Structure of Atom

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. Who discovered the electron, using cathode rays?

(a) James Chadwick **(b)** Niels Bohr
(c) Ernest Rutherford **(d)** J. J. Thomson

2. The number of electrons in $^{24}_{12}Mg^{2+}$ is:

(a) 10 **(b)** 12 **(c)** 24 **(d)** 11

3. The energy of one photon of light of wavelength 400 nm is: ($h = 6.626 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m/s)

(a) 4.97×10^{-18} J **(b)** 4.97×10^{-16} J **(c)** 4.97×10^{-20} J **(d)** 4.97×10^{-19} J

4. Which set of quantum numbers is not possible for an electron?

(a) n = 1, l = 2, m_l = +1, m_s = +½ **(b)** n = 1, l = 0, m_l = 0, m_s = −½
(c) n = 4, l = 2, m_l = 0, m_s = −½ **(d)** n = 3, l = 1, m_l = +1, m_s = −½

5. An electron in a hydrogen atom falls from n = 5 to n = 2. The line emitted belongs to the:

(a) Balmer series (visible) **(b)** Paschen series (infrared)
(c) Lyman series (ultraviolet) **(d)** Brackett series (infrared)

6. What is the total number of nodes in a 1s orbital?

(a) 2 **(b)** 1 **(c)** 0 **(d)** 4

7. The ground-state electronic configuration of bromine (Z = 35) is:

(a) [Ar] $3d^{10}\ 4s^2\ 4p^5$ **(b)** [Ar] $3d^{10}\ 4s^2\ 4p^6$
(c) [Ar] $3d^{10}\ 4s^2\ 4p^4\ 5s^1$ **(d)** [Ar] $3d^{10}\ 4s^2\ 4p^4$

8. Assertion (A): An atom of copper (Z = 29) has 2 unpaired electrons in its ground state.
Reason (R): Electrons occupy the orbitals of a subshell singly, with parallel spins, before pairing (Hund's rule).

(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. State Hund's rule of maximum multiplicity.

10. Find the frequency and the wavenumber of radiation of wavelength 500 nm. ($c = 3.0 \times 10^8$ m/s)

11. How much energy is given out when the electron of a hydrogen atom falls from n = 4 to n = 1? ($E_n = -2.18 \times 10^{-18}/n^2$ J)

12. Find the wavenumber and wavelength of the line emitted when the electron of a hydrogen atom falls from n = 3 to n = 2. ($R = 109{,}677$ cm^{-1}) (2 decimal places where needed.)

13. Find the de Broglie wavelength of a ball of mass 200 g moving at 40 m/s. ($h = 6.626 \times 10^{-34}$ J s)

14. How many photons of wavelength 650 nm make up 20 J of energy? ($h = 6.626 \times 10^{-34}$ J s, $c = 3.0 \times 10^8$ m/s)

15. For the 4f subshell, give the values of n and l, the possible values of m_l, the number of orbitals and the maximum number of electrons.

16. The threshold frequency of a metal is 5.0×10^{14} Hz. Light of frequency 13.0×10^{14} Hz falls on it. Find the work function of the metal and the kinetic energy of the emitted electrons. ($h = 6.626 \times 10^{-34}$ J s)

Section C — Word problems — 4 × 4 = 16 marks

17. Describe Rutherford's α-particle scattering experiment. What did it show, and what was the main drawback of his model?

18. The electron of a hydrogen atom falls from n = 3 to n = 2. Find (a) the energy given out, (b) the wavelength of the light in nm, (c) the series and region of the spectrum. ($E_n = -2.18 \times 10^{-18}/n^2$ J; h = 6.626×10^{-34} J s; c = 3.0×10^{8} m/s)

19. For selenium (Z = 34): (a) write the ground-state electronic configuration in full, (b) give the number of unpaired electrons, (c) how many electrons have l = 1? (d) how many electrons have n = 3? (e) which subshell receives the last electron?

20. An ion with mass number 79 carries a charge of −1. It contains 22.22% more neutrons than electrons. (a) Find the numbers of electrons, protons and neutrons. (b) Identify the ion and write its symbol.

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Answer key

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Q	Answer	Working
1	**(d) J. J. Thomson**	—
2	**(a) 10**	Z = 12, A = 24: protons 12, neutrons 24 − 12 = 12, electrons 12 − 2 = 10
3	**(d) 4.97×10^{-19} J**	E = hc/λ, with λ in metres
4	**(a) n = 1, l = 2, m_l = +1, m_s = +½**	l must be less than n (here l = 2, n = 1)
5	**(a) Balmer series (visible)**	the series is named by the lower level, n = 2
6	**(c) 0**	total nodes = n − 1
7	**(a) [Ar] $3d^{10}$ $4s^2$ $4p^5$**	fill by the (n + l) rule: 1s 2s 2p 3s 3p 4s 3d 4p
8	**(d) A is false, but R is true.**	A is false: [Ar] $3d^{10}$ $4s^1$: 1 unpaired. R is true.
9	**Electrons enter the orbitals of a subshell singly, with parallel spins, before any pairing begins.**	—
10	**ν = 6.00×10^{14} Hz; $\bar{\nu}$ = 2.00×10^{6} m^{-1}**	ν = c/λ; $\bar{\nu}$ = 1/λ (λ in metres)
11	**2.04×10^{-18} J**	$\Delta E = 2.18 \times 10^{-18} (1/1^2 - 1/4^2)$
12	**$\bar{\nu}$ = 15,232.92 cm^{-1}; λ = 656.47 nm (Balmer series)**	$\bar{\nu} = R(1/2^2 - 1/3^2)$; λ = 1/$\bar{\nu}$ (1 cm = 10^7 nm)
13	**8.28×10^{-35} m**	λ = h/(mv), with m in kg; far too small to observe
14	**6.54×10^{19}**	number = total energy ÷ hc/λ
15	**n = 4, l = 3; m_l = −3, −2, −1, 0, +1, +2, +3; 7 orbitals; 14 electrons**	l = 3 for f; m_l from −l to +l
16	**W_0 = 3.313×10^{-19} J; KE = 5.301×10^{-19} J**	$W_0 = h\nu_0$; $KE = h(\nu - \nu_0)$
17	**A thin gold foil was bombarded with α-particles. Most passed straight through, a few were deflected through small angles, and very few (about 1 in 20,000) bounced back. So most of the atom is empty space, with its positive charge and almost all its mass in a tiny nucleus; electrons move around it. Drawback: an electron moving in a circle should radiate energy and spiral into the nucleus, so the model cannot explain the stability of the atom (or line spectra).**	—
18	**(a) 3.03×10^{-19} J; (b) 656.52 nm; (c) Balmer series, visible**	$\Delta E = 2.18 \times 10^{-18} (1/n_1^2 - 1/n_2^2)$; λ = hc/ΔE

Q	Answer	Working
19	**(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$; (b) 2; (c) 16; (d) 18; (e) 4p**	Aufbau order; Hund’s rule for unpaired electrons
20	**(a) electrons 36, protons 35, neutrons 44; (b) bromine: $^{79}_{35}Br^-$**	if electrons = x, neutrons = x(1 + 22.22/100) and protons = x − 1; protons + neutrons = 79

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