2014

PHYSICS

(Major)

Paper : 5.2

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct option : 1×7=7

(a) The maximum number of electrons in the *d*-subshell of an atom is

(i) 2

(ii) 8

(iii) 10

(iv) 18

(b) Into how many components the $2S_{1/2}$ level of Na may split when a weak magnetic field is applied to result in anomalous Zeeman effect?

(i) 2

(ii) 3

(iii) 4

(iv) 5

(c) From which of the following concepts an explanation of the Bohr quantum condition $L_n = N\frac{h}{2\pi}$ may be found?

(i) Rayleigh scattering

(ii) Planck's idea of quantum

(iii) Louis de Broglie matter wave

(iv) Raman effect

(d) An atom emits X-rays when an orbital electron makes a transition from the kth to the nth orbit, where $k > n$. Which of the following is the most probable case of X-ray emission?

(i) $n = 1,\ k = 2$

(ii) $n = 1,\ k = \infty$

(iii) $n = 4,\ k = 8$

(iv) $n = 4,\ k = \infty$

(e) A high-energy electron strikes a metal of high atomic number. If Q_L, Q_X, Q_S and Q_H be the amounts of energy that appear as light, X-rays, sound and heat respectively, then which of the following is correct?

(i) $Q_L = Q_S = 0$

(ii) $Q_S = 0,\ Q_H < Q_X$

(iii) $Q_L \neq 0,\ Q_H > Q_X$

(iv) $Q_X > Q_L,\ Q_H = 0$

(Continued)

(f) The energy levels of an atom are –20 eV, –10 eV, –5 eV, –2 eV and –0·5 eV, ... A high-energy electron accelerated through a potential difference V strikes and ionizes the atom. The value of V is

(i) 20 volt

(ii) 19·5 volt

(iii) 10 volt

(iv) 12 volt

(g) Which of the following cannot emit visible radiations?

(i) H

(ii) He

(iii) He^+

(iv) He^{++}

2. Answer any *four* of the following questions : 2×4=8

(a) In Rutherford α-scattering experiment, it was found that 1×10^6 particles were scattered at an angle 60° per minute. How many α-particles per minute were observed at an angle 180°?

(Turn Over)

(b) An electron in motion is equivalent to an electric current. Show that the electronic current I in a hydrogen-like atom is $I \propto \frac{Z^2}{n^3}$, where the symbols have their usual meanings.

(c) Mention two differences as regards wavelength and intensity of observed light in case of Rayleigh scattering and Raman effect.

(d) An X-ray tube operates at 40 kV and the partial vacuum inside the tube offers a resistance of 5 MΩ. How many electrons strike the target per second?

(e) The wavelength of the spectral lines emitted by a hydrogen-like atom for a transition $a \rightarrow b$ is given by

$$\lambda = \frac{120a^2}{a^2 - b^2} \text{ nm}$$

where $a > b$ and $b = 1$. What are the shortest and the longest wavelengths emitted by the atom?

(f) A particle of mass $3 \cdot 2 \times 10^{-27}$ kg passes through the velocity selector of a Bainbridge mass spectrograph. The electric field and the magnetic field used

in the velocity selector are respectively 30 kV m^{-1} and 0·1T. What is the kinetic energy, in eV, with which the particle enters the evacuated D-shaped chamber of the spectrograph?

3. Answer *(a)* and any *two* from *(b)*, *(c)* and *(d)* : 5×3=15

(a) Describe Paschen-Back effect, and show that using proper selection rules, one can get spectral lines corresponding to normal Zeeman effect.

(b) Show that the radii of stable orbits in a hydrogen-like atom are proportional to n^2 / Z, where n is the principal quantum number and Z is the atomic number.

(c) In an experiment on normal Zeeman effect, light of wavelength 600 nm was used. The applied magnetic field was $\frac{\pi}{10} T$. It was seen that the wavelength separation between the two component lines was 0·0102 nm. What was the value of e/m of electron determined from the experiment?

(d) Write a short note on any *one* of the following :

(i) Alkali spectra

(ii) Sommerfeld's relativistic correction of Bohr's atom model

(iii) X-ray spectra

4. Answer *(a)* and *(b)*, and any *one* from *(c)*, *(d)* and *(e)* : 10×3=30

(a) Draw a neat diagram of the experimental arrangement of Stern and Gerlach. What effect the magnetic field would have produced had it been uniform? Justify your answer mathematically. Show how two traces are produced by the atomic beam. 2+1+2+5=10

(b) A photon of X-ray with wavelength λ is incident on a free electron at rest. After the collision with the electron the photon is scattered at an angle α and its wavelength becomes λ', where $\lambda' > \lambda$. Show that $(\lambda' - \lambda)$ is proportional to $\sin^2\left(\frac{\alpha}{2}\right)$, assuming conservation of energy and the electron to recoil with relativistic speed. Is it possible for the electron to absorb the entire energy of the photon? Justify your answer mathematically. 7+1+2=10

(c) Describe Aston's mass spectrograph and discuss how the beam of positive ions is focussed. 2+8=10

(d) What do you mean by impact parameter? What happens when impact parameter becomes zero? A slow-moving proton is shot into a heavy atom at rest. The impact parameter of the collision is *b*. If the proton is scattered at an angle θ, then show that $\cot\frac{\theta}{2} \propto b$. Is it possible for the target atom to emit X-rays after the impact? Justify your answer. 1+1+6+1+1=10

(e) Write short notes on any *two* of the following : 5×2=10

(i) Raman effect

(ii) Moseley's law

(iii) *L-S* and *J-J* coupling

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