

How to use this worksheet. Thirty questions, about 35 minutes. Learn which level each series ends on — Lyman $n = 1$ (UV), Balmer $n = 2$ (visible), Paschen $n = 3$ (IR). For the shortest wavelength of any series, take $n = \infty$.

Formula sheet

$$r_n = 0.529n^2 \text{ \AA} \quad | \quad E_n = -13.6/n^2 \text{ eV} \quad | \quad mvr = nh/2\pi \quad | \quad E = hf = hc/\lambda$$

$$1/\lambda = R(1/n_1^2 - 1/n_2^2) \quad | \quad R = 1.097 \times 10^7 \text{ m}^{-1}$$

$$\text{Lyman } n_1 = 1 \text{ (UV)} \quad | \quad \text{Balmer } n_1 = 2 \text{ (visible)} \quad | \quad \text{Paschen } n_1 = 3 \text{ (IR)}$$

Section A · Level 1 — Rutherford, Bohr and the hydrogen spectrum

Ten questions. None should take more than twenty seconds.

- The alpha particle scattering experiment was performed under the direction of:
(1) J. J. Thomson (2) Rutherford (3) Bohr (4) Chadwick
- The alpha particle scattering experiment established that an atom has:
(1) A uniform distribution of charge (2) A small dense positively charged nucleus (3) No charged particles (4) Only electrons
- According to Bohr, the angular momentum of an electron in a stationary orbit is an integral multiple of:
(1) h (2) $h/2\pi$ (3) $2\pi h$ (4) h^2
- While an electron remains in a stationary orbit, it:
(1) Radiates energy continuously (2) Does not radiate energy (3) Absorbs energy continuously (4) Loses mass
- The energy of the electron in the ground state of the hydrogen atom is:
(1) -3.4 eV (2) -13.6 eV (3) $+13.6 \text{ eV}$ (4) -1.51 eV
- The ionisation energy of a hydrogen atom in its ground state is:
(1) 3.4 eV (2) 10.2 eV (3) 13.6 eV (4) 27.2 eV
- The radius of the n -th Bohr orbit is proportional to:
(1) n (2) n^2 (3) $1/n$ (4) $1/n^2$
- Which series of the hydrogen spectrum lies in the ultraviolet region?
(1) Lyman (2) Balmer (3) Paschen (4) Brackett
- An emission spectral line is produced when an electron:
(1) Jumps to a higher orbit (2) Jumps to a lower orbit (3) Stays in the same orbit (4) Leaves the atom
- The size of a nucleus compared with the size of an atom is roughly:
(1) The same (2) 10 times smaller (3) 10^5 times smaller (4) 10^2 times smaller

Working space — Questions 1 to 10

Write the formula before you substitute.

Section B · Level 2 — Energy levels, radii and spectral series

Ten questions. Know which level each series ends on.

- The energy of the electron in the $n = 2$ state of hydrogen is:
(1) -13.6 eV (2) -6.8 eV (3) -3.4 eV (4) -1.51 eV
- The energy required to excite a hydrogen atom from $n = 1$ to $n = 2$ is:
(1) 13.6 eV (2) 10.2 eV (3) 3.4 eV (4) 1.9 eV

13. The radius of the second Bohr orbit of hydrogen is closest to:

- (1) $0.529 \text{ \AA}$ (2) $1.06 \text{ \AA}$ (3) $2.12 \text{ \AA}$ (4) $4.76 \text{ \AA}$

14. For the Balmer series, the electron falls to the level:

- (1) $n = 1$ (2) $n = 2$ (3) $n = 3$ (4) $n = 4$

15. For the Paschen series, the electron falls to the level:

- (1) $n = 1$ (2) $n = 2$ (3) $n = 3$ (4) $n = 4$

16. The shortest wavelength line of a spectral series corresponds to a transition from:

- (1) $n = 2$ (2) $n = 3$ (3) $n_1 + 1$ (4) $n = \text{infinity}$

17. The velocity of an electron in the n -th Bohr orbit is proportional to:

- (1) n (2) n^2 (3) $1/n$ (4) $1/n^2$

18. A photon of energy 10.2 eV is absorbed by a hydrogen atom in its ground state. The electron moves to:

- (1) $n = 2$ (2) $n = 3$ (3) $n = 4$ (4) It is ionised

19. According to the Rydberg formula, the wavelength of a spectral line depends on:

- (1) Only the initial level (2) Only the final level (3) Both the initial and final levels (4) Neither level

20. The Bohr model successfully explains the spectrum of:

- (1) All atoms (2) Hydrogen and hydrogen-like ions (3) Only helium (4) Only heavy nuclei

Working space — Questions 11 to 20 Write the formula before you substitute.

Section C · Level 3 — Transitions, limits and the model's reach

Seven questions. Each needs a formula plus a piece of reasoning.

21. In the Bohr model, the total energy of the electron is related to its kinetic energy by:

- (1) $E = KE$ (2) $E = -KE$ (3) $E = 2KE$ (4) $E = -2KE$

22. The number of spectral lines produced when hydrogen atoms de-excite from the $n = 4$ level is:

- (1) 3 (2) 4 (3) 6 (4) 10

23. The wavelength of the series limit of the Lyman series in terms of the Rydberg constant R is:

- (1) $1/R$ (2) $4/R$ (3) $9/R$ (4) R

24. A limitation of the Bohr model is that it:

- (1) Cannot explain the hydrogen spectrum (2) Cannot explain the relative intensity of spectral lines (3) Predicts a continuous spectrum (4) Requires the nucleus to be large

25. As the principal quantum number n increases, the spacing between successive energy levels:

- (1) Increases (2) Decreases (3) Stays constant (4) First rises then falls

26. For a hydrogen-like ion of atomic number Z , the energy of the n -th level is:

- (1) $-13.6/n^2 \text{ eV}$ (2) $-13.6 Z/n^2 \text{ eV}$ (3) $-13.6 Z^2/n^2 \text{ eV}$ (4) $-13.6 n^2/Z^2 \text{ eV}$

27. The impact parameter for an alpha particle that is scattered straight back through 180° is:

- (1) Maximum (2) Zero (3) Equal to the nuclear radius (4) Infinite

Working space — Questions 21 to 27 Write the formula before you substitute.

Section D · Previous year questions — Straight from the AAI ATC papers

Three questions from the 2023 papers, recovered by optical character recognition of the scanned answer sheets and independently re-solved.

28. Which of the following spectral series lies in the visible region of the hydrogen spectrum? **[PYQ 2023 · Morning]**

(1) Lyman series (2) Balmer series (3) Brackett series (4) Paschen series

29. An electron in a hydrogen atom (Bohr model) makes a transition from the $n = 2$ state to the $n = 1$ state. The frequency of the emitted photon is (take $R = 1.0 \times 10^7 \text{ m}^{-1}$): **[PYQ 2023 · Morning]**

(1) $3.26 \times 10^{14} \text{ Hz}$ (2) $2.25 \times 10^{15} \text{ Hz}$ (3) $1.24 \times 10^{13} \text{ Hz}$ (4) $2.45 \times 10^{14} \text{ Hz}$

30. The shortest wavelength in the Paschen series, in terms of the Rydberg constant R , is: **[PYQ 2023 · Evening]**

(1) $1/R$ (2) $4/R$ (3) $9/R$ (4) $16/R$

Working space — Questions 28 to 30 Write the formula before you substitute.

Stuck on any of these? Bring them to a live class.

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