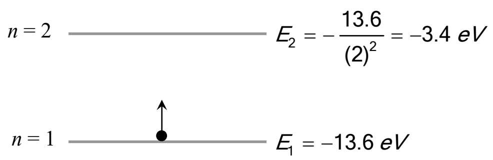
Answers and Solutions

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 2^{nd} 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
$= Z^2 \times 13.6\ volt = (2)^2 \times 13.6 = 54.4\ V$

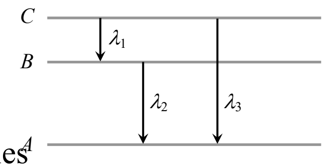
16. (c) Energy required $= \frac{13.6}{n^2} = \frac{13.6}{10^2} = 0.136\ eV$

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) $(E_{ion})_{Na} = Z^2(E_{ion})_H = (11)^2 13.6\ eV$

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,

$\Rightarrow \frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{16}$

$\therefore \frac{\lambda_2}{\lambda_1} = \frac{20}{27} \Rightarrow \lambda_1 = \frac{20}{27}\times 6561 = 4860\,\mathring{A}$

27. (d) $2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$

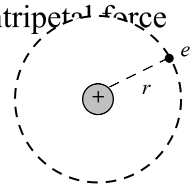
$\frac{4E}{3} - E = \frac{hc}{\lambda'} \Rightarrow \frac{E}{3} = \frac{hc}{\lambda'}\ \therefore \frac{\lambda'}{\lambda} = 3 \Rightarrow \lambda' = 3\lambda$

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



$\Rightarrow \frac{ze^2}{r^2} = \frac{mv^2}{r} \Rightarrow mv^2 = \frac{ze^2}{r}$

$\therefore$ 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

$\nu_{Lymen} = \frac{c}{\lambda_{max}} = Rc\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] = \frac{3RC}{4}$

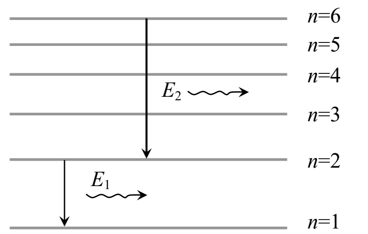
For Balmer series

$\nu_{Balmer} = \frac{c}{\lambda_{max}} = Rc\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5RC}{36}$

$\therefore \frac{\nu_{Lymen}}{\nu_{Balmer}} = \frac{27}{5}$

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.

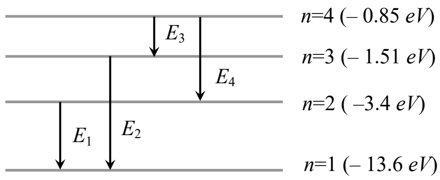
47. (c) Wave number $= \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first Balmer line $n_1 = 2, n_2 = 3$

$\therefore$ 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_2 = 2 and n_2 = 3

So, $\frac{\lambda_{\text{Lymen}}}{\lambda_{\text{Balmer}}} = \frac{5}{27}$

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) $v_n \propto \frac{1}{n} \Rightarrow \frac{v_5}{v_2} = \frac{2}{5} \Rightarrow v_5 = \frac{2}{5}v_2 = \frac{2}{5}v$

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) $r = \frac{n^2}{Z}(r_0)$; $\Rightarrow r_{(n=2)} = \frac{(2)^2}{2} \times 0.53 = 1.06\ \mathring{A}$

67. (c)

68. (a) $\bar{v} \propto \frac{1}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 =$ 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 $5 \to 2$, more energy is liberated as compared to transition from $4 \to 2$.

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) $E_n = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4 eV$

81. (a) $\frac{1}{\lambda_{Balmer}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$, $\frac{1}{\lambda_{Lyman}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$

$\therefore \lambda_{Lyman} = \lambda_{Balmer} \times \frac{5}{27} = 1215.4\ \mathring{A}$

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 $= \frac{\text{Excitation energy}}{e}$

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) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{\lambda_{3\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5R}{36}$

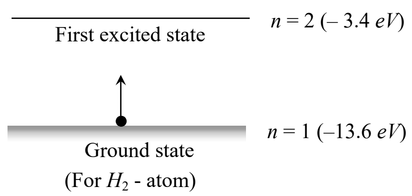
and $\frac{1}{\lambda_{4\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = \frac{3R}{16}$

$\therefore \frac{\lambda_{4\to 2}}{\lambda_{3\to 2}} = \frac{20}{27} \Rightarrow \lambda_{4\to 2} = \frac{20}{27}\lambda_0$

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^{th} orbit $= \frac{n^2h^2}{\pi mZe^2}$

v = speed of e^- in n^{th} orbit $= \frac{ze^2}{2\varepsilon_0 nh}$

$\therefore\ T = \frac{4\varepsilon_0^2 n^3 h^3}{mZ^2e^4} \Rightarrow T \propto \frac{n^3}{Z^2}$

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 $\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right] = \frac{R}{9}$

$\Rightarrow \lambda = \frac{9}{R} = \frac{9}{1.1\times 10^{-7}} = 8.225\times 10^{-7}m = 8225\ \mathring{A}$

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 $E_n =$

$U_n = 2E_n = -27.2\frac{z^2}{n^2}eV$ 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_n will increase but E_n and U_n 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_0 = Radius of the Bohr orbit in the ground state atom . So for He^+ third excited state $n = 4, Z = 2, r_0 = 0.5\mathring{A} \Rightarrow$

$r_4 = 0.5\times \frac{4^2}{2} = 4\,\mathring{A}$

115. (d) Speed of electron in n^{th} orbit (in CGS) $v_n = \frac{2\pi Ze^2}{nh}$ (k =

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) $r_n \propto n^2 \Rightarrow \frac{r_3}{r_1} = \frac{3^2}{1} \Rightarrow r_3 = 9r_1 = 9 \times 0.53 = 4.77 \mathring{A}$

124. (d) For first line in Lyman series $\lambda_{L_1} = \frac{4}{3R}$ ..... (i)

For first line in Balmer series $\lambda_{B_1} = \frac{36}{5R}$

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

..... (ii)

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) $E_n = -\frac{13.6 Z^2}{n^2}\ eV \Rightarrow E_1 = -\frac{13.6 \times (2)^2}{(1)^2} = -54.4\ eV$

141. (b) $\nu \propto Z^2 \Rightarrow \frac{\nu_{H_2}}{\nu_{He}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4} \Rightarrow \nu_{He} = 4\nu_{H_2} = 4\nu_0$

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

First condition $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow R = \frac{4}{3\lambda}$

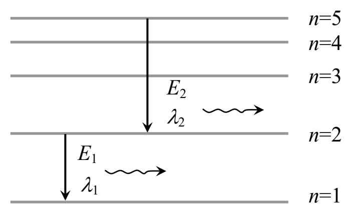
Second condition $\frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$

$\Rightarrow \lambda' = \frac{9}{8R} \Rightarrow \lambda' = \frac{9}{8 \times \frac{4}{3\lambda}} = \frac{27\lambda}{32}$

143. (b)

144. (a) $r_n \propto n^2$

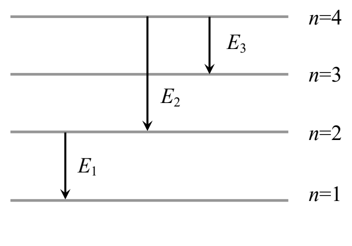
145. (d) $\because E_2 < E_1 \Rightarrow \lambda_2 > \lambda_1$



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

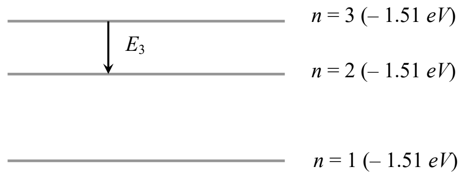
149. (b) $E_n = \frac{13.6}{n^2} \times Z^2$. For first excited state $n = 2$ and for Li^{++}, $z = 3 \Rightarrow E = \frac{13.6}{4} \times 9 = 30.6\ eV$

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)



$E_{3\to 2} = -3.4 - (-1.51) = -1.89\ eV \Rightarrow |E_{3\to 2}| \approx 1.9\ eV$

153. (a)

154. (a)

155. (c) Radius of n^{th} 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. $= 2 \times \text{Total energy} = 2 \times (-13.6) = -27.2\,\text{eV}$

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 $\Delta m = \frac{2.23}{931} = 0.0024$.

8. (b) Positron is the antiparticle of electron.

9. (b)

10. (c)

11. (a) B.E.= Δmc^2
$= [2(1.0087 + 1.0073) - 4.0015] = 28.4\ MeV$

12. (b) $\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{0.0303 \times 931}{4} \approx 7$

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 $= 9.1 \times 10^{-31} \times (3 \times 10^8)^2\ joule$

$= \frac{9.1 \times 10^{-31} \times (3 \times 10^8)^2}{1.6 \times 10^{-19}}\ eV = 510\ keV$

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 ≈ 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)

$V = \frac{4}{3}\pi r^3 \simeq \frac{4}{3}\pi\,[(1.25 \times 10^{-15}\ m)A^{1/3}]^3$

$\simeq (8.2 \times 10^{-45}\ m^3)A$

Hence, $\rho = \frac{m}{V} = \frac{A(1.67 \times 10^{-27}\ kg)}{(8.2 \times 10^{-45}\ m^3)A}$

$\simeq 2.0 \times 10^{17}\ kg/m^3$.

27. (c) We have $r \propto A^{1/3} \Rightarrow \frac{r_2}{r_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{206}{4}\right)^{1/3}$

$\therefore r_2 = 3\left(\frac{206}{4}\right)^{1/3} = 11.6\ Fermi$.

28. (c) Nucleus does not contains electron.

29. (a) Let the percentage of B^{10} atoms be x, then Average atomic weight

$= \frac{10x + 11(100 - x)}{100} = 10.81 \Rightarrow x = 19 \quad \therefore \frac{N_{B^{10}}}{N_{B^{11}}} = \frac{19}{81}$

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 $n \to n' + \pi^0$

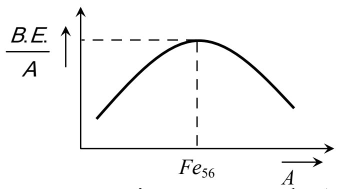
34. (c) Helium nucleus → ${}_2He^4$.

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 α – 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 $\frac{N}{Z} = 1$ and for heavier nuclei $\frac{N}{Z} > 1$.

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) $E = \Delta m.c^2 \ \Rightarrow E = \frac{0.3}{1000}\times(3\times10^8)^2 = 2.7\times10^{13}\ J$

$= \frac{2.7\times10^{13}}{3.6\times10^6} = 7.5\times10^6\ kWh$.

58. (a, d)

59. (c) ${}_5B^{10} + {}_0n^1 \to {}_3Li^7 + {}_2He^4$.

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 ${}_2He^4 + {}_zX^A \to {}_{z+2}Y^{A+3} + A$

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) ${}_1H^2 + {}_1H^2 \to {}_2He^4 + 24\ MeV$.

68. (b) Energy $\propto c^2$; $\therefore$ Decrease in energy $\propto \frac{4}{9}$.

69. (b) Fusion reaction requires a very high temperature =(10^7 *K*).

70. (d) ${}_4Be^9 + {}_2He^4 \to {}_6C^{12} + {}_0n^1$.

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) $m = \frac{E}{c^2} = \frac{931 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2} = 1.66 \times 10^{-27} kg.$

88. (d) $E = \Delta mc^2, \Delta m = \frac{0.1}{100} = 10^{-3} kg$

$\therefore E = 10^{-3} \times (3 \times 10^8)^2 = 10^{-3} \times 9 \times 10^{16} = 9 \times 10^{13} J.$

89. (d) Energy released by $\gamma -$rays for pair production must be greater than 1.02 *MeV*.

90. (a) ${}_8O^{18} + {}_1H^1 \rightarrow {}_9F^{18} + {}_0n^1$

91. (c) Power $= 1000\ kW = 10^6\ J/s$

Rate of nuclear fission $= \frac{10^6}{200 \times 1.6 \times 10^{-13}} =$ 3.125×10^{16}.

92. (b) $A = 238 - 4 = 234$ and $Z = 92 - 2 = 90$.

93. (a) $P = n\left(\frac{E}{t}\right) \Rightarrow 1000 = \frac{n \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$\Rightarrow \frac{n}{t} = 3.125 \times 10^{13}.$

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) ${}_{85}X^{297} \rightarrow {}_{77}Y^{281} + 4({}_2He^4)$

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) $\frac{\text{Energy}}{\text{Fission}} = 200\ MeV = 200 \times 10^6 \times 1.6 \times 10^{-19} J$

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) ${}_1H^1 + {}_1H^1 + {}_1H^2 \rightarrow {}_2He^4 + {}_{+1}e^0 +$ energy.

112. (c)

113. (b) ${}_0n^1 = {}_1p^1 + {}_{-1}e^0 + \bar{\nu}$

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) ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{92}U^{236}$ and

${}_{92}U^{236} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3{}_0n^1 + Q.$

122. (d) Fusion reaction of deuterium is

${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + 3.27\ MeV$

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

$= \frac{\text{Power output}}{\text{Energy released per fission}}$

$= \frac{3.2\times10^6}{200\times10^6\times1.6\times10^{-19}} = 1\times10^{17}$

$\Rightarrow$ Number of fission per minute $= 60\times10^{17} = 6\times10^{18}$

131. (c)

132. (a) $X(n,\alpha)\,{}^7_3Li \Rightarrow {}_ZX^A + {}_0n^1 \rightarrow 3Li^7 + {}_2He^4$

$Z = 3+2 = 5$ and A = 7+4 – 1 =10

$\therefore {}_5X^{10} = {}_5B^{10}$

133. (a)

134. (b) Mass of electron = mass of positron = 9.1 × $10^{-31}kg$

Energy released $E = (2m).c^2$

$= 2\times9.1\times10^{-31}\times(3\times10^8)^2 = 1.6\times10^{-13}J.$

135. (b) ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 +$ energy

Binding energy of a $({}_1H^2)$ deuterium nuclei $= 2\times1.1 = 2.2\ MeV$

Total binding energy of two deuterium nuclei $= 2.2\times2 = 4.4\ MeV$

Binding energy of a $({}_2He^4)$ nuclei $= 4\times7 = 28\ MeV$

So, energy released in fusion $= 28-4.4 = 23.6\ MeV$

136. (c) Mass of a uranium nucleus

$= 92\times1.6725\times10^{-27} + 143\times1.6747\times10^{-27}$

$= 393.35\times10^{-27}\ kg$

Number of nuclei in the given mass

$= \frac{1}{393.35\times10^{-27}} = 2.542\times10^{24}$

Energy released $= 200\times2.542\times10^{24}\ MeV$

$= 5.08\times10^{26}\ MeV = 8.135\times10^{13}\ J = 8.2\times10^{13}\ J$

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

$= (2.0141)\times2 = 4.0282\ amu$

Total mass of products $= 4.0024\ amu$

Mass defect $= 4.0282\ amu - 4.0024\ amu$

$= 0.0258\ amu$

$\therefore$ Energy released $E = 931\times0.0258 = 24\ MeV$

141. (b) ${}_7N^{14} + {}_2He^4 \rightarrow {}_8O^{17} + {}_1H^1$

142. (b)

143. (b)

144. (d) ${}_8O^{16} + {}_1H^2 \rightarrow {}_7N^{14} + {}_2He^4$

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 $= \frac{M-A}{A}$

154. (c) $B = [ZM_p + NM_n - M(N,Z)]c^2$

$\Rightarrow M(M,Z) = ZM_p + NM_n - B/c^2$

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 $P = \frac{\text{Energy}}{\text{time}} = \frac{mc^2}{t}$, $= 1 \times 10^{-6} \times (3 \times 10^8)^2$

$= 9 \times 10^{10}\, W = 9 \times 10^7\, kW$.

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

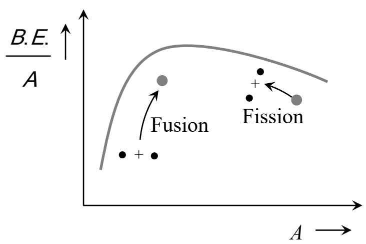
Number of neutrons = 40 – 18 = 22.

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) $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$\Rightarrow \frac{3.6}{r_2} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5} \Rightarrow r_2 = 6\, Fermi$

179. (b)

Radioactivity

1. (a)

2. (a) By formula $N = N_0\left(\frac{1}{2}\right)^{t/T}$ or $10^4 = 8 \times 10^4 \left(\frac{1}{2}\right)^{t/3}$

or $\left(\frac{1}{8}\right) = \left(\frac{1}{2}\right)^{t/3}$ or $\left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/3} \Rightarrow 3 = \frac{t}{3}$

Hence *t* = 9 *years*.

3. (d) Fraction $= \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{6400}{1600}} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$

4. (c) Negative $\beta-$decay is expressed by the equation

$n = p^+ + e^- + \nu^-$

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) $_{Z}X^{A} \xrightarrow{-1\beta^0} {}_{Z+1}Y^{A} \xrightarrow{2He^4(\alpha)}$

$_{Z-1}K^{A-4} \xrightarrow{0\gamma^0} {}_{Z-1}K^{A-4}$

12. (c) $N_t = N_0\left(\frac{1}{2}\right)^{t/T} = 50000\left(\frac{1}{2}\right)^{10/5} = 12500$

13. (c) $_{Z}X^{A} \xrightarrow{-1\beta^0} {}_{Z+1}X^{A}$

14. (c) $N = N_0\left(\frac{1}{2}\right)^{t/T} \Rightarrow \frac{N_0}{64} = N_0\left(\frac{1}{2}\right)^{30/T} \Rightarrow T = \frac{30}{6} = 5\sec$

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) $\beta-$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) $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 100 = 1600\left(\frac{1}{2}\right)^{\frac{8}{T_{1/2}}} \Rightarrow T_{1/2} = 2\,sec$

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 $N = N_0 e^{-\lambda t} \Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \Rightarrow 2 = e^{\lambda T_{1/2}}$

By taking $\log_e$ 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) ${}^{22}_{10}Ne \rightarrow {}^4_2He + {}^4_2He + {}^{14}_6X$; 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 $N = N_0 e^{-\lambda t}$ 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 α-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 β-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

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

$\Rightarrow \frac{N}{10.38} = \left(\frac{1}{2}\right)^5 \Rightarrow N = 10.38 \times \left(\frac{1}{2}\right)^5 = 0.32 gm$

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) ${}^A_Z X \rightarrow {}^{A-4}_{Z-2} Y + {}^4_2 He \rightarrow {}^{A-4}_{Z-3} Z + {}^0_1 B$

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 α – particles and four β – 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) $_Z X^A \xrightarrow{\alpha} {}_{Z-2}X^{A-4}$

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 γ – 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 $N=N_0e^{-\lambda t}$

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) $N=N_0e^{-t/T_{1/2}} \Rightarrow \frac{1}{4}=e^{-t/10}$

$\Rightarrow \left(\frac{1}{2}\right)^2=\frac{1}{e^{t/10}} \Rightarrow t=20\ years$

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) $A=A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{64}=\left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}}$

$\Rightarrow \left(\frac{1}{2}\right)^6=\left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}} \Rightarrow T_{1/2}=10\sec$

137. (a, c)

138. (b) ${}_{(Z=92)}U^{(A=238)} \xrightarrow{(8\alpha,6\beta)} {}_ZX^{A'}$

so $A'=A-4n_\alpha=238-4\times 8=206$

and $Z=n_\beta-2n_\alpha+z=6-2\times 8+92=82$.

139. (c) $A=A_0e^{-\lambda t}=A_0e^{-t/\tau}$; where $\tau=$ mean life

So $A_1=A_0e^{-t_1/T} \Rightarrow A_0=\frac{A_1}{e^{-t_1/T}}=A_1e^{t_1/T}$

$\therefore A_2=A_0e^{-t/T}=(A_1e^{t_1/T})e^{-t_2/T} \Rightarrow A_2=A_1e^{(t_1-t_2)/T}$

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 $=\frac{0.693}{\lambda}=0.693\times(\text{Averagelife})$

in single average life, more than 63% of radioactive nuclei decay

146. (b)

147. (d) $M=M_0e^{-\lambda t}$; given $t=2\left(\frac{1}{\lambda}\right)$

$\Rightarrow M=10e^{-\lambda\left(\frac{2}{\lambda}\right)}=10\left(\frac{1}{e}\right)^2 \Rightarrow M=1.35\ gm$

148. (b)

149. (b) $\lambda=\frac{\log_e\frac{A_1}{A_2}}{t}=\frac{\log_e\frac{5000}{1250}}{5}=0.4\ In\ 2$

150. (c) $Z_{\text{Resutingnucleus}}=92-8\times 2+4\times 1-2\times 1=78$

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 $t = 2hr$,

$N_1 = 8\times10^{10}\left(\frac{1}{2}\right)^{\frac{2}{1}} = 2\times10^{10}$

No. of atoms at $t = 4hr$,

$N_2 = 8\times10^{10}\left(\frac{1}{2}\right)^{\frac{4}{1}} = \frac{1}{2}\times10^{10}$

$\therefore$ No. of atoms decayed in given duration

$= \left(2-\frac{1}{2}\right)\times10^{10} = 1.5\times10^{10}$

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 $R = R_0 e^{-\lambda t}$

$\frac{R_0}{3} = R_0 e^{-\lambda\times9} \Rightarrow e^{-9\lambda} = \frac{1}{3}$ ...(i)

After further 9 years $R = Re^{-\lambda t} = \frac{R_0}{3}\times e^{-\lambda\times9}$ ...(ii)

From equation (i) and (ii) $R = \frac{R_0}{9}$.

158. (c) To reduce one fourth it takes time $t = 2(T_{1/2}) = 2\times40$

$= 80$ *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 $A' = A - 4n_\alpha$

$= 232 - 4\times6 = 208$

atomic number $Z' = Z + n_\beta - 2n_\alpha$

$= 90 + 4 - 2\times6 = 82$

165. (d)

166. (d) Using conservation of momentum $P_{daughter} = P_\alpha$

$\Rightarrow \frac{E_d}{E_\alpha} = \frac{m_\alpha}{m_d} \Rightarrow E_d = \frac{E_\alpha\times m_\alpha}{m_d} = \frac{6.7\times4}{214} = 0.125\ MeV$

167. (c)

168. (c)

169. (b) $N = N_0\times\left(\frac{1}{2}\right)^{11400/5700} = N_0\left(\frac{1}{2}\right)^2 = 0.25N_0$.

170. (d) Mean life $(T) = 1/\lambda = 100$ *second*

Half-life $= \frac{0.693}{\lambda} = \frac{0.693\times100}{60} = 1.155\ min.$

171. (b) By using $n_\alpha = \frac{A-A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

172. (c)

173. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{77} = 9\times10^{-3}\,/\,day$.

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

$\Rightarrow 5\times10^6\times1.6\times10^{-19} = \frac{1}{4\pi\varepsilon_0}\times\frac{(ze)(2e)}{r}$

For uranium $z = 92$, so $r = 5.3\times10^{-12}\,cm$

2. (c) Speed of electron in n^{th} orbit of hydrogen atom

$v = \frac{e^2}{2\varepsilon_0 nh}$

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

$$= \frac{h}{\lambda}$$

$$= hR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{hR \times 15}{16} = 6.8 \times 10^{-27}\ N \times \text{sec}$$