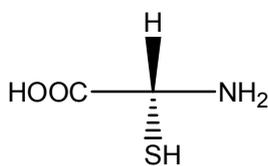
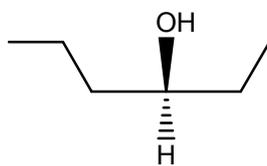


## TIFR-2012 CHEMISTRY

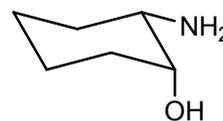
1. A quantum mechanical state Q is a superposition of two normalized energy eigenstates A and B in an amplitude ratio 2:1. If the two states are degenerate with a common eigenvalue E, what is the energy of the state Q?  
 (a) 0 (b) 3E (c) 5E (d) E
2. For the above, if the states were non-degenerate and 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  $S \rightleftharpoons P$  is catalyzed by a catalyst. The equilibrium constant  $K_{eq} = [P]/[S]$  is  $2 \times 10^3$ . The forward rate constant was found to be  $5 \times 10^4 \text{ sec}^{-1}$  and  $4 \times 10^{-6} \text{ sec}^{-1}$  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)  $5 \times 10^8 \text{ sec}^{-1}$  (b)  $2 \times 10^{-9} \text{ sec}^{-1}$  (c)  $0.8 \times 10^{-10} \text{ sec}^{-1}$  (d)  $5 \times 10^{-9} \text{ sec}^{-1}$
5. The molar extinction coefficient (at 550 nm) of compounds A and B are  $1 \times 10^4 \text{ M}^{-1} \text{ cm}^{-1}$  and  $1 \times 10^5 \text{ M}^{-1} \text{ cm}^{-1}$  respectively. Solutions of A and B are made at concentrations of  $1 \times 10^{-4} \text{ M}$  and  $2 \times 10^{-5} \text{ M}$  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)

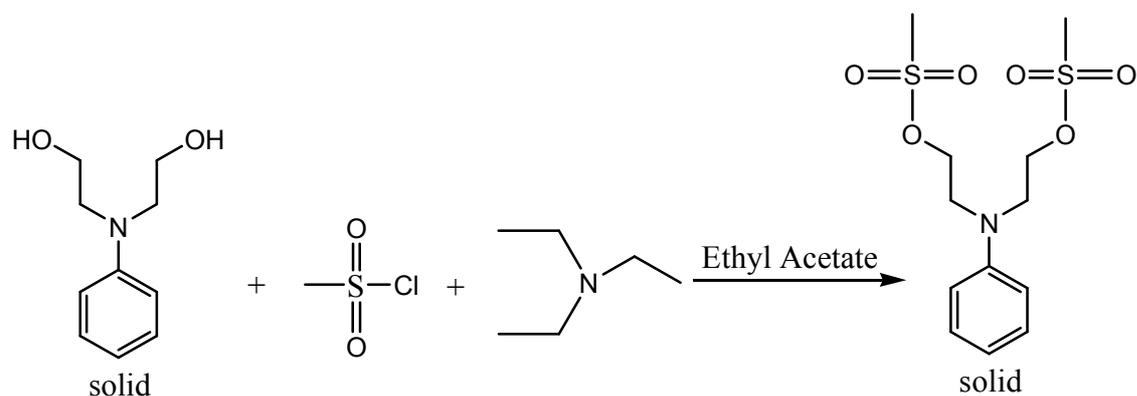


(2)



(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)  $\text{PdCl}_2$  (2)  $\text{Pd}(\text{PPh}_3)_4$  (3)  $\text{Pd}(\text{OAc})_2$  (4)  $\text{ArPdBr}$  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  $\mu\text{L}$ . The amount of starting material and the number of equivalents of each reagent is given.



Amount (mg) 100

equivalents 1

Density (g/mL)

$\mu\text{L}$

2 3

1.48 0.73

D E

(a) D = 126, E = 167

(c) D = 85, E = 229

(b) D = 0.085, E = 0.229

(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

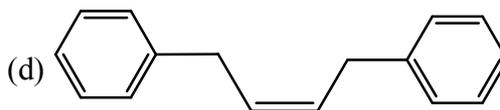
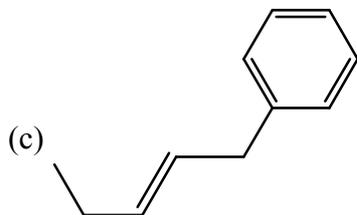
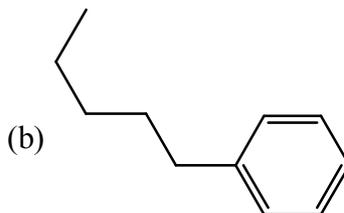
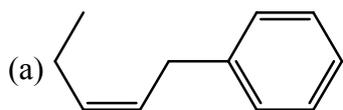
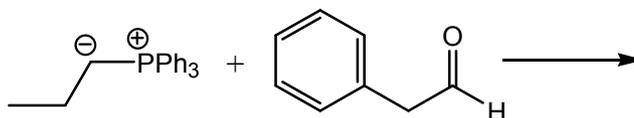
(a) Number of molecules

(b) Polarizability of the bond

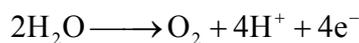
(c) Wavelength of radiation used

(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.



11. The standard redox potential of water oxidation to dioxygen is  $-1.23\text{ V}$ .



The redox potential of the same reaction at  $\text{pH} = 7$  would be

(a)  $-0.41\text{ V}$

(b)  $-1\text{ V}$

(c)  $-0.82\text{ V}$

(d)  $-1.64\text{ V}$

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 ( $\epsilon$ ) is given by (in SI units)  
 (a)  $q^2/4\pi\epsilon r$       (b)  $q^2/16\pi\epsilon r$       (c)  $q^2/4\pi\epsilon r^2$       (d)  $q^2/8\pi\epsilon r$
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

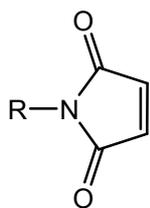
What is the order of the reaction?

- (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 25°C?
- $$\text{Glucose-1-phosphate} \rightleftharpoons \text{Glucose-6-phosphate}$$
- (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 hydrolysis 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  $^1\text{H NMR}$  spectrum shown below

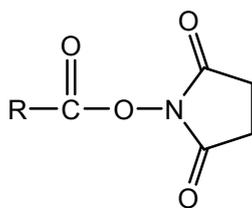


- (a)  $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{X}$       (b)  $\text{CH}_3\text{C}(\text{CH}_3)_2\text{CH}_2\text{CH}_2\text{X}$   
 (c)  $\text{CH}_3\text{CH}_2(\text{CH}_3)\text{CH}_2\text{X}$       (d)  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{X}$

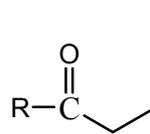
19. Which of the following compounds will react with R-SH in aqueous solutions between pH 6.5 and 8.5?



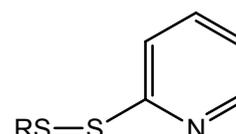
R1



R2



R3



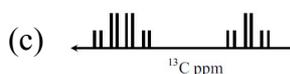
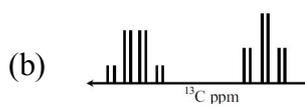
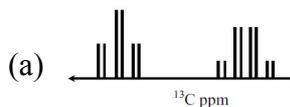
R4

- (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)  $drd\theta d\phi$       (b)  $r \sin \theta drd\theta d\phi$       (c)  $r^2 \sin^2 \theta drd\theta d\phi$       (d)  $r^2 \sin \theta drd\theta d\phi$
21. Rotational energy of a diatomic molecule is given by  $E_{\text{rot}} = J(J+1)hB_e$ , where  $E_{\text{rot}}$  is in Joules. If the rotational constant for  $\text{H}_2$  molecules is given as  $B_e = 1.8324 \times 10^{12}$  Hz, the rotational period of the  $\text{H}_2$  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 ethyl iodide 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)  $\text{Fe}^{3+}$       (b)  $\text{Co}^{3+}$       (c)  $\text{Co}^{2+}$       (d)  $\text{Cr}^{2+}$
26. In a certain axis of quantization, the z-component of the spin angular momentum,  $S_z$ , has the following matrix representation.

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



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



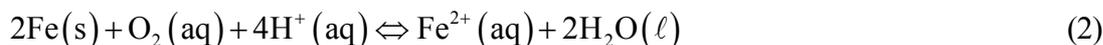
35. The roots of the equation  $x^3 + ax^2 - bx + c = 0$  are three consecutive integers. What is the maximum value of  $b$ ?

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

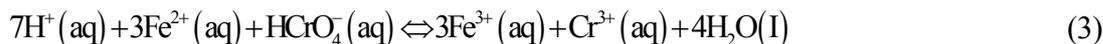
36. The corrosion of iron in contact with an acidic aqueous solution undergoes the following reaction



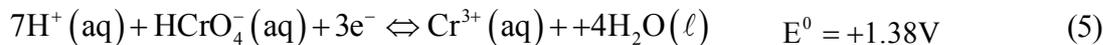
in the anaerobic condition, and the following reaction



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.



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



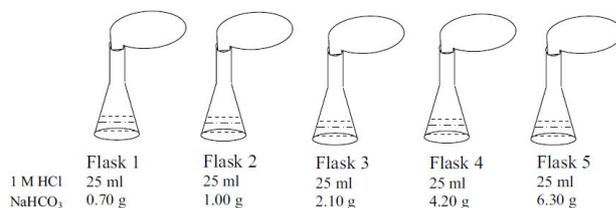
The standard potentials of these reactions are with respect to the normal hydrogen electrode. What would be the approximate value of the equilibrium constant of reaction 3 at 298K ?

(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 25°C; 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  $\text{NaHCO}_3$  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 partition coefficient of A between the two solvents is 10. 10 mL of a  $2 \times 10^{-5} \text{M}$  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)  $2 \times 10^{-9} \text{M}$                       (b)  $1.98 \times 10^{-7} \text{M}$                       (c)  $2 \times 10^{-6} \text{M}$                       (d)  $1.8 \times 10^{-7} \text{M}$