal masses, calculate how many times nuclear matter is denser than water. Take mass of a nucleon $= 1.67 \times 10^{-27} kg$ and $R_0 = 1.2 \times 10^{-15} m$.

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42. Calculate the binding energy if an α-particle in MeV Given : m_p (mass of proton) = 1.007825 amu, m_n (mass of neutron) = 1.008665 amu Mass of the nucleus `=4.002800 amu, 1 amu = 931 MeV.

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43. Calculate the binding energy per nucleon in the nuclei of $._{15} P^{31}$.

Given

$m(._{15} P^{31}) = 30.97376u, m(._0 n^1) = 1.00865u, m(._1 H^1) = 1.00782u.$

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44. Calculate the binding energy per nucleon (B.E./nucleon) in the nuclei of $._{26}Fe^{56}$. Given :

$mp\left[._{26}Fe^{56}\right] = 55.934939 \text{ amu}, m\left[._{0}n^{1}\right] = 1.00865 \text{ amu}, m\left[._{1}\text{II}^{1}\right] = 1.($

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45. Calculate binding energy per nucleon of $._{83}Bi^{209}$. Given :

$m\left(._{83}Bi^{209}\right) = 208.980388 \text{ amu}, m(\text{neutron}) = 1.008665 \text{ amu}, m(\text{proton}$

.

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46. The neutron separation energy is defined to be the energy required to remove a neutron form nucleus. Obtain the neutron separation energy of the nuclei $._{20}Ca^{41}$ and $._{13}Al^{27}$ from the following data :

$m\left(._{20}Ca^{40}\right) = 39.962591u$ and $m\left(._{20}Ca^{41}\right) = 40.962278u$

$m\left(._{13}Al^{26}\right) = 25.986895u$ and $m\left(._{13}Al^{27}\right) = 26.981541u$

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47. What are alpha prticles ? In the reaction :

$._{Z}X^{A} \rightarrow \alpha + Y$

give the atomic number of Y.

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48. An isotope $._{92}U^{238}$ decays successively to form $._{90}Th^{234}, ._{91}Pa^{234}, ._{92}Th^{234}, ._{90}Th^{230}$ and $._{88}Ra^{226}$. What are the radiations emitted in these five steps?

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49. Will neutron to proton ratio increase or decreases, when a radioactive nucleus emits (i) an alpha particle (ii) a beta particle ? Giveone example for each in support of your answer.

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50. Thorium isotope $._{90}Th^{232}$ emits some α-particle and some β-particle and gets transformed into lead isotope $._{82}Pb^{200}$. Find the number of α- and β-particles emitted.

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51. Half-life of a certain radioactive materal against α-decay is 138 days. After what lapse of time the undecayed fraction of the material will be 6.25 % ?

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52. The half-life period of a radioactive substance is 30 days. What is the time taken for 3/4 the of its original masss to disintegrate ?

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53. What $\%$ age of a given mass of a radioactive substance will be left undecayed after five half life periods?

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54. Calculate the half life period of a radioactive substance if its activity drops to $\frac{1}{16}$ th of its initial value in 30 years.

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55. The half-life of radium is 1600 years. After how many years 25 % of a radium block remains undecayed ?

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56. The half-life of radon is 3.8 days. Calculate how much radon will be left out of 25 mg after 19 days.

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57. 1 mg radium has 2.68×10^{18} atoms. Its half-life is 1620 years. How many radium atoms will disintegrate from 1 mg of pure radium in 3240 years ?

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58. A certain radioactive substance has a half-life period of 30 days. What is the disintegration constant ?

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59. The half-life of radium is 1500 years. After how many years will one gram of the pure radium

(i) reduce to one centigram ?

(ii) lose one milligram ?

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60. The half life of radon is 3.8 days . After how many days will only one twentieth of radon sample be left over ?

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61. The half -life of a radioactive substance is 1.192×10^7s against $\alpha -$ decay. Calculate the decay rate for 3.18×10^{15} atoms of the substance

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62. Calculate the number of disintegrations per second of 1 g of a radioactive sample whose half-life is $1.4 \times 10^{16} s$. The mass number of the sample is 238

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63. Determine the amount of $._{84} Po^{210}$ necessary to provide a source of α particles of 5 millicurie strength. The half life of Po is 138 days.

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64. The atomic weight of radius is 226. It is observed that 3.67×10^{10} $\alpha -$ particles are emitted per second from one gram of radium. Calculate in years the half period of radium.

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65. The half-life of $\hat{} 198Au$ is $2.7 days$. Calculate (a) the decay constant, (b) the average-life and (C) the activity of $1.00 mg$ of $\hat{} 198Au$. Take atomic weight of $\hat{} 198Au$ to be $198 g mol^{-1}$.

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66. The normal activity of living carbon -containing matter is found to be about 15 decay per minute for every gram of carbon. This activity arises form the small proportion of radioactive $._6 C^{14}$ present with the ordinary $._6 C^{12}$ isotope. When the organism is dead, its interaction with the atmosphere which maintains the above equilibrium activity, ceases and its activity begins to drop. from the known half life (=5730years) of $._6 C^{14}$, and the measured activity, the age of the specimen can be approximately estimated. This is the principle of $._6 C^{14}$ dating used in archaeology. Suppose a specimen from Mohenjo - daro gives an activity of 9 decays per minute per gram of carbon. Estimate the approximate age of the Indus Valley Civilization.

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67. There is a stream of neutrons with kinetic energy of 0.0327 eV. If half life of neutrons is 700s, what fraction of neutrons will decay before they travel a distance of 10m? Take mass of neutron $=1.675 \times 10^{-27} kg.$

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68. The nucleus $._{92}U^{238}$ is unstable angainst alpha decay with half-life of 4.5×10^9 years. Estimate the kinetic energy of the emitted α-particle.

Mass of the $._{92}U^{238}$ atom $= 238.05081u$

Mass of the $._{2}He^{4}$ atom $= 4.00260u$

Mass of the $._{90}Th^{234}$ atom $= 234.04363u$

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69. The nucleus $.^{23}Ne$ deacays by β-emission into the nucleus $.^{23}Na$. Write down the β-decay equation and determine the maximum kinetic energy of the electrons emitted. Given,$\left(m\left(._{11}^{23}Ne\right) = 22.994466amu\right.$ and $m\left(._{11}^{23}Na = 22.989770amu\right.$. Ignore the mass of antineuttino $(\bar{v})$.

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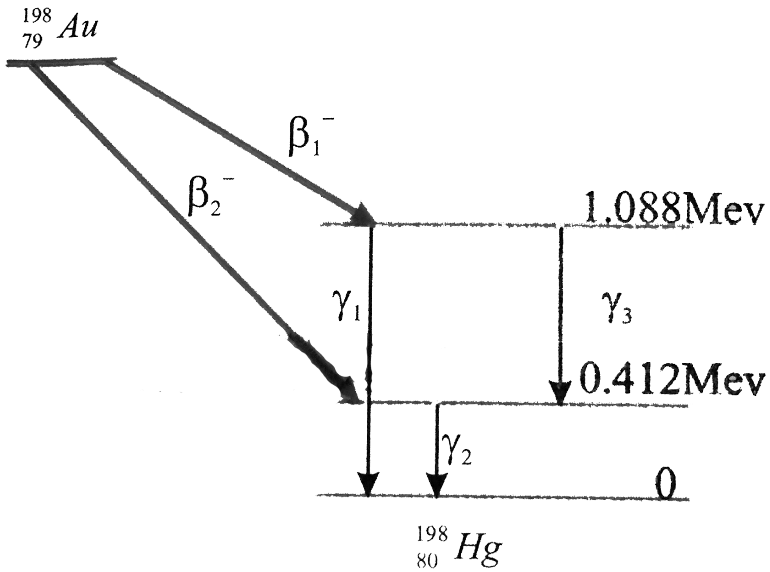
70. Obtain the maximum kinetic energy of β-particles, and the radiation frequencies of γ decays in the decay scheme shown in Fig. 14.6. You are given that $m(._{}^{198}Au) = 197.968233u$, $m(._{}^{198}Hg) = 197.966760u$



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71. A neutron is absorbed by a $._3 Li^6$ nucleus with subsequent emission of an alpha particle. Write the corresponding nuclear reaction. Calculate the energy released in this reaction.

$m(._3 Li^6) = 6.015126u$, $m(._2 He^4) = 4.0026044u$

$m(._0 n^1) = 1.0086654u$, $m(._1 He^3) = 3.016049u$

Take $1u = 931MeV$.

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72. The Q value of a nuclear reaction

A+b=C+d is defined by $Q = [m_A + m_b - m_C - m_d]c^2$ where the masses refer to the respective nuclei. Determine form the given data the Q value of the following reactions and state whether the reactions are exothermic of endothermic.

(i) $._1 H^1 + ._1 H^3 \rightarrow ._1 H^2 + ._1 H^2$

(ii) $._6 C^{12} + ._6 C^{12} \rightarrow ._{10} Ne^{20} + ._2 He^4$

Atomic masses are given to be

$m(._1 H^2) = 2.014102u, m(._1 H^3) = 3.016049u, m(._6 C^{12}) = 12.000000u,$

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73. Consider one of the fission reactions of U^{235} by thernmal neutrons :

$._{92} U^{235} + n \rightarrow ._{38} Sr^{94} + ._{54} Ce^{140} + 2n$

The fission fragments are, however, not stable. They unaergo successive $\beta -$ decays unit $._{38} Sr^{94}$ becomes $._{40} Zr^{94}$ and $._{54} Xe^{140}$ becomes $._{58} Ce^{140}$. Estimate the total energy released in the process. Is all that energy available as kinetic energy of the fission products (Zr and Ce)? You are given that

$m(U^{235}) = 255.0439amu, \quad m_n = 1.00866amu \quad m(Zr^{94}) = 93.9065am$

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74. If $200MeV$ energy is released in the fission of a single U^{235} nucleus, the number of fissions required per second to produce 1 kilowatt power shall be (Given $1eV = 1.6 \times 10^{-19} J$).

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75. Calculate the energy released by fission from $2g$ of $.^{235}{}_{92} U$ in kWh. Given that the energy released per fission is $200MeV$.

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76. It is estimated that the atomic bomb exploded at Hiroshima released a total energy of $7.6 \times 10^{13} J$. If on the average, 200MeV energy was released per fission, calculate

(i) the number of Uranium atoms fissioned,

(ii) the mass of Uranium used in the bomb.

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77. Suppose India has a target of producing by 2000 A.D., 100,000 MW of electric power , 10 percent of which is to be obtained from nuclear power plants. Suppose we are given that, on average the efficiency of utilisation (i.e., conversion to electric energy) of thermal energy porduced in a reactor is 25%. How much amount of fissionable uranium would our country need per year at the turn of this century ? Take the heat energy per fission of U^{235} to be about 200 MeV. Avogadro's Number $N = 6.023 \times 10^{23} mol^{-1}$.

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78. What is the power output of a $._{92}U^{235}$ reactor if it is takes 30 days to use up $2kg$ of fuel, and if each fission gives $185MeV$ of usable energy ?.

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79. In a star, three alpha particle join in a single reaction to form $._{6}C^{12}$ nucleus. Calcuate the energy released in the reaction

Given : $m(._{2}He^{4}) = 4.002604amu, \quad m(._{6}C^{12}) = 12.000000amu$

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80. Assuming that four hydrogen atom combine to form a helium atom and two positrons, each of mass $0.00549u$, calculate the energy released.

Given $m(._{1}H^{1}) = 1.007825u, m(._{2}He^{4}) = 4.002604u.$

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81. It is proposed to use the nuclear fusion reaction,

$._{1}^{2}H +_{1}^{2}H \rightarrow_{2}^{4}He$

in a nuclear reactor $200MW$ rating. If the energy from the above reaction is used with a 25 per cent efficiency in the reactor, how many grams of deuterium fuel will be needed per day?(The masses of $._{1}^{2}H$ and $._{2}^{4}He$ are 2.0141 atomic mass units and 4.0026 atomic mass units respectively.)

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82. Consider the so called D-T reaction (deuterium-tritium fusion)

$._{1}H^{2} + ._{1}H^{3} \rightarrow ._{2}He^{4} + n$

Calculate the energy released in MeV in this reaction from the data

$m(._{1}H^{2}) = 2.014102u, m(._{1}H^{3}) = 3.016049u$

(b) Consider the radius of both deuterium and tritium to be approximately 2.0fm. what is the kinetic energy needed to overcome the Coulomb repulsion between the two nuclei? To what temperature must the gases the be heated to initiate the reaction?

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Problem

1. Calculate the nearest distance of approach of an α-particle of energy 2.5 Me V being scattered by a gold nucleus (Z=79).

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2. Suppose the potential energy between an electron and aproton at a distance r is given by $-Ke^2/3r^3$. Use Bohr's theory to obtain energy level of such a hypothetical atom.

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3. A single electron orbits a stationary nucleus of charge $+Ze$, where Z is a constant and e is the magnitude of electronic charge . It requires $47.2eV$ to excite . Find

a the value of Z

b the energy required to excite the electron from the third to the fourth Bohr orbit.

the wavelength of electromagnetic rediation required to remove the electron from the first Bohr orbit to infinity.

d Find the KE, PE, and angular momentum of electron in the first Bohr orbit.

the redius of the first Bohr orbit

[The ionization energy of hydrogen atom $= 13.6eV$ Bohr radius $= 5.3 \times 10^{-11}m$, "velocity of light" $= 3 \times 10^{-8} jms^{-1}$, Planck's constant $= 6.6 \times 10^{-34} j - s]$

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4. An electron , in a hydrogen-like atom, is in excited state. It has a total energy of -3.4 eV. Calculate

(a) the kinetic energy and

(b) the de Broglie wavelength of the electron.

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5. How many revolutions does an electron in the first orbit of hydrogen atom make per second ? Calculate the orbital frequency. Given $h = 6.6 \times 10^{-34} Js, \quad m_e = 9.1 \times 10^{-31} kg, \quad r_0 = 0.53 Å$

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6. An electron moves about a proton in a circular orbit of radius $5 \times 10^{-11} m$. (i) find the orbital angular momentum of the electron about the proton (ii) Express total energy in electron volt.

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7. Using Bohr's formula for energy quantisation, determine (i) the largest wavelength in Balmer series of hydrogen atom spectrum and (ii) the excitation energy of $n = 3$ level of He^+ ion. Given $R = 1.097 \times 10^7 m^{-1}$

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8. Suppose a moving hydrogen atmo makes a head on inelastic collision with a stationary hydrogen atmo. Before collision both atoms are in ground state and after collision they move together. What is the minimum velocity of the moving hydrogen atom if one of the atom is to be given the minimum excitation energy after the collision ? $(m_H = 1.0078 amu, 1 amu = 1.66 \times 10^{-27} kg)$

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9. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 970.6Å. How many lines are possible in the resulting emission spectrum ? Calculate the longest wavelength amongst them. You may assume that the ionisation energy for hydrogen atom is 13.6 eV. Given Planck's constant $= 6.6 \times 10^{-34} Js, \quad c = 3 \times 10(8) ms^{-1}$

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10. A double ionised lithium atom is hydrogen like with atomic number 3

(i)Find the wavelength of the radiation to excite the electron in Li^{++} from the first to the third bohr orbit (Ionisation energy of the hydrogen atom equals $13.6eV$

(ii) How many spectral lines are observed in the emission spectrum of the above excited system ?

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11. A gas of hydrogen - like ion is perpendicular in such a way that ions are only in the ground state and the first excite state. A monochromatic light of wavelength $1216Å$ is absorbed by the ions. The ions are lifted to higher excited state and emit emit radiation of six wavelength , some higher and some lower than the incident wavelength. Find the principal quantum number of the excited state identify the nuclear charge on the ions . Calculate the values of the maximum and minimum wavelengths.

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12. A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. The excited atom can make a transition to the first excited state by successively emitting two photons of energy 10.2 eV and 17.0 eV, respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV and 5.95 eV, respectively Determine the values of n and Z. (Ionization energy of H-atom = 13.6 eV)

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13. The wavelength of the first line of Lyman series for hydrogen is identical to that of the second line of Balmer series for some hydrogen like ion x. Calculate energies of the first four levels of x.

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14. Two hydrogen-like atoms A and B are of different masses and each atom contains equal numbers of protons and neutrons. The difference in the energies between the first Balmer lines emitted by A and B , is $5.667eV$. When atom atoms A and B moving with the same velocity , strike a heavy target , they rebound with the same velocity in the process, atom B imparts twice the momentum to the target than that A imparts. Identify the atom A and B.

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15. The stopping potential for the photo-electrons emitted from a metal surface of work-function 1.7 eV is 10.4 eV. Find the wavelength of the radiation used. Also identify the energy-levels in hydrogen atom which will emit this wavelength.

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16. Light form a dicharge tube containing hydrogen atoms falls on the surface of a piece of sodium. The kinetic energy of the fastest photoelectrons emitted from sodium is 0.73 eV. The work function for sodium is 1.82 eV. Find (a) the energy of the photons causing the photoelectrons emission.

(b) the quantum numbers of the two levels involved in the emission of these photons.

(c) the change in the angular momentum of the electron in the hydrogen atom, in the above transition, and

(d) the recoil speed of the emitting atom assuming it to be at rest before the transition. (Ionization potential of hydrogen is 13.6 eV.)

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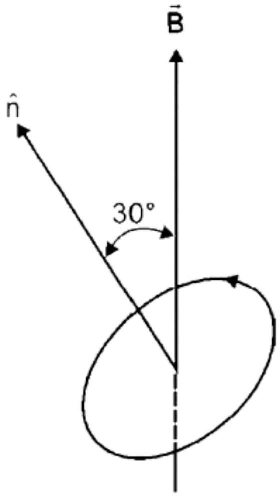
17. An electron in the ground state of hydrogen atom is revolving in anticlock-wise direction in a circular orbit of radius R.

(i) Obtain an experssion for the orbital magnetic dipole moment of the electron.

(ii) The atom is placed in a uniform magnetic induction $\vec{B}$ such that the plane - normal of the electron - orbit makes an angle of 30° with the magnetic induction . Find the torque experienced by the orbiting electron.



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18. A sample contains $10^{-2} kg$ each of two substances A and B with half lives 4 sec and 8 sec respectively. Their atomic weights are in the ratio $1:2$. Find the amounts of A and B after an interval of 16 seconds.

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19. The disintegration rate of a certain radioactive sample at any instant is 4750 disintegrations per minute. Five minutes later the rate becomes

2700 per minute. Calculate

(a) decay constant and (b) half-life of the sample

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20. At a given instant there are 25% undecayed radioactive nuclei in a sample. After $10s$ the number of undecayed nuclei reduces to 12.5%. Calculate

(a) mean life of the nuclei,

(b) the time in which the number of undecayed nuclei will further reduce to6.25% of the reduced number.

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21. The isotope of U^{238} and U^{235} occur in nature in the ratio $140:1$. Assuming that at the time of earth's formation, they were present in equal ratio, make an estimate of the age of earth. The half lives of U^{238} and U^{235} are 4.5×10^9 years and 7.13×10^8 years respectively. Given $\log_{10} 140 = 2.1461$ and $\log_{10} 2 = 0.3010$.

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22. The mean lives of a radioactive substance are 1620 years and 405 years for α emission and β emission respectively. Find out the time during which three fourth of a sample will decay if it is decaying both by α-emission and β-emission simultaneously. $(\log_e 4 = 1.386)$.

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23. Some amount of a radioactive substance (half-life= 10 days) is spread inside a room and consequently the level of radiation becomes 50 times the permissible level for normal occupancy of the room. After how many days the room will be safe for occupation?

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24. A small quantity of solution containing Na^{24} radio nuclide (half-life 15 hours) of activity 1.0 microcurie is injected into the blood of a person. A sample of the blood of volume $1cm^2$ taken after 5 hours shows an activity of 296 disintegrations per minute. Determine the total volume of blood in the body of the person. (1 curie $= 3.7 \times 10^{10}$ disintegrations per second.)

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25. In the chemical analysis of a rock the mass ratio of two radioactive isotopes is found to be $100:1$. The mean lives of the two isotopes are 4×10^9 years and 2×10^9 years, respectively. If it is assumed that at the time of formation the atoms of both the isotopes were in equal propotional, calculate the age of the rock. Ratio of the atomic weights of the two isotopes is $1.02:1$.

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26. A sample of uranium is a mixture of three isotopes $._{92}U^{234}$, $._{92}U^{235}$ and $._{92}U^{238}$ present in the ratio 0.006%, 0.71% and 99.284% respectively. The half lives of then isotopes are 2.5×10^5 years, 7.1×10^8

years and 4.5×10^9 years respectively. The contribution to activity (in $\%$) of each isotope in the sample respectively

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27. $10^{-3} kg$ of a radioactive isotope (atomic mass 226) emits $3.72 \times 10^{10} \alpha$ - particles in a second. Calculate the half-life of the isotope. If 4.2×10^2 joule energy is released in one hour in this process what is the average energy of the α-particles? Avogadro number is $6.02 \times 10^{26} /$ kmol and $\log_e 2 = 0.693$.

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28. Nuclei of radioactive element A are being produced at a constant rate. α. The element has a decay constant λ. At time $t = 0$, there are N_0 nuclei of the element.

(a) Calculate the number N of nuclei of A at time t.

(b) IF $\alpha = 2N_0\lambda$, calculate the number of nuclei of A after one half-life time of A and also the limiting value of N at $t \to \infty$.

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29. The element curium $._{96}^{248}Cm$ has a mean life of $10^{13}s$. Its primary decay modes are spontaneous fission and α-decay, the former with a probability of 8% and the later with a probability of 92%, each fission releases $200MeV$ of energy. The masses involved in decay are as follows

$._{96}^{248}Cm = 248.072220u$,

$._{94}^{244}P_u = 244.064100u$ and $._{2}^{4}He = 4.002603u$. Calculate the power output from a sample of 10^{20} Cm atoms. ($1u = 931MeV/c^2$)

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30. A nuclear reactor generates power at 50% efficiency by fission of $._{92}^{235}U$ into two equal fragments of $._{46}^{116}U$ into two equal fragments of $._{46}^{116}Pd$ with the emission of two gamma rays of 5.2 MeV each and three neutrons. The average binding energies per particle of $._{92}^{235}U$ and $._{46}^{116}Pd$ are 7.2 MeV and 8.2MeV respectiveley. Calculate the energy released in one fission event. Also-estimate the amount to $.^{235}U$ consumed per hour to produce 1600 megawatt power.

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31. A star initially has 10^{40} deuterons. It produces energy via the process $_(1)H^2 +_1 H^2 + \rightarrow_1 H^3 + p$. and $_(1)H^2 +_1 H^3 + \rightarrow_2 He^4 + n$ .If the average power radiated by the state is $10^{16}W$, the deuteron supply of the star is exhausted in a time of the order of .

The masses of the nuclei are as follows:

$M(H^2) = 2.014a\mu,$

$M(p) = 1.007a\mu, M(n) = 1.008a\mu, M(He^4) = 4.001a\mu.$

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32. A fusion reaction of the type given below

$.^2_1 D + .^2_1 D \rightarrow .^3_1 T + .^1_1 p + \Delta E$

is most promissing for the production of power. Here D and T stand for deuterium and tritium, respectively. Calculate the mass of deuterium required per day for a power output of $10^9 W$. Assume the efficiency of the process to be 50%.

Given : $m(._1^2 D) = 2.01458 amu$, $m(._1^3 T) = 3.01605 amu$

$m(._1^1 p) = 1.00728 amu$ and $1 amu = 930 MeV$.

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Problems For Self Practice

1. In a head-on collision between and α-particle and a gold nucleus, the distance of closest approach is 4.13 fermi. Calculate the energy of the particle. (1 fermi $= 10^{-15} m$)

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2. An α particle of $K.E. 10^{-12} J$ exhibits back scattering from a gold nucleus Z=79. What can be the maximum possible radius of the gold nucleus?

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3. A protom of energy 1 MeV is incident head-on on a gold nucleus (Z = 79), and is scattered through an angle of 180°. Calculate the distance of nearest approach.

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4. In a head-on collision between an α-particle and a gold nucleus, the minimum distance of approach is $3.95 \times 10^{4} m$. Calculate the energy of the α-particle.

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5. An α-particle of kinetic energy 7.68 MeV is projected towards the nucleus of copper (Z=29). Calculate its distance of nearest approach.

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6. An alpha particle of energy 4MeV is scattered through an angle of 180° by a gold foil (Z=79). Calculate the maximum volume in which positive charge of the atom is likely to be concentrated?

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7. What is the distance of closest approach to the nucleus for an α-particle of energy 5J MeV which undergoes scattering in the Gieger-Marsden experiment.

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8. What is the impact parameter at which the scattering angle is 10° for Z = 79 and initial energy of the α-particle is 5MeV ?

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9. A $10kg$ satellite circles earth once every $2hr$ in an orbit having a radius of $8000km$. Assuming that Bohr's angular momentum postulate applies to satellites just as it does to an electron in the hydrogen atom, find the quantum number of the orbit of the satellite.

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10. At what speed must an electron revolve around the nucleus of hydrogen atom so that it may not be pulled into the nucleus by electrostatic attraction? Given, mass of electron $= 9.1 \times 10^{-31} kg$, radius of orbit $= 0.5 \times 10^{-10} m$ and $e = 1.6 \times 10^{-19} C$.

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11. The innermost orbit of the hydrogen atom has a diameter of $1.06Å$ what is the Diameter of the tenth orbit:

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12. Calculate the energy of the hydrogen atom in the states n = 4 and n = 2. Determine the frequency and wavelength of the emitted radiation in a transition from n = 4 to n=2 state. Is this radiation visible?

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13. Calculate (i) the radius of the second orbit of hydrogen atom, and (ii) total energy of electron moving in the second orbit.

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14. Calculate the frequency of the photon, which can excite the electron to -3.4 eV from -13.6 eV.

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15. The ground state energy of hydrogen atom is $-13.6eV$. If an electron makes a transition form an energy level $-0.85eV$ to $-3.4eV$, calculate the wavelength of spectral line emitted. To which series of hydrogen spectrum does this wavelength belongs?

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16. Show that the ionisation potential of hydrogen atom is 13.6 volt.

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17. Calculate the ionisation potential of a single ionised He-atom.

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18. Calculate the minimum energy that must be given to a hydrogen atom so that it can emit the H_{β} line of Balmer series.

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19. What energy in eV will be required to excite the ground state electron of a hydrogen atom to h = 3 state ? Ground state energy $= -13.6eV$.

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20. By giving energy to a hydrogen atom in energy state n=1. If the potential energy of the atom in n=1 state be $-13.6eV$, calculate (a) potential enregy in state n=4, (b) energy absorbed by the atom in the transition, and (c) wavelength of radiation emitted during transition from n=4 to n=1 state.

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21. The wavelength of H_{α} line is Balmer series is 6563 Å. Compute the wavelength of H_{β} line of Balmer series.

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22. If the wavelength of the first member of Balmer series in hydrogen spectrum is 6563 Å, calculate the wavelength of the first member of Lymen series in the same spectrum.

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23. The second member of Lyman's series is hydrogen spectrum has a wavelength of 5400 Å. Calculate the wavelength of the first member.

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24. The energy of K-electron in tungsten is -20.0 keV and of an L-electron is -2.0 ke V. Find the wavelength of X-rays emitted when an electron jumps from L - shell to K-shell.

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25. The P.E. of a normal hydrogen atom in ground state is -27 eV. Calculate its K.E. and total energy in the same state.

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26. A photon of energy 12.09 eV is absorbed by an electron in ground state of a hydrogen atoms. What will be the energy level of electron ? The energy of electron in the ground state of hydrogen atom is $-13.6eV$

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27. The period of revolution of the electron in the third orbit in a hydrogen atom is $4.132 \times 10^{-15}s$. Hence find the period in the 5th Bohr orbit.

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28. The first excitation potential of sodium atom is 2.1 V. Calculate the longest wavelength of the emitted photon. Will the photon be visible ? To Which spectral series will this photon belong? Given $R = 1.097 \times 10^7 m^{-1}$

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29. In a hydrogen atom, a transition takes place from n = 3 to n = 2 orbit. Calculate the wavelength of the emitted photon. Will the photon be visible ? To which spectral series will this photon belong? Given $R = 1.097 \times 10^7 m^{-1}$

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30. What is the equivalent energy of a 10 mg mass ?

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31. Calculate the mass equivalent of 1amu.

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32. Express 1 electron volt in kilowatt hour.

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33. Find the effectiveness of a photon of energy 5 eV.

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34. Find the effective mass of a photon if the frequency of radiation is $6 \times 10^{14} Hz$.

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35. Find the effective mass of a photon if the wavelength of radiation is 3000Å.

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36. What is the order of energy, in eV for a photon of visible light?

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37. Natural Chlorine is found to be a mixture of two isotopes of masses 34.98 a.m.u and 36.98 a.m.u. respectively. Their relative abundances are 75.4 and 24.6% respectively. Find the composite atomic mass of natural chlorine.

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38. Obtain approximately the ratio of the radii of iron $._{26}Fe^{56}$ and calcium $._{20}Ca^{40}$. What is the approximate ratio of their nuclear mass densities?

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39. Calculate the nuclear radii of $._{56}Ba^{140}$ and $._{8}O^{17}$. Given $R_0 = 1.5 fm$.

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40. The nuclear radius of Pb^{208} is is 8.874 fm. What will be the nuclear radius of Ca^{44} ?

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41. A nucleus with $A = 235$ splits into two nuclei whose mass numbers are in the ratio $2 : 1$. IF $R_0 = 1.4$ fm, find the radii of the new nuclei.

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42. Calculate the density of hydrogen nucleus in SI units. Given $R_0 = 1.1$ fermi and $m_p = 1.007825amu.$

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43. The nucleus radius of $._8 O^{16}$ is $3 \times 10^{-15}m.$ Find the density of nuclear matter.

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44. Calculate the nuclear mass density of $._{92} U^{238}$. Given $R_0 = 1.5$ fermi and mass of each nucleon is $1.67 \times 10^{-27}kg.$

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45. The mass of $._{3}Li^{7}$ is 0.042 amu less than the sum of masses of its nucleons. Find the B.E. per nucleon.

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46. Calculate the binding energy per nucleon for a $._{6}C^{12}$ nucleus. Atomic mass of $._{6}C^{12} = 12amu$, mass of a photon = 1.007825 amu, mass of a neutron = 1.008665 amu.

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47. Calculate the binding energy of a deutron. Given that

mass of proton = 1.007825 amu

mass of neutron = 1.008665 amu

mass of deutron = 2.014103 amu

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48. The binding energy of $._{10}Ne^{20}$ is 160.6 MeV. Find its atomic mass. Take mass of proton =1.007825 u and mass of neutron =1.008665 u.

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49. The atomic mass of $._{8}O^{16}$ is 16.000000 amu. Calculate the binding energy of $._{8}O^{16}$ in MeV per nucleon.

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50. The binding enrgy of $._{17}^{35}Cl$ nucleus is 298 MeV. Find the atomic mass. Given, mass of a proton $(m_P) = 1.007825$ amu, mass of a neutron $(m_n) = 1.008665$ amu.

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51. Calculate the binding energy per nucleon of $._{20}Ca^{40}$ nucleus. Mass of $(._{20}Ca^{40}) = 39.962591 amu.$

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52. Calculate the binding energy in MeV of Uranium 238 from the following data

Mass of $._{}^{1} H_{1} = 1.008142 amu$, Mass of $._{0} n^{1} = 1.008982 amu$

Mass of $._{92} U^{238} = 238.124930 amu$

Also calculate the packing fraction.

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53. A uranium nucleus (atomic number 92, mass number 231) emits an α-particle and the resultant nucleus emits a β-particles. What are the atomic and mass numbers of the final nucleus? .

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54. $._{92} U^{238}$ on absorbing a neutron goes over to $._{92} U^{239}$. This nucleus emits an electron to go over to neptunium which on further emitting an

electron goes over to plutonium. How would you represent the resulting plutonium ?

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55. A radioactive nucleus undergoes a series of decays according to the sequence :

$$A \xrightarrow{\beta} A_1 \xrightarrow{\alpha} A_2 \xrightarrow{\alpha} A_3$$

If the mass number and atomic number of A_3 are 172 and 69 respectively, what rate the mass number and atomic number of A ?

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56. In the actinium, series, the first member $._{92}U^{235}$ emits in succession 7α particles and 4β particles and gets converted into a stable lead isotope lead isotope. Find the atomic number and mass number of the lead isotope so formed.

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57. Thorium $._{90}Th^{232}$ is converted into $._{89}Pb^{208}$ by radioactive transformations. How many α-and β-particles are emitted ?

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58. Tritium has a half life of 12.5 years against beta decay. What fraction of a sample of pure tritium will remain undecayed after 25 years?

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59. The half -life of polonium is 138 days against alpha decay . What fraction of a sample of pure polonium will remain undecayed after 276 days ?

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60. The half-life of $._6 C^{14}$ is 5730 years. What fraction of a sample of $._6 C^{14}$ will remain unchanged after a period of five half-llves ?

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61. After a certain lapse of time, fraction of radioactive polonium undecayed is found to be 12.5% of the initial quantity. What is the duration of this time lapsed if the half life of polonium is 138 days ?

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62. The half - life of a radioactive substance is 60 years. Calculate its decay constant given $\log e2 = 6930$

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63. The half life of Radon is 3.8 days. Calculate how much of 15 milligram of Radon will remain after 38 days.

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64. The life-life of Bi^{210} is 5 days. What time is taken by $(7/8)^t h$ part of the sample of decay ?

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65. A sample of a radioactive substance has 10^6 radioactive nuclei. Its half life time is 20 s How many nuclei will remain after 10 s ?

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66. The half life of polonium is 140 days. In what time will 15 g of polonium be disintegrated out of its initial mass of 16 g?

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67. 4g of a radioactive material of half life 10 years is kept in a store for 15 years. How much material is disntegrated ?

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68. One gram of radium is reduced by 2 miligram in 5 yers by α-decay. Calculate the half-life of radium.

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69. A nucleus of Ux_1 has a life of 24.1 days. How long a sample of Ux_2 will take to change to 90 % of it to Ux_2 ?

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70. The half - life of $._{92}U^{238}$ against $\alpha - decay$ is 4.5×10^9 years. How many disintegrations per second occur in 1 g of $._{92}U^{238}$?

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71. Lanthanum has a stable La^{139} and radioactive isotope La^{138} of half life 1.1×10^{10} years whose atoms are 0.1 % of those of the stable isotope. Estimate the rate of decay or activity of La^{138} with 1 kg of La^{139} Take Avogadro's number $N = 6 \times 10^{23} mol^{-1}$

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72. An accident occurs in a laboratory in which a large amount of a radioactive material, having a half life of 20 days, becomes embeded in the foor and walls so that the level of adiation is 32 times the permissible level. The laboratory can be safely occupied after

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73. For a given sample, the count rate is 47.5α particle per minute. After 5 minutes, the count is reduced to 27α particles per minute. Find the decay constant and half life of the sample.

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74. One milligram of thorium emits 22α particles per minute per unit solid angle. Calculate average life of thorium. Atomic weight of Thorium is 232.

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75. The half life of $._{90}Th^{225}$ is 8 minutes How many half lives are there in 2 hours ? How long would you have to wait before there is less than 1 % of $._{90}Th^{225}$ left in the sample ?

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76. A slow neutron strikes a nucleus of $._{92}U^{235}$ splitting it into lighter nuclei of barium and krypton and releasing three neutrons. Write the corresponding nuclear reaction. Also calculate the energy released on this reaction

Given $m(._{92}U^{235}) = 235.043933\text{amu}m(._{0}n^{1}) = 1.008665$ amu

$m(._{56}Ba^{141}) = 140.917700\text{amu}m(._{36}Kr^{92}) = 91.895400$ amu

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77. Calculate the Q - value of the reaction

$._{1}H^{2} + ._{1}H^{2} \rightarrow ._{1}H^{3} + ._{1}H^{1}$

$m(._{1}H^{2}) = 2.014103\text{amu}m(._{1}H^{3}) = 3.016049\text{amu}m(._{1H^{1}} = 1.007825$

amu

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78. Find the Q - value for the nuclear reaction:

$._{2}He^{4} + ._{7}N^{14} \rightarrow ._{8}O^{17} + ._{1}H^{1}$

$m(._2 He^4) = 4.0039 \text{amu} m(._7 N^{14}) = 14.0075 \text{amu} m(._8 O^{17}) = 17.0045$ amu

$m(._1 H^1) = 1.0082$ amu

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79. When $._{92} U^{235}$ undergoes fission, 0.1% of the original mass is released into energy. How much energy is released by an atom bomb which contains $10kg$ of $._{92} U^{235}$?

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80. If 200 MeV energy is released per fission of $._{92} U^{235}$ How many fissions must occur per second to produce a power of 1m W?

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81. Assuming that about $200 MeV$ of energy is released per fission of $._{92} U^{235}$ nuceli, the mass of U^{235} consumed per day in a fission ractor of power 1 megawatt will be approximately .

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82. When an atom of $._{92} U^{235}$ undergo fission, about 200 MeV energy is released Suppose that a reactor using $._{92} U^{235}$ has an output of 700 MW and is 20% efficient

(i) How much uranium atoms does it consume in one day ?

(ii) What mass of uranium does it consume each day ?

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83. One Mev positron encounters one MeV electron travelling in opposite direction. What is the wavelength of photons produced, given rest mass energy of electron or positron $= 0.512 MeV$? Take $h = 6.62 \times 10^{-34} J - s$.

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84. Calculate the energy released when a single helium nucleus is formed by the fusion of two deuterium nuclei Given $m(._1 H^2) = 2.01478$ amu and $m(._2 He^4) = 4.00388$ amu.

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85. Calculate the energy generated in kWh, when $100g$ of $._3 Li^7$. are converted into $._2 He^4$ by proton bombardment. Given mass of $._3 Li^7 = 7.0183 a.m.u,$ mass of $._2 He^4 = 4.0040 a.m.u,$ mass of $._1 H^1 = 1.0081 a.m.u.$

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86. The sun is believed to be getting its energy from the fusion of four protons to form a helium nucleus and a pair of positrons. Calculate the release of energy per fusion in MeV. Mass of proton=1.007825 a.m.u. , mass of positron =0.000549 a.m.u., mass of helium nucleus =4.002603 a.m.u. Take 1a.m.u. =931MeV.

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87. Energy evolved from the fusion reaction $2_1^2H =_1^4 He + Q$ is to be used for the production of power. Assuming the efficiency of the process to be 30%. Find the mass of deuterium that will be consumed in a second for an output of $50MW$.

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