Dilutions

In almost all laboratory and medical setting dilution of solutions of known concentrations are done. It is very important to be able to do them correctly.

Overview of this Lecture

• Review of Calculating Concentration of Solutions & Using Chemical Equations
• Introducing Dilution Calculations – Molarity
• Dilutions
  • %
  • g/ml
  • $M_dV_d=M_cV_c$
  • ppb
• Summary Calculations

Chemical Reaction and Molarity

• In our bodies we “burn” glucose to get energy.
• Burning glucose requires oxygen and produces carbon dioxide according to the following reaction

Concentrations and Reactions

• Nitrogen and hydrogen can react to form ammonia. The balance equation for this reaction is shown below.
  \[ 3H_2 + N_2 \rightarrow 2NH_3 \]
• How much Nitrogen will be used if 7.00 moles of $H_2$ react?
  \[ \frac{7.00\text{moles}H_2}{\left(\frac{1\text{mole}N_2}{3\text{moles}H_2}\right)} = 2.333\text{moles}N_2 \]
Concentrations and Reactions

If all of the ammonia made in this reaction is trapped in 3.000 L of water, what is the molar concentration of the ammonia in the water?

• \( 3H_2 + N_2 \rightarrow 2NH_3 \)
• Calculate the # of moles \( NH_3 \) made.

\[
7.00 \text{ moles} H_2 \left( \frac{2 \text{ mole} NH_3}{3 \text{ moles} H_2} \right) = 4.666 \text{ moles} NH_3
\]

Concentrations and Reactions

• Calculate the Molarity of this solution

\[
M \text{ NH}_3 = \left( \frac{\text{moles} \text{ NH}_3}{1 \text{ L} \text{ solution}} \right) = \left( \frac{4.666 \text{ moles} \text{ NH}_3}{3.000 \text{ L}} \right) = 1.555 \text{ M \text{ NH}_3} = 1.56 \text{ M \text{ NH}_3}
\]

• (There are 3 Sig. Fig. in the final answer because ...)

What is the % of the solution that is Ammonia?

Known:
• In 1 L of the solution there is 1.56 moles \( NH_3 \).
• Assume that 1L of solution weighs 1000g.

Needed:
• \( \%NH_3 = \frac{\text{gNH}_3}{\text{gSolution}} \)

1. Find the Mass of \( NH_3 \) in 1 liter

\[
1 \text{ Liter solution} \left( \frac{1.56 \text{ moles} \text{ NH}_3}{1 \text{ Liter solution}} \right) \left( \frac{17.031 \text{ g NH}_3}{1 \text{ mole NH}_3} \right) = 26.49 \text{ g NH}_3
\]

2. Determine the % by mass

\[
\left( \frac{26.49 \text{ g NH}_3}{1000 \text{ g solution}} \right) \times 100\% = 2.649\% = 2.65\%
\]

done
What would the concentration of a solution made with 5 ml of the 1.56M ammonia solution and 65 ml of water be?

Needed:
- 7 M dilute solution (moles NH₃/1 L solution)

Known:
- 5 ml Concentrated Solution
- 65 ml added volume
- 1.56 M concentrated solution

1. Find Moles NH₃ used in the dilution

\[
\frac{5 \text{ ml solution}}{1000 \text{ ml}} \times \frac{1.56 \text{ moles NH}_3}{1 \text{ L solution}} = 0.0078 \text{ moles NH}_3
\]

2. Get the concentration of the dilute volume

\[
\frac{\text{moles NH}_3}{1 \text{ L solution}} = \left( \frac{0.0078 \text{ moles NH}_3}{65 \text{ ml} + 5 \text{ ml}} \right) \times \frac{1000 \text{ ml}}{1 \text{ L solution}}
\]

\[
= \left( \frac{0.111 \text{ moles NH}_3}{1 \text{ L solution}} \right) = 0.111 M \text{ NH}_3
\]

done

What would the concentration of a solution made with 5 g of a 2.65% ammonia solution and 65 g water be?

Needed:
- 7 % dilute solution (g NH₃/g solution) x 100%

Known:
- 5 g Concentrated Solution
- 65 g H₂O added
- 2.65% NH₃ in the initial solution

1. Calculate the mass of NH₃ used in the dilution

\[
\frac{5 \text{ g solution}}{100 \text{ g solution}} \times \frac{26.5 \text{ g NH}_3}{100 \text{ g solution}} = 1.325 \text{ g NH}_3
\]

2. Calculate its % of the total mass

\[
\left( \frac{1.325 \text{ g NH}_3}{65 \text{ g} + 5 \text{ g}} \right) \times 100% = 1.89%
\]

done

How about the same calculation with % by mass

1. Calculate the mass of NH₃ used in the dilution

\[
\frac{5 \text{ g solution}}{100 \text{ g solution}} \times \frac{26.5 \text{ g NH}_3}{100 \text{ g solution}} = 1.325 \text{ g NH}_3
\]

2. Calculate its % of the total mass

\[
\left( \frac{1.325 \text{ g NH}_3}{65 \text{ g} + 5 \text{ g}} \right) \times 100% = 1.89%
\]

done
How about making the dilution

How much of a concentrated solution should you use to make a 30 ml solution with 10 mg A/ml? Your concentrated solution has 150 mg A/ml.

1. Find the # of mg you need in the final solution.

\[
30 \text{ ml dilute solution} \left( \frac{10 \text{ mg A}}{1 \text{ ml dilute solution}} \right) = 300 \text{ mg A}
\]

2. Find the volume of the concentrated solution you need to get that many moles.

\[
300 \text{ mg A} \left( \frac{1 \text{ ml conc. solution}}{150 \text{ mg A}} \right) = 2 \text{ ml conc. solution}
\]

done

Another way to look at this.

- # moles in dilute solution = # of moles in the concentrated solution
  
  \[M_d V_d = M_c V_c\]

- For Molar Concentrations

\[
\begin{align*}
\text{Moles Solute} & \left( \frac{\text{Volume of (in L)}}{1 \text{ L Dilute Solution}} \right) = \text{Moles Solute} & \left( \frac{\text{Volume of (in L)}}{1 \text{ L Conc. Solution}} \right) \\
\end{align*}
\]

Another Way - \(M_d V_d = M_c V_c\)

- Substituting from our earlier example

\[
M_d \left( \frac{1 \text{ L}}{70 \text{ ml}} \right) \left( \frac{1 \text{ L Conc. Solution}}{1000 \text{ ml}} \right) = 1.56 \text{ Moles NH}_3 \left( \frac{5 \text{ ml}}{1 \text{ L Conc. Solution}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right)
\]

\[
M_d = \frac{1.56 \text{ Moles NH}_3 \left( \frac{5 \text{ ml}}{1 \text{ L Conc. Solution}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right)}{70 \text{ ml}}
\]

\[= 0.111 M \text{ NH}_3\]
Problems with $M_dV_d = M_cV_c$

- Substituting in the wrong concentrations and volumes
- Mistakes in algebra
- Applying it when $M_dV_d \neq M_cV_c$
- I can’t recommend it unless you do a lot of dilution calculations. This is a simple equation that is attractive but dangerous.

ppb calculation

You have a patient who has been taking a tincture that has 15ppb Arsenic in it. The patient dilutes around 2 ml of the tincture in about 500ml water, and then drinks 400ml of this throughout the day. How much arsenic is the patient consuming?

**Known:**
- 15ppb As
- 2ml Tincture
- 500 ml dilution
- 400 ml dose
- Molar mass As

**Needed:**
- ? g As
- Intermediate ppb dilution

**ppb dilution to gAs**

(1g solution = 1ml solution)

1. Find g As in the dilute solution.

$$\frac{2g \text{ tincture}}{1,000,000,000g \text{ tincture}} = 3 \times 10^{-9} \text{ gAs}$$

2. Calculate ppb As in the dilute solution.

$$\frac{\frac{3 \times 10^{-4} \text{ gAs}}{500g \text{ dilute solution}}}{\frac{6 \times 10^{-11} \text{ gAs}}{1g \text{ dilute solution}}} = 2 \times 10^{-8} \mu\text{gAs}$$

**g As in daily dose**

3. Calculate ppb As in the dilute solution.

$$\frac{6 \times 10^{-11} \text{ gAs}}{1g \text{ dilute solution}} = 2.4 \times 10^{-3} gAs$$

$$= 2 \times 10^{-8} gAs$$

$$= 2 \times 10^{-2} \mu\text{gAs}$$

*done*
Summary

• Concentration calculations can be combined with calculations using chemical equations.
• Correctly determining the concentration of diluted solutions is the same as other calculations.
• Correctly determining how to make a diluted solution is the same as other calculations.
• The concepts that are part of dilution calculations can be extended to other circumstances.
• Use $M_d V_d = M_c V_c$ with care.