ICPY473 Nuclear Physics-Final Examination

MUIC, Third Trimester, 2021

Take Home Exam

Date: 07/22/2021, Due date: 07/23/2021

Exam note: write or type your solutions and submit in a single file to my email: *udom.rob@mahidol.ac.th*.
Exam Questions

1. (10 pt.) The decay equation of decay chain $X_1 \xrightarrow{\lambda_1} X_2 \xrightarrow{\lambda_2} X_3$, where X_3 is stable, reads

$$\frac{dN_1(t)}{dt} = -\lambda_1 N_1(t), \ \frac{dN_2(t)}{dt} = -\lambda_2 N_2(t) + \lambda_1 N_1(t), \ \frac{dN_3(t)}{dt} = \lambda_2 N_2(t)$$

Derive solutions of $N_1(t), N_2(t), N_3(t)$, with initial conditions $N_1(0) \neq 0, N_2(0) = N_3(0) = 0$.

2. (10 pt.) From liquid drop model of atomic nucleus, we have Bethe-Weizsacker formula for nuclear binding energy in the form

$$E_b = a_V A - a_S A^{2/3} - a_C \frac{Z(Z-1)}{A^{1/3}} - a_A \frac{(A-2Z)^2}{A^{1/3}} + \delta(A, Z)$$

where $a_V = 15.85MeV, a_S = 18.34MeV, a_C = 0.714MeV, a_A = 23.21MeV$ while

$$\delta(A, Z) = \begin{cases} +a_P/A^{1/2} & A, Z - even \\ 0 & A - odd \\ -a_P/A^{1/2} & A, Z - odd \end{cases}, \ a_P = 12.00MeV$$

3. (10 pt.) According to Gamow theory of alpha emission by quantum tunneling through Coulomb barrier, we derive Geiger-Nuttal law in the form

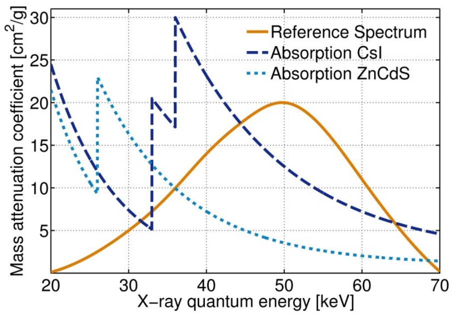
$$\log t_{1/2} = 1.61 \left(Z E_\alpha^{-1/2} - Z^{2/3} \right) - 28.9$$

Let estimate the half-life time the α-decay ${}^{239}_{94}Pu \to {}^{235}_{92}U + \alpha$. Evaluate the binding energy per nucleon of the following nuclei (a) ${}^{40}Ca$, (b) ${}^{58}Fe$, and (c) ${}^{208}Pb$.

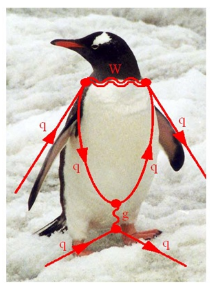
4. (10 pt.) Determine the nuclear reaction ${}^{197}_{79}Au(\alpha, d){}^{199}_{80}Hg$, evaluate the reaction energy Q. Is it exoergic or endoergic reaction? Evaluate threshold energy if it is endoergic reaction.

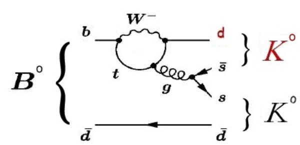
5. (10 pt.) Give a description of p-p cycle for thermonuclear process on the Sun, i.e., how many protons used in one cycle and how much energy released after one cycle, and what are the end elements of the cycle.

6. (10 pt.) Characteristic of gamma radiations interaction with matter is its Halve-Value Thickness (HVT) $x_{1/2}$. It relates to attenuation coefficient μ as $x_{1/2} = \frac{0.693}{\mu}$. Mass attenuation coefficient is defined to be $\mu_m = \frac{\mu}{\rho}$, where ρ is mass density of matter measure in unit of g/cm^3. Since $[\mu] = cm^{-1}$, so that $[\mu_m] = cm^2/gm$. From the graph of mu_m below, evaluate the HVL of 50 keV X-rays in CaI and ZnCdS. ($\rho_{CsI} = 4.51g/cm^3$, $\rho_{ZnCdS} = 4.0g/cm^3$)



7. (10 pt.) B mesons are mesons composed of a bottom antiquark, i.e., $B^0 = d\bar{b}$ and $M(B^0) = 5.279 GeV/c^2$. One of its hadronic decay mode is $B^0 \to K^0 + K^0$, it is represented by famous *penguin diagram* below. Evaluate the energy-momentum of two K^0 in the rest frame of B^0. $((M(K^0) = 497.661 MeV/c^2)$





8. (10 pt.) One of the basic strong interaction is $p + \bar{p} \to n + \bar{n}$. From quark compositions $p = uud, n = udd$, draw the Feynman diagram of the above interaction in term of quark interaction by gluon exchange. (Note that $\bar{p} = \bar{u}\bar{u}\bar{d}, \bar{n} = \bar{u}\bar{d}\bar{d}$.)

9. (10 pt.) Weak decay of Lambda baryon is $\Lambda^0 \to p + \mu^+ + \nu_\mu$. Quark structure of baryons are $\Lambda^0 = uds, p = uud$. Draw diagram of this weak decay in term of quark interaction by weak gauge boson W^-.

10. (10 pt.) Free discussion on your best understanding of part of the lecture I have been given, and your expectation to be derived from my class.