Solved Examples

1. The electron in a hydrogen atom make a transition from an excited state to the ground state. Which of the following statements is true?

(A) Its kinetic energy increases and its potential and total energy decrease.

(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same.

(C) Its kinetic and total energies decreases and its potential energy increases.

(D) its kinetic, potential and total energies decreases.

Solution:

(A)

The K.E and P.E of an orbital electron in a hydrogen atom is given by

$$(K.E.) = \frac{me^4}{8\epsilon_0^2 h^2 n^2}$$

$$(P.E.) = \frac{me^4}{8\epsilon_0^2 h^2 n^2}$$

During the transition from an excited state to lower orbits, n decreases and the K.E. increases and the potential energy become, more negative i.e. it decrease? Similarly the total energy becomes more negative.

2. A photoelectric cell is illuminated by a small bright source of light placed at 1m. If the same source of light is placed 2m away, the electrons emitted by the cathode

(A) each carries one quarter of its previous momentum.

(B) each carries one quarter of its previous energy.

(C) are half the previous number.

(D) are one quarter of the previous number.

Solution:

(D)

$1 \propto 1/d^2$

On doubling the distance the intensity becomes one fourth i.e. only one fourth of photons now strike the target in comparison to the previous number. Since photoelectric effect is a one photon-one electron phenomena, so only one-fourth photoelectrons are emitted out of the target hence reducing the current to one fourth the previous value.

3. As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of double ionzed Li atom (Z = 3) is:

(A) 1.51 (B) 13.6

(C) 40.8 (D) 122.4.

Solution:

(D)

According to Bohr's theory,

$E_n = RhcZ^2 / n^2 = 13.6z^2 / n^2 = eV$

Here z = 3, n = 1

Required energy $= |E_n| = 13.6 \times 9$

$= 122.4$

4. A hydrogen atom and a Li^{++} ion are both in the second excited state. If are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then:

(A) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$ (B) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$

(C) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$ (D) $l_H < l_{Li}$ and $|E_H| < |E_{Li}|$

Solution:

(B)

The angular momentum

And the total energy $E = -mz^2e^4 / 8\epsilon^2_0h^2$

Thus,

$|E_H| < |E_{Li}|$

5. A proton, a deutron and an alpha particle are accelerated through potentials of V, 2V and 4V respectively. Their velocities will bear a ratio.

(A) 1 : 1 : 1 (B) $1 : \sqrt{2} : 1$

(C) $\sqrt{2} : 1 : 1$ (D) $1 : 1 : \sqrt{2}$

Solution:

(D)

$v = \sqrt{2}qV / m$

6. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately

(A) 540 nm (B) 400 nm

(C) 310 nm (D) 220nm

Solution:

(C)

Work Function $\Phi_0 = hv_0 = hc / \lambda_{max}$

$\therefore \lambda_{max} = hc / \Phi_0 = 1240eVnm/4eV = 310$ nm

7. An electron is 2000 times lighter than a proton. Both are moving such that their matter waves have a length of 1Å. The ratio of their kinetic energy in approximation is

(A) 1 : 1 (B) 1 : 2000

(C) 2000 : 1 (D) 1 : 200

Solution:

(C)

Since both have same de Broglie wavelength, hence both must have equal value of momentum.

Since $E = p^2 / pm$

$\Rightarrow E_e / E_p = m_p / m_e = 1840 = 2000$ {nearest possible approximatin to answer}

8. An electron is lying initially in the n = 4 excited state. The electron de-excites itself to go to n = 1 state directly emitting a photon of frequency v_{41}. If the same electron first de-excites to n = 3 state by emitting a photon of frequency v_{43} and then goes from n = 3 to n = 1 state by emitting a photon of frequency v_{31}, then

(A) $v_{41} = v_{43} + v_{31}$ (B) $v_{41} = v_{43} - v_{31}$

(C) $v_{43} = v_{41} + 2v_{31}$ (D) Data Insufficient

Solution:

(A)

According to Ritz Combination Principle

$v_{m\to n} = v_{m\to i} + v_{i\to n}$

(for m < i < n)

e.g. $v_{4\to 1} = v_{4\to 3} + v_{3\to 1}$ or $v_{4\to 1} = v_{4\to 1} + v_{4\to 2} + v_{2\to 1}$

9. The K_a X-ray emission line of tungsten occurs at $\lambda = 0.021$ nm. The energy difference between K and L levels in this atom is about

(A) 0.51 MeV (B) 1.2 MeV

(C) 59 MeV (D) 13.6 MeV

Solution:

(C)

$\Delta E = hc/\lambda$

10. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6eV fall on it is 2eV. The stopping potential in volts is:

(A) 2 (B) 4

(C) 6 (D) 10

Solution:

(A)

According to Einstein's photoelectric equation

$hv = \Phi_0 + (KE)_{max} = \Phi_0 + eV_s$, where

$eV_s = (K.E.)_{max.}$

Slopping potential $V_s = (KE)_{max} / e = 2eV / e = 2V$

11. An electron enters electric field of 104 B/m perpendicular to the field with a velocity of $10^7 ms^{-1}$. The vertical displacement of electron after one mille second will be:

(A) $8/91 \times 10^8$ m (B) $91/8 \times 10^8$ m

(C) $8/91 \times 10^{10}$ m (D) $91/8 \times 10^{10}$ m

Solution:

The vertical displacement of electron

$y = 1/2\ at^2 = 1/2\ qE/m\ t^2$

Or $y = 1.6 \times 10^{-19} \times 10^{4} \times (10^{-3})^{2} / 2 \times 9.1 \times 10^{-31} = 8/91 \times 10^{-10}$ m

Hence the correct answer will be (C)

12. A stream of electrons of velocity 3×10^{7} m/s is deflected 2 mm in passing 10 cm through an electric field of 1800 V/m perpendicular to their path. The value of e/m for electrons will be :

(A) 1.78×10^{11} coul/kg (B) 2×10^{11} coul/kg

(C) 2.22×10^{11} coul/kg (D) 3.61×10^{11} coul/kg

Solution:

$y = 1/2\ at^2 = 1/2\ qE/m\ x^2/v^2$

$e/m = 2yv / Ex^2$

$2\times2\times10^{3}(3\times107)^{2} / 1000 \times(.1)^{2} = 20^{11}$

Hence the correct answer will be (B)

13. An electron beam passes through a magnetic field of 10^{-3} Wb/m^2 and an electric field of 3.0 $\times 10^{4}$ V/m, both acting simultaneously. If the path of the electrons remains undeviated, then the speed of electrons will be:

(A) 3×10^{7} m/s (B) $1/3 \times 10^{7}$ m/s

(C) 3×10^{5} m/s (D) $1/3 \times 10^{5}$ m/s

Solution:

For undeviated beam of electrons eE = evB

or $v = E/B = 3.0 \times 10^{4} / 10^{-3} = 3 \times 10^{7}$ m/s

Hence the correct answer will be (A)

14. If the above problem, if the electric field is removed, then the radius of electron path will be:

(A) 1.77 m (B) 1.77 cm

(C) 1.77 mm (D) None of these

Solution:

If electric field is removed, then the path of the electron becomes circular

$mv^2/r = Bev$

Or $r = \frac{mv}{eB} = \frac{9.1\times10^{-31}\times3\times10^7}{1.6\times10^{-19}\times10^{-3}}$ = 0.0177m = 1.77 cm

Hence the correct answer will be (B)

15. In Q.3, if the length of field region is 10 cm, then on removing the magnetic field, the vertical displacement of the electron will be:

(A) 2.9 m (B) 2.9 cm

(C) 2.9 mm (D) None of these

Solution:

$$y = \frac{1}{2}at^2 = \frac{1eE}{2m}\frac{1^2}{v^2}$$

Or $$y = \frac{1.6\times10^{-19}\times3\times10^4\times(.1)^2}{2\times9.1\times10^{-31}\times(3\times10^7)^2} = \frac{8}{273}m = 2.9\ cm$$

Hence the correct answer will be (B)

16. A charged oil drop is suspended in a uniform electric field of 300 V/cm. If the mass of the drop is 9.75×10^{-12} gm, then charge on it will be:

(A) 29.67×10^{-19} Coul. (B) 67.29×10^{-19} Coul.

(C) 31.85×10^{-19} Coul. (D) None of these

Solution:

In the stationary state of drop $qE = mg$

or $q / mg/E = 9.75 \times 10^{-15} \times 9.8 / 300 \times 10^{2} = 31.85 \times 10^{-19}$

Hence the correct answer will be (C)

17. The distance between the plates of a C.R.O. is 6.25×10^{-3} m and potential difference between them is 3.25×10^{3} V. The acceleration of an electron in between the plates will be:

(A) 8.9×10^{13} m/s^2 (B) 8.9×10^{14} m/s^2

(C) 8.9×10^{15} m/s^2 (D) 8.9×10^{16} m/s^2

Solution:

$a = F/m\ eE/m = eV/md$

or $a = 1.6\times10^{-19}\times3.125\times10^{2}/9.1\times10^{-31}\times6.25\times10^{-3} = 8.9 \times 10^{16}$ m/s^2

Hence the correct answer will be (D)

18. In a cathode ray tube the distance between the cathode and the anode is 0.5 m and the potential difference is 50 kV. If an electron starts from rest from the cathode, then it will strike the anode with a velocity:

(A) 2.66×10^{8} m/s (B) 1.33×10^{8} m/s

(C) 0.66×10^{8} m/s (D) 0.33×10^{8} m/s

Solution:

Kinetic energy of electron

$$\frac{1}{2}mv^2 = eV$$

$$\therefore v = \sqrt{\frac{2eV}{m}}$$

Or $$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 50 \times 10^{3}}{9.1 \times 10^{-31}}} = 1.33 \times 10^{8}\ m/s$$

Hence the correct answer will be (B)

19. An electron with energy 880 eV enters a uniform magnetic field of induction 2.5×10^{-3}T. The radius of path of the circle will approximately be:

(A) 4 km (B) 4 m

(C) 4 cm (D) 4 mm

Solution:

$$\because evB = \frac{mv^2}{r}$$

$$\therefore r = \frac{mv}{eB} = \frac{\sqrt{2mE}}{eB}$$

Or $$r = \frac{\sqrt{2 \times 9.1 \times 10^{-31} \times 880 \times 1.6 \times 10^{-19}}}{1.6 \times 10^{-19} \times 2.5 \times 10^{-9}} \approx 0.04m = 4\ cm$$

Hence the correct answer will be (C)

20. The potential difference between cathode and anode of a C.R. tube is 200kV and distance between them is 25 cm. The intensity of electric field inside the tube will be:

(A) 8×10^{5} v/m (B) 8×10^{4} v/m

(C) 8×10^3 v/m (D) 0

Solution:

$E = V/d = 200 \times 103/0.25 = 8 \times 10^5$ v/m

Hence the correct answer will be (A)

21. In the above problem, energy gained by the electron will be:

(A) 3.2×10^{-14} eV (B) 3.2×10^{-14} erg

(C) 3.2×10^{-14} MeV (D) 3.2×10^{-14} Joule

Solution:

$E = eV = 1.6 \times 120^{-19} \times 2 \times 10^5$

$= 3.2 \times 10^{-14}$ Joule

Hence the correct answer will be (D)

22. A beam of electrons is under the effect of 1.36×10^4 V applied across two parallel plates 4 cm apart and a magnetic field of induction 2×10^{-3} T at right angles to each other. If the two fields combiningly produce no deflection in the electron beam, then the velocity of electrons will be:

(A) 2.7×10^7 m/s (B) 1.7×10^7 m/s

(C) 2.7×10^8 m/s (D) 1.7×10^8 m/s

Solution:

$v = E/B = v/Bd = 1.36 \times 10^4 / 0.04 \times 0.002 = 1.7 \times 10^8$ m/s

Hence the correct answer will be (D)

23. In the above problem if the electric field is made zero, the the radius of the path of electron will be:

(A) 0.4834 m (B) 0.8434 m

(C) 0.3484 m (D) 0.4304 m

Solution:

$r = mv/eB = 9.1 \times 10^{-31} \times 1.7 \times 10^{8} / 1.6 \times 10^{-19} \times 0.002 = 0.4834$ m

Hence the correct answer will be (A)

24. In Q.1, if the length of field region is 20 cm, then on removing the magnetic field the deflection of electrons produced by electric field will be:

(A) 4.14 km (B) 4.14 m

(C) 4.14 cm (D) 4.14 mm

Solution:

$$y = \frac{1}{2}\frac{eE}{eB}\frac{l^2}{v^2} = \frac{1.6\times10^{-19}\times1.36\times10^{4}\times0.04}{2\times0.04\times9.1\times10^{-31}\times1.7^{2}\times10^{16}} = 4.14 \text{ cm}$$

Hence the correct answer will be (C)

25. In Thomson's experiment for the measurement of e/m of an electron, the beam remains undeflected when the electric field is 10^{5} V/m and the magnetic field is 10^{-2} T. The beam was originally accelerated through a potential difference of 285 volt. The value of specific charge of electron will be:

(A) 1.67×10^{11} C/kg (B) 1.47×10^{11} C/kg

(C) 1.74×10^{11} C/kg (D) None of these

Solution:

$1/2\ mv^2 = ev$ and $eE = Bev$

or $= 1.74 \times 10^{11}$ C/kg

Hence the correct answer will be (C)

26. In a Thomson set-up, electrons accelerated through 2500 V enter the region of crossed electric and magnetic fields of strengths 36×10^{4} V/m and 1.2×10^{-3} T respectively and pass through undeflected. The e/m of electrons will be:

(A) 1.6×10^{11} C/kg (B) 1.7×10^{11} C/kg

(C) 1.8×10^{11} C/kg (D) None of these

Solution:

$e/m = E^2/2.VB^2 = 3.6^2 \times 10^8 / 2 \times 2500 \times 1.2^2 \times 10^{-6}$

$P = 1.8 \times 10^{11}$ C/kg

Hence the correct answer will be (C)

CMP:A gas of identical hydrogen like atoms has some atoms in ground state and some atoms in a particular excited state and there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy state by absorbing monochromatic light of wavelength subsequently, the atoms emit radiation of only six different photon energies. Some of emitted photons have wavelength some have wavelength more and some have less than .

27. Find the principal quantum number of the initially excited state.

(A) 1 (B) 2

(C) 3 (D) 4

Solution:

(B)

During de-excitation, photons of six different wavelengths are emitted; therefore, principal quantum number of highest excited level is 4.

$E_{incidence} = hc / 340\ A^o = 40.8$ ev

$E_{min} = E_4 + E_3$

Since, some of emitted photons have energy less that 40.8 eV, Therefore $E_{min} < 40.8$ eV

Also, $E_{max} = E_4 - E_1$, but some of emitted photons have energy greater than 40.8 eV.

Therefore $E_{max} > 40.8$ eV.

As the atoms of the gas make transition by absorbing photons of energy 40.8 eV. Since, atoms of ground state do not absorb the incident radiation hence the incident radiation is absorbed by initially excited atom which may belong to either n = 2 or there transition is not possible.

Therefore, the only possible value of principal quantum number of initially excited level is n=2.

28. Identify the gas (Z =?).

(A) 5 (B) 2

(C) 33 (D) 4

Solution: (D)

The atoms of n = 2 make transition to n = 4 by absorbing photons of energy 40.8 eV.

$E_4 – E_2 = 40.8$ eV

But $E_n = –13.6z^2 / n^2$ eV …(i)

$E_4 = –13.6z^2 / 16$, $E_2 = 13.6z^2 / 4$

Substituting these values in (i), we get

$13.6z^2 (–1/16 + 1/14) = 40.8 \Rightarrow Z = 4$

29. Find the ground state energy (in eV).

(A) 13.6 eV (B) – 54.4 eV

(C) – 122.4 eV (D) – 217.6 eV

Solution: (D)

$Ei = –13.6(4)^2 / 1^2 = –217.6$ eV