General & organic Chemistry

Lecture 6

L6: Ch4 Cont

31/oct/2024

*General & organic Chemistry, L6: Ch4 continue

- Simple rules of solubility - [to know if something is soluble or not]

So [Precipitates] are insoluble substances

★ Most nitrate (NO_3^-) Salts are soluble

★ Most alkali metal [group 1A] (except hydrogen) salts and NH_4^+ are soluble

★ Most Cl^-, Br^-, & I^- salts are soluble except (insoluble: Ag^+, Pb^{2+}, Hg_2^{2+})

★ Most sulfate (SO_4^{2-}) salts are soluble except ($BaSO_4$, $PbSO_4$, Hg_2SO_4, $CaSO_4$)

★ Most OH^- are slightly soluble (we consider them as insoluble)
but ($NaOH$, KOH) are completely soluble
and ($Ba(OH)_2$, $Ca(OH)_2$) are marginally soluble (70-ish% soluble)
so we consider them as soluble

★ Most S^{2-}, CO_3^{2-}, CrO_4^{2-}, PO_4^{3-} salts are slightly soluble
so we consider them insoluble except for those containing cations in Rule 2 (alkali metal group [1A] & NH_4^+)
those are soluble salts

★ Describing reactions in solution

1) Formula Equation (Molecular Equation):

- Gives the overall reaction stoichiometry but not necessarily the actual forms of reactants & products in solution
(bc in solution and we are talking about a soluble substance it will be in the form of Ions and NOT molecules)

- Reactants & Products usually are shown as compounds
- we use solubility rules to determine which compounds are aqueous and which are solids

Ex: $Ag(NO_3)_{(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$

2) Complete ionic Equation:
- Here, all substances that are strong electrolytes are represented as ions [all substances that are able to dissociate to ions are represented as ones]

Ex: $Ag^+_{(aq)} + NO_3^-(aq) + Na^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)} + Na^+_{(aq)} + NO^-_{3(aq)}$

as we notice not all ions had changes, like (NO_3^-, Na^+) and those are called spectator ions or counter ions

3) So we use the Net ionic Equation to show the ions that undergo changes and actually react

So the formula becomes:

$Ag^+_{(aq)} + Cl^-_{(aq)} \longrightarrow AgCl_{(s)}$

NO_3^- and Na^+ are spectator/counter ions

[if it was aqueous, there won't be a reaction, just ions swimming, therefore you won't have a net ionic equation]

Practice: Concept check

write the equation [Molecular formula equation, complete ionic, net ionic]

Cobalt (II) chloride & Sodium hydroxide

↓ $CoCl_2$ ↓ $NaOH$

Molecular (Formula) equation:

$$CoCl_{2(aq)} + \underline{2}NaOH_{(aq)} \longrightarrow \underline{2}NaCl_{(aq)} + Co(OH)_{2(s)}$$

[Balancing]

bc its insoluble

[from solubility rules]

Complete Ionic equation:

we saw that the Na^+ and Cl^- didn't react or (didn't change) so they are spectator ions

$$Co^{2+}_{(aq)} + 2Cl^-_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \longrightarrow 2Na^+_{(aq)} + 2Cl^-_{(aq)} + Co(OH)_{2(s)}$$

$CoCl_2$ 2NaOH

Net Ionic equation:

we remove the spectator ions

$$Co^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Co(OH)_{2(s)}$$

★ Stoichiometry of Precepitation reactions :

★ to solve stoichiometry reactions Problems we:

1. Identify species / substances present in combined solution & decide what reaction is going
2. write the balanced net ionic equation
3. calculat the moles of reactants
4. determine which is the limiting reactant
5. Calculat moles of products and convert them to grams as required

- And since we are talking about a solution, it is easier to calculate the volume than mass

and from volume & Molarity you can get the number of moles

$\boxed{n = M.V}$

Practice, Concept Check, 3 Part question

10.0 mL of a 0.30 M Sodium Phosphate Solution reacts with 20.0 mL of a 0.20 M Lead(II) Nitrate solution [assuming no volume change]

① what precipitate will form, & what mass of Precipitate will form

$Pb^{2+} \times PO_4^{-3}$

$\boxed{Pb_3(PO_4)_2}$

$$2Na_3PO_{4(aq)} + 3Pb(NO_3)_{2(aq)} \longrightarrow 6NaNO_{3(aq)} + Pb_3(PO_4)_{2(s)}$$

$\boxed{Pb_3(PO_4)_2 \rightarrow \text{will form}}$

from the question:

$n = M.V$

$10.0\,mL = 0.01\,L$

$20.0\,mL = 0.02\,L$

$0.01 \times 0.30 = \underline{0.003\,mol}\ Na_3PO_4$

$0.02 \times 0.20 = \underline{0.004\,mol}\ Pb(NO_3)_2$

to know which is the limiting reactant

$\frac{2\ mol\ Na_3PO_4}{3\ mol\ \cancel{Pb(NO_3)_2}} \cdot 0.004\ \cancel{mol\ Pb(NO_3)_2}$ = so we need 0.0026 mol Na_3PO_4 and we have 0.003 mol of that so we have excess amount of it therefore it is the exess reactant and the $Pb(NO_3)_2$ is the limiting reactant

so: $\frac{1\ mol\ Pb_3(PO_4)_2}{3\ mol\ \cancel{Pb(NO_3)_2}} \cdot 0.004\ mol\ \cancel{Pb(NO_3)_2}$

$= \boxed{0.0013\ mol\ Pb_3(PO_4)_2}$ – that's how much we get from the reaction [the limiting reaction is always the one which decides how much product we have]

So to get m we use $n = \frac{m}{Mr} \Rightarrow m = n.Mr$ bc we have n and Mr

$m = 0.0013 \times 811.5$

$\boxed{m = 1.05\,g}$

From Periodic table

↳ Mr of Pb = 207.2

Mr of PO_4 = 94.971

Mr of $Pb_3(PO_4)_2 = (3 \times 207.2) + (94.971 \times 2)$

$= \underline{811.5\,g/mol}$

(2) what is the concentration of Nitrate ions left in solution after the reaction is complete (NO_3^-)

$$2NaPO_{4(aq)} + 3Pb(NO_3)_{2(aq)} \longrightarrow 6NaNO_{3(aq)} + Pb_3(PO_4)_{2(s)}$$

we want M of NO_3^-, we have the volume [which is the whole volume of solution combined]

10.0 mL + 20.0 mL
= 30.0 mL = $\boxed{0.03\ L}$

So we need the mols of NO_3^- (n):

$$\frac{2\ \cancel{6}\ mol\ NaNO_3}{\cancel{3\ mol\ Pb(NO_3)_2}} \cdot 0.004\ \cancel{mol\ Pb(NO_3)}$$

$$= \boxed{0.008\ mol\ NaNO_3}$$

$$M = \frac{n}{V} = \frac{0.008}{0.03} = \boxed{0.27\ M} \text{ of } NO_3^-$$

☆ NO_3^- is a spectator ion so it didn't react therefore its number of moles (n) didn't change the only thing that has changed about it is its concentration because we have more volume

(3) what is the concentration of phosphate ions (PO_4^{3-}) left in the solution after the reaction was complete

$$2Na_3PO_{4(aq)} + 3Pb(NO_3)_{2(aq)} \rightarrow 6NaNO_{3(aq)} + Pb_3(PO_4)_{2(s)}$$

we need M of PO_4^{3-}, we have the volume (0.03L) and we need the number of moles (n)

PO_4^{3-} did react and it's not spectator ion, it is an excess reactant therefore some of it is left unreacted, bc if it was a limiting reactant its concentration would be zero

So we need to know how many moles are unreacted

in part (1) we found that we needed 0.0026 mol of Na_3PO_4 to react and we had 0.003 mols

So the unreacted part is $0.003 - 0.0026 = \boxed{0.0004 \text{ mols of } Na_3PO_4 \text{ unreacted}}$

So $M = \frac{n}{V} = \frac{0.0004 \text{ mol}}{0.03 L} = \boxed{0.013 M}$

★ Acid-Base reactions (Brønsted-Lowry)

Acid: is the Proton donor

Base: is the Proton acceptor

if a strong acid & a strong Base reacted:

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(L)}$$

↳ as molecules

This is the net ionic equation for it

★ Calculations in acid-base reactions are just like Precipitation reactions calculations

- we list the substances in solution and decide what is the reaction
- write the balanced net equation
- Calculat moles
- determine the limiting reactat
- calculate as requested

*Acid - Base Titrations

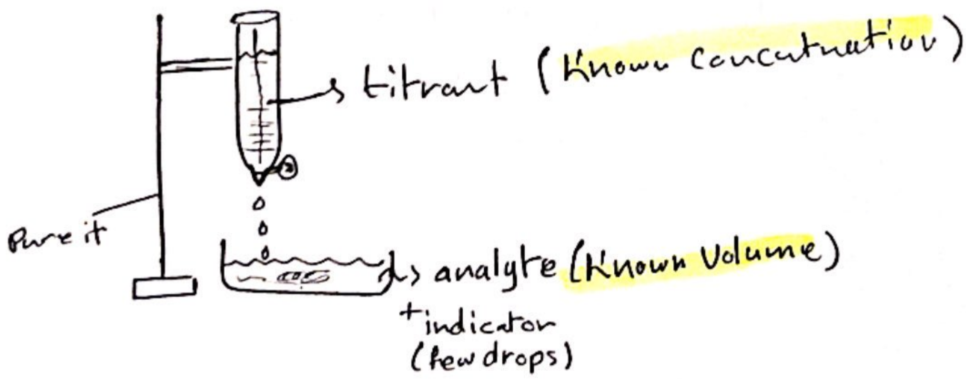
Titration _ delivery of a measured volume of a solution of Known Concentration [the titrant], into a solution Containing the substance being analyzed [the analyte] to Know its Concentration

Ex: we have an unlabeled bottle of HCl (Don't Know the Concentration)

So we get a strong Base like NaOH that you Know its Concentration and use it to Know the concentration of the HCl

Equivalence Point: enough titrant added to react exactly with the analyte [you won't find a change in color]

End Point: the indicator changes color so you can tell the equivalence point has been reached



Ex: $HCl + NaOH \longrightarrow NaCl + H_2O$

$$n_{HCl} = n_{NaOH}$$

$$(M \cdot V)_{HCl} = (M \cdot V)_{NaOH}$$

$$M_{HCl} = \frac{(M \cdot V)_{NaOH}}{V_{HCl}}$$

Concept check:

titration of Suluric acid (H_2SO_4) with sodium hydroxyde (NaOH)

How many moles of sodium hydroxide would be required to react with 1.00 L of 0.500M (H_2SO_4) to reach endpoint

$H_2SO_4 \Rightarrow V = 1\ L$
$M = 0.5\ M$

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

we need 2 $\underset{NaOH}{\text{moles}}$ for every 1 mole of H_2SO_4

$n_{H_2SO_4} = 0.5$ mol

$$\frac{2\ \underset{\text{mols}}{\text{NaOH}}}{1\ \text{mol}\ \cancel{H_2SO_4}} \cdot 0.5\ \cancel{H_2SO_4} = \boxed{1\ \text{mol NaOH}}$$