10 Surface Chemistry

• NUMERICAL PROBLEMS •

1. What would be the total surface area of a cube of edge length 1 cm? Also what would be the total surface area of the same material if it were subdivided into colloidal size cubes, each having an edge length of 10^{-7} cm ?
2. Calculate the surface area of a catalyst that adsorbs 10^3 cm^3 of nitrogen reduced to STP per gram in order to form the monolayer. The effective area occupied by N_2 molecule on the surface is 1.62×10^{-15} cm^2.
3. Calculate the volume at 300 K and 1 atm and the amount adsorbed of O_2 per g by 2g solid surface, if 4g O_2 is allowed to be adsorbed at 300 K and 0.8 atm.
4. 1.30 litre N_2 gas at 2 atm and 300 K in 1.30 litre container is exposed to 4g of solid surface. After complete adsorption the pressure of N_2 is reduced by 30%. Calculate the value of x / m.
5. 1g of activated charcoal has a surface area 10^3 m^2. If complete monolayer coverage is assumed and effective surface area of NH_3 molecule is 0.129 nm^2, how much NH_3 in cm^3 at STP could be adsorbed on 25 g of charcoal?
6. H_2 gas was adsorbed on 1 g powdered copper surface forming monolayer of molecules. On desorption total H_2 collected measured 1.36 cm^3 at STP. Assuming volume of 1 molecule of H_2 4.742×10^{-23} cm^3, calculate specific area of copper powder.
7. A solution of palmitic acid (molar mass = 256 g mol^{-1}) in benzene contains 4.24 g of acid per litre. This solution on pouring on water surface forms a monomolecular level of palmitic acid as benzene gets evaporated. If 500 cm^2 area of water surface is to be covered by a monolayer, what volume of solution in benzene is needed? Area covered by one molecule of palmitic acid is 0.21 nm^2.
8. One gram of activated charcoal has a surface area of 10^3 m^2. If complete coverage by monolayer is assumed, how much NH_3 in cm^3 at STP would be adsorbed on the surface of 25 g of the charcoal? Given diameter of NH_3 molecule = 0.3 nm.
9. 20% surface sites have adsorbed N_2. On heating N_2 gas is evolved from sites and were collected at 0.001 atm and 298 K in a container of volume 2.46 cm^3. Density of surface sites is 6.023×10^{14} cm^{-2} and surface area is 1000 cm^2. Find out the number of surface sites occupied per molecule of N_2. **(IIT 2005)**
10. 1 g of charcoal adsorbs 100 mL of 0.5 *M* CH_3COOH to form a monolayer and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = 3.01×10^2 m^2/g. **(IIT 2003)**
11. It is observed that five hours are needed to dissolve a 1 cm cube of NaCl in large amount of water. Calculate the time required for dissolution, if the cube is ground to a powder containing 10^{16} equal sized spheres. Assume that the rate of dissolution is directly proportional to initial area of contact between NaCl and water.
12. The chemisorption of H_2 on an activated surface becomes 40% faster if temperature is raised from 500 K to 1000 K. Calculate energy of activation.
13. An aqueous solution having different concentration is placed with charcoal which adsorbs a part of solute from solution as reported below at equilibrium. Calculate the value of k and n.

$C_{sol.} \times 10^2$	2.0	4.0
x / m	0.185	0.290

SOLUTIONS (Numerical Problems)

1. Surface area of cube of edge length 1 cm $= \mathbf{6 \times 1\ cm^2}$

Surface area of cube of edge length 1×10^{-7} cm

$= 6\times10^{-14}$ cm^2

Let n cubes of 6×10^{-14} cm^2 are present on breaking the cube of 6 cm^2

$\therefore$ $n\times$ volume of cube of edge length 10^{-7} cm = volume of cube of edge length 1 cm.

$$n\times\frac{4}{3}\times\pi\times[10^{-7}]^3 = \frac{4}{3}\times\pi\times(1)^3$$

$\therefore$ $\quad n = \mathbf{10^{21}}$

$\therefore$ New total surface area

$= 10^{21}\times6\times10^{-14} = \mathbf{6\times10^7}$

2. No. of N_2 molecules $= \dfrac{10^3\times6.023\times10^{23}}{22400} = 2.69\times10^{22}$

Total area covered by $N_2 = 2.69\times10^{22}\times1.62\times10^{-15}$

$= 435\times10^5$ cm^2

$= \mathbf{4350\ m^2}$

3. Mass of solid $(m) = 2$ g

Amount of O_2 adsorbed = 4g

$\therefore$ $\quad \dfrac{x}{m} = \dfrac{4}{2} = \mathbf{2\ g}$

Also V_{O_2} adsorbed at 1 atm and 300 K $= \dfrac{wRT}{Pm}$

$= \dfrac{4\times0.0821\times300}{1\times32} = 3.078$ litre

$\therefore$ $\quad V_{O_2}$ adsorbed per g $= \dfrac{3.078}{2} = \mathbf{1.539\ litre}$

4. $P_{N_2} = 2$ atm, P_{N_2} left $= \dfrac{2\times70}{100} = 1.4$ atm

$\therefore$ w_{N_2} adsorbed $= \dfrac{PV\times m}{RT} = \dfrac{(2-1.4)\times1.3\times28}{0.0821\times300} = 0.89$ g

$\therefore$ $\quad \dfrac{x}{m} = \dfrac{0.89}{4} = \mathbf{0.22\ g}$

5. Total surface area available for adsorption $= 25\times10^3$ m^2

Effective surface area of one NH_3 molecule

$= 0.129\times10^{-18}$ m^2

$\therefore$ No. of molecules of NH_3 adsorbed $= \dfrac{25\times10^3}{0.129\times10^{-18}}$

$= 1.94\times10^{23}$

$\therefore$ $\quad$ Moles of $NH_3 = \dfrac{1.94\times10^{23}}{6\times10^{23}} = 0.323$

$\therefore$ $V_{NH_3} = \dfrac{nRT}{P} = \dfrac{0.323\times0.0821\times273}{1} = 7.2395$ litre

$= \mathbf{7239.5\ cm^3}$

6. No. of molecules of H_2 in 1.36 cm$^3 = \dfrac{6.023\times10^{23}\times1.36}{22400}$

$= 3.66\times10^{19}$

$\therefore$ $\quad$ Volume of H_2 molecule $= 4.742\times10^{-23}$

$\therefore$ $\quad \dfrac{4}{3}\pi r^3 = 4.742\times10^{-23}$

$\therefore$ $\quad r = 2.246\times10^{-8}$ cm

$\therefore$ Area of cross-section of H_2 molecule $= \pi r^2$

$= 3.14\times(2.246\times10^{-8})^2$

$= 1.583\times10^{-15}$ cm^2

Area of molecules adsorbed

$= (3.66\times10^{19})\times1.583\times10^{-15}$ cm^2

= Area of adsorption of Cu powder

= specific area of Cu powder, *i.e.*, area /g.

$\therefore$ Specific area of adsorption of Cu

$= 1.583\times10^{-15}\times3.66\times10^{19}$

$= \mathbf{5.79\times10^4\ cm^2}$

7. Let V litre of solution be needed to do so

Mass of palmitic acid $= V\times d = V\times4.24$ g

Moles of palmitic acid $= \dfrac{V\times4.24}{256}$

$\therefore$ No. of molecules of palmitic acid

$= \dfrac{4.24\times V\times6.023\times10^{23}}{256}$

$\therefore$ Total area covered $= \dfrac{4.24\times V\times6.023\times10^{23}}{256}\times0.21\times10^{-18}\times10^4$ cm^2

or $\quad 500 = \dfrac{4.24\times V\times6.023\times10^{23}\times0.21\times10^{-18}\times10^4\ \text{cm}^2}{256}$

$\therefore$ $\quad V = \mathbf{2.386\times10^{-5}\ litre}$

8. Total surface area to be covered $= 25\times10^3$ m

$2r$ for $NH_3 = 0.3\times10^{-9}$ nm $= 0.3\times10^{-9}\times10^2$ cm

$= 0.3\times10^{-7}$ cm

$\therefore$ $\quad r = 1.5\times10^{-8}$ cm

$\therefore$ Surface area of 1 molecule $= \pi r^2 = 3.14\times(1.5\times10^{-8})^2$

$= 7.065\times10^{-16}$ cm^2

No. of NH_3 molecules adsorbed

$= \dfrac{25\times10^3}{7.065\times10^{-20}} = 3.539\times10^{23}$

$\therefore$ Mole of NH_3 adsorbed $= \dfrac{3.539\times10^{23}}{6.023\times10^{23}} = 0.5875$

Now using $PV = nRT$

$$V = \frac{0.05875\times0.0821\times273}{1}$$

$\therefore$ $\quad V = \mathbf{13.168\ litre}$

9. For adsorbed N_2 on surface sites

$P_{N_2} = 0.001$ atm, $V = 2.46\ \text{cm}^3 = 2.46\times10^{-3}$ litre, $T = 298$ K

$\therefore$ $\quad n_{N_2} = \dfrac{PV}{RT} = \dfrac{0.001\times2.46\times10^{-3}}{0.0821\times298} = 1.0\times10^{-7}$ mol

$\therefore$ Molecules of adsorbed $N_2 = 1.0\times10^{-7}\times6.023\times10^{23}$
$= 6.023\times10^{16}$

Total surface sites available
= Number of sites per cm^2 × Area
$= 6.023\times10^{14}\times1000 = 6.023\times10^{17}$

Surface sites on which N_2 is adsorbed
= 20% × Available sites
$= \frac{20}{100}\times6.023\times10^{17} = 12.046\times10^{16}$

$\therefore$ Number of sites adsorbed per molecule of N_2
$= \frac{12.046\times10^{16}}{6.023\times10^{16}} = \mathbf{2}$

10. Millimole of acetic acid taken $= 100\times0.5 = 50$
Millimole of acetic acid left $= 100\times0.49 = 49$
Millimole of acetic acid adsorbed $= 50-49 = 1$
Molecules of acetic acid adsorbed
$= 1\times10^{-3}\times6.023\times10^{23} = 6.023\times10^{20}$
Total area of 1 g charcoal covered by these molecules
$= 3.01\times10^{2}\ m^2$

$\therefore$ Area covered by 1 molecule $= \frac{3.01\times10^{2}}{6.023\times10^{20}}$
($\because$ unilayer adsorption)
$= \mathbf{5\times10^{-19}\ m^2}$

11. Volume of 1 cm cube $= 1cm^3$

Volume of powder in spherical shape $= 10^{16}\times\frac{4}{3}\pi r^3$

(Volume of one sphere $= \frac{4}{3}\pi r^3$)

$\therefore$ $\frac{4}{3}\pi r^3\times10^{16} = 1cm^3$

$\therefore$ $r = 2.88\times10^{-6}$

$\therefore$ Total surface area $= \pi r^2$
$= \frac{22}{7}\times(2.88\times10^{-6})^2\times10^{16} = 2.61\times10^{5}$

Initial surface area of cube $= 6\times1^2 = 6cm^2$

Rate of dissolution $\propto$ surface area or $\frac{ds}{dt} \propto$ surface area

Thus, time required for dissolution of same amount is

$$t \propto \frac{1}{\text{surface area}} \quad \therefore \quad 5 \propto \frac{1}{6}$$

$$t \propto \frac{1}{2.61\times10^{5}}$$

$\therefore$ $t = 1.15\times10^{-4}$ hr $= 1.15\times10^{-4}\times3600$ sec $= \mathbf{0.41\ sec}$

12. Rate of chemisorption at 500 K $= a$

Rate of chemisorption at 1000 K $= \frac{a\times40}{100} + a = 1.4\,a$

Since, rate $\propto \theta$ (where θ is surface covered) $= K\theta$

$\therefore$ $2.303\log\frac{K_2}{K_1} = \frac{E_a}{R}\frac{(T_2-T_1)}{T_1T_2}$

$2.303\log\frac{1.4\,a}{a} = \frac{E_a}{8.314}\left[\frac{1000-500}{1000\times500}\right]$

$E_a = 2798\ J = \mathbf{2.8\ kJ}$

13. $\log\frac{x}{m} = \frac{1}{n}\log C + \log k$

$\therefore$ $\log 0.185 = \frac{1}{n}\log 2\times10^{-2} + \log k$

$\log 0.290 = \frac{1}{n}\log 4\times10^{-2} + \log k$

Thus, $n = \mathbf{1.5312}$, $k = \mathbf{2.380}$, and $\log k = \mathbf{0.376}$

• SINGLE INTEGER ANSWER PROBLEMS •

1. How many of the following represents surface phenomenon?
   Adsorption, Surface tension, Surface energy, Viscosity, Absorption, Dissolution of soap in water, Silica gel in presence of moisture
2. 11.42 g O_2 gas is adsorbed on 2 g of metal powder. The volume of O_2 adsorbed in litre/g of metal powder at STP is .....
3. What is the surface area in cm^2 of a cube having an edge length of 1 cm ?
4. 10^a cubes of edge length 10^{-4} cm should be fused to get a cube of edge length 1 cm. What is the value of a.
5. For chemical adsorption obeying Langmuir adsorption isotherm for a given gaseous adsorbate-adsorbent system, $a = 0.6\ bar^{-1}$ and $b = 0.3\ bar^{-1}$. At what pressure 75% of the surface be covered.
6. A cationic surfactant solution shows micellization at $1.2 \times 10^{-3}\ M$. Assuming that 1 mm^3 of solution contains on an average of 2.4×10^{12} micelle particles, the number of ions present in one micelle is 3×10^a (Av. no. is 6×10^{23}). What to the value of a.

ANSWERS

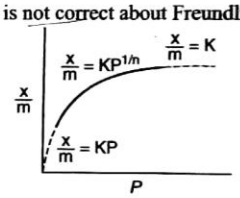
1. Five 2. Four 3. Six 4. Eight 5. Two 6. Two

OBJECTIVE PROBLEMS (One Answer Correct)

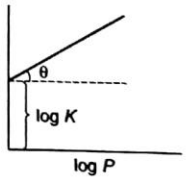
1. The gas which is more adsorbed on activated charcoal is :
   (a) SO_2 (b) N_2
   (c) O_2 (d) H_2
2. About positive catalyst or negative catalyst, which one is incorrect :
   (a) positive catalyst lowers the energy of activation
   (b) negative catalyst increases the energy of activation
   (c) positive catalyst increases the rate of reaction
   (d) negative catalyst functions to remove active intermediates
3. Which is wrong about a positive catalyst?
   (a) Lowers the energy of activation of forward reaction
   (b) Lowers the threshold energy level
   (c) Lowers the energy of activation of backward reaction
   (d) Makes the reaction more exothermic or endothermic
4. Catalytic poisoning is due to :
   (a) increasing activation energy
   (b) adsorption of poisoner on the reactants surface
   (c) adsorption of poisoners on the catalyst surface
   (d) increase in heat of reaction
5. Which is not correct about the reaction?

$$RCOCl + H_2 \xrightarrow[Pd\text{-}BaSO_4]{} RCHO + HCl$$

   (a) Pd acts as positive catalyst
   (b) It is Rosenmunds reaction
   (c) $BaSO_4$ acts as poison for Pd
   (d) $BaSO_4$ acts as promoter for Pd
6. Which of the following is not correct?
   (a) Acid hydrolysis of ester is reversible
   (b) Hydrolysis of ester becomes faster after sometime due to the formation of CH_3COOH
   (c) H^+ formed during hydrolysis acts as autocatalyst
   (d) Alkaline hydrolysis of ester is reversible
7. Select the incorrect statement :
   (a) Enzyme catalysed reactions are usually hydrolytic in nature.
   (b) Enzyme catalysed reactions takes place with evolution of gases.
   (c) The rate of reaction does not depend upon enzyme concentration.
   (d) Enzymes are colloidal in nature.
8. Which one is not correct about zeolites?
   (a) These are water softners
   (b) These do not act as molecular sieves
   (c) Zeolites are complex oxide catalyst commonly used in petrochemical industries
   (d) The activity of zeolites is increased by heating them in vacuum
9. Select the incorrect statement :
   (a) Physical adsorption is multilayer, non-directional, non-specific and decreases with temperature.
   (b) Chemical adsorption is unilayer, directional, specific and increases with temperature initially.
   (c) Rate of fruit fermentation increases with time.
   (d) Langmuir adsorption is not valid for chemisorption.
10. The lowering of activation energy by catalyst is due to :
   (a) formation of adsorbed activated complex and to provide new pathway to reaction
   (b) adsorption is always exothermic
   (c) the adsorbed activated complex possesses lower energy level than simple activated complex
   (d) all of the above
11. Which one is not correct about Freundlich isotherm if?



   (a) $n = \frac{1}{\tan\theta}$ at average pressure
   (b) $\theta = 45°$ at low pressure
   (c) $\theta = 45°$ at high pressure
   (d) $\log\left(\frac{x}{m}\right)$



12. Which statement is not correct?
   (a) Colloidal state is a particular state and not a class of compounds.
   (b) The dispersed phase may consists of a single macro molecule or an aggregate of atoms or ions.
   (c) The sol particles can be seen under microscope.
   (d) Colloidal state is an intermediate (but heterogeneous) state between true solution and suspension state.
13. Which of the following cannot be used to prepare an emulsion of benzene in water?
   (a) 
   (b) 
   (c) 
   (d) $(CH_3)_4\overset{+}{N}\,Br^-$

14. Addition of KI drop by drop to $AgNO_3$ aqueous solution gives an impure sol of AgI. The impurities needed not to be removed by dialysis is :
(a) suspended state of AgI (b) excess of $AgNO_{3(aq.)}$
(c) excess of $KI_{(aq.)}$ (d) excess of $KNO_{3(aq.)}$

15. Cementation process involves formation of :
(a) gel (b) emulsion
(c) sol (d) solid aerosol

16. Which of the following will show more intensity of scattering?
(a) Protein sol (b) Starch sol
(c) Gold sol (d) Milk

17. Alum is used in purifying water by :
(a) forming silicon complex with clay particles
(b) sulphate part combines with dirt and removes it
(c) coagulating the mud particles
(d) making mud water soluble

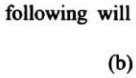
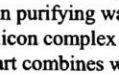
18. Which is not correct for physical adsorption?
(a) Adsorption is spontaneous
(b) Both enthalpy and entropy of adsorption are negative
(c) Adsorption on solid is reversible
(d) Adsorption increases with increase in temperature

19. Identify the correct statement regarding enzymes :
(a) Enzymes are specific biological catalysts and their action is independent of pH
(b) Enzymes are normally heterogeneous catalyst that are very specific in their action
(c) Enzymes are specific biological catalyst that cannot be poisoned
(d) Enzymes are specific biological catalysts that can normally function at very high temperature ($T = 1000$ K)

20. The volume of colloidal particles, V_c as compared to the volume of solute particles in true solution, V_s could be :
(a) ~ 1 (b) $\sim 10^{23}$
(c) $\sim 10^{-3}$ (d) $\sim 10^{3}$

21. The dispersed phase in colloidal iron (III) hydroxide and colloidal gold is positively and negatively charged respectively which of the following statement is not correct?
(a) Magnesium chloride solution coagulates gold sol readily thin iron (III) hydroxide sol
(b) Sodium sulphate solution causes coagulation in both sol
(c) Mixing of the two sols has no effect
(d) Coagulation in both sol can be brought about by electrophoresis

22. In Langmuir's model of adsorption of a gas on a solid surface:
(a) the rate of desorption of adsorbed molecules from the surface does not depend on the surface covered
(b) the adsorption at a single site on the surface may involve multiple molecules at the same time
(c) the mass of gas striking a given area of surface is proportional to the pressure of the gas
(d) the mass of gas striking a given area of surface is independent of the pressure of the gas

23. Non-electrolytic colloidal surfactant is :
(a) $C_{17}H_{35}COONa$
(b) 
(c) $C_nH_{2n+1}(OCH_2CH_2)_x.OH$
(d) 

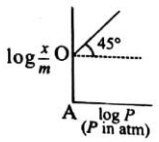
24. Gaseous adsorption on solid surface is exothermic because, adsorption brings in:
(a) increase in enthalpy
(b) increase in entropy
(c) increase in free energy
(d) interaction forces developed between gaseous molecule and solid surface

25. Adsorption of gases on solid surface depends upon:
(a) critical temperature of gas
(b) the value of van der Waals' constant of attraction
(c) pressure and temperature of gas
(d) all of these

26. Bredig's arc method involves:
(a) dispersion
(b) condensation
(c) peptization
(d) dispersion and condensation both

27. Which is not correct for an oil-water emulsion?
(a) Imparts dye colour with water soluble dye
(b) Can be diluted with water
(c) Has higher viscosity in comparison to water-oil emulsion
(d) Consists of vanishing cream

28. A graph plotted between $\log \frac{x}{m}$ *vs.* $\log P$ is shown in figure given below



If intercept is equal to log 3, then value of $\frac{x}{m}$ at a pressure of 3 atm :
(a) 2 (b) 9
(c) 6 (d) 8

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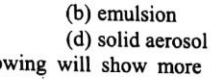
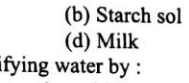
(b) 
(c) $C_nH_{2n+1}(OCH_2CH_2)_x \cdot OH$
(d) 
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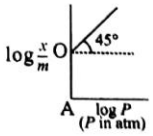


If intercept is equal to log 3, then value of $\frac{x}{m}$ at a pressure of 3 atm :
(a) 2 (b) 9
(c) 6 (d) 8
29. 50 mL of 0.3 *M* acetic acid is shaken with 5 g activated charcoal. The concentration of acetic acid is reduced to 1/3 of original molarity. The mass of acetic acid adsorbed per g of charcoal is:

(a) 2×10^{-4} g (b) 1.2×10^{-2} g
(c) 2×10^{-2} g (d) 3×10^{-2} g

30. One g of activated charcoal has total surface area equal to 10^3 m^2. If radius of a gaseous molecule is 10^{-8} cm and the gas shows only monolayer adsorption on the surface of charcoal, then volume of gas at STP adsorbed on total surface of $\frac{22}{7}$ g charcoal is:
(a) 3.73 litre (b) 7.46 litre
(c) 22.4 litre (d) 24.5 litre

31. A catalyst has total surface area of 10^3 cm^2 and adsorption sites available on it are 6×10^{15} sites/cm^2. H_2 gas is adsorbed on this surface occupying only 5% of the available sites of total surface area. On heating catalyst releases H_2 back and whole of the H_2 adsorbed is measured to occupy 2.46 mL at 0.03 atm and 300 K. The no. of H_2 molecules adsorbed on each site is equal to:
(a) 6 (b) 2
(c) 3 (d) 4

32. A cationic colloidal electrolyte forms micelle at 10^{-4} *M* concentration in water. If 1 mm^3 solution contains 10^{12} micelle structure, then the no. of cations involved in one micelle are :
(a) 20 (b) 40
(c) 60 (d) 80

33. One litre vessel having 20 g charcoal (density 2.0 g/cm^3) was filled with a gas at 300 K. The pressure of a gas was 760 torr. Due to adsorption the pressure of gas falls to 608 torr. What is the no. of gas molecule adsorbed per g of charcoal?
(a) 2.4×10^{21} (b) 2.4×10^{20}
(c) 2.4×10^{22} (d) 2.4×10^{23}

34. A negatively charged sol of $[AgI]^{I^-}$ will not be coagulated by :
(a) $[AgI]^{Ag^+}$ (sol) (b) $FeCl_3$ (aq)
(c) $[As_2S_3]^{S^{2-}}$ (sol) (d) $MgCl_2$

35. A negatively charged sol will require minimum amount of which electrolyte for its coagulation:
(a) $NaNO_3$ (b) $Mg(NO_3)_2$
(c) $Al(NO_3)_3$ (d) $Th(NO_3)_4$

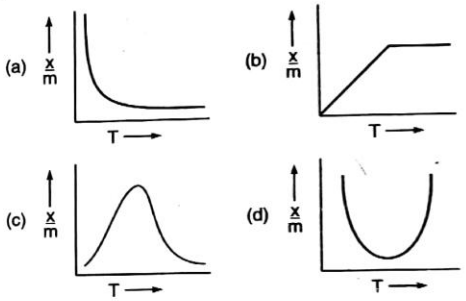
36. Gel on standing excludes small amount of liquid. The phenomenon is called :
(a) Synerisis (b) Efflorescence
(c) Adsorption (d) Thixotropy

37. The density of gold is 19 g / cm^3. If 1.9×10^{-4} g of gold is dispersed in one litre of water to give a sol having spherical gold particles of radius 10 nm, then the number of gold particles per mm^3 of the sol will be :
(a) 1.9×10^{12} (b) 6.3×10^{14}
(c) 6.3×10^{10} (d) 2.4×10^{6}

38. The heat of adsorption are ..... kJ mol^{-1} for physisorption and chemisorption respectively :
(a) 20–40, 40–400 (b) 20–40, 80–100
(c) 60–80, 80–100 (d) 80–100, 20–40

39. Number of layers formed during chemisroption is :
(a) 1 (b) 2
(c) 3 (d) 4

40. Which plot represents for chemisorption at constant pressure ?



41. 1 g charcoal show chemical adsorption of some acetic acid on coming in contact with 100 mL of 0.50 *M* acetic acid and the molarity of acetic acid is reduced to 0.49 *M*. If surface area of charcoal is 3.015×10^2 m^2/g, the surface area of each chemically adsorbed molecule of acetic acid is :
(a) 3.015×10^2 m^2 (b) 5×10^{-19} m^2
(c) 2.5×10^{-19} m^2 (d) 1.25×10^{-19} m^2

42. A plot for $\log\frac{x}{m}$ *vs* $\log P$ shows a straight line with an angle 60° and intercept of 0.3010 on *y*-axis. The amount of gas adsorbed per g of adsorbent if initial pressure is 1 atm is :
(a) 1 (b) 2
(c) 3 (d) 4

43. Efficiency of a catalyst does not depends upon :
(a) molar mass (b) free valencies
(c) physical state (d) amount used

44. Which one is correct match for catalyst used in given process ?

1. Haber's process for NH_3	A. V_2O_5 or Pt
2. Ostwald's process for HNO_3	B. NO
3. Bosch process for H_2	C. Fe + Mo
4. Chamber process for H_2SO_4	D. $Fe_2O_3 + Cr_2O_3$

(a) 1—C, 2—B, 3—A, 4—D
(b) 1—C, 2—D, 3—B, 4—A
(c) 1—C, 2—A, 3—D, 4—B
(d) 1—D, 2—A, 3—D, 4—B

45. Tetra ethyl lead minimises the knocking effect when mixed with petrol. It acts as :
(a) positive catalyst (b) negative catalyst
(c) poison (d) auto catalyst

46. Which one is correct for catalyst and poisoners used in given process?

Process		Poison
1. Hydrogenation of ethylene	A	CO
2. Hydrogenation of oils	B	Br_2 (vapours)
3. Rosenmund's reaction	C	$BaSO_4$
4. Decomposition of H_2O_2	D	HCN

(a) 1—A, 2—D, 3—B, 4—C
(b) 1—A, 2—B, 3—C, 4—D
(c) 1—A, 2—B, 3—C, 4—D
(d) 1—A, 2—D, 3—B, 4—C

47. Select the correct statements :
(i) greater is the valency of effective in electrolyte more will be coagulation power of electrolyte for a given sol.
(ii) greater is the valency of effective ion in electrolyte lesser will be its coagulation value for a given sol.
(iii) peptisation is a characteristic property of colloidal solution.
(iv) micelle formation occurs only above Kraft's temperature as well as above critical micelle concentration.
(v) lower is the gold number more is protecting power of colloid.
(a) (i), (ii), (iii) and (iv) only
(b) all of these
(c) (i), (ii), (iv) and (v) only
(d) (ii), (iii), (iv) only

48. Select the correct statements about colloids :
(i) soaps are anionic class of detergents.
(ii) butter is water dispersed in fat and milk is fat dispersed in water
(iii) floculation value is reported in milli mol/litre
(iv) during electro osmosis, dispersion medium moves in presence of electric field
(v) special methods are required for preparation of hydrophilic colloidal solution
(a) (ii), (iii) and (iv) only
(b) all of these
(c) (i), (ii), (iii) and (iv) only
(d) (ii), (iii), (iv) and (v) only

49. Select the correct statements :
(i) gold and As_2S_3 solution are multimolecular colloids and hydrophobic sols.
(ii) cleansing action of soap is due to adsorption of oily, dirt and greasy material at hydrophobic centres of soap
(iii) hydrophobic part of soap penetrates in oil and hydrophilic part in water to impart stability to emulsion
(iv) hydrophobic solution show more brighter tyndall light than hydrophilic solution
(v) conductance of soap solution changes sharply at CMC
(a) (ii), (iii), (iv) and (v) only
(b) (i), (ii), (iii) and (iv) only
(c) (i), (ii), (iii) and (v) only
(d) all of these

50. A soap of sodium stearate in solution starts micellisation at 1.2×10^{-3} *M*. A colloidal (micelle) particle, on an average contains 2.4×10^{13} molecules of soap in 1 mm^3. The average number of anions (stearate ions) is :
(a) 120 (b) 90
(c) 60 (d) 30

51. Addition of KI drop by drop to $AgNO_3$ aqueous solution gives an impure sol of AgI. The impurities needed not to be removed by dialysis is :
(a) suspended state of AgI (b) excess of $AgNO_3$ (*aq.*)
(c) excess of KI(*aq.*) (d) excess of KNO_3 (*aq.*)

52. Cementation process involves formation of :
(a) gel (b) emulsion
(c) sol (d) solid aerosol

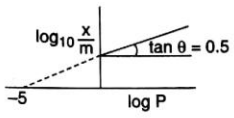
53. Which of the following will show more intensity of scattering ?
(a) Protein sol (b) Starch sol
(c) Gold sol (d) Milk

54. Alum is used in purifying water by :
(a) forming silicon complex with clay particles
(b) sulphate part combines with dirt and removes it
(c) coagulating the mud particles
(d) making mud water soluble

55. Which of the following cannot be used to prepare an emulsion of benzene in water?
(a) 
(b) 
(c) 
(d) $(CH_3)_4\overset{+}{N}Br^-$

56. Gold number of casein, haemoglobin and gelatin are 0.01, 0.03 and 0.005 respectively. Which is most powerful protecting agent?
(a) Casein
(b) Haemoglobin
(c) Gelatin
(d) All are equally having same power

57. The adsorption of a gas on metal surface obeys Freundlich adsorption isotherm : $\frac{x}{m} = KP^{1/n}$,



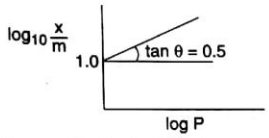
where K and n are constant and P is pressure of gas. If $\log_{10}\frac{x}{m}$ *vs* $\log P$ graph is :

The correct values of intercept and n are :

(a) 0.25, 2 (b) 0.5, 0.5

(c) 0.25, 4 (d) 0.5, 1

58. A gas showing Freundlich adsorption isotherm leads a graph between $\log_{10}\frac{x}{m}$ *vs* $\log P$ as :



The mass of N_2 gas adsorbed at 0.1 atm per g on charcoal surface is equal to :

(a) 0.0316 g (b) 0.316 g

(c) 3.16 g (d) 33.16 g

59. Which of the following gas can displace all the remaining gases from adsorbent surface :

(a) H_2 (b) N_2

(c) O_2 (d) NH_3

60. A monolayer of N_2 molecules is adsorbed on the surface of 1g of $Fe \mid Al_2O_3$ catalyst at 77 K. Upon warming the desorbed N_2 molecules occupied 2.86 cm^3 at 0°C and 760 torr. If effective area of N_2 molecules is 0.167 nm^2, what is surface area (in nm^2) of catalyst.

(a) 0.167 (b) 1.284×10^{19}

(c) 1.67×10^{19} (d) 1.40×10^{19}

61. Which one of the following statements is not correct?

(a) Catalyst does not initiate any reaction.

(b) The value of equilibrium constant is changed in the presence of a catalyst in the reaction at equilibrium.

(c) Enzymes catalyse mainly bio-chemical reactions

(d) Coenzymes increase the catalytic activity of enzyme.

SOLUTIONS (One Answer Correct)

1. (a) Lower is the critical temperature of gas, more are van der Waals' forces of attractions among gaseous molecules, more is adsorption.

2. (b) Working of negative catalyst is their nature to terminate the chain reaction.

3. (d) Catalyst cannot make the reaction more exothermic or endothermic; $\Delta H = E_{a(f)} - E_{a(b)}$.

4. (c) Negative catalyst is adsorbed on the surface of catalyst to make it inert.

5. (d) $BaSO_4$ deactivates the activity of Pd so that —CHO formed is not oxidised to —COOH.

6. (d) Alkaline hydrolysis of ester also called saponification is irreversible.

7. (c) The rate of enzyme catalysed reaction depends upon enzyme concentration.

8. (b) Zeolites are shape selective catalyst. The ions or molecules of the right size can be adsorbed by them and thus they act as molecular sieves.

9. (d) Langmuir adsorption is valid for chemisorption.

10. (d) All these leads to lower energy of activation.

$$R \longrightarrow \underset{\text{activated complex}}{\text{Intermediate}} \longrightarrow \text{Product}$$

$$R + C \longrightarrow \underset{\text{adsorbed - activated complex; } \Delta H = -\text{ve}}{\text{Intermediate}} \longrightarrow \text{Product}$$

11. (c) At high pressure $\frac{x}{m} = K$

12. (c) Sol particles are not detected even in microscope.

13. (d) Surface active agents are used as emulsifiers. The surface active agents must have hydrophobic chain $(R) \geq 5$.

14. (a) Dialysis is used to remove soluble impurities present in sol.

15. (a) Water is dispersed in silica and other components of cement.

16. (c) Gold sol is lyophobic and it will show more scattering due to larger size of gold particles and more $\Delta\mu(\mu_G \sim \mu_{\text{water}})$.

17. (c) Alum contains trivalent Al^{3+} which coagulates negative sol of clay and dirt in water.

18. (d) Adsorption decreases with increase in temperature because increase in temperature leads to increase in kinetic energy of molecules.

19. (b) It is a fact.

20. (d) $\frac{V_c}{V_s} = \frac{\frac{4}{3}\pi r_c^3}{\frac{4}{3}\pi r_s^3} = \frac{r_c^3}{r_s^3} = \left(\frac{10}{1}\right)^3 = 10^3$

Diameter of sol particles $\simeq$ 10 Å.

Diameter of true solution particle $\simeq$ 1 Å.

21. (c) Mixing of +ve and −ve sols causes mutual coagulation.

22. (c) According to Langmuir, $\frac{x}{m} \propto P$

(specifically for chemisorption)

23. (c) It does not possess ionisable species.

24. (d) Attraction always leads to decrease in heat enthalpy and thus ΔH = –ve.

25. (d) Higher is the value of a, T_c, P, more will be adsorption.

26. (d) First of all on passing electric arc, metal vapours are formed (dispersion) which are than condensed in water to form sol particles.

27. (c) Water in oil emulsions (butter) are more viscous than oil in water (milk) emulsion.

28. (b) $OA = \log \frac{x}{m}$ at $\log P = 0$, *i.e.*, at $P = 1$, $\log \frac{x}{m} = \log 3$

$\therefore \frac{x}{m} = K = 3$; $\because \frac{x}{m} = KP^{1/n}$ and $n = 1$ ($\tan\theta = 1$)

if $P = 3$ atm then $\frac{x}{m} = 3 \times 3 = 9$

29. (b) Initial milli mole = $50 \times 0.3 = 1.5$

milli mole left after adsorption = $50 \times 0.3 \times \frac{1}{3} = 0.5$

$\therefore$ milli mole of acid adsorbed = $1.5 - 0.5 = 1.0$

$\therefore$ mole of acid adsorbed = 1.0×10^{-3}

mole adsorbed per g = $\frac{1.0 \times 10^{-3}}{5} = 2 \times 10^{-4}$

mass adsorbed per g = $2 \times 10^{-4} \times 60 = 0.012$ g

30. (a) Total surface area of $\frac{22}{7}$ g charcoal

$$= \frac{22}{7} \times 10^3 \text{ m}^2 = \frac{22}{7} \times 10^7 \text{ cm}^2$$

Total surface area of one molecule of gas

$$= \pi r^2 = \frac{22}{7} \times 10^{-16} \text{ cm}^2$$

$\therefore$ No. of gaseous molecules adsorbed on charcoal surface = $\frac{\frac{22}{7} \times 10^7}{\frac{22}{7} \times 10^{-16}} = 10^{23}$

$\therefore$ mole of gas adsorbed = $\frac{10^{23}}{6 \times 10^{23}} = \frac{1}{6}$

$\therefore$ $V = \frac{22.4}{6} = 3.73$ litre

31. (a) Total mole of H_2 adsorbed

$$= \frac{PV}{RT} = \frac{0.03 \times 2.46 \times 10^{-3}}{0.0821 \times 300} = 3 \times 10^{-6}$$

$\therefore$ No. of H_2 molecules adsorbed

$$= 3 \times 10^{-6} \times 6 \times 10^{23} = 18 \times 10^{17}$$

Total no. of sites available

$$= 6 \times 10^{15} \times 10^3 = 6 \times 10^{18}$$

18×10^{17} molecules were adsorbed on

$$\frac{6 \times 10^{18} \times 5}{100} \text{ sites} = 3 \times 10^{17} \text{ sites}$$

$\therefore$ No. of H_2 molecules/site = 6

32. (c) No. of particles of cationic colloidal electrolyte/litre before micelle formation = $10^{-4} \times 6 \times 10^{23} = 6 \times 10^{19}$

$\therefore$ No. of particles of cationic colloidal electrolyte/mm^3 = $6 \times 10^{19} \times 10^{-6} = 6 \times 10^{13}$

Number of micelles formed = 10^{12}/mm^3

$\therefore$ Number of cations in one micelle = $\frac{6 \times 10^{13}}{10^{12}} = 60$

33. (b) Volume occupied by charcoal = $\frac{20}{2.0} = 10$ cm^3

Volume of container left for gas = $1000 - 10 = 990$ cm^3

Moles of gas adsorbed

$$= \frac{(760 - 608) \times 990}{760 \times 1000 \times 0.0821 \times 300} = 8.04 \times 10^{-3} \text{ mole}$$

$\therefore$ Molecules of gas adsorbed

$$= 8.04 \times 10^{-3} \times 6 \times 10^{23} = 4.8 \times 10^{21}$$

$\therefore$ Molecules of gas adsorbed per g

$$= \frac{4.8 \times 10^{21}}{20} = 2.4 \times 10^{20}$$

34. (c) Negative sols are either coagulated by +ve sol or by electrolyte.

35. (d) Higher is the valency of effective ion (carrying charge opposite to sol particles) more is coagulating power, lesser is coagulating value.

36. (a) Spontaneous outcome of internal liquid (Dispersed phase) from a gel a called synerisis, whereas outcome of internal liquid from a gel on shear is called thixotropy.

37. (d) Volume of gold used = $\frac{m}{d} = \frac{1.9 \times 10^{-4}}{19} = 1 \times 10^{-5}$ cm^3

Volume of one gold particle = $\frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times \frac{22}{7} \times (10 \times 10^{-7})^3$$

$$= 4.19 \times 10^{-18} \text{ cm}^3$$

$\therefore$ Total no. of particles = $\frac{1 \times 10^{-5}}{4.19 \times 10^{-18}} = 2.4 \times 10^{12}$

Thus 2.4×10^{12} particles of gold are present in 1 litre or 10^{-3} m^3.

$\therefore$ Number of particles per mm^3 = $\frac{2.4 \times 10^{12}}{10^{-3} \times 10^9}$

$$= 2.4 \times 10^6$$

38. (b) This is a fact, chemisorption is stronger than physisorption.

39. (a) Chemisorption is unilayer.

40. (c) Chemisorption first increases and then decreases with temperature.

41. (b) milli mole of acetic acid used = $100 \times 0.5 = 50$

milli mole of acetic acid left = $100 \times 0.49 = 49$

Thus milli mole of acetic acid adsorbed = $50 - 49 = 1$

$\therefore$ Molecules of acetic acid adsorbed

$$= 6.023 \times 10^{23} \times 1 \times 10^{-3}$$

$$= 6.023 \times 10^{20}$$

$\therefore$ Surface area of one molecule adsorbed = $\frac{3.015 \times 10^2}{6.023 \times 10^{20}} = 5 \times 10^{-19}$ m^2

42. (b) $\tan 60° = 1.73 = \frac{1}{n}$ (slope of $\log \frac{x}{m} = \frac{1}{n} \log P + \log K$)

$\log K = 0.3010$

$\therefore \quad \log \frac{x}{m} = 0.3010 + 1.73 \log 1$

$\log \frac{x}{m} = 0.301$

$\therefore \quad \frac{x}{m} = 2$

43. (a) Molar mass has no role on efficiency of catalyst.

44. (c) These are facts.

45. (b) TEL acts as negative catalyst for combustion of petrol.

46. (b) This is fact.

47. (c) Peptisation is a method to prepare sol.

48. (c) Special methods are required for preparation of hydrophobic solutions.

49. (d) Gold and As_2S_3 are hydrophobic, less stable solutions.

50. (d) 1 litre soap solution contains 1.2×10^{-3} mole of soap or 10^6 mm^3 soap solution contains 1.2×10^{-3} mole $= 1.2 \times 10^{-3} \times 6 \times 10^{23}$ molecules of soap

or 1 mm^3 soap solution contains 7.2×10^{14} molecules of soap

$\because$ 1 mm^3 of colloidal particle contains 2.4×10^{13} molecules of soap

$\therefore$ No. of colloidal particles or micelle formed $= \frac{7.2 \times 10^{14}}{2.4 \times 10^{13}} = 30$

51. (a) Dialysis is used to remove soluble impurities present in sol.

52. (a) Water is dispersed in silica and other components of cement.

53. (c) Gold sol is hydrophobic and it will show more scattering due to larger size of gold particles and more $\Delta\mu (\mu_G \sim \mu_{water})$.

54. (c) Alum contains trivalent Al^{3+} which coagulates negative sol of clay and dirt in water.

55. (d) Surface active agents are used as emulsifiers. The surface active agents must have hydrophobic chain $(R) \geq 5$.

56. (c) Higher is gold no. lesser is protecting power.

57. (a) $\log_{10} \frac{x}{m} = \log K + \frac{1}{n} \log P$

$\frac{1}{n} = 0.5$

$\therefore \quad n = 2$

$\because \quad \log_{10} \frac{x}{m} = 0, \quad$ at $\log P = -5$

Also, $0 = \log K + \frac{1}{2} \times (-0.5)$

$\log K = 0.25 \quad$ (intercept)

58. (c) $\log \frac{x}{m} = \log K + \frac{1}{n} \log P$

$\because \quad \tan \theta = 0.5 \quad \therefore \quad n = 2$

$\log \frac{x}{m} = 1 + \frac{1}{2} \log 0.1$

$\log \frac{x}{m} = 1 + \frac{1}{2} \times (-1.0) = 0.5$

$\therefore \quad \frac{x}{m} = 3.16$

$m = 1 \quad \therefore \quad x = 3.16$

59. (d) NH_3 being polar possesses preferential adsorption. Preferential order of adsorption of some gases is $SO_2 > NH_3 > HCl > CO$

60. (b) $V_{N_2} = 2.86 cm^3$ at NTP

Thus, $n_{N_2} = \frac{6.023 \times 10^{23} \times 2.86}{22400} = 7.69 \times 10^{19}$

$\therefore$ Surface area of catalyst $= 7.69 \times 10^{19} \times 0.167 \, nm^2$

$= 1.284 \times 10^{19} \, nm^2$

61. (b) Catalyst does not affect the value of equilibrium constant.

• PREVIOUS YEARS PROBLEMS •

1. In multimolecular colloidal sol, atoms or molecules are held together by :
   (a) H-bonding (b) van der Waals' forces
   (c) ionic bonding (d) covalent bonding
2. Rate of physisorption increases with : **(IIT 2003)**
   (a) decrease in temperature (b) increase in temperature
   (c) decrease in pressure (d) decrease in surface area
3. Adsorption of gases on solid surface is generally exothermic because : **(IIT 2004)**
   (a) enthalpy is positive (b) entropy decreases
   (c) entropy increases (d) free energy increases
4. Lyophilic sols are : **(IIT 2005)**
   (a) irreversible sols
   (b) they are prepared from inorganic compounds
   (c) not coagulated by adding electrolytes
   (d) self stabilizing
5. Pick out the wrong statement : **(IIT 2007)**
   (a) Micelles are formed by surfactant molecules above the cmc.
   (b) The conductivity of a solution having surfactant molecules decreases sharply at the cms.
   (c) Lower is the cmc of detergent, more is its detergency.
   (d) Cleansing action is not related to micelle.
6. Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient conditions is : **(IIT 2008)**
   (a) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$
   (b) $CH_3(CH_2)_{11}OSO_3^-Na^+$
   (c) $CH_3(CH_2)_6COO^-Na^+$
   (d) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$
7. Among the electrolytes Na_2SO_4, $CaCl_2$, $Al_2(SO_4)_3$ and NH_4Cl the most effective coagulating agent for Sb_2S_3 sol is : **(IIT 2009)**
   (a) Na_2SO_4 (b) $CaCl_2$
   (c) $Al_2(SO_4)_3$ (d) NH_4Cl
8. The coagulating power of electrolytes having ions Na^+, Al^{3+} and Ba^{2+} for arsenic sulphide solution increases in the order : **[JEE (Main) 2013]**
   (a) $Ba^{2+} < Na^+ < Al^{3+}$ (b) $Al^{3+} < Na^+ < Ba^{2+}$
   (c) $Al^{3+} < Ba^{2+} < Na^+$ (d) $Na^+ < Ba^{2+} < Al^{3+}$
9. Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25°C. For this process, the correct statement is : **[JEE (Advanced) II 2013]**
   (a) The adsorption requires activation at 25°C
   (b) The adsorption is accompanied by a decrease in enthalpy
   (c) The adsorption increases with increase of temperature
   (d) The adsorption is irreversible
10. 3 g of activated charcoal was added to 50 mL of acetic acid solution (0.06 N) in a flask. After an hour it was filtered and the strength of the filtrate was found to be 0.042 N. The amount of acetic acid adsorbed (per gram of charcoal) is : **[JEE (Main) 2015]**
    (a) 18 mg (b) 36 mg
    (c) 42 mg (d) 54 mg
11. For a linear plot of $\log(x/m)$ *versus* $\log p$ in a Freundlich adsorption isotherm, which of the following statements is correct? (k and n are constants) **[JEE (Main) 2016]**
    (a) $1/n$ appears as the intercept
    (b) Only $1/n$ appears as the slope
    (c) $\log(1/n)$ appears as the intercept
    (d) Both k and $1/n$ appear in the slope term
12. Which of the following is an anionic detergent? **[JEE (Main) 2016]**
    (a) Sodium lauryl sulphate
    (b) Cetyltrimethyl ammonium bromide
    (c) Glyceryl oleate
    (d) Sodium stearate
13. The Tyndall effect is observed only when following conditions are satisfied : **[JEE (Main) 2017]**
    (1) The diameter of the dispersed particles is much smaller than the wavelength of the light used
    (2) The diameter of the dispersed particle is not much smaller than the wavelength of the light used
    (3) The refractive indices of the dispersed phase and dispersion medium are almost similar in magnitude
    (4) The refractive indices of the dispersed phase and dispersion medium differ greatly in magnitude
    (a) (1) and (4) (b) (2) and (4)
    (c) (1) and (3) (d) (2) and (3)

SOLUTIONS (Previous Years Problems)

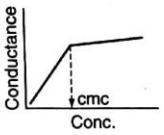
1. (b) It is a fact.

2. (a) Adsorption is exothermic.

3. (b) Randomness decreases during adsorption.

4. (d) Lyophilic sols usually organic, self stabilizing because there sols are reversible and are highly hydrated in solution.

5. (d) Cleansing action is due to micellisation and emulsifying action. Also point (b) is wrong because at cmc, conductivity of solution either becomes constant or show a little increase after cmc with increasing concentration of surfactant.



6. (a) Larger is the hydrophobic chain, lesser is cmc.

7. (c) As_2S_3 is negative sol. Higher is the valence of effective ion (*i.e.*, positive ion) more is coagulating power.

8. (d) Greater is the charge on effective ion (carrying +ve charge) opposite to charge on sol (As_2S_3 is –ve sol) more is coagulating power. This is Hardy-Schulze rule.

9. (b) Adsorption is physisorption and hence energy of activation is not required. Physisorption is exothermic and reversible and it decreases with increase in temperature.

10. (a) meq. of acetic acid present = $50 \times 0.06 = 3$

meq. of acetic acid left = $50 \times 0.042 = 2.1$

meq. of acetic acid adsorbed = $3 - 2.1 = 0.9$

Thus weight of acetic acid adsorbed

$$= \frac{0.9 \times 60}{1000} = 0.054$$

$\therefore$ Weight of acetic acid adsorbed per gram charcoal

$$= \frac{0.054}{3} = 0.018 = 18 \text{ mg}$$

11. (b) According to the Freundlich Adsorption Isotherm

$$\frac{x}{m} = kP^{1/n}$$

$$\log \frac{x}{m} = \log K + \frac{1}{n} \log P$$

$\log \frac{x}{m}$ *vs.* $\log p$ plots leads to straight line with slope $1/n$.

12. (a,d)

Sodium lauryl sulphate = detergent, anionic

(The anionic part undergoes aggregation)

Cetyltrimethyl ammonium bromide = detergent, cationic

(The cationic part undergoes aggregation)

Glyceryl oleate = detergent, non-ionic

(Whole undergoes aggregation)

Sodium stearate = soap, anionic

(The anionic part undergoes aggregation)

Note : Soaps are also anionic class of detergents and thus question has two answers (a) and (d).

13. (b) More is $\Delta\mu$ (*i.e.*, $\mu_{DP} \sim \mu_{DM}$) more is scattering. Also larger is size of dispersed phase, more is scattering.

OBJECTIVE PROBLEMS (More Than One Answer Correct)

1. Select the correct statements :
   (a) Lamp black in water is passed in colloid state on addition of gum.
   (b) White precipitate of $BaSO_4$ on washing continuously with water gives $BaSO_4$ sol.
   (c) Electrodialysis is used to remove ionic impurities faster.
   (d) Brownian motion was noticed in colloidal solution by Brown.
2. Which statements are correct about colloidal solution?
   (a) Coagulating value $\propto \frac{1}{\text{Coagulating power}}$
   (b) Coagulating value $\propto$ Charge on effective ion
   (c) Gold number $\propto \frac{1}{\text{Protective power}}$
   (d) Scattering $\propto \frac{1}{\lambda^4}$
3. Which statements are correct?
   (a) Addition of $Fe(OH)_3$ sol to As_2S_3 sol brings in mutual coagulation.
   (b) Addition of $[AgI]^{Ag^+}$ sol to $[AgI]^{I^-}$ sol brings in mutual coagulation.
   (c) Cloud Burst is due to mutual coagulation.
   (d) $Th(NO_3)_4$ cannot coagulate +ve sol.
4. Which are correct regarding stability of sol?
   (a) Lyophilic sols are stabilised due to a layer of solvent round sol particles
   (b) Lyophobic sols are stabilised due to presence of charge
   (c) Addition of lyophilic brings in more stability to lyophobic
   (d) Addition of lyophobic brings in more stability to lyophobic
5. Select the correct statements :
   (a) Blood is positively charged.
   (b) Haemoglobin particles in blood carry +ve charge.
   (c) $FeCl_3$ is very good coagulant for blood.
   (d) Blood is categorised in sol category.
6. Which are not examples of autocatalysis?
   (a) Breakdown of atomic fuel in reactor
   (b) Shock decomposition of glycerol trinitrate
   (c) ZSM-5 used to convert alcohol in petrol
   (d) Storage of chloroform along with little ethanol
7. Which are characteristic of adsorption?
   (a) Exothermic (b) Decreases entropy
   (c) Spontaneous (d) $\Delta H \gtrless T\Delta S$
8. Select the correct statements :
   (a) Gold sol prepared by different methods has altogether different colours due to size of gold particles in water.
   (b) The potential difference between fixed layer and movable layer is called zeeta potential.
   (c) At CMC, surfactant molecules undergo aggregation to form micelle.
   (d) Micelle formation is independent of temperature.
9. Select the correct statements :
   (a) Medicines are more effective in colloidal state due to smaller surface area.
   (b) The spontaneous outcome of internal liquid phase from gels is called weaping of gels or syneresis.
   (c) The outcome of internal liquid phase on shear from gels is called thixotropy.
   (d) The detergency action of detergents is due to their emulsifying nature and micellisation.
10. Select the correct statements :
    (a) Surface active agents possess surface activity to lower the surface area, *i.e.*, to reduce the surface energy.
    (b) Detergents possesses the property of surface activity and detergency.
    (c) All the surfactants are detergents.
    (d) Soaps are anionic class of surfactant.
11. A catalyst is a substance that :
    (a) helps in attaining equilibrium faster if any
    (b) increases the rate of forward and backward reaction (if any)
    (c) lowers the threshold energy level
    (d) provides new pathway to reaction
12. A catalyst :
    (a) lowers the energy of activation
    (b) makes the reaction more exothermic
    (c) makes the reaction less endothermic
    (d) has no effect on the magnitude of equilibrium constant
13. Which of the following are correct?
    (a) Silica gel adsorbs H_2O
    (b) $CaCl_2$ anhy. adsorbs H_2O
    (c) Gas masks works on the principle of selective adsorption
    (d) Zeolites are shape selective catalyst and water softners
14. Select the correct statements :
    (a) Physical adsorption is weak, multilayer, non-directional and non-specific.
    (b) Chemical adsorption is strong, unilayer, directional and strong.
    (c) Adsorption decreases with temperature.
    (d) Chemical adsorption is more stronger than physical adsorption.
15. Select the correct statements about adsorption :
    (a) $\Delta G = -$ ve (b) $\Delta H = -$ ve
    (c) $\Delta S = -$ ve (d) $\Delta G > T\Delta S$
16. Spontaneous adsorption of H_2 on glass surface also involves the change $H_2 \rightarrow 2H$ during adsorption. Which are correct for adsorption of H_2 on glass surface?
    (a) $\Delta H = +$ ve (b) $\Delta S = +$ ve
    (c) $T\Delta S > \Delta H$ (d) $\Delta G = -$ ve

17. Which one is not correct about Freundlisch adsorption isotherms if $\frac{x}{m}$ is amount adsorbed per unit mass of adsorbent?
(a) $\frac{x}{m} \propto (P)^{1/n}$
(b) $\log \frac{x}{m} = \log K + \frac{1}{n} \log P$
(c) $\frac{x}{m} \propto P$ (at V. low P)
(d) $\frac{x}{m} = K$ (at V. high P)

18. Which reactions represents heterogeneous catalysis?
(a) Decomposition of $KClO_3$ in presence of MnO_2
(b) Ostwald process for HNO_3
(c) Contact process for H_2SO_4
(d) Acidic hydrolysis of ester

19. Select the correct statements :
(a) Enzyme catalysed reactions are highly specific
(b) Enzyme catalysed reactions are highly susceptible to pH and temperature
(c) Decomposition of glycerol trinitrate is an example of autocatalysis
(d) The acid hydrolysis and alkaline hydrolysis of ester are reversible

20. Which of the following are correct about Langmuir adsorption isotherm at very high pressure?
(a) It is valid for chemisorption
(b) $\frac{x}{m} = \frac{a}{b}$
(c) $\ln \frac{x}{m} = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT}$
(d) At very high pressure rate of adsorption > rate of desorption

21. What happens when detergent is added to water?
(a) Surface tension increase
(b) Surface tension decrease
(c) Viscosity increases
(d) Viscosity decreases

22. Which of the following are true for hydrophilic solution?
(a) They do not require electrolytes for stability
(b) Their coagulation is irreversible
(c) Their surface tension is usually lower than water
(d) Their viscosity is of the order of water

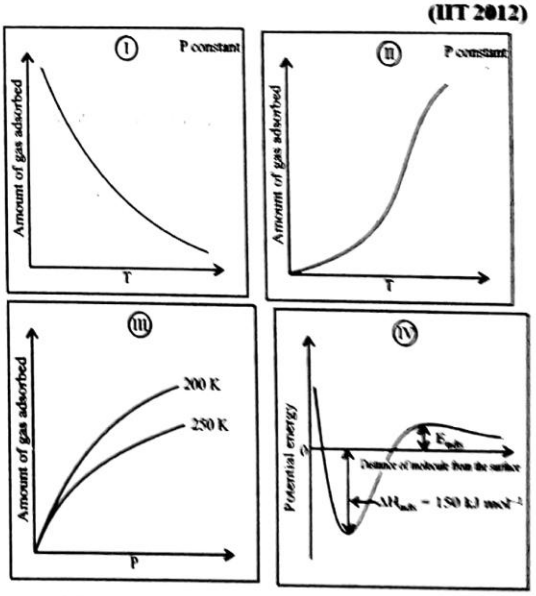
23. Which of the following statements is correct for the spontaneous adsorption of a gas ?
(a) ΔS is negative and therefore, ΔH should be highly positive
(b) ΔS is negative and therefore, ΔH should be highly negative
(c) ΔS is positive and therefore, ΔH should be negative
(d) ΔS is positive and therefore, ΔH should also be highly positive

24. Select the correct statement :
(a) Sols are destabilized by ageing and coagulation
(b) Spontaneous destabilization of sol is ageing
(c) Spontaneous destabilization is coagulation
(d) Electrolytes cause coagulation of sol

25. The correct statement (s) pertaining to the adsorption of a gas on solid surface is (are) : **(IIT 2011)**
(a) Adsorption is always exothermic
(b) Physisorption may transform into chemisorption at high temperature
(c) Physisorption increases with increasing temperature but chemisorption decreases with increasing temperature
(d) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation

26. Choose the correct reason(s) for the stability of the lyophobic colloidal particles. **(IIT 2012)**
(a) Preferential adsorption of ions on their surface from the solution
(b) Preferential adsorption of solvent on their surface from the solution
(c) Attraction between different particles having opposite charges on their surface
(d) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles

27. The given graphs/data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and pressure. Which of the following choice(s) about I, II, III and IV is (are) correct? **(IIT 2012)**



(a) I is physisorption and II is chemisorption
(b) I is physisorption and III is chemisorption
(c) IV is chemisorption and II is chemisorption
(d) IV is chemisorption and III is chemisorption

28. The correct statement(s) about surface properties is (are):
(a) cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium
(b) adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system
(c) brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution
(d) the critical temperatures of ethane and nitrogen are 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen on same amount of activated charcoal at a given temperature

SOLUTIONS (More Than One Answer Correct)

1. (a,b,c) Brownian motion was no doubt given by *R.* Brown in pollen grains suspended in water. However the phenomenon was noticed in colloidal solution by Zsigmondy using ultramicroscope.

2. (a,c,d) More is the charge on effective ion (ion having charge opposite to sol), more is its coagulating power, lesser is coagulating value.

3. (a,b,c) Th^{4+} coagulates –ve sol whereas NO_3^- coagulates +ve sol.

4. (a,b,c) Protection is the property of lyophilic.

5. (a,b,c) Blood is emulsion.

6. (a,c,d) Due to the mixture of gases which acts as autocatalyst.

$$4C_3H_5(ONO_2)_3 \longrightarrow 12CO_2 + 10H_2O + 6N_2 + O_2$$

7. (a,b,c,d) Adsorption is spontaneous only when $T\Delta S < \Delta H$. $\Delta G = \Delta H - T\Delta S$

8. (a,b,c) Micelle formation occurs below Kraft point. Each surfactant has its own Kraft temperature.

9. (a,b,c,d) No doubt medicines are more effective in colloidal solution. It is due to larger surface area available for adsorption.

10. (a,b,d) All the detergents are surfactants. The reverse is not true.

11. (a,b,c,d) All are facts.

12. (a,d) —do—

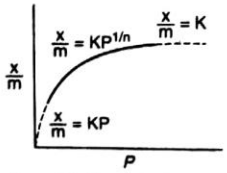
13. (a,c,d) $CaCl_2$ adsorbs H_2O.

14. (a,b,d) Chemisorption first increases with temperature as it requires energy of activation.

15. (a,b,c,d) $\Delta G = \Delta H - \Delta S \times T$ ΔH is always –ve and ΔS = – ve for adsorption.

16. (a,b,d) ΔG = – ve

17. (a,b,c,d) According to Freundlich : $\frac{x}{m} = KP^{1/n}$



18. (a,b,c) In acidic hydrolysis *R* and catalyst (H^+) both are miscible liquids.

19. (a,b,c) Alkaline hydrolysis of ester (saponification) is irreversible.

20. (a,b,c) At very high pressure rate of adsorption = rate of desorption. This $\frac{x}{m} = \frac{a}{b} = K_{eq.}$ or eq. is attained.

$$\Delta G^\circ = -2.303\,RT \log \frac{x}{m}$$

$$\Delta H^\circ - T\Delta S^\circ = -2.303\,RT \log \frac{x}{m}$$

21. (b,c) These are facts.

22. (a,c) These are facts.

23. (b) For spontaneous adsorption ΔS = –ve, ΔH = highly –ve. Thus ΔG = –ve.

24. (a,b,d) Destabilization of sol by artificial means is called coagulation.

25. (a,b,d) Chemisorption first increases than decreases with temperature. Physisorption decreases with temperature.

26. (a,d) Lyophobic sols are stable due to preferential adsorption of ions on their surface from solution and potential difference arised between the fixed layer and the diffused layer of opposite charges around the colloidal particles provides stability to lyophobic sol.

27. (a,c) Graph (I) and (III) represent physisorption because, in physisorption, the amount of adsorption decreases with the increase of temperature and increases with the increase of pressure.
Graph (II) represents chemisorption, because in chemisorption amount of adsorption increase with the increase of temperature. Graph (IV) represents the minima is potential energy at short distance and thus involves chemisorption. In physisorption, minima or potential energy is noticed at long distance.

28. (b,d) Adsorption is an exothermic process and is accompanied by decrease is entropy
ΔH_{sys} = –ve ; ΔS_{sys} = –ve
More is critical temperature (T_c), more are intermolecular forces of attraction and thus more will be adsorption clouds which are liquid dispersed in gas (aerosol) Brownian motion also depends on size of sol particles

COMPREHENSION BASED PROBLEMS

Comprehension 1 : The catalytic activity and colloidal nature of a substance area surface phenomenon. Both these properties depend upon the property of adsorption. Adsorption may be physisorption or chemisorption. Adsorption is spontaneous and always leads to decrease in entropy along with evolution of heat. Chemisorption is irreversible with temperature, unilayer, specific and directional. Adsorbate molecules adsorb on catalyst surface and thus, lower the energy of activation of reaction to provide a new pathway for reaction. In colloidal state dispersed phase particles possess the adsorption characteristics at the interface.

[A] Select the correct statements :

1. Adsorption is spontaneous at all the temperatures.
2. Gases having high critical temperature possess more tendency for adsorption.
3. An adsorbent possesses more tendency for adsorption if it is in colloidal state.
4. Chemical adsorption first decreases with increase in temperature and then increases.
5. Water molecules are adsorbed in $CaCl_2(s)$.

(a) 1, 2, 3, 4, 5 (b) 2, 3, 4
(c) 1, 2, 3, 4 (d) 2, 3

[B] Which statements are correct?

1. Addition of $AgNO_3$ drop by drop in excess of KI leads to the formation of +vely charged sol of AgI.
2. Adsorption characteristic of an adsorbent may be increased by passing it in finely divided form.
3. Catalyst helps in attaining the equilibrium earlier but does not influence equilibrium constant in reversible reactions.
4. Decolorisation of raw sugar is based on absorption.
5. Gas masks containing animal charcoal act on the basis of selective adsorption.
6. The micelle formation of soaps depends upon hydrophobic and hydrophilic entities present in soap.

(a) 2, 3, 5, 6 (b) 2, 3, 4, 5
(c) 1, 2, 5, 6 (d) 1, 2, 3, 4

SOLUTIONS

Comprehension 1

[A] (b)

1. Adsorption decreases with increase in temperature but $\Delta G = -$ve at high temperature,
   $\Delta H = -$ve and $\Delta S = -$ve, thus $T\Delta S = -$ve.
   $\therefore\ \Delta G = \Delta H - T\Delta S = -\text{ve} - (-\text{ve}) =$ less negative
2. Gases having high critical temperature are easily liquefiable due to higher forces of attractions among molecules and thus, also show more adsorption.
3. Adsorption extent of an adsorbent is more if its surface area is more.
4. Chemisorption requires energy of activation.
5. H_2O is absorbed in $CaCl_2$ and not adsorbed.

[B] (a)

1. Addition of $AgNO_3$ in KI_{excess} gives –ve sol due to adsorption of I^- on AgI, *i.e.*, preferential adsorption.
2. An increase in surface area of adsorbent increases the adsorption sites.
3. The forward reaction is catalysed and takes place fastly whereas the increase in products concentration makes reverse reaction fast and thus, equilibrium is attained earlier.
4. Animal charcoal adsorbs colouring matter of sugar.
5. CH_4 and CO are preferencially adsorbed on animal charcoal.
6. It is the reason why soaps form micelles.

STATEMENT EXPLANATION PROBLEMS

In each sub question given below a statement **(S)** and explanation **(E)** is given. Choose the correct answers from the codes (a), (b), (c) and (d) given for each question:

(a) **S** is correct but **E** is wrong
(b) **S** is wrong but **E** is correct
(c) Both **S** and **E** are correct and **E** is correct explanation of **S**
(d) Both **S** and **E** are correct but **E** is not correct explanation of **S**

1. **S :** Now-a-days term catalyst means specifically for a substance that accelerates the reaction.
   E : The terms inhibitor is commonly used for substances which retards the rate of reaction.
2. **S :** The activity of catalyst is more or less specific.
   E : A catalyst for one reaction is not necessary to catalyse the other reaction.
3. **S :** The effectiveness of catalyst has found more applications in solid catalyst and gaseous reactant systems.
   E : A large number of industrial preparations are based on this type of reactions.
4. **S :** Thermal decomposition of $KClO_3(s)$ in presence of $MnO_2(s)$ is an example of homogeneous catalysis.
   E : A homogeneous catalysis involves phase $P = 1$.
5. **S :** A catalyst lowers the threshold energy level for reaction.
   E : Catalyst combines with reactant to form an exothermic intermediate and provide another pathway to reaction.
6. **S :** Lead tetraethyl acts as inhibitor for combustion of gasoline.
   E : It retards the precombustion of gasoline.
7. **S :** Enzymes are proteins and enzyme catalysed reactions are called biological catalysis.
   E : The activity of enzyme as catalyst is increased in presence of vitamins.
8. **S :** Zeolites are water softner as well as catalyst.
   E : The catalytic action of zeolites is based upon their shape selectivity.
9. **S :** Oxidation of Na_2SO_3 is not caused by air but in presence of Na_3AsO_3 both undergo oxidation simultaneously.
   E : Neither Na_2SO_3 nor Na_3AsO_3 is oxidised by air.
10. **S :** Physical adsorption is weaker than chemical adsorption.
    E : Activated complex formed during adsorption possess lower energy level in chemisorption as it is more exothermic.
11. **S :** A negative catalyst retards rate of chemical reaction.
    E : Presence of negative catalyst boosted up the energy of activation.
12. **S :** Presence of catalyst alters the individual energies of reactants and products.
    E : The numerical value of ΔH or ΔU for the given reaction does not change in presence of catalyst.
13. **S :** A colloidal state, a dispersion of a dispersed phase in a dispersion medium is a heterogeneous state.
    E : The particle size of dispersed phase ranges between true solution and suspension state.
14. **S :** The stability of lyophobic sols is lesser than lyophilic sols.
    E : Lyophilic sols possess loving nature for liquid.
15. **S :** The charge on lyophobic particles is responsible for their nature to exist as sol.
    E : It is the formation of thin layer around sol particles which is responsible for stability of lyophilic sols.
16. **S :** The separation of insoluble impurities from a colloidal solution requires dialysis.
    E : The ionic impurities present in colloidal solution are separated by electrodialysis.
17. **S :** The blue colour of sky is due to scattering of light by dirt or dust particles present in air.
    E : Larger size of dispersed phase particles show more scattering as well as higher is the wavelength of light longer is scattering.
18. **S :** A yellow coloured As_2S_3 sol on mixing with red coloured $Fe(OH)_3$ sol gives colourless solution.
    E : The –ve charge of As_2S_3 sol particles is neutralised by +ve charge of $Fe(OH)_3$ sol particles and thus, sols are destabilized and show mutual coagulation.
19. **S :** Gelatin is often used as protective colloid.
    E : Protection is a property of lyophilic colloids.
20. **S :** $C_{12}H_{25}NH_3Cl$ and $C_{12}H_{25}COONa$ are colloidal electrolyte.
    E : The substances which behave as electrolyte at lower concentration and above definite concentration forms sol are called colloidal electrolyte.
21. **S :** The micelle formation by a surfactant takes place at certain concentration at definite temperature.
    E : The temperature above which a surfactant forms micelle is called Kraft point.
22. **S :** The concentration of sulphide ores by froth floatation is based on emulsification.
    E : Pine oil in water forms emulsion.
23. **S :** The digestion of fat in intestine involves emulsification.
    E : Bile salts stabilize the emulsion so formed.

24. **S :** Addition of $AgNO_3$ (aq) to $KI(aq)$ gives –ve sol whereas addition of $KI(aq)$ to $AgNO_3$ gives +ve sol of AgI.
E : The sol particles adsorbs the common ions present in solution and acquire their charge.

25. **S :** Hard water consumes more soap.
E : The ion responsible for cleansing action is precipitated out by Ca^{2+} or Mg^{2+} ion.

26. **S :** Sol particles show Tyndall effect.
E : The scattering is directly proportional to size of sol particle.

27. **S :** Creaming from milk is known as phase inversion.
E : An agitation of milk brings in a change of D.P. into D.M. and *vice-versa.*

28. **S :** A needle can float on clear water but sinks when some detergent is added to it.
E : Detergent reduces the surface tension of water.

29. **S :** Medicines are more effective in colloidal form than in tablet form.
E : The colloidal state possess larger surface area than coarse form.

30. **S :** Micelles are formed by surfactants above CMC.
E : The conductivity of a solution having surfactant molecule decreases sharply at CMC. **(IIT 2007)**

ANSWERS (Statement Explanation Problems)

1. (d) Both are different facts but true.
2. (d) Both are different facts but true.
3. (c) Explanation is correct reason for statement.
4. (b) Heterogeneous system has $P \geq 2S + S$ has $P = 2$.
5. (c) Catalyst lowers energy of activation and threshold energy and provide another pathway to reaction.
6. (c) Explanation is correct reason for statement.
7. (d) Both are different facts but true.
8. (d) Both are different facts but true.
9. (a) It is called induced oxidation.
10. (c) Explanation is correct reason for statement.
11. (a) Working of negative catalyst is not related to energy of activation.
12. (b) The threshold energy level changes and not E_R or E_P.
13. (c) Explanation is correct reason for statement.
14. (c) Explanation is correct reason for statement.
15. (d) Both are different facts but true.
16. (b) Soluble impurities are removed by dialysis.
17. (c) Explanation is correct reason for statement.
18. (c) Explanation is correct reason for statement.
19. (d) Both are different facts but true.
20. (c) Explanation is correct reason for statement.
21. (d) Both are different facts but true.
22. (c) Explanation is correct reason for statement.
23. (c) Explanation is correct reason for statement.
24. (c) $AgNO_3 + \underset{\text{Excess}}{KI} \longrightarrow [AgI]^{I^-}$
$KI + \underset{\text{Excess}}{AgNO_3} \longrightarrow [AgI]^{Ag^+}$
The preferential adsorption of common ion on AgI particles provides –ve and +ve charge.
25. (c) $2RCOONa + Ca^{2+} \longrightarrow \underset{\text{Insoluble}}{(RCOO)_2\,Ca} + 2Na^+$
26. (c) Sol particles show Tyndall effect due to **scattering of light.**
Also the scattering is directly proportional to size of sol particles.
27. (c) Milk is o/w emulsion, cream is w/o emulsion. To convert a o/w emulsion into w/o emulsion is known as phase inversion which can be achieved by mechanical agitation.
28. (c) Explanation is correct reason for statement.
29. (c) Larger surface area provides more pronounced adsorption of medicine over tissues and thus effectiveness increases.
30. (d) Both are facts.

MATCHING TYPE PROBLEMS

Type I : Only One Match is Possible

1.

List A	List B
(A) CMC	1. Centrifuge
(B) Ge ; s	2. Phase inversion
(C) Demulsification	3. Syneresis
(D) Creaming of milk	4. van der Waals' bonding
(E) Detergency	5. Kraft temperature
(F) Multimolecular colloid	6. Lyophobic
(G) Macromolecular colloid	7. Lyophilic

Type II : More Than One Match are Possible

2. Match the following. More than one match are possible:

List A	List B
(A) $2KClO_3(s) \xrightarrow{MnO_2(s)} 2KCl + 3O_2(g)$	1. Homogeneous catalysis
(B) $2H_2O_2(l) \xrightarrow{Hg(l)} 2H_2O(g) + O_2(g)$	2. Heterogeneous catalysis
(C) $2H_2O_2(l) \xrightarrow{Pt} 2H_2O(g) + O_2(g)$	3. $\Delta n_{reaction} > 1$
(D) $2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$	4. $\Delta n_{reaction} < 1$

3.

List A	List B
(A) Homogeneous catalysis	1. Enzyme catalysis
(B) Heterogeneous catalysis	2. Manufacture of NH_3
	3. Hydrolysis of sugar
	4. Mutarotation of glucose
	5. Cracking of petroleum

Type III : Only One Match From Each List

4.

List A	List B	List C
A. Lyophilics	1. Froth floatation	a. Charge depends on pH
B. Lyophobics	2. Organic substances	b. Charge is independent of pH
C. Protection	3. Artificial rain	c. Digestion of food
D. Smoke	4. Inorganic substances	d. Spray of AgI
E. Coagulation	5. Blue tinge	e. Gelatin
F. Emulsification	6. Gold number	f. Tyndall effect

ANSWERS

1. A – 5; B – 3; C – 1; D – 2; E – 4; F – 6; G – 7
2. A – 2, 3; B – 2, 3; C – 2, 3; D – 1, 4
3. A – 1, 3, 4; B – 2, 5
4. A – 2 – a; B – 4 – b; C – 6 – e; D – 5 – f; E – 3 – d; F – 1 – c