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Monday/Tuesday, October 21 & 22, 2019 - Chapter 4 Part 1: Solution Stoichiometry & Precipitation Reactions

I. Big Idea-

I can take a solid chemical and throw it into a solution, and it will either dissolve or not dissolve. If the solid dissolves, then it will either make ions or stay together in solutions. You might see the words "electrolytes" and "non-electrolytes" to describe this, shown in the box to the right.

Electrolytes – break up into ions in solution

e.g. – NaCl, H_2SO_4

Non-electrolytes – stay together in solution

e.g – $C_6H_{12}O_6$

The unit we use to describe the concentration of a solution is called molar (mol/L). .

1. A 12.0-g sample of HF is dissolved in water to give 3.1 × 10^2 mL of solution. The concentration of the solution is

$$\frac{12.0 g\ HF\ (\frac{1\ mol\ HF}{20\ g\ HF})}{3.1\ \times 10^2 mL\ (\frac{1\ L}{1000\ mL})} = 1.9\ M\ HF$$

2. The concentration of a 293.0-mL sample of a calcium chloride solution is 0.422 *M*. What is the mass of the solute? $0.422\ M = \frac{n}{0.293\ L}$; $n = 0.1236\ mol\ CaCl_2\ (\frac{110.98\ g}{1\ mol\ CaCl_2}) = 13.72\ g\ CaCl_2$

3. To calculate the concentration in molarity of a salt solution, you need to know
(A) the mass of the salt added to the solution and the volume of water added to the solution.
(B) the mass of the salt added to the solution and the total volume of the solution.
(C) the mass of the salt added, the molar mass of the salt, and the total volume of the solution.
(D) the molar mass of the salt and the total volume of the solution.
(E) the mass of the salt added, the molar mass of the salt, the volume of water added, and the total volume of the solution.

(C) is the correct answer. If we looked at the two problems above, if I had some weighed mass of a compound and I knew the volume of the solution, I could use the molar mass to change from grams to moles, and mol/L is my unit of molarity.

II. Molarity & Dilution Problems

<u>*Dilutions*</u> –

$n_1 = n_2$

$M_1V_1 = M_2V_2$

Do not use this formula for titrations!

1. How much 9.0 M HCl is needed to prepare 10.0 L of 0.50 M HCl? $(9.0 MHCl)V_1 = (10.0L)(0.50MHCl)$

$$V_1 = 0.55\ L$$

2. A 10.00 mL sample of 2.05 M KNO_3 is diluted to a volume of 250.0 mL. What is the concentration of the diluted solution?

$$(10\ mL)(2.05\ M\ KNO_3) = (M_2)(250.0\ mL);\quad M_2 = 0.082\ M\ KNO_3$$

3. What volume of 0.460 M barium nitrate solution is needed to prepare 213.0 mL of 0.268 M nitrate ion solution? $0.460\ M\ Ba(NO_3)_2 = \frac{0.460\ mol\ Ba(NO_3)_2}{1\ L} \times \frac{2\ mol\ NO_3^-}{1\ mol\ Ba(NO_3)_2} \times \frac{0.92\ mol\ NO_3^-}{1L}$

$$(0.92\ M\ NO_3^-)(V_1) = (213.0\ mL)(0.268\ M\ NO_3^-)$$

$$V_1 = 62.\ mL$$

4. Calculate the molarity of the resulting solution prepared by diluting 25.0 ml of 18.0% by mass ammonium chloride (density = 1.05 g/mL) to a final volume of 80.0 ml.
(A) 0.059 M (B) 0.0536 M (C) 1.11 M (D) 0.292 M (E) None of the above

$$\frac{18.0\ g\ NH_4Cl}{100g\ sol'n} \times \frac{1.05\ g\ sol'n}{1\ mL} \times \frac{1000\ mL}{1L} \times \frac{1\ mol\ NH_4Cl}{52.5\ g\ NH_4Cl} = 3.53\ M\ NH_4Cl$$

$$(3.5M\ NH_4Cl)(25.0\ mL) = (80\ mL)\ (M_2)$$

$$M_2 = 1.11M \quad Answer\ (C)$$

5. A 230.-mL sample of a 0.275 *M* solution is left on a hot plate overnight (please don't do this without your TA's supervision); the following morning the solution is 1.10 *M*. What volume of solvent has evaporated from the 0.275 *M* solution? (Assume volumes are additive.)
(A) 58.0 mL (B) 63.3 mL (C) 172 mL (D) 230. mL (E) 288 mL

$$(230\ mL)(0.275\ M) = (1.10\ M)(V_2) \quad ; \quad V_2 = 57.5\ mL$$
$$230\ mL - 57.5\ mL = 172\ mL$$

III. Solubility Rules

1. . Which pair of ions would *not* be expected to form a precipitate when dilute solutions of each are mixed?
(A) Cu^{2+}, S^{2-} (B) Ag^+, Cl^- (C) Ca^{2+}, PO_4^{3-}
(D) Mn^{2+}, OH^- (E) Mg^{2+}, SO_4^{2-}
(E) is correct. Magnesium sulfate is a soluble compound.

2. Which of the following solutions contains the greatest total ion concentration in aqueous solution?
(A) One mole of potassium chloride dissolved in 1.0 L of aqueous solution. 2 ions
(B) One mole of iron(II) nitrate dissolved in 1.0 L of aqueous solution. 3 ions
(C) One mole of potassium hydroxide dissolved in 1.0 L of aqueous solution. 2 ions
(D) One mole of calcium phosphate dissolved in 1.0 L of aqueous solution. ~~5 ions~~ (Insoluble)
(E) At least two of these solutions have an equal number of ions, and these contain the greatest total ion concentration.
(B) is correct.

Precipitate – solid that forms in a solution during a chemical reaction.

If a substance dissolves significantly in a solvent (usually water), it is called soluble . If a substance does not dissolve more than -0.1M in a solvent, it is called insoluble.

Solubility & Precipitation Rules -

Soluble –
1. Nitrate salts
2. Alkali metal/ammonium salts
3. Chloride salts (except $AgCl$, $PbCl_2$, Hg_2Cl_2)
4. Sulfate salts (except $BaSO_4$, $SrSO_4$, $CaSO_4$)

Insoluble –
1. Hydroxide salts (except $NaOH$, KOH, and kinda $Ca(OH)_2$
2. Most Sulfide, carbonate, and phosphate salts

IV. Precipitation Reactions

Draw a beaker with ions in it below:

Imagine that I have a beaker where I mix the following solutions together. What are the (a) molecular, (b) complete ionic, and (c) net ionic reactions when the following are mixed? If no reaction occurs write no reaction. Do not forget to include states.

1. $Fe(NO_3)_3$ (aq) and $(NH_4)_2SO_4$

Molecular: NO RXN

Complete Ionic: NO RXN

Net Ionic: NO RXN

2. $CaCl_2$(aq) and K_2SO_4(aq)

Molecular: $CaCl_2$ (aq) + K_2SO_4 (aq) → 2KCl (aq) + $CaSO_4$ (s)

Complete Ionic: Ca^{2+} (aq) + $2Cl^-$ (aq) + $2K^+$ (aq) + SO_4^{2-} (aq) → $2K^+$ (aq) + $2Cl^-$ (aq) + $CaSO_4$ (s)

Net Ionic: Ca^{2+} (aq) + SO_4^{2-} (aq) → $CaSO_4$ (s)

3. An aqueous solution of silver nitrate is added to an aqueous solution of potassium chromate, and this reaction produces a solid. What is the formula for the solid?

(A) AgK (B) $AgCrO_4$ (C) KNO_3 (D) K_2NO_3 (E) Ag_2CrO_4

Here our ions in solution would be Ag^+ , K^+, NO_3^-, and CrO_4^{2-} . Nitrates will not form precipitates. Our precipitate (and make sure your formula is balanced) is Ag_2CrO_4 Answer (E).

4. An aqueous solution of barium nitrate reacts with an aqueous solution of sodium sulfate. Identify the solid and indicate its coefficient in the balanced equation.

(A) $NaNO_3$, 1 (B) $BaSO_4$, 1 (C) $NaNO_3$, 2 (D) $BaSO_2$, 2
(E) none of these

$Ba(NO_3)_2$ (aq) + Na_2SO_4 (aq) → $BaSO_4$ (s) + $2NaNO_3$ (aq)

Since nitrates will not form precipitates, we know the precipitate is barium sulfate. Balancing the equation above, the coefficient in front of the barium sulfate is 1.

5. Reacting 42.8 mL of 0.320 M $AgNO_3$ with 55.8 mL of 0.580 M K_2CrO_4 results in what mass of solid formed?

This is a limiting reagent problem. I give you two solutions that will react to form a precipitate, and I want to know how much precipitate forms. We can test and see what happens when both reactants run out.

$$42.8mL \times \frac{1L}{1000\ mL} \times \frac{0.320\ mol\ AgNO_3}{1\ L} \times \frac{1\ mol\ Ag}{1\ mol\ AgNO_3} \times \frac{1\ mol\ Ag_2CrO_4}{2\ mol\ Ag} \times \frac{331.73\ g}{1\ mol\ Ag_2CrO_4} = 2.27\ g$$

$$55.8mL \times \frac{1L}{1000\ mL} \times \frac{0.580\ mol\ K_2CrO_4}{1\ L} \times \frac{1\ mol\ CrO_4}{1\ mol\ K_2CrO_4} \times \frac{1\ mol\ Ag_2CrO_4}{1\ mol\ CrO_4} \times \frac{331.73\ g}{1\ mol\ Ag_2CrO_4} = 10.74\ g$$

Silver nitrate is my limiting reagent. I will make 2.27 g of solid product.

V. Extra section - A couple ways precipitation reactions help us out in the lab:

We're starting to get to some cool stuff in the lab, so I included a little extra page here at the bottom about how we use precipitation reactions in the lab. You will be trying these out in Exp. 3 Weeks 1 & 2!

a) Maybe I want to make a certain compound and I know it is insoluble in water. If I mix different solutions together We might have a problem where we want to make a certain compound, and we can do it by precipitating it from solution:

"Kevin is trying to synthesize isoamericanol again, and he needs some silver chromate this time around to use as an oxidizing agent. He looks in his lab cabinets and finds 0.320M silver nitrate and 0.580M potassium chromate. What volumes of each should Kevin add to make 2.27 g of Ag_2CrO_4?"

If you look at the problem #5 right before this, you need 42.8 mL of 0.320 M $AgNO_3$ with 55.8 mL of 0.580 M K_2CrO_4 to make that amount.

b) Maybe I have an unknown chemical solution and I want to find out what's inside of it. Precipitation and metal flame tests are some qualitative methods we could use to help us find out. (I put an infographic about flames tests up under "Chemistry Web Resources" for anyone interested!)

"Nichrome wire was dipped in the solution and held over a Bunsen burner. Without a didymium glass filter, you observe a bright yellow flame color, and with the filter, you observe a light purple flame color. Addition of silver nitrate yielded a precipitate. When HCl is added, bubbles are observed to form. What ions are present in the solution?"

The strong yellow flames tells you that there's sodium in the sample, and the lilac purple tells you there's sodium. Bubbles in the presence of acid tells you that there was carbonates in the solution.

c) Maybe I want to find out quantitatively how much of a certain ion or substance is dissolved in solution, so we can precipitate it out (and you'll learn all the purification nuances if you take Chem 1CL).

"One year when Kevin was in high school, swim league finals were at the rival high school's pool, which was notorious for burning swimmers' eyes. (The eye-burning and pool smell is actually caused by reactions between ammonia and ammonia-like compounds from human sweat and urine with hypochlorous acid in the pool to make chloramines – there's an inforgraphic about this too). Kevin's back and this time he's trying to use silver nitrate to figure out how much how much chlorine is in that pool. Plan an experiment that would help Kevin do this without spending all his money on silver nitrate. The pool is 50m x 25.0m x 3.0m in volume, and for reference the average balance of chlorine to water in a swimming pool is 0.00013 ounces of chlorine per gallon.

Good luck with that one.