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PHYSICS

(Major)

Paper : 5.2

(Atomic Physics)

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) In Compton scattering as the scattering angle of photon varies from 0 to π, the angle of recoil electron varies from

(i) π to 0

(ii) 0 to π

(iii) $\frac{\pi}{2}$ to 0

(iv) 0 to $\frac{\pi}{2}$

(b) A beam of electromagnetic radiation is allowed to pass through hydrogen gas at room temperature. The radiation has wavelengths extending from UV to

IR region. The absorption lines will be observed in the

(i) Lyman series

(ii) Balmer series

(iii) Paschen series

(iv) All of the above

(c) X-rays from a tube pass through a metal foil. The transmitted intensity is I_0. When the thickness of the foil is doubled, the transmitted intensity becomes I. Then

(i) $I_0 = 2I$

(ii) $I_0 = I$

(iii) $I_0 = \frac{I}{2}$

(iv) None of the above

(d) When a magnetic field is applied to an orbital electron, the electron gains ε energy. If the field direction is reversed, the change in energy will be

(i) 2ε

(ii) 0

(iii) ε

(iv) $\frac{\varepsilon}{2}$

(e) Which among the following is *not* true about Raman effect?

(i) Scattered lines have frequencies greater and lesser than the incident frequency

(ii) Frequency shift is independent of the scatterer

(iii) Elastic collision takes place between photon and molecule

(iv) Scattered lines are polarized

(f) The atoms taken in the Stern and Gerlach experiment had

(i) $J = L + S$

(ii) $J = L$

(iii) $J = S$

(iv) $J = 0$

(g) If λ_1 and λ_2 are the wavelengths of the K_β lines in the characteristic X-rays of two elements with atomic numbers z_1 and z_2, then

(i) $\lambda_1 < \lambda_2$ if $z_1 > z_2$

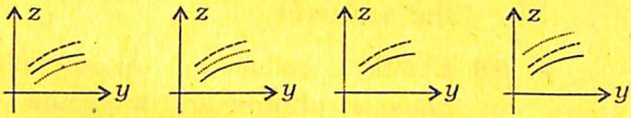
(ii) $\lambda_1 = \lambda_2$ if $z_1 > z_2$

(iii) $\lambda_1 > \lambda_2$ if $z_1 > z_2$

(iv) $2\lambda_1 = \lambda_2$ if $2z_1 < z_2$

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

(a) When four different samples of the same element are taken in Thomson's experiment, the following four sets of parabolic traces are obtained :



What inference can be drawn as regards the isotopic composition of the element from the traces?

(b) The velocity selector in a Bainbridge mass spectrograph uses an electric field of 30 kV m^{-1} and a magnetic field of 2×10^3 gauss. Find the speed of the ions which will ultimately strike the photographic plate.

(c) An atom has 18 electrons in *M*-shell. Write symbolically how the electrons are distributed in the *s*, *p*, *d*, ··· sub-shells, using proper spectral notation.

(d) Show that the unit of Bohr magneton may also be written as $\mathrm{A\,m^2}$.

(e) The energy levels of an atom are respectively -15 eV, -9 eV, -6 eV and -3 eV. What is the maximum momentum of photon that the atom can emit?

(f) Two fields are applied one after the other on an electron confined in an orbit. In one case the orbit is distorted, and in the other case the electron speeds up. Which field corresponds to which case? Explain with the help of two diagrams.

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

(a) A hydrogen atom in its ground state undergoes a collision and turns into an ion. Find the wavelength of light emitted if it regains its ground state.

If the electron is replaced by a negative muon (μ^-) with mass $m_\mu \approx 200\, m_e$, then calculate the wavelength of light emitted by the modified atom in the transition $n = 3$ to $n = 2$. Assume Rydberg constant $R = 1 \times 10^7$ m^{-1}.

In which region of the electromagnetic spectrum this radiation will fall?

(b) What is the difference between anomalous Zeeman effect and Paschen-Back effect? A proton is shot into a tin nucleus ($z = 50$). If the proton stops at a distance of $1 \cdot 6 \times 10^{-3}$ Å from the centre of the nucleus before retracing its path, then find the energy (in MeV) with which the proton was shot.

(c) What is Ritz combination principle? Using this principle, show that the wave number of the second line in Balmer series is the sum of the wave numbers of the first lines in Paschen series and Balmer series.

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

(i) Alkali spectra

(ii) Normal Zeeman effect

(iii) Sommerfeld modification of Bohr's atom model

4. Answer questions *(a)* and *(b)*; and any *one* from *(c)*, *(d)* and *(e)* :

(a) Draw a neat labelled diagram of Aston's mass spectrograph.

Discuss mathematically how the electric field disperses and the magnetic field converges a beam of ions in the apparatus. Hence, arrive at the condition of focussing of the beam.

3+6+1=10

(b) Deduce Rutherford's formula on scattering of α-particles from a metal target. 10

(c) An X-ray photon of frequency ν strikes a free electron of rest mass m_0. The photon undergoes an inelastic collision and gets scattered at an angle θ and has a reduced frequency ν'. Show that

$$\nu' = \frac{\nu}{1 + \frac{2h\nu}{m_0 c^2} \sin^2 \frac{\theta}{2}}$$ 10

(d) Give the mathematical theory of Stern-Gerlach experiment. Draw the schematic diagram of the apparatus.

In the apparatus the magnetic field has a gradient of 2 Wb m^{-2} per mm and a neutral atom of mass $9 \cdot 27 \times 10^{-22}$ g is projected at a speed of 400 ms^{-1}. The atom travels a distance of 40 cm inside the field and is deflected from its original path by an amount of 2 cm, then find the magnetic moment of the atom in the unit of Bohr magneton.

5+1+4=10

(e) Give the quantum theory of Raman effect. What are Stokes' and anti-Stokes' lines? In an experiment on Thomson's determination of q/M of positive rays an

x-y-z coordinate system is such that the origin of the system is at the point at which the ion enters the fields $\vec{E}$ and $\vec{B}$ where $\vec{E} = \hat{k}E$ and $\vec{B} = \hat{k}B$, and the velocity of the ion of mass M and charge q is $\vec{v} = \hat{j}v$. If the fields extend to a length l, then determine the final coordinates $P(x, y, z)$ of the ion just after it comes out of the field region.

4+½+½+5=10

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