2013

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) A hydrogen atom in the ground state absorbs an electromagnetic wave of energy 18 eV and emits its electron. The kinetic energy of the electron is

(i) 31·6 eV *(ii)* 18 eV

(iii) 13·6 eV *(iv)* 4·4 eV

(b) All ions entering the Bainbridge mass spectrograph have the same

(i) mass

(ii) velocity

(iii) momentum

(iv) charge

(c) The operating voltage of an X-ray tube is increased by 10%. The minimum wavelength of the X-rays emitted

(i) remains the same

(ii) increases by 10%

(iii) decreases by 10%

(iv) initially increases by 10% and then decreases by 10%

(d) Which of the following is *not* true about Raman effect?

(i) Collision between photon and molecules takes place

(ii) Electrons may be ejected from molecules

(iii) Frequency shift depends on scattering molecules

(iv) Frequency shift does not depend on the frequency of the incident radiation

(e) Which of the following is *not* true about Stark effect?

(i) Electric field splits spectral lines

(ii) The effect can be observed in Balmer series of hydrogen spectra

(iii) Frequency shift of component lines is independent of the strength of the electric field

(iv) Magnetic field is not needed

(f) Which element has a hydrogen-like spectrum with spectral lines having wavelength nine times smaller than the hydrogen lines?

(i) He^{+}

(ii) Li^{++}

(iii) Be^{+++}

(iv) B^{++++}

(g) The Landé g factor of the $3^2S_{1/2}$ energy level is

(i) $\frac{1}{2}$

(ii) 2

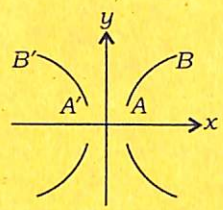
(iii) $\frac{2}{3}$

(iv) 3

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

(a) An element emits a discrete line spectrum. At very high temperatures the same element emits a continuous spectrum. Briefly explain, why.

(b) The photographic plate in Thomson's experiment on positive rays shows the parabolic trace AB of a particular type of ion. A similar trace $A'B'$ on the other side of the y-axis is seen on the same plate. Briefly state how $A'B'$ is formed.



(c) The energy levels of a gas are respectively -20 eV, -10 eV, -4 eV, -2 eV, $-0 \cdot 5$ eV .... The gas is irradiated with electromagnetic radiations with wavelengths 860 nm, 743 nm, 621 nm, 555 nm, 511 nm, 207 nm and 194 nm. Which wavelengths will be missing in the transmitted radiations? Take $hc = 1242$ eV nm.

(d) The quantity $(m_L + 2m_S)$ is called the strong field quantum number. Show that this may be used to explain normal Zeeman effect.

(e) The first spectral line of a gas is found to be 414 nm. What is the first excitation potential of the gas?

(f) Mention what happens to the $\vec{L}$ and the $\vec{S}$ vectors of an atom when it is placed in a *(i)* weak and *(ii)* strong external magnetic fields.

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

(a) Inside the apparatus used in the Stern-Gerlach experiment a stream of atoms, each with mass 2×10^{-22} g, is shot with a velocity of $0 \cdot 6$ km s^{-1} along the x-axis into a magnetic field which varies as $\frac{dB_Z}{dZ} = 3 \cdot 6$ T per mm. The magnetic moment of each atom is 1 Bohr magneton. If the magnetic field extends from $x_1 = 5$ cm to $x_2 = 7$ cm, find the separation of the two beams at x_2.

(b) How did Sommerfeld try to improve upon Bohr's model of the atom? What was the result of the attempt? Mention two achievements of the vector atom model.

(c) Using Moseley's law discuss briefly how the X-ray spectral lines are characteristics of the elements from which they are emitted.

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

(i) Anomalous Zeeman effect

(ii) Paschen-Back effect

(iii) Alkali spectra

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

(a) Deduce Rutherford's formula on scattering of alpha particles by a nucleus. Calculate the distance of closest approach of 1·6 MeV alpha particles scattered by a silver nucleus ($Z = 47$). Take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ SI units. 7+3=10

(b) Briefly explain the origin of magnetism in an atom. How does normal Zeeman effect confirm that atom behaves as a magnetic dipole? Distinguish between anomalous Zeeman effect and Paschen-Back effect. When a source emitting a single-spectral line with wavelength 600 nm is placed in a magnetic field of $4\pi \times 10^{-2}$ T, the Zeeman shift of the two components is found to be 0·0216 Å. Use the data to calculate the value of e/m of electron. 2+2+2+4=10

(c) Draw a neat and labelled diagram of the apparatus used by Thomson for determination of q/M of positive rays. Show mathematically, that positive ions with the same q/M value trace out a parabola. Explain how the mass of an isotope can be determined from the parabolic traces. 2+6+2=10

(d) What is Rayleigh scattering? Why fog lamps in cars use yellow colour light? Mention two differences between Rayleigh scattering and Compton scattering. A photon of energy $h\nu$ undergoes Compton scattering due to an electron by an angle θ. Show that the energy of the scattered photon is

$$\frac{h\nu}{1+\frac{h\nu}{m_0c^2}(1-\cos\theta)}$$

where m_0 is the rest mass of the electron and c is the speed of light in vacuum. 1+2+2+5=10

(e) Describe the working of a Bainbridge mass spectrograph and draw a neat diagram of the apparatus. Explain how it can be used to measure the masses of isotopes. Mention two advantages of Bainbridge mass spectrograph over Aston's mass spectrograph. It is seen that three traces are formed on the photographic plate in a Bainbridge mass spectrograph. The traces are at 2 mm, 2·8 cm and 3·2 cm from the edge of the plate. If the 2 mm trace is due to hydrogen, then identify the other two elements. 4+1+2+3=10

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