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CHAPTER 26

Atoms

1. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from $n = 2$ is **[2002]**
   (a) 10.2 eV (b) 0 eV
   (c) 3.4 eV (d) 6.8 eV

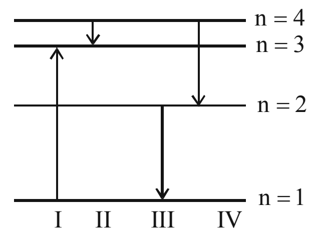
2. Which of the following atoms has the lowest ionization potential ? **[2003]**
   (a) ${}^{14}_{7}N$ (b) ${}^{133}_{55}Cs$
   (c) ${}^{40}_{18}Ar$ (d) ${}^{16}_{8}O$

3. The wavelengths involved in the spectrum of deuterium $\left({}^{2}_{1}D\right)$ are slightly different from that of hydrogen spectrum, because **[2003]**
   (a) the size of the two nuclei are different
   (b) the nuclear forces are different in the two cases
   (c) the masses of the two nuclei are different
   (d) the attraction between the electron and the nucleus is differernt in the two cases

4. If the binding energy of the electron in a hydrogen atom is 13.6eV, the energy required to remove the electron from the first excited state of Li^{++} is **[2003]**
   (a) 30.6 eV (b) 13.6 eV
   (c) 3.4 eV (d) 122.4 eV

5. The manifestation of band structure in solids is due to **[2004]**
   (a) Bohr's correspondence principle
   (b) Pauli's exclusion principle
   (c) Heisenberg's uncertainty principle
   (d) Boltzmann's law

6. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy? **[2005]**



   (a) IV (b) III
   (c) II (d) I

7. Which of the following transitions in hydrogen atoms emit photons of highest frequency? **[2007]**
   (a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 6$
   (c) $n = 6$ to $n = 2$ (d) $n = 2$ to $n = 1$

8. Suppose an electron is attracted towards the origin by a force $\frac{k}{r}$ where 'k' is a constant and 'r' is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the n^{th} orbital of the electron is found to be 'r_n' and the kinetic energy of the electron to be 'T_n'. Then which of the following is true? **[2008]**
   (a) $T_n \propto \frac{1}{n^2}, r_n \propto n^2$
   (b) T_n independent of $n, r_n \propto n$
   (c) $T_n \propto \frac{1}{n}, r_n \propto n$
   (d) $T_n \propto \frac{1}{n}, r_n \propto n^2$

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9. The transition from the state $n = 4$ to $n = 3$ in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from : **[2009]**

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

10. Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is : **[2011]**

(a) 36.3 eV (b) 108.8 eV
(c) 122.4 eV (d) 12.1 eV

11. Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be : **[2012]**

(a) 2 (b) 3
(c) 5 (d) 6

12. In a hydrogen like atom electron make transition from an energy level with quantum number n to another with quantum number (n – 1). If n>>1, the frequency of radiation emitted is proportional to : **[2013]**

(a) $\frac{1}{n}$ (b) $\frac{1}{n^2}$
(c) $\frac{1}{n^{3/2}}$ (d) $\frac{1}{n^3}$

13. Hydrogen $({}_1H^1)$, Deuterium $({}_1H^2)$, singly ionised Helium $({}_2He^4)^+$, and doubly ionised lithium $({}_3Li^6)^{++}$ all have one electron around the nucleus. Consider an electron transition from n = 2 to n = 1. If the wavelengths of emitted radiation are $\lambda_1, \lambda_2, \lambda_3$ and λ_4 respectively then approximately which one of the following is correct? **[2014]**

(a) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$
(b) $\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$
(c) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$
(d) $\lambda_1 = 2\lambda_2 = 3\lambda_3 = 4\lambda_4$

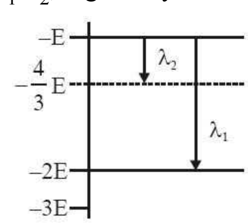
14. As an electron makes a transition from an excited state to the ground state of a hydrogen - like atom/ion : **[2015]**

(a) kinetic energy decreases, potential energy increases but total energy remains same
(b) kinetic energy and total energy decrease but potential energy increases
(c) its kinetic energy increases but potential energy and total energy decrease
(d) kinetic energy, potential energy and total energy decrease

15. A particle A of mass m and initial velocity v collides with a particle B of mass $\frac{m}{2}$ which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is **[2017]**

(a) $\frac{\lambda_A}{\lambda_B} = \frac{2}{3}$ (b) $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$
(c) $\frac{\lambda_A}{\lambda_B} = \frac{1}{3}$ (d) $\frac{\lambda_A}{\lambda_B} = 2$

16. Some energy levels of a molecule are shown in the figure. The ratio of the wavelengths $r = \lambda_1/\lambda_2$, is given by **[2017]**



(a) $r = \frac{3}{4}$ (b) $r = \frac{1}{3}$
(c) $r = \frac{4}{3}$ (d) $r = \frac{2}{3}$

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(c)	(b)	(c)	(a)	(b)	(b)	(d)	(b)	(c)	(b)	(d)	(d)	(c)	(c)	(d)
16														
(b)														

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SOLUTIONS

1. **(c)** The energy of nth orbit of hydrogen is given by

$$E_n = -\frac{13.6}{n^2} \text{ eV/atom}$$

For $n = 2$, $E_n = \frac{-13.6}{4} = -3.4\,eV$

Therefore the energy required to remove electron from $n = 2$ is $+3.4$ eV.

2. **(b)** The ionisation potential increases from left to right in a period and decreases from top to bottom in a group.

Therefore ceasium will have the lowest ionisation potential.

3. **(c)** The wavelength of spectrum is given by

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

$$\text{where } R = \frac{1.097 \times 10^7}{1 + \frac{m}{M}}$$

where m = mass of electron

M = mass of nucleus.

For different M, R is different and therefore λ is different

4. **(a)** $E_n = -\frac{13.6}{n^2} Z^2 \text{eV/atom}$

For lithium ion $Z = 3$; $n = 2$ (for first excited state)

$$E_n = -\frac{13.6}{2^2} \times 3^2 = -30.6 \text{ eV}$$

5. **(b)** Pauli's exclusion principle.

6. **(b)** $E = Rhc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

E will be maximum for the transition for which $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum. Here n_2 is the higher energy level.

Clearly, $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum for the third transition, i.e. $2 \to 1$. I transition represents the absorption of energy.

7. **(d)** We have to find the frequency of emitted photons. For emission of photons the transition must take place from a higher energy level to a lower energy level which are given only in options (c) and (d).

Frequency is given by

$$h\nu = -13.6\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$$

For transition from $n = 6$ to $n = 2$,

$$\nu_1 = \frac{-13.6}{h}\left(\frac{1}{6^2} - \frac{1}{2^2}\right) = \frac{2}{9} \times \left(\frac{13.6}{h}\right)$$

For transition from n = 2 to n = 1,

$$\nu_2 = \frac{-13.6}{h}\left(\frac{1}{2^2} - \frac{1}{1^2}\right) = \frac{3}{4} \times \left(\frac{13.6}{h}\right).$$

$\therefore\ \nu_1 > \nu_2$

8. **(b)** When $F = \frac{k}{r}$ = centripetal force, then

$$\frac{k}{r} = \frac{mv^2}{r}$$

$\Rightarrow mv^2$ = constat $\Rightarrow$ kinetic energy is constant $\Rightarrow T$ is independent of n.

9. **(c)** It is given that transition from the state n =4 to $n = 3$ in a hydrogen like atom result in ultraviolet radiation. For infrared radiation the energy gap should be less. The only option is $5 \to 4$.

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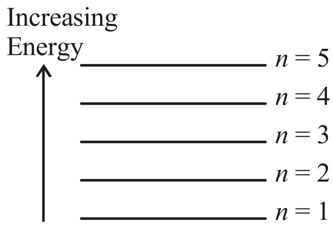
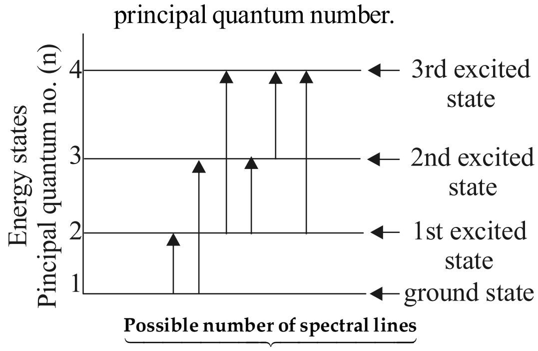


10. **(b)** Energy of excitation,

$$\Delta E = 13.6\,\pi^2\left(\frac{1}{\eta_1} - \frac{1}{\eta_2}\right) eV$$

$$\Rightarrow \Delta E = 13.6\,(3)^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 108.8\, eV$$

11. **(d)** For ground state, the principal quantum no. $(n) = 1$. There is a 3rd excited state for principal quantum number.



The possible number of the spectral lines is given

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

12. **(d)** $\Delta E = h\nu$

$$\nu = \frac{\Delta E}{h} = k\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{k(2n-1)}{n^2(n-1)^2}$$

$$\approx \frac{2k}{n^3} \quad \text{or} \quad \nu \propto \frac{1}{n^3}$$

13. **(c)** Wave number $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n^2}\right]$

$$\Rightarrow \lambda \propto \frac{1}{Z^2}$$

By question $n = 1$ and $n_1 = 2$

Then, $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$

14. **(c)** $U = -K\frac{ze^2}{r}$; $T.E = -\frac{k}{2}\frac{ze^2}{r}$

$K.E = \frac{k}{2}\frac{ze^2}{r}$. Here r decreases

15. **(d)** From question, $m_A = M;\ m_B = \frac{m}{2}$

$u_A = V \quad u_B = 0$

Let after collision velocity of $A = V_1$ and velocity of $B = V_2$

Applying law of conservation of momentum,

$$mu = mv_1 + \left(\frac{m}{2}\right)v_2$$

or, $24 = 2v_1 + v_2$ ....(*i*)

By law of collision

$$e = \frac{v_2 - v_1}{u - 0}$$

or, $u = v_2 - v_1$ ....(*ii*)

[$\because$ collision is elastic, $e = 1$]

using eqns (*i*) and (*ii*)

$$v_1 = \frac{4}{3} \text{ and } v_2 = \frac{4}{3}u$$

de-Broglie wavelength $\lambda = \frac{h}{p}$

$$\therefore \quad \frac{\lambda_A}{\lambda_B} = \frac{P_B}{P_A} = \frac{\frac{m}{2} \times \frac{4}{3}u}{m \times \frac{4}{3}} = 2$$

16. **(b)** From energy level diagram, using $\Delta E = \frac{hc}{\lambda}$

For wavelength $\lambda_1 \Delta E = -E - (-2E) = \frac{hc}{\lambda_1}$

$$\therefore \quad \lambda_1 = \frac{hc}{E}$$

For wavelength $\lambda_2 \Delta E = -E - \left(-\frac{4E}{3}\right) = \frac{hc}{\lambda_2}$

$$\therefore \quad \lambda_2 = \frac{hc}{\left(\frac{E}{3}\right)} \quad \therefore\ r = \frac{\lambda_1}{\lambda_2} = \frac{1}{3}$$