UNIVERSITY OF SRI JAYEWARDENEPURA
FACULTY OF APPLIED SCIENCES

Bachelor of Science Degree Second Year Second Semester Course Unit Examination – February/March 2024

DEPARTMENT OF PHYSICS

PHY 208 1.0 and Atomic & Nuclear Physics

Time: Two (01) hour | No. of questions: 20 | No. of pages: 04 | Total marks: 100

Instructions:

1. Write your Index number in the box.
2. Answer ALL questions.
3. Select and circle correct answers or fill in the blanks with appropriate words or statements on the exam paper. Symbols have their usual meanings.
4. The following Physical constants are provided.

Index #:

$1\,eV = 1.6 \times 10^{-19}\,J$, $h = 6.624 \times 10^{-34}\,Js$, $c = 3 \times 10^{8}\,ms^{-1}$, and $\frac{1}{4\pi\epsilon_0} = 9 \times 10^{9}$ SI units

1-4. Fill in the blanks by selecting suitable words from the list given below.

(discrete, bar code readers, scanning electron microscope, continuous, frequencies, force, wavelengths, momentum, atomic force microscope, GPS, atoms)

i. Atomic clocks and lasers use transitions between …….. energy levels to produce photons with precisely defined …….. .

ii. They are used in many applications, including the ……, …… and CD and DVD players.

iii. The …… between two atoms is also large enough to be measured in an ……, which uses this …… to form an image of …… on the surface of an object.

**(Total: 16 marks)**

5. Which statement is **incorrect** about the four quantum numbers which describe electrons in atoms?

i. n = principal quantum number, n = 1, 2, 3, .....
ii. $l$ = azimuthal quantum number, $l$ = 1, 2, 3, ... , (n+1)
iii. $m_l$ = magnetic quantum number, $m_l$ = (-$l$), .... , 0, .... , (+$l$)
iv. $m_s$ = spin quantum number, $m_s$ = +1/2 or -1/2.
v. $m_l$ is related to the orientation of atomic orbitals in space.

**(Total: 04 marks)**

6. Which atomic orbital is spherical in shape?

i. 2s
ii. 3p
iii. 3d
iv. 4f
v. they are all spherical

**(Total: 04 marks)**

7. A neutral atom of an element has 2 electrons in the first energy level, 8 in the second energy level and 8 in the third energy level. This information does not necessarily tell us about which one of the followings?

i. the atomic number of the element.
ii. anything about the element's chemical properties.
iii. the total number of electrons in s orbitals.
iv. the total number of electrons in p orbitals.
v. the number of neutrons in the nucleus of an atom of the element.

**(Total: 04 marks)**

8. Which one of the following sets of quantum numbers **could** be those of the distinguishing electron of the outer most shell of Molybdenum (Mo)? (Mo; atomic number is 42)

i. $n = 4, l = 0, m_l = 0, m_s = +1/2$
ii. $n = 5, l = 1, m_l = 9, m_s = -1/2$
iii. $n = 4, l = 2, m_l = -1, m_s = +1/2$
iv. $n = 5, l = 2, m_l = +2, m_s = -1/2$
v. $n = 3, l = 2, m_l = 0, m_s = +1/2$

**(Total: 04 marks)**

Question numbers **9** and **10** are based on the following information.
A $K_\alpha$ X-ray photon is emitted from a tungsten anode in an X-ray tube. Consider that, two electrons occupy a filled K shell and a vacancy in this shell would leave one electron. For multi-electron atoms, the nuclear charge Ze is largely canceled or shielded by the negative charge of inner electrons. For allowed energies, for one electron atom in various orbits is given by,

$$E_n = \left(\frac{-13.6\, Z_{eff}^2}{n^2}\right) eV \text{ , for tungsten, Z = 74.}$$

9. What is the energy of the emitted $K_\alpha$ X-ray photon?

i. 66.09 keV
ii. 54.4 keV
iii. 47.4 keV
iv. 72.47 keV

10. What is the wavelength of the emitted $K_\alpha$ X-ray photon?

i. 0.188 Å
ii. 0.228 Å
iii. 0.358 Å
iv. 0.488 Å

**(Total: 08 marks)**

11. Rutherford's Gold foil experiments demonstrated the existence of which of the following?

i. proton
ii. neutron
iii. nucleus
iv. positron

**(Total: 04 marks)**

12. Which pair of species will have the same electronic configuration for both members?

i. He and $Ne^+$
ii. H and Li
iii. C and $N^+$
iv. $Li^+$ and $Na^+$

**(Total: 04 marks)**

13. . What is the naturally occurring isotope in a banana that gives it its radioactivity?

i. K-40
ii. O-16
iii. H-1
iv. C-12

**(Total: 04 marks)**

14. Scattering experiments help us to study matter too small to be observed directly. There is a relationship between the impact parameter $p$ and the scattering angle $\theta$.

$$\tan\frac{\theta}{2} = \frac{2Ze^2}{8\pi\epsilon_0 Kp} \quad ; \quad \text{and } K \text{ is the Kinetic energy.}$$

What is the impact parameter of a 5 MeV alpha particle scattered by $10^0$ when it approaches a gold nucleus? For Gold Z = 79.

i. $2.6 \times 10^{-19}\, m$
ii. $5.6 \times 10^{-14}\, m$
iii. $1.6 \times 10^{-19}\, m$
iv. $1.5 \times 10^{-14}\, m$

**(Total: 04 marks)**

15. The Balmer series, or Balmer lines in atomic physics, is one of a set of six named series describing the spectral line emissions of the hydrogen atom. The wavelength of Balmer $H_\alpha$ line is 6563 Å. What is the wavelength of $H_\beta$ line?

i. 4861 Å
ii. 4340 Å
iii. 4100 Å
iv. 4200 Å

**(Total: 04 marks)**

16. The tracer ${}^{123}_{53}I$ (iodine)is used to treat thyroid problems. This nucleus is produced by bombarding xenon with protons in the reaction.

$${}^{1}_{1}H + {}^{124}_{54}Xe \rightarrow {}^{123}_{53}I + ?$$

Assuming the question mark represents a single type of nucleus, what is that nucleus?

i. $2\,{}^{1}_{1}H$
ii. ${}^{6}_{3}Li$
iii. ${}^{4}_{2}He$
iv. ${}^{2}_{2}H$

**(Total: 04 marks)**

17. The isotope ${}^{20}_{9}F$ is used in a medical procedure called positron emission tomography. (PET). The half-life of ${}^{20}_{9}F$ is approximately 110 minutes. If your doctor has a sample with 16 g pure ${}^{20}_{9}F$ at t=0, how much ${}^{20}_{9}F$ will he have 330 minutes later?

i. 12 g
ii. 8g
iii. 4g
iv. 2g

**(Total: 04 marks)**

18. Who invented nuclear fission?

i. Rutherford
ii. Hans Bethe
iii. Otto Han
iv. Marie Curie

**(Total: 04 marks)**

19. In the fission reaction $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{138}_{54}Xe + ^{95}_{38}Sr + 3^{1}_{0}n$ , the isotope $^{235}_{92}U$ has a mass of 235.04392 u, the mass of $^{124}_{54}Xe$ is 137.91395 u and the mass of $^{95}_{38}Sr$ is 94.91936 u. How much energy does this reaction release?
(the mass of neutron is 1.008 u and 1 u = 931.5 MeV/$c^2$)

i. 180 MeV
ii. 400 MeV
iii. 100 MeV
iv. 380 MeV

**(Total: 04 marks)**

20. **Webinar Question**: Briefly discuss the potential advantages and disadvantages of adopting nuclear power, considering factors such as economic feasibility, safety considerations, and public perception. Propose recommendations for policymakers on whether to pursue nuclear energy as a significant component of Sri Lanka's energy mix.

**(Total: 24 marks)**

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