JEE Advanced

Single Correct Answer type

1. The number of neutrons in dipositive zinc ion with mass number 70 is **(IIT-JEE 1979)**
   a. 34 **b.** 36 **c.** 38 **d.** 40
2. Rutherford's experiment on the scattering to α-particles showed for the first time that the atom has
   a. electrons **b.** protons
   c. nucleus **d.** neutrons
   (IIT-JEE 1981)
3. Any *p*-orbital can accommodate up to
   a. four electrons
   b. six electrons
   c. two electrons with parallel spins
   d. two electrons with opposite spins **(IIT-JEE 1983)**
4. The principal quantum number of an atom is related to the
   a. Size of the orbital
   b. Spin angular momentum
   c. Orientation of the orbital in space

5. Rutherford's scattering experiment is related to the size of the
   a. nucleus **b.** atom **c.** electron **d.** neutron
   (IIT-JEE 1983)

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
   a. e, p, n, α **b.** n, p, e, α
   c. n, p, α, e **d.** n, α, p, e
   (IIT-JEE 1984)

7. Correct set of four quantum numbers for the valence (outermost) electron of rubidium ($Z = 37$) is:
   a. 5, 0, 0, +1/2 **b.** 5, 1, 0 +1/2
   c. 5, 1, 1 +1/2 **d.** 6, 0, 0 +1/2
   (IIT-JEE 1984)

8. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon?
   a. 3*s* **b.** 2*p* **c.** 2*s* **d.** 1*s*
   (IIT-JEE 1984)

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

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

11. Electromagnetic radiation with the maximum wavelength is:
    a. ultraviolet **b.** radio wave
    c. X-ray **d.** infrared **(IIT-JEE 1985)**

12. Rutherford's alpha particle scattering experiment eventually led to the conclusion that:
    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 **(IIT-JEE 1986)**

13. Which one of the following sets of quantum number represents an impossible arrangement?

	n	l	m_l	m_s
a.	3	2	–2	1/2
b.	4	0	0	1/2
c.	3	2	–3	1/2
d.	5	3	0	–1/2

(IIT-JEE 1986)

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

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

16. The wavelength of a spectral line for an electronic transition is inversely related to:
    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 electrons undergoing the transition
    (IIT-JEE 1988)

17. The orbital diagram in which the Aufbau principle is violated is:

	2s	2p
a.	↑↓	↑↓ | ↑ |
b.	↑	↑↓ | ↑ | ↑
c.	↑↓	↑ | ↑ | ↑
d.	↑↓	↑↓ | ↑ | ↑

(IIT-JEE 1988)

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

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

20. The correct set of quantum numbers for the unpaired electron of chlorine atom is:

	n	l	m_l
a.	2	1	0
b.	2	1	1
c.	3	1	1
d.	3	0	0

(IIT-JEE 1989)

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

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

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

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

25. The first use of quantum theory to explain the structure of atom was made by

a. Heisenberg **b.** Bohr
c. Planck **d.** Einstein **(IIT-JEE 1997)**

26. For a *d*-electron, the orbital angular momentum is

a. $\sqrt{6}(h/2\pi)$ **b.** $\sqrt{2}(h/2\pi)$
c. $(h/2\pi)$ **d.** $2(h/2\pi)$ **(IIT-JEE 1997)**

27. 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 the order of increasing energy, from the lowest to highest, as

a. (iv) < (ii) < (iii) < (i) **b.** (ii) < (iv) < (i) < (iii)
c. (i) < (iii) < (ii) < (iv) **d.** (iii) < (i) < (iv) < (ii)
(IIT-JEE 1999)

28. The number of nodal planes in a p_x orbital is

a. one **b.** two **c.** three **d.** zero
(IIT-JEE 2000)

29. The electronic configuration of an element is $1s^2, 2s^2, 2p^6, 3s^2, 3d^5, 4s^1$. This represents its

a. excited state **b.** ground state
c. cationic form **d.** anionic form
(IIT-JEE 2000)

30. The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order

a. 10^{-10} m **b.** 10^{-20} m **c.** 10^{-30} m **d.** 10^{-40} m
(IIT-JEE 2001)

31. The quantum numbers +1/2 and −1/2 for the electron spin represent

a. rotation of the electron in clockwise and anticlockwise directions respectively
b. rotation of the electron in anticlockwise and clockwise directions respectively
c. magnetic moment of the electron pointing up and down respectively
d. two quantum mechanical spin states which have no classical analogue **(IIT-JEE 2001)**

32. Rutherford's experiment, which established the nuclear model of the atom, used a beam of

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 **(IIT-JEE 2002)**

33. 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.

a. Heisenberg uncertainty principle
b. Hund's rule
c. Pauli exclusion principle
d. Bohr postulate of stationary orbits
(IIT-JEE 2002)

34. The radius of which of the following orbit is the same as that of the first Bohr's orbit of hydrogen atom?

a. He^+ ($n = 2$) **b.** Li^{2+} ($n = 2$)
c. Li^{2+} ($n = 3$) **d.** Be^{3+} ($n = 2$)
(IIT-JEE 2004)

35. The numbers of radial nodes of 3*s* and 2*p* orbitals are respectively

a. 2, 0 **b.** 0, 2 **c.** 1, 2 **d.** 2, 1
(IIT-JEE 2005)

36. 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

a. 55.85 **b.** 55.95 **c.** 55.75 **d.** 56.05
(IIT-JEE 2009)

37. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius]:

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.** $\frac{h^2}{64\pi^2 m a_0^2}$
(IIT-JEE 2012)

Multiple Correct Answers type

1. An isotope of $^{76}_{32}Ge$ is:

a. $^{77}_{32}Ge$ **b.** $^{77}_{33}As$ **c.** $^{77}_{34}Se$ **d.** $^{78}_{34}Se$
(IIT-JEE 1984)

2. Many elements have non-integral atomic masses because:

a. they have isotopes
b. their isotopes have non-integral masses
c. their isotopes have different masses
d. the constituents, neutrons, protons and electrons, combine to given fractional masses **(IIT-JEE 1984)**

3. When alpha particles are sent through a thin metal foil, most of them go straight through the foil because:

a. alpha articles are much heavier than electrons
b. alpha particles are positively charged
c. most part of the atom is empty space
d. alpha particles move with high velocity
(IIT-JEE 1984)

4. The sum of the number of neutrons and proton in the isotope of hydrogen is:

a. 6 **b.** 2 **c.** 4 **d.** 3
(IIT-JEE 1986)

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)

a. −3.4 eV **b.** −4.2 eV **c.** −6.8 eV **d.** −1.5 eV
(IIT-JEE 1998)

6. Which of the following statement(s) is (are) correct?
   a. The electronic configuration of Cr is $[Ar]3d^5 4s^1$. (Atomic Number of Cr is 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 is 47).
   d. The oxidation state of nitrogen in HN_3 is –3.

(IIT-JEE 1998)

7. The ground state electronic configuration of nitrogen atom can be represented by

   a. [↑↓] [↑↓] [↑][↑][↑] b. [↑↓] [↑↓] [↑][↓][↑]

   c. [↑↓] [↑↓] [↑][↓][↓] d. [↑↓] [↑↓] [↓][↓][↓]

(IIT-JEE 1999)

Linked Comprehension Type

Paragraph for Problems 1–3

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. **(IIT-JEE 2010)**

1. The state S_1 is
   a. 1*s* b. 2*s* c. 2*p* d. 3*s*
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

Matching Column Type

1. According to Bohr's theory
   E_n = Total energy, K_n = Kinetic energy, V_n = Potential energy, r_n = Radius of *n*th orbit **(IIT-JEE 2006)**

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. **(IIT-JEE 2008)**

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's 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

Integer Answer 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

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

(IIT-JEE 2011)

2. The maximum number of electrons that can have principal quantum number *n* = 3, and spin quantum number $m_s = -\frac{1}{2}$ is **(IIT-JEE 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 Advanced 2013)**
4. In an atom, the total number of electrons having quantum numbers *n* = 4, $|m_\ell| = 1$ and $m_s = -\frac{1}{2}$ is **(JEE Advanced 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 Advanced 2015)**

Fill in the Blanks Type

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

8. The $2p_x$, $2p_y$, and $2p_z$ orbitals of atom have identical shapes but differ in their __________. **(IIT-JEE 1993)**
9. The outermost electronic configuration of Cr is ________. **(IIT-JEE 1994)**

True / False Type

1. The outer electronic configuration of the ground state chromium atom is $3d^4 4s^2$. **(IIT-JEE 1982)**
2. Gamma rays are electromagnetic radiations of wavelengths of 10^{-6} cm to 10^{-5} cm. **(IIT-JEE 1983)**
3. The energy of the electron in the $3d$-orbital is less than that in the $4s$ orbital in the hydrogen atom. **(IIT-JEE 1983)**
4. The electron density in the XY plane in $3d_{x^2-y^2}$ orbital is zero. **(IIT-JEE 1986)**

Subjective Type

1. Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of the natural boron is 10.81. Calculate the percentage of each isotope in natural boron. **(IIT-JEE 1978)**
2. Account for the following. Limit your answer to two sentences:
   Atomic weights of most of the elements are fractional. **(IIT-JEE 1979)**
3. The energy of the electron in the second and 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. **(IIT-JEE 1981)**
4. Calculate the wavelength in Angstroms 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 ionisation potential of the ground state hydrogen atom is 2.17×10^{-11} erg per atom. **(IIT-JEE 1982)**
5. The electron energy in hydrogen atom is given by $E = (-21.7 \times 10^{-12})/n^2$ erg. 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? **(IIT-JEE 1985)**
6. Give reason why the ground state outermost electronic configuration of silicon is:
   3s [↑↓] 3p [↑][↑][ ] and not 3s [↑↓] 3p [↑][↓][ ] **(IIT-JEE 1985)**
7. 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? **(IIT-JEE 1985)**
8. According to Bohr's theory, the electronic energy of hydrogen atom in the nth Bohr's orbit is given by $E_n = \dfrac{-21.76 \times 10^{-19}}{n^2}$ J. Calculate the longest wavelength of light that will be needed to remove an electron from the third Bohr orbit of the He^+ ion. **(IIT-JEE 1990)**
9. Estimate the difference in energy between the 1st 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-like species does this atomic number correspond to? **(IIT-JEE 1993)**
10. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition, $n = 4$ to $n = 2$ of He^+ spectrum? **(IIT-JEE 1993)**
11. Find out the number of waves made by a Bohr electron in one complete revolution in its 3rd orbit. **(IIT-JEE 1994)**
12. 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 the iodine atoms. (Bond energy of $I_2 = 240$ kJ mol^{-1}) **(IIT-JEE 1995)**
13. Calculate the wave number for the shortest wavelength transition in the Balmer series of atomic hydrogen. **(IIT-JEE 1996)**
14. 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. **(IIT-JEE 1996)**
15. With what velocity should an α-particle travel towards the nucleus of a copper atom so as to arrive at a distance 10^{-13} m from the nucleus of the copper atom? **(IIT-JEE 1997)**
16. An electron beam can undergo diffraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.54 Å? **(IIT-JEE 1997)**
17. 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}. **(IIT-JEE 2000)**
18. Wavelength of high energy transition of H-atoms is 91.2 nm. Calculate the corresponding wavelength of He^+ atoms. **(IIT-JEE 2003)**
19. **a.** The Schrödinger wave equation for hydrogen atom is

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

   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.
   b. A ball of mass 100 g is moving with 100 ms^{-1}. Find its wavelength. **(IIT-JEE 2004)**
20. 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 $h/2\pi$. **(IIT-JEE 2005)**

Answer Key

JEE Advanced

Single Correct Answer Type

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.** b.
26. a.	**27.** a.	**28.** a.	**29.** b.	**30.** a.
31. d.	**32.** d.	**33.** c.	**34.** d.	**35.** a.
36. b.	**37.** c.			

Multiple Correct Answers Type

1. b., d. **2.** a., c. **3.** a., c. **4.** b., d. **5.** a., d.
6. a., b., c. **7.** a., d.

Linked Comprehension Type

1. b. **2.** c. **3.** b.

Matching Column Type

1. (a) → (r); (b) → (q); (c) → (p); (d) → (s)
2. (a) → (q); (b) → (p), (q), (r), (s); (c) → (p), (q), (r); (d) → (p), (q), (r)

Integer Answer Type

1. (4) **2.** (9) **3.** (5) **4.** (6) **5.** (3)

Fill in the Blanks Type

1. 1.66×10^{-27} kg **2.** neutrons
3. antiparallel **4.** isobars
5. Heisenberg, de-Brogile **6.** photons
7. orbitals **8.** orientation in space **9.** $4s^1, 3d^5$

True/False Type

1. False **2.** False **3.** True **4.** False

Subjective Type

1. 80% **3.** 6.604 Å **4.** 1220 Å **5.** 3.67×10^{-5}
8. 2055 Å **11.** 3 **12.** 2.105×10^{-20} J
13. 27419.25 cm^{-1} **17.** 98.17 kJ
18. 22.8 nm

Hints and Solutions

JEE Advanced

Single Correct Answer type

1. d. No. of neutrons = Mass number – Atomic number (Ion formation never changes neutrons) = 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 up to six electrons. Any one orbital can accommodate maximum of two 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. 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.

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

∴ An electron in 1s 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. The following is the increasing order of wavelength or decreasing order of energy of electromagnetic radiations:

Cosmic rays
λ-rays
X-rays
UV-rays
Visible
Infrared radiation
Microwaves
Radiowaves

(↓ 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).

i.e. 14 – 6 = 8
15 – 7 = 8
17 – 9 = 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. 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. 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 ionize gases and cannot get deflected by electric and magnetic fields, wavelength of these rays is 150 to 0.1 Å. Thus the wave length of X-rays is shorter than that of UV rays.

22. d. As packet of energy equal to $h\nu$; as wave having frequency ν.

23. c. Total nodes = $n - 1$

No. of radial nodes = $n - l - 1$

No. of angular nodes = l

For 3*p* sub-shell, $n = 3$, $l = 1$

∴ No. of radial nodes = $n - l - 1 = 3 - 1 - 1 = 1$

∴ No. of angular nodes = $l = 1$

24. b. Orbital angular momentum (mvr) = $\frac{h}{2\pi}\sqrt{l(l+1)}$ it depends only on l.

For 2*s* orbital, l (azimuthal quantum number) = 0

∴ Orbital angular momentum = 0.

25. b. Bohr's theory was based upon some postulates of classical physics and some postulates of the newly proposed quantum theory of Planck.

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

27. a. 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

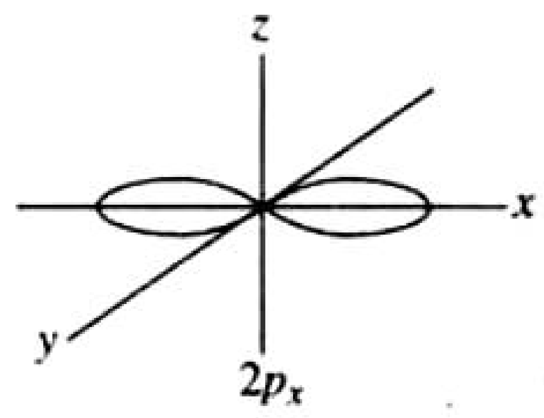
i. $n + l = 4 + 1 = 5$ **ii.** $n + l = 4 + 0 = 4$

iii. $n + l = 3 + 2 = 5$ **iv.** $n + l = 3 + 1 = 4$

Hence, the order of increasing energy is

(iv) < (ii) < (iii) < (i)

28. a. p_x orbital being dumbbell shaped, have number of nodal planes = 1, in yz plane.



29. b. $3d^5 4s^1$ system is more stable than $3d^4 4s^2$, hence former is the ground state configuration.

30. a. 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

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

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

31. 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.

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

33. c. As per Pauli's 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 direction of spins are opposite".

34. d. $r_n = 0.529 \frac{n^2}{Z}$ Å

For hydrogen, $n = 1$ and $Z = 1$; $\therefore\ r_H = 0.529$

For Be^{3+}, $n = 2$ and $Z = 4$

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

35. a. 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)

36. b. Average atomic mass of Fe

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

37. 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, $r = \frac{a_0 \times n^2}{z}$

So, for 2nd Bohr orbit

$$r = \frac{a_0 \times 2^2}{1} = 4a_0$$

$$KE = \frac{1}{2} m \left(\frac{2^2 h^2}{4\pi^2 m^2 \times (4a_0)^2} \right)$$

$$KE = \left(\frac{h^2}{32\pi^2 m a_0^2} \right)$$

Multiple Correct Answers Type

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; e.g. Cl^{35} and Cl^{37} are present in ratio 3 : 1 in nature.

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

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 $E_n = -\frac{13.6 \text{ eV}}{n^2}$ 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 as $m_l = -l \ldots 0 \ldots +l$

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, d.

According to Hund's rule pairing of electrons starts only when each of the orbital in a subshell has one electron each of parallel spin.

∴ (a) and (d) are correct ground state electronic configurations of nitrogen atom in the ground state.

Linked Comprehension Type

1. b. For, S_1 (spherically symmetrical)

node = 1

$\Rightarrow \quad n - 1 = 1$

$n = 2$

For S_2, radial node = 1

$$E_{S_2} = \frac{-13.6 \times z^2}{n^2} = E_H \text{ in ground state} = -13.6$$

$$E = \frac{-13.6 \times 9}{n^2} \Rightarrow n = 3$$

So, state S_1 is $2s$ and S_2 is $3p$.

2. c. $\dfrac{E_{s_1}}{E_{H(ground)}} = \dfrac{-13.6 \times 9}{4 \times (-13.6)} = 2.25$

3. b. Azimuthal quantum number for $S_2 = \ell = 1$.

Matching Column Type

1. (a) → (r); (b) → (q); (c) → (p); (d) → (s)

(a) $\dfrac{V_n}{K_n} = \dfrac{-Kze^2/r}{Kze^2/r} = -2$; where $K = \dfrac{i}{4\pi\varepsilon_0}$ ∴ (a) → (r)

(b) $r_n \propto (E_n)$–1; ∴ (b) → (q)

(c) Angular momentum of electron in lowest ($1s$) orbital

$= \sqrt{\ell(\ell+1)}\dfrac{h}{2\pi}$; ∴ (c) → (p)

(d) $\dfrac{1}{r^n} \propto Z^1$; ∴ (d) → (s)

2. (a) → (q); (b) → (p, q, r, s); (c) → (p, q, r); (d) → (p, q, r)

(a) Orbital angular momentum (L) = $\sqrt{\ell(\ell+1)}\dfrac{h}{2\pi}$

i.e. L depends on azimuthal quantum number only.

(b) To describe a one electron wave function, three quantum number n, l and m are needed. Further to abide by Pauli exclusion principle, spin quantum number(s) is also needed.

(c) For shape, size and orientation, only n, l and m are needed.

(d) Probability density (ψ^2) can be determined if n, l and m are known.

Integer Answer Type

1. (4) $h\upsilon$ = Energy of incident photon and $h\upsilon_0$ = Work function cr threshold energy

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

$$E = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9}} \text{J}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{eV} = 4.16 \text{ eV}$$

If $h\upsilon \geq h\upsilon_0$ or ϕ then it will show photoelectric effect

Li, Na, K, Mg have $h\upsilon > h\upsilon_0$.

2. (9) Maximum number of electrons = $2n^2$ in an orbit, out of which half have $+\frac{1}{2}$ spin and half have $-\frac{1}{2}$ spin.

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

∴ Number of orbitals = 9

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

3. (5) Since,

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

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

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) $n = 4$

$l = 0, 1, 2, 3$

$|m_l| = 1 \Rightarrow \pm 1 \quad m_s = \frac{1}{2}$

for $l = 0$, $m_l = 0$

$l = 1$, $m_l = -1, 0, +1$

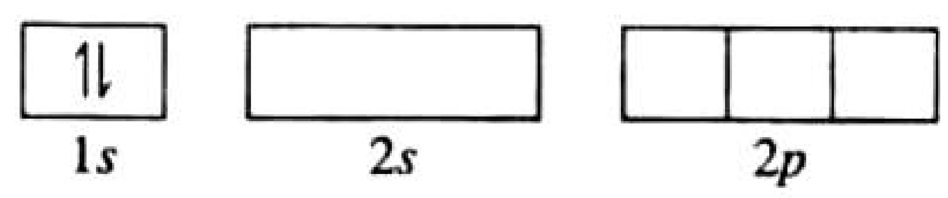
$l = 2$, $m_l = -2, -1, 0, +1, +2$

$l = 3$, $m_l = -3, -2, -1, 0, +1, +2, +3$

so, six electrons can have $|m_\ell| = 1$ and $m_s = -\frac{1}{2}$.

5. (3) Ground state configuration

H^-:



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

Fill in the Blanks Type

1. 1.66×10^{-27} kg

Mass of Hydrogen atom

$$= \frac{\text{Atomic mass of hydrogen}}{\text{Avogadro number}} = \frac{1.008}{6.02 \times 10^{23}}$$

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

2. neutrons, for example, ${}^1_1H$, ${}^2_1H$, ${}^3_1H$ have 0, 1, 2 neutrons.

3. antiparallel; or opposite to follow Pauli's exclusion principle.

4. isobars, for example, ${}^{40}_{19}K$, ${}^{40}_{20}Ca$

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 $3d^5$, $4s^1$.

True / False Type

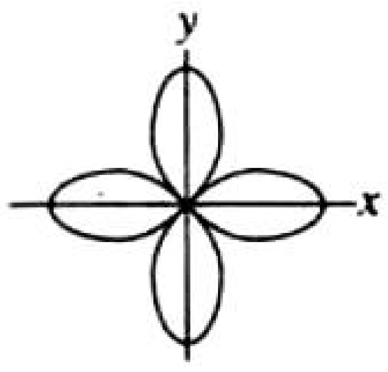
1. False:

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 $3d_{x^2-y^2}$ lies along *X*- and *Y*-axis where electron density is maximum.



Subjective Type

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

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

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

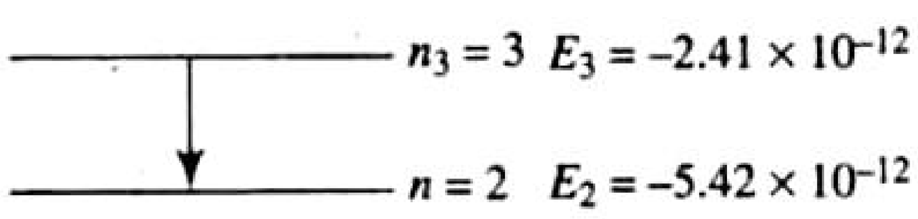
$$\Rightarrow \quad 10.81 = \frac{x \times 10.01 + (100 - x) \times 11.01}{100}$$

$\therefore \quad x = 20$

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

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

2. Elements usually have one or more isotopes and these isotopes have different atomic masses. So atomic weights are fractional number.

3. 

$\Delta E = E_2 - E_2$

$\Delta E = (-5.42 \times 10^{-12}) - (-2.41 \times 10^{12})$

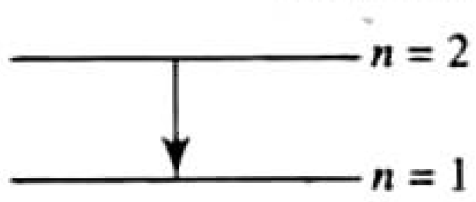
$\Delta E = -3.01 \times 10^{-12}$

$\Rightarrow$ Energy released = 3.01×10^{-12}

As $\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$

$$\therefore \quad \lambda = \frac{6.626 \times 10^{-27} \times 3 \times 10^{10}}{3.01 \times 10^{-12}}$$

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

4. 

i. Energy of *n*th orbit $E_n = \frac{E_1}{n^2}$ and $E_1 = -\text{I.E}$

$= -2.17 \times 10^{-11}$ erg atom^{-1}

as IE $= E_\infty - E_1$ and $E_\infty = 0$

ii. Difference in energy $(\Delta E) = E_1 - E_2 = h\nu = \frac{hc}{\lambda}$

$\therefore$ Energy of second orbit

$$E_n = \frac{E_1}{h^2}$$

$$\Rightarrow E_2 = \frac{-2.17 \times 10^{-11}}{2^2} = -0.5425 \times 10^{-11} \text{erg}$$

$\Delta E = E_1 - E_2$

$= -2.17 \times 10^{-11} - (-0.5425 \times 10^{-11})$

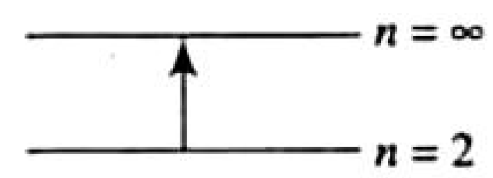
$= -1.6275 \times 10^{-11}$ erg

$\Rightarrow$ Energy released is 1.6275×10^{-11} erg so wavelength of emitted radiation.

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

5. To calculate the energy required to remove electron from atom, means e^- is to be taken to ∞.

Energy of an electron in the *n*th orbit of hydrogen is given by



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

$$\Delta E = E_\infty - E_2$$

$$= \frac{-21.7 \times 10^{-12}}{\infty^2} - \frac{-21.7 \times 10^{-12}}{2^2}$$

$$= -21.7 \times 10^{-12}\left(\frac{1}{\infty^2} - \frac{1}{4}\right)$$

$$= -21.7 \times 10^{-12}\left(0 - \frac{1}{4}\right) = +5.42 \times 10^{-12} \text{ergs}$$

$\Rightarrow$ Energy required is 5.42×10^{-12} ergs.

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

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

or $\quad \lambda = \frac{hc}{\Delta E}$

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

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

6. Ground state electronic configuration of Si

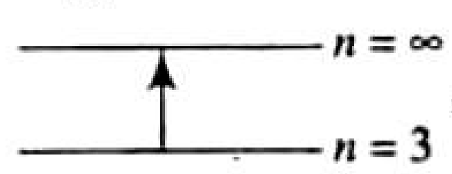
3s	3p_x	3p_y	3p_z
↑↓	↑	↑	

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.

7. For $n = 3$ and $l = 2$ (i.e., 3*d* 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.

8. Energy needed to remove means to bring electron to infinity.



$\Rightarrow$ Energy required $= E_\infty - E_3 = \Delta E$

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

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

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

$$\Delta E = \left(\frac{-21.76 \times 10^{-19}}{\infty^2}\right) - \left(\frac{-21.76 \times 10^{-19}}{3^2}\right) \times 2^2$$

$$\therefore \quad \Delta E = \frac{21.76 \times 10^{-19}}{9} \times 4 \text{ J}$$

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.

$$\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{6.625\times10^{-34}\times3\times10^{8}\times9}{21.76\times10^{-19}\times4}$$

$$= 2055\times10^{-10}\,\text{m} = 2055\,\text{Å}$$

9. As $E_n = \dfrac{-21.76\times10^{-19}}{n^2}\times Z^2$ J/atom

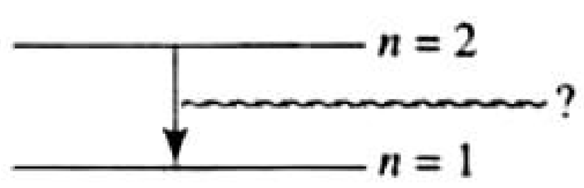
a. To find $E_2 - E_1 = \Delta E$ for hydrogen

$$\Delta E = \frac{-21.76\times10^{-19}}{2^2} - \frac{-21.76\times10^{-10}}{1^2}$$

$$\Delta E = -21.76\times10^{-19}\left(\frac{1}{4}-\frac{1}{1}\right)$$

$$\Delta E = -21.76\times10^{-19}\times-\frac{3}{4} = 16.32\times10^{-19}\ \text{J/atom}$$

b.



$\lambda = 3\times10^{-8}$ m

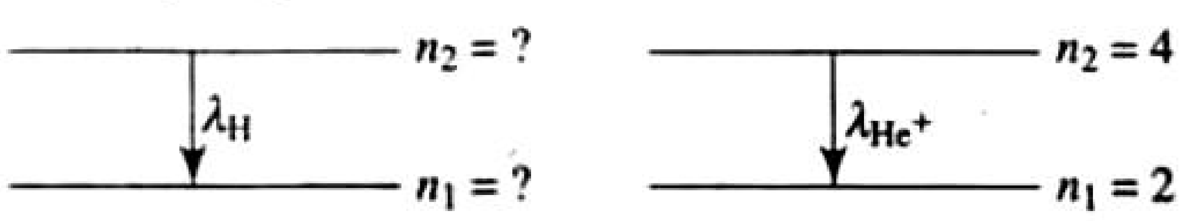
for which element

$$\Delta E = E_2 - E_1 = \frac{hc}{\lambda} = 16.32\times10^{-19}\times Z^2$$

$$Z^2 = \frac{6.63\times10^{-34}\times3\times10^{8}}{3\times10^{-8}\times16.32\times10^{-19}}$$

$$Z^2 = 4.06 \approx 4 \Rightarrow Z = 2 \Rightarrow He^+$$

10. Aim: Hydrogen He$^+$



Given: $\lambda_H = \lambda_{He^+} \Rightarrow \bar{\upsilon}_H = \bar{\upsilon}_{He^+}$ as $\bar{\upsilon} = R_H\left(\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right)^{Z^2} Z^2$

For He$^+$

$$\bar{\upsilon}_{He^+} = R_H = \left(\frac{1}{2^2}-\frac{1}{4^2}\right)2^2,\ \bar{\upsilon}_H = R_H\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)1^2$$

as $\bar{\upsilon}_{He^+} = \bar{\upsilon}_H$ so

$$R_H\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) = R_H\left(\frac{1}{1}-\frac{1}{4}\right) = \left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

On comparing

$n_1 = 1$ and $n_2 = 2$ in case of hydrogen.

11. No. of waves in one round $= \dfrac{2\pi r_3}{\lambda}$

as $\lambda = \dfrac{h}{mv}$

So, no. of waves in one round in 3rd orbit is $= \dfrac{2\pi r_3 m v_3}{h}$

r_n for $H = r_1 \times n^2$

r_3 for $H = 0.529\times3^2\times10^{-8}$ cm

$= 0.529\times9\times10^{-10}$ m ($\because r_1 = 0.529$ Å)

Also $u_n = Z\dfrac{u_1}{n}$;

$$\therefore\quad u_3 = \frac{2.19\times10^{8}}{3}\text{cm sec}^{-1} = \frac{2.19\times10^{6}}{3}\text{m sec}^{-1}$$

($\because u_1 = 2.19\times10^{8}$ cm sec^{-1})

Also

$\therefore$ No. of waves in one round

$$= \frac{2\pi r_3}{\lambda} = \frac{2\pi r_3}{h/mv_3} = \frac{2\pi r_3\times u_3\times m}{h}$$

$$= \frac{2\times22\times0.529\times9\times10^{-10}\times2.19\times10^{6}\times9.108\times10^{-31}}{7\times3\times6.62\times10^{-34}}$$

$= 3$

12. Bond energy of $I_2 = 240$ kJ mol^{-1} $= 240\times10^3$ J mol^{-1}

$$= \frac{240\times10^3}{6.023\times10^{23}}\ \text{J molecule}^{-1}$$

$= 3.984\times10^{-19}$ J molecule^{-1}

$$\text{Energy absorbed} = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\,\text{Js}\times3\times10^{8}\,\text{ms}^{-1}}{4500\times10^{-10}\,\text{m}}$$

$= 4.417\times10^{-19}$ J

Kinetic energy = Absorbed energy – Bond energy

$\therefore$ Kinetic energy $= 4.417\times10^{-19} - 3.984\times10^{-19}$ J

$= 0.433\times10^{-19}$ J/molecule

$= 4.33\times10^{-20}$ J/molecule

$\therefore$ Kinetic energy of each atom of iodine

$$= \frac{4.33\times10^{-20}}{2} = 2.165\times10^{-20}\ \text{J.}$$

13. Balmer means $n = 2$, $Z = 1$

Shortest wavelength means max. frequency means max. energy means limiting line means $n_2 = \infty$.

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

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

$= 27419.25$ cm^{-1}

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

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

This work done is equal to the total energy of an electron in its ground state in the hydrogen atom. At this statge, the electron is not moving and does not possess any KE, so this total energy is equal to the potential energy.

$$\text{TE} = \text{PE} + \text{KE} = \text{PE} = -\frac{e^2}{4\pi\varepsilon_0\cdot a_0}$$

In order for the electron to be captured by proton to form a ground state hydrogen atom it should also attain KE $\dfrac{e^2}{8\pi\varepsilon_0\cdot a_0}$

(It is given that magnitude of KE is half the magnitude of PE Note that PE is –ve and KE is +ve)

$$\therefore\quad \text{TE} = \text{PE} + \text{KE} = -\frac{e^2}{4\pi\varepsilon_0\cdot a_0} + \frac{e^2}{8\pi\varepsilon_0\cdot a_0}$$

$$\text{or}\quad \text{TE} = \frac{e^2}{8\pi\varepsilon_0\cdot a_0}$$

$$PE = 2 \times TE = 2 \times \frac{-e^2}{8\pi\varepsilon_0 \cdot a_0} \text{ or } PE = \frac{-e^2}{4\pi\varepsilon_0 \cdot a_0}$$

15. Potential energy (PE) of α-particle $= \dfrac{-Z_1 \times Z_2 e^2}{(4\pi\varepsilon_0)r}$

r = Distance from nucleus = 10^{-13} m

$Z_1 = 29$ for copper and $e^- = 1.6 \times 10^{-19}$ C

$Z_2 = 4$ (Number of orbit) and $\varepsilon_0 = 8.85 \times 10^{-12}\ J^{-1}C^2m^{-1}$

So $$V = \frac{29 \times 4(1.6 \times 10^{-19} C)^2}{4 \times 3.14 \times 8.85 \times 10^{-12} J^{-1} C^2 m^{-1} \times 10^{-13} m}$$

$= -2.67 \times 10^{-13}$ J

Velocity of α-particle

$$(v) = \sqrt{\frac{2V}{m}} \quad \text{(where } m \rightarrow \text{Mass of α-particle)}$$

$$= \sqrt{\frac{2 \times 2.67 \times 10^{-13} J}{4 \times 10^{-13} kg\ mol/6.023 \times 10^{13}}} = 8.97 \times 10^6 m\ sec^{-1}.$$

16. $\frac{1}{2}mu^2 = eV$

where $e = 1.6 \times 10^{-19}$C and V is potential difference

also $\lambda = \dfrac{h}{mu}$ or $V = \dfrac{h}{m\lambda}$

$$\therefore \quad \frac{1}{2} m \frac{h^2}{m^2\lambda^2} = eV \text{ or } V = \frac{1}{2}\frac{h^2}{m\lambda^2 e}$$

$$V = \frac{1 \times (6.62 \times 10^{-34})^2}{2 \times 9.108 \times 10^{-31} \times (1.54 \times 10^{-10}) 1.602 \times 10^{-19}} = 63.3 \text{ volt}$$

17. **Step I:** 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 $H_2 \rightarrow 2H$; $\Delta H = 436$ kJ mol^{-1}

Energy required to bring 0.0409 moles of hydrogen gas to atomic state = 436 × 0.0409 = 17.83 kJ

Step II: Calculation of total number of hydrogen atoms in 0.0409 mole of H_2 gas

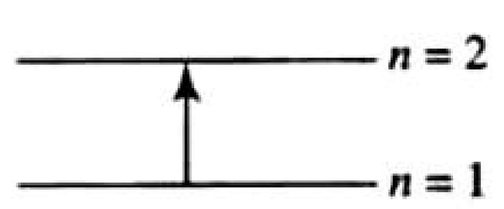
1 mole of H_2 gas has 6.02×10^{23} molecules

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

$6.02 \times 10^{23} \times 0.409$ 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

$$\Delta E = E_2 - E_1 = \frac{-21.7 \times 10^{-19}}{2^2} - \frac{-21.7 \times 10^{-19}}{1^2}$$

$$\Delta E = -21.7 \times 10^{-19}\left(\frac{1}{4} - \frac{1}{1}\right)$$

$$= 21.7 \times 10^{-19} \times \frac{-3}{4} = 16.3 \times 10^{-19} J$$

$$= 1.63 \times 10^{-21} kJ$$

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

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

Therefore total energy required = 17.83 + 80.3 = 98.17 kJ

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

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

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, $\lambda_{He^+} = \dfrac{1}{4} \times 91.2 = 22.8$ nm

19. **a.** At radial node, ψ^2 must vanishes, i.e.

$$\psi_{2s}^2 = 0 = \left[\frac{1}{4\sqrt{2\pi}}\right]^2\left(2 - \frac{r_0}{a_0}\right)^2 e^{-\frac{r_0}{a_0}}$$

$$\Rightarrow \quad 2 - \frac{r_0}{a_0} = 0 \Rightarrow r_0 = 2a_0$$

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

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

20. Radius a_0 means Bohr's radius, i.e., radius of the first orbit

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

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

de-Broglie wavelength.

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

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

For 2p, $l = 1$

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