Chapter 4 : Reactions in Aqueous Solution

Chapter 4 (p 147-151)

- 4.5 Concentration of solutions (Molarity and dilution) .

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A ***solution*** is a homogenous mixture of 2 or more substances

The ***solute*** is(are) the substance(s) present in the smaller amount(s)

The ***solvent*** is the substance present in the larger amount

Solution	Solvent	Solute
Soft drink (*l*)	H_2O	Sugar, CO_2
Air (*g*)	N_2	O_2, Ar, CH_4
Soft Solder (*s*)	Pb	Sn

Concentration of Solutions

The ***concentration*** of a solution (which is an intensive property) is the amount of solute present in a given quantity of solvent or solution.

The ***molarity*** is the number of moles of solute per liter of solution .

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

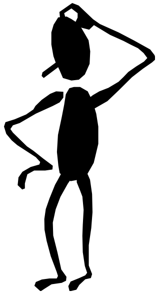
$$M = \frac{n}{V}$$

n (number of moles) = M (molarity) × V (L)

$$\frac{m(g)}{M(g/mol)} = M(molarity) \times V(L)$$

$$\mathbf{m\ (g) = M \times \mathit{M} \times \mathit{V\ (L)}}$$

وزن المادة بالجرام = الوزن الجزيئي × المولارية × الحجم باللتر



What mass of KI is required to make 500 mL of a 2.80 *M* KI solution?

$$m\,(g) = \mathrm{M} \times M \times V\,(L)$$

M of KI = 39.10 + 126.9
= 166 g/mol

m (g) = 166 × 2.80 × 500/1000

mL → L

m (g) = 232.4 g

Example 4.6

DCM, Worked Examples

How many grams of potassium dichromate ($K_2Cr_2O_7$) are required to prepare a 250-mL solution whose concentration is 2.16 *M*?

Strategy How many moles of $K_2Cr_2O_7$ does a 1-L (or 1000 mL) 2.16 *M* $K_2Cr_2O_7$ solution contain? A 250-mL solution? How would you convert moles to grams?

Solution The first step is to determine the number of moles of $K_2Cr_2O_7$ in 250 mL or 0.250 L of a 2.16 *M* solution. Rearranging Equation (4.1) gives

$$\text{moles of solute} = \text{molarity} \times \text{L soln}$$

Thus,

$$\text{moles of } K_2Cr_2O_7 = \frac{2.16 \text{ mol } K_2Cr_2O_7}{1 \text{ }\cancel{\text{L soln}}} \times 0.250 \text{ }\cancel{\text{L soln}}$$
$$= 0.540 \text{ mol } K_2Cr_2O_7$$

The molar mass of $K_2Cr_2O_7$ is 294.2 g, so we write

$$\text{grams of } K_2Cr_2O_7 \text{ needed} = 0.540 \text{ }\cancel{\text{mol } K_2Cr_2O_7} \times \frac{294.2 \text{ g } K_2Cr_2O_7}{1 \text{ }\cancel{\text{mol } K_2Cr_2O_7}}$$
$$= 159 \text{ g } K_2Cr_2O_7$$

Check As a ball-park estimate, the mass should be given by [molarity (mol/L) × volume (L) × molar mass (g/mol)] or [2 mol/L × 0.25 L × 300 g/mol] = 150 g. So the answer is reasonable.

Practice Exercise What is the molarity of an 85.0-mL ethanol (C_2H_5OH) solution containing 1.77 g of ethanol?

How many grams of potassium dichromate ($K_2Cr_2O_7$) are required to prepare a 250-mL solution whose concentration is 2.16 *M*?

$$M\ (g/mol)\ of\ K_2Cr_2O_7 = 2(39.1) + 2(52) + 7(16) = 294.2\ g$$

$$\mathbf{m\ (g) = M \times \mathit{M} \times \mathit{V\ (L)}}$$

$$m\ (g) = 294.2 \times 2.16 \times 250/1000 = 158.868\ g \approx 159\ g$$

mL → L

Example 4.7

DCM, Worked Examples

In a biochemical essay, a chemist needs to add 3.81 g glucose to a reaction mixture. Calculate the volume in milliliters of a 2.53 *M* glucose solution she should use for the addition.

Strategy We must first determine the number of moles contained in 3.81 g of glucose and then use Equation (4.2) to calculate the volume.

Solution From the molar mass of glucose, we write

$$3.81\ \text{g}\ C_6H_{12}O_6 \times \frac{1\ \text{mol}\ C_6H_{12}O_6}{180.2\ \text{g}\ C_6H_{12}O_6} = 2.114 \times 10^{-2}\ \text{mol}\ C_6H_{12}O_6$$

Next, we calculate the volume of the solution that contains 2.114×10^{-2} mole of the solute. Rearranging Equation (4.2) gives

$$\begin{aligned} V &= \frac{n}{M} \\ &= \frac{2.114 \times 10^{-2}\ \text{mol}\ C_6H_{12}O_6}{2.53\ \text{mol}\ C_6H_{12}O_6/\text{L soln}} \times \frac{1000\ \text{mL soln}}{1\ \text{L soln}} \\ &= 8.36\ \text{mL soln} \end{aligned}$$

Check One liter of the solution contains 2.53 moles of $C_6H_{12}O_6$. Therefore, the number of moles in 8.36 mL or 8.36×10^{-3} L is (2.53 mol $\times 8.36 \times 10^{-3}$) or 2.12×10^{-2} mol. The small difference is due to the different ways of rounding off.

Practice Exercise What volume (in milliliters) of a 0.315 *M* NaOH solution contains 6.22 g of NaOH?

In a biochemical essay, a chemist needs to add 3.81 g glucose to a reaction mixture. Calculate the volume in milliliters of a 2.53 *M* glucose solution she should use for the addition.

m (g) = M × *M* × *V (L)*

$$3.81 = 180.2 \times 2.53 \times V\ (L)$$

$$V\ (L) = 3.81/(180.2 \times 2.53)$$

$$= 0.008357\ L$$

$$= 8.36\ mL$$

L → mL

×1000

- What is the molarity of an 85 ml ethanol C_2H_5OH solution containing 1.77g of ethanol?

- Molar mass C_2H_5OH
  = 46.068 g/mol

m (g) = M × *M* × *V (L)*

$$1.77 = 46.068 \times M \times 85/1000$$

$$M = 0.452\ \text{M}$$

mL → L

- **What is the volume (in ml) of 0.315M NaOH solution contains 6.22g of NaOH?**

- Molar mass NaOH= 40 g/mol

$$\mathbf{m\ (g) = M \times \mathit{M} \times \mathit{V\ (L)}}$$

$$6.22 = 40 \times 0.315 \times V$$

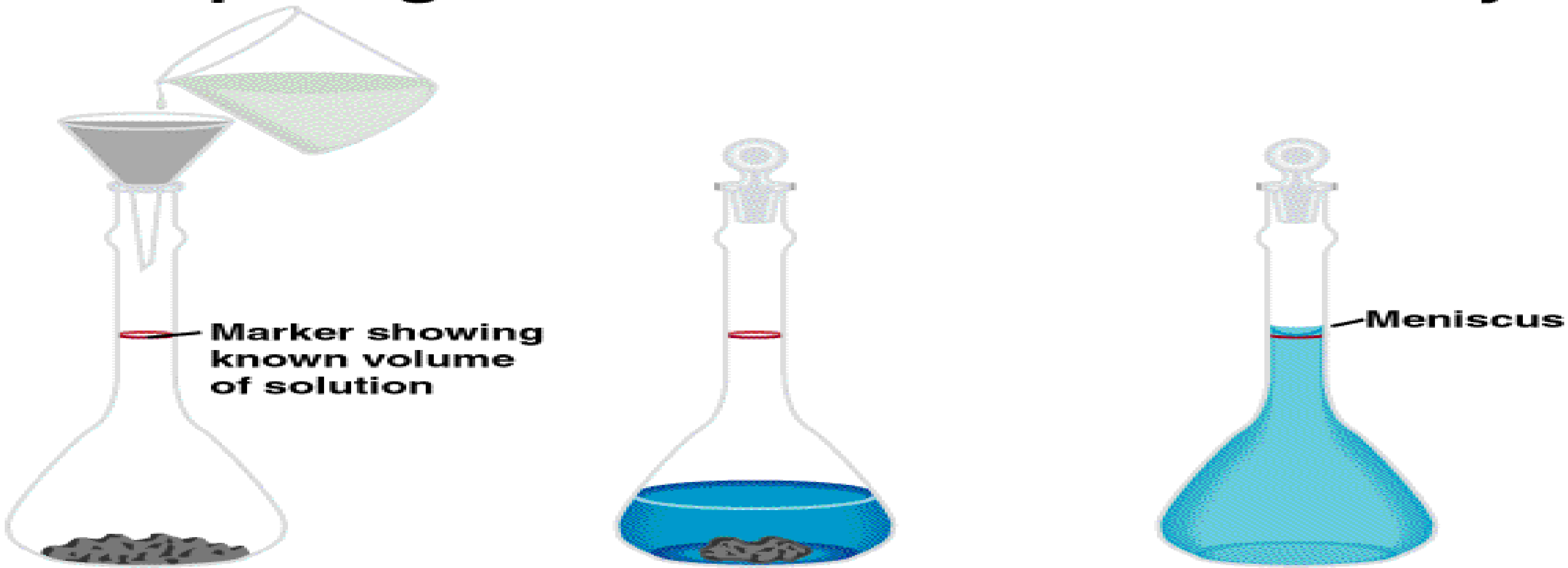
$$V = 0.4937\ \text{L}$$

$$= 493.7\ \text{mL}$$

$$\approx 494\ \text{mL}$$

$$\text{L} \xrightarrow{\times 1000} \text{mL}$$

Preparing a Solution of Known Molarity



(a) (b) (c)

(a) (b) (c) (d)

KCl is a strong electrolyte

$$KCl_{(s)} \xrightarrow{H_2O} K^{+}_{aq} + Cl^{-}_{aq}$$

1 *M* KCl ⟶ 1mole of K^+ ions and 1mole of Cl^- ions

$[K^+] = 1M$

$[Cl^-] = 1M$

Ba $(NO_3)_2$ is strong electrolyte

$$Ba(NO_3)_{2(s)} \xrightarrow{H_2O} Ba^{2+}_{aq} + 2NO^{-}_{3_{aq}}$$

1 *M* $Ba(NO_3)_2$ ⟶ 1mole of Ba^{2+} ions and 2mole of NO_3^- ions

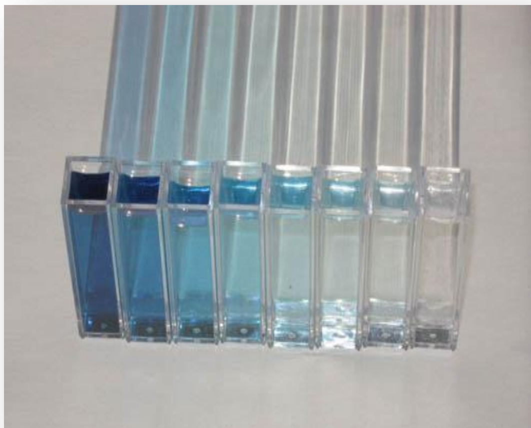
$[Ba^{2+}] = 1M$

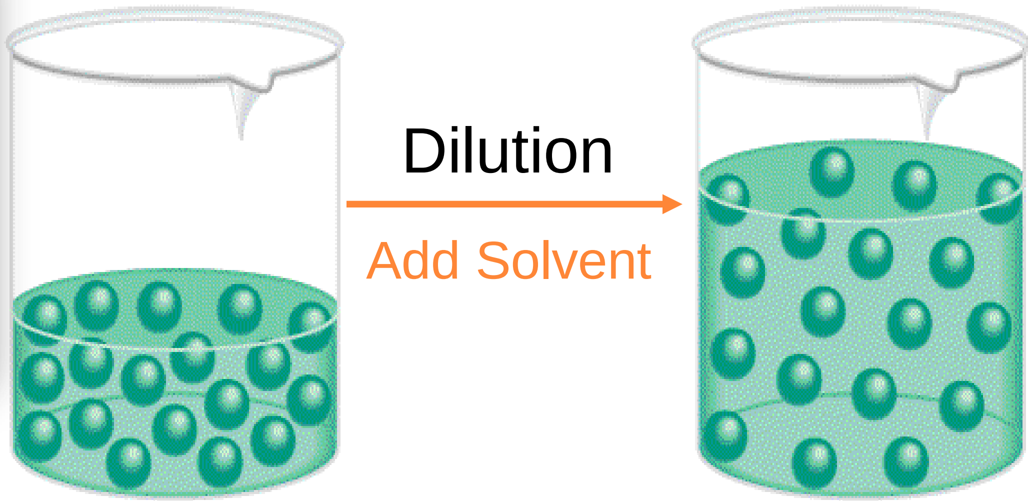
$[NO^-_3] = 2M$

Dilution is the procedure for preparing a less concentrated solution from a more concentrated solution.

Calculation based on that the number of moles of solute is constant we add only solvent

Dilution law: قانون التخفيف

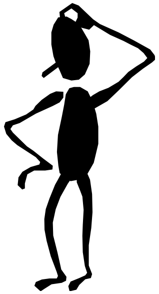




Moles of solute before dilution (i) = Moles of solute after dilution (f)

$$M_i V_i = M_f V_f$$

قبل التخفيف | بعد التخفيف



How would you prepare 60.0 mL of 0.200 *M* HNO_3 from a stock solution of 4.00 *M* HNO_3?

$$M_i V_i = M_f V_f$$

The units of V_i & V_f must be the same (mL or L)

$M_i = 4.00$ $M_f = 0.200$ $V_f = 0.06$ L $V_i = ?$ L

$$V_i = \frac{M_f V_f}{M_i} = \frac{0.200 \times 0.06}{4.00} = 0.003 \text{ L} = 3 \text{ mL}$$

3 mL of acid + 57 mL of water = 60 mL of solution

Example 4.8

DCM, Worked Examples

Describe how you would prepare 5.00×10^2 mL of a 1.75 *M* H_2SO_4 solution, starting with an 8.61 *M* stock solution of H_2SO_4.

Strategy Because the concentration of the final solution is less than that of the original one, this is a dilution process. Keep in mind that in dilution, the concentration of the solution decreases but the number of moles of the solute remains the same.

Solution We prepare for the calculation by tabulating our data:

$$M_i = 8.61\ M \qquad M_f = 1.75\ M$$
$$V_i = ? \qquad V_f = 5.00 \times 10^2\ \text{mL}$$

Substituting in Equation (4.3),

$$(8.61\ M)(V_i) = (1.75\ M)(5.00 \times 10^2\ \text{mL})$$
$$V_i = \frac{(1.75\ M)(5.00 \times 10^2\ \text{mL})}{8.61\ M}$$
$$= 102\ \text{mL}$$

Thus, we must dilute 102 mL of the 8.61 *M* H_2SO_4 solution with sufficient water to give a final volume of 5.00×10^2 mL in a 500-mL volumetric flask to obtain the desired concentration.

Check The initial volume is less than the final volume, so the answer is reasonable.

Practice Exercise How would you prepare 2.00×10^2 mL of a 0.866 *M* NaOH solution, starting with a 5.07 *M* stock solution?

$$M_i V_i = M_f V_f$$

$M_i = 8.61\ M$ $M_f = 1.75\ M$ $V_f = 5 \times 10^2$ mL $V_i = ?$ L

$$V_i = \frac{M_f V_f}{M_i} = \frac{1.75 \times 5 \times 10^2}{8.61} = 101.6 \approx 102 \text{ mL}$$

102 mL of acid + 398 mL of water = 500 mL of solution

Practice exercise 4.8

How would you prepare 200 mL of 0.866 *M* NaOH from a stock solution of 5.07 *M* NaOH?

$$M_i V_i = M_f V_f$$

M_i = 5.07 M_f = 0.866 V_f = 200 mL V_i = ? mL

$$V_i = \frac{M_f V_f}{M_i} = \frac{0.866 \times 200}{5.07} = 34.2 \text{ mL}$$

Practice

- How many mL of 5.0 M $K_2Cr_2O_7$ solution must be diluted to prepare 250 mL of 0.10 M solution?

V_i = ?

M_i = 5.0M V_f = 250 mL M_f = 0.10M

$M_i = M_f V_f / V_i$ V_i = 250 mL ×0.1M/5mL = 5 mL

- If 10.0 mL of a 10.0 M stock solution of NaOH is diluted to 250 mL, what is the concentration of the resulting solution?

M_f= ?

V_i= 10.0 mL M_i = 10.0M V_f = 250 mL

$M_i = M_f V_f / V_i$ M_i = 10mL ×10M/250mL = 0.4 M

- *Problems*
- 4.60 – 4.62 – 4.64 – 4.66 – 4.70 – 4.74