Class 11 Chemistry · Chapter 2: Structure of Atom

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. Light of wavelength 480 nm (photon energy 2.59 eV) falls in turn on Li, Na, K, Mg, Cu and Ag, whose work functions are given in Table 2.2 of NCERT (Li 2.42, Na 2.3, K 2.25, Mg 3.7, Cu 4.8, Ag 4.3 eV). Photoelectrons are ejected from [1]

(a) all six metals
(b) K only
(c) Mg, Cu and Ag only
(d) Li, Na and K only

Answer: (d) An electron is ejected only when hν exceeds the work function W_0. 2.59 eV is more than 2.42, 2.3 and 2.25 eV but less than 3.7, 4.8 and 4.3 eV, so Li, Na and K emit and the other three do not.

2. Which species has as many neutrons as $^{23}_{11}Na^+$ has electrons? [1]

(a) $^{19}_{9}F^-$
(b) $^{16}_{8}O$
(c) $^{24}_{12}Mg^{2+}$
(d) $^{14}_{7}N$

Answer: (a) Na^+ has 11 − 1 = 10 electrons. Neutrons = A − Z: F^- 19 − 9 = 10; O 8; Mg^{2+} 12 (the charge does not change the neutrons); N 7.

3. Which pair of atoms are isobars? [1]

(a) $^{35}_{17}Cl$ and $^{37}_{17}Cl$
(b) $^{14}_{6}C$ and $^{16}_{8}O$
(c) $^{12}_{6}C$ and $^{13}_{6}C$
(d) $^{40}_{18}Ar$ and $^{40}_{20}Ca$

Answer: (d) Isobars have the same mass number and different atomic numbers: Ar and Ca both have A = 40. The chlorine and carbon pairs are isotopes; ^{14}C and ^{16}O have the same number of neutrons (8) but different A.

4. In a discharge tube the gas is changed from hydrogen to neon, everything else kept the same. Which of these changes? [1]

(a) the charge to mass ratio of the cathode rays
(b) the charge to mass ratio of the canal rays
(c) the direction in which cathode rays travel
(d) the sign of the charge on the cathode rays

Answer: (b) Cathode rays (electrons) do not depend on the gas or the electrodes. Canal rays are positive ions of the gas itself, so their mass, and hence their charge to mass ratio, depends on the gas.

5. An absorption line in a spectrum is recorded at a wavenumber of 2000 cm^{-1}. Its wavelength is [1]

(a) 50 µm
(b) 0.50 µm
(c) 5.0 µm
(d) 20 µm

Answer: (c) $\lambda = 1/\bar{\nu} = 1/2000$ cm $= 5.0 \times 10^{-4}$ cm $= 5.0 \times 10^{-6}$ m = 5.0 µm. 50 µm and 0.50 µm slip the cm to µm conversion by ten; 20 µm inverts the wrong quantity.

6. State Hund's rule of maximum multiplicity. Using it, draw the orbital diagrams of the 2p electrons of nitrogen and oxygen and say how many unpaired electrons each has. [2]

Hund's rule: in orbitals of the same subshell, electrons do not pair until each orbital holds one electron. N, $2p^3$: [↑][↑][↑], three unpaired. O, $2p^4$: [↑↓][↑][↑], the fourth electron pairs only after all three are singly filled, two unpaired.

- statement of Hund's rule (1)
- N $2p^3$ ↑ ↑ ↑ (3 unpaired) and O $2p^4$ ↑↓ ↑ ↑ (2 unpaired) (1)

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7. Give two reasons why the Bohr model of the atom is not acceptable in the light of de Broglie's and Heisenberg's ideas. [2]

(i) The Bohr model treats the electron only as a charged particle and ignores its wave character (dual behaviour of matter). (ii) It places the electron in a definite circular orbit, which would need its exact position and velocity at the same time; the uncertainty principle forbids this.

- ignores the wave nature (dual behaviour) of the electron (1)
- definite orbit contradicts the uncertainty principle (1)

8. An iron rod heated in a furnace glows dull red, then brighter red, and at very high temperature white and then bluish. Explain this using the way the radiation of a hot body depends on temperature. [2]

The intensities of the wavelengths a hot body emits depend on its temperature: at each temperature intensity rises with wavelength to a maximum and then falls. As temperature rises the maximum shifts to shorter wavelength, so a larger share of the visible light is of short wavelength; the glow moves from red (long λ) towards white and then blue (short λ).

- emission spectrum depends only on temperature, with an intensity maximum (1)
- maximum shifts to shorter wavelength as T rises, hence red → white → blue (1)

9. The position of chromium (Z = 24) suggests the configuration $[Ar]3d^4 4s^2$, but its ground state is $[Ar]3d^5 4s^1$. Give two reasons for this, and state the number of unpaired electrons in a chromium atom. [3]

(i) Symmetry: a half-filled $3d^5$ subshell has a symmetrical distribution of electrons; electrons in the same subshell shield one another little and are held more strongly, so it is more stable. (ii) Exchange energy: electrons of parallel spin in degenerate orbitals can exchange positions, releasing exchange energy; the number of exchanges is largest for a half-filled set (10 for d^5, against 6 for d^4), so the 4s to 3d shift lowers the total energy. Unpaired electrons: five in 3d and one in 4s, six in all.

- symmetrical distribution of a half-filled subshell (1)
- maximum exchange energy for d^5 (1)
- 6 unpaired electrons (1)

10. What did Thomson's model of the atom lead Rutherford to expect when α-particles were fired at a thin gold foil? State what was actually observed, and the conclusion drawn from each observation. [3]

Expected: with positive charge and mass spread evenly through each atom, the α-particles should pass through, slowing and turning only by small angles. Observed and concluded: (i) most passed undeflected, so most of the atom is empty space; (ii) a small fraction was deflected by small angles and (iii) a very few (about 1 in 20,000) bounced back by nearly 180°, so the positive charge and most of the mass are concentrated in a very small region, the nucleus, whose volume is negligible compared with the atom's.

- expected small deflections from uniform charge and mass (Thomson) (1)
- most undeflected: atom mostly empty (1)
- few deflected/rebounded: positive charge concentrated in a tiny nucleus (1)

11. Chlorine molecules split into atoms when they absorb light, which is how the reaction of chlorine with methane starts in sunlight. Breaking one mole of Cl–Cl bonds needs 242 kJ (given). (i) Calculate the energy of one mole of photons of wavelength 400 nm, in kJ mol^{-1}. (ii) Can these photons break Cl–Cl bonds, and how much energy per mole of photons is left over? (iii) Can the 589 nm light of a sodium lamp break the bonds? ($h = 6.626 \times 10^{-34}$ J s, $c = 3.0 \times 10^{8}$ m s^{-1}, $N_A = 6.022 \times 10^{23}$ mol^{-1}) [3]

(i) E (one photon) $= hc/\lambda = (6.626 \times 10^{-34} \times 3.0 \times 10^{8})/(400 \times 10^{-9}) = 4.97 \times 10^{-19}$ J; one mole: $4.97 \times 10^{-19} \times 6.022 \times 10^{23} = 2.99 \times 10^{5}$ J = 299 kJ mol^{-1}. (ii) 299 kJ is more than 242 kJ, so each photon can break one bond; 299 − 242 = 57 kJ per mole is left over (as kinetic energy of the atoms). (iii) $E \propto 1/\lambda$: one mole of 589 nm photons carries 299 × 400/589 = 203 kJ, less than 242 kJ; each photon is absorbed singly, so the energy of two photons cannot be pooled to break one bond: no.

- 299 kJ mol^{-1} for 400 nm photons (1)
- yes; 57 kJ mol^{-1} left over (1)
- 589 nm: 203 kJ mol^{-1} < 242, cannot break the bond (1)

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