IJSO 2021 Chemistry MCQ Solution

Question 1

In a titration of acid mixture with base, the teacher prepared an acid mixture by mixing 4mL of 4M HCl, 4mL of 18M H_2SO_4 and a certain volume of 4M HNO_3, and then made up 3 L of solution using distilled water. She used an aqueous solution of Sodium Carbonate ($Na_2CO_3.10H_2O$) as base for the titration, that was prepared by dissolving 2g of ($Na_2CO_3.10H_2O$) in water and diluting to 100 mL with distilled water. After performing the titration, she observed that 15 mL of the acid mixture required 7.5 mL of Sodium Carbonate solution for complete neutralisation. The amount of nitrate ions in the acid mixture is

a) 0.124 g
b) 3.1 g correct answer
c) 0.31 g
d) 1.24 g

Solution:

Let the volume of HNO_3 acid be V mL.

Total equiv.of the acid mixture = [(4 x V)+ (4 x 4) + (36 x 4)]/1000

= (4V+ 16+144)/1000 = (4V+160) /1000

equiv.of acid in 15mL of this acid mixt. = $\frac{(160+ 4V)/1000]}{3000}$ X 15 Eq.1

Now Normality of $Na_2CO_3.10H_2O$ solution = (g/L)/ eq.wt.= 20/143

equiv. of 7.5mL of $Na_2CO_3.10H_2O$ solution = $\frac{(20/143)X 7.5}{1000}$

Thus equiv. of 15mL of acid mixt. = .equiv. of 7.5mL of $Na_2CO_3.10H_2O$ solution. Eq. 2

$\frac{(160+ 4V/1000) X 15}{3000} = \frac{(20/143) X 7.5}{1000}$

V= 12.44mL

equiv. of 4N HNO_3in acid mixture = (4 X 12.44)/1000= 0.04976

Equivalent of HNO_3 = 50/1000= 0.05

Equivalence of NO_3^{1-} =0.05

Weight of NO_3^{1-} = eq. X xeq.wt. of NO_3^{1-} = 0.05X62= 3.1g

Alternate Solution:

Let the volume of HNO_3 acid be V mL.

Total mmol of acid in mixture = (4X4) + (4X18)+ 4V

HCl H_2SO4 HNO_3

mmol of H^+ in acid in mixture= (4X4) + (4X18x2)+ 4V

Therefore Conc. Of H^+ in acid mixt. = (16+144+4V)/3000 mol/L

Reaction : $2H^+ + Na_2CO_3 \rightarrow H_2O + CO_2 + 2Na^+$

2mol of H^+ = 1 mol Na_2CO_3

15mL acid mixt. = $\left[\frac{(160+4V)/1000}{3000}\right]$ X 15 mol H^+ Eq.1

For Na_2CO_3 mol in 7.5mL = (2/286)X (7.5)/100) mol Na_2CO_3

As per stiochiometry

{[160+4V/1000]/3000} x15 = 2x(20/286)x(7.5/1000)

Mol H^+ mol Na_2CO_3

V= 12.44 mL

equiv. of 4N HNO_3in acid mixture = (4 X 12.44)/1000= 0.04976

Equivalent of HNO_3 = 50/1000= 0.05

Equivalence of NO_3^{1-} =0.05

Weight of NO_3^{1-} = eq. X xeq.wt. of NO_3^{1-} = 0.05X62= 3.1g

Question 2

UAE has vast reserves of limestone particularly in the eastern and northern parts of the Emirates. Jabel Hafeet Mountain is the part of Hajar mountains and made of predominantly tertiary sedimentary rock –Limestone. It is primarily composed of Calcite which is chemically Calcium carbonate. Calcite is used on a large scale as a building material.

A mason was designing a pattern of transparent calcite tiles that were to be fixed in the laboratory. He spread the tiles on the table to arrange different patterns. Accidently two tiles from the pattern came loose and fell in a container having 100g of hydrochloric acid solution. Each pure calcite tile weighs exactly 20g, and hydrochloric acid solution in the container contains one tenth of its weight of pure acid. Assuming that both tiles dissolve equally, what is the weight of each tile that remain undissolved?

a) 26.31 g

b) 13.15 g correct answer

c) 6.31g

d) 13.69 g

Solution:

Chemical equation is $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

100g 73g 111g 44g 18g

Wt. of HCl taken = 100g. Wt. of pure acid in 100g of HCl solution = 100X0.1=10g

From the equation,

73 g of HCl dissolves100g of calcite tile

10 g of HCl dissolves 100/73) X 10= 13.69.g of tile

Amount of each tile undissolved = (40-13.69)/2= 26.31/2g = 13.15 g

Question 3

The solid fuel in the booster stage of the space shuttle is a mixture of ammonium perchlorate (NH_4ClO_4) and aluminium powder. On the ignition of this mixturethe products obtained are solid aluminium oxide, gaseous hydrochloride, water, and nitrogen gas. Using following data find out the standard enthalpy change at 298K for the reaction.

$\Delta_f°H$ of $NH_4ClO_4(s) = -295 kJ·mol^{-1}$ $\Delta_f°H$ of $Al_2O_3(s) = -1675.7 kJ·mol^{-1}$

$\Delta_f°H$ of $HCl(g) = -92.3 kJ·mol^{-1}$ $\Delta_f°H$ of $H_2O(l) = -285.8 kJ·mol^{-1}$

a) –9769 kJ

b) –9732.7 kJ correct answer

c) –8625.1 kJ

d) –8132.1 kJ

Solution:

$10Al_{(s)} + 6NH_4ClO_{4(s)} \rightarrow 5Al_2O_{3(s)} + 6HCl_{(g)} + 9H_2O_{(l)} + 3N_{2(g)}$

$\Delta H = H_P - H_R$

$H_P = 5(-1675.7) + 6(-92.3) + 9(-285.8)$

$= -8378.5 - 553.8 - 2572.2 = -11504.5$ kJ

$H_R = 6(-295.3) = -1771.8$

$\Delta H = (-11504.8) - (-1771.8) = -9732.7$kJ

Question 4

When a certain weight of solid potassium permanganate was treated with an excess of hydrogen peroxide at STP, the volume of oxygen formed was 168 L. What is the weight in kg of potassium permanganate used?

a) 3.16 kg
b) 0.158 kg
c) 0.790 kg correct answer
d) 7.90 kg

Solution:

$2\ KMnO_4 + 3\ H_2O_2 \rightarrow 2MnO_2 + 2\ KOH + 2\ H_2O + 3\ O_2$

Volume at STP = 168 L hence mol of O_2 = 168/22.4 = 7.5mol

2 mol $KMnO_4$ ≡ 3 mol O_2. Hence mol $KMnO_4$reqd = (2 x 7.5)/3 = 5mol

= 5 x 158 = 790g = 0.790 kg

Question 5

X ray diffraction studies show that an alkaline earth metal has a face centred cubic structure with a unit cell width 0.197 nm. If the density of the metal is 1.55 $g \cdot cm^{-3}$, the number of atoms present in 40 g of the metal are:

a) 3.37×10^{24}
b) 6.74×10^{24}
c) 1.35×10^{25} correct answer
d) 2.70×10^{25}

Solution:

Volume of unit cell =(0.197×10^{-9} m)^3= (0.197×10^{-7}cm)^3= 7.65×10^{-24}cm^3

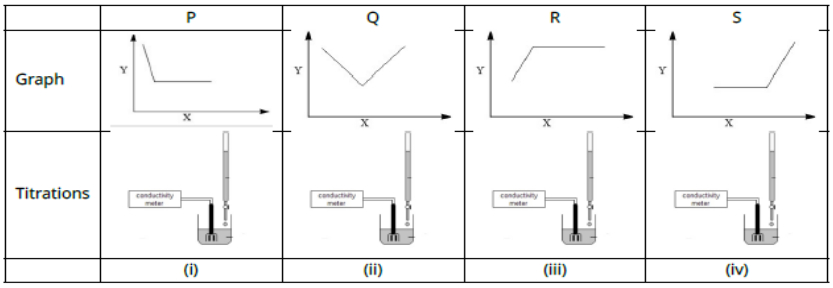
Volume of 40 g of metal= mass/density=40/1.55=25.81 cm^3

Number of unit cells in this volume=25.81 / 7.65×10^{-24} = 3.37×10^{24}

Number of atoms in this volume = 4[3.37×10^{24}] =1.35×10^{25}

Question 6

The graphs in the table below represent conductometric titrations. Choose the appropriate entry/entries from graphs to match each of the entries in titrations. All entries in titrations refer to aqueous solutions. (Hint: Conductance depends on number of ions as well as nature of the ions).



Graph and diagram Specifications:
X = Conductance; Y = Volume in the burette solution
(i). Acetic acid vs. Ammonia (in burette),
(ii) Silver nitrate vs. Potassium chloride (in burette)
(iii) Nitric acid vs. Ammonia (in burette)
(iv) Magnesium Sulphate vs. Barium Hydroxide (in burette)

a) (i) → (R), (ii) → (S), (iii) → (Q), (iv) → (P)
b) (i) → (R), (ii) → (S), (iii) → (P), (iv) → (Q) correct answer
c) (i) → (P), (ii) → (S), (iii) → (R), (iv) → (Q)
d) (i) → (S), (ii) → (Q), (iii) → (R), (iv) → (P)

Solution:

1- Ammonium acetate is a strong electrolyte.

2- Number of ions increases as potassium chloride is added.

3- Ammonium ion conducts less than proton.

4- $Mg(OH)_2$ and $BaSO_4$ precipitate out.

Question 7

When a l g piece of metal (Atomic Weight 89) was dropped into dilute sulphuric acid, a large amount of gas was evolved. All the gas was collected and dried to remove moisture and was found to occupy a volume of 378cm^3 at STP. The resulting solution was electrolysed between platinum electrodes using a current of 1A for a period of 15 minutes. The following statements can be made about the above entire process:

(A) The metal sulphate is MSO_4
(B) Oxygen is liberated at anode.

(C) The gas collected is hydrogen.
(D) Persulfate is produced at the anode.
(E) The metal sulphate is $M_2(SO_4)_3$
(F) The percentage of metal recovered by electrolysis is about 26-27%.

Choose the right options:

a) only options A, C, D are correct.
b) only options B, C, E, F are correct. Correct answer
c) only options C, D, E are correct.
d) only options A, B, C, F are correct.

Solution

22400 cm^3 of hydrogen = 2 equivalents of hydrogen.
378 cm^3 of hydrogen = 0.03375 equivalents of hydrogen.

Metal produced=0.03375 equivalents = 1 g.
Equivalent mass of the metal -=1/0.03375=29.63

Valency of metal= atomic mass/equivalent mass=89/29.63 = 3. The metal sulphate is $M_2(SO_4)_3$

Charge passing through = 1 x 15 x 60 = 900 C
96500 Coulombs →1 equiv of M gets liberated.
Hence 900C → only 0.0093 equivalents of metal gets liberated.
Therefore % recovery (0.0093/0.03375)x100= 26.6%

Question 8

Ion exchange Resins are used to soften water. They contain sodium ions which get exchanged with 'hard' ions like Ca^{2+} and Mg^{2+}. Resins are not 100% efficient *i.e*. all sodium ions present in the resin do not get exchanged at once and may need repeated passage of a solution through the column to attain full efficiency.

Molecular formula of a commercial ion –exchange resin is $C_7H_6SO_3Na$. A 100 cm^3 solution containing 0.3 mol L^{-1} of Mg^{2+} is passed through a column of ion exchange resin weighing 20g only once. What are the molarities of Mg^{2+} andNa^{+}, respectively, in the solution obtained after passing through the column, if the exchange efficiency is only 25 %.

a) 0.13 M and 0.26 M

b) 0.26 M and 0.17 M
c) 0.17M and 0.26 M correct answer
d) 0.21 M and 0.14 M

Solution:
Molar mass of the resin =193
2 molecules of the resin take up one Mg^{2+} ion.
386g of resin takes up 1mol of Mg^{2+} ions.
1g of the resin can take 2.59X 10^{-3}mol of Mg^{2+}
20g of the resin can take 51.8X 10^{-3}mol of Mg^{2+} or 51.8 mmol
Exchange efficiency is only 25% →0.25 x 51.8 mmol of Mg^{2+} is exchanged = 12.95 m mol of $Mg^{2+}$is exchanged.
Initial amount of Mg^{2+} is 100 X 0.3 = 30 mmol
Amount exchanged = 12.95 mmol.
Amount left = 30-12.95= 17.05 mmol
Molarity= 17.05 / 100= 0.17 M

Na^{+} molarity is twice the molarity of Mg^{2+} exchanged = 25.9/100= 0.259 M

Question 9

The electrode reactions involved in the charging process of a lead storage battery are:

$PbSO_4 + 2\ e \rightarrow Pb + SO_4^{2-}$
$PbSO_4 + 2\ H_2O \rightarrow PbO_2 + SO_4^{2-} + 4\ H^{+} + 2\ e$

In a certain lead storage battery containing 2 L of aqueous sulphuric acid, the specific gravity of the electrolyte was found to be 1.14 (20% H_2SO_4 by weight). This was charged using average current of 1.67 A till the specific gravity rose to 1.28 (36.9% H_2SO_4 by weight). What was the duration of the charging process?

a) 80 hours correct answer
b) 100 hours
c) 160 hours
d) 188 hours

Solution:
Overall rxn is $2\ PbSO_4 + 2\ H_2O \rightarrow Pb + PbO_2 + 2\ H_2SO_4$
Hence in this rxn., .eq. wt of H_2SO_4 = mol wt = 98 (2 moles electrons for 2 mol H_2SO_4)
Before charging: (100/1.14) mL H_2SO_4 soln contains (20/98) eq of H_2SO_4
2000 mL soln = (20/98) x 2000 /(100/1.14) = 4.65 eq

After charging: 2000 mL = (36.9/98) x 2000 x (1.28/100) = 9.64 eq

No of eq H_2SO_4 added = no of Faradays of charge used = 4.99 F
= 4.99 x 96500 coulombs
Av current = Charge in coulombs / time in sec

Time required for charging = 4.99 x 96500 / 1.67 = 288344 sec = 80 hours

Question 10

Arrange the molecules H_2O, H_2S, $BF_3$and NH_3in order of their increasing dipole moment.

a) $BF_3 > NH_3 > H_2S > H_2O$
b) $BF_3 < H_2S < H_2O < NH_3$
c) $BF_3 < H_2S < NH_3 < H_2O$ correct answer
d) $H_2S > NH_3 > BF_3 > H_2O$

Molecule	Dipole Moment (D)
BF_3	0
H_2S	0.95
NH_3	1.47
H_2O	1.85

Solution:

BF_3 is symmetric,zero dipole

NH_3 is pyramidal, N-H bond moment is larger than S-H bond moment

O-H bond moment larger than S-H bond moment

O is more electronegative than S