

M. Sc. (Physics) 4th Semester Examination 2019 PHY 522 (Nuclear Reactions and Nuclear Astrophysics)

nswer in your own words as far as practicable. The marks on the right-hand margin indicate the full marks for the question.

_{ull} Marks: 50

Time: 2 Hours

Answer Q. 1 and any three from the rest

1. Answer any five

- (a) Write the steps of 3α reaction and explain the formation of ${}^{12}C$. What is the spin and parity of the Hoyle resonance in ${}^{12}C$ and why?
- (b) In primordial nucleosynthesis, why the nucleosynthesis started so late until the thermal energy kT is around 100 keV and why did it stop after producing A=7 nuclei?
- (c) Why is germanium more preferred for γ -ray detection, compared to silicon? Why is hyper pure germanium used for detector material ? Why are germanium detectors operated at liquid nitrogen temperature ?
- (d) What is the difference between photoelectric absorption and Compton scattering? How is the probability of photoelectric absorption dependent on the atomic number of the medium? For a 10 MeV photon undergoing Compton scattering, which among a forward and a backward angle is more probable direction for the scattered photon?
- (e) What is the dimension of stopping power? What is range and energy straggling of charged particles passing through a given medium ? Illustrate the quantities, mean range and extrapolated range. through a plot.
- (f) Write down the expression of Q value for the alpha transfer reaction ${\rm ^{12}C(^6Li,d)}$. Explain why alpha transfer is a probable reaction in this case.
- 2. a) Using the Breit Wigner one-level formula for an isolated resonance, find out the expression for $\langle \sigma v \rangle$, the reaction rate per interacting particle pair forming the resonance, in terms of the resonance strength.
 - b) Show that the resonance strength is proportional to the area under the resonance curve.

c) In a capture reaction, if the energy of a resonance between the two intercating particles lies much below the Coulomb barrier between the two, then the resonance strength and reaction rate depend strongly on the particle decay width. Explain.

5 + 2 + 3

 4×5

3. (a) Derive the expression for the excitation energy of the compound nucleus (^{A+1}X) formed by the following neutron induced reaction on the target ${}^{A}X$

$$n + A X \to A+1 X$$

(b)Calculate the excitation energy when the target is (i) ²³⁵U and (ii) ²³⁸U when the neutron has no kinetic energy (Given Binding energies per nucleon of 235, 236, 238 and 239 Uranium isotopes 6 + 4are 7.591, 7.586, 7.570 and 7.559 MeV respectively.)

4. (a) What is Compton suppression and why is it required in γ -ray spectroscopy ?

(b) Why do semiconductor detectors have better energy resolution than scintillator based ones?

(c) Which among ionization chamber and proportional counter would you prefer for detection of low energy radiation and why ?

(d) What is list mode data? How is it more detailed than the histogram mode?

(e) Determine the linear calibration coefficients of a system wherein the centroid of the 1173.2 keV energy peak appears at channel number 1399 and that of 1332.5 keV at 1588 of the corresponding spectrum. Mention the units of the calibration coefficients.

3+1+2+2+2

5. (a) Write the reaction steps in *ppI* chain of hydrogen burning stage of stellar nucleosynthesis and construct the rate equations for each step.

(b) Find the relation between the concentration ratio of deuteron to hydrogen at equilibrium and the mean lifetimes of the reactions p + p and d + p in the pp chain.

(c) Taking the total energy production rate in the Sun undergoing hydrogen burning stage as $5.1 \times 10^7 MeV.g^{-1}.s^{-1}$ and its luminosity as $2.4 \times 10^{39} MeV.s^{-1}$, find

i) Mass of hydrogen used up in the process to maintain the luminosity; ii) Number of processes converting $4H \rightarrow {}^{4}He$ required to generate the luminosity; iii) The age of the Sun for the given rate of energy production.

Given the mass of H as 1.6×10^{-19} g and energy produced in converting $4H \rightarrow {}^{4}He$ is 26.7 MeV.

3 + 2 + 5

6. (a) Show that if the scattering wavefunction is expressed as

$$\chi = \sum_{n=1}^{N} A_n \omega_n$$

the basis functions ω_n , ω_m for two different resonance states are orthogal i.e.

$$\int_{0}^{R_{0}}\omega_{n}\omega_{m}dr=0~~(n
eq m)$$

(b) Using the orthonormality of the basis functions show that the one channel N pole R-matrix at energy E is given by the expression

$$R(E) = \sum_{n=1}^{N} \frac{\gamma_n^2}{\epsilon_n - E}$$

where γ_n^2 is the reduced width and ϵ_n are the pole energies.

4+6