

Volumetric Calculations

How to analyze titration data
and
perform dilution calculations

Volumetric procedures

- Involve the careful measurement of volumes of solutions
- Dissolve materials in water and run reaction in solution - titration in Erlenmeyer flask (designed for swirling to mix reactants)
- Buret is the measuring device - can read volumes to 0.01 mL
- Pipets may also be used, especially to transfer solutions - good to 0.01 mL

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Some terminology

- Analyte Substance being analyzed
- Titrant Solution in the buret
- Standard solution Solution of known concentration
- Equivalence point Stoichiometric point
- End point

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At the equivalence point

- For a 1-to-1 reaction such as:

$$\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$$

$$\text{mole}_{\text{acid}} = \text{mole}_{\text{base}}$$

- moles = molarity x volume in liters
- So

$$M_{\text{acid}} \times V_{\text{acid}} = M_{\text{base}} \times V_{\text{base}}$$

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What is the end point?

- The end point is the point where an indicator changes color.
- This is the visual sign to stop or end the titration. If the indicator is selected correctly, the change is at or very near the equivalence point!
- Example is phenolphthalein
colorless in acid
pink in base

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Example of calculation

- A 25.07 mL sample of vinegar is titrated with 37.31 mL of 0.5119 M NaOH. What is the molarity of the acetic acid in vinegar?

$$\text{Moles NaOH} = 0.5119 \text{ moles/L} \times 37.31 \text{ mL} \times 1\text{L}/1000\text{mL}$$

$$\text{Moles acetic acid} = \text{moles NaOH} = 0.01910 \text{ moles}$$

$$M_{\text{aa}} = \text{moles/volume} = 0.01910 \text{ moles}/0.02507 \text{ L} = 0.7618 \text{ M}$$

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- What is the percent acetic acid in the vinegar? Vinegar has a density near water so our 25.07 mL sample has a mass of 25.07 g.

$$\begin{aligned} \text{Mass of acetic acid} &= \text{moles} \times \text{MM} \\ &= 0.01910 \text{ moles} \times 60.00 \text{ g/mole} \\ &= 1.146 \text{ g acetic acid} \end{aligned}$$

$$\begin{aligned} \text{Percent} &= \text{part} \times 100/\text{total} \\ &= 1.146 \text{ g acetic acid} \times 100/ 25.07 \text{ g sample} \\ &= 4.47\% \text{ acetic acid} \end{aligned}$$

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A Back Titration -

- An indirect analysis for antacids, since they are insoluble
- Antacids, which are bases, are reacted with excess acid and this excess acid is titrated with standard base.

$$\text{Antacid} + \text{HCl (initial)} \rightarrow \text{neutralized antacid} + \text{HCl (leftover)}$$

$$\text{HCl (leftover)} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$$

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Back Titration Calculation-


- moles HCl initially = $M_{\text{HCl}} \times V_{\text{HCl}}$
- moles HCl left-over = moles NaOH = $M_{\text{NaOH}} \times V_{\text{NaOH}}$
- mole HCl reacted = moles HCl initially - moles HCl left-over
- moles antacids - depends on reaction stoichiometry such as:

$$\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$$

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Dilution -

- Process of adding solvent, usually water, to lower the concentration of a solution
- Used to make working standards for spectrophotometry
- Used to bring a sample into range for analysis
- Typically done using a pipet (TD) and volumetric flask (TC)



Solute is constant.
Solvent is being added.

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Dilution continued

- Since the solute is constant, then

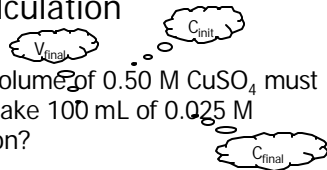
$$\text{moles}_{\text{initial}} = \text{moles}_{\text{final}}$$
- So the dilution equation becomes

$$C_{\text{init}} V_{\text{init}} = C_{\text{final}} V_{\text{final}}$$

where $V_{\text{final}} = V_{\text{init}} + V_{\text{water}}$

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Dilution Calculation



- What initial volume of 0.50 M CuSO_4 must be used to make 100 mL of 0.025 M CuSO_4 solution?
- $C_{\text{init}} V_{\text{init}} = C_{\text{final}} V_{\text{final}}$ and rearrange
- $V_{\text{init}} = C_{\text{final}} V_{\text{final}} / C_{\text{init}}$

$$= 0.025 \text{ M} \times 100 \text{ mL} / 0.50 \text{ M} = 5.0 \text{ mL}$$

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Dilution continued

- A graduated cylinder is a volume measuring device to contain (TC). Could you do a dilution in it? Explain why or why not.
- Dilution factor = $V_{\text{init}}/V_{\text{final}}$
1 mL into 100 mL is a df of 1/100

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Dilution continued

- Serial dilution – successive dilutions for large scale dilutions in steps
 - A is diluted by 1/100 to B
 - B is diluted by 1/100 to C
 - C is 1/10,000 of A

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