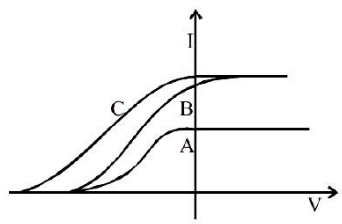
11 Dual Nature of Radiation and Matter

Multiple Choice Questions (MCQs)

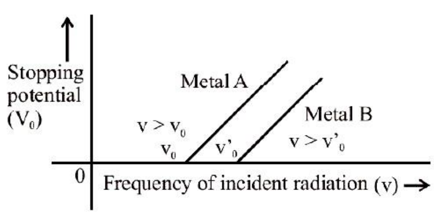
DIRECTIONS : *This section contains multiple choice questions. Each question has four choices (a), (b), (c) and (d) out of which only one is correct.*

1. In a photoelectric experiment, anode potential (V) is plotted against plate current (I)



(a) A and B will have different intensities while B and C will have different frequencies.
(b) B and C will have different intensities while A and C will have different frequencies.
(c) A and B will have different intensities while A and C will have equal frequencies.
(d) A and B will have equal intensities while B and C will have different frequencies.

2. Select true/false statements according to the graph

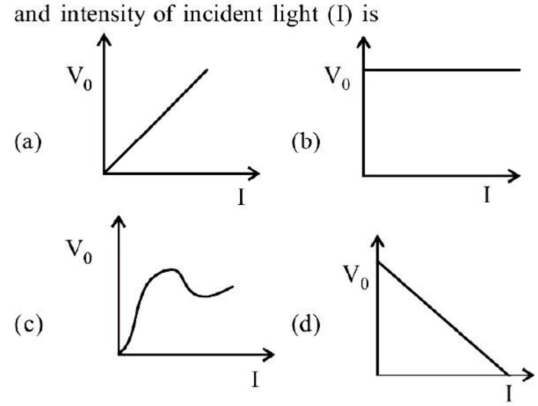


I. the stopping potential varies linearly with the frequency of incident radiation for the given metal.
II. the work function of metal *A* is greater than that for metal *B*.
III. stopping potential depends upon the angle of incident light.
IV. the stopping potential is independent of the intensity of incident radiation.

(a) T, F, T, F (b) T, F, F, T
(c) F, T, F, T (d) T, T, F, T

3. A strong argument for the particle nature of cathode rays is that they
(a) produce fluoroscence
(b) travel through vacuum
(c) get deflected by electric and magnetic fields
(d) cast shadow

4. The correct graph between the stopping potential (V_0) and intensity of incident light (I) is

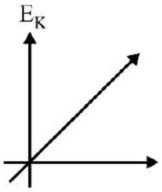


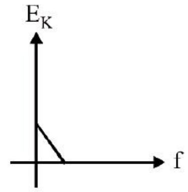
5. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons
(a) will be possible
(b) will not be possible
(c) data is incomplete
(d) depends upon the density of the surface

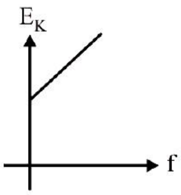
6. Which of the following is/are true/false regarding cathode rays?
I. They produce heating effect
II. They don't deflect in electric field
III. They cast shadow
IV. They produce fluorescence

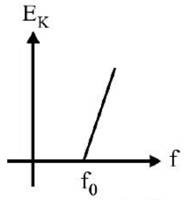
(a) F, T, T, T (b) T, T, T, T
(c) F, F, F, T (d) T, F, T, T

7. Which one of the following graphs represents the variation of maximum kinetic energy (E_K) of the emitted electrons with frequency f in photoelectric effect correctly?

(a) 

(b) 

(c) 

(d) 

8. If a photon and an electron have same de-Broglie wavelength, then
(a) both have same kinetic energy
(b) proton has more K.E. than electron
(c) electron has more K.E. than proton
(d) both have same velocity

9. If E_1, E_2, E_3 are the respective kinetic energies of an electron, an alpha-particle and a proton, each having the same de-Broglie wavelength, then
(a) $E_1 > E_3 > E_2$ (b) $E_2 > E_3 > E_1$
(c) $E_1 > E_2 > E_3$ (d) $E_1 = E_2 = E_3$

10. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be
(a) 1 : 2 (b) 1 : 1
(c) 1 : 3 (d) 1 : 4

11. A particle is dropped from a height H. The de-Broglie wavelength of the particle as a function of height is proportional to
(a) H (b) $H^{1/2}$
(c) H^0 (d) $H^{-1/2}$

12. Photons of energies 1 eV and 2 eV are successively incident on a metallic surface of work function 0.5 eV. The ratio of kinetic energy of most energetic photoelectrons in the two cases will be **[CBSE 2020]**
(a) 1:2 (b) 1:1
(c) 1 : 3 (d) 1 : 4

13. Consider a beam of electrons (each electron with energy E_0) incident on a metal surface kept in an evacuated chamber. Then,
(a) no electrons will be emitted as only photons can emit electrons
(b) electrons can be emitted but all with an energy, E_0
(c) electrons can be emitted with any energy, with a maximum of $E_0 - \phi$ (ϕ is the work function)
(d) electrons can be emitted with any energy, with a maximum of E_0

14. A proton, a neutron, an electron and an α-particle have same energy. Then, their de-Broglie wavelengths compare as
(a) $\lambda_p = \lambda_n > \lambda_e < \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

15. An electron is moving with an initial velocity $v = v_0 \vec{i}$ and is in a magnetic field $B = B_0 \vec{j}$. Then, it's de-Broglie wavelength
(a) remains constant
(b) increases with time
(c) decreases with me
(d) increases and decreases periodically

16. An electron (mass m) with an initial velocity $v = v_0 i$ ($v_0 > 0$) is in an electric field $E = -E_0 \hat{i}$ (E_0 = constant > 0). It's de-Broglie wavelength at time t is given by
(a) $\dfrac{\lambda_0}{\left(1+\dfrac{eE_0}{m}\dfrac{t}{v_0}\right)}$ (b) $\left(1+\dfrac{eE_0 t}{mv_0}\right)$
(c) λ_0 (d) $\lambda_0 t$

17. An electron (mass m) with an initial velocity $v = v_0\hat{i}$ is in an electric field $E = E_0\hat{j}$. If $\lambda_0 = h/mv$, it's de-Broglie wavelnegth at time t is given by
(a) λ_0 (b) $\lambda_0\sqrt{1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}}$
(c) $\dfrac{\lambda_0}{\sqrt{1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}}}$ (d) $\dfrac{\lambda_0}{\left(1+\dfrac{e^2E_0^2t^2}{m^2v_0^2}\right)}$

18. The photoelectrons emitted from a metal surface are such that their velocity
(a) is zero for all
(b) is same for all
(c) lies between zero and infinity
(d) lies between zero and a finite maximum

19. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons
(a) will be possible
(b) will not be possible
(c) Data is incomplete
(d) Depends upon the density of the surface

20. In a photoelectric experiment the stopping potential for the incident light of wavelength 4000Å is 2 volt. If the wavelength be changed to 3000 Å, the stopping potential will be
(a) 2V (b) zero
(c) less than 2 V (d) more than 2 V

21. A free particle with initial kinetic energy *E*, de-Broglie wavelength λ, enters a region wherein it has a potential energy *V*, what is the new de-Broglie wavelength?
(a) $\lambda(1 + E/V)$ (b) $\lambda(1 - V/E)$
(c) $\lambda(1 + V/E)^{0.5}$ (d) $\lambda/(1 - V/E)^{0.5}$

22. Cathode rays and canal rays produced in a certain discharge tube are deflected in the same direction if
(a) a magnetic field is applied normally
(b) an electric field is applied normally
(c) an electrin field is applied tangentially
(d) a magnetic field is applied tangentially

23. A material particle with a rest mass m_0 is moving with speed of light c. The de-Broglie wavelength associated is given by
(a) $\frac{h}{m_0 c}$ (b) $\frac{m_0 c}{h}$ (c) zero (d) ∞

24. The ratio of de-Broglie wavelengths of proton and α-particle having same kinetic energy is
(a) $\sqrt{2}:1$ (b) $2\sqrt{2}:1$ (c) 2 : 1 (d) 4 : 1

25. When the speed of electrons increase, then the value of its specific charge
(a) increases
(b) decreases
(c) ramains unchanged
(d) increases upto some velocity and then begins to decrease

26. A steel ball of mass m is moving with a kinetic energy K. The de Broglie wavelength associated with the ball is
(a) $\frac{h}{2mK}$ (b) $\sqrt{\frac{h}{2mK}}$
(c) $\frac{h}{\sqrt{2mK}}$ (d) $\sqrt{\frac{h}{3mk}}$

27. If the two particles have fallen through the same height, the heavier of the two particles has ____ de Broglie wavelength.
(a) same (b) greater (c) smaller (d) None

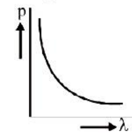
28. The de-Broglie wavelength of neutron in thermal equilibrium at temperature T is
(a) $\frac{30.8}{\sqrt{T}}$ Å (b) $\frac{3.08}{\sqrt{T}}$ Å (c) $\frac{0.308}{\sqrt{T}}$ Å (d) $\frac{0.0308}{\sqrt{T}}$ Å

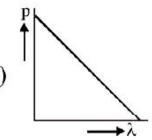
29. The wavelength λ_e of an electron and λ_p of a proton are of same energy E are related by
(a) $\lambda_p \propto \lambda_e$ (b) $\lambda_p \propto \sqrt{\lambda_e}$
(c) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (d) $\lambda_p \propto \lambda_e^2$

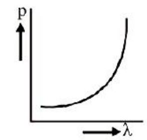
30. If the kinetic energy of a free electron doubles, it's deBroglie wavelength changes by the factor
(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

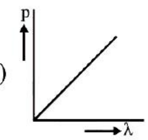
31. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ Js) :
(a) 2.4 Å (b) 0.5 Å (c) 1.7 Å (d) 1.2 Å

32. The de Broglie wavelength of a neutron at 927 °C is λ. What will be its wavelength at 27 °C ?
(a) $\frac{\lambda}{2}$ (b) λ (c) 2λ (d) 4λ

33. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?
(a) 

(b) 

(c) 

(d) 

34. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is :
(a) 25 (b) 75 (c) 60 (d) 50

35. The phenomenon which can be explained only by quantum nature of light is
(a) photoelectric effect (b) reflection
(c) interference (d) polarization

36. Photoelectric effect is the phenomenon in which
(a) photons come out of a metal when it is hit by a beam of electrons.
(b) photons come out of the nucleus of an atom under the action of an electric field.
(c) electrons come out of a metal with a constant velocity which depends on the frequency and intensity of incident light wave.
(d) electrons come out of a metal with different velocities not greater than a certain value which depends only on the frequency of the incident light wave and not on its intensity.

37. In which of the following, emission of electrons does not take place?
(a) Thermionic emission
(b) Photoelectric emission
(c) Secondary emission
(d) None of these

38. In the photoeletric effect, electrons are emitted
(a) at a rate that is proportional to the amplitude of the incident radiation
(b) with a maximum velocity proportional to the frequency of the incident radiation
(c) at a rate that is independent of the emitter
(d) only if the frequency of the incident radiations is above a certain threshold value

39. The wavelength of a photon is 4000 Å. Calculate its energy.
(a) 49.5×10^{-19} J (b) 495×10^{-19} J
(c) 4.95×10^{-19} kJ (d) 4.95×10^{-19} J

40. What is the kinetic energy gained by an electron due to acceleration through a potential difference of 1 V?
(a) 1 eV (b) 1 joule (c) 5 Nm (d) 10 Nm

41. The work function of photoelectric substance is 3.3eV. The value of threshold frequency will be
(a) 4×10^{11} Hz (b) 8×10^{10} Hz
(c) 5×10^{33} Hz (d) 8×10^{14} Hz

42. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to

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

43. If the wavelength of incident light falling on a photosensitive material decreases, then

(a) photoelectric current increases
(b) stopping potential decreases
(c) stopping potential remains constant
(d) stopping potential increases

44. A photosensitive metal is not emitting photo–electrons when irradiated. It will do so when threshold is crossed. To cross the threshold we need to increase

(a) intensity (b) frequency
(c) wavelength (d) None of these

45. The number of photoelectrons emitted for light of a frequency ν (higher than the threshold frequency ν_0) is proportional to:

(a) Threshold frequency (ν_0)
(b) Intensity of light
(c) Frequency of light (ν)
(d) $\nu - \nu_0$

46. The wavelength of a 1 ke V photon is 1.24×10^{-9}m. What is the frequency of 1 MeV photon?

(a) 1.24×10^{15} (b) 2.4×10^{20}
(a) 1.24×10^{18} (b) $2 \times 4 \times 10^{23}$

47. Einstein's photoelectric equation is $E_k = h\nu - \phi$. In this equation E_k refers to

(a) kinetic energy of all the emitted electrons
(b) mean kinetic energy of emitted electrons
(c) maximum kinetic energy of emitted electrons
(d) minimum kinetic energy of emitted electrons

48. A monochromatic source of light operating at 200 W emits 4×10^{20} photons per second. Find the wavelength of light.

(a) 400 nm (b) 200 nm
(c) 4×10^{-10} Å (d) None of these

49. The photoelectric threshold of Tungsten is 2300Å. The energy of the electrons ejected from the surface by ultraviolet light of wavelength 1800Å is

(a) 0.15 eV (b) 1.5 eV
(c) 15 eV (d) 150 eV

50. Using light of wavelength 6000 Å stopping potential is obtained 2.4 volt for photoelectric cell. If light of wavelength 4000 Å is used then stopping potential would be

(a) 2.9 V (b) 1.9 V (c) 3.43 V (d) 9.4 V

51. In an electron gun, the potential difference between the filament and plate is 3000 V. What will be the velocity of electron emitting from the gun?

(a) 3×10^8 m/s (b) 3.18×10^7 m/s
(c) 3.52×10^7 m/s (d) 3.26×10^7 m/s

52. No photoelectrons are emitted from a metal if the wavelength of the light exceeds 600 nm. The work function of the metal is approximately equal to

(a) 3×10^{-16} J (b) 3×10^{-19} J
(c) 3×10^{-20} J (d) 3×10^{-22} J

53. The shortest wavelength of X-ray emitted from an X-ray tube operated at 2×10^6 volt, is of the order of

(a) 10^{-5} Å (b) 10^{-2} Å (c) 0.15 Å (d) 1 Å

54. What is the energy of k_α X-ray photon of copper (Z = 29)?

(a) 7.99 keV (b) 8.29 keV
(c) 8.25 keV (d) 7.19 keV

55. When ultraviolet radiation is incident on a surface, no photoelectrons are emitted. If a second beam causes photoelectrons to be ejected, it may consists of

(a) infra-red waves (b) X-rays
(c) visible light rays (d) radio waves

56. The maximum kinetic energy of the electrons hitting a target so as to produce X-ray of wavelength 1 Å is

(a) 1.24 keV (b) 12.4 keV
(c) 124 keV (d) None of these

57. The ratio of the energy of an X-ray photon of wavelength 1 Å to that of visible light of wavelength 5000 Å is

(a) 1 : 5000 (b) 5000 : 1
(c) $1 : 25 \times 10^6$ (d) 25×10^6

58. An X-rays tube is being operated at 20 kV, the maximum speed of electrons striking the anticathode will be

(a) 8.4 m/s (b) 8.4×10^7 m/s
(c) 4.4×10^7 m/s (d) zero

59. When the minimum wavelength of X-rays is 2Å then the applied potential difference between cathode and anticathode will be

(a) 6.2 kV (b) 2.48 kV (c) 24.8 kV (d) 62 kV

60. The maximum distance between interatomic lattice planes is 15 Å. The maximum wavelength of X-rays which are diffracted by this crystal will be

(a) 15 Å (b) 20 Å (c) 30 Å (d) 45 Å

61. An X-ray tube is operated at 15 kV. Calculate the upper limit of the speed of the electrons striking the target.

(a) 7.26×10^7 m/s (b) 7.62×10^7 m/s
(c) 7.62×10^7 cm/s (d) 7.26×10^9 m/s

62. The glancing angle in a X-ray diffraction is 30° and the wavelength of X-rays used is 20 nm. The interplanar spacing of the crystal dffracting these X-rays will be

(a) 40 nm (b) 20 nm (c) 15 nm (d) 10 nm

63. An element with atomic number Z = 11 emits k_αx-ray of wavelength λ then the atomic number of the element which emits k_αx-ray of wavelength 4λ is:

(a) 11 (b) 44 (c) 6 (d) 5

64. The X-rays of wavelength 0.5 Å are scattered by a target. What will be the energy of incident X-rays, if these are scattered at an angle of 72° ?

(a) 12.41 keV (b) 6.2 keV
(c) 18.6 keV (d) 24.82 keV

65. An X-ray tube with Cu target is operated at 25 kV. The glancing angle for a NaCl crystal for the Cu k_α line is 15.8°. Find the wavelength of this line.
(d for NaCl = 2.82 Å, h = 6.62×10^{-27} erg-sec)

(a) 3.06 Å (b) 1.53 Å
(c) 0.75 Å (d) None of these

Case/Passage Based Questions

DIRECTIONS : *Study the given Case/Passage and answer the following questions.*

Case/Passage-I

A physicist wishes to eject electrons by shining light on a metal surface. The light source emits light of wavelength of 450 nm. The table lists the only available metals and their work functions.

Metal	W_0 (eV)
Barium	2.5
Lithium	2.3
Tantalum	4.2
Tungsten	4.5

66. Which metal(s) can be used to produce electrons by the photoelectric effect from given source of light ?
(a) Barium only
(b) Barium or lithium
(c) Lithium, tantalum or tungsten
(d) Tungsten or tantalum

67. Which option correctly identifies the metal that will produce the most energetic electrons and their energies ?
(a) Lithium, 0.45 eV (b) Tungston, 1.75 eV
(c) Lithium, 2.30 eV (d) Tungston, 2.75 eV

68. Suppose photoelectric experiment is done separately with these metals with light of wavelength 450 nm. The maximum magnitude of stopping potential amongst all the metals is-
(a) 2.75 volt (b) 4.5 volt
(c) 0.45 volt (d) 0.25 volt

69. The photoelectric effect is based on the law of conservation of
(a) momentum (b) energy
(c) angular momentum (d) mass

70. The momentum of photon whose frequency f is
(a) $\frac{hf}{c}$ (b) $\frac{hc}{f}$ (c) $\frac{h}{f}$ (d) $\frac{c}{hf}$

Case/Passage-II

According to de-Broglie a wave is associated with moving material particle called matter waves or de-Broglie wave.
De Broglie proposed wavelength of a particle of momentum p as

$$\lambda = \frac{h}{p} = \frac{h}{mv};$$ m = mass of particle, v = speed

λ = wavelength of matter wave or de Broglie wavelength.

71. If the momentum of electron is changed by P, then the de- Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be
(a) 200 P (b) 400 P
(c) $\frac{P}{200}$ (d) 100 P

72. If the kinetic energy of a free electron doubles, it's de-Broglie wavelength changes by the factor
(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

73. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is :
(a) 25 (b) 75 (c) 60 (d) 50

74. A proton and α-particle are accelerated through the same potential difference. The ratio of their de-Broglie wavelength will be
(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) $2\sqrt{2}:1$

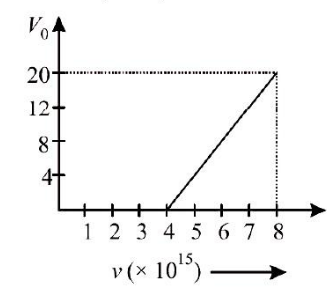
75. An α-particle and a singly ionized $_4Be^8$ atom are accelerated through the same potential difference. What is the ratio of the de-Broglie wave lengths in the two cases?
(a) 1 : 2 (b) 1 : 1 (c) 2 : 1 (d) 4 : 1

Case/Passage-III

When a high frequency electromagnetic radiation is incident on a metallic surface, electrons are emitted from the surface. Energy of emitted photoelectrons depends only on the frequency of incident electromagnetic radiation and the number of emitted electrons depends only on the intensity of incident light.
Einstein's photoelectric equation $[K_{max} = hv - \phi]$ correctly explains the PE, where υ = frequency of incident light and ϕ = work function.

76. Light of wavelength 3300 is incident on two metals A and B, whose work functions are 4 eV and 2 eV, respectively. Then
(a) A will emit photoelectrons but B will not
(b) B will emit photoelectrons, but A will not
(c) both A and B will not emit photoelectrons
(d) neither A nor B will emit photoelectrons

77. For photoelectric effect in a metal, the graph of the stopping potential V_0 (in volt) versus frequency υ (in hertz) of the incident radiation is shown in fig. The work function of the metal (in eV) is



(a) 12.5 (b) 14.5 (c) 16.5 (d) 18.5

78. The slope of the graph shown in fig. [here h is the Planck's constant and e is the charge of an electron] is
(a) $\frac{h}{e}$ (b) eh (c) h (d) $\frac{e}{h}$

79. The magnitude of saturation photoelectric current depends upon

(a) frequency (b) intensity
(c) work function (d) stopping potential

80. The number of photo-electrons emitted per second from a metal surface increases when
(a) the energy of incident photons increases
(b) the frequency of incident light increases
(c) the wavelength of the incident light increases
(d) the intensity of the incident light increases

Assertion & Reason

DIRECTIONS : *Each of these questions contains an assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*
(a) If both **Assertion** and **Reason** are **correct** and the 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 the **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If the **Assertion** is **incorrect** but the **Reason** is **correct**.

81. **Assertion :** In photoelectric effect on increasing the intensity of light, kinetic energy of electrons increased but photoelectric current remains unchanged.
Reason : The photoelectric current depends on frequency of light.

82. **Assertion :** The kinetic energy of photoelectrons emitted from metal surface does not depend on the intensity of incident photon
Reason : The ejection of electrons from metallic surface is not possible with frequency of incident photons below the threshold frequency.

83. **Assertion :** Though light of a single frequency (monochromatic) is incident on a metal, the energies of emitted photoelectrons are different.
Reason : The energy of electrons emitted from inside the metal surface, is lost in collision with the other atoms in the metal.

84. **Assertion :** The photon behaves like a particle.
Reason : If E and P are the energy and momentum of the photon, then $p = E/c$.

Match the Following

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in column-I have to be matched with statements (1, 2, 3, 4) in column-II.*

85. Match the Columns I and II.

Column I	Column II
(A) Field emission	(1) Heat is supplied to the metal surface
(B) Photoelectric emission	(2) Electric field is applied to the metal surface
(C) Thermionic emission	(3) Light of suitable frequency illuminates the metal surface
(D) Secondary emission	(4) Striking fast moving electrons on the metal surface

(a) (A) → (2); (B) → (3); C → (1); (D) → (4)
(b) (A) → (1); (B) → (3); C → (2); (D) → (4)
(c) (A) → (4); (B) → (1); C → (3); (D) → (2)
(d) (A) → (4); (B) → (3); C → (2); (D) → (1)

Fill in the Blanks

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

86. Photoelectric emmision occurs only when the incident light has more than a certain minimum ________.

87. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then_______ is the ratio of their threshold wavelengths.

88. A steel ball of mass m is moving with a kinetic energy K. The de-Broglie wavelength associated with the ball is________.

89. The wavelength of the matter wave is independent of ________ .

90. The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nuclear with 1 MeV energy is nearly__________ nm.

True / False

DIRECTIONS : *Read the following statements and write your answer as true or false.*

91. If a proton and electron have the same de Broglie wavelength, then momentum of electron > momentum of proton

92. In a photoelectric experiment, if both the intensity and frequency of the incident light are doubled, then the saturation photoelectric current is doubled.

93. If in a photoelectric cell, the wavelength of incident light is changed from 4000Å to 3000 Å then change in stopping potential will be 0.33 V.

94. When the X-ray tube is operated at 1kV, then X-rays of minimum wavelength 6.22 Å are produced. If the tube is operated at 10 kV, then the minimum wavelength of X-rays will be 0.622 Å.

ANSWER KEY & SOLUTIONS

1. **(a)** From the graph it is clear that A and B have the same stopping potential and therefore the same frequency. Also B and C have the same intensity.
2. **(b)**
3. **(c)** As cathode rays are deflected by electric and mangetic fields, it shows that cathode rays carry charged particles (i.e. electrons)
4. **(b)** Stoping potential does not depend upon intensity of incident light (I).
5. **(b)** For emission of electrons incident energy of each photon must be greater than work function (threshold energy).
6. **(d)** Cathode rays deflect in electric field.
7. **(d)** $hf - hf_0 = E_K$, according to photoelectric equation, when $f = f_0$, $E_K = 0$.
Graph (d) represents $E_K - f$ relationship.
8. **(c)** $\lambda = \frac{h}{m_p v_p} = \frac{h}{m_e v_e}$; then $m_p v_p = m_e v_e$

or $\frac{v_p}{v_e} = \frac{m_e}{m_p}$

$$\frac{E_p}{E_e} = \frac{\frac{1}{2}m_p v_p^2}{\frac{1}{2}m_e v_e^2} = \frac{m_p}{m_e} \times \left(\frac{m_e}{m_p}\right)^2 = \frac{m_e}{m_p} < 1$$

$\therefore \quad E_p < E_e$

9. **(a)** According to relation, $E = \frac{1}{2}mv^2$

$$\sqrt{\frac{2E}{m}} = v$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

Because $m_1 < m_3 < m_2$

So for same λ, $E_1 > E_3 > E_2$.

10. **(c)** *K.E.* = Photon energy – Work function.

$$\therefore \quad \frac{K.E_1}{K.E_2} = \frac{1-0.5}{2-0.5} = \frac{0.5}{1.5} = \frac{1}{3}$$

11. **(d)** Velocity of a body freely falling from a height H is

$v = \sqrt{2gH}$

So, $\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{2gH}} \Rightarrow = \frac{h}{m\sqrt{2g}\sqrt{H}}$

(h, m and g are constant)

Here, $\frac{h}{m\sqrt{2g}}$ is also constant

So, $h \propto \frac{1}{\sqrt{H}} \Rightarrow$ or $\boxed{\lambda \propto H^{-1/2}}$

12 Option (c) is correct.

K.E. = Photon energy – Work function.

$$\therefore \quad \frac{K.E_1}{K.E_2} = \frac{1-0.5}{2-0.5} = \frac{0.5}{1.5} = \frac{1}{3}$$

13. **(d)** When a beam of electrons of energy E_0 is incident on a metal surface kept in vacuum or evacuated chamber so electrons can be emitted with maximum energy E_0 (due to elastic collision) and with any energy less than E_0, when part of incident energy of electron is used in liberating the electrons from the surface of metal. So maximum energy of emitted electrons can be E_0.
14. **(b)** The relation between λ and K is given by

$$\lambda = \frac{h}{\sqrt{2mK}}$$

So, for the given value of kinetic energy K,

$\frac{h}{\sqrt{2K}}$ is a constant.

Thus, $\lambda \propto \frac{1}{\sqrt{m}}$

$\therefore \quad \Rightarrow \lambda_p : \lambda_n : \lambda_e : \lambda_\alpha$

$$\Rightarrow \quad = \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_n}} : \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_\alpha}}$$

if $(m_p = m_n)$, then $\lambda_p = \lambda_n$
if $(m_\alpha > m_p)$, then $\lambda_\alpha < \lambda_p$
if $(m_e < m_n)$, then $\lambda_e > \lambda_n$
Hence, $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$.

15. **(a)** As given that, $v = v_0\ \vec{i}$ and $B = B_0\ \vec{j}$

Force on moving electron due to perpendicular magnetic field B is, $F = -e\,(v \times B)$

$$F = -e\left[v_0\hat{i} \times B_0\hat{i}\right] = -e\, v_0\, B_0\,(\hat{i} \times \hat{j})$$

$$\Rightarrow \quad = -ev_0B_0\hat{k} \qquad (\because \hat{k} = \hat{i} \times \hat{j})$$

So, the force is perpendicular to v and B, both as the force is $\perp$ to the velocity so the magnitude of v will not change, so momentum is (= mv) will remain same or constant in magnitude. Hence,

de-Broglie wavelength $\lambda = \frac{h}{mv}$ remains constant.

16. **(a)** de-Brogile wavelength of electron,

$$\lambda_0 = \frac{h}{mv_0} \quad ...(i)$$

Force on electron

$$\Rightarrow \quad F = -eE = (-e)(-E_0\hat{i}) = eE_0\hat{i}$$

Acceleration of electron

$$a = \frac{F}{m} = \frac{eE_0\hat{i}}{m} \quad (\because F = ma)$$

Velocity of electron after time t, is $v = (v_0 + at)$

$$v = v_0\hat{i} + \left(\frac{eE_0\hat{i}}{m}\right)t = \left(v_0 + \frac{eE_0}{m}t\right)\hat{i}$$

$$v = v_0\left(1 + \frac{eE_0}{m}t\right)\hat{i}$$

Now for new de-Broglie wavelength associated with electron at time t is

$$\lambda = \frac{h}{mv} \Rightarrow \lambda = \frac{h}{v_0 m\left[\left(1 + \frac{eE_0 t}{mv_0}\right)\hat{i}\right]} = \frac{\lambda_0}{\left[1 + \frac{eE_0}{mv_0}t\right]} \quad \left[\because \lambda_0 = \frac{h}{mv_0} \; |\hat{i}| = 1\right]$$

$$\lambda = \frac{\lambda_0}{\left[1 + \left(\frac{eE_0}{mv_0}\right)t\right]}$$

17. **(c)** 18. **(d)**

19. **(b)** For emission of electrons incident energy of each photon must be greater than work function (threshold energy).

20. **(d)** $eV_s = \frac{hc}{\lambda} - W_0$. If λ decreases, V_s increases

21. **(b)**

22. **(a)** In discharge tube cathode rays (a beam of negative particles) and canal rays (positive rays) move opposite to each other. They will experience a magnetic force in the same direction, if a normal magnetic field is applied.

23. **(c)** $\lambda = \frac{h}{mv}$, $v = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, $v \to c$, $m \to \infty$

hence, $\lambda \to 0$.

24. **(c)** de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mE_{K.E}}}$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} = \sqrt{\frac{4m_p}{m_p}} = \frac{2}{1} \; [\because E_{K.E(\alpha)} = E_{K.E(p)}]$$

25. **(b)** Here the velocity of electron increases, so as per Einstein's equation mass of the electron increases, hence the specific charge $\frac{e}{m}$ decreases.

26. **(c)** de-Broglie's relation, $\lambda = \frac{h}{p}$; $p = \sqrt{2mE}$

$$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mK}} \quad (\because E = K)$$

27. **(c)**

28. **(a)** From formula $\lambda = \frac{h}{\sqrt{2mKT}}$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 1.38 \times 10^{-23} T}} = \frac{30.8}{\sqrt{T}} Å$$

29. **(a)**

30. **(d)** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(K.E)}} \;\therefore\; \lambda \propto \frac{1}{\sqrt{K.E}}$

If K.E is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

31. **(c)** $\lambda = \frac{h}{P} = \frac{h}{mv} = \frac{h}{\sqrt{2mqV}}$

or, $\lambda = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 50}} = 1.7$ Å

32. **(c)** de-Broglie wavelength of a material particle at temperature T is given by

$$\lambda = \frac{h}{\sqrt{2mkT}}, \Rightarrow \quad \lambda \propto \frac{1}{\sqrt{T}}$$

$$\therefore \; \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{T_1}{T_2}} \text{ or } \frac{\lambda_2}{\lambda_1} = \sqrt{\frac{1200}{300}} = 2$$

$$\therefore \; \lambda_2 = 2\lambda_1 = 2\lambda$$

33. **(a)** According to De-broglie $p = \frac{h}{\lambda}$ or $P \propto \frac{1}{\lambda}$

$P \propto \frac{1}{\lambda}$ represents rectangular hyperbola.

34. **(b)** As we know

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mK}} \text{ or } \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{16K}{K}} = \frac{4}{1}$$

Therefore the percentage change in de-Broglie wavelength $= \frac{1-4}{4} \times 100 = -75\%$

35. **(a)** Photoelectric effect can be explained only by quantum nature of light.

36. **(d)** 37. **(d)**

38. **(d)** Photoelectrons are emitted if the frequency of incident light is greater than the threshold frequency.

39. **(d)** $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} = 4.95 \times 10^{-19}$ J

40. **(a)** Gain in K.E. = q V = $(1.6 \times 10^{-19} \times 1)$ J = 1 eV.

41. **(d)** W = 3.3 eV; $h\nu_0 = 3.3 \times 1.6 \times 10^{-19}$ J.

$$\nu_0 = \frac{3.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 8 \times 10^{14} \text{ Hz}$$

42. **(c)** We know that work function is the energy required and energy $E = h\upsilon$

$$\therefore \frac{E_{Na}}{E_{Cu}} = \frac{h\upsilon_{Na}}{h\upsilon_{Cu}} = \frac{\lambda_{Cu}}{\lambda_{Na}}$$

$$\therefore \frac{\lambda_{Na}}{\lambda_{Cu}} = \frac{E_{Cu}}{E_{Na}} = \frac{4.5}{2.3} \approx \frac{2}{1}$$

43. **(d)** Stopping potential increases if wavelength of light falling on a photosensitive material decreases.

44. **(b)**

45. **(b)** The number of photoelectrons emitted is proportional to the intensity of incident light. Saturation current $\propto$ intensity.

46. **(b)** Here, $\frac{hc}{\lambda} = 10^3$ eV and $h\nu = 10^6$ eV

Hence, $\nu = \frac{10^3 c}{\lambda}$

47. **(c)**

48. **(a)** The energy of each photon $= \frac{200}{4 \times 10^{20}} = 5 \times 10^{-19}$ J

Wavelength $= \lambda = \frac{hc}{E} = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{5 \times 10^{-19}}$

$\Rightarrow \lambda = 4.0 \times 10^{-7} = 400$ nm

49. **(a)**

$$E_k = \frac{hc}{c}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)(\text{in eV})$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19}}\left(\frac{10^{10}}{1800} - \frac{10^{10}}{2300}\right) = 0.15\text{eV}$$

50. **(c)** $V_0 = \frac{hc}{e\lambda} - \frac{\phi_0}{e}$,

$$2.4 = \frac{hc}{6000 \times 10^{-10} e} - \frac{\phi_0}{e} \quad ....(1)$$

$$V_0 = \frac{hc}{4000 \times 10^{-10} e} - \frac{\phi_0}{e} \quad ....(2)$$

Eq. (1) – Eq.(2), and solving it, we get
$V_0 = 2.4 + 1.03 = 3.43$ V

51. **(d)** $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 3000}{9.1 \times 10^{-31}}} = 3.26 \times 10^7$ m/s.

52. **(b)** $W = \frac{hc}{\lambda_0} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{600 \times 10^{-9}}$ J $= 3.31 \times 10^{-19}$ J

53. **(b)** $E = eV = 2 \times 10^6 \times 1.6 \times 10^{-19}$ J

$\Rightarrow \lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3.2 \times 10^{-13}} \approx 10^{-2}$ Å

54. **(a)** $E(k_\alpha) = 10.2\,(Z-1)^2$ eV
$= 10.2 \times 28^2 = 7.997$ keV $= 8$ KeV

55. **(b)** Energy of photon of *X*-rays is more than energy of photon of ultraviolet rays. Because frequency of *X* rays is more than ultraviolet rays.

56. **(b)** $\lambda_{min} = 1$ Å (given) $\because \lambda_{min} = \frac{1240}{E}$ (eV) (nm)

Thus, $E = \frac{1240(\text{eV})(\text{nm})}{0.01(\text{nm})} = 12400$ eV; $E = 12.4$ KeV

57. **(b)** $E = h\nu = h\frac{c}{\lambda} \therefore \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{5000}{1}$

58. **(b)** $v_{max} = \sqrt{\frac{2eV}{m}}$

$$= \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 20 \times 10^3}{9.1 \times 10^{-31}}} = 8.4 \times 10^7 \text{ m/s}$$

59. **(a)** $V = \frac{12400}{\lambda_{min}(\text{Å})}$ Volt $\Rightarrow V = \frac{12400}{2} = 6.2$ KV

60. **(c)** $\lambda_{max.} = \frac{2d\sin\theta}{n_{min.}} = \frac{2 \times 15 \times \sin 90^o}{1} = 30$Å

61. **(a)** The maximum kinetic energy of an electron accelerated through a potential difference of V volt is $\frac{1}{2}mv^2 = eV$

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

$$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 15000}{9.1 \times 10^{-31}}} \Rightarrow v = 7.26 \times 10^7 \text{ m/s}$$

62. **(b)** $2d\sin\theta = n\lambda$ or $d = \frac{n\lambda}{2\sin\theta} = \frac{1 \times 20}{2 \times \sin 30^o} = 20$ nm

63. **(c)**

64. **(d)** Energy $= \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.5 \times 10^{-10}}$ J

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{5 \times 10^{-11} \times 1.6 \times 10^{-19}}\text{eV} = 24.82 \text{ keV}$$

65. **(b)** According to Bragg's law, $\Rightarrow 2d\sin\theta = n\lambda$,
n = 1 for first order
$\Rightarrow 2 \times 2.82 \sin 15.8 = \lambda \Rightarrow \lambda = 5.64 \times 0.2723 = 1.53$ Å

66. **(b)** $\Delta E = \frac{12400}{4.500\text{Å}} = 2.75$ eV

For photoelectric effect, $\Delta E > W_0$ (work function).

67. **(a)** $\Delta E = W_0 + E$; $(E_k) = \Delta E - W_0$

For maximum value of (E_k), W_0 should be minimum

W_0 for lithium = 2.3 eV

$\therefore (E_k) = 2.75 - 2.3 = 0.45$ eV

68. **(c)** The maximum magnitude of stopping potential will be for metal of least work function.

$\therefore$ required stopping potential is

$$V_s = \frac{hv - \phi_0}{e} = 0.45 \text{ volt.}$$

69. **(b)** Photoelectric effect is based on law of conservation of energy.

70. **(a)** Moment of photon $= p = \frac{h}{\lambda}$ $\because E = mc^2$

But, $p = mc$ $\therefore E = mc.c$ So, $E = pc$ or $E = \frac{hc}{\lambda}$

$\therefore \frac{hc}{\lambda} = pc$ or $p = \frac{h}{\lambda}$ and $\lambda = \frac{c}{f}$ $\therefore p = \frac{hf}{c}$

71. **(a)** The de-Broglie's wavelength associated with the moving electron $\lambda = \frac{h}{P}$

Now, according to problem

$$\frac{d\lambda}{\lambda} = -\frac{dp}{P}$$

$$\frac{0.5}{100} = \frac{P}{P'}$$

72. **(d)** de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(K.E)}}$$

$$\therefore \lambda \propto \frac{1}{\sqrt{K.E}}$$

If K.E is doubled, λ becomes $\frac{\lambda}{\sqrt{2}}$

73. **(b)** As we know

$$\lambda = \frac{h}{P} = \frac{h}{\sqrt{2mK}}$$

$$(\because P = \sqrt{2mKE})$$

or $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{16K}{K}} = \frac{4}{1}$

Therefore the percentage change in de-Broglie wavelength

$$= \frac{1-4}{4} \times 100 = -75\%$$

74. **(d)** $qV = \frac{1}{2}mv^2$ or $mv = \sqrt{2qVm}$;

So $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2qVm}}$ *i.e.*, $\lambda \propto \frac{1}{\sqrt{qm}}$;

so $\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{q_\alpha m_\alpha}{q_p m_p}} = \sqrt{2 \times 4} = 2\sqrt{2}$

75. **(b)**

76. **(b)** Energy of incident photon

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10}} = 3.75 \text{ eV}$$

A will not emit photoelectrons because energy of incident photon is less than work function of A.

77. **(c)** $eV_0 = h(v - v_0)$

When $V_0 = 0$, $v = v_0$, the threshold frequency.

From the graph it follows that

$v_0 = 4 \times 10^{15}$ Hz

Therefore, work function is

$\phi = hv_0 = 6.6 \times 10^{-34} \times 4 \times 10^{15} = 16.5$ eV

78. **(a)** $eV_0 = hv - hv_0$

$$V_0 = \frac{h}{e}v - \frac{h}{e}v_0$$

$Y = mn + e$

Slope $= \frac{h}{e}$

79. **(b)**

80. **(d)** Intensity $\propto$ no. of photons $\propto$ no. of photoelectrons.

81. **(d)** On increasing the intensity of incident light, the current in photoelectric cell will increase. The energy of the photon (hv) will however not increase with increase in intensity, and hence the kinetic energy of the emitted electrons will not increase. The photoelectric current does not depends on frequency of light.

82. **(b)** According to Einstein's equation, KE $= hv - hv_0$

KE depends upon the frequency. Photoelectrons are emitted only if incident frequency is more than threshold frequency.

83. **(a)** When a light of single frequency falls on the electrons of inner layer of metal, then this electron comes out of the metal surface after a large number of collisions.

84. **(a)**

85. **(a)** (A) $\rightarrow$ (2); (B) $\rightarrow$ (3); (C) $\rightarrow$ (1); (D) $\rightarrow$ (4)

86. (Frequency) For occurence of photoelectric effect, the incident light should have frequency more than a certain minimum which is called the threshold frequency (v_0).

We have, $\frac{1}{2}mv^2 = hv - hv_0$

For photoelectric effect emission $\nu > \nu_0$

where ν is the frequency of the incident light.

87. (2:1) $hc/\lambda_0 = W_0$; $\frac{(\lambda_0)_1}{(\lambda_0)_2} = \frac{(W_0)_2}{(W_0)_1} = \frac{4.5}{2.3} = 2:1.$

88. $\left(\frac{h}{\sqrt{2mk}}\right)$ de-Broglie's relation, $\lambda = \frac{h}{p}$

momentum $p = \sqrt{2mE}$

$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mK}} \quad (\because E = K)$

89. (Charge) The wavelength of the matter wave is independent of charge.

90. (1.2×10^{-3} nm) Energy of a photon is $E = \frac{hc}{\lambda}$

Where λ is the minimum wavelength of the photon required to eject the proton from nucleus.

Energy of photon must be equal to the binding energy of proton.

So, energy of a photon, $E = 1$ MeV $\Rightarrow 10^6$eV (given)

Now, $\left(E = \frac{hc}{\lambda}\right)$

So, $\lambda = \frac{hc}{E} = \left(\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{10^6 \text{eV}}\right)$

$\Rightarrow$ So, $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{10^6 \times 1.6 \times 10^{-19} \text{J}}$

$= 1.24 \times 10^{-9} \times 10^{-3} = 1.24 \times 10^{-3}$ nm

91. (False) de Broglie wavelength, $\lambda = \frac{h}{p}$

As $\lambda_{proton} = \lambda_{electron}$ (Given)

$\therefore\ p_{electron} = p_{proton}$

92. (True)

93. (False) $eV_1 = h\nu_1 - h\nu_0; eV_2 = h\nu_2 - h\nu_0$

$V_2 - V_1 = \frac{hc}{e}\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 1.03 \text{ eV}$

94. (True) $\frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{V_1}{V_2} \Rightarrow \lambda_{m_2} = \frac{6.22 \times 10^3}{10^4} = 0.622$ Å