UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	ATOMIC AND NUCLEAR PHYSICS
COURSE CODE	:	BWC 20903
PROGRAMME	:	BWC
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

Q1 (a) Explain the structure of an atomic nucleus.

(4 marks)

(b) The radius r of a nucleus with mass number A can be estimated by $r = r_0 A^{1/3}$. Determine r_0 in unit femtometer [fm] (femto = 10^{-15}) if the density of all nuclei is approximately a constant with the value of 2.3×10^{17} kg m^{-3}. (The average mass of a nucleon is equal to 1.6738×10^{-27} kg)

(6 marks)

(c) Explain the mechanism of nuclear force and electromagnetic force that are present inside the atomic nuclei.

(6 marks)

(d) Describe **TWO (2)** properties of the atomic nuclei that permit the establishment of the liquid drop model.

(4 marks)

Q2 (a) The nuclear binding energy B for ${}^{235}_{92}U$ that corresponds to its mass defect is 1782.9042 MeV. Calculate the rest mass of ${}^{235}_{92}U$ in unit u.
(Given that 1u = 1.6605×10^{-27} kg = 931.494 MeV/c^2 , rest mass of a proton= 1.6726×10^{-27} kg, rest mass of a neutron=1.6749×10^{-27} kg and rest mass of an electron= 9.109×10^{-31} kg)

(6 marks)

(b) The nuclear binding energy B (in MeV) from liquid drop model using Weizsäcker Bethe- semi empirical mass formula is given by:

$$B = (i)15.56A \quad (ii)17.23A^{2/3} \quad (iii)0.697\frac{Z^2}{A^{1/3}} \quad (iv)23.285\frac{(N-Z)^2}{A} + \delta,$$

$$\delta = \begin{cases} +\dfrac{130}{A} & \text{(for even-even nuclei)} \\ 0 & \text{(for even-odd or odd-even nuclei)} \\ -\dfrac{130}{A} & \text{(for odd-odd nuclei)} \end{cases}$$

(i) State the name of the terms and predict the suitable sign ("+" or "-") for (i), (ii), (iii) and (iv) of the above equation.

(8 marks)

(ii) Using the equation, calculate B value for ${}^{235}_{92}U$ and compare the result with the nuclear binding energy stated in **Q2(a)**.

(6 marks)

Q3 (a) According to the nuclear shell model, the energy states in the ascending order of nucleons inside a nucleus are as depicted in the **Figure Q3(a)**. The degeneracy of each level is due to the effect of spin-orbital interaction.

(i) In **Figure Q3(a)**, the spin, j for 1s and 1g level are already given. Estimate the spin, j for the rest of the quantized energy levels.

(6 marks)

(ii) Determine the nuclear spin for the following nuclides: ${}^{16}_{8}O$, ${}^{101}_{44}Ru$, and ${}^{113}_{49}In$.

(6 marks)

(b) Determine the energy released in the alpha decay of:

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

The mass of ${}^{238}_{92}U$, ${}^{234}_{90}Th$, and ${}^{4}_{2}He$ are 238.048608u, 234.043583u and 4.002603u, respectively. (Use $c^2 = 931.494$ MeV/u)

(4 marks)

(c) Distinguish the positive electron emission decay and negative electron emission decay. Provide the suitable decay equations representing each decay process.

(4 marks)

Q4 (a) The rate of change of the number of radioactive nuclei N is given by:

$$\frac{dN}{dt} = -\lambda N$$

where λ is the nuclei's decay constant. Assuming that the number of this radioactive nuclei at $t = 0$ is N_0, prove that the number of radioactive nuclei N decreases exponentially with time.

(6 marks)

(b) A rock sample contains traces of ^{238}U, ^{235}U, ^{232}Th, ^{208}Pb, ^{207}Pb, and ^{206}Pb. The analysis shows that the ratio of the amount of ^{238}U to ^{206}Pb is 1.164. Assuming that the rock originally contained no lead, calculate the age of the rock. (Given the half-life $T_{1/2}$ of ^{238}U is 4.47×10^9 year)

(6 marks)

(c) One of the reactions that occurs when ^{10}B (boron) is bombarded by neutrons is

$${}^{10}B(n,\alpha)^{7}Li,$$

where n refers to the bombarding neutron. The mass for ^{10}B, n, alpha particle and ^{7}Li are 10.012937u, 1.008665u, 4.002603u and 7.016004u, respectively. Calculate the Q value of this reaction and subsequently conclude whether this reaction is exothermic or endothermic. (Use $c^2 = 931.494\,MeV/u$)

(4 marks)

(d) An aluminum foil of thickness 0.30 mm is bombarded by energetic neutrons. The aluminum nuclei undergo neutron capture according to the process ^{27}Al(n,γ)^{28}Al, with a measured capture cross section of 2.0×10^{-31} m^2. Assuming the flux of incident neutrons to be 5.0×10^{12} neutrons/ cm$^2\cdot$s, calculate the number of neutrons captured per second by 1.0 cm^2 of the foil. (The density of aluminum is 2.7 g cm^{-3})

(4 marks)

Q5 (a) Explain the importance of chain reaction in fission reactor.

(4 marks)

(b) The rate of public acceptance towards nuclear power is considerably low, even in a well developed nation. Indentify the causes and suggest appropriate approaches in order to enhance this rate.

(6 marks)

(c) In fusion reaction, atoms are ionized and thus the system consists of a collection of electrons and nuclei, commonly referred to as plasma. The success of fusion reaction relies heavily on the confinement of the plasma.

(i) Differentiate the mechanism of magnetic field confinement and inertia confinement.

(6 marks)

(ii) List **TWO (2)** technological challenges for fusion reactor, other than the confinement of plasma.

(4 marks)

- END OF QUESTIONS -

FINAL EXAMINATION

SEMESTER/ SESSION	: SEM I/ 2019/2020	PROGRAMME CODE	: BWC
COURSE NAME	: ATOMIC AND NUCLEAR PHYSICS	COURSE CODE	: BWC 20903

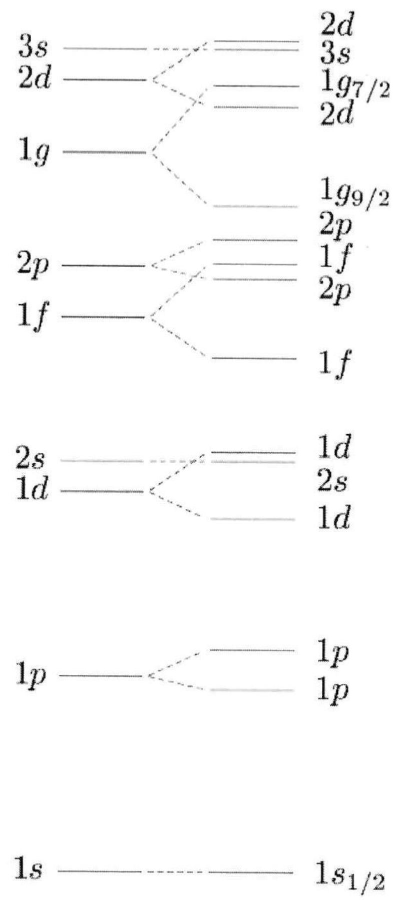

Figure Q3 (a)