## TIFR-2012 (CHEMISTRY)

1. A quantum mechanical state Q is a superposition of two normalized enregy eigenstates A and B in an amplitude ratio 2:1. If the two states are degenerate with a common eigenvalue E, what is the energy of the state Q?
(a) 0 (b) 3E (c) 5E (d) E

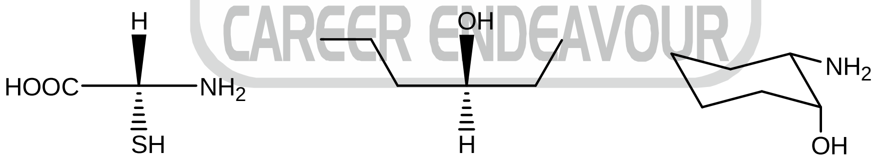
2. For the above, if the states were non-degenerate and with energy eigenvalues E and –E respectively, then what would be the expectation value of the energy?
(a) 3E (b) 5E (c) E (d) None of the above.

3. Suppose we inscribe a circle inside an equilateral triangle, and then inscribe a square inside this circle. What is the ratio of the side of the square to the side of the triangle?
(a) $1:\sqrt{3}$ (b) 2 : 5 (c) $1:\sqrt{6}$ (d) 1 : 2

4. The reversible reaction $S \longleftrightarrow P$ is catalyzed by a catalyst. The equilibrium constant $K_{eq} = [P]/[S]$ is $2\times10^3$. The forward rate constant was found to be $5\times10^4$ sec$^{-1}$ and $4\times10^{-6}$ sec$^{-1}$ in the presence and in the absence of the catalyst respectively. What is the expected rate constant for the reverse reaction in the absence of the catalyst?
(a) $5\times10^8$ sec$^{-1}$ (b) $2\times10^{-9}$ sec$^{-1}$ (c) $0.8\times10^{-10}$ sec$^{-1}$ (d) $5\times10^{-9}$ sec$^{-1}$

5. The molar extinction coefficient (at 550 nm) of compounds A and B are $1\times10^4$ M$^{-1}$ cm$^{-1}$ and $1\times10^5$ M$^{-1}$ cm$^{-1}$ respectively. Solutions of A and B are made at concentrations of $1\times10^{-4}$ M and $2\times10^{-5}$ M respectively. In a spectrophotometer set at 550 nm, the percentage of light transmitted by solution A and B (in two separate experiments) will be
(a) The same
(b) B will transmit 10 times less light compared to A
(c) B will transmit 5 times less light compared to A
(d) B will transmit 2 times light compared to A

6. What are the configurations (R or S) of the chiral centers in the following molecules.

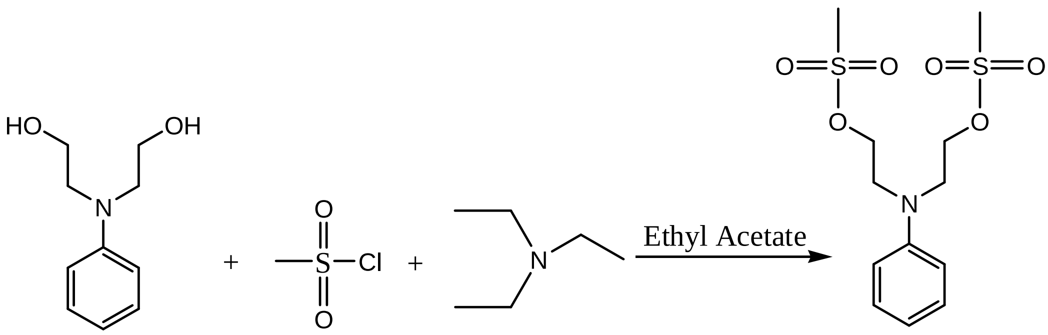



(1) (2) (3)

(a) Compound 1 = R; Compound 2 = R; Compound 3 = 1S, 2S
(b) Compound 1 = R; Compound 2 = S; Compound 3 = 1R, 2S
(c) Compound 1 = S; Compound 2 = S; Compound 3 = 1S, 2R
(d) Compound 1 = R; Compound 2 = S; Compound 3 = 1S, 2R

7. What are the oxidation states of the metal ion in the following compounds
(1) $PdCl_2$ (2) $Pd(PPh_3)_4$ (3) $Pd(OAc)_2$ (4) ArPdBr where Ar is Aryl
(a) 2, 4, 2, 2 (b) 2, 0, 2, 1 (c) 2, 0, 2, 2 (d) 0, 0, 0, 2

8. Methanesulfonyl chloride is used commonly to form methanesulfonates upon reaction with alcohols. Methanesulfonates are good leaving groups in nucleophilic substitution reaction. In the following reaction calculate the volumes of methanesulfonyl chloride and triethylamine required in μL. The amount of starting material and the number of equivalents of each reagent is given.




solid solid

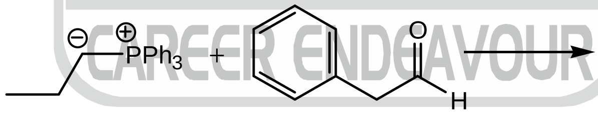
| | | | |
|---|---|---|---|
| Amount (mg) | 100 | | |
| equivalents | 1 | 2 | 3 |
| Density (g/mL) | | 1.48 | 0.73 |
| μL | | D | E |

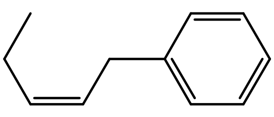
(a) D = 126, E = 167
(b) D = 0.085, E = 0.229
(c) D = 85, E = 229
(d) D = 1.1, E = 1.65

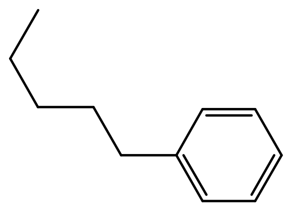
9. The vibrational Raman effect, a considerably weak scattering phenomena, was first reported by Late Sir CV Raman in 1928. The intensity of the individual vibrational resonances observed in a Raman spectrum is proportional to

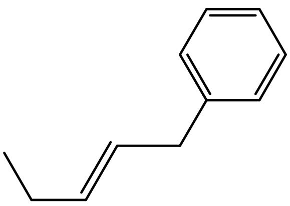
(a) Number of molecules
(b) Polarizibility of the bond
(c) Wavelength of radiation used
(d) All of the above.

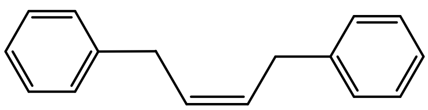
10. The Wittig reaction is a reaction with an aldehyde or ketone with a phosphonium yield. Predict the product of the following reaction.




(a) 

(b) 

(c) 

(d) 

11. The standard redox potential of water oxidation to dioxygen is –1.23 V.

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

The redox potential of the same reaction at pH = 7 would be

(a) –0.41 V  (b) –1V  (c) –0.82 V  (d) –1.64 V

12. Amino acid side-chains in proteins have hydrogen bonds for structural and catalytic reasons. One such combination of H-bonding partners is Histidine associated with a partnering residue such as Tyrosine (X–H ... N–His, where X is the partnering amino acid). If the pKa of Histidine is 6.1, estimate the pKa of the partnering residue (X–H) such that protonation of His at pH 6.5 is a favorable process

(a) pKa > 10  (b) pKa < 1  (c) pKa < 6  (d) pKa > 6.5

13. The total energy expended to charge (total charge = +q) a sphere of radius ‘r’ in a dielectric medium $(\varepsilon)$ is given by (in SI units)

(a) $q^2/4\pi\varepsilon r$  (b) $q^2/16\pi\varepsilon r$  (c) $q^2/4\pi\varepsilon r^2$  (d) $q^2/8\pi\varepsilon r$

14. A substance A is consumed by a reaction of unknown order. The initial concentration is 1mM, and concentrations at later times are as shown

| Time(min) | [A](mM) |
|---|---|
| 1 | 0.83 |
| 2 | 0.72 |
| 4 | 0.56 |
| 8 | 0.38 |
| 16 | 0.24 |

What is the order of the reaction?

(a) Zero  (b) First-order  (c) Second-order  (d) Pseudo-first order

15. $\Delta G^0$ values for the hydrolysis of glucose-1-phosphate and glucose-6-phosphate are –21 kJ/mol and –14 kJ/mol, respectively. What is the equilibrium constant for the following equilibrium at 25ºC?

$$\text{Glucose-1-phosphate} \rightleftharpoons \text{Glucose}-6-\text{phosphate}$$

(a) 0.06  (b) 16.9  (c) 4798  (d) 284

16. In a double stranded DNA, if the sequence 5’ AGATCC3’ appears on one strand of DNA, what sequence in the complementary strand?

(a) 5’ AGATCC3’  (b) 5’ CCTAGA3’  (c) 5’ GGATCT3’  (d) 5’ TCTAGG3’

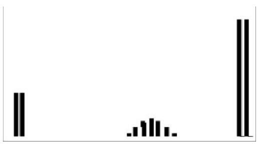
17. One sequence of amino acids repeats for long distances in silk protein. Complete hydrolysis of one mole of a fragment with this sequence gives 2 mol alanine, 3 mol glycine, and 1 mol serine. Partial hydrolysi yields Ala-Gly-Ala, Gly-Ala-Gly, Gly-Ser-Gly, and Ser-Gly-Ala peptides. What is the amino acid repeat?

(a) Gly-Gly-Ser-Ala-Gly-Ala  (b) Gly-Gly-Gly-Ala-Ala-Ser

(c) Ser-Ala-Ala-Gly-Gly-Gly  (d) Gly-Ser-Gly-Ala-Gly-Ala



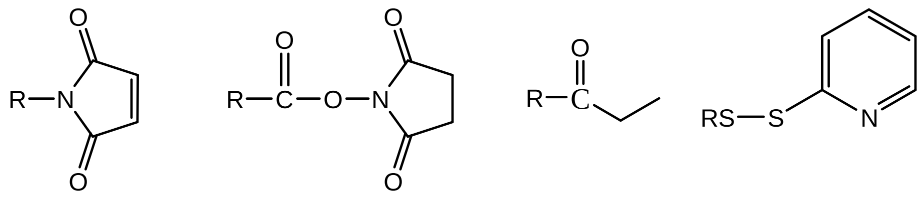
18. Which of the following compounds would give the $^1H$ NMR spectrum shown below



(a) $CH_3CH(CH_3)CH_2X$  (b) $CH_3C(CH_3)_2CH_2CH_2X$

(c) $CH_3CH_2(CH_3)CH_2X$      (d) $CH_3CH_2CH(CH_3)X$

19. Which of the following compounds will react with R-SH in aqueous solutions between pH 6.5 and 8.5?



R1    R2    R3    R4

(a) R1, R2 and R3    (b) R2, R3 and R4    (c) R4, R2 and R1    (d) R1, R3 and R4

20. In a spherical polar coordinate system, a point A at (x, y, z) in the Cartesian coordinate system can be described by $(r, \theta, \phi)$ where $r, \theta$ and $\phi$ have their usual meaning. Expression for the volume of an infinitesimally small cube confined by dx, dy and dz in terms of the spherical coordinate system is given by

(a) $dr d\theta d\phi$    (b) $r \sin\theta dr d\theta d\phi$    (c) $r^2 \sin^2\theta dr d\theta d\phi$    (d) $r^2 \sin\theta dr d\theta d\phi$

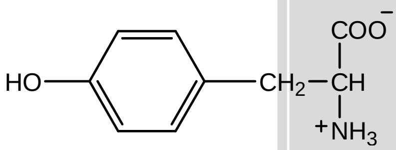
21. Rotational energy of a diatomic molecule is given by $E_{rot} = J(J+1)hB_e$, where $E_{rot}$ is in Joules. If the rotational constant for $H_2$ molecules is given as

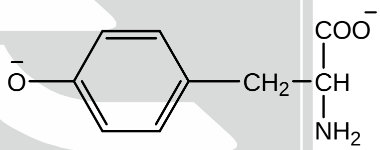
$B_e = 1.8324 \times 10^{12}$ Hz, the rotational period of the $H_2$ molecule in J = 10 level will be

(a) $1.33 \times 10^{-19}$ sec    (b) $5.0 \times 10^{-15}$ sec

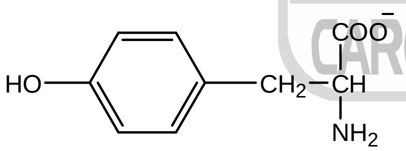
(c) $5.46 \times 10^{-13}$ sec    (d) $7.39 \times 10^{-7}$ sec

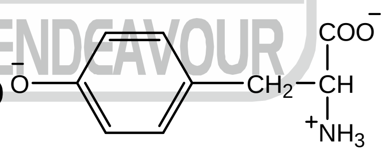
22. Tyrosine, at pH 12, has the following structure

(a) 

(b) 



(c) 

(d) 

23. Quartz crystal watches lose or gain about a second a week. What is accuracy of these watches in ppm?

(a) 1    (b) 1000    (c) 0.605    (d) 1.653

24. The reaction of sodium ethoxide with ethyliodide to form diethyl ether is termed

(a) electrophilic substitution    (b) nucleophilic substitution

(c) electrophilic addition    (d) radical substitution

25. Of the following metal ions, which has the largest magnetic moment in its low-spin octahedral complexes?

(a) $Fe^{3+}$    (b) $Co^{3+}$    (c) $Co^{2+}$    (d) $Cr^{2+}$

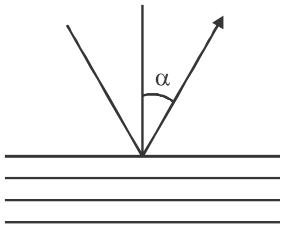
26. In a certain axis of quantization, the z-component of the spin angular momentum, $S_z$, has the following matrix representation.

$$S_z = \hbar \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

What would be the trace of the matrix of $S_x^{\ 2}$ (square of the x-component) in the same representation?

(a) $0\hbar^2$ (b) $1\hbar^2$ (c) $2\hbar^2$ (d) None of the above.

27. X-rays of $CuK_\alpha$ (wavelength 154 pm) are diffracted by a set of atomic planes in a crystal in the following manner. The separation of the layers in the crystal is 404 pm. Find the angle $\alpha$ along which the first-order reflection will occur.




(a) 79º (b) 45º (c) 11º (d) None of the above.

28. How many molecules of cetanol (of cross-sectional area $2.58\times10^{-19}$ $m^2$) can be adsorbed on the surface of a spherical drop of dodecane of radius 7.8 nm?
(a) $3.90\times10^3$ (b) $1.54\times10^4$ (c) $1.54\times10^2$ (d) $6.5\times10^{-5}$.

29. The velocity of $Li^+$ ion in water is $2\times10^{-2}$ cm/sec when 100V is applied between two electrodes separated by 2 cm. The mobility of $Li^+$ ion in water is,

(a) $4\times10^{-4}\ cm^2s^{-1}V^{-1}$ (b) $1\times10^{-4}s^{-1}V^{-1}$

(c) $4V\ cm^2s^{-1}$ (d) $2.5\times10^5\ V\ s\ cm^{-2}$

30. The melting point of lithium metal is 454K, and that of sodium is 371K. Which of the following statements can explain this difference in their melting points?
(I) Metallic bonding in lithium is stronger than metallic bonding in sodium.
(II) The delocalised electrons are more strongly attracted to the metal cation of lithium.
(III) The lithium cations have a greater charge density than sodium cation.
(IV) $Li^+$ cations are smaller than $Na^+$ cations.
(a) Only I and II (b) Only II and III (c) Only IV (d) I, II, III, IV

31. What is the final product after the following reaction has gone to completion?

$$\text{Benzene}(\text{liquid}) + \text{Chlorine}(\text{gas}) \xrightarrow[?]{\text{Sunlight}} ?$$

(a) Benzene (b) Benzenehexachloride
(c) Chlorobenzene (d) Dichlorobenzene

32. The transition probability for spontaneous emission from state 'm' to state 'n' is given by an expression.

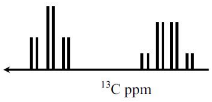
$$A_{m\to n} = \left(\frac{64\pi^4 V_{mn}^3}{3hc^3}\right).\left(\left|\langle m|\hat{d}|n\rangle\right|^2\right)$$

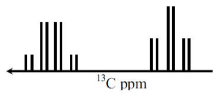
where, $V_{mn}$ is the frequency of transition, and the term in the parenthesis is the transition dipole. Assuming that the magnitude of the transition dipole is same for all types of transitions, arrange the average lifetimes for the electronic, vibrational, and rotational transitions in the proper order.
(a) electronic < vibrational < rotational (b) vibrational < rotational < electronic
(c) rotational < vibrational < electronc (d) electronic < rotational = vibrational

33. At 20ºC, the standard EMF of a certain cell is +0.2699V, and at 30ºC it is +0.2669V. What can you say about the standard entropy of this reaction? Assume that the standard $\Delta H^0$ and $\Delta S^0$ are independent of temperature.

(a) $\Delta S^0 = 0$ (b) $\Delta S^0 = +\text{ve}$ (c) $\Delta S^0 = -\text{ve}$ (d) Not enough information is given

34. Which of the following most closely resembles the $^{13}C$ NMR spectrum of ethanol? Assume a scalar coupling of 150Hz among the $^{1}H$ and the $^{13}C$ nuclei within a functional group, a scalar coupling of 50 Hz between the $^{13}C$ nuclei, a static magnetic field of 11.7 T and a temperature of 300 K.

(a) 


(b) 


(c) 


(d) 


35. The roots of the equation $x^3 + ax^2 - bx + c = 0$ are three consecutive integers. What is the maximum value of b?

(a) –2 (b) 0 (c) 1 (d) 2

36. The corrosion of iron in contact with an acidic aqueous solution undergoes the following reaction

$$Fe(s) + 2H^+(aq) \Leftrightarrow Fe^{2+}(aq) + H_2(g) \qquad (1)$$

in the anaerobic condition, and the following reaction

$$2Fe(s) + O_2(aq) + 4H^+(aq) \Leftrightarrow Fe^{2+}(aq) + 2H_2O(\ell) \qquad (2)$$

in the aerobic condition. During the corrosion, Fe (II) ions are formed in both conditions. If the water is polluted with Cr(IV), the following reaction may take place.

$$7H^+(aq) + 3Fe^{2+}(aq) + HCrO_4^-(aq) \Leftrightarrow 3Fe^{3+}(aq) + Cr^{3+}(aq) + 4H_2O(I) \qquad (3)$$

Reaction (3) be broken down to the following redox half-reactions:

$$3Fe^{3+} + 3e^- \Leftrightarrow 3Fe^{2+}(aq) \qquad E^0 = +0.77\ V \qquad (4)$$

$$7H^+(aq) + HCrO_4^-(aq) + 3e^- \Leftrightarrow Cr^{3+}(aq) + +4H_2O(\ell) \qquad E^0 = +1.38V \qquad (5)$$

The standard potentials of these reactions are with respect to the normal hydrogen electrode. What would be the approximate value of the equilibrium constant of reaction 3 at 298K ?

(a) $10^{11}$ (b) $10^{31}$ (c) $10^{-31}$ (d) $10^{-11}$

37. Consider a container of volume 5.0 L that is divided into two compartments of equal size. In the left compartment there is nitrogen at 1.0 atm and 25ºC; in the right compartment there is hydrogen at the same temperature and pressure. What will happen when the partition is removed?

(a) The entropy increases, and the free energy decreases.

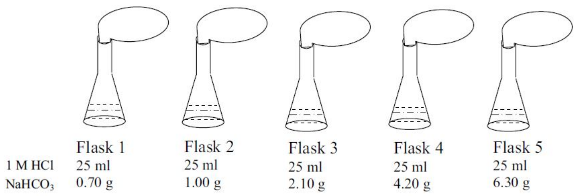
(b) The entropy decreases, and the free energy decreases.

(c) The entropy increases, and the free energy increases.

(d) The entropy decreases, and the free energy increases.

38. Each of the following flasks contains 25ml of 1M HCl solution in water. To them a certain amount of sodium bicarbonate is added and, as shown the picture, then the mouths of the flasks are quickly closed by rubber

balloons of identical size. The masses of $NaHCO_3$ added to the flask 1 through the flask 5 are 0.70 g, 1.00g, 2.10 g, 4.20 g and 6.30 g, respectively. After waiting for a sufficiently long time, predict the relative size of the 5 balloons.




(a) The Size of Balloon 1 = Balloon 2 = Balloon 3 = Balloon 4 = Balloon 5.
(b) The Size of Balloon 1 < Balloon 2 < Balloon 3 < Balloon 4 < Balloon 5.
(c) The Size of Balloon 1 < Balloon 2 < Balloon 3 = Balloon 4 = Balloon 5.
(d) The Size of Balloon 1 < Balloon 2 < Balloon 3 < Balloon 4 = Balloon 5.

39. The degeneracy of the energy level $12h^2/8ma^2$ of a particle in a three dimensional cube of length "a" is

(a) 1 (b) 3 (c) 6 (d) 12

40. Compound A is more soluble in solvent X when compared to solvent Y. X and Y are immiscible. The partitition coefficient of A between the two solvents is 10. 10 mL of a $2\times10^{-5}$M solution of A in solvent Y is mixed vigorously with 100 mL of solvent X and the two phases are allowed to separate out. The concentration of A in phase Y after the separation would be

(a) $2\times10^{-9}$ M (b) $1.98\times10^{-7}$ M (c) $2\times10^{-6}$ M (d) $1.8\times10^{-7}$ M