



Indian Association for the Cultivation of Science
(Deemed to be University under *de novo* Category)
Integrated Bachelor's-Master's Program
End-Semester Examination (Spring Semester- 2019)

Comprehensive Examination for Lab Courses (Biology, Chemistry and Physics)
Full Marks: 60 Time Allotted: 3 h

Section-A (Biology)

[There are TEN questions in this section. Answer ALL the questions. Each question carries 2 marks]

[1] The absorbance of pyrene changes in presence of 5 mM and 20 mM concentrations of SDS. Explain the reason.

[2] (a) Which media is generally used for the solid plate culture of bacteria?

(b) Which method is generally used to sterilize the media and other requirements for culture?

[3] (a) what is the optimum condition for an incubator, to be set up with, for culturing the mammalian cells?

(b) The cell culture media, DMEM, is generally red in color. Which dye is responsible for this color of the media?

[4] During the determination of diffusion co-efficient of a dye, which physical law is used to calculate the same? Explain the law with its relation to the diffusion coefficient of a material.

[5] What is the role of trypsin in dislodging the plated cells during cell culture?

[6] During the determination of an unknown concentration of a protein by Bradford assay, SDS has been used at above CMC concentration. What will be the effect on the determination of protein concentration?

[7] What are the instruments normally used for counting the number of cells?

[8] The absorbance of a protein changes in presence of urea. Explain the reason.

[9] Why trypan blue is generally added in the cell suspensions while counting the number of cells?

[10] What is the role of UV light exposure during sterilization?

$$J = -D \frac{dx}{dt}$$

Section-B (Chemistry)

[There are SIXTEEN questions in this section, answer ALL]

Write down the correct answer from the options given for the questions 1-10 each carrying one mark.

1. (i) Which of the following is correct about a phase transfer catalyst?

- a. It is part of the product.
- b. It makes a two-layer system into a one-layer system.
- c. It gets used up completely in the reaction.
- d. It removes the product of the reaction as it is formed.
- e. It transports the reactant between phases.

2. In the determination of a melting point, indicate which of the following statements is false?

- a. An impurity usually raises the melting point of an organic compound.
- b. A eutectic mixture has a sharp melting point.
- c. An impurity usually lowers the melting point of an organic compound.
- d. It is important that the height of the sample in the capillary be only 1-2 mm, and that it be packed firmly.
- e. The lower end of the melting point range is the temperature at which the first drop of liquid is seen.

3. An aqueous solution of this reagent will extract p-nitroaniline from a dichloromethane solution of p-nitroaniline, benzoic acid and naphthalene:

- a. hydrochloric acid
- b. sodium chloride
- c. sodium hydroxide
- d. both b and c will work
- e. all a, b and c will work

4. Which of the following statements regarding recrystallization is true?

- a. As the amount of impurity increases, the loss of pure product decreases.

- b. Two substances with nearly equal solubility behavior, present in equal amounts, may be easily separated.
- c. It is undesirable to have a high concentration of solute near the boiling point of the solvent.
- d. To achieve a high recovery of pure crystals, the solute should be dissolved in a minimum amount of solvent when the solvent is near its boiling point.
- e. A good recrystallization solvent should dissolve a large amount of the impure compound at all temperatures.

5. The advantage of steam distillation is that it allows the distillation of:

- a. water soluble compounds that possess a high boiling point
- b. water insoluble compounds that possess a high boiling point
- c. water insoluble compounds that possess a low boiling point
- d. water soluble compounds that possess a low boiling point
- e. ionic compounds

6. In thin layer chromatography, the observed R_f will change upon changing any of the following parameters, except:

- a. the solvent
- b. the functionality of the compound
- c. the absorbent
- d. the level of saturation of the developing chamber with solvent vapors
- e. the distance traveled by the solvent front

7. Which of the following is not a desirable characteristic of a solvent to be used in an extraction?

- a. The solvent should be immiscible with the solvent of the solution.
- b. The solvent should have the most favorable distribution coefficient for the component which is to be separated and the most unfavorable coefficients for the impurities or other components.
- c. The solvent should not react chemically with the components of the mixture.
- d. The solvent should be readily separable from the solute.
- e. The solvent should be non-volatile.

8. Which of the following statements is false for recrystallization as a method for purification of organic compounds?

- a. Low solubility of the compound at low temperatures minimizes the amount of the purified compound that will be lost during recrystallization.

- b. If the impurities are soluble, they may be removed by filtration at high temperatures.
- c. Scratching the side of the beaker with a stirring rod may induce crystallization.
- d. Recrystallization is often used to purify solids.
- e. A good recrystallization solvent should be reasonably volatile.

9. A student was given 2.00 g of a very impure solid. After recrystallization and drying the student obtained 2.00 g of recovered material. Which of the following statements is true?

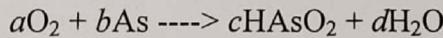
- a. The recrystallization yield of pure compound was 100%.
- b. The melting point range should be broader and the upper limit higher.
- c. The melting point range should be narrower and the upper limit lower.
- d. Since all of the material was recovered, no purification occurred.
- e. The melting point range was broader and the upper limit lower.

10. The elution power of a solvent is determined by

- a) Its overall polarity
- b) The polarity of the stationary phase
- c) The nature of the sample components
- d) All of the mentioned

11. Permanganometric titrations are performed in acidic pH using sulfuric acid? Why concentrated HCl is not used? [2]

12. What would be the values for a , b , c and d in the following reactions? [2]

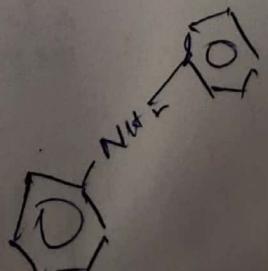


13. During the estimation of iron in a sample by redox titration, a student does not observe the expected silky white solution after addition of SnCl_2 followed by addition of HgCl_2 . The student rather observes a gray precipitate. Do you think that the student would be able to estimate correctly the total iron content in the sample? Explain your answer. [2]

14. Though sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, can be obtained chemically pure, why it is not used as a primary standard in iodometric titrations? [1].

15. Why a small amount of NH_4SCN is added near the end point of titration in the estimation of copper by thiosulfate? [1.5]

16. Why sodium diphenylamine sulfonate is used as the redox indicator in chromatometric titration? What is the problem if diphenylamine is used? [1.5]

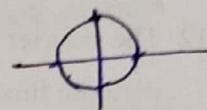
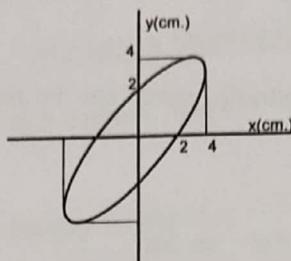


Section-C (Physics)

[There are TWELVE questions in this section. Answer any TEN. Each question carries 2 marks]

1. The Lissajous pattern shown in figure.1 is observed on the CRT screen. Find the phase shift between the signals applied to the X and Y inputs of the scope. Find the condition for circular Lissajous figure.

→ Hand 1 A.P.



2. Draw a series and a parallel LC circuit. Plot qualitatively the impedance as function of frequency for ($L \sim 20 \text{ mH}$, $C \sim 0.01 \text{ micro Farad}$). Here, which one is band stop and band pass filter?

$$Z = \sqrt{4\pi L - \frac{1}{\omega C}}$$

3. Draw schematic of a series LCR circuit with an applied ac voltage $V(t) = V_0 \sin(\omega t)$ and write down the differential equation for current with respect to time.

$$\frac{di}{dt} - \frac{1}{L} i = \frac{V_0}{R} \sin(\omega t)$$

4. Write down the Newton's law for a forced damped harmonic oscillator and map the electrical quantities appearing in a series LCR circuit with corresponding mechanical quantities.

5. What do you mean by interference of light? What are interference fringes? Is there any loss of energy in interference phenomenon?

6. Why the interference fringes are circular in the Newton's ring experiment? What are the factors which govern the radius of a ring?

7. A ray of white light is incident upon a glass prism and dispersed into its various colour components. However, for glass slab we don't see similar dispersion. Explain, why?

8. A ray of light passing through a glass prism of refracting angle 60° , undergoes a minimum deviation of 30° . Calculate the velocity of light in glass if the velocity of light in air is $3 \times 10^{10} \text{ cm s}^{-1}$.

$$\mu = \frac{\sin \left(\frac{A + S_m}{2} \right)}{\sin \left(\frac{A}{2} \right)} = \frac{c/v}{c/V} = \frac{3 \times 10^8}{V}$$

$A = 60^\circ$
 $S_m = 30^\circ$

What is Parallax error? How it is eliminated?

10. What is dispersive power of prism? A ray of white light, incident upon a glass prism, is dispersed into its various color components. Which one of the following colors experiences the greatest amount of refraction?

- (a) orange (b) violet (c) red (d) green

11. Explain Thevenin's and Norton's theorem. Are they also valid if the capacitive elements are used instead resistors?

12. The Fourier expression for a "sawtooth wave" can be represented by the following periodic function,

$$f(t) = 2 \left(\frac{\sin \pi t}{1} - \frac{\sin 2\pi t}{2} + \frac{\sin 3\pi t}{3} - \frac{\sin 4\pi t}{4} + \frac{\sin 5\pi t}{5} - \dots \right)$$

(a) What is the frequency of the sawtooth wave described by the expression above?

(b) Sketch the Fourier spectrum for this wave, including frequencies up to 5th harmonics.

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Indian Association for the Cultivation of Science

(Deemed to be University under the *de novo* Category)

Integrated Bachelor's-Master's Program

End-Semester Examination-2018 (Semester- I)

Comprehensive Examination for Lab Courses (Biology, Chemistry and Physics)

Full Marks: 60

Time Allotted: 2 h

Section-A (Biology)

[There are ELEVEN questions in this section, answer ALL]

- ✓ 1. (i) Arrange the following solvents in order of their increasing polarity: (a) chloroform; (b) methanol; and (c) hexane. [2]
(ii) Carotenoids are more soluble in which of following solvent as you have observed during the extraction procedure of carotenoids from carrot? (a) hexane; (b) ethanol and (c) water. [2]
- ✓ 2. You are provided with an unknown concentration of human serum albumin (HSA) in PBS buffer (pH 7.4) and pure sample of HSA. Explain the process for the determination of the concentration of HSA in the supplied sample. [2]
- ✓ 3. You are provided with a mixture having compounds of different polarity. The mixture contains β -carotene and chlorophyll-a. By which method one can separate and purify both of these compounds? Assign the position (as per Rf values) of these compounds in a single thin layer chromatography (TLC) plate using 30% acetone - 70% hexane as the eluting media. [1+1]
- ✓ 4. What is absorbance maximum in case of β -carotene and DCIP? [$\frac{1}{2} + \frac{1}{2}$]
- ✓ 5. Explain the change in color of DCIP during the Hill reaction with their chemical structures. [2]
- ✓ 6. Name the photosynthetic stage which is related with Hill reaction [1]
- ✓ 7. Name is the light source used in the spectrometer? [1]
- ✓ 8. What apparatus is used to select a particular wavelength in the spectrometer? [1]
- ✓ 9. What is the name of the detector used in the spectrometer? [1]
- ✓ 10. What is the use of a lux meter? Mention the useable wavelength range of the lux meter that you used. [1+1]

11. What is absorbance? In absorbance vs concentration plot that you made, why is it important that your plot should be linear? [1+2]

Section-B (Chemistry)

[There are NINE questions in this section, answer ALL]

1. (a) Which one of the following is not a volumetric glassware?
Graduated pipet, graduated cylinder, burette, volumetric flask.
(b) Give an example of a TD type volumetric glassware.
(c) "A" is a pure and very stable compound. It is readily available and inexpensive for use. It is used when preparing standard solutions. What is "A"?
(d) A farmer grows blue hydrangea flower in his garden. Some of his customers ask him to supply pink hydrangea. If that farmer consults you for advice, what would be your suggestions to him? [2]

2. A sample of impure potassium hydrogen phthalate (MW = 204.22 g/mol) weighing 2.1283 g required 42.58 mL of a 0.1084 M NaOH solution for titration to the phenolphthalein end point. Calculate the % purity of the sample. [2.5]

3. As you have observed, the viscosity of aqueous solutions of glycerol increase/decrease with glycerol concentration, and the reason is

[1+2]

4. The unit of surface tension is _____ and it can be defined as

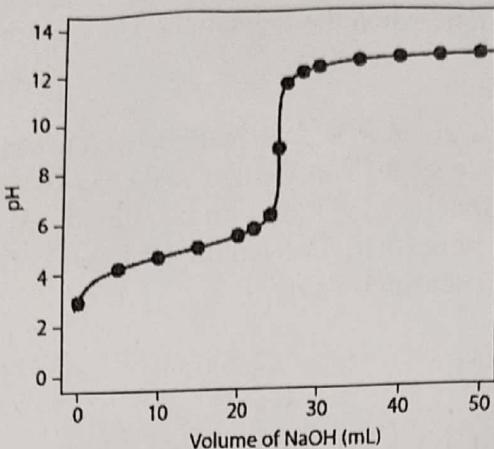
[1+1]

5. A 0.2178 g sample of impure Mg(OH)₂ (58.3197 g/mol) was dissolved in 50.00 mL of 0.1204 M HCl (1st standard reagent). Back-titration of the excess acid required 3.76 mL of 0.0948 M NaOH (2nd reagent). Calculate the % purity of the Mg(OH)₂. [3]

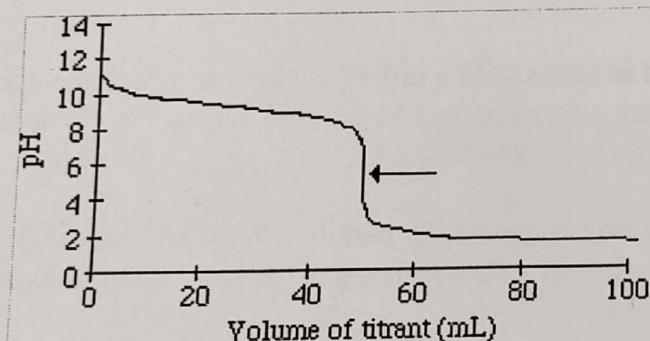
6. 1.00 mole of acetic acid and 0.50 mole of sodium acetate are added to water and the resulting solution diluted to 1 L with water at 25°C. Calculate the pH of the final solution. (K_a of acetic acid is 1.8×10^{-5} at 25°C). [2.5]

7. (a) Although the mathematical relationship of activity and temperature may be complicated, the actual change of pK_a with temperature is approximately linear. Based on this information, do you think that temperature will have effect on pH of a solution. [1]
(b) Given the dissociation constant of methanol at 25°C is 1.45×10^{-17} , compared to 1.0×10^{-14} for water, should a small amount of methanol added to the aqueous medium have any affect the pH of a buffer solution or small traces of water in methanol can change the pH of the organic solvent? [1.5]
- 2/1/2024

8. From the acid-base titration curve given below, comment on the nature of acid titrated against NaOH. How the titration curve would look like if a very weak acid were titrated against NaOH? [2]



9. The relationship between pH and an indicator's color defines pH values where HIn and In^- are the predominate species. The indicator changes color when the pH is between $\text{pKa} - 1$ and $\text{pKa} + 1$. From the titration curve for 50.0 mL of 0.100 M NH_3 with 0.100 M HCl and the information given, comment on the choice of indicator in the titration. [1.5]



Indicator	pKa
Methyl Yellow	3.3
Methyl Orange	4.2
Bromothymol Blue	7.1
Phenolphthalein	9.1

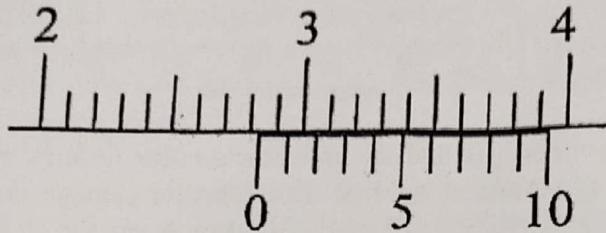
Section-C (Physics)

[There are TWELVE questions in this section/ Answer any TEN. Your answers should be brief and to the point. Each question carries 2 marks]

- What is moment of inertia (I)? What is the value of I for a solid sphere about the diameter? You are given two solid spheres of equal mass; one sphere is made of wood and the other with iron. Which one of them will have larger value of I ?
- Explain validity of law of conservation of energy with respect to flywheel experiment. Is it possible to store energy in the flywheel and its possible use?
- Is the value of g (acceleration due to gravity) is independent of mass of the falling body? Hope you have noticed that a brick falls faster than a feather from your rooftop. If the value of g is mass independent, why brick falls faster? How does g vary at points above and below the earth's surface?

✓ 4. What would be the value of Young's modulus (Y) and depression (s) if we reduce the distance between two knife edges by half keeping other parameters constant? What is the work done when the rectangular bar material is depressed by an amount s ?

✓ 5. Suppose you are given a Vernier caliper which has 1 cm divided into 10 equal divisions on the main scale. The Vernier scale has 10 equal divisions that correspond to 11 main scale divisions. (i) Can you use this Vernier for your measurement? If yes, find the least count. (ii) The readings of the Vernier caliper are shown in the figure. What is the measured value?



✓ 6. What is the angle of refraction in a medium if the angle of incidence in air is 48° and the refractive index of the medium is 1.48? In which medium light will travel faster, (i) glass, (ii) water?

✓ 7. Why ammeters are connected in series with a circuit element in which the current is to be measured and voltmeters are connected in parallel across the element for which the potential difference is to be measured?

✓ 8. Why Light bulbs at your home are connected in parallel? What will happen if they are connected in series? Why sensitivity of a voltmeter is too low, when it is used to measure voltage across a low resistance?

✓ 9. How thermo emf is generated when we make junction of two dissimilar metals and keep the junctions at different temperatures? What is the direction of current in case of Copper- Constantan thermocouple?

✓ 10. What is Peltier effect? Explain the difference between Joule heating and Peltier effect?

✓ 11. What types of thermometers do you know? How they measure temperature? Can you use thermocouple to measure temperature? What are the advantages and disadvantages of using thermocouple over mercury thermometer?

✓ 12. Why work is done when electric current passes through a conductor? What are the factors that determine the amount of work done?

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2.8
0.7
4
0.7
2.8

$\frac{4}{10}$

1.1



$10 \text{ VSD} \rightarrow 10 \text{ VSD}$

$0.001 \text{ A} = 10^{-3} \text{ A}$
 $\frac{1}{10} = 0.1$
 $\frac{0.1}{10} = 0.01$

$\frac{0.1}{10} = 0.01$



Indian Association for the Cultivation of Science
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Integrated Bachelor's-Master's Program in Science

End-Semester Examination-2019 (Spring Semester)

Paper: Electricity, Magnetism & Optics
Full Marks: 100

Paper Code: PHS1201
Time Allotted: 3hr

Part-A

Attempt any three questions

1. (a) Find electric field and potential at a distance r from a uniformly charged disc on a axis perpendicular to the plane of the disc. (7 marks)
(b) For a force whose components are, $F_x = x - 2y$, $F_y = 2x - y$ and $F_z = 2z$, is the work done independent of the path? (3 marks)
2. (a) Consider a uniformly charged rod along z -axis extending from $(0, 0, -L/2)$ to $(0, 0, L/2)$. Find the associated electric field on the $z = 0$ plane at a point $(x, y, 0)$. (5 marks)
(b) Find the electric field associated with the above charge configuration as $L \rightarrow \infty$. Can you test the validity of your result using Gauss divergence theorem. (5 marks)
3. (a) A circular loop is carrying an electric current of magnitude i . Find the magnetic field at the centre of the loop. (5 marks)
(b) As the size of the above current carrying loop goes to zero, show that the magnetic field becomes that of a magnetic dipole. Find the associated dipole moment. (5 marks)
4. (a) Prove the uniqueness theorem associated with electrostatic field. (5 marks)
(b) Find the surface charge density of a infinite charged plane, if it is known that two equipotential surfaces separated by 1 m has a potential difference of 5 V. (5 marks)

Part-B

Attempt any seven questions

1. (a) State the Fermat's principle. Using this principle derive the laws of refraction from a plane surface separating two medium of refractive index n_1 and n_2 . (5 marks)
(b) Using Fermat's principle or otherwise, derive the laws of reflection from a curved mirror with radius of curvature R . (5 marks)

- 2^n \times h + 1 - 2^y*
- (a) If a ray of light passing through air gets refracted into a medium of refractive index n through a curved surface of radius of curvature R , the object distance x and the image distance y are related by the relation $(1/x) + (n/y) = (n - 1)/R$. Given this find out the focal length of a lens in terms of the radii of curvature of the two surfaces. Hence derive the Lens formula. (5 marks)

Marks

- (b) An equi-convex lens has focal length of 20 cm. Find out the radius of curvature of its surfaces. If an object is placed at a distance of 40 cm from the lens, where the image will form? Subsequently, if one places the object at a distance of 10 cm from the lens, what will be the location of the image? (5 marks)

- (a) Suppose there are two slits at a distance d apart and both are being illuminated by monochromatic light from a distant point source. As a result interference pattern is observed on a screen which is D distance away from the slits. Show that the locus of the bright as well as dark fringes are hyperbolas with the two sources at the foci. (5 marks)

- (b) If one introduces a thin slab of refractive index n in the path of one of the light ray forming interference pattern, the central bright fringe moves to the location of m th bright fringe. Find out the thickness of the slab. (5 marks)

- (a) If a ray falls on a glass slab of thickness d and refractive index n with reflection coefficient r and transmission coefficient $t = 1 - r^2$, show that the total normalized intensity of the reflected ray is,

$$I_r = \frac{g^2 \sin^2 \left(\frac{\Delta}{2} \right)}{1 + g^2 \sin^2 \left(\frac{\Delta}{2} \right)}$$

where, $\Delta = (4\pi/\lambda)nd \cos \phi$ with ϕ being the angle of refraction. Find out the normalized intensity of the transmitted ray and hence demonstrate that the intensity of the reflected ray is maximum for $2nd \cos \phi = (2m \pm 1)(\lambda/2)$. (5 marks)

- (b) Find out the fringe width between two consecutive Newton's rings. (5 marks)

- (a) When a narrow monochromatic source of light ($\lambda = 589.3$ nm) is placed at a distance of 50 cm from the bi-prism (refractive index=1.5), width of the fringes obtained on a screen placed 1m from the bi-prism is found to be 0.12 mm. Find the obtuse angle of the bi-prism. (5 marks)

- (b) In a Newton's ring experiment, the rings are formed using a source of light which has two wavelengths λ_1 and λ_2 . If m th order dark ring due to λ_1 coincides with the $(m + 1)$ th order dark ring due to λ_2 , prove that the radius of m th dark ring of λ_1 is equal to $\sqrt{\lambda_1 \lambda_2 R / (\lambda_1 - \lambda_2)}$. Here R is the radius of curvature of the lower surface. (5 marks)

- (a) A thin transparent plate of refractive index 1.5 is introduced in one arm of Michelson interferometer. It causes 10 fringe shift. Find the thickness of the plate. Assume the wavelength of light to be 600 nm. (5 marks)

- (b) Find the least number of lines that a diffraction grating must have in order to resolve in the first order, the red doublet originating from the mixture of hydrogen and deuterium. The wavelength difference is 0.18 nm and the mean wavelength is 656.3 nm. (5 marks)

- (a) Suppose a parallel beam of light falls on two slits, each of width a and separation between them being b . Hence show that the relative intensity of the pattern seen on a screen placed a large distance away is $(\sin^2 \alpha / \alpha^2) \cos^2 \beta$. Determine α and β in terms of a and b . (5 marks)

- (b) The intensity of light coming out of diffraction grating corresponds to, $(\sin^2 \alpha / \alpha^2) (\sin^2 N\beta / \sin^2 \beta)$. Given this find out the conditions on β leading to principal maxima as well as secondary maxima and minima. (5 marks)

- (a) Derive an expression for the resolving power and angular dispersive power of a diffraction grating, given the condition of principal maximum being, $(a + b) \sin \theta = m\lambda$, while the condition for secondary

minima is $N(a + b) \sin \theta = p\lambda$. Here a is the width of the slit and b is the separation between the two slits. (5 marks)

(b) A diffraction grating, which is 2 cm wide is just able to resolve the Sodium lines at 589 nm and 589.6 nm as they are incident normally to the diffraction grating at second order. Hence find the number of rulings per mm. (5 marks)

9. (a) Consider two electric fields, one along the x-direction and another along the y-direction with identical magnitude. Show that if these two fields differ in phase by $\pm n\pi$, then we have plane polarized light, while if these two fields differ by a phase $\mp(\pi/2) \pm 2n\pi$ then we have circular polarized light. (5 marks)

(b) Suppose you have placed two polarizers at 90° between their pass axis. Another polarizer is placed between them, which is rotated at a constant angular velocity ω about their common central axis. If un-polarized light of intensity I_0 is incident on the first polarizer, then show that the intensity of transmitted light is $(I_0/16)(1 - \cos 4\omega t)$. (5 marks)

10. (a) Discuss the three processes by which energy can enter or exit from a two level system. Which one of these three processes is important for Laser? In normal circumstances do we expect a system to exhibit Laser-like emission? Explain. (5 marks)

(b) Define the A and B coefficients of Einstein. Using the Planck's distribution function find out the relationship between these coefficients. (5 marks)



Indian Association for the Cultivation of Science
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Integrated Bachelor's and Master's Program
End-Semester Examination (Spring Semester-2019)

Subject: Mathematics & Computer
Full Marks: 100

Subject Code(s): MCS 1201
Time Allotted: 3 h

Group - A
Answer any three questions.

1. (i) (a) With proper justification, give an example of an infinite group whose every element is of finite order. [2]
- (b) Define quotient group of a group. Let G be a group and H be a normal subgroup of G such that G/H be a commutative group. Is G necessarily commutative? Justify your answer. [2+1]
- (ii) Let G be a group and $Z(G)$ be the centre of G .
(a) If $G/Z(G)$ is cyclic then show that G is a commutative group. [3]
(b) If G is a finite noncommutative group then show that $|Z(G)| \leq \frac{1}{4}|G|$. [2]
2. (i) Let G be a commutative group of order $2n$, where n is an odd positive integer. Show that G has unique element of order 2. Is the condition of commutativity of G essential? Justify your answer. [3+2]
- (ii) (a) If H is the only subgroup of order n in a group G then show that H is a normal subgroup of G . [2]
(b) Let H and K be two normal subgroups of a group G . If $H \cap K = \{e_G\}$ then show that $ab = ba$ for all $a \in H$ and $b \in K$. [3]
3. (i) State and prove Lagrange's Theorem for group. [1+4]
- (ii) (a) If $A = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}$ then find rank of the matrix $A + A^2 + A^3$. [3]
(b) Give example of two matrices with same eigen values but they are not similar to each other. [2]
4. (i) (a) If for given A and B , the matrix equation $AX = B$ has more than one solution then show that it has infinitely many solutions. [2]
(b) If the system of equations $ax + by + cz = 0$, $bx + cy + az = 0$, $cx + ay + bz = 0$ have a nonzero solution then show that either $a + b + c = 0$ or $a = b = c$. [3]
- (ii) (a) Let A be a 2×2 real matrix with trace 5 and determinant value 6. Find the eigen values of the matrix $B = A^2 - 2A + I_2$. [2]
(b) When is a matrix said to be diagonalizable? Let A be a diagonalizable matrix. Show that the rank of A is equal to the number of nonzero eigen values of A . [1+2]

$\tan \frac{\pi}{2} = \infty$

Group - B
Answer any three questions.

1. Evaluate:

(a). $\int \frac{dx}{x^4(x^2-1)^{\frac{1}{2}}}$ (b). $\int \frac{dx}{(x-2)^3(x-1)^2}$ (c). $\int \frac{dx}{\sin x(a+b\cos x)}$ [3+4+3]

2. (a) Evaluate: $\int_0^1 \frac{\log(x+1)}{(1+x^2)} dx$ [4]

(b) Evaluate

$$\int_a^b \cos x dx$$
 [3]

from the definition of a definite integral as limit of a sum.

(c) Find the value of:

$$\lim_{n \rightarrow \infty} \left[\frac{\sqrt{n+1}}{n^{\frac{3}{2}}} + \frac{\sqrt{n+2}}{n^{\frac{3}{2}}} + \dots + \frac{\sqrt{2n}}{n^{\frac{3}{2}}} \right]$$
 [3]

3. (a) Test the convergence of the improper integral

$$\int_0^{\frac{\pi}{2}} (\cos x)^l (\sin x)^m dx$$

(l, m to be real numbers).

(b) Find the value of:

$$\Gamma\left(\frac{1}{9}\right) \Gamma\left(\frac{2}{9}\right) \dots \Gamma\left(\frac{8}{9}\right)$$

$$1 - \frac{1}{9} = \frac{8}{9}$$
 [3]

$$\frac{8}{9} - 1 = -\frac{8}{9} = \frac{1}{9}$$
 [4]

(c) Evaluate :

$$\int_0^1 \frac{dx}{\sqrt{1-x^4}}$$
 [3]

4. (a) Evaluate:

$$\iint y^2 \sqrt{a^2 - x^2} dx dy$$

over the disc $x^2 + y^2 \leq a^2$.

(b) Determine the area of the ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

between the curve and its latera recta.

(c) Find the centre of gravity of a quadrant of a circle.

Group - C: Computer

Answer any four questions from this group.

1. (a) What are the 8-bit two's complement binary representations of decimal numbers 12 and -10 ? [5]

(b) Let **A** = 1111 1011 and **B** = 0000 0100 be two 8-bit two's complement binary numbers. What is their product in 8-bit two's complement binary form? [5]

2. (a) Consider the following recursive function definition of Fibonacci number generator in C++:

```
int f(int arg) {
    if (arg < 2) return 1;
    else return f(arg-1) + f(arg-2);
}
```

[5]

What is the value of **f(7)**?

(b) Suppose you have the following C++ functions available as library:

char *head(char *s): returns string having first character of s, e.g.

head("XYZ") returns "X"

char *tail(char *s): returns all but first character of a string, e.g.

tail("XYZ") returns "YZ"

char *concat(char *s1, char *s2): returns concatenated string, e.g.

concat("X", "Y") returns "XY"

If a string is declared as; char *s = "COMPUTER";

What is the value of concat(head(s), head(tail(concat(s))))? [5]

3. (a) Does this code execution produce an output or face a seg fault? Justify.

```
int main() {
    int x = 30;
    int *p = &x;
    p++;
    cout << p << ", " << *p)
    return 0;
}
```

[5]

(b) What does the following C++ code snippet print?

```
char x[] = "INFORMATION";
char *p = x;
cout << p + p[3] - p[1] << endl;
```

[5]

4. A program is given as follows:

```
class INTGR {
    int m;
public:
    INTGR(int a) {m = a;}
    ~INTGR();
};
```

```
int main() {
    int x = 3;
    INTGR y = x;
    y++ = ++y;
    x = y;
    return 0;
}
```

What extra functions / operators are required in the **INTGR** class to make the main program work? Don't depend on the compiler provided functions / operators. Provide suitable implementation for the added functions / operators. [10]

5. (a) Why cannot we pass an object by value to a copy constructor? [5]

(b) Why does the overloaded postfix increment operator take a dummy parameter? [5]

6. Some of the most commonly used binary operators in C++ are the arithmetic operators e.g. plus (+), minus (-), multiplication (*), and division (/). There are three different ways to overload these operators: putting as member, declaring as friend or the non-member way. Which approach is more appropriate? Justify your answer with suitable example. [10]



Indian Association for the Cultivation of Science
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Integrated Bachelor's and Master's Program
End-Semester Examination (Spring Semester-2019)

Subject: Biophysics
Full marks: 100

Subject Code(s): BIS 1202
Time allotted: 3 h

PART - A
Answer all questions

1. (a) Draw the picture of an eukaryotic cell and show various components. [3]
(b) Of which substance are microtubules made? What are the dynamic instability phases of a microtubule? [1+2]
(c) Draw the cell cycle phases. What are the major differences between Mitosis and Meiosis? [2+1]
(d) Describe the polymerization/depolymerization cycle of an active biopolymer. [3]
(e) Describe the steps in actin-based cell motility. [3]
2. (a) Sketch the crossbridge cycle of a molecular motor and label each step showing ATP hydrolysis and working distance.
(b) Explain the duty cycle and the processivity of a molecular motor.
(c) Estimate the force exerted during a single step by kinesin. The kinesin motor moves 8 nm per ATP hydrolysis event. Given, that the thermal energy scale $k_B T \sim 4 \text{ pN nm}$ and the free energy of ATP hydrolysis $\sim 20 k_B T$. [4+3+3]
3. Consider a protein in a fluid as a viscoelastic object.
(a) Draw an appropriate diagram using spring and dashpot for studying dynamics of the protein.
(b) Schematically show how the size/shape of the protein will reach equilibrium when subjected to a constant external force.
(c) Consider a bacterium swimming through water at velocity $v(0) = 25 \mu\text{m/s}$. How long will the bacterium continue to coast after its motors have stopped. Consider the bacterium as a sphere of radius $r = 1 \mu\text{m}$ and density $\rho = 1000 \text{ kg/m}^3$ and drag coefficient $\gamma = 20 \text{ nN s/m}$. Comment on the distance covered.
- [3+3+4]

4. Consider receptors on a spherical cell of radius a not fast enough to adsorb all the ligand molecules diffusing into them. The effective current or the number of ligand molecules adsorbed per unit time is given by $\frac{dn}{dt} = Nk_{on}c(a)$, where N is the number of surface-bound receptors, k_{on} is the finite rate of adsorption, $c(a)$ is the concentration of ligand at the surface of the cell (i.e. $r = a$) and $c(\infty) = c_0$ at $r = \infty$.

- (a) Using Fick's law find an expression for $c(a)$.
- (b) Show that for large k_{on} you can recover the limit of perfect adsorbers.
- (c) Find an estimate for N when the adsorption rate is half that of the completely adsorbing sphere as given by $4\pi Dac_0$, where D is the diffusion constant of the ligand molecules. Comment on your estimation of N for a cell that requires many different types of receptors.

[6+3+6]

OR

- (a) In a genome sequence the appearance of a particular subunit can often be predicted via a binomial distribution. Consider that the probability of having k occurrences of the particular subunit in a sequence of total segment length n with probability p is given by binomial distribution $P(k; n, p) = \binom{n}{k} p^k q^{n-k}$ where $\binom{n}{k} = \frac{n!}{k!(n-k)!}$. Find the mean and the standard deviation.
- (b) Show that the binomial distribution is normalized.
- (c) A species of fly lays eggs in domestic fruit bowls, which leads to fruit being damaged. A bowl contains three items of fruit, and each piece has an independent 10% chance of being damaged in this way. What are the possible numbers of damaged fruit, and what are the probabilities of each. What is the expected value for the number of damaged fruit.

[6+3+6]

PART - B
Answer all questions

5. State True or False and Explain. Each question carries [0.5+1.5] marks.
- (a) No two cells in our body have the identical nucleotide sequence of the DNA.
 - (b) In E. coli, where the replication fork travels at 500 nucleotide pairs per second, the DNA ahead of the fork must rotate at nearly 3000 revolutions per minute.
 - (c) When bidirectional replication forks from adjacent origins meet, a leading strand always runs into a lagging.
 - (d) Since introns are largely genetic "junk," they do not have to be removed precisely from the primary transcript during RNA splicing.
 - (e) Protein enzymes are thought to greatly outnumber ribozymes in modern cells because they catalyze a much greater variety of reactions at much faster rates than ribozymes.
 - (f) Difference in DNA sequence give rise to different cell types of an individual.

- (g) Co-translational translocation require ATP hydrolysis.
- (h) A concave lens modifies a plane wave front into spherical wavefront.
- (i) During total internal reflection no light penetrate into the second medium.
- (j) Phase shift ring is used in DIC microscopy to enhance contrast.

6. Each question carries [3] marks

- (a) Describe the difference between ~~lysosome~~ and ribosome? ~~lysosome~~ ~~ribosome~~
- (b) Describe the interactions that lead to formation of transient lipid nano domains (phase segregation) in a lipid bilayer composed of mixture of different lipids
- (c) Depict the schematic of Vesicular transport across two organelle
- (d) How does the cell distinguishes an ER resident protein from other proteins
- (e) Define optical resolution. What are the factors that limit the resolution λ / NA

7. Answer any three. Each question carries [5] marks

- (a) How is the interaction of RNAPolymerase with DNA tuned to change from initiation to elongation state.
- (b) Define free energy. Describe the importance of free energy in biochemical reactions within the cell
- (c) Describe distinct modes of protein transport (i) Gated, ii) Translocation and iii) Vesicular)
- (d) Describe the working of Confocal microscope

END



Indian Association for the Cultivation of Science
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Integrated Bachelor's-Master's Program in Science

End-Semester Examination-2019 (Spring Semester)

Paper: Electricity, Magnetism & Optics
Full Marks: 100

Paper Code: PHS1201
Time Allotted: 3hr

Part-A

Attempt any three questions

1. (a) Find electric field and potential at a distance r from a uniformly charged disc on a axis perpendicular to the plane of the disc. (7 marks)
(b) For a force whose components are, $F_x = x - 2y$, $F_y = 2x - y$ and $F_z = 2z$, is the work done independent of the path? (3 marks)
2. (a) Consider a uniformly charged rod along z -axis extending from $(0, 0, -L/2)$ to $(0, 0, L/2)$. Find the associated electric field on the $z = 0$ plane at a point $(x, y, 0)$. (5 marks)
(b) Find the electric field associated with the above charge configuration as $L \rightarrow \infty$. Can you test the validity of your result using Gauss divergence theorem. (5 marks)
3. (a) A circular loop is carrying an electric current of magnitude i . Find the magnetic field at the centre of the loop. (5 marks)
(b) As the size of the above current carrying loop goes to zero, show that the magnetic field becomes that of a magnetic dipole. Find the associated dipole moment. (5 marks)
4. (a) Prove the uniqueness theorem associated with electrostatic field. (5 marks)
(b) Find the surface charge density of a infinite charged plane, if it is known that two equipotential surfaces separated by 1 m has a potential difference of 5 V. (5 marks)

Part-B

Attempt any seven questions

1. (a) State the Fermat's principle. Using this principle derive the laws of refraction from a plane surface separating two medium of refractive index n_1 and n_2 . (5 marks)
(b) Using Fermat's principle or otherwise, derive the laws of reflection from a curved mirror with radius of curvature R . (5 marks)

2. (a) If a ray of light passing through air gets refracted into a medium of refractive index n through a curved surface of radius of curvature R , the object distance x and the image distance y are related by the relation $(1/x) + (n/y) = (n - 1)/R$. Given this find out the focal length of a lens in terms of the radii of curvature of the two surfaces. Hence derive the Lens formula. (5 marks)
- (b) An equi-convex lens has focal length of 20 cm. Find out the radius of curvature of its surfaces. If an object is placed at a distance of 40 cm from the lens, where the image will form? Subsequently, if one places the object at a distance of 10 cm from the lens, what will be the location of the image? (5 marks)
3. (a) Suppose there are two slits at a distance d apart and both are being illuminated by monochromatic light from a distant point source. As a result interference pattern is observed on a screen which is D distance away from the slits. Show that the locus of the bright as well as dark fringes are hyperbolas with the two sources at the foci. (5 marks)
- (b) If one introduces a thin slab of refractive index n in the path of one of the light ray forming interference pattern, the central bright fringe moves to the location of m th bright fringe. Find out the thickness of the slab. (5 marks)
4. (a) If a ray falls on a glass slab of thickness d and refractive index n with reflection coefficient r and transmission coefficient $t = 1 - r^2$, show that the total normalized intensity of the reflected ray is,
- $$I_r = \frac{g^2 \sin^2(\frac{\Delta}{2})}{1 + g^2 \sin^2(\frac{\Delta}{2})}$$
- where, $\Delta = (4\pi/\lambda)nd \cos \phi$ with ϕ being the angle of refraction. Find out the normalized intensity of the transmitted ray and hence demonstrate that the intensity of the reflected ray is maximum for $2nd \cos \phi = (2m \pm 1)(\lambda/2)$. (5 marks)
- (b) Find out the fringe width between two consecutive Newton's rings. (5 marks)
5. (a) When a narrow monochromatic source of light ($\lambda = 589.3$ nm) is placed at a distance of 50 cm from the bi-prism (refractive index=1.5), width of the fringes obtained on a screen placed 1m from the bi-prism is found to be 0.12 mm. Find the obtuse angle of the bi-prism. (5 marks)
- (b) In a Newton's ring experiment, the rings are formed using a source of light which has two wavelengths λ_1 and λ_2 . If m th order dark ring due to λ_1 coincides with the $(m+1)$ th order dark ring due to λ_2 , prove that the radius of m th dark ring of λ_1 is equal to $\sqrt{\lambda_1 \lambda_2 R / (\lambda_1 - \lambda_2)}$. Here R is the radius of curvature of the lower surface. (5 marks)
6. (a) A thin transparent plate of refractive index 1.5 is introduced in one arm of Michelson interferometer. It causes 10 fringe shift. Find the thickness of the plate. Assume the wavelength of light to be 600 nm. $\Delta x = \frac{m\lambda}{2(n-1)}$ (5 marks)
- (b) Find the least number of lines that a diffraction grating must have in order to resolve in the first order, the red doublet originating from the mixture of hydrogen and deuterium. The wavelength difference is 0.18 nm and the mean wavelength is 656.3 nm. (5 marks)
7. (a) Suppose a parallel beam of light falls on two slits, each of width a and separation between them being b . Hence show that the relative intensity of the pattern seen on a screen placed a large distance away is $(\sin^2 \alpha / \alpha^2) \cos^2 \beta$. Determine α and β in terms of a and b . (5 marks)
- (b) The intensity of light coming out of diffraction grating corresponds to, $(\sin^2 \alpha / \alpha^2)(\sin^2 N\beta / \sin^2 \beta)$. Given this find out the conditions on β leading to principal maxima as well as secondary maxima and minima. (5 marks)
8. (a) Derive an expression for the resolving power and angular dispersive power of a diffraction grating, given the condition of principal maximum being, $(a+b)\sin \theta = m\lambda$, while the condition for secondary

minima is $N(a + b) \sin \theta = p\lambda$. Here a is the width of the slit and b is the separation between the two slits. (5 marks)

(b) A diffraction grating, which is 2 cm wide is just able to resolve the Sodium lines at 589 nm and 589.6 nm as they are incident normally to the diffraction grating at second order. Hence find the number of rulings per mm. (5 marks)

9 (a) Consider two electric fields, one along the x-direction and another along the y-direction with identical magnitude. Show that if these two fields differ in phase by $\pm n\pi$, then we have plane polarized light, while if these two fields differ by a phase $\mp(\pi/2) \pm 2n\pi$ then we have circular polarized light. (5 marks)

(b) Suppose you have placed two polarizers at 90° between their pass axis. Another polarizer is placed between them, which is rotated at a constant angular velocity ω about their common central axis. If un-polarized light of intensity I_0 is incident on the first polarizer, then show that the intensity of transmitted light is $(I_0/16)(1 - \cos 4\omega t)$. (5 marks)

10 (a) Discuss the three processes by which energy can enter or exit from a two level system. Which one of these three processes is important for Laser? In normal circumstances do we expect a system to exhibit Laser-like emission? Explain. (5 marks)

(b) Define the A and B coefficients of Einstein. Using the Planck's distribution function find out the relationship between these coefficients. (5 marks)



Indian Association for the Cultivation of Science
(Deemed to be University under the *de novo* Category)
Integrated Bachelor's-Master's Program

End-Semester Examination (Spring Semester-2019)

Subject: Environmental Science
Full Marks: 50

Subject Code(s): SEC 1201
Time Allotted: 3 h

Group A: Multiple choice questions (Answer any 30 questions) : [30 x 0.5=15]

- ✓ 1. Which of the following is NOT an extinct animal:
a) Dodo b) African black rhino c) Cheetah d) Olive Ridley Turtle
- ✓ 2. Water hyacinth is an aquatic weed introduced as an ornamental plant in India from South America. This is an example of
a) biopiracy b) biological invasion, c) bioaugmentation d) bioremediation
- ✓ 3. World Heritage Day is celebrated on
a) 21st March b) 18th April c) 22nd April d) 22nd May
- ✓ 4. Which of the following is NOT a threat to sustainable development:
a) Population explosion b) Rapid urbanization c) Afforestation d) urban migration
- ✓ 5. Which of the following fact regarding Bio-diesel is NOT true?
a) clean fuel b) needs a modified diesel engine c) biodegradable iv) blending with petroleum/diesel is possible
- ✓ 6. Which of the following instrument is NOT used to control of air pollution?
a) Cyclone separator b) Electrostatic precipitator c) Catalytic convertor d) Spectrophotometer
- ✓ 7. The disease caused due to exposure in UV radiation is
a) skin cancer b) lung cancer c) kidney cancer d) liver cancer
- ✓ 8. To measure suspended particulate matter in air, the instrument used is
a) High volume sampler b) Hygrometer c) Baro-meter d) Personal sampler
- ✓ 9. The maximum permissible limit of total dissolved solids (TDS) in drinking water is
a) 2000 ppm b) 20 pppm c) 500 ppm d) 50 ppm

- ✓10. The head office of IUCN is located in
 a) Japan b) India c) Switzerland d) Japan china
- ✓11. To protect the environmental resource, an act implemented in 2002 in India, which is known as
 a) forest conservation act b) biodiversity act c) water act d) wild life protection act
- ✓12. The disaster happened in Bhopal in the year
 a) 1980 b) 1984 c) 1974 d) 1992
- ✓13. The disease "Itai-Itai" is due to _____ toxicity.
 a) arsenic b) lead c) cadmium, d) mercury
- ✓14. Biochemical Oxygen Demand (BOD) of the aquatic bodies represents the
 a) oxygen solubility in the water b) Biodiversity of the system c) organic load of the system d) total dissolved solids.
- ✓15. Which fraction of the particulate matter in the air is most hazardous to human health
 a) coarse particle b) PM 2.5 micron size class c) PM 10 micron size class d) aerosol
- ✓16. The percentage of solar radiation absorbed by Earth's surface is almost
 a) 20% b) 80% c) 50% d) 100%
- ✓17. Inter-tropical convergence zone is the region, where
 a) NE and SE trade winds meet b) westerlies and polar easterlies meet c) Sun is directly over during summer solstice d) Sun is directly over during winter solstice.
- ✓18. The distribution of global surface vegetation is primarily controlled by
 a) temperature and solar radiation b) temperature and rain fall c) soil texture and rainfall d) O₂ and CO₂ level in the atmosphere
- ✓19. Tundras are cold dominated ecosystem found in
 a) high latitudes and high altitudes b) low latitudes and low altitudes c) mid latitudes and mid altitudes d) coastal region
- ✓20. Global deserts are found around
 a) Torpic of Capricorn and Cancer b) Inter-tropical convergence zone c) Polar region d) Equator
- ✓21. Deciduous forests grow in the region of
 a) high precipitation and low temperature b) moderate precipitation and mild temperature c) low precipitation and low temperature d) deserts
- ✓22. The primary productivity is highest in the
 a) Boreal forest b) Tundra forest c) Tropical rainforest d) Grass land



Indian Association for the Cultivation of Science
(Deemed to be University under *de novo* Category)

Integrated Bachelor's-Master's Program
End-Semester Examination (Spring Semester-2019)

Subject: Chemistry-II
Full Marks: 100

Subject Code(s): CHS 1201
Time Allotted: 3 h

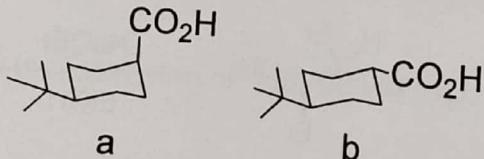
Section-A

(There are FOUR questions in this Section. Answer any THREE.)

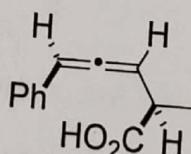
1. Answer any five from the following questions.

[2x5 = 10]

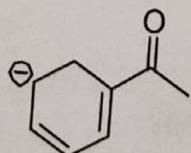
- trans
cis.
- a) cis-1,2-Dimethylcyclohexane exists in a non-resolvable racemic mixture. Explain.
b) Explain E1cB reaction with proper example.
c) Upon changing solvent from methanol (CH_3OH) to acetonitrile (CH_3CN), rate of the reaction between 1-bromopentane and sodium cyanide is increased many fold. Explain.
d) Which one among the following acids (a and b) would have lower pK_a value in water medium? Justify your answer.



- e) What would be the configuration of the final product when MeMgBr addition takes place on *Re* face of benzaldehyde?
f) What would be the Cahn-Ingold-Prelog stereochemical designation of the following molecule?

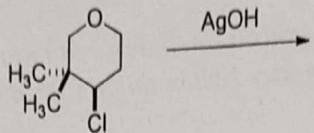


- g) Draw all the possible resonance structures along with the resonance hybrid of the following anion?

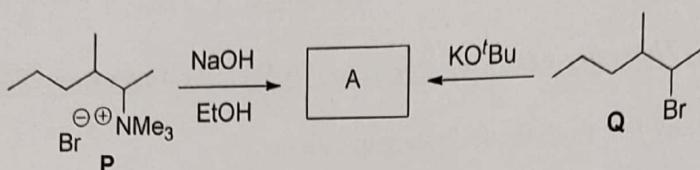


2. a) Draw the most stable conformer of *cis*- and *trans*-1-bromo-4-t-butylcyclohexane and explain which one would undergo substitution more rapidly with NaSPh? [3]

b) Predict the major product for the following reaction and justify your answer. [2]

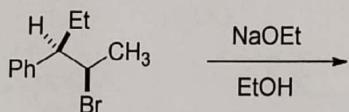


c) Below shown reactions deliver a major product A. Draw the correct structure of A and explain the observation with proper justification. [3]

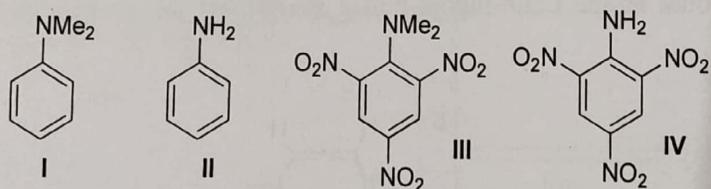


d) Ethyl chloride (EtCl) is more reactive than chloroethene ($\text{CH}_2=\text{CHCl}$) towards substitution reaction for both $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ mechanism. Explain. [2]

3. a) Predict the major product of the following reaction and explain the origin of product selectivity with a proper reaction mechanism of the following reaction. [3]



b) Compound III is 40,000 times stronger base than the compound IV, whereas *N,N*-dimethylaniline (I) and aniline (II) differ very little in their basic strength. Explain. [3]

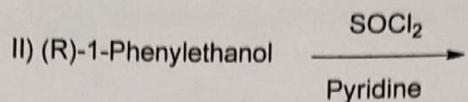
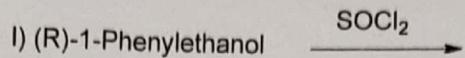


$$[\text{p}K_{\text{a}}(\text{I}) - \text{p}K_{\text{a}}(\text{II})] \ll [\text{p}K_{\text{a}}(\text{III}) - \text{p}K_{\text{a}}(\text{IV})]$$

c) Draw the most stable conformer of 1-methyl-1-phenylcyclohexane and justify your answer. [2]

d) Discuss the differences between $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ reaction? [2]

4. a) Write down the expected products of the following reactions with proper mechanism. [4]



b) Draw the most stable conformer of *cis*- and *trans*-1-iodo-4-*tert*-butylcyclohexane and explain which one would undergo elimination more rapidly when treated with sodium ethoxide? [3]

c) S_N1 reactions usually give products with complete racemization of the stereogenic centre. Under what condition racemization is expected in S_N2 mechanism? Explain your answer with a proper design of such S_N2 reaction. [3]

Section-B

(There are EIGHT questions in this section. Answer any SEVEN.)

5. (a) For IF_5 molecule: (i) Draw the Lewis structure and (ii) explain the geometry using the VSEPR model. [5]

(b) Explain (on the basis of Lewis structure and charge distribution due to resonance) the observation that the cyanate ion (NCO^-) is stable, the fulminate ion (CNO^-) is explosive, and CON^- does not exist. [3]

(c) The bond angle in H_2O is slightly larger than that in F_2O . Explain. [2]

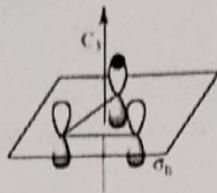
6. (a) Molecules of the type AX_5 with no lone pair of electron on A are not stereochemically very stable. Explain the statement. How such molecules may be made stereochemically stable? [3]

(b) What are the symmetry elements present in PCl_3 ? What is the point group of the molecule? [3]

(c) Explain why BF_3 possesses an S_3 axis, but NF_3 does not? [2]

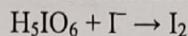
(d) Consider a nonlinear molecule which does not belong to cubic group. The molecule has C_3 axis and $3C_2 \perp C_3$ axes but there is no $\sigma_h \perp C_3$. However, the molecule has σ planes and an inversion center? [2]

7. (a) From the diagram given below, show that $S_3^2 = C_3^2$. [3]



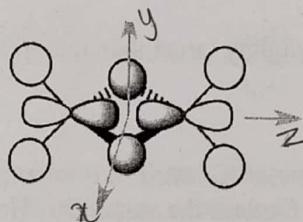
(b) Helium-hydride ion (HeH^+) which was predicted to exist in the interstellar medium, has been detected recently (April 2019) in a nebula. What is the point group of the molecule? Should the molecule show dipole moment? Draw the MO diagram of the molecule and comments on its proton donor ability. [5]

(c) Balance the following redox reaction in acidic solution: [2]

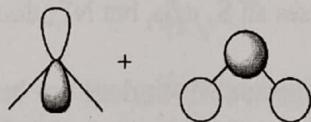


8. (a) Draw the MO diagram of H_3^+ by adding the MOs of H_2 with the atomic orbital of H. Show the energy ordering of the resulting MOs. [6]

(b) In the diagram of a MO given below, identify all the interactions that are important in evaluating the overall bonding or antibonding character of this MO? [4]

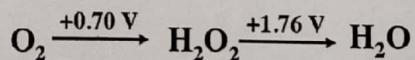


9. (a) Show how the new bonding and antibonding pair would look like upon mixing the following MOs. Will the new antibonding MO be stabilized or destabilized when the L-M-L angle becomes 180° ? [5]



(b) From the Nernst equation show that for a spontaneous redox reaction $E_{1/2}^0(\text{oxidant}) > E_{1/2}^0(\text{reductant})$. [2]

(c) Using the following Latimer diagram for O_2 , calculate $E^0_{1/2}(\text{O}_2/\text{H}_2\text{O})$. [3]



10. (a) From the Latimer diagram below, draw a frost diagram of iron.

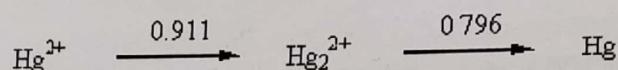
[6]

oxidation state	+6	+3	+2	0
acid solution	$\text{FeO}_4^{2-} \xrightarrow{-1.9}$	$\text{Fe}^{3+} \xrightarrow{+0.77}$	$\text{Fe}^{2+} \xrightarrow{-0.44}$	Fe
alkaline solution	$\text{FeO}_4^{2-} \xrightarrow{+0.9}$	$\text{Fe(OH)}_3 \xrightarrow{-0.56}$	$\text{Fe(OH)}_2 \xrightarrow{-0.89}$	Fe

(b) In the Frost diagram of iron, which species is the strongest oxidizing agent and under what condition? Will the strongest oxidant be able to oxidize water? If so, write the balanced redox reaction. [4]

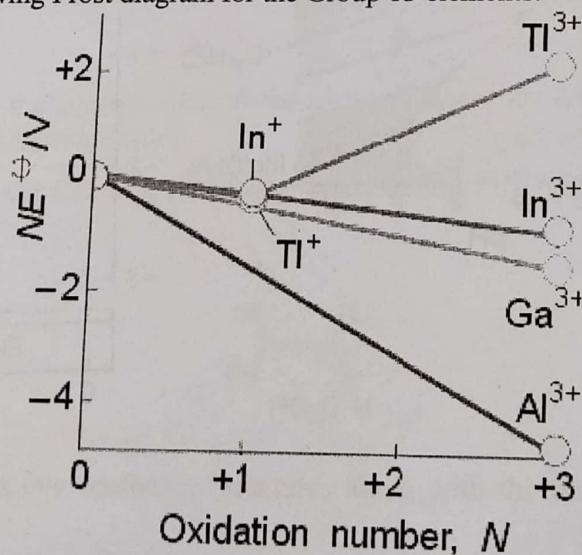
11. (a) How many non-bonding orbitals are present in HF molecule? Give proper explanation to your answer. (Valence state ionization energy of H 1s, F 2s, and F 2p orbitals are 13.6, 40.2, 18.6 eV, respectively) [4]

(b) Draw a Frost diagram for mercury in acid solution given the following Latimer diagram:



Comment on the tendency of any of the species to act as an oxidizing agent, a reducing agent, or to undergo disproportionation. [3]

(c) Which element(s) in Group 13 are not stable in the 3+ oxidation state? Which element(s) are stable in the 1+oxidation state? What is the origin of this difference? Consider the following Frost diagram for the Group 13 elements: [3]



[5]

12. (a) Consult the Pourbaix diagram of Mn and answer the following:

(i) What form(s) will manganese take in lake and stream water, where the pH = 6-8 and $E^\circ = 0.6\text{-}0.7 \text{ V}$?

(ii) We find that Mn has a quite high concentration in mammalian tissue (about 1 ppm), but very low concentration in ocean water (10⁻³ ppm). Explain.

(b) We don't talk much about the lanthanoid elements, but they are commercially important. With the help of Pourbaix diagram of Eu, answer the following: [5]

(i) Should it be possible to find metallic europium in the Earth's crust?

(ii) Does the reaction $\text{Eu(OH)}_3(s) \rightarrow \text{Eu}^{3+} + 3\text{OH}^-$ become more favorable or less, with increasing pH?

