CHAPTER 2

Structure of Atom

Section-A JEE Advanced/ IIT-JEE

A Fill in the Blanks

1. The mass of a hydrogen atom is .... kg. *(1982 - 1 Mark)*
2. Isotopes of an element differ in the number of .... in their nuclei. *(1982 - 1 Mark)*
3. When there are two electrons in the same orbital, they have .... spins. *(1982 - 1 Mark)*
4. Elements of the same mass number but of different atomic numbers are known as .... *(1983 - 1 Mark)*
5. The uncertainty principle and the concept of wave nature of matter were proposed by .... and .... respectively. (Heisenberg, Schrodinger, Maxwell, de Broglie) *(1988 - 1 Mark)*
6. The light radiations with discrete quantities of energy are called .... *(1993 - 1 Mark)*
7. Wave functions of electrons in atoms and molecules are called .... *(1993 - 1 Mark)*
8. The $2p_x$, $2p_y$ and $2p_z$ orbitals of atom have identical shapes but differ in their .... *(1993 - 1 Mark)*
9. The outermost electronic configuration of Cr is .... *(1994 - 1 Mark)*

B True / False

1. The outer electronic configuration of the ground state chromium atom is $3d^4 4s^2$. *(1982 - 1 Mark)*
2. Gamma rays are electromagnetic radiations of wavelengths of 10^{-6} cm to 10^{-5} cm. *(1983 - 1 Mark)*
3. The energy of the electron in the $3d$-orbital is less than that in the $4s$-orbital in the hydrogen atom. *(1983 - 1 Mark)*
4. The electron density in the XY plane in $3d_{x^2-y^2}$ orbital is zero. *(1986 - 1 Mark)*
5. In a given electric field, β-particles are deflected more than α-particles in spite of α-particles having larger charge. *(1993 - 1 Mark)*

C MCQs with One Correct Answer

1. The number of neutrons in dipositive zinc ion with mass number 70 is *(1979)*
   (a) 34 (b) 36
   (c) 38 (d) 40
2. Rutherford's experiment on scattering of α-particles showed for the first time that the atom has *(1981 - 1 Mark)*
   (a) electrons (b) protons
   (c) nucleus (d) neutrons
3. Any p-orbital can accommodate upto *(1983 - 1 Mark)*
   (a) four electrons
   (b) six electrons
   (c) two electrons with parallel spins
   (d) two electrons with opposite spins
4. The principal quantum number of an atom is related to the *(1983 - 1 Mark)*
   (a) size of the orbital
   (b) spin angular momentum
   (c) orbital angular momentum
   (d) orientation of the orbital in space
5. Rutherford's scattering experiment is related to the size of the *(1983 - 1 Mark)*
   (a) nucleus (b) atom
   (c) electron (d) neutron
6. The increasing order (lowest first) for the values of e/m (charge/mass) for electron (e), proton (p), neutron (n) and alpha particle (α) is : *(1984 - 1 Mark)*
   (a) e, p, n, α (b) n, p, e, α
   (c) n, p, α, e (d) n, α, p, e
7. Correct set of four quantum numbers for the valence (outermost) electron of rubidium ($Z = 37$) is : *(1984 - 1 Mark)*
   (a) 5, 0, 0, +½ (b) 5, 1, 0, +½
   (c) 5, 1, 1, +½ (d) 6, 0,0, +½
8. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon? *(1984 - 1 Mark)*
   (a) $3s$ (b) $2p$
   (c) $2s$ (d) $1s$

9. Bohr model can explain : *(1985 - 1 Mark)*
(a) the spectrum of hydrogen atom only
(b) spectrum of an atom or ion containing one electron only
(c) the spectrum of hydrogen molecule
(d) the solar spectrum

10. The radius of an atomic nucleus is of the order of : *(1985 - 1 Mark)*
(a) 10^{-10} cm (b) 10^{-13} cm
(c) 10^{-15} cm (d) 10^{-8} cm

11. Electromagnetic radiation with maximum wavelength is : *(1985 - 1 Mark)*
(a) ultraviolet (b) radiowave
(c) *X*-ray (d) infrared

12. Rutherford's alpha particle scattering experiment eventually led to the conclusion that : *(1986 - 1 Mark)*
(a) mass and energy are related
(b) electrons occupy space around the nucleus
(c) neutrons are buried deep in the nucleus
(d) the point of impact with matter can be precisely determined.

13. Which one of the following sets of quantum numbers represents an impossible arrangement? *(1986 - 1 Mark)*

	n	l	m_l	m_s
(a)	3	2	–2	½
(b)	4	0	0	½
(c)	3	2	–3	½
(d)	5	3	0	–½

14. The ratio of the energy of a photon of 2000Å wavelength radiation to that of 4000Å radiation is : *(1986 - 1 Mark)*
(a) ¼ (b) 4
(c) ½ (d) 2

15. The triad of nuclei that is isotonic is *(1988 - 1 Mark)*
(a) ${}^{14}_{6}C,\ {}^{15}_{7}N,\ {}^{17}_{9}F$ (b) ${}^{12}_{6}C,\ {}^{14}_{7}N,\ {}^{19}_{9}F$
(c) ${}^{14}_{6}C,\ {}^{14}_{7}N,\ {}^{17}_{9}F$ (d) ${}^{14}_{6}C,\ {}^{14}_{7}N,\ {}^{19}_{9}F$

16. The wavelength of a spectral line for an electronic transition is inversely related to : *(1988 - 1 Mark)*
(a) the number of electrons undergoing the transition
(b) the nuclear charge of the atom
(c) the difference in the energy of the energy levels involved in the transition
(d) the velocity of the electron undergoing the transition.

17. The orbital diagram in which the Aufbau principle is violated is : *(1988 - 1 Mark)*

	2s	2p
(a)	[↑↓]	[↑↓][↑][ ]
(b)	[↑]	[↑↓][↑][↑]
(c)	[↑↓]	[↑][↑][↑]
(d)	[↑↓]	[↑↓][↑][↑]

18. The outermost electronic configuration of the most electronegative element is *(1988 - 1 Mark)*
(a) $ns^2\ np^3$ (b) $ns^2\ np^4$
(c) $ns^2\ np^5$ (d) $ns^2\ np^6$

19. The correct ground state electronic configuration of chromium atom is : *(1989 - 1 Mark)*
(a) $[Ar]\ 3d^5\ 4s^1$ (b) $[Ar]\ 3d^4\ 4s^2$
(c) $[Ar]\ 3d^6\ 4s^0$ (d) $[Ar]\ 4d^5\ 4s^1$

20. The correct set of quantum numbers for the unpaired electron of chlorine atom is : *(1989 - 1 Mark)*

	n	l	m
(a)	2	1	0
(b)	2	1	1
(c)	3	1	1
(d)	3	0	0

21. Which of the following does not characterise *X*-rays? *(1992 - 1 Mark)*
(a) The radiation can ionise gases
(b) It causes ZnS to fluorescence
(c) Deflected by electric and magnetic fields
(d) Have wavelengths shorter than ultraviolet rays

22. Which of the following relates to photons both as wave motion and as a stream of particles? *(1992 - 1 Mark)*
(a) Inference (b) $E = mc^2$
(c) Diffraction (d) $E = h\nu$

23. A 3*p* orbital has : *(1995S)*
(a) two non spherical nodes
(b) two spherical nodes
(c) one spherical & one non spherical node
(d) one spherical and two non spherical nodes

24. The orbital angular momentum of an electron in 2*s* orbital is: *(1996 - 1 Mark)*
(a) $+\frac{1}{2}\cdot\frac{h}{2\pi}$ (b) Zero
(c) $\frac{h}{2\pi}$ (d) $\sqrt{2}.\frac{h}{2\pi}$

25. For a *d*-electron, the orbital angular momentum is *(1997 - 1 Mark)*
(a) $\sqrt{6}(h/2\pi)$ (b) $\sqrt{2}(h/2\pi)$
(c) $(h/2\pi)$ (d) $2(h/2\pi)$

26. The electrons, identified by quantum numbers n and l, (i) $n = 4, l = 1$, (ii) $n = 4, l = 0$, (iii) $n = 3, l = 2$, and (iv) $n = 3, l = 1$ can be placed in order of increasing energy, from the lowest to highest, as *(1999 - 2 Marks)*
(a) (iv) < (ii) < (iii) < (i) (b) (ii) < (iv) < (i) < (iii)
(c) (i) < (iii) < (ii) < (iv) (d) (iii) < (i) < (iv) < (ii)

27. The number of nodal planes in a p_x orbital is *(2000S)*
(a) one (b) two
(c) three (d) zero

28. The electronic configuration of an element is $1s^2$, $2s^2\ 2p^6$, $3s^2\ 3p^6\ 3d^5$, $4s^1$. This represents its *(2000S)*
(a) excited state (b) ground state
(c) cationic form (d) anionic form

29. The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order *(2001S)*
(a) 10^{-10} m (b) 10^{-20} m
(c) 10^{-30} m (d) 10^{-40} m

30. The quantum numbers +1/2 and –1/2 for the electron spin represent *(2001S)*
(a) rotation of the electron in clockwise and anticlockwise direction respectively
(b) rotation of the electron in anticlockwise and clockwise direction respectively
(c) magnetic moment of the electron pointing up and down respectively
(d) two quantum mechanical spin states which have no classical analogue

31. Rurtherford's experiment, which established the nuclear model of the atom, used a beam of *(2002S)*
(a) β -particles, which impinged on a metal foil and got absorbed
(b) γ -rays, which impinged on a metal foil and ejected electrons
(c) helium atoms, which impinged on a metal foil and got scattered
(d) helium nuclei, which impinged on a metal foil and got scattered

32. If the nitrogen atom has electronic configuration $1s^7$, it would have energy lower than that of the normal ground state configuration $1s^2 2s^2 2p^3$, because the electrons would be closer to the nucleus. Yet $1s^7$ is not observed because it violates. *(2002S)*
(a) Heisenberg uncertainty principle
(b) Hund's rule
(c) Pauli exclusion principle
(d) Bohr postulate of stationary orbits

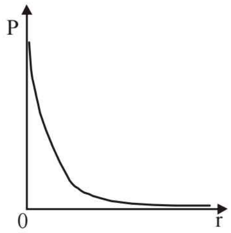
33. The radius of which of the following orbit is same as that of the first Bohr's orbit of hydrogen atom? *(2004S)*
(a) He^+ $(n=2)$ (b) Li^{2+} $(n=2)$
(c) Li^{2+} $(n=3)$ (d) Be^{3+} $(n=2)$

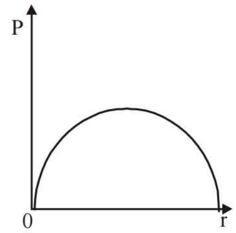
34. The number of radial nodes of 3*s* and 2*p* orbitals are respectively *(2005S)*
(a) 2, 0 (b) 0, 2
(c) 1, 2 (d) 2, 1

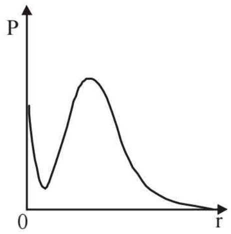
35. Given that the abundances of isotopes ^{54}Fe, ^{56}Fe and ^{57}Fe are 5%, 90% and 5%, respectively, the atomic mass of Fe is *(2009S)*
(a) 55.85 (b) 55.95
(c) 55.75 (d) 56.05

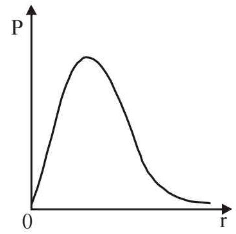
36. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius] : *(2012)*
(a) $\frac{h^2}{4\pi^2 m a_0^2}$ (b) $\frac{h^2}{16\pi^2 m a_0^2}$
(c) $\frac{h^2}{32\pi^2 m a_0^2}$ (d) $\frac{h^2}{64\pi^2 m a_0^2}$

37. P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness, dr, at a distance r from the nucleus. The volume of this shell is $4\pi r^2 dr$. The qualitative sketch of the dependence of P on r is *(JEE Adv. 2016)*

(a) 

(b) 

(c) 

(d) 

D MCQs with One or More Than One Correct

1. An isotone of $^{76}_{32}Ge$ is : *(1984 - 1 Mark)*
(a) $^{77}_{32}Ge$ (b) $^{77}_{33}As$
(c) $^{77}_{34}Se$ (d) $^{78}_{34}Se$

2. Many elements have non-integral atomic masses because : *(1984 - 1 Mark)*
(a) they have isotopes
(b) their isotopes have non-integral masses
(c) their isotopes have different masses
(d) the constitutents, neutrons, protons and electrons, combine to give fractional masses

3. When alpha particles are sent through a thin metal foil, most of them go straight through the foil because : *(1984 - 1 Mark)*
(a) alpha particles are much heavier than electrons
(b) alpha particles are positively charged
(c) most part of the atom is empty space
(d) alpha particle move with high velocity

4. The sum of the number of neutrons and proton in the isotope of hydrogen is : *(1986 - 1 Mark)*
   (a) 6 (b) 2
   (c) 4 (d) 3

5. The energy of an electron in the first Bohr orbit of H atom is –13.6 eV. The possible energy value(s) of the excited state(s) for electrons in Bohr orbits of hydrogen is (are) *(1998 - 2 Marks)*
   (a) –3.4 eV (b) –4.2 eV
   (c) –6.8 eV (d) –1.5 eV

6. Which of the following satement(s) is (are) correct? *(1998 - 2 Marks)*
   (a) The electronic configuration of Cr is [Ar] $3d^5 4s^1$. (Atomic Number of Cr = 24)
   (b) The magnetic quantum number may have a negative value.
   (c) In silver atom, 23 electrons have a spin of one type and 24 of the opposite type. (Atomic Number of Ag = 47)
   (d) The oxidation state of nitrogen in HN_3 is – 3.

7. Decrease in atomic number is observed during *(1998 - 2 Marks)*
   (a) alpha emission (b) beta emission
   (c) positron emission (d) electron capture.

8. Ground state electronic configuration of nitrogen atom can be represented by *(1999 - 3 Marks)*
   (a) [↑↓] [↑↓] [↑][↑][↑] (b) [↑↓] [↑↓] [↑][↓][↑]
   (c) [↑↓] [↑↓] [↑][↓][↓] (d) [↑↓] [↑↓] [↓][↓][↓]

E Subjective Problems

1. Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of natural boron is 10.81. Calculate the percentage of each isotope in natural boron. *(1978)*

2. The energy of the electron in the second and the third Bohr's orbits of the hydrogen atom is -5.42×10^{-12} erg and -2.41×10^{-12} erg respectively. Calculate the wavelength of the emitted radiation when the electron drops from the third to the second orbit. *(1981 - 3 Marks)*

3. Calculate the wavelength in Angstrom of the photon that is emitted when an electron in the Bohr orbit, $n = 2$ returns to the orbit, $n = 1$ in the hydrogen atom. The ionization potential of the ground state hydrogen atom is 2.17×10^{-11} erg per atom. *(1982 - 4 Marks)*

4. The electron energy in hydrogen atom is given by $E = (-21.7 \times 10^{-12})/n^2$ ergs. Calculate the energy required to remove an electron completely from the $n = 2$ orbit. What is the longest wavelength (in cm) of light that can be used to cause this transition? *(1984 - 3 Marks)*

5. Give reasons why the ground state outermost electronic configuration of silicon is : *(1985 - 2 Marks)*

   3s [↑↓] 3p [↑][↑][ ] and not 3s [↑↓] 3p [↑][↓][ ]

6. What is the maximum number of electrons that may be present in all the atomic orbitals with principal quantum number 3 and azimuthal quantum number 2? *(1985 - 2 Marks)*

7. According to Bohr's theory, the electronic energy of hydrogen atom in the n^{th} Bohr's orbit is given by

$$E_n = \frac{-21.76 \times 10^{-19}}{n^2} \text{ J}.$$

Calculate the longest wavelength of light that will be needed to remove an electron from the third Bohr orbit of the He^+ ion. *(1990 - 3 Marks)*

8. Estimate the difference in energy between Ist and 2nd Bohr orbit for a hydrogen atom. At what minimum atomic number, a transition from $n = 2$ to $n = 1$ energy level would result in the emission of X-rays with $\lambda = 3.0 \times 10^{-8}$ m ? Which hydrogen atom-like species does this atomic number correspond to ? *(1993 - 5 Marks)*

9. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition $n = 4$ to $n = 2$ of He^+ spectrum? *(1993 - 3 Marks)*

10. Find out the number of waves made by a Bohr electron in one complete revolution in its 3rd orbit. *(1994 - 3 Marks)*

11. Iodine molecule dissociates into atoms after absorbing light of 4500 Å. If one quantum of radiation is absorbed by each molecule, calculate the kinetic energy of iodine atoms. (Bond energy of I_2 = 240 kJ mol^{-1}) *(1995 - 2 Marks)*

12. Calculate the wave number for the shortest wavelength transition in the Balmer series of atomic hydrogen. *(1996 - 1 Mark)*

13. Consider the hydrogen atom to be a proton embedded in a cavity of radius a_0 (Bohr radius) whose charge is neutralised by the addition of an electron to the cavity in vacuum, infinitely slowly. Estimate the average total energy of an electron in its ground state in a hydrogen atom as the work done in the above neutralisation process. Also, if the magnitude of the average kinetic energy is half the magnitude of the average potential energy, find the average potential energy. *(1996 - 2 Marks)*

14. Calculate the energy required to excite one litre of hydrogen gas at 1 atm and 298 K to the first excited state of atomic hydrogen. The energy for the dissociation of H–H bond is 436 kJ mol^{-1}. *(2000 - 4 Marks)*

15. Wavelength of high energy transition of H–atoms is 91.2nm. Calculate the corresponding wavelength of He atoms. *(2003 - 2 Marks)*

16. The Schrodinger wave equation for hydrogen atom is *(2004 - 2 Marks)*

$$\Psi_{2s} = \frac{1}{4\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{3/2}\left(2-\frac{r_0}{a_0}\right)e^{-r_0/a_0}$$

Where a_0 is Bohr's radius. If the radial node in 2s be at r_0, then find r_0 in terms of a_0.

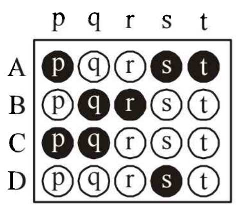
17. A ball of mass 100 g is moving with 100 ms^{-1}. Find its wavelength. *(2004 - 1 Mark)*

18. Find the velocity (ms^{-1}) of electron in first Bohr's orbit of radius a_0. Also find the de Broglie's wavelength (in m). Find the orbital angular momentum of 2p orbital of hydrogen atom in units of $h/2\pi$. *(2005 - 2 Marks)*

F Match the Following

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



1. According to Bohr's theory, *(2006 - 6M)*
E_n = Total energy, K_n = Kinetic energy, V_n = Potential energy, r_n = Radius of n^th orbit
Match the following :

Column I	Column II
(A) $V_n / K_n = ?$	(p) 0
(B) If radius of n^th orbit $\propto E_n^x$, $x = ?$	(q) –1
(C) Angular momentum in lowest orbital	(r) –2
(D) $\frac{1}{r^n} \propto Z^y$, $y = ?$	(s) 1

2. Match the entries in Column I with the correctly related quantum number(s) in Column II. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS *(2008 - 6M)*

Column I	Column II
(A) Orbital angular momentum of the electron in a hydrogen-like atomic orbital	(p) Principal quantum number
(B) A hydrogen-like one-electron wave function obeying Pauli principle	(q) Azimuthal quantum number
(C) Shape, size and orientation of hydrogen- like atomic orbitals	(r) Magnetic quantum number
(D) Probability density of electron at the nucleus in hydrogen-like atom	(s) Electron spin quantum number

G Comprehension Based Questions

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom. *(2010)*

1. The state S_1 is :
(a) 1s (b) 2s (c) 2p (d) 3s

2. Energy of the state S_1 in units of the hydrogen atom ground state energy is :
(a) 0.75 (b) 1.50 (c) 2.25 (d) 4.50

3. The orbital angular momentum quantum number of the state S_2 is :
(a) 0 (b) 1 (c) 2 (d) 3

H Assertion & Reason Type Questions

1. **ASSERTION :** Nuclide $^{30}_{13}$Al is less stable than $^{40}_{20}$Ca *(1998 - 2 Marks)*
REASON : Nuclides having odd number of protons and neutrons are generally unstable.
(a) If both *assertion* and *reason* are correct, and *reason* is the correct explanation of the *assertion*.
(b) If both *assertion* and *reason* are correct, but *reason* is not the correct explanation of the *assertion*.

(c) If *assertion* is correct but *reason* is incorrect.
(d) If *assertion* is incorrect but *reason* is correct.

2. This question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason) and has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.
STATEMENT-1 : Band gap in germanium is small. because
STATEMENT-2 : The energy gap of each germanium atomic energy level is infinitesimally small. *(2007)*
(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1
(b) Statement-1 is True, Statement-2 is True; Statement-2 is not a correct explanation for Statement-1
(c) Statement-1 is True, Statement-2 is False
(d) Statement-1 is False, Statement-2 is True.

3. **STATEMENT-1 :** The plot of atomic number (y-axis) versus number of neutrons (x-axis) for stable nuclei shows a curvature towards x-axis from the line of 45° slope as the atomic number is increased.
STATEMENT-2 : Proton-proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides. *(2008)*
(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(c) Statement-1 is True, Statement-2 is False
(d) Statement-1 is False, Statement-2 is True

I Integer Value Correct Type

1. The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is *(2011)*

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
ϕ (eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

2. The maximum number of electrons that can have principal quantum number, $n = 3$, and spin quantum $m_s = -\frac{1}{2}$, is *(2011)*

3. The atomic masses of 'He' and 'Ne' are 4 and 20 a.m.u., respectively. The value of the de Broglie wavelength of 'He' gas at —73°C is "M" times that of the de Broglie wavelength of 'Ne' at 727°C 'M' is *(JEE Adv. 2013)*

4. In an atom, the total number of electrons having quantum numbers $n = 4$, $|m_l| = 1$ and $m_s = -\frac{1}{2}$ is *(JEE Adv. 2014)*

5. Not considering the electronic spin, the degeneracy of the second excited state (n = 3) of H atom is 9, while the degeneracy of the second excited state of H^- is *(JEE Adv. 2015)*

Section-B JEE Main / AIEEE

1. In a hydrogen atom, if energy of an electron in ground state is 13.6. ev, then that in the 2nd excited state is **[2002]**
(a) 1.51 eV (b) 3.4 eV
(c) 6.04 eV (d) 13.6 eV.

2. Uncertainty in position of a minute particle of mass 25 g in space is 10^{-5} m. What is the uncertainty in its velocity (in ms^{-1})? ($h = 6.6 \times 10^{-34}$ Js) **[2002]**
(a) 2.1×10^{-34} (b) 0.5×10^{-34}
(c) 2.1×10^{-28} (d) 0.5×10^{-23}.

3. The number of d-electrons retained in Fe^{2+} (At. no. of Fe = 26) ion is **[2003]**
(a) 4 (b) 5
(c) 6 (d) 3

4. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{l(l+1)}\cdot\frac{h}{2\pi}$. This momentum for an s-electron will be given by **[2003]**
(a) zero (b) $\frac{h}{2\pi}$
(c) $\sqrt{2}\cdot\frac{h}{2\pi}$ (d) $+\frac{1}{2}\cdot\frac{h}{2\pi}$

5. Which one of the following groupings represents a collection of isoelectronic species ?(At. nos. : Cs : 55, Br : 35) **[2003]**
(a) N^{3-}, F^-, Na^+ (b) Be, Al^{3+}, Cl^-
(c) Ca^{2+}, Cs^+, Br (d) Na^+, Ca^{2+}, Mg^{2+}

6. 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 **[2003]**
(a) $5 \to 2$ (b) $4 \to 1$
(c) $2 \to 5$ (d) $3 \to 2$

7. The de Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 metres per second is approximately **[2003]**
(a) 10^{-31} metres (b) 10^{-16} metres
(c) 10^{-25} metres (d) 10^{-33} metres
Planck's constant, $h = 6.63 \times 10^{-34}$ Js

8. Which of the following sets of quantum numbers is correct for an electron in 4f orbital ? **[2004]**
(a) $n = 4, \ell = 3, m = +1, s = +\frac{1}{2}$
(b) $n = 4, \ell = 4, m = -4, s = -\frac{1}{2}$
(c) $n = 4, \ell = 3, m = +4, s = +\frac{1}{2}$
(d) $n = 3, \ell = 2, m = -2, s = +\frac{1}{2}$

9. Consider the ground state of Cr atom (X = 24). The number of electrons with the azimuthal quantum numbers, $\ell = 1$ and 2 are, respectively [2004]
(a) 16 and 4 (b) 12 and 5
(c) 12 and 4 (d) 16 and 5

10. The wavelength of the radiation emitted, when in a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant = $1.097 \times 10^7\ m^{-1}$) [2004]
(a) 406 nm (b) 192 nm
(c) 91 nm (d) 9.1×10^{-8} nm

11. Which one of the following sets of ions represents the collection of isoelectronic species? [2004]
(a) $K^+, Cl^-, Mg^{2+}, Sc^{3+}$ (b) $Na^+, Ca^{2+}, Sc^{3+}, F^-$
(c) $K^+, Ca^{2+}, Sc^{3+}, Cl^-$ (d) $Na^+, Mg^{2+}, Al^{3+}, Cl^-$
(Atomic nos. : F = 9, Cl = 17, Na = 11, Mg = 12, Al = 13, K = 19, Ca = 20, Sc = 21)

12. In a multi-electron atom, which of the following orbitals described by the three quantum members will have the same energy in the absence of magnetic and electric fields? [2005]
(A) $n = 1, l = 0, m = 0$ (B) $n = 2, l = 0, m = 0$
(C) $n = 2, l = 1, m = 1$ (D) $n = 3, l = 2, m = 1$
(E) $n = 3, l = 2, m = 0$
(a) (D) and (E) (b) (C) and (D)
(c) (B) and (C) (d) (A) and (B)

13. Of the following sets which one does NOT contain isoelectronic species? [2005]
(a) $BO_3^{3-}, CO_3^{2-}, NO_3^-$ (b) $SO_3^{2-}, CO_3^{2-}, NO_3^-$
(c) CN^-, N_2, C_2^{2-} (d) $PO_4^{3-}, SO_4^{2-}, ClO_4^-$

14. According to Bohr's theory, the angular momentum of an electron in 5th orbit is [2006]
(a) $10\ h/\pi$ (b) $2.5\ h/\pi$
(c) $25\ h/\pi$ (d) $1.0\ h/\pi$

15. Uncertainty in the position of an electron (mass = 9.1×10^{-31} kg) moving with a velocity 300 ms^{-1}, accurate upto 0.001% will be [2006]
(a) 1.92×10^{-2} m (b) 3.84×10^{-2} m
(c) 19.2×10^{-2} m (d) 5.76×10^{-2} m
($h = 6.63 \times 10^{-34}$ Js)

16. Which one of the following sets of ions represents a collection of isoelectronic species? [2006]
(a) $N^{3-}, O^{2-}, F^-, S^{2-}$ (b) $Li^+, Na^+, Mg^{2+}, Ca^{2+}$
(c) $K^+, Cl^-, Ca^{2+}, Sc^{3+}$ (d) $Ba^{2+}, Sr^{2+}, K^+, Ca^{2+}$

17. Which of the following sets of quantum numbers represents the highest energy of an atom? [2007]
(a) $n = 3, l = 0, m = 0, s = +1/2$
(b) $n = 3, l = 1, m = 1, s = +1/2$
(c) $n = 3, l = 2, m = 1, s = +1/2$
(d) $n = 4, l = 0, m = 0, s = +1/2$.

18. Which one of the following constitutes a group of the isoelectronic species? [2008]
(a) C_2^{2-}, O_2^-, CO, NO (b) $NO^+, C_2^{2-}, CN^-, N_2$
(c) $CN^-, N_2, O_2^{2-}, C_2^{2-}$ (d) N_2, O_2^-, NO^+, CO

19. The ionization enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from n = 1 to n = 2 is [2008]
(a) 8.51×10^5 J mol^{-1} (b) 6.56×10^5 J mol^{-1}
(c) 7.56×10^5 J mol^{-1} (d) 9.84×10^5 J mol^{-1}

20. Calculate the wavelength (in nanometer) associated with a proton moving at $1.0 \times 10^3\ ms^{-1}$.
(Mass of proton = 1.67×10^{-27} kg and $h = 6.63 \times 10^{-34}$ Js)
(a) 0.40 nm (b) 2.5 nm [2009]
(c) 14.0 nm (d) 0.32 nm

21. In an atom, an electron is moving with a speed of 600 m/s with an accuracy of 0.005%. Certainity with which the position of the electron can be located is ($h = 6.6 \times 10^{-34}$ kg m^2s^{-1}, mass of electron, $e_m = 9.1 \times 10^{-31}$ kg) : [2009]
(a) 5.10×10^{-3} m (b) 1.92×10^{-3} m
(c) 3.84×10^{-3} m (d) 1.52×10^{-4} m

22. The energy required to break one mole of Cl – Cl bonds in Cl_2 is 242 kJ mol^{-1}. The longest wavelength of light capable of breaking a single Cl – Cl bond is
($c = 3 \times 10^8\ ms^{-1}$ and $N_A = 6.02 \times 10^{23}\ mol^{-1}$). [2010]
(a) 594 nm (b) 640 nm
(c) 700 nm (d) 494 nm

23. Ionisation energy of He^+ is 19.6×10^{-18} J $atom^{-1}$. The energy of the first stationary state ($n = 1$) of Li^{2+} is [2010]
(a) 4.41×10^{-16} J $atom^{-1}$ (b) -4.41×10^{-17} J $atom^{-1}$
(c) -2.2×10^{-15} J $atom^{-1}$ (d) 8.82×10^{-17} J $atom^{-1}$

24. A gas absorbs a photon of 355 nm and emits at two wavelengths. If one of the emissions is at 680 nm, the other is at: [2011]
(a) 1035 nm (b) 325 nm
(c) 743 nm (d) 518 nm

25. The electrons identified by quantum numbers n and ℓ :

(A) $n = 4, \ell = 1$ (B) $n = 4, \ell = 0$

(C) $n = 3, \ell = 2$ (D) $n = 3, \ell = 1$

can be placed in order of increasing energy as : **[2012]**

(a) $(C) < (D) < (B) < (A)$ (b) $(D) < (B) < (C) < (A)$

(c) $(B) < (D) < (A) < (C)$ (d) $(A) < (C) < (B) < (D)$

26. Energy of an electron is given by $E = -2.178 \times 10^{-18} J\left(\frac{Z^2}{n^2}\right)$.

Wavelength of light required to excite an electron in an hydrogen atom from level n = 1 to n = 2 will be :

($h = 6.62 \times 10^{-34}$ Js and $c = 3.0 \times 10^8$ ms^{-1}) **[JEE M 2013]**

(a) 1.214×10^{-7} m (b) $2.816 \times 10.^{-7}$ m

(c) 6.500×10^{-7} m (d) 8.500×10^{-7} m

27. The correct set of four quantum numbers for the valence electrons of rubidium atom ($Z = 37$) is: **[JEE M 2014]**

(a) $5, 0, 0, +\frac{1}{2}$ (b) $5, 1, 0, +\frac{1}{2}$

(c) $5, 1, 1, +\frac{1}{2}$ (d) $5, 0, 1, +\frac{1}{2}$

28. Which of the following is the energy of a possible excited state of hydrogen ? **[JEE M 2015]**

(a) –3.4 eV (b) +6.8 eV

(c) +13.6 eV (d) –6.8 eV

29. A stream of electrons from a heated filaments was passed two charged plates kept at a potential difference V esu. If e and m are charge and mass of an electron, respectively, then the value of h/λ (where λ is wavelength associated with electron wave) is given by: **[JEE M 2016]**

(a) $\sqrt{meV}$ (b) $\sqrt{2meV}$

(c) meV (d) $2meV$

2 Structure of Atom

Section-A : JEE Advanced/ IIT-JEE

A 1. 1.66×10^{-27} Kg 2. neutrons 3. antiparallel or opposite 4. isobars 5. Heisenberg, de-Broglie
6. Photons 7. oribtals 8. orientation in space 9. $3d^5\,4s^1$

B 1. F 2. F 3. T 4. F 5. T

C

1. (d)	2. (c)	3. (d)	4. (a)	5. (a)	6. (d)	7. (a)
8. (d)	9. (b)	10. (b)	11. (b)	12. (b)	13. (c)	14. (d)
15. (a)	16. (c)	17. (b)	18. (c)	19. (a)	20. (c)	21. (c)
22. (d)	23. (c)	24. (b)	25. (a)	26. (a)	27. (a)	28. (b)
29. (a)	30. (d)	31. (d)	32. (c)	33. (d)	34. (a)	35. (b)
36. (c)	37. (d)					

D 1. (b, d) 2. (a, c) 3. (a, c) 4. (b,d) 5. (a) 6. (a, b, c) 7. (a, c, d)
8. (a, d)

E 1. 80% 2. 6.603 Å 3. 1220 Å 4. 5.42×10^{-12} ergs, 3.67×10^{-5} cm
6. 10 7. 2055 Å 8. 10.22 eV, 2, He^+ 9. $n = 2$ to $n = 1$ 10. 3
11. 2.165×10^{-20} 12. 27419.25 cm^{-1} 13. $-\dfrac{e^2}{4\pi\varepsilon_0 . a_0}, \dfrac{-e^2}{8\pi\varepsilon_0 a_0}$ 14. 98.17 kJ
15. 22.8 nm 16. $2a_0$ 17. 6.627×10^{-35}m 18. 3.34×10^{-10} m, $\sqrt{2}\dfrac{h}{2\pi}$

F 1. (A)-r, (B)-q, (C)-p, (D)-s 2. (A)-q,r; (B)-p,q,r,s; (C)-p, q, r; (D)-p, q

G 1. (b) 2. (c) 3. (b)

H 1. (c) 2. (b) 3. (a)

I 1. 4 2. 9 3. 5 4. 6 5. 3

Section-B : JEE Main/ AIEEE

1. (a)	2. (c)	3. (c)	4. (a)	5. (a)	6. (a)	7. (d)	
8. (a)	9. (b)	10. (c)	11. (c)	12. (a)	13. (b)	14. (b)	
15. (a)	16. (c)	17. (c)	18. (b)	19. (d)	20. (a)	21. (b)	
22. (d)	23. (b)	24. (c)	25. (b)	26. (a)	27. (a)	28. (a)	29. (b)

Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. **1.66×10^{-27} kg**

Mass of hydrogen atom

$$= \frac{\text{Atomic mass of hydrogen}}{\text{Avogadro number}} = \frac{1.008}{6.02\times10^{23}}$$

$= 0.166 \times 10^{-23}$ g $= 1.66 \times 10^{-27}$ kg

2. **neutrons;**
3. **antiparallel; or opposite**
4. **isobars;**
5. **Heisenberg, de-Broglie;**
6. **photons**
7. **orbitals**
8. **orientation in space**
9. **$4s^1$, $3d^5$;**

The electronic configuration of Cr is : $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1, 3d^5$.

∴ Outermost electronic configuration is $3d^5, 4s^1$.

B. True/False

1. **False :** The outer electronic configuration of the ground state chromium atom is $3d^5 4s^1$, as half filled orbitals are more stable than nearly half filled orbitals.
2. **False :** Gamma rays are electromagnetic radiations of wavelengths 10^{-9} cm to 10^{-10} cm.
3. **True :** Although energies of the *s* and *p* orbitals for the same principal quantum number are very close to each other; the energy of the corresponding *d* orbitals is much higher. For example, the energy of 3*d* orbitals is much more than that of 3*s* and 3*p*; orbitals but less than 4*s* orbitals in case of H atom.
4. **False :** The orbital $3d_{x^2-y^2}$ lie along *X* and *Y* axis where electron density is maximum.
5. **True :** β-particles are deflected more than α-particles because they have very-very large *e/m* value as compared to α-particles due to the fact that electrons are much lighter than He^{2+} species.

C. MCQs with One Correct Answer

1. **(d)** No. of neutrons = Mass number – Atomic number $= 70 - 30 = 40$.
2. **(c)** Rutherford's scattering experiment led to the discovery of nucleus.
3. **(d)** One *p*-orbital can accommodate up to two electrons with opposite spin while *p*-subshell can accommodate upto six electrons.
4. **(a)** The principal quantum number (n) is related to the size of the orbital ($n = 1, 2, 3.....$)
5. **(a)** According to Rutherford's experiment. "The central part consisting of whole of the positive charge and most of the mass, called nucleus, is extremely small in size compared to the size of the atom."
6. **(d)** $\frac{e}{m}$ for neutron $= \frac{0}{1} = 0$; α-particle $= \frac{2}{4} = 0.5$;

   proton $= \frac{1}{1} = 1$; electron $= \frac{1}{1/1837} = 1837$
7. **(a)** Rb has the configuration : $1s^2 2s^2p^6 3s^2p^6d^{10} 4s^2p^6 5s^1$; so $n = 5, l = 0, m = 0$ and $s = +½$ is correct set of quantum numbers for valence shell electron of Rb.
8. **(d)** **NOTE :** Energy is emitted when electron falls from higher energy level to lower energy level and energy is absorbed when electron moves from lower level to higher level.

   1*s* is the lowest energy level of electron in an atom.

   ∴ An electron in 1*s* level of hydrogen can absorb energy but cannot emit energy.
9. **(b)** Bohr model can explain spectrum of atoms/ions containing one electron only.
10. **(b)** The radius of nucleus is of the order of 1.5×10^{-13} to 6.5×10^{-13} cm or 1.5 to 6.5 Fermi (1 Fermi $= 10^{-13}$ cm)
11. **(b)** **TIPS/Formulae :** The following is the increasing order of wavelength or decreasing order of energy of electromagnetic radiations :

    cosmic rays
    γ-rays
    X-rays
    UV-rays
    Visible
    Infra-red radiation
    Micro waves
    Radio waves

    (↓ Increasing λ, Decreasing ν)

    Among given choices radiowaves have maximum wavelength.
12. **(b)** Electrons in an atom occupy the extra nuclear region.
13. **(c)** If $l = 2$, $m \neq -3$, *m* will vary from –2 to +2. i.e. possible values of *m* are –2, –1, 0, + 1 and + 2.
14. **(d)** $E = \frac{hc}{\lambda}$; $\lambda_1 = 2000$ Å; $\lambda_2 = 4000$ Å;

    so $\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{4000}{2000} = 2$
15. **(a)** Isotones have same number of neutrons. All atoms in triad (a) have same number of neutrons ($= A - Z = 8$).
16. **(c)** Difference in the energy of the energy levels involved in the transition.
17. **(b)** According to Aufbau principle, the orbital of lower energy (2*s*) should be fully filled before the filling of orbital of higher energy starts.
18. **(c)** **TIPS/Formulae :** The element having highest tendency to accept the electron will be most electronegative element.

    Configuration ns^2, np^5 means it requires only one electron to attain nearest noble gas configuration. So, it will be most electronegative element among given choices.
19. **(a)** **NOTE :** Exactly half filled orbitals are more stable than nearly half filled orbitals.

    Cr (At. no. 24) has configuration [Ar] $3d^5, 4s^1$.
20. **(c)** Electronic configuration of chlorine is [Ne] $3s^2, 3p^5$

    ∴ Unpaired electron is found in 3*p* sub-shell.

    ∴ $n = 3, l = 1, m = 1$
21. **(c)** **X-rays** can ionise gases and cannot get deflected by electric and magnetic fields, wavelength of these rays is 150 to 0.1Å. Thus the wavelength of *X*-rays is shorter than that of u.v. rays.
22. **(d)** As packet of energy equal to *h*ν; as wave having frequency ν.

23. **(c)** **TIPS/Formulae :** Total nodes = $n - l$
No. of radial nodes = $n - l - 1$
No. of angular nodes = l
For $3p$ sub-shell, $n = 3$, $l = 1$
$\therefore$ No. of radial nodes = $n - l - 1 = 3 - 1 - 1 = 1$
$\therefore$ No. of angular nodes = $l = 1$

24. **(b)** **TIPS/Formulae :**

Orbital angular momentum $(mvr) = \frac{h}{2\pi}\sqrt{l(l+1)}$

For $2s$ orbital, l (azimuthal quantum number) = 0
$\therefore$ Orbital angular momentum = 0.

25. **(a)** The expression for orbital angular momentum is

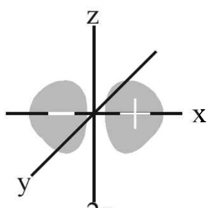
Angular momentum $= \sqrt{l(l+1)}\left(\frac{h}{2\pi}\right)$

For d orbital, $l = 2$.

Hence, $L = \sqrt{2(2+1)}\left(\frac{h}{2\pi}\right) = \sqrt{6}\left(\frac{h}{2\pi}\right)$

26. **(a)** **TIPS/Formulae :** The two guiding rules to arrange the various orbitals in the increasing energy are:
(i) Energy of an orbital increases with increase in the value of $n + l$.
(ii) Of orbitals having the same value of $n + l$, the orbital with lower value of n has lower energy.
Thus for the given orbitals, we have
(i) $n + l = 4 + 1 = 5$ (ii) $n + l = 4 + 0 = 4$
(iii) $n + l = 3 + 2 = 5$ (iv) $n + l = 3 + 1 = 4$
Hence, the order of increasing energy is
(iv) < (ii) < (iii) < (i)

27. **(a)** p_x orbital being dumbell shaped, have number of nodal planes = 1, in yz plane.



$2p_x$

28. **(b)** $3d^54s^1$ system is more stable than $3d^44s^2$, hence former is the ground state configuration.

29. **(a)** **TIPS/Formulae :** According to de-Broglie's equation

$\lambda = \frac{h}{p} = \frac{h}{mv}$

Given, $h = 6.6 \times 10^{-34}$ Js, $m = 200 \times 10^{-3}$ kg

$v = \frac{5}{60 \times 60}$ m/s

$\lambda = \frac{6.6 \times 10^{-34}}{200 \times 10^{-3} \times 5/(60 \times 60)} = 2.38 \times 10^{-10}$ m

30. **(d)** The term spin implies that this magnetic moment is produced by the electron charge as the electron rotates about its own axis. Although this conveys a vivid mental picture of the source of the magnetism, the electron is not an extended body and its rotation is meaningless. Electron spin has no classical counterpart; the magnetic moment is a consequence of relativistic shifts in local space and time due to the high effective velocity of the electron in the atom.

31. **(d)** Rutherford's experiment was actually α-particle scattering experiment. α-Particle is doubly positively charged helium ion i.e., He - nucleus.

32. **(c)** As per Pauli Exclusion Principle "no two electrons in the same atom can have all the four quantum numbers equal or an orbital cannot contain more than two electrons and it can accommodate two electrons only when their directions of spins are opposite".

33. **(d)** **TIPS/Formulae :** $r_n = 0.529\frac{n^2}{Z}$ Å
For hydrogen, $n = 1$ and $Z = 1$; $\therefore r_H = 0.529$
For Be^{3+}, $n = 2$ and $Z = 4$;

$\therefore r_{Be^{3+}} = \frac{0.529 \times 2^2}{4} = 0.529$

34. **(a)** **TIPS/Formulae :**
Number of radial nodes = $(n - l - 1)$
For $3s$: $n = 3$, $l = 0$ (Number of radial node = 2)
For $2p$: $n = 2$, $l = 1$ (Number of radial node = 0)

35. **(b)** Average atomic mass of Fe

$= \frac{(54 \times 5) + (56 \times 90) + (57 \times 5)}{100} = 55.95$

36. **(c)** As per Bohr's postulate,

$mvr = \frac{nh}{2\pi}$ So, $v = \frac{nh}{2\pi mr}$

$KE = \frac{1}{2}mv^2$ So, $KE = \frac{1}{2}m\left(\frac{nh}{2\pi mr}\right)^2$

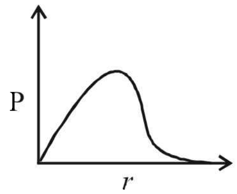
Since, $r = \frac{a_o \times n^2}{z}$

So, for 2nd Bohr orbit

$r = \frac{a_o \times 2^2}{1} = 4a_o$

$KE = \frac{1}{2}m\left(\frac{2^2h^2}{4\pi^2m^2 \times (4a_o)^2}\right) = \frac{h^2}{32\pi^2 m a_o^2}$

37. **(d)** Radial probability function curve for $1s$ is (D).
Here P is $4\pi r^2R^2$.



D. MCQs with One or More Than One Correct

1. **(b, d)** $^{77}_{33}As$ and $^{78}_{34}Se$ have same number of neutrons $(= A - Z)$ as $^{76}_{32}Ge$.

2. **(a, c)** Because they have isotopes with different masses. The average atomic mass is the weighed mean of their presence in nature; eg. Cl^{35} and Cl^{37} are present in ratio 3 : 1 in nature.

So $A = \dfrac{35 \times 3 + 37 \times 1}{4} = 35.5$

3. **(a, c)** α-particles pass through because most part of the atom is empty.

4. **(b,d)** In tritium (the isotope of hydrogen) nucleus there is one proton and 2 neutrons. $\therefore n + p = 3$. In deuterium nucleus there is one proton and one neutron $\therefore n + p = 2$.

5. **(a,d)** The energy of an electron on Bohr orbits of hydrogen atoms is given by the expression

$$E_n = -\frac{\text{Constant}}{n^2}$$

Where n takes only integral values. For the first Bohr orbit, $n = 1$ and it is given that $E_1 = -13.6$ eV

Hence $E_n = -\dfrac{13.6\text{eV}}{n^2}$ of the given values of energy, only – 3.4 eV and – 1.5 eV can be obtained by substituting n =2 and 3 respectively in the above expression.

6. **(a,b,c)** (a) $_{24}Cr = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1 = [Ar]\,3d^5, 4s^1$

(b) For magnetic quantum number (m), negative values are possible.

For s - subshell, $l = 0$, hence $m = 0$

for p - subshell, $l = 1$, hence $m = -1, 0, +1$

(c) $_{47}Ag = 1s^2, 2s^2\,2p^6, 3s^2 3p^6 3d^{10}, 4s^2\,4p^6\,4d^{10}, 5s^1$

Hence 23 electrons have a spin of one type and 24 of the opposite type.

(d) Oxidation state of N in HN_3 is –1/3.

7. **(a,c,d)** (a) $_zX^A \xrightarrow{-\alpha} {}_{z-2}Y^{A-4}$ (α - emission);

(b) $_zX^A \xrightarrow{-\beta} {}_{z+1}Z^A$ (β - emission);

(c) $_zX^A \xrightarrow{-{}_{+1}e^0} {}_{z-1}D^A$ (positron - emission);

(d) $_zX^A + {}_{-1}e^0 \rightarrow {}_{z-1}D^A$ (electron - capture)

Atomic number increases during β-emission

8. **(a,d)** According to Hund's rule pairing of electrons starts only when each of the orbital in a sub shell has one electron each of parallel spin.

$\therefore$ (a) and (d) are correct ground state electronic configurations of nitrogen atom in ground state.

E. Subjective Problems

1. Let the % of isotope with At. wt. 10.01 = x

$\therefore$ % of isotope with At. wt. 11.01 = $(100 - x)$

At. wt. of boron = $\dfrac{x \times 10.01 + (100 - x) \times 11.01}{100}$

$\Rightarrow 10.81 = \dfrac{x \times 10.01 + (100 - x) \times 11.01}{100} \quad \therefore x = 20$

Hence % of isotope with At. wt. 10.01 = 20%

$\therefore$ % of isotope with At. wt. 11.01 = 100 – 20 = **80%**.

2. **TIPS/Formulae :** $\Delta E = E_3 - E_2 = h\nu = \dfrac{hc}{\lambda}$ or

$$\lambda = \frac{hc}{E_3 - E_2}$$

Given $E_2 = -5.42 \times 10^{-12}$ erg, $E_3 = -2.41 \times 10^{-12}$ erg

$$\therefore \lambda = \frac{6.626 \times 10^{-27} \times 3 \times 10^{10}}{-2.41 \times 10^{-12} - (-5.42 \times 10^{-12})}$$

$$= \frac{19.878 \times 10^{-17}}{3.01 \times 10^{-12}} = 6.604 \times 10^{-5}\text{ cm} = \mathbf{6.604 Å}$$

3. **TIPS/Formulae :** (i) Energy of n^{th} orbit = $E_n = \dfrac{E_1}{n^2}$

(ii) Difference in energy = $E_1 - E_2 = h\nu = \dfrac{hc}{\lambda}$

or $\lambda = \dfrac{hc}{E_1 - E_2}$

Given $E_1 = 2.17 \times 10^{-11}$

$\therefore$ Energy of second orbit = $E_2 = \dfrac{2.17 \times 10^{-11}}{2^2}$

$= 0.5425 \times 10^{-11}$ erg

$\Delta E = E_1 - E_2 = 2.17 \times 10^{-11} - 0.5425 \times 10^{-11}$
$= 1.6275 \times 10^{-11}$ erg

$$\lambda = \frac{6.62 \times 10^{-27} \times 3 \times 10^{10}}{1.6275 \times 10^{-11}} = 12.20 \times 10^{-6}\text{ cm} = \mathbf{1220\ Å}$$

4. **TIPS/Formulae :** To calculate the energy required to remove electron from atom, $n = \infty$ is to be taken.

Energy of an electron in the n^{th} orbit of hydrogen is given by

$$E = -21.7 \times 10^{-12} \times \frac{1}{n^2}\text{ ergs}$$

$$\therefore \Delta E = -21.7 \times 10^{-12}\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$= -21.7 \times 10^{-12}\left(\frac{1}{4} - 0\right) = -21.7 \times 10^{-12} \times \frac{1}{4}$$

$= \mathbf{-5.42 \times 10^{-12}}$ **ergs**

Now we know that $\Delta E = h\nu$

$$\therefore \quad \Delta E = \frac{hc}{\lambda} \quad \left(\because \nu = \frac{c}{\lambda}\right) \quad \text{or} \quad \lambda = \frac{hc}{\Delta E}$$

Substituting the values, $\lambda = \dfrac{6.627 \times 10^{-27} \times 3 \times 10^{10}}{5.42 \times 10^{-12}}$

$= \mathbf{3.67 \times 10^{-5}\ cm}$

5. Ground state electronic configuration of Si

↑↓		↑	↑	
$3s$		$3p_x$	$3p_y$	$3p_z$

is in accordance with Hund's rule which states that electron pairing in any orbital (*s*, *p*, *d* or *f*) cannot take place until each orbital of the same sub-level contains 1 electron each of like spin.

6. For $n = 3$ and $l = 2$ (*i.e.*, $3d$ orbital), the values of m varies from –2 to +2, i.e. –2, –1, 0, +1, +2 and for each '*m*' there are 2 values of '*s*', i.e. +½ and –½.

$\therefore$ Maximum no. of electrons in all the five *d*-orbitals is **10**.

7. E_n of $H = \dfrac{-21.76 \times 10^{-19}}{n^2}$ J

$\therefore E_n$ of $He^+ = \dfrac{-21.76 \times 10^{-19}}{n^2} \times Z^2$ J

$\therefore E_3$ of $He^+ = \dfrac{-21.76 \times 10^{-19} \times 4}{9}$ J

Hence energy equivalent to E_3 must be supplied to remove the electron from 3rd orbit of He^+. Wavelength corresponding to this energy can be determined by applying the relation.

$$E = \frac{hc}{\lambda} \quad \text{or} \ \lambda = \frac{hc}{E} = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8} \times 9}{21.76 \times 10^{-19} \times 4}$$

$= 2055 \times 10^{-10}\ \text{m} = \mathbf{2055\ Å}$

8. **TIPS/Formulae :** $\Delta E = RhcZ^2 \left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

Here, $R = 1.0967 \times 10^7\ \text{m}^{-1}$

$h = 6.626 \times 10^{-34}$ J sec, $c = 3 \times 10^8$ m/sec

$n_1 = 1, n_2 = 2$ and for H-atom, $Z = 1$

$$E_2 - E_1 = 1.0967 \times 10^7 \times 6.626 \times 10^{-34} \times 3 \times 10^8 \left(\frac{1}{1} - \frac{1}{4}\right)$$

$$\Delta E = 1.0967 \times 6.626 \times 3 \times \frac{3}{4} \times 10^{-19}\ \text{J}$$

$= 16.3512 \times 10^{-19}$ J

$= \dfrac{16.3512 \times 10^{-19}}{1.6 \times 10^{-19}}$ eV $= \mathbf{10.22\ eV}$

$$\Delta E = \frac{hc}{\lambda} = RhcZ^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{1}{\lambda} = RZ^2 \left(\frac{1}{1} - \frac{1}{4}\right) = RZ^2 \times \frac{3}{4}$$

Given, $\lambda = 3 \times 10^{-8}$ m

$$\therefore \frac{1}{3 \times 10^{-8}} = 1.0967 \times Z^2 \times \frac{3}{4} \times 10^7$$

$$\therefore Z^2 = \frac{10^8 \times 4}{3 \times 3 \times 1.0967 \times 10^7} = \frac{40}{9 \times 1.0967} \approx 4 \qquad \therefore Z = \mathbf{2}$$

So it corresponds to He^+ which has 1 electron like hydrogen.

9. For He^+ ion, we have

$$\frac{1}{\lambda} = Z^2 R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= (2)^2 R_H \left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = R_H \frac{3}{4} \qquad ...(i)$$

Now for hydrogen atom $\dfrac{1}{\lambda} = R_H \left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$ ...(*ii*)

Equating equations (*i*) and (*ii*), we get

$$\frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{3}{4}$$

Obviously, $n_1 = 1$ and $n_2 = 2$

Hence, the transition $\boldsymbol{n = 2}$ to $\boldsymbol{n = 1}$ in hydrogen atom will have the same wavelength as the transition, $n = 4$ to $n = 2$ in He^+ species.

10. **TIPS/Formulae :** Number of waves $= \dfrac{n(n-1)}{2}$

where n = Principal quantum number or number of orbit

Number of waves $= \dfrac{3(3-1)}{2} = \dfrac{3 \times 2}{2} = 3$

11. Bond energy of $I_2 = 240\ \text{kJ mol}^{-1} = 240 \times 10^3\ \text{J mol}^{-1}$

$= \dfrac{240 \times 10^3}{6.023 \times 10^{23}}$ J molecule^{-1}

$= 3.984 \times 10^{-19}$ J molecule^{-1}

Energy absorbed $= \dfrac{hc}{\lambda} = \dfrac{6.626 \times 10^{-34}\ \text{Js} \times 3 \times 10^8\ \text{ms}^{-1}}{4500 \times 10^{-10}\ \text{m}}$

$= 4.417 \times 10^{-19}$ J

Kinetic energy = Absorbed energy – Bond energy

$\therefore$ Kinetic energy $= 4.417 \times 10^{-19} - 3.984 \times 10^{-19}$ J

$= 4.33 \times 10^{-20}$ J

$\therefore$ Kinetic energy of each atom of iodine

$$= \frac{4.33 \times 10^{-20}}{2} = \mathbf{2.165 \times 10^{-20}}$$

12. The shortest wavelength transition in the Balmer series corresponds to the transition

$n = 2 \rightarrow n = \infty$. Hence, $n_1 = 2, n_2 = \infty$ Balmer

$$\bar{\nu} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = (109677\text{cm}^{-1})\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$= \mathbf{27419.25\ cm^{-1}}$

13. Work done while bringing an electron infinitely slowly from infinity to proton of radius a_0 is given as follows

$$W = -\frac{e^2}{4\pi\varepsilon_0 . a_0}$$

NOTE : This work done is equal to the total energy of an electron in its ground state in the hydrogen atom. At this stage, the electron is not moving and do not possess any K.E., so this total energy is equal to the potential energy.

$$\text{T.E.} = \text{P. E} + \text{K. E.} = \text{P. E.} = -\frac{\boldsymbol{e^2}}{\boldsymbol{4\pi\varepsilon_0 . a_0}} \quad ...(1)$$

In order the electron to be captured by proton to form a ground state hydrogen atom it should also attain

$$\text{K.E.} \frac{e^2}{8\pi\varepsilon_0 a_0}$$

(It is given that magnitude of K.E. is half the magnitude of P.E. Note that P.E. is –ve and K.E is +ve)

$$\therefore \text{T.E} = \text{P. E.} + \text{K. E.} = -\frac{e^2}{4\pi\varepsilon_0 a_0} + \frac{e^2}{8\pi\varepsilon_0 a_0}$$

or $\quad \text{T.E.} = -\dfrac{e^2}{8\pi\varepsilon_0 a_0}$

$$\text{P.E.} = 2 \times \text{T.E.} = 2 \times \frac{-e^2}{8\pi \in_0 a_0} \text{ or P.E.} = \frac{\boldsymbol{-e^2}}{\boldsymbol{4\pi \in_0 a_0}}$$

14. Determination of number of moles of hydrogen gas,

$$n = \frac{PV}{RT} = \frac{1 \times 1}{0.082 \times 298} = 0.0409$$

The concerned reaction is $H_2 \longrightarrow 2H$; $\Delta H = 436$ kJ mol^{-1}

Energy required to bring 0.0409 moles of hydrogen gas to atomic state $= 436 \times 0.0409 = \mathbf{17.83\ kJ}$

Calculation of total number of hydrogen atoms in 0.0409 mole of H_2 gas

1 mole of H_2 gas has 6.02×10^{23} molecules

0.0409 mole of H_2 gas $= \dfrac{6.02 \times 10^{23}}{1} \times 0.0409$ molecules

Since 1 molecule of H_2 gas has 2 hydrogen atoms

$6.02 \times 10^{23} \times 0.0409$ molecules of H_2 gas

$= 2 \times 6.02 \times 10^{23} \times 0.0409 = 4.92 \times 10^{22}$ atoms of hydrogen

Since energy required to excite an electron from the ground state to the next excited state is given by

$$E = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)\text{eV} = 13.6 \times \left(\frac{1}{1} - \frac{1}{4}\right) = 13.6 \times \frac{3}{4} = 10.2\text{eV}$$

$= 1.632 \times 10^{-21}$ kJ

Therefore energy required to excite 4.92×10^{22} electrons

$= 1.632 \times 10^{-21} \times 4.92 \times 10^{22}$ kJ $= 8.03 \times 10 = 80.3$ kJ

Therefore total energy required $= 17.83 + 80.3 = \mathbf{98.17\ kJ}$

15. For maximum energy, $n_1 = 1$ and $n_2 = \infty$

$$\frac{1}{\lambda} = R_H Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Since R_H is a constant and transition remains the same

$$\frac{1}{\lambda} \propto Z^2 \ ; \ \frac{\lambda_{He}}{\lambda_H} = \frac{Z_H^2}{Z_{He}^2} = \frac{1}{4}$$

Hence, $\lambda_{He} = \dfrac{1}{4} \times 91.2 = \mathbf{22.8\ nm}$

16. $\psi_{2s}^2 =$ probability of finding electron within 2s sphere

$\psi_{2s}^2 = 0$ (at node)

($\because$ probability of finding an electron is zero at node)

$$\therefore 0 = \frac{1}{32\pi}\left(\frac{1}{a_0}\right)^3\left(2 - \frac{r_0}{a_0}\right)^2 . e^{-\frac{2r_0}{a_0}}$$

(Squaring the given value of ψ_{2s})

or $\left[2 - \dfrac{r_0}{a_0}\right] = 0$; $\therefore$ $2 = \dfrac{r_0}{a_0}$; $\mathbf{2a_0} = r_0$

17. $\lambda = \dfrac{h}{mu} = \dfrac{6.627 \times 10^{-34}}{0.1 \times 100}$

or $\lambda = \mathbf{6.627 \times 10^{-35}\ m = 6.627 \times 10^{-25}}$**Å**

18. For hydrogen atom, $Z = 1, n = 1$

$$v = 2.18 \times 10^6 \times \frac{Z}{n}\text{ms}^{-1} = 2.18 \times 10^6\ \text{ms}^{-1}$$

de Broglie wavelength,

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{9.1 \times 10^{-31} \times 2.18 \times 10^6}$$

$= \mathbf{3.34 \times 10^{-10}\ m} = 3.3$ Å

For 2p, $l = 1$

$$\therefore \text{Orbital angular momentum} = \sqrt{l(l+1)}\frac{h}{2\pi} = \sqrt{2}\frac{\boldsymbol{h}}{\boldsymbol{2\pi}}$$

F. Match the Following

1. **(A) - (r); (B) - (q); (C) - (p); (D) - (s)**

(i) $\frac{V_n}{K_n} = \frac{-Kze^2/r}{Kze^2/2r} = -2$; where $K = \frac{i}{4\pi\varepsilon_0}$ $\therefore$ (i) – (c)

(ii) $r_n \propto (E_n)^{-1}$; $\therefore$ (ii) – (b)

(iii) Angular momentum of electron in lowest (1*s*) orbital

$= \sqrt{\ell(\ell+1)}\frac{h}{2\pi} = \sqrt{0(0+1)}\frac{h}{2\pi} = 0$; $\therefore$ (iii) – (a)

(iv) $\frac{1}{r^n} \propto Z^1$; $\therefore$ (iv) – (d)

2. **A-q,r; B-p,q,r,s; C-p, q, r; D-p, q**

G. Comprehension Based Questions

For 1-3 The spherically symmetric state S_1 of Li^{2+} with one radial node is 2*s*. Upon absorbing light, the ion gets excited to state S_2, which also has one radial node. The energy of electron in S_2 is same as that of *H*-atom in its ground state.

$\therefore$ $E_n = \frac{Z^2}{n^2}E_1$ where E_1 is the energy of H-atom in the ground state $= \frac{(3)^2 E_1}{n^2}$ for Li^{2+}

$E_n = E_1 \Rightarrow n = 3$

$\therefore$ State S_2 of Li^{2+} having one radial node is 3*p*.
Orbital angular momentum quantum number of 3*p* is 1.

Energy of state $S_1 = \frac{(3)^2}{(2)^2}E_1 = 2.25\,E_1$

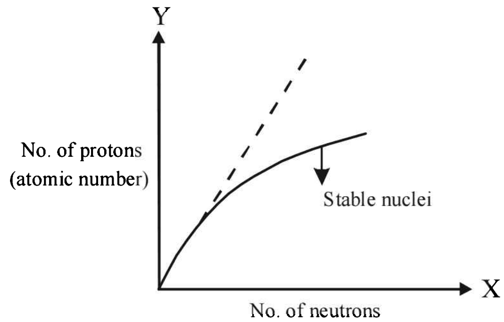
1. **(b)** **2.** **(c)** **3.** **(b)**

H. Assertion & Reason Type Questions

1. **(c)** Nuclides having both even number of protons and neutrons have maximum stability. So the reason is incorrect. But the assertion is correct as $^{40}Ca_{20}$ has even number of neutrons and protons as compared to $^{30}Al_{13}$, which has odd neutrons and protons.

2. **(b)** Statement-1 is correct because as we go down a group, energy gap between successive orbits decreases which causes decrease in the energy gap betwen valence band and conduction band. Statement-2 is also correct because each band is a collection of closely spaced large number of atomic energy levels. But this is not true correct explanation of statement-1.

3. **(a)**



A look at the above curve shows that for stable nuclei it shows a curvature towards x-axis from the line of 45° slope (dotted line) as the atomic number (i.e. number of protons) increases. So statement 1 is true.
The proton - proton repulsion would overcome the attractive force of proton and neutron. Thus statement 2 in True. Also this statement 2 is a correct explanation for statement 1. Therefore the correct answer is option (a).

I. Integer Value Correct Type

1. **4**

Energy associated with incident photon $= \frac{hc}{\lambda}$

$E = \frac{6.6\times10^{-34}\times3\times10^8}{300\times10^{-9}}$ J

$= \frac{6.6\times10^{-34}\times3\times10^8}{300\times10^{-9}\times1.6\times10^{-19}}$ eV $= 4.16$ eV

Photoelectric effect can take place only when $E_{photon} > \phi$

Thus, number of metals showing photoelectric effect will be 4 (*i.e.* Li, Na, K and Mg).

2. **9**

Maximum number of electrons (n^2) when $n = 3 = 3^2 = 9$

$\therefore$ Number of orbitals = 9

$\therefore$ Number of electrons with $m_s = -\frac{1}{2}$ will be 9.

3. **(5)** Since,

$\lambda = \frac{h}{mV} = \frac{h}{\sqrt{2M\,K.E}}$ (since K.E. $\propto$ T)

$\Rightarrow \lambda \propto \frac{1}{\sqrt{MT}}$

For two gases,

$\frac{\lambda_{He}}{\lambda_{Ne}} = \sqrt{\frac{M_{Ne}T_{Ne}}{M_{He}T_{He}}} = \sqrt{\frac{20}{4}\times\frac{1000}{200}} = 5$

4. **(6)** $|m_l| = 1$ means m_l can be +1 and –1.

So, for $n = 4$, six orbitals are possible and each has 1 electron with $s = -\frac{1}{2}$. So total number of electrons = 6.

5. **(3)** Ground state configuration:

H^-: [↑↓] 1*s* [ ] 2*s* [| |] 2*p*

in second excited state, electron will jump from 1s to 2p, so degeneracy of second excited state of H^- is 3.

Section-B JEE Main/ AIEEE

1. **(a)** 2^{nd} excited state will be the 3^{rd} energy level.

$$E_n = \frac{13.6}{n^2} eV \text{ or } E = \frac{13.6}{9} eV = 1.51 \text{ eV}.$$

2. **(c)** **TIPS/Formulae :**

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

$$\therefore \Delta v = \frac{6.62\times10^{-34}}{4\times3.14\times0.025\times10^{-5}} = 2.1\times10^{-28} ms^{-1}$$

3. **(c)** $Fe^{++}(26-2=24) = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$ hence no. of d electrons retained is 6.

[Two 4s electron are removed]

4. **(a)** **TIPS/Formulae :**

For s-electron, $\ell = 0$

$$\therefore \text{Orbital angular momentum} = \sqrt{0(0+1)}\frac{h}{2\pi} = 0$$

5. **(a)** N^{3-}, F^- and Na^+ contain 10 electrons each.

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

7. **(d)** $\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{60\times10^{-3}\times10} = 10^{-33}$ m

8. **(a)** The possible quantum numbers for 4f electron are

$n=4, \ell=3, m=-3,-2-1,0,1,2,3$ and $s=\pm\frac{1}{2}$

Of various possiblities only option (a) is possible.

9. **(b)** Electronic configuration of Cr atom $(z=24)$

$= 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$

when $\ell = 1$, p - subshell,

Numbers of electrons = 12

when $\ell = 2$, d - subshell,

Numbers of electrons = 5

10. **(c)** **TIPS/Formulae :**

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{1} - \frac{1}{\infty}\right) = 1.097\times10^7$$

$$\lambda = 91.15\times10^{-9} m \approx 91 nm$$

11. **(c)** ${}_{19}K^+$, ${}_{20}Ca^{2+}$, ${}_{21}Sc^{3+}$, ${}_{17}Cl^-$

each contains 18 electrons.

12. **(a)** The energy of an orbital is given by $(n + l)$ in (d) and (c). $(n + l)$ value is $(3+2) = 5$ hence they will have same energy, since there n values are also same.

13. **(b)** Calculating number of electrons

1. $BO_3^{3-} \longrightarrow 5+8\times3+3 = 32$, $CO_3^{2-} \longrightarrow 6+8\times3+2 = 32$, $NO_3^- \longrightarrow 7+8\times3+1 = 32$ } iso-electronic species

2. $SO_3^{2-} \longrightarrow 16+8\times3+2 = 42$, $CO_3^{2-} \longrightarrow 32$, $NO_3^- \longrightarrow 32$ } not iso-electronic species

3. $CN^{2-} \longrightarrow 6+7+1 = 14$, $N_2 \longrightarrow 7\times2 = 14$, $C_2^{2-} \longrightarrow 6\times2+2 = 14$ } iso-electronic species

4. $PO_4^{3-} \longrightarrow 15+8\times4+3 = 50$, $SO_4^{2-} \longrightarrow 16\times4+8+2 = 50$, $ClO_4^- \longrightarrow 17+8\times4+1 = 50$ } iso-electronic species

Hence the species in option (b) are not isoelectronic.

14. **(b)** Angular momentum of an electron in nth orbital is given by ,

$$mvr = \frac{nh}{2\pi}$$

For n = 5, we have

$$\text{Angular momentum of electron} = \frac{5h}{2\pi} = \frac{2.5h}{\pi}$$

15. **(a)** Given $m = 9.1\times10^{-31 kg}$, $h = 6.6\times10^{-34}$ Js

$$\Delta v = \frac{300\times.001}{100} = 0.003 ms^{-1}$$

From Heisenberg's uncertainity principle

$$\Delta x = \frac{6.62\times10^{-34}}{4\times3.14\times0.003\times9.1\times10^{-31}} = 1.92\times10^{-2} m$$

16. **(c)** (a) $N^{3-} = 7+3 = 10e^-$, $O^- \longrightarrow 8+2 = 10e^-$

$F^- = 9+1 = 10e^-$, $S^{--} \longrightarrow 16+2 = 18e^-$

(not iso electronic)

(b) $Li^+ = 3+1 = 4e^-$, $Na^+ = 11-1 = 10e^-$,

$Mg^{++} = 12-2 = 10e^-$

$Ca^{++} = 20-2 = 18e^-$ (not isoelectronic)

(c) $K^+ = 19-1 = 18e^-$, $C\ell^- = 17+1 = 18e^-$,

$Ca^{++} = 20-2 = 18e$, $Sc^{3+} = 21-3 = 18e^-$

(isoelectronic)

(d) Ba^{++} $56-2 = 54e$, Sr^{++} $38-2 = 36e^-$

$K^+ = 9-1 = 18e^-$, $Ca^{++} = 20-2 = 18e^-$

(not isoelectronic)

17. (c) (a) $n = 3, \ell = 0$ means 3s-orbital and $n + l = 3$
(b) $n = 3, \ell = 1$ means 3p-orbital $n + l = 4$
(c) $n = 3, \ell = 2$ means 3d-orbital $n + l = 5$
(d) $n = 4, \ell = 0$ means 4s-orbital $n + l = 4$
Increasing order of energy among these orbitals is
$3s < 3p < 4s < 3d$
$\therefore$ 3d has highest energy.

18. (b) Species having same number of electrons are **isoelectronic** calculating the number of electrons in each species given here, we get.
$CN^-(6 + 7 + 1 = 14)$; $N_2(7 + 7 = 14)$;
$O_2^{2-}(8 + 8 + 2 = 18)$; $C_2^{2-}(6 + 6 + 2 = 14)$;
$O_2^-(8 + 8 + 1 = 17)$; $NO^+(7 + 8 - 1 = 14)$
$CO(6 + 8 = 14)$; $NO(7 + 8 = 15)$
From the above calculation we find that all the species listed in choice (b) have 14 electrons each so it is the correct answer.

19. (d) (ΔE), The energy required to excite an electron in an atom of hydrogen from n = 1 to n = 2 is ΔE (difference in energy E_2 and E_1)
Values of E_2 and E_1 are,
$E_1 = -1.312 \times 10^6$ J mol^{-1}

$$E_2 = \frac{-1.312 \times 10^6 \times (1)^2}{(2)^2} = -3.28 \times 10^5 \text{ J mol}^{-1}$$

ΔE is given by the relation,
$\therefore \Delta E = E_2 - E_1 = [-3.28 \times 10^5] - [-1.312 \times 10^6]$ J mol^{-1}
$= (-3.28 \times 10^5 + 1.312 \times 10^6)$ J mol^{-1}
$= 9.84 \times 10^5$ J mol^{-1}
Thus the correct answer is (d)

20. (a) $$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 1 \times 10^3}$$
$= 3.97 \times 10^{-10}$ meter $= 0.397$ nanometer

21. (b) According to Heisenberg uncertainty principle.

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

Here $\Delta v = \frac{600 \times 0.005}{100} = 0.03$

So, $$\Delta x = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 0.03}$$
$= 1.92 \times 10^{-3}$ meter

22. (d) Energy required to break one mole of Cl – Cl bonds in Cl_2

$$= \frac{242 \times 10^3}{6.023 \times 10^{23}} = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\therefore \lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8 \times 6.023 \times 10^{23}}{242 \times 10^8}$$
$= 0.4947 \times 10^{-6}$ m $= 494.7$ nm

23. (b) $$\text{I.E} = \frac{Z^2}{n^2} \times 13.6\text{eV} \quad ...(i)$$

or $$\frac{I_1}{I_2} = \frac{Z_1^2}{n_1^2} \times \frac{n_2^2}{Z_2^2} \quad ...(ii)$$

Given $I_1 = -19.6 \times 10^{-18}$, $Z_1 = 2$, $n_1 = 1$, $Z_2 = 3$ and $n_2 = 1$
Substituting these values in equation (ii).

$$-\frac{19.6 \times 10^{-18}}{I_2} = \frac{4}{1} \times \frac{1}{9}$$

or $I_2 = -19.6 \times 10^{-18} \times \frac{9}{4} = -4.41 \times 10^{-17}$ J/atom

24. (c) Energy of absorbed photon = Sum of the energies of emitted photon

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \text{ or } \frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\frac{1}{355 \times 10^{-9}} = \frac{1}{680 \times 10^{-9}} + \frac{1}{\lambda_2}$$

$$\frac{1}{\lambda_2} = \frac{1}{355 \times 10^{-9}} - \frac{1}{680 \times 10^{-9}} = 1.346 \times 10^6$$

or $\lambda_2 = 1/1.346 \times 10^6 = 743 \times 10^{-9}$m $= 743$ nm

25. (b) (a) 4 p (b) 4 s (c) 3 d (d) 3 p
Accroding to Bohr Bury's $(n + \ell)$ rule, increasing order of energy (D) < (B) < (C) < (A).
Note : If the two orbitals have same value of $(n + \ell)$ then the orbital with lower value of n will be filled first.

26. (a) $$\Delta E = 2.178 \times 10^{-18}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{hc}{\lambda}$$

$$2.17 \times 10^{-18} \times \frac{3}{4} = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\lambda = \frac{6.62 \times 10^{-34}}{2.17 \times 10^{-18}} \frac{3 \times 10^8 \times 4}{\times 3} = 1.214 \times 10^{-7} m$$

27. (a) The electronic configuration of Rubidium (Rb = 37) is
$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^1$
Since last electron enters in 5s orbital
Hence $n = 5, l = 0, m = 0, s = \pm\frac{1}{2}$

28. (a) Total energy $= \frac{-13.6Z^2}{n^2}$eV
where n = 2, 3, 4 ....
Putting n = 2

$$E_T = \frac{-13.6}{4} = -3.4\text{eV}$$

29. (b) As electron of charge 'e' is passed through 'V' volt, kinetic energy of electron will be eV

Wavelength of electron wave $(\lambda) = \frac{h}{\sqrt{2m.K.E}}$

$$\lambda = \frac{h}{\sqrt{2meV}} \Rightarrow \therefore \frac{h}{\lambda} = \sqrt{2meV}$$