

**T.Y.B.Sc. Sem. – VI**  
**Sample Questions**  
**Physical Chemistry Paper - I**  
**Unit – I**  
**Applied Electrochemistry**

1. Concentration polarization can be minimized by .....
  - a. Decreasing temperature
  - b. Decreasing concentration of solution
  - c. Stirring the solution
  - d. (a) and (c)
2. Overvoltage means .....
  - a. Reversible potential of the cell
  - b. Potential in excess than the reversible potential required for continuous electrolysis
  - c. Minimum external potential required for continuous electrolysis
  - d. Back emf
3. Which of the following is true?
  - a.  $E_d < E_r$
  - b.  $E_d > E_r$
  - c.  $E_d = E_r$
  - d.  $E_d \leq E_r$
4. In experimental determination of decomposition potential, Ammeter is used to...
  - a. Measure the current
  - b. Measure the overvoltage
  - c. Measure the applied potential
  - d. Apply different potential
5. In experimental determination of decomposition potential, stirrer is used to...
  - a. Form thin layer of oxide over the electrode surface
  - b. Increase the overvoltage
  - c. To raise the temperature
  - d. Minimize concentration polarization
6. In experimental determination of overvoltage, potential of working electrode is measured in...
  - a. Voltmeter
  - b. Ammeter
  - c. Potentiometer by combining it with reference electrode
  - d. Voltmeter by combining it with reference electrode

7. Tafel's equation of hydrogen overvoltage is.....
- $\eta = a - b \log(i)$
  - $\eta = a + b \log(i)$
  - $a = \eta - b \log(i)$
  - $\eta = b + a \log(i)$
8. During electrolysis of HCl solution using Lead cathode, the observed hydrogen overvoltage is 0.57 V. if the current density is increased 10 times, what will be the value of new hydrogen overvoltage?
- 0.57 V
  - 0.45 V
  - 0.69 V
  - 1.77 V
9. Hydrogen overvoltage would be least for which of the following cathode?
- Platinum
  - Bismuth
  - Platinised platinum
  - Mercury
10. Which of the following step is slow and rate determining step during evolution of H<sub>2</sub> gas at cathode?
- Diffusion of H<sup>+</sup> ions towards cathode
  - Adsorption of H-atom on cathode
  - Combination of two H-atoms to form H<sub>2</sub> molecule
  - Neutralization of H<sup>+</sup> ion by electron to form H-atom
11. Slope value in Tafel's plot of  $\eta$  verses  $\log(i)$  is.....
- 0.012 V
  - 0.12 V
  - 1.2 V
  - 0.0592
12. Overvoltage ..... with increasing the current density.
- Increases
  - Decreases
  - Remains same
  - Doubled
13. The overvoltage of hydrogen on smooth platinum is 0.34 volts. What will be the discharge potential of hydrogen from a solution of pH = 3 at this electrode?
- + 0.5176 volts
  - 0.5176 volts
  - + 0.1624 volts
  - 0.1624 volts

## Electrochemistry

- 1) Ionic strength of 0.1 mMgSO<sub>4</sub> is
  - a) 0.1
  - b) 0.4
  - c) 0.2
  - d) 0.3
- 2) KCL is used for preparing Salt Bridge because  $t_{K^+}$  is -----
  - a) 0.5
  - b) 0.6
  - c) 0.7
  - d) 0.8
- 3) Give emf equation for- Electrolyte concentration cell with transference reversible to Cation
  - a)  $E_t = 2 t_- 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
  - a)  $E_t = 2 t_+ 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - b)  $E_{cell} = 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - c)  $E_{cell} = 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
- 4) Electrolyte Concentration cells are-
  - a. Those in which concentration of two electrolyte is different
  - b. Those in which concentration of two electrolyte is same
  - c. Those in which two identical electrons are involved but at different activities
  - d. those in which two identical electrodes are involved but at same activities
- 5) A saturated solution of KCl is used for making the Salt Bridge because-----
  - a. velocity of K<sup>+</sup> and Cl<sup>-</sup> is nearly same
  - b. velocity of K<sup>+</sup> and Cl<sup>-</sup> is different
  - c. KCL is soluble in water
  - d. KCL is insoluble in water
- 6) Debye Huckel limiting law correlates-----
  - a. Activity of electrolyte with ionic strength
  - b. Mean ionic activity coefficient with ionic strength
  - c. Mean activity with ionic strength
- 7) Relationship between activity concentration and activity Coefficient is given as----
  - a)  $a = m \times \gamma$
  - b)  $\mu = \frac{1}{2} m_i Z_i^2$
  - c) None of above
  - d) Both

8) For an ideal solution activity coefficient  $\gamma =$  ==

- a)  $\gamma = 0$
- b)  $\gamma = 1$
- c)  $\gamma > 0$
- d)  $\gamma < 0$

9) In Chemical Cell EMF is due ----- taking place with in a cell

- a) Chemical reaction
- b) Thermal reaction
- c) Photochemical reaction
- d) None of the above

10) In Concentration cell EMF is due to transfer of ----- from one half cell to another.

- a) Matter
- b) Energy
- c) Particle
- d) Charge

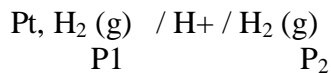
11) Concentration cells are-

- a) Those in which concentration of two electrolyte is different
- b) Those in which concentration of two electrolyte is same
- c) Those in which two identical electrons are involved but at different activities
- d) Those in which two identical electrodes are involved but at same activities

12) At infinite dilution, ie concentration = ----- or in extremely dilute solution all the electrolytes behave ideally.

- a) 0
- b) 1
- c) 2
- d) 3

13) Identify the following cell-



- a) Electrode concentration cell without transference
- b) Electrode concentration cell with transference
- c) Electrolyte concentration cell with out transference
- d) Electrolytic concentration cell with transference

- 14)  $\text{Pt, H}_2(\text{g}) / \text{H}^+ (\text{a}_1) / \text{H}^+ (\text{a}_2) / \text{H}_2(\text{g})$   $P_1$   $P_2$
- Electrode concentration cell without transference
  - Electrode concentration cell with transference .
  - Electrolytic concentration cell without transference
  - Electrolytic concentration cell with transference
- 15)  $\text{Ag-AgCl(s) / HCl (a}_1\text{) / HCl (a}_2\text{) / AgCl(s) - Ag(s)}$   $^-$   $^+$
- Electrode concentration cell without transference reversible to cation
  - Electrode concentration cell without transference reversible to anion
  - Electrolyte concentration cell with out transference reversible to Cation
  - Electrolytic concentration cell without transference reversible to anion
- 16) Give emf equation for- Electrolyte concentration cell with transference reversible to anion
- $E_t = 2 t - 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
  - $E_t = 2 t + 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - $E_{\text{cell}} = 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - $E_{\text{cell}} = 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
- 17) Give emf equation for- Electrolyte concentration cell without transference reversible to anion-----
- $E_t = 2 t - 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
  - $E_t = 2 t + 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - $E_{\text{cell}} = 0.0592 \log \left[ \frac{m_1 \gamma_1}{m_2 \gamma_2} \right]$
  - $E_{\text{cell}} = 0.0592 \log \left[ \frac{m_2 \gamma_2}{m_1 \gamma_1} \right]$
- 18) In voltaic cells, such as those diagrammed in your text, the salt bridge \_\_\_\_\_ .
- is not necessary in order for the cell to work
  - acts as a mechanism to allow mechanical mixing of the solutions
  - allows charge balance to be maintained in the cell
  - is tightly plugged with firm agar gel through which ions cannot pass
  - drives free electrons from one half-cell to the other
- 19) Calculate the EMF of the cell at 298 K ,
- $\text{Pt, I}_2(\text{s}) / \text{HI (m=0.1, } \gamma = 0.72) / \text{HI (m= 0.005, } \gamma = 0.952) / \text{I}_2(\text{s}), \text{Pt}$   $^-$   $^+$
- The transference number of iodide ions is 0.23 in the given range of concentration.
- 0.1076 V
  - 0.1075V
  - 0.1074V
  - 0.1073 V

- 20) Double line between two factor indicates the----- of type of cell
- a ) Without transference
  - b ) With transference
- 21) The standard notation for a voltaic cell, the double vertical line "||" represents:
- (a) A phase boundary
  - (b) Gas electrode
  - (c) A wire (metal) connection
  - (d) A salt bridge
  - (e) A standard hydrogen electrode

## Unit – II

### Polymers

1. Which of the following is semi synthetic polymer?
  - a. Cellulose nitrate
  - b. Bakelite
  - c. Polyvinyl alcohol
  - d. Silk
2. Which of the following is inorganic polymer?
  - a. Cellulose nitrate
  - b. Bakelite
  - c. polystyrene
  - d. Glass
3. Degree of polymerization gives .....
  - a. Number of polymer molecules
  - b. Number of repeat units
  - c. Polydispersity index
  - d. Average molecular weights
4. For natural polymers, weight average molecular weight is normally .....  
in magnitude than number average molecular weight.
  - a. Less
  - b. Greater
  - c. Equal
  - d. Double
5. What are used as adhesives and sealing agents?
  - a. Plastics
  - b. Elastomer
  - c. Fibers
  - d. Liquid resins
6. Chemically modified natural polymer is called.....
  - a. Synthetic polymer
  - b. Semisynthetic polymer
  - c. Elastomer
  - d. Liquid resin
  - e. .
7. Which of the following statement is incorrect for thermosetting polymer?
  - a. They can be formed by condensation polymerization.
  - b. They can be reclaimed from wastes.
  - c. They cannot be reshaped.
  - d. They are insoluble in organic solvent

8. High density polyethylene is an example of .....
- Linear polymer
  - Crossed linked polymer
  - Cyclic polymer
  - Branched chain polymer
9. Which of the following is a characteristic of linear polymers?
- They are regularly packed
  - They have high densities
  - They have low boiling or melting points
  - They have high tensile strengths
10. Bakelite is an example of .....
- Linear polymer
  - Crossed linked polymer
  - Cyclic polymer
  - Branched chain polymer
11. Which of the following have strong intermolecular forces like hydrogen bonding?
- Elastomers
  - Plastics
  - Fibers
  - Liquid resins
12. Which of the following is thermoplastic polymer?
- Epoxy polymers
  - Polyester resins
  - Polyethylene
  - Vulcanized rubber
13. For synthetic polymers, Polydispersity Index (PDI) is .....
- = 1
  - > 1
  - < 1
  - $\leq 1$
  - $\leq 1$
14. What is the linear form of Mark-Houwink Equation?
- $\log [\eta_i] = \log \alpha + k \log M$
  - $\log [\eta_i] = \log k + \alpha \log M$
  - $\log M = \log k + \alpha \log [\eta_i]$
  - $\log [\eta_i] = \log M + \alpha \log k$



15. Which of the following is light emitting polymer?
- Polyvinyl chloride
  - Cellulose
  - Poly (p -phenylene vinylene)
  - Polyvinyl alcohol
16. Viscosity of polymer solution ..... with increase in concentration
- Increases
  - Decreases
  - Remains same
  - Not affected
17. Reduced viscosity is .....
- $\eta_{rel} - 1$
  - $\eta_{int} / C$
  - $\eta_{sp} / C$
  - $\eta / \eta_0$
18. Absolute viscosity is determined by using.....
- Arrhenius equation
  - Gibb's equation
  - Poiseuille equation
  - Lindeman equation
19. Light emitting polymers are plastic materials that convert .....'
- Electrical power into visible light
  - Electrical power into chemical energy
  - Electrical power into microwave radiation
  - Chemical energy into electrical energy
20. Substances used to improve the physical and mechanical properties of polymer are called .....
- Decomposers
  - Colorants
  - Antioxidant and stabilizers
  - Emulsifiers
21. Primary antioxidants used in polymers acts as .....
- Cationic scavengers
  - Anionic scavengers
  - Hydroperoxides scavengers
  - Radical scavengers

22. The polymer sample has 10 and 20 molecules of polymers with molecular weights 10000 and 20000 respectively. Calculate number average molecular weight.
- 17000
  - 16666.666
  - 15000
  - 14500
23. The polymer sample has 10 g and 20 g of polymers with molecular weights 10000 and 20000 respectively. Calculate weight average molecular weight.
- 17000
  - 16666.666
  - 15000
  - 14500
24. The intrinsic viscosity of polymer in water is found to be  $1.2 \text{ dl}^{-1}$ . Mark Houwink constants are  $k = 5.8 \times 10^{-5}$  and  $\alpha = 0.72$ . Calculate viscosity average molecular weight of polymer.
- 986510.562
  - 115439.666
  - 867346.764
  - 346729.089
25. The intrinsic viscosity of polymer in water is found to be  $2.7 \text{ dl}^{-1}$ . Mark Houwink constants are  $k = 3.6 \times 10^{-5}$  and  $\alpha = 0.64$ . Calculate viscosity average molecular weight of polymer.
- 41426975.171
  - 49765840.893
  - 56432234.746
  - 78592346.666

**Unit - III**  
**Quantum Chemistry**

- 1) According to the classical theory in the black body spectrum the peak shifts towards ----- frequency with increase in temperature
- Lower
  - Higher
  - No shift
  - First higher then lower
- 2) According to Photoelectric effect ,the kinetic energy of the electrons emitted from the surface of the metal is-----
- Directly proportional to intensity of light
  - Inversely proportional to intensity of light
  - Directly proportional to frequency of the light
  - inversely proportional to frequency of the light
- 3) Dual character in matter was proposed by-----
- Einstein
  - Schrodinger
  - de Broglie
  - Hisenberg
- 4) Which of the following waves cannot be radiated through vacuum?
- longitudinal waves
  - Electromagnetic waves
  - Transverse waves
  - Matter waves
- 5) According to Max Born m the probability of finding the particle between  $x$  and  $(x+ dx)$  ie within infinitesimal distance element  $dx$  is-----
- Directly proportional to  $[\psi] dx$
  - Directly proportional to  $[\psi]^2 dx$
  - Inversely proportional to  $[\psi] dx$
  - Inversely proportional to  $[\psi]^2 dx$
- 6) For the quantum number  $n=4$  the number of nodes are-----
- 1
  - 2
  - 3
  - 4
  - 9)
- 7) If  $f(x) = 5 \sin 5x$  and  $A = \frac{d^2}{dx^2}$  then eigen value of the function is-----
- 125
  - 100
  - 75
  - 25

8) The total energy operator of wave function  $\psi$  is called-----

- a) Laplacian operator
- b) Linear operator
- c) Hermitian operator
- d) Hamiltonian operator

9) The wave function has----- value

- a) Positive
- b) Negative
- c) Zero
- d) Either positive or negative

10) Give the expression for de Broglie wave equation -----

- a)  $\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} = - \frac{8\pi^2 m}{h^2} (E - U)\psi$
- b)  $\Delta x \cdot \Delta p \geq h/4\pi$
- c)  $\lambda = h / m v$
- d)  $E = hc / \lambda$

11) Photoelectric effect is discovered by-----

- a) Einstein
- b) Maxwell
- c) Rutherford
- d) Max planck

12) Dual particle experiment is done by scientists-----

- a) Einstein
- b) Maxwell
- c) Davisson and Germer
- d) Rutherford

13) Scattering of X-rays is the wavelength of the scattered radiation was found to be greater than wavelength of scattered light is -----

- a) Photoelectric effect
- b) Compton effect
- c) Black body radiation
- d) None of the above

14) The energy of an emitted electron depends on-----

- a) The intensity of the radiation
- b) The frequency of the radiation
- c) The nature of the metal surface
- d) None of above

15) The black body radiation problem-----

- a) Assuming dual nature of radiation
- b) Assuming dual nature of matter
- c) Assuming quantization of energy
- d) None of the above

16) De Broglie relationship can't be applied to everyday objects because-----

- a) It can be applied only to sub atomic particles
- b) The momentum of the ball is too large compared to the magnitude of the Planck's constant
- c) The normal objects do not have an associated wave
- d) All the above

17) Heisenberg's uncertainty principle is applied to----- 2

- a) Any two variables of the system
- b) Dynamic variables of the system
- c) Conjugate variables of the system
- d) None of the above

18) The wave function defined for a system has to be-----

- a) single-valued
- b) Finite
- c) All the above
- d) None of the above

19) The eigen function of an operator is-----

- a) Any function on which the operator works
- b) A function that is real
- c) Any function that fulfills the eigen value equation

20) Eigen value represents-----

- a) Number
- b) Value of the dynamic variable of the system
- c) Both above
- d) None of the above

21) Standing waves are-----

- a) Transverse waves
- b) Stationary waves
- c) Longitudinal Waves

22) The black body radiation problem was solved by ----- using the concept of quantization of energy

- a) Dalton
- b) Maxwell
- c) Rutherford
- d) Max plank

23)  $\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} + \frac{8\pi^2 m}{h^2} (E - V)\psi = 0$  in this the term  $\psi$  is -----

- a) Wave function of the particle
- b) Mass
- c) Potenetial energy
- d) Total energy

24) Photoelectric effect was explained by-----

- a) Einstein
- b) Maxwell
- c) Rutherford
- d) Max plank

25) de Broglie equation was verified by the diffraction patterns produced by----- with a metal surface

- a) Electron beam
- b) Gamma rays
- c) Alpha particles
- d) Positrons

26) The wave that does not propagate beat time is called as-----

- a) Standing
- b) Longitudinal
- c) Transverse
- d) Propagating

What are the eigen values of the following function of  $\frac{d^2}{dx^2}$ -----

27)  $3x^2 =$  -----

- a) 6
- b) 7
- c) 8
- d) 9

28)  $5e^{5x} =$  -----

- a) 25
- b) 7
- c) 8
- d) 9

29)  $\sin 3x =$  -----

- a) -9
- b) -10
- c) 8
- d) 9

30) Which of the following statement is incorrect -----

- a)  $\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} = - \frac{8\pi^2 m}{h^2} (E - U)\psi$
- b)  $\Delta x \cdot \Delta p \geq h/2\pi$
- c)  $\lambda = h / m v$
- d)  $E = hc / \lambda$

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## Renewable Energy Resources

1. Principle of solar cell is .....
  - a. Conversion of light into electricity
  - b. Conversion of electricity into chemical energy
  - c. Conversion of light into chemical energy
  - d. Conversion of chemical energy into electricity
2. Which of the following impurity in small amount can be added in pure semiconductor to get p-type semiconductor?
  - a. Antimony
  - b. Aluminum
  - c. Arsenic
  - d. Silicon
3. The energy gap between valence band and conduction band is zero for ...
  - a. Conductors
  - b. Semiconductors
  - c. Insulators
  - d. Plastics
4. The energy gap between valence band and conduction band is very large for ...
  - a. Conductors
  - b. Semiconductors
  - c. Insulators
  - d. Copper
5. Hydrogen is produced by .....
  - a. Direct electrolysis of water
  - b. Boiling the water and condensation of water vapours
  - c. Sublimation of water
  - d. Fusion of ice



**Unit IV**  
**NMR and ESR Spectroscopy**

1. If the nucleus contains even number of protons and even number of neutrons then the total spin of the nucleus is
  - a. Zero
  - b. Integral
  - c. Half integral
  - d. Always one
2. If the total spin of the nucleus is half integral then nucleus contains ,,,,,,
  - a. Even number of protons and even number of neutrons
  - b. Even number of protons and odd number of neutrons
  - c. Odd number of protons and odd number of neutrons
  - d. All the above types
3. Tritium has .....spin
  - a. Zero
  - b. Integral
  - c. Half integral
  - d. Half
4.  ${}_{15}\text{P}^{30}$  has ..... spin
  - a. Zero
  - b. Integral
  - c. Half integral
  - d. Always one
5. Which of the following is NMR active?
  - a.  ${}_{20}\text{Ca}^{40}$
  - b.  ${}_{8}\text{O}^{16}$
  - c.  ${}_{2}\text{He}^4$
  - d.  ${}_{1}\text{H}^2$
6. For NMR inactive nucleus the total nuclear spin is .....
  - a. Zero
  - b. Integral
  - c. Half integral
  - d. One
7. An NMR spectrum is obtained due to absorption of ..... radiations by the nucleus
  - a. Microwave
  - b. Radiofrequency
  - c. IR
  - d. UV

8. For the given value of spin quantum number ( $I$ ), number of possible orientations can be calculated by ..... formula
- $(I + 1)$
  - $(2I + 1)$
  - $(2I - i)$
  - $(I - i)$
9. For the nucleus with  $I = \frac{1}{2}$ , the possible orientations are .....
- 0
  - 2
  - 3
  - 4
10. The phenomenon by which the nuclei in higher energy state transfer its energy to the environment and return to its lower energy state is called....
- Radiation process
  - Relaxation process
  - Transition process
  - Spin process
11. When radiation energy is absorbed by a spin  $\frac{1}{2}$  nucleus in a magnetic field, what happens?
- The precessional frequency of the nucleus increases
  - The nucleus spins faster
  - The nuclei come down to the lower energy state
  - The angle of precession flips so that the magnetic moment of the nucleus opposes the applied fields
12. Which of the following is not a part of NMR spectrometer?
- Sweep Generator
  - Radiofrequency Oscillator
  - Wave meter
  - A strong magnet
13. Which of the following is used as an internal standard in NMR spectroscopy?
- $\text{CDCl}_3$
  - $\text{CCl}_4$
  - Tetramethylsilane
  - $\text{CS}_2$
14. Which of the following solvent is not used in NMR spectroscopy?
- $\text{CDCl}_3$
  - $\text{CCl}_4$
  - Water
  - $\text{CS}_2$

15. In NMR spectra, gyromagnetic ratio ( $\gamma$ ) =
- $H_0/2\pi\nu$
  - $2\pi\nu/H_0$
  - $2\pi\nu H_0$
  - $\pi\nu/H_0$
16. The basic unit of nuclear moment of nucleus is known as.....
- Tesla
  - Bohr magneton
  - Nuclear magneton
  - Tau
17. The process of transfer of nuclei from lower to higher energy state by absorption of radiation is called .....
- Relaxation process
  - Fluorescence
  - Flipping
  - Excitation
18. For a free electron, the value of 'g' is .....
- 1.9002
  - 2.2145
  - 2.0023
  - 2.1457
19. Which of the following is not application of ESR spectroscopy?
- Study of rates and mechanism of reactions
  - Structure elucidation of organic and inorganic molecules
  - Assay of drugs
  - Study of biological systems using spin labeling technique
20. EPR Spectroscopy can be carried out by.....
- By varying the magnetic field and keeping the frequency constant
  - By varying the magnetic field and keeping the current constant
  - By varying the current and keeping the magnetic field constant
  - By varying the frequency and keeping the current constant
21. The selection rules in ESR are .....
- $\Delta m_I = 0$  and  $\Delta m_S = +$  or  $-1$
  - $\Delta m_I = +$  or  $-1$  and  $\Delta m_S = 0$
  - $\Delta m_I = 0$  and  $\Delta m_S = 0$
  - $\Delta m_I = +$  or  $-1$  and  $\Delta m_S = +$  or  $-1$

22. Hydrogen atom contains .....
- a. One proton, one neutron and one electron
  - b. One proton, two neutrons and one electron
  - c. One proton, zero neutron and one electron
  - d. One proton, two neutrons and two electron
23. ESR spectroscopy is a technique used for studying .....
- a. Chemical species that have one or more unpaired electrons
  - b. All organic molecules
  - c. All inorganic chemical species
  - d. Assay of drugs
24. The number of hyperfine signals for hydrogen is.....
- a. One
  - b. Two
  - c. Three
  - d. Zero
25. Bohr magneton equals to .....
- a.  $e^2h/4\pi m_e$
  - b.  $eh/2\pi m_e$
  - c.  $e^2h/2\pi m_e$
  - d.  $eh/4\pi m_e$