Chapter

2 Structure of Atom

TYPE A : MULTIPLE CHOICE QUESTIONS

1. The configuration $1s^2, 2s^2 2p^5, 3s^1$ shows :

(a) excited state of O_2^- ***[1997]***

(b) excited state of neon atom

(c) excited state of fluorine atom

(d) ground state of fluorine atom

2. The total number of orbitals in a shell with principal quantum number '*n*' is : ***[1997]***

(a) n^2 (b) $n+1$

(b) $2n$ (d) $2n^2$

3. Positron is : ***[1997]***

(a) electron with positive charge

(b) a nucleus with one neutron and one proton

(c) a nucleus with two protons

(d) a helium nucleus

4. The wavelength of visible light is : ***[1998]***

(a) 2000 Å – 3700 Å (b) 7800 Å – 8900 Å

(c) 3800 Å – 7600 Å (d) None of these

5. The wavelength of a 150 g rubber ball moving with a velocity of 50 ms^{-1} is : ***[1998]***

(a) 3.43×10^{-33} cm (b) 5.86×10^{-33} cm

(c) 7.77×10^{-33} cm (d) 8.83×10^{-33} cm

6. If $e = 1.60206\times10^{-19}$ C, ***[1999]***

$\frac{e}{m} = 1.75875\times10^{11} C\,kg^{-1}$

then the mass of electron is

(a) 7.5678×10^{-31} kg (b) 9.1091×10^{-31} kg

(c) 11.2531×10^{-31} kg (d) 13.0513×10^{-31} kg

7. The energy of electron in first energy level is -21.79×10^{-12} erg per atom. The energy of electron in second energy level is : ***[1999]***

(a) -54.47×10^{-12} erg $atom^{-1}$

(b) -5.447×10^{-12} erg $atom^{-1}$

(c) -0.5447×10^{-12} erg $atom^{-1}$

(d) -0.05447×10^{-12} erg $atom^{-1}$

8. Deuterium nucleus contains: ***[2000]***

(a) 1 proton, 1 electron

(b) 1 proton, 1 neutron

(c) 2 protons, 1 electron

(d) 1 proton, 2 electrons

9. The outermost configuration of most electronegative element is: ***[2000]***

(a) ns^2np^5 (b) ns^2np^6

(c) ns^2np^4 (d) ns^2np^3

10. Bohr's theory is not applicable to: ***[2000]***

(a) H (b) He^+

(c) Li^{2+} (d) H^+

11. The de-Broglie wavelength of an electron in the ground state of hydrogen atom is :

[K.E. = 13.6 eV ; 1eV = 1.602×10^{-19} J] ***[2000]***

(a) 33.28 nm (b) 3.328 nm

(c) 0.3328 nm (d) 0.0332 nm

12. The de-Broglie wavelength associated with a particle of mass 10^{-6} kg moving with a velocity of 10 ms^{-1} is : ***[2001]***

(a) 6.63×10^{-7} m (b) 6.63×10^{-16} m

(c) 6.63×10^{-21} m (d) 6.63×10^{-29} m

13. The velocity of electron in second shell of hydrogen atom is : ***[2001]***

(a) 10.94×10^6 ms^{-1} (b) 18.88×10^6 ms^{-1}

(c) 1.888×10^6 ms^{-1} (d) 1.094×10^6 ms^{-1}

14. Which of the following element is represented by electronic configuration $1s^2\ 2s^2\ 2p_x^1 2p_y^1 2p_z^1$? ***[2001]***

(a) nitrogen (b) oxygen
(c) fluorine (d) sulphur

15. Quantum numbers of an atom can be defined on the basis of ***[2002]***

(a) Hund's rule
(b) Pauli's exclusion principle
(c) Aufbau's principle
(d) Heisenberg's uncertainity principle

16. Spectrum of Li^{2+} is similar to that of ***[2002]***

(a) H (b) Be
(c) He (d) Ne

17. Azimuthal quantum number defines ***[2002]***

(a) e/m ratio of electron
(b) angular momentum of electron
(c) spin of electron
(d) magnetic momentum of electron

18. The quantum number 'm' of a free gaseous atom is associated with : ***[2003]***

(a) the effective volume of the orbital
(b) the shape of the orbital
(c) the spatial orientation of the orbital
(d) the energy of the orbital in the absence of a magnetic field

19. For principle quantum number $n = 4$, the total number of orbitals having $l = 3$ is : ***[2004]***

(a) 3 (b) 7
(c) 5 (d) 9

20. The isoelectronic pair is : ***[2005]***

(a) Cl_2O_3 and ICl_2^- (b) ICl_2^- and ClO_2
(c) IF_2^+ and I_3^- (d) ClO_2^- and ClF_2^+

21. The most probable radius (in pm) for finding the electron in He^+ is ***[2005]***

(a) 0.0 (b) 52.9
(c) 26.5 (d) 105.8

22. The de Broglie wavelength associated with a ball of mass 1 kg having kinetic energy 0.5 J is : ***[2006]***

(a) 6.626×10^{-34} m (b) 13.20×10^{-34} m
(c) 10.38×10^{-21} m (d) 6.626×10^{-34} Å

23. The uncertainties in the velocities of two particles, A and B are 0.05 and 0.02 ms^{-1} respectively. The mass of B is five times to that of the mass of A. What is the ratio of uncertainties $\frac{\Delta x_A}{\Delta x_B}$ in their positions ? ***[2008]***

(a) 2 (b) 0.25
(c) 4 (d) 1

24. Find the frequency of light that corresponds to photons of energy 5.0×10^{-5} erg ***[2010]***

(a) $7.5 \times 10^{-21}\ sec^{-1}$ (b) 7.5×10^{-21} sec
(c) $7.5 \times 10^{21}\ sec^{-1}$ (d) 7.5×10^{21} sec

25. Ratio of energy of photon of wavelength 3000 Å and 6000Å is ***[2012]***

(a) 3 : 1 (b) 2 : 1
(c) 1 : 2 (d) 1 : 3

26. Which of the following combinations of quantum numbers is allowed? ***[2013]***

	n	l	m	m_s
(a)	3	2	1	0
(b)	2	0	0	$-\frac{1}{2}$
(c)	3	–3	–2	$+\frac{1}{2}$
(d)	1	0	1	$+\frac{1}{2}$

27. Among the following groupings which represents the collection of isoelectronic species? ***[2013]***

(a) $NO^+, C_2^{2-}, O_2^-, CO$
(b) N_2, C_2^{2-}, CO, NO
(c) CO, NO^+, CN^-, C_2^{2-}
(d) NO, CN^-, N_2, O_2^-

28. The electrons, identified by quantum numbers n and l (i) n = 4, l = 1 (ii) n = 4, l = 0 (iii) n = 3, l = 2 (iv) n = 3, l = 1 can be placed in order of increasing energy, from the lowest to highest, as ***[2014]***

(a) (iv) < (ii) < (iii) < (i)
(b) (ii) < (iv) < (i) < (iii)
(c) (i) < (iii) < (ii) < (iv)
(d) (iii) < (i) < (iv) < (ii)

29. In hydrogen atomic spectrum, a series limit is found at 12186.3 cm^{-1}. Then it belong to ***[2014]***

(a) Lyman series (b) Balmer series
(c) Paschen series (d) Brackett series

30. Based on equation $E = -2.178 \times 10^{-18} J\left(\frac{Z^2}{n^2}\right)$, certain conclusions are written. Which of them is not correct ? ***[2015]***

(a) Larger the value of *n*, the larger is the orbit radius.
(b) Equation can be used to calculate the change in energy when the electron changes orbit.
(c) For $n = 1$, the electron has a more negative energy than it does for $n = 6$ which mean that the electron is more loosely bound in the smallest allowed orbit.
(d) The negative sign in equation simply means that the energy or electron bound to the nucleus is lower than it would be if the electrons were at the infinite distance from the nucleus.

31. Let m_p be the mass of a proton, m_n that of a neutron, M_1 that of a $^{20}_{10}Ne$ nucleus and M_2 that of a $^{40}_{20}Ca$ nucleus. Then ***[2015]***

(a) $M_2 = 2M_1$ (b) $M_1 < 10(m_p + m_n)$
(c) $M_2 > 2M_1$ (d) $M_1 = M_2$

32. Which transition in the hydrogen atomic spectrum will have the same wavelength as the transition, n = 4 to n = 2 of He^+ spectrum? ***[2016]***

(a) n = 4 to n = 3 (b) n = 3 to n = 2
(c) n = 4 to n = 2 (d) n = 2 to n = 1

33. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ***[2017]***

(a) $5 \rightarrow 2$ (b) $4 \rightarrow 1$
(c) $2 \rightarrow 5$ (d) $3 \rightarrow 2$

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 34-42) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

34. **Assertion :** An atom is electrically neutral
Reason : Atom contains equal number of protons and neutrons. ***[1997]***

35. **Assertion :** The sum of protons and neutrons is always different in isobars.
Reason : Isobars are atoms of different elements having same mass number but different atomic number. ***[1997]***

36. **Assertion :** All photons possess the same amount of energy.
Reason : Energy of photon does not depend upon wavelength of light used. ***[1998]***

37. **Assertion :** Atoms are not electrically neutral.
Reason : Number of protons and electrons are different ***[1999]***

38. **Assertion :** For Balmer series of hydrogen spectrum, the value $n_1 = 2$ and $n_2 = 3, 4, 5$.
Reason : The value of *n* for a line in Balmer series of hydrogen spectrum having the highest wave length is 4 and 6. ***[2002]***

39. **Assertion :** Absorption spectrum consists of some bright lines separated by dark spaces.
Reason : Emission spectrum consists of dark lines. ***[2002]***

40. **Assertion :** Nuclear binding energy per nucleon is in the order $^{9}_{4}Be > ^{7}_{3}Li > ^{4}_{2}He$.
Reason : Binding energy per nucleon increases linearly with difference in number of neutrons and protons. ***[2004]***

41. **Assertion :** A spectral line will be observed for a $2p_x - 2p_y$ transition.

Reason : The energy is released in the form of wave of light when electron drops from $2p_x$ to $2p_y$ orbital. ***[2008]***

42. **Assertion :** An orbital designated by $n = 3$, $l = 1$ has double dumb-bell shape.

Reason : It belongs to *p*-subshell. ***[2011]***

Directions for (Qs.43-46) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.

(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.

(c) If Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

43. **Assertion :** Angular momentum of an electron in any orbit is given by angular momentum $= \frac{n.h}{2\pi}$, where *n* is the principal quantum number.

Reason : The principal quantum number, *n*, can have any integral value. ***[2012, 13]***

44. **Assertion :** Spin quantum number can have two values, $+\frac{1}{2}$ and $-\frac{1}{2}$.

Reason : + and – signs signify the positive and negative wave functions. ***[2014]***

45. **Assertion :** It is impossible to determine the exact position and exact momentum of an electron simultaneously.

Reason : The path of an electron in an atom is clearly defined. ***[2016]***

46. **Assertion :** The radius of the first orbit of hydrogen atom is 0.529Å. ***[2017]***

Reason : Radius of each circular orbit (r_n) - 0.529Å (n^2/Z), where n = 1, 2, 3 and Z = atomic number.

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (b) Atomic number of the given element = 10
Electronic configuration = $1s^2, 2s^2 2p^6$
$1s^2 2s^2 2p^6$ is electronic configuration of Ne.
$1s^2 2s^2 2p^5 3s^1$ is excited oxidation state.

2. (a) The total no of orbital in a shell is n^2.

3. (a) Positron is electron with positive charge, ${}_{+1}e^0$

4. (c) Wavelength of visible light is 3800Å – 7600Å.

5. (d) From the de-Broglie formula for wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{150 \times 50} = 8.83 \times 10^{-33} \text{ cm.}$$

6. (b) $\frac{e}{m} = 1.75875 \times 10^{11}$

$$\frac{1.60206 \times 10^{-19}}{m} = 1.75875 \times 10^{11}$$

$$m = \frac{1.60206 \times 10^{-19}}{1.75875 \times 10^{11}} = \frac{1.60206}{1.75875} \times 10^{-30}$$

$= 9.1091 \times 10^{-31}$ kg.

7. (b) For a particular element,

$$E_n = \frac{13.6 Z^2}{n^2} \text{ erg atm}^{-1}$$

$$\therefore \quad E_n \propto \frac{1}{n^2}$$

$$\therefore \quad \frac{E_1}{E_2} = \frac{(n_2^2)}{(n_1)^2}$$

$$\text{or } E_2 = \frac{(1)^2 \times (-21.79 \times 10^{-12})}{(2)^2}$$

$= -5.447 \times 10^{-12}$ erg atm^{-1}

8. (b) Deuterium nucleus contains 1 proton and 1 neutron because it is an isotope of hydrogen.

9. (a) Most electronegative element corresponds to ns^2np^5 configuration.

10. (d) Bohr's Theory is not applicable to H^+ as it has no electron.

11. (c) We know that

$$K.E. = \frac{1}{2} mv^2$$

$$\therefore \quad v = \sqrt{\frac{2 \times K.E.}{m}}$$

$$= \sqrt{\frac{2 \times 13.6 \times 1.602 \times 10^{-19}}{9.1 \times 10^{-31}}}$$

$= 2.18824 \times 10^6$ m/s

No since, $\lambda = \frac{h}{mv}$

$$= \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 2.18824 \times 10^6}$$

$= 0.3328 \times 10^{-9} = 0.3328$ nm

12. (d) $\lambda = \frac{h}{mc} = \frac{6.6 \times 10^{-34}}{10^{-6} \times 10} = 6.63 \times 10^{-29}$ m

13. (d) According to Bohr, velocity (v) of an electron is given by relation.

$$v = 2.188 \times 10^6 \frac{Z}{n} \text{ m/s}$$

Here $n = 2$, and Z (for H) = 1

$$\therefore \quad v = \frac{2.188 \times 10^6 \times 1}{2}$$

$= 1.094 \times 10^6$ m/s

14. (a) Electronic configuration corrosponds to atomic number 7; hence the element is nitrogen.

15. (b) Quantum numbers of an atom can be defined on the basis of Pauli's exclusion principle which states that no two electrons can have the same value of all the four quantum numbers.

16. (a) Li^{2+} will have only one electron in its outer-most electron. Its spectrum will be very similar to that of hydrogen.

17. (b) Azimuthal quantum no. 'm' defines angular momentum of electron.

18. (c) Magnetic quantum no. 'm' represents the spatial orientation of the orbital.

19. (b) For $n = 4$ and $\ell = 3$, the orbital is 4 *f*.
No. of values of $m = (2\ell + 1) = 7$

20. (d) No. of electrons in ClO_2^- = 17 + 16 + 1 = 34

No. of electrons in ClF_2^+ = 17 + 9 × 2 – 1 = 34

21. (c) Bohr's radius (*r*)

$$= \frac{0.529 \times 10^{-10} n^2}{Z} \text{m} = \frac{52.9 n^2}{Z} \text{pm}$$

Here n (No of shell) = 1
Z (At. No) = 2

$$\therefore \quad r = \frac{52.9 \times 1^2}{2} = 26.45 \text{ pm}$$

22. (a) $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

$$= \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 1 \times 0.5}} = 6.6 \times 10^{-34} \text{m}$$

23. (a) Using the relation,

$$\Delta x.\ \Delta v = \frac{h}{4\pi m}$$

[Heisenberg' uncertainty principle]

$$\text{or } \Delta x = \frac{h}{4\pi m.\Delta v}$$

$$\text{Thus, } \Delta x_A = \frac{h}{4\pi \times 0.05 \times m} \quad \ldots(i)$$

$$\Delta x_B = \frac{h}{4\pi \times 0.02 \times 5m} \quad \ldots(ii)$$

Dividing (i) by (ii), we get

$$\frac{\Delta x_A}{\Delta x_B} = \frac{0.02 \times 5}{0.05} = \frac{10}{5} \text{ or } 2$$

24. (c) Using E = hν, we get

$$\nu = \frac{E}{h} = \frac{5.0 \times 10^{-5} \text{erg}}{6.63 \times 10^{-34} \text{Js}}$$

$$= \frac{5.0 \times 10^{-5} \text{erg}}{6.63 \times 10^{-34} \times 10^7 \text{ erg sec}}$$

$[\because 1\text{J} = 10^7 \text{ erg}]$

$= 7.54 \times 10^{21} \text{ sec}^{-1}$

25. (b) $E = \frac{hc}{\lambda}; \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{6000}{3000} = 2:1$

26. (b)

27. (c) The species CO, NO^+, CN^- and C_2^{2-} contain 14 electrons each.

28. (a) (n + *l*) rule the higher the value of (n + *l*), the higher is the energy. When (n + *l*) value is the same see value of n.

	i	ii	iii	iv
(n + *l*)	(4 + 1)	(4 + 0)	(3 + 2)	(3 + 1)
	5	4	5	4

$\therefore$ iv < ii < iii < i

29. (c) Series limit is the last line of the series, i.e. $n_2 = \infty$.

$$\therefore \bar{\upsilon} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{n_1^2} - \frac{1}{\infty^2}\right] = \frac{R}{n_1^2}$$

$$\because \bar{\upsilon} = 12186.3 = \frac{109677.76}{n_1^2}$$

$$\Rightarrow n_1^2 = \frac{109677.76}{12186.3} = 9 \Rightarrow n_1 = 3$$

$\therefore$ The line belongs to Paschen series.

30. (c) Energy of an electron at infinite distance from the nucleus is zero. As an electron approaches the nucleus, the electron attraction increases and hence the energy of electron decreases and thus becomes negative. Thus as the value of *n* decreases, *i.e.* lower the orbit is, more negative is the energy of the electron in it.

31. (a) $^{20}_{10}Ne$ contains 10 protons and 10 neutrons
$\therefore M_1 = 10\, m_p + 10 m_n$
$^{40}_{20}Ca$ contains 20 protons and 20 neutrons
$\therefore M_2 = 20\, m_p + 20\, m_n$
$\therefore M_2 = 2M_1$

32. (d) For He^+ ion, $\frac{1}{\lambda} = Z^2 R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$(2)^2 R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{4}$$

For hydrogen atom, $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\frac{3R}{4} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{ or } \frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{3}{4}$$

$n_1 = 1$ and $n_2 = 2$.

33. (a) The lines falling in the visible region comprise Balmer series. Hence the third line would be n_1=2, n_2 = 5 i.e. 5 $\rightarrow$ 2.

Type B : Assertion Reason Questions

34. (c) Atom is electrically neutral. Atoms necessarily contain equal number of protons and electrons, but not neutrons.

35. (e) Isobars have the same atomic mass (sum of protons and neutrons) but different atomic numbers.

36. (d) Energy of a photon = $h\nu = h.\frac{c}{\lambda}$.
So, energy depends upon wavelength.

37. (d) Atoms are electrically neutral as number of electrons and protons are same.

38. (c) The value of n for a line in Balmer series of hydrogen spectrum having the highest wave length will be $n_1 = 2$ and $n_2 = 3$ because this transition will have lowest energy and so highest wavelength.

39. (d) Absorption spectrum consists of dark lines separated by bright space and emission spectrum consists of bright lines.

40. (d) Binding energy depends on the mass defect (mass lost when the constituent protons and neutrons combine to form nucleus). Binding energy is direct measurement of stability of nucleus Higher the binding energy (means high loss of energy during formation of nucleus from protons and neutrons) per nucleon, higher is stability of the nucleus. The order of binding energy is

$^{4}_{2}He > {}^{7}_{3}Li > {}^{9}_{4}Be$

41. (d) In this case both assertion and reason are false. Both $2p_x$ and $2p_y$ orbitals have equal energy ($2p$ orbitals are degenerate), there is no possibility of electron transition and hence no energy is released and thus no spectral line will be observed.

42. (d) The orbital has dumb-bell shape and belongs to p-subshell.

43. (b) Both assertion and reason are correct. Reason is **not** the correct explanation of assertion.

44. (c) Plus and minus signs of spin quantum numbers imply that spin angular momentum of the electron, a vector quantity, acts in the same or opposite directions of orbital angular momentum.

45. (c)

46. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

Radius, $r_n = \frac{n^2h^2}{4\pi e^2 mZ} = \frac{n^2}{Z} \times 0.529\text{Å}.r_n$

For first orbit of H-atom

$n = 1$

$r_1 = \frac{(1)^2}{1} \times 0.529\,\text{Å} = 0.529\,\text{Å}$