2020

(Held in 2021)

PHYSICS

(Major)

Paper : 5.2

(Atomic Physics)

Full Marks : 42

Time : 2 hours

The figures in the margin indicate full marks for the questions

GROUP—A

(*Marks* : 21)

1. Choose the correct option : 1×2=2

(a) The orbital angular momentum of the first excited state of hydrogen is

(i) $\sqrt{2}\,(h/2\pi)$

(ii) $\sqrt{2}h$

(iii) $2h$

(iv) None of the above

(b) In Compton scattering, the incident photon loses maximum energy to the electron when the photon is scattered at

(i) 0°

(ii) 45°

(iii) 90°

(iv) 180°

2. Answer the following questions : 2×2=4

(a) The longest wavelength in the Lyman series is 121·5 nm. Use this wavelength together with the values of c and h to find ionization energy of hydrogen.

(b) Using vector atom model, determine the possible values of angular momentum of an f-electron ($l = 3$).

3. Answer any *three* of the following questions : 5×3=15

(a) (i) What is fine structure of spectral lines? 2

(ii) Show that the Rydberg constant for hydrogen is given by

$$R_H = R_\alpha \Big/ \left(1 + \frac{m}{M}\right)$$

where m is the electronic mass and M is the proton mass. Hence prove that

$$(m / M) = (R_{He} - R_H) / (R_H - R_{He} / 4)$$

R_{He} is the Rydberg constant of He^+. 3

(b) Write any *one* explanatory note on the following :

(i) Vector atom model

(ii) Continuous and characteristic X-rays

(iii) Ritz combination principle

(c) Write any *one* explanatory note on the following :

(i) Pauli exclusion principle

(ii) Raman effect and compare Raman spectra with infrared spectra

(d) An atomic state is denoted by $^4D_{5/2}$. Give the values of L, S and J. What should be the minimum number of electrons involved for this state? Give a possible electronic configuration.

(e) X-rays emitted from a copper target and from a molybdenum target are found to contain a line of wavelength 2·285 Å attributed to K_α line of an impurity element. The K_α line of copper ($Z = 29$) and molybdenum ($Z = 42$) have wavelengths 1·542 Å and 0·712 Å respectively. Using Moseley's law, find the atomic number of the impurity element present in the target sample.

GROUP—B

(*Marks* : 21)

4. Answer any *three* of the following questions : 7×3=21

(a) (i) Explain why electrons are not effective in scattering of α-particles and protons.

(ii) Rutherford scattering formula fails to agree with the data at very small scattering angles. What is the reason?

(iii) What is the impact parameter of a 5·0 MeV alpha particle scattered by 10° when it approaches a gold nucleus? 2+1+4=7

(b) A photon of energy $h\nu$ in Compton effect scattered through an angle α. Show that the ratio of the kinetic energy of the recoil electron to the energy of the photon is

$$\frac{\beta(1-\cos\alpha)}{1+\beta(1-\cos\alpha)}$$

where $\beta = h\nu / m_0c^2$. 7

(c) In a Bainbridge mass spectrograph, show that the radius r of the ion-path is linearly proportional to the ion-mass M for the same ionic charge q.

Singly ionized atom of ^{20}Ne passes into the deflection chamber of a Bainbridge mass spectrograph with a velocity of 10^5 m/second. They are deflected by a magnetic field of 0·07 tesla. What are radii of their path? Where should ^{22}Ne ion fall if they possessed the same velocity initially? 4+1+2=7

(d) Describe the Stern-Gerlach experiment and indicate the importance of the result obtained.

A beam of silver atom in a Stern-Gerlach experiment obtained from an oven heated to a temperature of 1500 kelvin,

passes through an inhomogeneous magnetic field having a field gradient of 2 weber/m^2/cm perpendicular to the beam. The pole faces are 10 cm long. What is the separation between the two components of the beam on a photograph placed at a distance of 50 cm? 4+3=7

(e) What is Zeeman effect? Describe experimental arrangement for studying the Zeeman effect. Use the classical ideas to explain normal Zeeman effect. Show that the Zeeman shift is

$$d\lambda = \pm (Be\lambda^2 / 4\pi mc)$$ 1+3+3=7

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