37.1. a) Using Wein's law,

$$\lambda_p = \frac{(2.9\times 10^{-3}\,m\,K)}{T} = \frac{2.90\times10^{-3}\,m\,K}{273\,K} = 1.06\times10^{-5}\,m$$

The wavelength corresponds to far infrared.

b) $$\lambda_p = \frac{2.9\times10^{-3}\,m\,K}{3500\,K} = 8.29\times10^{-7}\,m$$

This wavelength is in infrared.

c) $$\lambda_p = \frac{2.9\times10^{-3}\,m\,K}{4.2K} = 6.9\times10^{-4}\,m$$

The wavelength is in ~~mic~~ microwave region.

d) $$\lambda_p = \frac{2.9\times10^{-3}\,m\,K}{2.725K} = 1.06\times10^{-3}\,m$$

This wavelength is also in microwave region.

37.7. The energy in a wave packet is -

$$E_1 = hf_1 = \frac{hc}{\lambda_1} = \frac{(6.63\times10^{-34}\,J\,s)(3\times10^8\,m/s)}{410\times10^{-9}\,m} = 4.85\times10^{-19}\,J\left(\frac{1eV}{1.6\times10^{-19}J}\right)$$

$$= 3.03\,eV$$

$$E_2 = hf_2 = \frac{hc}{\lambda_2} = \frac{(6.63\times10^{-34}\,J\,s)(3\times10^8\,m/s)}{750\times10^{-9}\,m} = 2.65\times10^{-19}\,J\left(\frac{1eV}{1.6\times10^{-19}J}\right)$$

$$= 1.66\,eV$$

The range of energy is $2.7\times10^{-19}\,J < E < 4.9\times10^{-19}\,J$

OR $1.7\,eV < E < 3.0\,eV$

37.8. $$\lambda = \frac{c}{f} = \frac{hc}{hf} = \frac{hc}{E} = \frac{(6.63\times10^{-34}\,J.s)(3\times10^8\,m/s)}{(1.6\times10^{-19}\,J/eV)(380\times10^3\,eV)}$$

$$= 3.27\times10^{-12}\,m$$

Diffraction would take place when the wavelength is of the order of the opening of the door which is not the case in real life.

37.14. We know that energy is carried by the photons in a wave. If there are n photons, the min. energy carried by them is -

$$E_{min} = nhf$$

$$n = \frac{E_{min}}{hf} = \frac{E_{min}}{h}\times\frac{\lambda}{c} = \frac{(10^{-18}J)(550\times10^{-9}\,m)}{(6.63\times10^{-34}\,J.s)(3\times10^8\,m/s)} = 2.77 \simeq 3$$

37.17. The max. energy will be emitted when the associated wavelength is min.

$$K_{max} = hf - W_o = \frac{hc}{\lambda} - W_o = \frac{1240\ eV.nm}{410nm} - 2.48\ eV = 0.54\ eV$$

37.42. From De Broglie' wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{mV} \quad \therefore V = \frac{h}{m\lambda}$$

$$= \frac{6.63\times10^{-34}\ J.s}{(9.11\times10^{-31}\ Kg)(0.21\times10^{-9}m)} = 3.466\times10^6 m/s$$

The change in kinetic energy occurs due to change in potential energy -

$$K = eV = \frac{1}{2}mv^2 = \frac{\frac{1}{2}(9.11\times10^{-31}\ Kg)(3.466\times10^6 m/s)^2}{(1.6\times10^{-19}J/eV)}$$

$$= 34.2\ eV$$

Thus the potential associated is $= \frac{34.2eV}{e} = 34.2\ V$

37.46. The de Broglie eq. gives -

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

$$V = \frac{h}{m\lambda} = \frac{6.63\times10^{-34}\ J.s}{(1.67\times10^{-27}\ Kg)(0.3\times10^{-9}m)} = 1300m/s$$

The speed obtained is much smaller compared to relativistic speeds.

37.57. Doubly ionised lithium has same no. of electrons as hydrogen but three positive charges $(z=3)$ instead. We use the result of ionisation as that of hydrogen by replacing e^2 by Ze^2.

$$E_{ion.} = 0 - E_1 = 0 - \left(-\frac{z^2(13.6\ eV)}{n^2}\right)$$

$$= \frac{3^2(13.6\ eV)}{(1)^2} = 122\ eV$$

37.69. The energy emitted is difference in two energy levels.

$$\Delta E = E_U - E_L$$

$$E_U = -\frac{13.6eV}{n^2} = E_L + \Delta E$$

$$\therefore n = \sqrt{\frac{-13.6eV}{E_L + \Delta E}} = \sqrt{\frac{-13.6eV}{-13.6eV + 12.75eV}} = 4$$

The possible transitions from $n=4$ excited state are - $(4\to3)$, $(4\to2)$, $(4\to1)$, $(3\to2)$, $(3\to1)$, $(2\to1)$.

The wavelengths associated are -

$$\frac{1}{\lambda} = (1.097\times10^{7}\,m^{-1})\left(\frac{1}{n_i^2}-\frac{1}{n_f^2}\right)$$

n_i, n_f being the initial and final state of the system.

$$\frac{1}{\lambda_{43}} = 1.097\times10^{7}\,m^{-1}\left(\frac{1}{3^2}-\frac{1}{4^2}\right)$$

$$\therefore \lambda_{43} = 1875\,nm$$

Similarly others are $\lambda_{42} = 486.2\,nm$, $\lambda_{41} = 97.23\,nm$, $\lambda_{32} = 656.3\,nm$, $\lambda_{31} = 102.6\,nm$, $\lambda_{21} = 121.5\,nm$

38.3. $\Delta x\,\Delta p \geqslant \hbar$ $\qquad \hbar = h/2\pi$

$$\Delta x \geqslant \frac{\hbar}{\Delta p} = \frac{\hbar}{m\Delta V} = \frac{1.055\times10^{-34}\,J.s}{1.67\times10^{-27}\,Kg\,(1200\,m/s)} = 5.3\times10^{-11}\,m$$

38.13. a) $\Delta E\,\Delta t \geqslant \hbar$

$$\Delta E \geqslant \frac{\hbar}{\Delta t} = \frac{1.055\times10^{-34}\,J.s}{10^{-8}\,s} = 1.055\times10^{-26}\,J\left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right)$$

$$= 6.59\times10^{-8}\,eV \simeq 10^{-7}\,eV$$

b) The transition energy -

$$\Delta E = E_2 - E_1 = -13.6\,eV\left(\frac{1^2}{2^2}-\frac{1^2}{1^2}\right) = 10.2\,eV$$

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

$$\frac{\Delta E}{E_2-E_1} = \frac{6.59\times10^{-8}\,eV}{10.2\,eV} = 6.46\times10^{-9}$$

c) The wavelength emitted in this transition -

$$\Delta E = hf = \frac{hc}{\lambda}$$

$$\therefore \lambda = \frac{hc}{\Delta E} = \frac{(6.63\times10^{-34}\,J.s)(3\times10^{8}\,m/s)}{10.2\,eV\left(\frac{1.6\times10^{-19}\,J}{eV}\right)} = 1.22\times10^{-7}\,m = 122\,nm$$

$$d\lambda = -\frac{hc}{(E)^2}\,dE \qquad \left(\because E = \frac{hc}{\lambda}\right)$$

$$\Delta\lambda = -\frac{hc}{(E)^2}\,\Delta E = -\frac{\lambda\Delta E}{E}$$

$$|\Delta\lambda| = \lambda\frac{\Delta E}{E} = (122\,nm)(6.46\times10^{-9}) = 7.88\times10^{-7}\,nm$$

38.24. The energy levels for a particle in a box is given by-

$$E_n = \frac{n^2 h^2}{8 m l^2}$$

$$\Delta E = h\nu = \frac{hc}{\lambda} = E_4 - E_1 = \frac{h^2}{8ml^2}(4^2-1^2) = \frac{15h^2}{8ml^2}$$

$$l = \sqrt{\frac{15h\lambda}{8mc}} = \sqrt{\frac{15(6.63\times10^{-34}\,J\,s)(340\times10^{-9}\,m)}{8(9.11\times10^{-31}\,kg)(3\times10^{8}\,m/s)}} = 1.2\times10^{-9}\ m$$

39.1. $l = 0, \ldots, n-1$

$= 0, 1, 2, 3, 4, 5, 6$

39.2. $m_l = -l, -l+1, \ldots, l$

$l = 3, \quad m_l = -3, -2, -1, 0, 1, 2, 3.$ $\qquad m_s = \pm\frac{1}{2}$ for hydrogen atom

39.15. The probability of finding an electron depends on $|\psi_{100}|^2$.

$$\frac{P(r=r_0)}{P(r=2r_0)} = \frac{\left.\frac{4r^2}{r_0^2} e^{-\frac{2r}{r_0}}\right|_{r=r_0}}{\left.\frac{4r^2}{r_0^2} e^{-\frac{2r}{r_0}}\right|_{r=2r_0}} = \frac{\frac{4r_0^2}{r_0^2} e^{-\frac{2r_0}{r_0}}}{\frac{4(2r_0)^2}{r_0^2} e^{-\frac{4r_0}{r_0}}} = \frac{e^{-2}}{4e^{-4}} = \frac{e^2}{4}$$

$\simeq 1.85$

39.28. For $Z=8$, we start with $n=1$ and then go to $n=2$ listing the quantum numbers as (n, l, m_l, m_s).

$(1,0,0,-\frac{1}{2})$, $(1,0,0,\frac{1}{2})$, $(2,0,0,-\frac{1}{2})$, $(2,0,0,\frac{1}{2})$, $(2,1,-1,-\frac{1}{2})$, $(2,1,0,-\frac{1}{2})$
$(2,1,-1,\frac{1}{2})$, $(2,1,0,\frac{1}{2})$.

However $(2,1,1,\frac{1}{2})$, $(2,1,1,-\frac{1}{2})$ could replace last four choices as well.

39.35. The Bohr radius is given by-

$$r_n = \frac{n^2}{Z}(0.529\times10^{-10}\,m) = \frac{1}{92}(0.529\times10^{-10}\,m) = 5.75\times10^{-13}\ m$$

The ionisation energy is given by-

$$|E_n| = (13.6\,eV)\frac{Z^2}{n^2} = (13.6\,eV)\frac{(92)^2}{(1)^2} = 1.15\times10^{5}\ eV$$

The energy required to remove the electron is the opposite of the total energy of the system.

39.42. The wavelength associated with X ray emission is given by-

$$\frac{1}{\lambda} = \left(\frac{e^4 m}{8\varepsilon_0^2 h^3 c}\right)(Z-1)^2\left(\frac{1}{n'^2} - \frac{1}{n^2}\right) = (1.097\times10^{7}\,m^{-1})(27-1)^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$= 5.562\times10^{9}\ m^{-1}$$

$$\lambda = 1.798\times10^{-10}\ m$$

41.12. The kinetic energy initially should be equal to the potential energy on the surface of uranium as it comes to rest there.

$$K_i + U_i = K_f + U_f$$

$$K_\alpha + 0 = 0 + \frac{1}{4\pi\epsilon_0} \frac{q_\alpha q_U}{(r_\alpha + r_U)}$$

$$K_\alpha = (8.988\times10^9\,Nm^2/C^2)\frac{(2)(92)(1.6\times10^{-19}\,C)^2}{(4^{\frac{1}{3}} + 238^{\frac{1}{3}})(1.2\times10^{-15}\,m)(1.6\times10^{-19}\,J/eV)}$$

$$= 2.832\times10^7\,eV \simeq 28\,MeV$$

41.16. a) ${}^7_3Li$ has three protons and ~~th~~ four neutrons.

Binding energy $= [3m({}^1_1H) + 4m({}^1_0n) - m({}^7_3Li)]c^2$

$= [3(1.007825\,u) + 4(1.008665\,u) - (7.016005\,u)]c^2(931.5\,\frac{MeV}{uc^2})$

$=$ ~~$39.24\times10^6\,eV$~~

$= 39.24\,MeV$

Binding energy per nucleon $= \frac{39.24}{7} = 5.61\,MeV/nucleon$

b) ${}^{197}_{79}Au$ has 79 protons and 118 neutrons.

Binding energy $= [79m({}^1_1H) + 118m({}^1_0n) - m({}^{197}_{79}Au)]c^2$

$= [79(1.007825\,u) + 118(1.008665\,u) - (196.966569\,u)]c^2(931.5\,MeV/uc^2)$

$= 1559\,MeV$

Binding energy per nucleon $= \frac{1559\,MeV}{197} = 7.91\,MeV/nucleon$

41.20. ${}^3_1H \rightarrow {}^3_2He + {}^0_{-1}e + \bar{\nu}$

On adding an electron to both sides, if we use the atomic masses, we see that the mass of β particle is included in mass of ${}^3_2He$.

Energy released $= [m({}^3_1H) - m({}^3_2He)]c^2$

$= [(3.016049\,u) - (3.016029\,u)]c^2(931.5\,MeV/uc^2)$

$= 0.019\,MeV$

41.27. a) By balancing charge and mass numbers -

$Z(X) = Z(U) - Z(He) = 92 - 2 = 90$

$A(X) = A(U) - A(He) = 238 - 4 = 234$

$X = {}^{234}_{90}Th$

b) The kinetic energy of α particle will be the Q value of the reaction.

$$K = Q = [m(^{238}_{92}U) - m(^{234}_{90}Th) - m(^{4}_{2}He)]c^2$$

$$m(^{234}_{90}Th) = m(^{238}_{92}U) - m(^{4}_{2}He) - \frac{K}{c^2}$$

$$= \left[238.050788\,u - 4.002603\,u - \frac{4.20\,MeV}{c^2}\left(\frac{1u}{931.5\,MeV/c^2}\right)\right]$$

$$= 234.043\,68\,u$$

41.40. $R = R_0 e^{-\lambda t} = R_0 e^{-\frac{\ln 2}{T_{1/2}} t}$

$$T_{1/2} = -\frac{\ln 2}{\ln \frac{R}{R_0}} t = -\frac{\ln 2}{\ln \frac{320}{1280}} (3.6h) = 1.8h$$

41.43. After ~~I~~ every half life we are left with half of original sample.

$$\frac{N}{N_0} = \left(\frac{1}{2^6}\right) = 0.015625$$

41.44. By equating equal activity, we have-

$$\lambda_1 N_1 = \lambda_{Co} N_{Co}$$

$$\lambda_1 N_0 e^{-\lambda_1 t} = \lambda_{Co} N_0 e^{-\lambda_{Co} t} \qquad \frac{\lambda_1}{\lambda_{Co}} = e^{(\lambda_1 - \lambda_{Co})t}$$

$$t = \frac{\ln(\lambda_1/\lambda_{Co})}{\lambda_1 - \lambda_{Co}} = \frac{\ln\left(\frac{T_{Co\,1/2}}{T_{I\,1/2}}\right)}{\frac{\ln 2}{T_{I\,1/2}} - \frac{\ln 2}{T_{Co\,1/2}}} = \frac{\ln\left[\frac{(5.271\,y)(365.25\,d/y)}{8.0233\,d}\right]}{\ln 2\left[\frac{1}{8.0233\,d} - \frac{1}{(5.271\,y)(365.25\,d/y)}\right]}$$

$$= 63.703\,d$$

41.47. The decay constant is-

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{(8.0233\text{ days})(24h/\text{day})(3600s/h)} = 9.99905 \times 10^{-7}\,s^{-1}$$

N_0 being the no. of nuclei initially.

$$N_0 = \frac{782 \times 10^{-6}\,g}{130.906\,g/mol} \times (6.023 \times 10^{23}\text{ atoms/mol})$$

$\downarrow$ Avogrados no. - no. of atoms in a mol.

$$= 3.596 \times 10^{18}\text{ nuclei}$$

a) $$\left.\frac{dN}{dt}\right|_0 = 9.99905 \times 10^{-7}(3.596 \times 10^{18}) = 3.5957 \times 10^{12}\text{ decays/s}$$

b) $\left.\frac{dN}{dt}\right|_{1h} = (3.\cancel{8}5957 \times 10^{12}\ \text{decay}/s)\ e^{-(9.99905\times10^{-7}s^{-1})(3600s)}$

$\simeq 3.58 \times 10^{12}$ decays/s

c) $\left.\frac{dN}{dt}\right|_{1/3 yr} = (3.5957 \times 10^{12}\ \text{decays}/s)\ e^{-(9.99905\times10^{-7}s^{-1})(0.333 yr)(3.156\times10^7 s/yr)}$

$\simeq 9.72 \times 10^{7}$ decays/s

41.60. We use atomic weight of $^{12}_{6}C$ as atomic weight (85g) due to its abundance. We use the activity to find age of club.

$N_{^{12}_{6}C} = \frac{85 g}{(12 g/mol)} \times 6.02\times10^{23}$ atoms/mol $= 4.264\times10^{24}$ atoms

$N_{^{14}_{6}C} = (1.3\times10^{-12})(4.264\times10^{24}) = 5.543\times10^{12}$ nuclei

$\lambda N_{^{14}_{6}C} = (\lambda N_{^{14}_{6}C})_0\, e^{-\lambda t}$

$t = -\frac{1}{\lambda}\ln\left(\frac{\lambda N_{^{14}_{6}C\ tod.}}{\lambda N_{^{14}_{6}C\ 0}}\right) = -\frac{5730\ yr}{\ln 2}\ln\left[\frac{7\ \text{decays}/s}{\frac{\ln 2}{(5730 yr)(3.156\times10^7 s/yr)}(5.543\times10^{12}\ \text{nuclei})}\right]$

$= 9178$ yr

42.10. The kinetic energy is released which arrives from Q value of reaction –

$Q = m_d c^2 + m_{^{13}_6C} c^2 - m_{^{14}_7N} c^2 - m_n c^2$

$= c^2[2.0140820 + 13.0033550 - 14.0030740 - 1.0086650](931.5\ MeV/c^2/u)$

$= 5.308$ MeV

The total kinetic energy

$K = K_{react.} + Q = 44.4\ MeV + 5.308\ MeV = 49.7\ MeV$

42.24. $Q = m_n c^2 + m_{^{235}_{92}U} c^2 - m_{^{88}_{38}Sr} c^2 - m_{^{136}_{54}Xe} c^2 - 12 m_n c^2$

$= [1.008665u + 235.043930u - 87.905612u - 135.907219u - 12(1.008665)u]\left(\frac{931.5\ MeV/c^2}{u}\right)c^2$

$= 126.5$ MeV

42.28.a) Nucleon no. should be conserved.

no. of n $= N(n) + N(^{235}_{92}U) - N(^{133}_{51}Sb) - N(^{98}_{41}Nb)$

$= 1 + 235 - 133 - 98 = 5$

b) $Q = m_{^{235}_{92}U} c^2 + m_n c^2 - m_{^{133}_{51}Sb} c^2 - m_{^{98}_{41}Nb} c^2 - 5 m_n c^2$

$= [235.043930\,u + 1.008665\,u - 132.915250\,u - 97.910328\,u - 5(1.008665)u] \times \dfrac{(931.5\,MeV)c^2}{uc^2}$

$= 171.1\,MeV$

42.36. $Q = m_{^2_1H} c^2 + m_{^3_1H} c^2 - m_{^4_2He} c^2 - m_n c^2$

$= [2.0140820\,u + 3.0160490\,u - 4.0026030\,u - 1.0086650\,u] \left(\dfrac{931.5\,MeV/c^2}{u}\right) c^2$

$= 17.57\,MeV$

42.63. $c = f\lambda \qquad \lambda = \dfrac{c}{f} = \dfrac{2.998 \times 10^8\,m/s}{42.58 \times 10^6\,Hz} = 7.041\,m$

This corresponds to radio wave spectrum.

36.1. The contracted length is given by-

$l_0 = \dfrac{l}{\sqrt{1 - v^2/c^2}} = \dfrac{38.2\,m}{\sqrt{1 - (0.85)^2}} = 72.5\,m$

36.2. $\Delta t_0 = \Delta t \sqrt{1 - v^2/c^2}$

$= (4.76 \times 10^{-6}\,s)\sqrt{1 - \dfrac{(2.7 \times 10^8\,m/s)^2}{(3 \times 10^8\,m/s)^2}} = 2.07 \times 10^{-6}\,s$

36.7. The speed is found from contracted dist. and the time determined from speed and contracted dist.

$l = l_0 \sqrt{1 - v^2/c^2}$

$v = c\sqrt{1 - \left(\dfrac{l}{l_0}\right)^2} =$

$t = \dfrac{l}{v} = \dfrac{l}{c\sqrt{1 - \dfrac{l^2}{l_0^2}}} = \dfrac{25\,ly}{c\sqrt{1 - \left(\dfrac{25\,ly}{65\,ly}\right)^2}} = \dfrac{(25\,y)\,c}{(0.923)\,c}$

$= 27\,y$

36.13. a) In the earth's frame, the enterprise will run slow.

$\Delta t_0 = \Delta t \sqrt{1 - v^2/c^2} = (5\,yr)\sqrt{1 - (0.74)^2} = 3.4\,yr$

b) On reversing the process -

$\Delta t_0 = \Delta t \sqrt{1 - v^2/c^2} \Rightarrow \quad \Delta t = \dfrac{\Delta t_0}{\sqrt{1 - v^2/c^2}} = \dfrac{5\,yr}{\sqrt{1 - (0.74)^2}}$

$= 7.4\,yr$

36.17. The vertical dimensions will not change but horizontal data will be contracted.

$$l_{base} = \left(\sqrt{1 - v^2/c^2}\right) l = l\sqrt{1-(0.95)^2} = 0.31\,l$$

The angles of the sides with respect to base –

$$\theta = \cos^{-1}\left(\frac{0.5\,l}{2\,l}\right) = 75.52°$$

$$l_{vert.} = 2\,l \sin\theta = 2l \sin 75.52° = 1.936\,l \quad \text{(unchanged)}$$

Horizontal component – $2\,l\cos\theta = 2\,l\left(\frac{1}{4}\right) = 0.5\,l$ at rest.

$$l_{hor.} = 0.5\,l\sqrt{1-\frac{v^2}{c^2}} = 0.5\,l\sqrt{1-(0.95)^2} = 0.156\,l$$

From Pythagoras theorem,

$$l_{leg} = \sqrt{l^2_{hor.} + l^2_{ver.}} = \sqrt{(0.156\,l)^2 + (1.936\,l)^2} = 1.942\,l$$