Extra

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester 2018-19

Date of Examination : ____________ Session (FN/AN) ____ Duration 2 hrs Full Marks ____

Subject No.: PH41019 Subject: NUCLEAR AND PARTICLE PHYSICS -II

Department/Center/School ______________________

Specific charts, graph paper, log book etc., required ____________

Special Instructions (if any) : ______________________

Answer all questions Marks 30

1. The Q-value of the reaction

$$\left[{}^{14}N\left({}^{1}H, {}^{3}H\right){}^{12}N\right]$$

is $Q = -22.1355$ MeV/c^2 (1 u = 931.5 MeV/c^2). Given the mass of $m({}^{3}H) = 3.016\ u$, and the mass differences:

$$m(C_9H_{20}) - m(C_{10}H_8) = 0.0939\ u; \quad \text{and} \quad m(C_2H_4) - m(N_2) = 0.02515\ u$$

find $m({}^{12}N)$.

2. A compound nucleus ${}_{30}Zn^{64}$ may be formed by either bombarding a ${}_{28}Ni^{60}$ with an alpha (α) particle or bombarding a ${}_{29}Cu^{63}$ with a proton. The compound nucleus ${}_{30}Zn^{64}$ then decays producing $n, 2n$ and pn. Write down all the six reactions involved in the above processes and describe how these reactions could be used to prove Bohr's hypothesis of compound nucleus. Show that the decay rate of the compound nucleus ($G_C(y)$) depends only on the cross-section of the decay channel ($\sigma_C(y)$) and not the cross-section of formation of the compound nucleus($\sigma_C(x)$).

3. Given the scattering cross-section in the form

$$\sigma_{sc} = \frac{\pi}{k^2}|1 - \eta|^2$$

show that the reaction cross-section is proportional to Im[1/a], where

$$\eta = e^{2i\delta}$$

and the phase shift δ is related to the scattering length 'a' by the relation:

$$k\ \cot\delta = -\frac{1}{a}.$$

4. Starting with the effective magnetic dipole moment of the neutron-proton system,

$$\vec{\mu}_{eff} = \vec{\mu}_p \, \vec{\sigma}_p + \vec{\mu}_n \, \vec{\sigma}_n + \vec{L} \, \vec{\mu}_N$$

where $\vec{\sigma}$ are the Pauli matrices and related to the intrinsic spin of the neutrons and protons

$$\vec{s}_{p,n} = \frac{1}{2} \, \vec{\sigma}_{p,n}$$

determine the deuteron magnetic dipole moment for the states $\ell = 0$ and $\ell = 2$. Explain why there are no contibutions to the magnetic dipole moment of the deuteron from the $\ell = 1$ or $\ell = 3$ state.

5. The asymptotic form of the wave function (for $\ell = 0$) is given as

$$\psi(r) = \frac{\sin kr}{kr}$$

for $V = 0$ (in absence of nuclear force). Include the phase shift δ due to the nuclear interaction $V \neq 0$ in the asymptotic form of the wave function and calculate the total scattering cross-section in terms of the scattering length defined as

$$a = \lim_{k \to 0} \left(-\frac{\sin \delta}{k} \right).$$

Interpret the sign of the scattering length, plotting the wave function for small 'k'.

6. For a resonant scattering at $E = E_R$, expand the function $\cot \delta_\ell(E)$ around $E = E_R$ and define

$$\left(\frac{\partial \cot \delta_\ell}{\partial E} \right)_{E=E_R} = -\frac{\Gamma}{2}$$

where δ_ℓ is the phase shift for the angular momentum state ℓ. Find the scattering cross-section and interpret the significance of the decay width Γ drawing a typical resonance diagram for the scattering cross-section versus energy. State the relationship between Γ and the lifetime of the resonance, when there are multiple decay channels.