UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF PHYSICS

MODULE **PHY 8X16**
Nuclear Physics 1

CAMPUS **APK**

EXAM **Supplementary, July, 2019**

DATE: July, 2019 **SESSION:** 08:30 – 10:30

ASSESSOR(S): Prof S Karataglidis

EXTERNAL MODERATOR: Dr R Bark (iThemba LABS)

DURATION: 2 Hours **MARKS**: 90

NUMBER OF PAGES: 5 pages including cover and information sheets.

INSTRUCTIONS:

1. ANSWER ALL QUESTIONS.
2. PENCILS AND CELLPHONES ARE **NOT** PERMITTED.
3. NON-PROGRAMMABLE CALCULATORS ARE PERMITTED.

QUESTION 1 (20)

Fig. 1 shows the low-energy isobar diagram for the mass-18 nuclei.

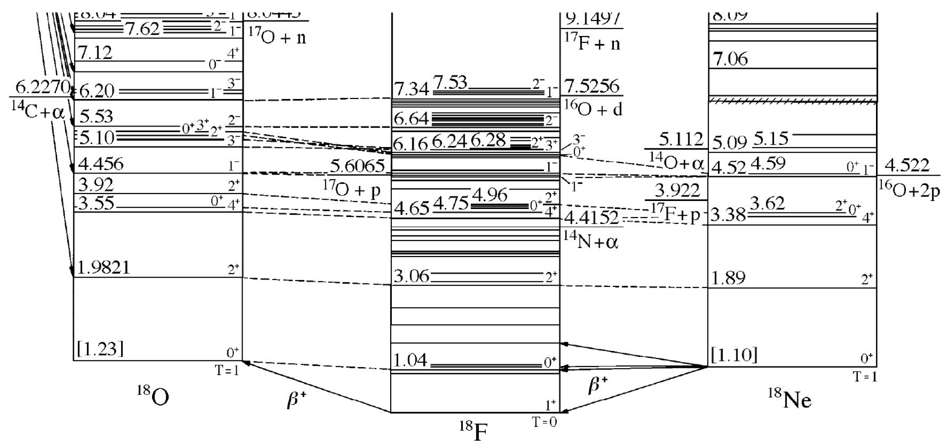

Fig. 1 Low-energy isobaric diagram for the mass-18 system.

(a) Fig. 1 shows the low-lying states in the mass-18 nuclei. Identify the isotriplets relative to the ground state energy of ^{18}F.

(10)

(b) Describe the simplest wave functions of the ground states of ^{18}O, ^{18}F, and ^{18}Ne. Are these realistic? Discuss in terms of the energies of these states.

(10)

QUESTION 2 (30)

(a) Show that

$$\psi_0 = e^{i\delta_0} \frac{\sin(kr + \delta_0)}{kr}$$

is a solution of the Schrödinger equation for $l = 0$ and $V = 0$.

(10)

(b) Matching $l = 0$ wave functions at the boundary $r = b$ of a square well, repulsive core, potential for np scattering gives the condition

$$K \cot Kd = k \cot(kb + \delta_0)$$

for s-wave scattering. Assuming that the triplet S phase shift $\delta_0 = 0$ at $E = 350$ MeV, $V_0 = 73$ MeV, and $d(= b - c) = 1.337$ fm find the repulsive core parameter c.

(10)

(c) By appealing to the uncertainty principle, determine the mass of the exchange meson in the Yukawa picture of the nucleon-nucleon interaction. What may be the best candidate for such a meson? Discuss.

(10)

QUESTION 3 (20)

(a) What are the possible angular momenta for the ground states states of ${}^{7}_{3}$Li, ${}^{11}_{6}$C, ${}^{13}_{6}$C, ${}^{17}_{8}$O, and ${}^{53}_{20}$Ca?

(10)

(b) What are the possible angular momenta for the ground states of ${}^{14}_{7}$N, ${}^{18}_{9}$F, and ${}^{42}_{19}$K?

(10)

QUESTION 4 (20)

Fig. 2 shows the low-lying spectrum for ^{114}Cd.

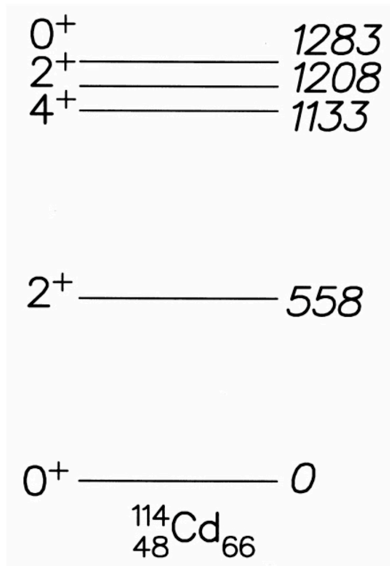

Fig. 2 Part of the spectrum for ^{114}Cd (energies in keV).

(a) Identify the kind of collective motion suggested by this spectrum. Briefly explain, and determine the parameter(s) involved.

(10)

(b) Is this type of collective motion an appropriate description for this nucleus? Discuss.

(10)

FORMULAE SHEET FOR NUCLEAR PHYSICS

Radial Schrödinger Equation:

$$\frac{d^2u}{du^2} + \frac{2\mu}{\hbar^2}\left[E - V - \frac{l(l+1)}{2\mu r^2}\right]u = 0;\ u = rR_{nl}(r).$$

Shell model The ordering of the orbits are

$$0s_{1/2},\ 0p_{3/2},\ 0p_{1/2},\ 0d_{5/2},\ 1s_{1/2},\ 0d_{5/2},\ 0f_{7/2},\ 1p_{3/2},\ 0f_{5/2},\ 1p_{1/2},$$
$$0g_{9/2},\ 1d_{5/2},\ 0g_{7/2},\ 2s_{1/2},\ 1d_{3/2}.$$

Energy levels of a vibrational nucleus:

$$E_{n_\beta n_\gamma} = \hbar\omega_\beta\left(n_\beta + \frac{1}{2}\right) + \hbar\omega_\gamma\,(2n_\gamma + 1)$$
$$n_\beta, n_\gamma = 0, 1, 2, 3, \ldots$$

Energy levels of a rotational nucleus:

$$E_K(J) = \frac{\hbar^2}{2\mathcal{J}_0}\left[J(J+1) - K^2\right]$$