# Atoms

Standard difficulty · 20 questions · 40 marks · Time: 38 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.** The radius of the 3rd Bohr orbit in a hydrogen atom is: ($r_1$ = 0.53 Å for hydrogen)

**(a)** 14.31 Å **(b)** 1.59 Å **(c)** 9.54 Å **(d)** 4.77 Å

**2.** The energy of an $Li^{2+}$ ion with its electron in the n = 5 level is:

**(a)** −4.896 eV **(b)** −8.16 eV **(c)** 4.896 eV **(d)** −0.544 eV

**3.** The energy of the photon emitted when a hydrogen electron falls from n = 3 to n = 2 is:

**(a)** 1.51 eV **(b)** 2.27 eV **(c)** 3.4 eV **(d)** 1.89 eV

**4.** The energy needed to remove the electron from a hydrogen atom in the n = 4 level is:

**(a)** 1.7 eV **(b)** 13.6 eV **(c)** 3.4 eV **(d)** 0.85 eV

**5.** In Rutherford's experiment, most α-particles passed straight through the foil, showing that:

**(a)** the nucleus is negative **(b)** the atom is solid

**(c)** most of the atom is empty space **(d)** electrons are heavy

**6.** Hydrogen atoms are excited to the n = 6 level. The largest number of different spectral lines they can emit on returning to the ground state is:

**(a)** 15 **(b)** 36 **(c)** 5 **(d)** 6

**7.** The line emitted when a hydrogen electron falls from n = 6 to n = 5 belongs to the:

**(a)** Balmer series (visible) **(b)** Pfund series (infrared)

**(c)** Paschen series (infrared) **(d)** Lyman series (ultraviolet)

**8.** Assertion (A): The energy of a hydrogen atom in the n = 6 level is −0.38 eV.
Reason (R): In the Bohr model, the energy of level n is −13.6/n eV.

**(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.** For the electron in the n = 3 orbit of a hydrogen atom, find its kinetic energy, potential energy and total energy.

**10.** Find the energy and wavelength of the photon emitted when a hydrogen electron falls from n = 7 to n = 3. (hc = 1240 eV nm)

**11.** An α-particle of kinetic energy 2 MeV heads straight at an aluminium nucleus (Z = 13). Find its distance of closest approach. ($ke^2$ = 1.44 MeV fm)

**12.** Find the speed of the electron in the n = 5 orbit of an $He^+$ ion, and the radius of that orbit. (for hydrogen $v_1 = 2.18 \times 10^6$ m/s, $r_1$ = 0.53 Å)

**13.** Find the ratio of the radii, and of the energies, of the n = 5 and n = 4 orbits of hydrogen.

**14.** How much energy must a hydrogen atom absorb to lift its electron from n = 1 to n = 5? What is the angular momentum of the electron in the upper orbit?

**15.** Find the longest and shortest wavelengths of the Pfund series (lines ending on n = 5) of $He^+$ ion. (hc = 1240 eV nm)

**16.** Hydrogen atoms in the ground state are lifted to n = 9. How many different lines can they emit? Which transition gives the longest wavelength?

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

**17.** A hydrogen atom with its electron in the n = 2 level absorbs a photon of 3.02 eV. To which level does the electron rise? List the photon energies it can emit as it falls back to n = 2.

**18.** Find the energy and wavelength of the photon emitted in the n = 7 → n = 4 transition of hydrogen, name its series, and find the longest wavelength in that series. (hc = 1240 eV nm)

**19.** α-particles of 6 MeV and 3 MeV are aimed head-on at gold nuclei (Z = 79). Find the distance of closest approach for each, and explain what this says about the size of the nucleus. ($ke^2$ = 1.44 MeV fm)

**20.** For the n = 2 orbit of a hydrogen atom, find the radius, the speed of the electron, its total energy, and the energy needed to remove the electron from there. (for hydrogen $r_1$ = 0.53 Å, $v_1 = 2.18 \times 10^6$ m/s, $E_1$ = −13.6 eV)

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# Answer key

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| Q | Answer | Working |
|---|---|---|
| 1 | **(d) 4.77 Å** | $r_n = n^2 r_1/Z = 3^2 \times 0.53/1$ |
| 2 | **(a) −4.896 eV** | $E_n = -13.6Z^2/n^2$ eV with Z = 3 |
| 3 | **(d) 1.89 eV** | $13.6(1/2^2 - 1/3^2)$ |
| 4 | **(d) 0.85 eV** | $13.6 \times 1^2/4^2$ |
| 5 | **(c) most of the atom is empty space** | — |
| 6 | **(a) 15** | $n(n-1)/2$ |
| 7 | **(b) Pfund series (infrared)** | lines ending on n = 5 make the Pfund series |
| 8 | **(c) A is true, but R is false.** | A is true: $E_n = -13.6/6^2 = -0.38$ eV. R is false. |
| 9 | **KE = 1.51 eV; PE = −3.02 eV; total = −1.51 eV** | $KE = -E$, $PE = 2E$, $E = -13.6Z^2/n^2$ |
| 10 | **1.23 eV; 1,005.22 nm** | $\Delta E = 13.6(1/3^2 - 1/7^2)$; $\lambda = 1240/\Delta E$ |
| 11 | **18.72 fm** | $K = k(2e)(Ze)/d \Rightarrow d = 1.44 \times 2 \times 13/2$ |
| 12 | **8.72 × $10^5$ m/s; 6.625 Å** | $v_n = Zv_1/n$; $r_n = n^2 r_1/Z$ |
| 13 | **radii 25 : 16; energies 16 : 25** | $r \propto n^2$, $E \propto 1/n^2$ |
| 14 | **13.06 eV; 5h/(2π)** | $\Delta E = 13.6(1/1^2 - 1/5^2)$; $L = nh/2\pi$ |
| 15 | **longest 1,864.97 nm; shortest 569.85 nm** | longest: n = 6 → 5; shortest: n = ∞ → 5; energies × $Z^2 = 4$ |
| 16 | **36 lines; n = 9 → 8** | the smallest energy gap gives the longest wavelength |
| 17 | **n = 6; 3→2: 1.89 eV, 4→2: 2.55 eV, 5→2: 2.856 eV, 6→2: 3.02 eV, 4→3: 0.66 eV, 5→3: 0.97 eV, 6→3: 1.13 eV, 5→4: 0.306 eV, 6→4: 0.47 eV, 6→5: 0.17 eV** | $-13.6/2^2 + 3.02 = -13.6/n^2$ |
| 18 | **0.57 eV; 2,166.13 nm; Brackett; longest 4,052.29 nm** | $\lambda = 1240/\Delta E$ |
| 19 | **37.92 fm and 75.84 fm; the nucleus must be smaller than these distances, so it is only a few tens of femtometres across at most** | $d = 2Zke^2/K$ |
| 20 | **2.12 Å; 1.09 × $10^6$ m/s; −3.4 eV; 3.4 eV** | $r_n = n^2 r_1/Z$; $v_n = Zv_1/n$; $E_n = Z^2 E_1/n^2$ |



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