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CHEM 2115: General Chemistry Laboratory

Experiment 7: Volumetric Analysis & Consumer Chemistry

The key behind volumetric analysis is that at the end point (when the color changed) the moles of acid in solution equal the moles of base (NaOH) you added from the buret. Knowing the concentration of the acid or base solution allows you to determine the concentration or amount of the other.

1. Standardization of NaOH: you are trying to determine the concentration of your NaOH by titrating it against a known amount of acid, in this case KHP (potassium hydrogen phthalate, MW = 204.2 g/mol).

   You start by dissolving a known mass of KHP in water, which means you know how many moles of KHP you start with. This can be found by taking the mass of KHP and dividing it by the molecular weight of KHP:

   $$\text{moles KHP} = \frac{\text{mass KHP } (g)}{MW_{KHP}\ (g/mol)} \tag{1}$$

   At the end point, the moles of KHP = moles of base (NaOH) added to the solution. We can write the moles of base as:

   $$\underbrace{\text{moles NaOH}}_{equal\ to\ moles\ KHP\ (acid)} = \underbrace{V_{NaOH}\ (L)}_{volume\ added\ to\ reach\ endpoint} \times \underbrace{M_{NaOH}\ (mol/L)}_{UNKNOWN-what\ we\ want\ to\ solve\ for} \tag{2}$$

   where V_{NaOH} is the volume of base, in liters, you added from the buret and M_{NaOH} is the **unknown** molarity of your NaOH.

   Equating Equations 1 and 2 we get:

   $$\frac{\text{mass KHP (g)}}{MW_{KHP}\ (g/mol)} = V_{NaOH}\ (L) \times M_{NaOH}\ (mol/L) \tag{3}$$

   Rearranging to solve for the unknown, which is the concentration of NaOH (M_{NaOH}):

   $$\boxed{M_{NaOH}\ (mol/L) = \frac{\text{mass KHP (g)}}{MW_{KHP}\ (g/mol) \times V_{NaOH}\ (L)}}$$

2. Vinegar Analysis: weight percent acetic acid in vinegar: We now want to use our solution of NaOH, of known concentration from part 1, to determine the amount of acetic acid (CH_3COOH) in commercial vinegar.

   The strategy is the same. We'll add the NaOH to the vinegar until we reach the end point, at which the moles of NaOH added equals the moles of acetic acid in vinegar. What we ultimately want is the mass percent of acetic acid in vinegar, so we need to know the mass of acetic acid in vinegar and the total mass of our vinegar sample

   $$\text{mass percent acetic acid} = \frac{\text{mass acetic acid in sample } (g)}{\text{total mass of vinegar sample } (g)} \times 100 \tag{4}$$

   So, since we know that:

   $$\text{moles base at end point} = \text{moles acid at end point} \tag{5}$$

   $$V_{NaOH}\ (L) \times M_{NaOH}\ (mol/L) = \frac{m_{CH_3COOH}\ (g)}{MW_{CH_3COOH}\ (g/mol)} \tag{6}$$

   where V_{NaOH} is the volume of base you add from the buret in liters, M_{NaOH} is the average molarity of the NaOH you determined in part 1, MW_{CH_3COOH} is the molecular weight of acetic acid, and m_{CH_3COOH} is the mass of acetic acid in the vinegar sample (which is what we want to solve for):

$$\boxed{m_{CH_3COOH}\ (g) = V_{NaOH}\ (L) \times M_{NaOH}\ (mol/L) \times MW_{CH_3COOH}\ (g/mol)}$$

Finally since we know the total mass of the vinegar sample, which we weighed before the titration, we get the mass percent:

$$\boxed{\text{mass percent acetic acid} = \frac{m_{CH_3COOH}\ \ (g)}{\text{total mass of vinegar sample}\ (g)} \times 100}$$

3. Antacid Analysis: determining the neutralizing power of a commercial antacid: for this part we are again going to use our NaOH solution from part 1. This time we want to determine the amount of neutralizing power (a.k.a. the amount of base) in a commercial antacid. To do this we will use a special kind of titration known as a back titration.

   In this back titration you will add some HCl to the antacid. The antacid will neutralize some of the HCl added, leaving some HCl leftover. The amount of HCl reacting with the antacid equals the amount of base in the antacid. Now, using our NaOH solution, we will titrate this leftover HCl to determine the amount leftover.

$$\text{moles base in antacid} = \text{moles HCl reacting} = \text{initial moles of HCl added} - \text{leftover moles of HCl} \quad (7)$$

   Since we know the concentration of the HCl and the volume we initially added, we can get the initial moles of HCl ($M_{HCl} \times V_{HCl}$). And from the back titration you can find the moles of HCl leftover:

$$\text{leftover moles of HCl} = M_{NaOH}\ (mol/L) \times V_{NaOH}\ (L) \quad (8)$$

   where M_{NaOH} is the concentration of your NaOH solution determined in part 1 and V_{NaOH} is the volume of NaOH you added from your buret.

   Putting this all together we get:

$$\boxed{\text{moles base in antacid} = \underbrace{M_{HCl}\ (mol/L) \times V_{HCl}\ (L)}_{initial\ moles\ HCl\ added} - \underbrace{M_{NaOH}\ (mol/L) \times V_{NaOH}\ (L)}_{leftover\ moles\ HCl}}$$

   where V_{HCl} is the volume of HCl you added initially, M_{HCl} is the concentration of the HCl, which can be read off the bottle, M_{NaOH} is the concentration of your NaOH solution determined in part 1, and V_{NaOH} is the volume of NaOH you added from your buret.

   Since we now know the amount of base in the antacid, we can compare the "power" of each brand by finding the antacid cost per mole of base in the antacid

$$\boxed{\text{cost of antacid per mole of base} = \frac{\text{cost of antacid}}{\text{gram of antacid}} \times \frac{\text{grams of antacid}}{\text{mole of base}}}$$