



**INDIAN INSTITUTE OF SCIENCE
BANGALORE - 560012**

ENTRANCE TEST FOR ADMISSIONS - 2009

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**Program : Integrated Ph.D
Entrance Paper : Chemical Sciences
Paper Code : CS**

Day & Date
SUNDAY, 26TH APRIL 2009

Time
2.00 P.M. TO 5.00 P.M.

INSTRUCTIONS

1. This question paper consists of only multiple-choice questions. All questions carry one mark each.
2. Answers are to be marked in the OMR sheet provided.
3. For each question, darken the appropriate bubble to indicate your answer.
4. Use only HB pencils for bubbling answers.
5. Mark only one bubble per question. If you mark more than one bubble, the answer will be evaluated as incorrect.
6. If you wish to change your answer, please erase the existing mark completely before marking the other bubble.
7. There will be **NEGATIVE** marking. **NEGATIVE** marking for each wrong answer will be 1/3.
8. Some useful physical constants:

(A) Universal gas constant

$$R = 8.31451 \text{ J mol}^{-1} \text{ K}^{-1}$$
$$= 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

(B) Planck's constant,

$$h = 6.626 \times 10^{-34} \text{ J.s}$$

(C) Acceleration due to gravity

$$g = 9.8 \text{ m s}^{-2}$$

(D) Speed of light in vacuum

$$c = 2.998 \times 10^8 \text{ m s}^{-1}$$

(E) Avogadro's number

$$N = 6.023 \times 10^{23} \text{ mol}^{-1}$$

(F) Boltzmann constant

$$k = 1.380 \times 10^{-23} \text{ J K}^{-1}$$

(G) Electron charge

$$e = 1.602 \times 10^{-19} \text{ C}$$

(H) Electron mass

$$m_e = 9.109 \times 10^{-31} \text{ Kg}$$

(I) Permittivity of the vacuum

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ F m}^{-1}$$

(J) Faraday constant

$$F = 9.65 \times 10^4 \text{ C mol}^{-1}$$

(K) 1 Calorie

$$= 4.184 \text{ J}$$

(L) 1 atm

$$= 760 \text{ Torr}$$

(M) 1 eV

$$= 1.6022 \times 10^{-19} \text{ J}$$

(N) 1 atm

$$= 101 \text{ kPa}$$

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Chemical Sciences

1. For the hydrolysis of adenosine triphosphate (ATP), $\Delta H^\circ = -21.0 \text{ kJ/mol}$ and $\Delta G^\circ = -30.6 \text{ kJ/mol}$ at 298K. The ΔS° for this reaction is:

- (A) -32.2 J/mol.K
- (B) 32.2 J/mol.K
- (C) -70.0 J/mol.K
- (D) 70.0 J/mol.K

2. The number of modes of vibration possessed by acetylene molecule is:

- (A) 1
- (B) 7
- (C) 6
- (D) 3

3. The pH of 0.048 M solution of hypochlorous acid (HClO) is 4.42. The K_a of the acid is:

- (A) 3.0×10^{-8}
- (B) 3.0×10^8
- (C) 3.0×10^{-7}
- (D) 3.0×10^6

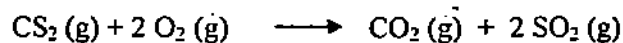
4. Which of the following is NOT true about the effect of an increase in temperature on the distribution of molecular speeds in a gas?

- (A) The average speed shifts to higher values
- (B) The most probable speed increases
- (C) The fraction of the molecules with the most probable speed increases
- (D) The area under the distribution curve remains the same.

5. A weather balloon filled with He has a volume of 1.0×10^4 litres at 1 atmosphere and 30°C . It rises to an altitude at which the pressure drops to 0.6 atmospheres and the temperature is -30°C . What would be the volume of the balloon? Assume that the pressure inside the balloon is nearly the same as outside.

- (A) 2.8×10^4 litres
- (B) 1.34×10^4 litres
- (C) 2.0×10^4 litres
- (D) 4.0×10^4 litres

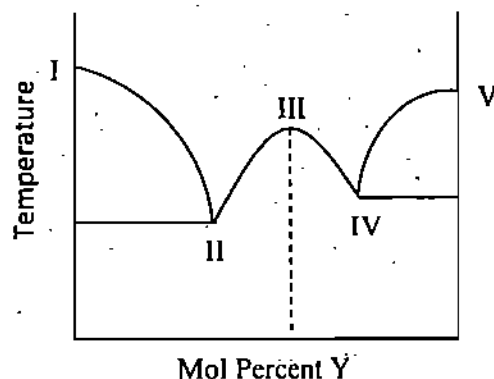
6. Carbon disulfide burns in the presence of oxygen according to the following equation:



When the reaction was carried out 7 L of products were formed. The volume of SO_2 formed at the same T and P is:

- (A) 14 L
- (B) 3.5 L
- (C) 4.67 L
- (D) 2.33 L

7. The phase diagram of a two-component system of substances X and Y is shown below.

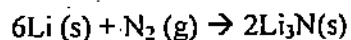


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A eutectic point is represented by which of the following?

- (A) II only
- (B) III only
- (C) I and V only
- (D) II and IV only

8. Lithium reacts with molecular nitrogen as follows.



How many grams of lithium nitride can be prepared from 4.5 g of lithium metal and 9.5 g of molecular nitrogen? (Take the atomic masses of Li and N to be 7 and 14, respectively)

- (A) 14 g
- (B) 23.75 g
- (C) 7.5 g
- (D) 36.5 g

9. The role of copper in hemocyanin is:

- (A) CO_2 fixation
- (B) N_2 fixation
- (C) O_2 binding and transport
- (D) Epoxidation of olefins

10. Which one of the following is the strongest oxidizing agent in an acidic medium?

- (A) KMnO_4
- (B) Cl_2
- (C) Zn^{3+}
- (D) $\text{K}_3\text{Fe}(\text{CN})_6$

11. Which one of the following pair is isoelectronic:

- (A) B_2H_4 and C_2H_4
- (B) CN^- and BN^+
- (C) CN^- and BN^-
- (D) $\text{B}_2\text{H}_4^{2-}$ and C_2H_4

12. The crystal field stabilization energy of $[\text{FeF}_6]^{3-}$ is:

- (A) $0 Dq$
- (B) $-20 Dq$
- (C) $10 Dq$
- (D) $20 Dq$

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13. Which one of the following complexes displays antiferromagnetic behavior?

- (A) K_2PtCl_4
- (B) $\text{Hg}[\text{Co}(\text{NCS})_4]$
- (C) $\text{MnCl}_2 \cdot 6\text{H}_2\text{O}$
- (D) $\text{Cu}(\text{CH}_3\text{CO}_2)_2 \cdot \text{H}_2\text{O}$

14. Which one of the following electronic configurations gives a kinetically inert 3d-metal octahedral complex?

- (A) d^0
- (B) d^3
- (C) d^4
- (D) d^7

15. Which one of the following molecules does not obey the 18-electron rule?

- (A) $[\text{Mn}(\text{CO})_6]^+$
- (B) $[\text{Cr}(\text{CO})_5]^{2-}$
- (C) $[\text{Mn}(\text{CO})_4\text{Cl}_2]^{2-}$
- (D) $\text{Fe}(\text{CO})_5$

16. The pair of elements that are related by a diagonal relationship is:

- (A) P and S
- (B) Si and C
- (C) Mg and Li
- (D) Al and Ga

17. An example of the complex having a quadruple bond is:

- (A) $\text{Hg}_2(\text{CH}_3\text{COO})_2$
- (B) $\text{Co}_2(\text{CO})_8$
- (C) $\text{Re}_2\text{Cl}_8^{2-}$
- (D) $\text{Cr}_2\text{O}_7^{2-}$

18. In nature, the noble gases exist as:

- (A) monatomic gaseous atoms
- (B) the gaseous fluorides
- (C) the sulfides
- (D) alkali metal salts

19. The two main isotopes of potassium are ^{39}K and ^{41}K . The atomic mass of potassium is 39.1. The abundances of the isotopes are:

- (A) 10% ^{39}K and 90% ^{41}K
- (B) 90% ^{39}K and 10% ^{41}K
- (C) 5% ^{39}K and 95% ^{41}K
- (D) 95% ^{39}K and 5% ^{41}K

20. In which of the following pairs, the ions/molecules have similar shape?

- (A) CO_2 and H_2O
- (B) BF_3 and H_3C^+
- (C) CCl_4 and PtCl_4
- (D) NH_3 and BF_3

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21. How many α -particles and β -particles are emitted in passing from ${}_{90}\text{Th}^{232}$ to ${}_{82}\text{Pb}^{208}$?

- (A) 4α and 4β
- (B) 6α and 6β
- (C) 4α and 8β
- (D) 6α and 4β

22. The pair of compounds containing peroxy ($-\text{O}-\text{O}-$) bond is:

- (A) H_2SO_5 and PbO_2
- (B) HClO_4 and $\text{H}_2\text{S}_2\text{O}_8$
- (C) P_2O_5 and MnO_2
- (D) H_2SO_5 and $\text{H}_2\text{S}_2\text{O}_8$

23. Which one of the following high-spin complexes has the highest CFSE?

- (A) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$
- (B) $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$
- (C) $[\text{Mn}(\text{H}_2\text{O})_6]^{3+}$
- (D) $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$

24. The bond angle in XeO_3 is:

- (A) 60°
- (B) 90°
- (C) 109.5°
- (D) 120°

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25. The order of increasing E-O (E = halogen) bond length is:

- (A) $\text{ClO}_3^- < \text{BrO}_3^- < \text{IO}_3^-$
- (B) $\text{BrO}_3^- < \text{IO}_3^- < \text{ClO}_3^-$
- (C) $\text{IO}_3^- < \text{ClO}_3^- < \text{BrO}_3^-$
- (D) $\text{IO}_3^- < \text{BrO}_3^- < \text{ClO}_3^-$

26. Which one of the following compounds has the highest thermal stability?

- (A) K_2CO_3
- (B) Na_2CO_3
- (C) CaCO_3
- (D) BeCO_3

27. The pair of metal carbonyl complexes that are isoelectronic is:

- (A) $[\text{Ni}(\text{CO})_4]$ and $[\text{V}(\text{CO})_6]$
- (B) $[\text{Co}(\text{CO})_4]^-$ and $[\text{Ni}(\text{CO})_4]$
- (C) $[\text{Cr}(\text{CO})_6]$ and $[\text{V}(\text{CO})_6]$
- (D) $[\text{Fe}(\text{CO})_4]^-$ and $[\text{Cr}(\text{CO})_6]$

28. Which of the following statements about $[\text{CoF}_6]^{3+}$ is correct?

- (A) weak field complex, diamagnetic
- (B) strong field complex, diamagnetic
- (C) weak field complex, paramagnetic
- (D) strong field complex, paramagnetic

29. How many orbitals are there in the shell with a principle quantum number, $n = 3$?

- (A) 4
- (B) 9
- (C) 16
- (D) 3

30. Addition of SbF_5 to HF will cause its acidity to:

- (A) Increase
- (B) Decrease
- (C) Remain the same
- (D) First increase and then decrease

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31. The fraction of the volume occupied by Al atoms in an f.c.c lattice is:

- (A) 0.633
- (B) 0.740
- (C) 0.950
- (D) 0.50

32. Using the 18-electron rule as a guide, the predicted number of carbonyl ligands (n) in $[(\eta^3\text{-C}_5\text{H}_5)\text{Rh}(\text{CO})_n]$ would be:

- (A) 1
- (B) 2
- (C) 3
- (D) 4

33. Arrange the following in terms of increasing melting point: Ar, NaCl, HCl and SiO₂:

- (A) Ar < NaCl < SiO₂ < HCl
- (B) HCl < Ar < SiO₂ < NaCl
- (C) Ar < HCl < NaCl < SiO₂
- (D) SiO₂ < NaCl < HCl < Ar

34. Of the following Si-compounds - SiO₂, Na₄SiO₄, Si(CH₃)₄, which of them is soluble in water?

- (A) SiO₂
- (B) Na₄SiO₄
- (C) Si(CH₃)₄
- (D) None of the above

35. The rate constant of a reaction at 298 K is k_1 . If the activation energy of the reaction is 25 kJ mol⁻¹, the rate constant of the reaction will be $2k_1$ at approximately:

- (A) 596 K
- (B) 300 K
- (C) 308
- (D) 320

36. A piece of iron weighing 72.4 g is heated to 100° C and dropped into 100 g of water kept at 10° C. Calculate the final temperature of water, if no heat was lost to the surroundings. Take specific heats of iron and water as 0.449 Jg⁻¹K⁻¹ and 4.18 Jg⁻¹K⁻¹ respectively.

- (A) 33° C
- (B) 16.5° C
- (C) 8.25° C
- (D) 4.125

37. The gas that will get evolved at the anode when K₂SO₄ (aqueous) is electrolyzed is:

- (A) oxygen
- (B) hydrogen
- (C) sulphur dioxide
- (D) sulphur trioxide

38. An electrolyte with specific conductivity of $0.001 \text{ Ohm}^{-1} \text{ cm}^{-1}$ has a resistance of 500 Ohms, when measured using a Pt conductivity cell with each electrode area of 1.2 cm^2 . What is the distance between the Pt electrodes ?

- (A) 2 mm
- (B) 4 mm
- (C) 6 mm
- (D) 8 mm

39. Passage of 30 A current for 70.2 minutes corresponds to:

- (A) 1.31 C
- (B) 1.31 F
- (C) 2100 C
- (D) 2100 F

40. $3A + B \rightarrow 2P$

The following data about the initial rates were obtained for the stoichiometric reaction above.

Experiment	$[A]_0, \text{M}$	$[B]_0, \text{M}$	Initial rate = $d[A]/dt$
1	0.20	0.20	$-1.2 \times 10^{-8} \text{ M s}^{-1}$
2	0.20	0.60	$-1.2 \times 10^{-8} \text{ M s}^{-1}$

For a third experiment, a plot of $1/[A]$ versus time was found to be linear. The order of the reaction with respect to the concentrations of A and B, respectively is:

- (A) 3 and 0
- (B) 2 and 1
- (C) 3 and 1
- (D) 2 and 0

41. How many electrons per minute pass through a copper wire carrying a current of 1×10^{-16} A?

- (A) 3.75×10^{-4}
- (B) 3.75×10^{-2}
- (C) 3.75×10^2
- (D) 3.75×10^1

42. In Bragg's law: $2d\sin\theta = n\lambda$, that describes X-ray diffraction, d represents

- (A) The distance between the atoms in the crystal
- (B) The distance between the X-Ray source and the crystal
- (C) The inter-planar distance in the crystal lattice
- (D) The distance between the two molecules in the crystal

43. During the titration of aqueous acetic acid with aqueous NaOH solution, which of the following statements is true?

- (A) conductance decreases up to equivalent point and then increases
- (B) conductance increases up to equivalent point and then decreases
- (C) conductance slowly increases up to equivalent point and then rapidly decreases
- (D) conductance slowly increases up to equivalent point and then rapidly increases

44. Which one of the following statements is correct?

- (A) 2s atomic orbital has no nodes.
- (B) $3p_z$ orbital has only the XY plane as the node.
- (C) $3d_{xy}$ orbital has two nodes
- (D) The wave function for 1s atomic orbital vanishes at the nucleus.

45. The electronic transitions of the conjugated molecule – octatetraene, may be modelled using the particle in a box model. If the π electrons are assumed to be confined to a box of length L , then the wave number of the longest wavelength absorption of the molecule may be estimated using the formula

- (A) $\frac{9h}{8mL^2c}$
- (B) $\frac{9h}{8mL^2}$
- (C) $\frac{9h^2}{8mL^2c}$
- (D) $\frac{9h}{2mL^2c}$

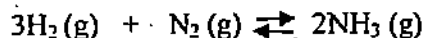
46. The heat from the combustion of 1.00 g of benzene in the liquid state (for which the standard enthalpy of combustion is $-3268 \text{ kJ mol}^{-1}$) is absorbed by 100 g of water at 0°C . The final temperature of the water is:

- (A) 45.3°C
- (B) 62.0°C
- (C) 81.8°C
- (D) 100°C

47. The osmotic pressure of an aqueous solution of a protein, containing 0.25 g of the protein in 50 mL of the solution, was found to be 1.52 kPa at 25° C. The molar mass of the protein is therefore about

- (A) 400 g mol⁻¹
- (B) 4000 g mol⁻¹
- (C) 800 g mol⁻¹
- (D) 8000 g mol⁻¹

48. In the reaction



all of the following will lead to the production of more ammonia, EXCEPT

- (A) a decrease in the volume of the container
- (B) addition of hydrogen
- (C) removal of NH₃
- (D) addition of a non-reactive gas

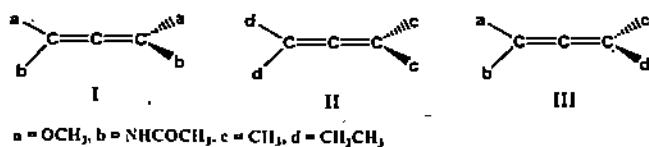
49. A four component system is found to coexist in 3 phases. All of the following statements about this are true, EXCEPT

- (A) The system has 3 independent intensive variables
- (B) The temperature and pressure of the system and the mole fraction of the components are capable of independent variation.
- (C) The system has 3 degrees of freedom.
- (D) The mole-fractions of two of the components, along with the temperature and pressure of the system can be varied independently.

50. At 25° C, the vapour pressure of benzene and toluene are, respectively, 94.6 Torr and 29.1 Torr. In a mixture of the two liquids in which the mole-fraction of benzene is 0.65, the corresponding vapour pressure at 25° C is:

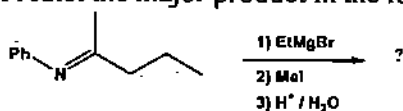
- (A) 124 Torr
- (B) 80.4 Torr
- (C) 52 Torr
- (D) 71.7 Torr

51. Which of the following compounds are optically active?

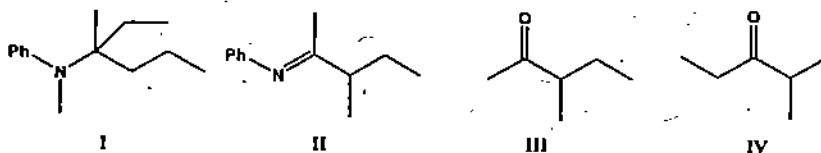


- (A) I only
 (B) III only
 (C) I and III
 (D) II and III

52. Predict the major product in the following reaction:



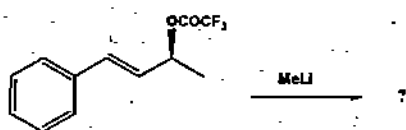
Choices:



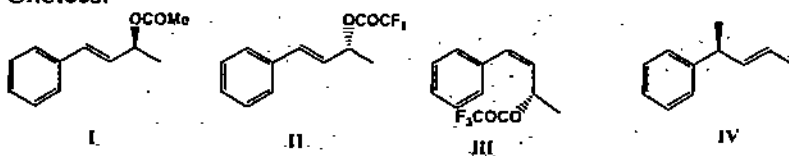
- (A) I
 (B) II
 (C) III
 (D) IV

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53. Predict the major product in the following reaction:

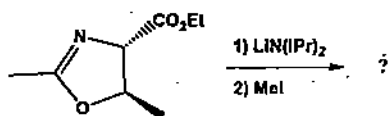


Choices:

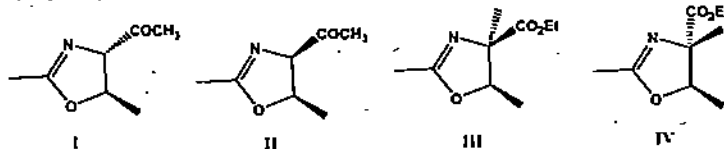


- (A) I
 (B) II
 (C) III
 (D) IV

54. Predict the major product in the following reaction:

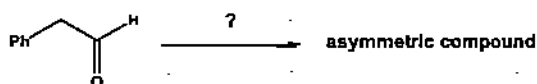


Choices:



- (A) I
(B) II
(C) III
(D) IV

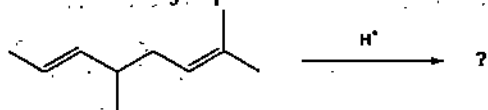
55. Choose the reaction condition which will enable phenylacetaldehyde to be converted to an asymmetric compound.



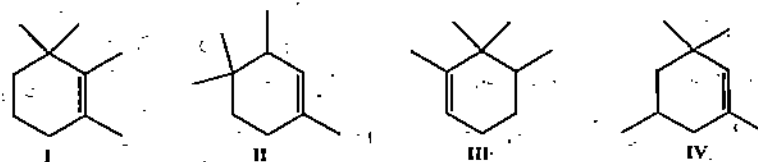
- (A) $\text{NaBH}_4 / \text{MeOD}$
(B) $\text{NaBD}_4 / \text{MeOH}$
(C) $\text{Ph-NH}_2 / \text{MeOD} / \text{reflux}$
(D) $\text{Ph-ND}_2 / \text{MeOH} / \text{reflux}$

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56. Predict the major product in the following reaction:

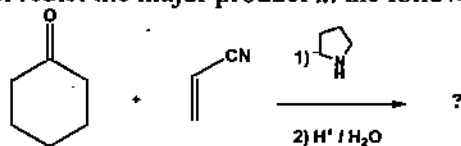


Choices:

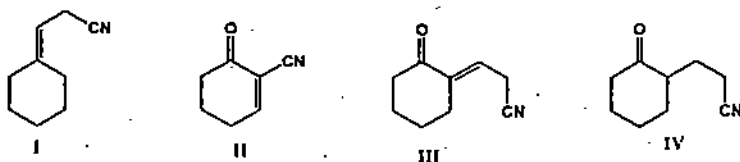


- (A) I
(B) II
(C) III
(D) IV

57. Predict the major product in the following reaction:

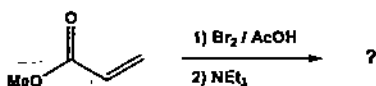


Choices:

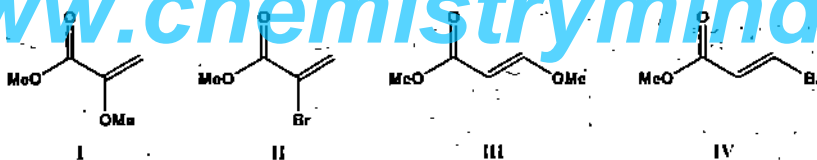


- (A) I
- (B) II
- (C) III
- (D) IV

58. Predict the major product in the following reaction:



Choices:

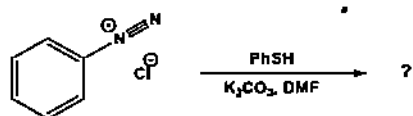


- (A) I
- (B) II
- (C) III
- (D) IV

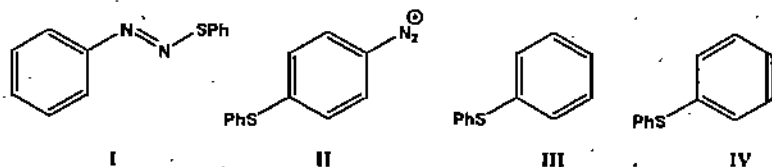
59. Major product in the reaction of 2-bromoanisole with sodamide is:

- (A) Aniline
- (B) Anisole
- (C) 4-methoxy aniline
- (D) 3-methoxy aniline

60. Predict the major product in the following reaction:



Choices:



- (A) I
- (B) II
- (C) III
- (D) IV

61. Reaction of anisole with lithium in liquid ammonia in presence of tert-butanol yields:

- (A) Phenol
- (B) Aniline
- (C) 3-methoxycyclohexa-1,4-diene
- (D) 1-methoxycyclohexa-1,4-diene

62. Which of the following reagent is suitable for the transformation of benzaldehyde to 2-phenyl-2-aminoacetonitrile?

- (A) NH_3/KCN
- (B) $\text{H}_2\text{SO}_4/\text{KCN}$
- (C) NaN_3/KCN
- (D) $\text{Li}/\text{liq. NH}_3$

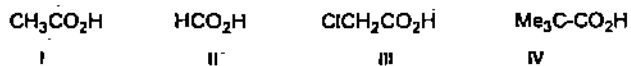
63. Reaction of triphenylmethanol with benzene in the presence of AlCl_3 yields:

- (A) Chlorotriphenylmethane
- (B) Tetraphenylmethane
- (C) Triphenylmethane
- (D) Benzophenone

64. Among 2-heptanol, 3-heptanol, 4-heptanol, which of them can exhibit optical activity?

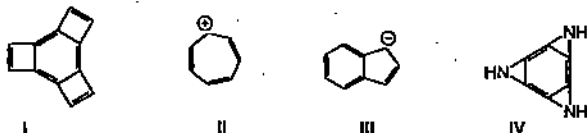
- (A) all three
- (B) 4-heptanol only
- (C) 2-heptanol and 3-heptanol
- (D) 2-heptanol and 4-heptanols

65. Arrange the following organic acids in their decreasing order of acidities.



- (A) I > IV > III > II
 (B) II > III > IV > I
 (C) IV > I > II > III
 (D) III > II > I > IV

66. For the compounds given below,







which one of the following statements is true:

- (A) II and IV are aromatic and I and III are antiaromatic
 (B) III and IV are aromatic and I and II are antiaromatic
 (C) II and III are aromatic and I and IV are antiaromatic
 (D) I and II are aromatic and III and IV are antiaromatic

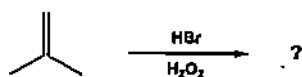
67. The major product formed in the following reaction



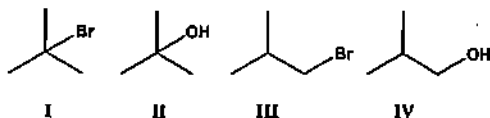
is:

- (A) 
- (B) 
- (C) 
- (D) 

68. Predict the major product in the following reaction:

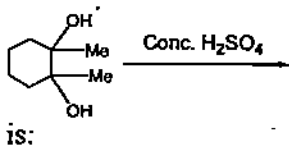


Choices:

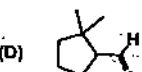
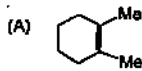


- (A) I
- (B) II
- (C) III
- (D) IV

69. The major product of the following reaction



is:

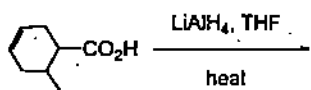


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70. In which of the following name reactions an isocyanate is obtained?

- (A) Favorskii rearrangement
- (B) Curtius rearrangement
- (C) Bayer-Villiger rearrangement
- (D) Wulff rearrangement

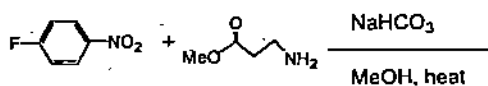
71. The major product of the reaction



is:

- (A) CC1CCCCC1C(=O)O
- (B) CC1CCCCC1CO
- (C) CC1CCCCC1C
- (D) CC1CCCCC1CO

72. The major product of the reaction

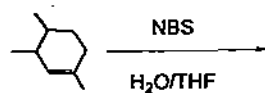


is:

- (A) CCNCCOC(=O)c1ccc([N+](=O)[O-])cc1
- (B) CCNCCOC(=O)c1ccc(F)cc1
- (C) CCNCCOC(=O)c1ccc(F)c([N+](=O)[O-])c1
- (D) CCNCCOC(=O)c1ccc([N+](=O)[O-])cc1

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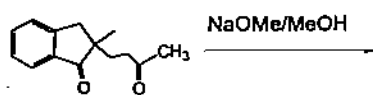
73. The major product of the reaction



is:

- (A)
- (B)
- (C)
- (D)

74. The product of the reaction

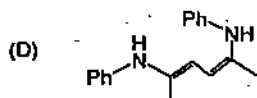
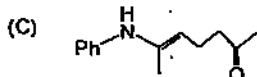
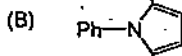
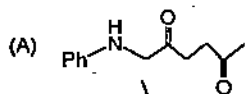
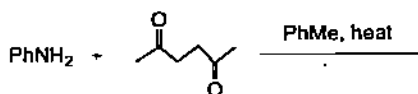


is:

- (A)
- (B)
- (C)
- (D)

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75. Identify the major product formed in the reaction



76. An electron moves with a velocity at an angle θ to a uniform magnetic field B . The electron will traverse the field

- (A) in a straight line without any change of direction
- (B) making a circular orbit
- (C) in an elliptical orbit
- (D) in a helical path

77. In an imaginary world, light travels at a speed of 30 m/sec, instead of 3×10^8 m/sec. In this world, a rod of length 1 meter is placed in a train pointing in the direction of motion and the train is traveling at a speed of 72 km/h. For a person on the ground, the rod will now appear to have a length:

- (A) 1.34 m
- (B) 1.0 m
- (C) 0.74 m
- (D) 5 m

78. A train is moving away from an observer at a speed of 36 km/h. It sounds a whistle whose frequency is 1 kHz. Given that the speed of sound in air is 340 m/s, the apparent frequency of the whistle heard by a stationary observer is:

- (A) 1 kHz
- (B) 520 Hz
- (C) 1250 Hz
- (D) 970 Hz

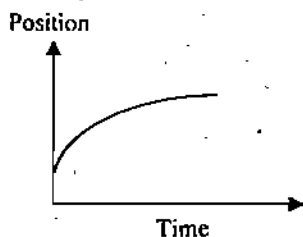
79. The energy of the first excited state of the hydrogen atom is:

- (E) -13.6 eV
- (F) -6.8 eV
- (G) -3.4 eV
- (H) ∞ eV

80. In a reversible adiabatic process, the entropy of the system

- (A) Increases
- (B) Decreases
- (C) Remains unchanged
- (D) is not defined

81. The position versus time of a car along a straight road is shown in the graph. From the graph it is clear that the car is:



- (A) speeding up
- (B) slowing down
- (C) moving at constant velocity
- (D) speeding up for some time and slowing down for part of the time

82. A ferromagnetic material has a Curie temperature of 100K. If the temperature of the material is decreased from 300K to 200K, its magnetic susceptibility will roughly

- (A) increase by a factor 3/2
- (B) increase by a factor 2
- (C) stay the same
- (D) decrease by a factor 3/2

83. Choose the correct Heisenberg uncertainty relation:

- (A) $\Delta p_x \cdot \Delta y \approx \hbar$
- (B) $\Delta p_x \cdot \Delta t \approx \hbar$
- (C) $\Delta p_x \cdot \Delta E \approx \hbar$
- (D) $\Delta p_x \cdot \Delta x \approx \hbar$

84. The frequency of a parallel resonance circuit made up of an inductor of value $4 \mu\text{H}$ and a capacitor 25 pf is given by (choose the nearest value)

- (A) 10^5 Hz
- (B) 6.25 MHz
- (C) 159 MHz
- (D) 53 GHz

85. A spectral line of wave number 3000 cm^{-1} corresponds to a frequency

- (A) 3000 Hz
- (B) $1 \times 10^7 \text{ Hz}$
- (C) $9 \times 10^{13} \text{ Hz}$
- (D) 10 kHz

86. There are 10 apple trees in an orchard, each tree produces 8000 apples. For each additional tree planted in the orchard, the output per tree drops by 100 apples. How many trees should be added to the orchard in order to maximize the total output of apples?

- (A) 25
- (B) 35
- (C) 45
- (D) 55

87. If $y = \ln(\ln \cos x)$, then dy/dx is =

- (A) $-\tan(x)/\ln(\cos(x))$
- (B) $-\sin(x)\cos(x)/\ln(\cos(x))$
- (C) $\ln(\cos(x))\sin(x)/\cos(x)$
- (D) $-\ln(\cos(x))\cos(x)/\sin(x)$

88. A basket contains 3 white and 4 red balls. A ball is randomly chosen and put back into the basket. What is the approximate probability that the first 5 balls chosen will contain exactly 2 white balls?

- (A) 0.35
- (B) 0.70
- (C) 0.18
- (D) 0.65

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89. The $D = \begin{vmatrix} 1 & x & 0 \\ 0 & 2 & x \\ 0 & x & 3 \end{vmatrix}$ derivative of the determinant D is

- (A) $-2x^2$
- (B) 0
- (C) $-2x$
- (D) $6-x^2$

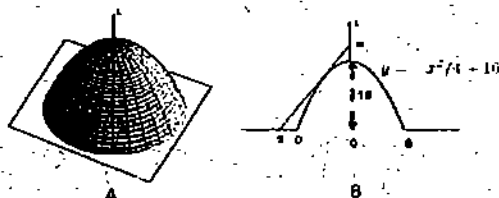
90. The eigen-values of the matrix M given below are

$$M = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

- (A) $-\sqrt{2}, 0, \sqrt{2}$
- (B) $-1, 0, 0$
- (C) $-2, 0, 2$
- (D) $-1, 0, 1$

91. As a part of celebrating the festival Holi, a parabolic hill was constructed (Fig. A). Its cross section is shown in figure B. The parabolic part in Fig. B is described by the equation $y = 16 - x^2/4$ for $|x| < 8$ and $y = 0$ for $|x| > 8$. $y = 0$ is the ground level. It is desired to put a light L on top of the hill at such that no point at the bottom of the hill is in the shadow (for example if one puts it at point N (see figure B), the region SD will be in the shadow). The minimum height from the ground, at which the light has to be placed, is:

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- (A) 32
- (B) 16
- (C) 48
- (D) 24

92. The moment of inertia of a thin circular disc about an axis perpendicular to it, and passing through its centre is I. Its moment of inertia, about an axis passing through its centre and lying in its plane is:

- (A) I
- (B) I/2
- (C) 2I
- (D) I/3

93. A heavy uniform rope hangs vertically from the ceiling, with its lower end free. A disturbance on the rope that travels upward from the lower end has a velocity v at a distance x from the lower end. The velocity v would be proportional to:

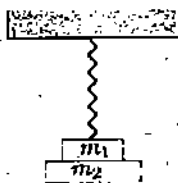
- (A) x
- (B) $1/\sqrt{x}$
- (C) \sqrt{x}
- (D) x^2

94. In figures A and B, electric currents are flowing in the directions indicated by the arrows. The magnitude of the currents is the same. Which of the following statements about the setup is true?



- (A) As the wires are neutral, there is no attraction or repulsion between them.
- (B) As the two wires are charged, there is repulsion between them.
- (C) Magnetic forces between the two wires cause attraction between them in the case A and repulsion in the case B.
- (D) Magnetic forces between the two wires cause attraction between them in the case B and repulsion in the case A.

95. Two blocks of mass m_1 and m_2 (see figure) are attached to the lower end of a vertical spring of force constant k . The upper end of the spring is fixed.



When the system is resting at equilibrium, the lower block, of mass m_2 drops off. The other block will:

- (A) remain where it was.
- (B) oscillate vertically with a time period $2\pi\sqrt{m_1/k}$.
- (C) not execute oscillations, but will move a distance m_2g/k upward and will remain at rest there.
- (D) undergo vertical oscillations with time period $2\pi\sqrt{(m_1 + m_2)/k}$

96. The length of the curve connecting the two points $(0, 0)$ to $(2, \cosh(2))$, along the curve $y = \cosh(x)$, is:

- (A) $\sinh(2)$
- (B) $\cosh(2)$
- (C) $\tanh(2)$
- (D) $\sqrt{\sinh(4)}$

97. There is a narrow road around a perfectly circular stadium (see figure). A boy sitting in an open car, going around the stadium at a speed of 100 km/h throws a ball vertically upward with a speed of 50 km/h. The ball will land at a point



- (A) along the circular road itself.
- (B) outside the circular road. The point will be along a line joining the position of the boy at the instant of the throw, to the center of the stadium.
- (C) in the stadium
- (D) outside the circular road, but not as in choice (B)

98. The area enclosed between the two curves: $y = x^2$ and $x = y^2$ (the shaded area marked as A in the figure) is:

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- (A) $1/3$
- (B) $2/3$
- (C) 2
- (D) $1/4$

99. If $y = e^{x+y}$, then the dy/dx is:

- (A) $y/(1 - y)$
- (B) $y/(1 + y)$
- (C) e^{x+y}
- (D) e^x

100. A positive point charge, which is free to move, is inside a hollow conducting sphere that carries a net negative charge. If it is originally placed at a point away from the centre of the sphere, it will

- (A) remain where it was placed.
- (B) move to the centre of the sphere.
- (C) move towards the wall nearest to it.
- (D) oscillate between the point and the centre.

End of question paper

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