PHYSICAL CHEMISTRY

MOLE CONCEPT

1. The treatment of an aqueous solution of 3.74 g of $Cu(NO_3)_2$ with excess KI results in a brown solution along with the formation of a precipitate. Passing H_2S through this brown solution gives another precipitate X. The amount of X (in g) is _____.

[Given : Atomic mass of H = 1, N = 14, O = 16, S = 32, K = 39, Cu = 63, I = 127]

[JEE(Advanced) 2022]

2. Dissolving 1.24 g of white phosphorous in boiling NaOH solution in an inert atmosphere gives a gas **Q**. The amount of $CuSO_4$ (in g) required to completely consume the gas **Q** is _____.

[Given : Atomic mass of H = 1, O = 16, Na = 23, P = 31, S = 32, Cu = 63] **[JEE(Advanced) 2022]**

3. To check the principle of multiple proportions, a series of pure binary compounds (P_mQ_n) were analyzed and their composition is tabulated below. The correct option(s) is(are) **[JEE(Advanced) 2022]**

Compound	Weight % of P	Weight % of Q
1	50	50
2	44.4	55.6
3	40	60

(A) If empirical formula of compound **3** is P_3Q_4, then the empirical formula of compound **2** is P_3Q_5.

(B) If empirical formula of compound **3** is P_3Q_2 and atomic weight of element P is 20, then the atomic weight of Q is 45.

(C) If empirical formula of compound **2** is PQ, then the empirical formula of the compound **1** is P_5Q_4.

(D) If atomic weight of P and Q are 70 and 35, respectively, then the empirical formula of compound **1** is P_2Q.

Question Stem for Question Nos. 4 and 5

Question Stem

Reaction of **x** g of Sn with HCl quantitatively produced a salt. Entire amount of the salt reacted with **y** g of nitrobenzene in the presence of required amount of HCl to produce 1.29 g of an organic salt (quantitatively).

(Use Molar masses (in g mol^{-1}) of H, C, N, O, Cl and Sn as 1, 12, 14, 16, 35 and 119, respectively).

[JEE(Advanced) 2021]

4. The value of **x** is _____.

5. The value of **y** is _____.

6. Aluminium reacts with sulfuric acid to form aluminium sulfate and hydrogen. What is the volume of hydrogen gas in liters (L) produced at 300 K and 1.0 atm pressure, when 5.4 g of aluminium and 50.0 mL of 5.0 M sulfuric acid are combined for the reaction ?

(Use molar mass of aluminium as 27.0 g mol^{-1} , R = 0.082 atm L mol^{-1} K^{-1}) **[JEE(Advanced) 2020]**

7. The ammonia prepared by treating ammonium sulphate with calcium hydroxide is completely used by $NiCl_2.6H_2O$ to form a stable coordination compound. Assume that both the reactions are 100% complete. If 1584 g of ammonium sulphate and 952g of $NiCl_2.6H_2O$ are used in the preparation, the combined weight (in grams) of gypsum and the nickel-ammonia coordination compound thus produced is_____.

(Atomic weights in g mol^{-1}: H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Ca = 40, Ni = 59)

[JEE(Advanced) 2018]

8. If the value of Avogadro number is 6.023×10^{23} mol^{-1} and the value of Boltzmann constant is 1.380×10^{-23} JK^{-1}, then the number of significant digits in the calculated value of the universal gas constant is

[JEE(Advanced) 2014]

SOLUTIONS

1. Ans. (0.31 – 0.33)

Sol. $2Cu(NO_3)_2 + 5KI \longrightarrow Cu_2I_2 + KI_3 + 4KNO_3$

0.02 0.01

$KI_3 + H_2S \longrightarrow S\downarrow + KI + 2HI$

0.01 0.01

$n_S = 0.01$ mole

weight of sulphur = $32 \times 0.01 = 0.32$ gm

2. Ans. (2.37 - 2.41)

Sol. Mole of $P_4 = \dfrac{1.24}{31\times 4} = 0.01$

$P_4 + 3NaOH + 3H_2O \longrightarrow PH_3 + 3NaH_2PO_2$

0.01 mole 0.01 mole

$2PH_3 + 3CuSO_4 \rightarrow Cu_3P_2 + 3H_2SO_4$

$0.01 \quad \dfrac{3}{2} \times 0.01$

$= \dfrac{0.03}{2}$ moles

$W_{CuSO_4} = \dfrac{0.03}{2}\times 159 = 2.385$ gm

Ans. = 2.38 or 2.39

3. Ans. (B, C)

Sol.

Compound	Weight % of P	Weight % of Q
1	50	50
2	44.4	55.6
3	40	60

For option (A)

Let atomic mass of P be M_P and atomic mass of Q be M_Q

Molar ratio of atoms P : Q in compound 3 is

$$\frac{40}{M_P}:\frac{60}{M_Q} = 3:4$$

$$\frac{2M_Q}{3M_p} = \frac{3}{4} \Rightarrow 9M_P = 8M_Q$$

Molar ratio of atoms P : Q in compound 2 is

$$\frac{44.4}{M_P}:\frac{55.6}{M_Q}$$

$= 44.4\ M_Q : 55.6\ M_P$

$= 44.4\ M_Q : 55.6 \times \dfrac{8M_Q}{9}$

$= 44.4 : 55.6 \times \dfrac{8}{9} = 9 : 10$

$\Rightarrow$ Empirical formula of compound 2 is therefore P_9Q_{10}

Option (A) in incorrect

For option (B)

Molar Ratio of atoms P : Q in compound 3 is $\frac{40}{M_P}:\frac{60}{M_Q}=3:2$

$$\frac{2M_Q}{3M_P}=\frac{3}{2}\Rightarrow 9M_P=4M_Q$$

If $M_P = 20 \quad \Rightarrow M_Q=\frac{9\times 20}{4}=45$

Option (B) is correct

For option (C)

Molar ratio of atoms P : Q in compound 2 is

$$\frac{44.4}{M_P}:\frac{55.6}{M_Q}=44.4M_Q:55.6\,M_P=1:1$$

$$\Rightarrow \frac{M_P}{M_Q}=\frac{44.4}{55.6}$$

Molar ratio of atoms P : Q in compound 1 is

$$\frac{50}{M_P}:\frac{50}{M_Q}=M_Q:M_P$$

= 55.6 : 44.4

$\simeq$ 5 : 4

Hence, empirical formula of compound 1 is P_5Q_4

Hence, option (C) is correct

For option (D)

Molar ratio of atoms P : Q in compound 1 is

$$\frac{50}{M_P}:\frac{50}{M_Q}=M_Q:M_P$$

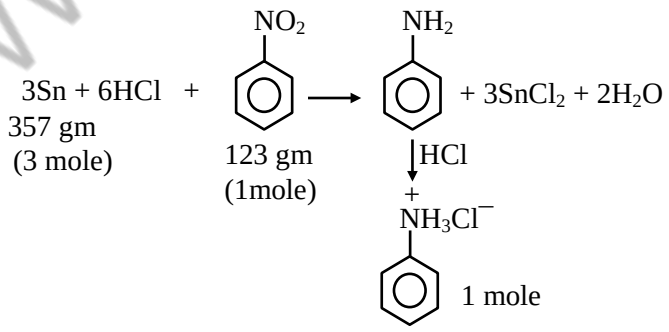
= 35 : 70 = 1 : 2

Hence, empirical formula of compound 1 is PQ_2

Hence, option (D) is incorrect

4. Ans. (3.57)

Sol. The value of **x** is



(72 + 8 + 35) + 14 = 129gm (molecular weight of organic salt)

So to get 1.29 gm organic salt.

We have to form 0.01 mole salt.

So 0.01 mole nitrobenzene is required.

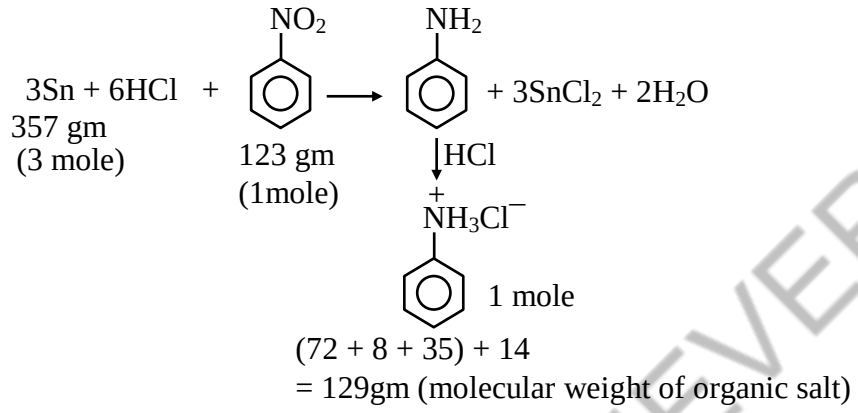
0.03 mole Sn is required.

So the amount of nitrobenzene = 0.01 × 123 = 1.23 gm

the amount of Sn required = 0.01 × 357 = 3.57 gm

5. Ans. (1.23)

Sol. The value of **y** is



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the amount of Sn required = 0.01 × 357 = 3.57 gm

Ans. 3.57 & 1.23

6. Ans. (6.00 - 6.20)

Sol. $2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$

Moles of Al takes = $\frac{5.4}{27} = 0.2$

moles of H_2SO_4 taken = $\frac{50 \times 5.0}{1000} = 0.25$

As $\frac{0.2}{2} > \frac{0.25}{3}$, H_2SO_4 is limiting reagent

Now, moles of H_2 formed = $\frac{3}{3} \times 0.25 = 0.25$

$\therefore$ Volume of H_2 gas formed = $\frac{nRT}{P} = \frac{0.25 \times 0.082 \times 300}{1} = 6.15$ L

7. Ans. (2992)

Sol. $\underset{\substack{1584\,g\\=12\ mol}}{(NH_4)_2SO_4} + Ca(OH)_2 \rightarrow \underset{\substack{\text{gypsum (M=172)}\\12\ mol}}{CaSO_4.2H_2O} + \underset{24\,mole}{2NH_3}$

$$\underset{952\,g=4\ mol}{NiCl_2 \cdot 6H_2O} + \underset{24\,mol}{6NH_3} \rightarrow \underset{\substack{(M=232)\\4\ mol}}{\left[Ni(NH_3)_6\right]}Cl_2 + 6H_2O$$

Total mass = 12 × 172 + 4 × 232 = 2992 g

8. Ans. (4)

Sol. Universal gas constant R = kN_A

where k= Boltzman constant and N_A = Avogadro number

$\therefore$ R = $1.380 \times 10^{-23} \times 6.023 \times 10^{23}$ J/K-mole

= 8.31174

$\cong 8.312$

So significant figures = 4