CLASS XII – PHYSICS (042)
STEP-BY-STEP SOLUTIONS AND MARKING SCHEME

Chapter 12: Atoms – Practice Paper (35 Marks)

Answer key – Section A

Q.	1	2	3	4	5	6	7	8	9
Ans.	(c)	(a)	(d)	(b)	(c)	(a)	(d)	(a)	(c)

Marks are shown in square brackets. Equivalent correct methods are acceptable. Key relations: $E_n = -13.6/n^2$ eV; $h\nu = E_i - E_f$; $\lambda(\text{nm}) = 1240/E(\text{eV})$; $r_n \propto n^2$; $v_n \propto 1/n$; $d = 2Ze^2/(4\pi\varepsilon_0 K)$.

SECTION A

Q.1 (c)

The impact parameter is the perpendicular distance of the initial velocity line from the nucleus. Particle A is aimed almost head-on (smallest impact parameter) and is turned back through nearly 180°. B (medium impact parameter) is deflected through about 90°, and C (largest impact parameter) is deflected only slightly. So A has the smallest impact parameter and the largest scattering angle. **[1]**

Q.2 (a)

Number = $1.6 \times 10^6/8000 = 200$. **[1]**

Q.3 (d)

At closest approach all the kinetic energy becomes electrostatic potential energy: $K = (1/4\pi\varepsilon_0)(2e)(Ze)/d$, so $d = 2Z(e^2/4\pi\varepsilon_0)/K = 2 \times 50 \times 1.44$ MeV fm/7.2 MeV = 144/7.2 = 20 fm. **[1]**

Q.4 (b)

Photon energy = difference of the levels: A (2→1) = 10.2 eV; B (3→2) = 1.89 eV; C (4→2) = 2.55 eV; D (3→1) = 12.09 eV. Wavelength $\lambda = hc/E$ is longest for the smallest energy, i.e. B. **[1]**

Q.5 (c)

The series limit is the $n = \infty$ to $n = 2$ transition, with photon energy 3.4 eV. $\lambda = 1240/3.4 = 365$ nm. **[1]**

Q.6 (a)

$r_n \propto n^2$, so $r_3/r_2 = 9/4$, i.e. 9 : 4. **[1]**

Q.7 (d)

An atom absorbs a photon only if its energy equals the difference between two levels. From n = 1: to n = 2, 13.6 − 3.4 = 10.2 eV (absorbed); to n = 3, 13.6 − 1.51 = 12.09 eV (absorbed); to n = 4, 12.75 eV. 11.0 eV and 13.0 eV match no level difference, and 13.0 eV is also less than the ionisation energy 13.6 eV, so neither is absorbed. **[1]**

Q.8 (a)

Both are true and R explains A. The revolving electron has centripetal acceleration; accelerated charges radiate, so the electron loses energy and spirals into the nucleus. **[1]**

Q.9 (c)

A is true: an atom emits photons in transitions between its discrete energy levels. R is false: the electron's energy in the atom has only the discrete values $E_n = -13.6/n^2$ eV. **[1]**

SECTION B

Q.10

(a) The electron revolves round the nucleus, so it has centripetal acceleration. According to classical electromagnetic theory an accelerated charge radiates energy continuously. The electron therefore loses energy, its orbit shrinks, and it spirals into the nucleus. **[1]**

(b) As the electron spirals inwards its speed and its frequency of revolution change continuously, so the frequency of the radiation emitted also changes continuously, giving a continuous

spectrum. The observed spectrum is a line spectrum. **[1]**

Q.11

(a) Ratio = $10^{-10}/10^{-15} = 10^5$. **[1]**

(b) Size of the atom = 2 cm × 10^5 = 2 × 10^5 cm = 2 km. **[1]**

Q.12

(A) $E_3 - E_2 = -1.51 - (-3.40) = 1.89$ eV. $\lambda = hc/E = 1240/1.89 \approx 656$ nm. **[1]**

The transition ends on n = 2, so the line belongs to the Balmer series (it is its first, red line). **[1]**

OR (B) Second postulate: the electron revolves only in those orbits for which its angular momentum is an integral multiple of h/2π, i.e. L = nh/2π, n = 1, 2, 3, … **[1]**

Third postulate: an electron may make a transition from a higher-energy orbit to a lower-energy orbit, and a photon is emitted whose energy equals the energy difference: $h\nu = E_i - E_f$. **[1]**

Q.13

(a) Model 1 is Thomson's model (plum pudding model); Model 2 is Rutherford's nuclear model. Observation: about 1 in 8000 α-particles is scattered through more than 90°, which needs a large repulsive force from a tiny, massive, positive core; this is impossible in Thomson's model, where the charge is spread uniformly. **[1]**

(b) Rutherford's model cannot explain the stability of the atom (the electron should spiral into the nucleus), or it cannot explain the line spectra of atoms (any one). **[1]**

SECTION C

Q.14

(a) Energy needed to reach n = 3 from n = 1 is 12.09 eV, and to reach n = 4 is 12.75 eV. A 12.5 eV electron can give 12.09 eV but not 12.75 eV, so the atoms can be excited at most to n = 3. **[1]**

(b) Transitions from n = 3 and n = 2 give three lines: 3→1, 2→1 and 3→2. The first two belong to the Lyman series and 3→2 to the Balmer series. **[1]**

(c) The longest wavelength is for the smallest energy, 3→2: E = 1.89 eV, λ = 1240/1.89 ≈ 656 nm. **[1]**

Q.15

(A) (a) The number detected is very large at small angles and decreases rapidly as the angle of scattering increases; at angles above 90° it is very small (about 1 in 8000 of those incident). **[1]**

(b) Most α-particles pass through almost undeviated, so most of the atom is empty space. **[1]**

A very small number are scattered through large angles, so the positive charge and almost all the mass of the atom are concentrated in a tiny region, the nucleus. **[1]**

OR (B) Initially the energy is only the kinetic energy K. At closest approach d the α-particle is momentarily at rest and all the energy is electrostatic potential energy. Energy conservation gives $K = (1/4\pi\varepsilon_0)(2e)(Ze)/d$. **[1]**

So $d = 2Ze^2/(4\pi\varepsilon_0 K)$. **[1]**

Since $d \propto 1/K$, if K is doubled, d becomes half. **[1]**

Q.16

$r_n = n^2 r_1$: $r_2 = 4 \times 0.53 = 2.12$ Å; $r_3 = 9 \times 0.53 = 4.77$ Å (≈ 4.8 Å). **[1]**

$v_n = v_1/n$: $v_2 = 2.2/2 = 1.1 \times 10^6$ m s^{-1}; $v_3 = 2.2/3 \approx 0.73 \times 10^6$ m s^{-1}. **[1]**

$E_n = -13.6/n^2$: $E_2 = -3.4$ eV; $E_3 = -13.6/9 = -1.51$ eV. **[1]**

n	rn (Å)	vn (× 10^6 m/s)	En (eV)
1	0.53	2.2	–13.6
2	2.12	1.1	–3.4
3	4.77	0.73	–1.51

SECTION D

Q.17

(i) (b). Group Q (the Balmer series) ends on n = 2; its lines (656 nm, 486 nm, …) are in the visible region. Group P lies in the ultraviolet and group R in the infrared. **[1]**

(ii) (c). The longest wavelength in P is for 2→1: E = 10.2 eV, so λ = 1240/10.2 ≈ 122 nm. **[1]**

(iii) (b). $E = E_3 - E_1 = -1.51 + 13.6 = 12.09$ eV. **[1]**

(iv) (c). The shortest wavelength in R is for ∞→3: E = 1.51 eV, so λ = 1240/1.51 ≈ 820 nm. **[1]**

OR (iv) (c). $E = E_4 - E_2 = -0.85 + 3.40 = 2.55$ eV, so λ = 1240/2.55 ≈ 486 nm. **[1]**

SECTION E

Q.18

(A) (a) The electron (mass m, speed v) moves in a circle of radius r. The Coulomb force provides the centripetal force: $e^2/(4\pi\varepsilon_0 r^2) = mv^2/r$. Bohr's quantisation condition: $mvr = nh/2\pi$. **[1]**

Eliminating $v = nh/(2\pi mr)$ gives $r_n = (n^2/m)(h/2\pi)^2(4\pi\varepsilon_0/e^2) = n^2h^2\varepsilon_0/(\pi me^2)$. **[1]**

Kinetic energy $K = e^2/(8\pi\varepsilon_0 r)$, potential energy $U = -e^2/(4\pi\varepsilon_0 r)$, so $E = K + U = -e^2/(8\pi\varepsilon_0 r_n) = -me^4/(8n^2\varepsilon_0^2h^2) = -13.6/n^2$ eV. **[1]**

(b) From n = 4 the atom can fall to n = 3, 2, 1 and so on, giving the lines 4→3, 4→2, 4→1, 3→2, 3→1 and 2→1: 6 lines. **[1]**

The shortest wavelength is for 4→1: E = 13.6 − 0.85 = 12.75 eV, λ = 1240/12.75 ≈ 97 nm. **[1]**

OR (B) (a) A standing wave on the orbit forms only if the circumference of the orbit holds a whole number of de Broglie wavelengths: $2\pi r_n = n\lambda$ (the figure shows n = 3). **[1]**

The de Broglie wavelength is $\lambda = h/mv_n$. **[1]**

Substituting, $2\pi r_n = nh/mv_n$, i.e. $mv_n r_n = nh/2\pi$, which is Bohr's quantisation of angular momentum. **[1]**

(b) $\lambda = 2\pi r/n = (2 \times 3.14 \times 4.77)/3 \approx 30/3 = 10$ Å (1.0 nm). **[1]**

$L = nh/2\pi = 3 \times 6.6 \times 10^{-34}/(2 \times 3.14) \approx 3.15 \times 10^{-34}$ J s. **[1]**

— End of Solutions —