Section 8.3 Concentrations of Solutions

Solutions for Practice Problems

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41. Practice Problem (page 381)

Determine the molar concentration of each saline solution.

a. 0.60 mol NaCl(s) dissolved in 0.40 L of solution

b. 0.90 g NaCl(s) dissolved in 100 mL of solution

What Is Required?

You need to determine the molar concentration of two NaCl(aq) solutions.

What Is Given?

You know the following information:

a. NaCl(aq): $n = 0.60$ mol; $V = 0.40$ L of solution

b. NaCl(aq): $m = 0.90$ g; $V = 100$ mL of solution

Plan Your Strategy

a. 0.60 mol NaCl(aq)

Write the formula for molar concentration.

Substitute the given data into the formula to calculate the concentration.

b. 0.90 g NaCl(aq)

Determine the molar mass of NaCl(aq).

Determine the amount in moles of NaCl(aq) using the relationship $n = \dfrac{m}{M}$.

Convert the volume of the solution from millilitres to litres: 1 mL = 1×10^{-3} L

Write the formula for molar concentration.

Substitute the given data into the formula to calculate the concentration.

Act on Your Strategy

a. 0.60 mol NaCl(aq)

Molar concentration, c:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.60\ \text{mol}}{0.40\ \text{L}} \\ &= 1.5\ \text{mol/L} \end{aligned}$$

The molar concentration is 1.5 mol/L.

b. 0.90 g NaCl(aq)
Molar mass, *M*, of NaCl(aq):

$$\begin{aligned} M_{NaCl} &= 1M_{Na} + 1M_{Cl} \\ &= 1(22.99 \text{ g/mol}) + 1(35.45 \text{ g/mol}) \\ &= 58.44 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of the NaCl(aq):

$$\begin{aligned} n_{NaCl} &= \frac{m}{M} \\ &= \frac{0.90 \cancel{\text{ g}}}{58.44 \cancel{\text{ g}}\text{/mol}} \\ &= 0.01540 \text{ mol} \end{aligned}$$

Volume (in litres) of the solution, *V*:

$$\begin{aligned} V &= 100 \cancel{\text{ mL}} \times 1 \times 10^{-3} \text{ L/}\cancel{\text{mL}} \\ &= 0.100 \text{ L} \end{aligned}$$

Molar concentration, *c*:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.01540 \text{ mol}}{0.100 \text{ L}} \\ &= 0.154 \text{ mol/L} \end{aligned}$$

The molar concentration is 0.154 mol/L.

Check Your Solution
The concentrations seem reasonable, and have the correct units and number of significant digits.

42. Practice Problem (page 381)
What volume of 0.25 mol/L solution can be made using 14 g of sodium hydroxide?

What Is Required?
You need to determine the volume of sodium hydroxide, NaOH(aq).

What Is Given?
You know the molar concentration of the NaOH(aq): 0.25 mol/L
You know the mass of the NaOH(s): 14 g

Substitution to calculate the volume, V:

$$\begin{aligned} V &= \frac{n}{c} \\ &= \frac{0.350\ \cancel{\text{mol}}}{0.25\ \cancel{\text{mol}}/\text{L}} \\ &= 1.4\ \text{L} \end{aligned}$$

The volume of sodium hydroxide solution is 1.4 L.

Check Your Solution
The correct units have been used and the number of significant digits agrees with the given data.
The calculated answer seems reasonable.

43. Practice Problem (page 381)
Calculate the molar concentration of each solution.
a. 14 g of copper(II) sulfate, $CuSO_4(s)$, dissolved in 70 mL of solution
b. 5.07 g of sucrose, $C_{12}H_{22}O_{11}(s)$, dissolved in 23.6 mL of solution
c. 1.1 g of calcium nitrate, $Ca(NO_3)_2(s)$, dissolved in 70 mL of solution

What Is Required?
You need to determine the molar concentrations of three solutions.

What Is Given?
You know the masses and volumes of the three solutions:
a. $CuSO_4(s)$: m = 14 g; V = 70 mL
b. $C_{12}H_{22}O_{11}(s)$: m = 5.07 g; V = 23.6 mL
c. $Ca(NO_3)_2(s)$: m = 1.1 g; V = 70 mL

Plan Your Strategy
Determine the molar mass of each solute.

Calculate the amount in moles of each solute using the relationship $n = \frac{m}{M}$.

Convert the volume of each solution from millilitres to litres:
1 mL = 1 × 10^{-3} L
Calculate the molar concentration of each solution using the relationship

$$c = \frac{n}{V}.$$

Act on Your Strategy

a. copper(II) sulfate

Molar mass, *M*, of $CuSO_4$(s):

$$\begin{aligned} M_{CuSO_4} &= 1M_{Cu} + 1M_{S} + 4M_{O} \\ &= 1(63.55\ \text{g/mol}) + 1(32.07\ \text{g/mol}) + 4(16.00\ \text{g/mol}) \\ &= 159.62\ \text{g/mol} \end{aligned}$$

Amount in moles, *n*, of the $CuSO_4$(s):

$$\begin{aligned} n_{CuSO_4} &= \frac{m}{M} \\ &= \frac{14\ \cancel{\text{g}}}{159.62\ \cancel{\text{g}}/\text{mol}} \\ &= 0.087708\ \text{mol} \end{aligned}$$

Volume, *V*, of the $CuSO_4$(aq):

$$\begin{aligned} V &= 70\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.070\ \text{L} \end{aligned}$$

Molar concentration, *c*:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.087708\ \text{mol}}{0.070\ \text{L}} \\ &= 1.253\ \text{mol/L} \\ &= 1.2\ \text{mol/L} \end{aligned}$$

The molar concentration of copper(II) sulfate is 1.2 mol/L.

b. sucrose

Molar mass, *M*, of $C_{12}H_{22}O_{11}$(s):

$$\begin{aligned} M_{C_{12}H_{22}O_{11}} &= 12M_{C} + 22M_{H} + 11M_{O} \\ &= 12(12.01\ \text{g/mol}) + 22(1.01\ \text{g/mol}) + 11(16.00\ \text{g/mol}) \\ &= 342.34\ \text{g/mol} \end{aligned}$$

Amount in moles, n, of the $C_{12}H_{22}O_{11}$(s):

$$\begin{aligned} n_{C_{12}H_{22}O_{11}} &= \frac{m}{M} \\ &= \frac{5.07\ \cancel{g}}{342.34\ \cancel{g}/\text{mol}} \\ &= 0.014809\ \text{mol} \end{aligned}$$

Volume, V, of $C_{12}H_{22}O_{11}$(aq):

$$\begin{aligned} V &= 23.6\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.0236\ \text{L} \end{aligned}$$

Molar concentration, c:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{0.014809\ \text{mol}}{0.0236\ \text{L}} \\ &= 0.6275\ \text{mol/L} \\ &= 0.628\ \text{mol/L} \end{aligned}$$

The molar concentration of sucrose is 0.628 mol/L.

c. calcium nitrate
Molar mass, M, of $Ca(NO_3)_2$(s):

$$\begin{aligned} M_{Ca(NO_3)_2} &= 1M_{Ca} + 2M_N + 6M_O \\ &= 1(40.08\ \text{g/mol}) + 2(14.01\ \text{g/mol}) + 6(16.00\ \text{g/mol}) \\ &= 164.1\ \text{g/mol} \end{aligned}$$

Amount in moles, n, of the $Ca(NO_3)_2$(s):

$$\begin{aligned} n_{Ca(NO_3)_2} &= \frac{m}{M} \\ &= \frac{1.1\ \cancel{g}}{164.1\ \cancel{g}/\text{mol}} \\ &= 0.006703\ \text{mol} \end{aligned}$$

Volume, V, of $Ca(NO_3)_2$(aq):

$$\begin{aligned} V &= 70\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.0700\ \text{L} \end{aligned}$$

Molar concentration, c:

$$c = \frac{n}{V}$$
$$= \frac{0.006703 \text{ mol}}{0.0700 \text{ L}}$$
$$= 0.095757 \text{ mol/L}$$
$$= 0.096 \text{ mol/L}$$

The molar concentration of calcium nitrate is 0.096 mol/L.

Check Your Solution
The correct units have been used and the number of significant digits in each case agrees with the given data. The calculated answers seem reasonable.

44. Practice Problem (page 381)
At 20°C, a saturated solution of calcium sulfate, $CaSO_4(aq)$, has a concentration of 0.0153 mol/L. A student takes 65 mL of this solution and evaporates it. What mass of solute should be left in the evaporating dish?

What Is Required?
You need to determine the mass of solute.

What Is Given?
You know the molar concentration of a solution of $CaSO_4(aq)$: 0.0153 mol/L
You know the volume of the solution: 65 mL

Plan Your Strategy
Convert the volume of the solution, V, from millilitres to litres: 1 mL = 1×10^{-3} L
Write the formula for molar concentration.
Rearrange the expression to solve for the amount in moles.
Substitute the data into the equation to calculate the amount in moles of $CaSO_4(aq)$.
Determine the molar mass of $CaSO_4(s)$.
Determine the mass of the $CaSO_4(s)$ using the relationship $m = n \times M$.

Act on Your Strategy
Volume conversion:

$$V = 65 \cancel{\text{mL}} \times 1 \times 10^{-3} \text{ L}/\cancel{\text{mL}}$$
$$= 0.065 \text{ L}$$

45. Practice Problem (page 381)

Find the mass of solute in each aqueous solution.

a. 28 mL of 0.045 mol/L calcium hydroxide, $Ca(OH)_2(aq)$

b. 50 mL of 4.0 mol/L acetic acid, $CH_3COOH(aq)$

c. 5.31 L of 0.675 mol/L ammonium phosphate, $(NH_4)_3PO_4(aq)$

What Is Required?

You need to determine the mass of solute in each solution.

What Is Given?

You know the volume and molar concentration of each solution:

a. $Ca(OH)_2(aq)$: V = 28 mL; c = 0.045 mol/L

b. $CH_3COOH(aq)$: V = 50 mL; c = 4.0 mol/L

c. $(NH_4)_3PO_4(aq)$: V = 5.31 L; c = 0.675 mol/L

Plan Your Strategy

Where necessary, convert each volume of solution from millilitres to litres: 1 mL = 1×10^{-3} L

Write the formula for molar concentration.

Rearrange the expression to solve for the amount in moles.

Substitute data into the formula to calculate the amount in moles, n, of each solute.

Determine the molar mass of each solute.

Determine the mass of each solute using the relationship $m = n \times M$.

Act on Your Strategy

a. calcium hydroxide

Volume conversion:

$$\begin{aligned}\text{volume of } Ca(OH)_2(aq) \text{ solution} &= 28 \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.028\ \text{L}\end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

$$\begin{aligned}c \times V &= \frac{n}{\cancel{V}} \times \cancel{V} \\ n &= c \times V\end{aligned}$$

Substitution to calculate the amount in moles, *n*, of $Ca(OH)_2(aq)$:

$$\begin{aligned} n_{Ca(OH)_2} &= c \times V \\ &= 0.045\ \text{mol}/\cancel{\text{L}} \times 0.028\ \cancel{\text{L}} \\ &= 1.260 \times 10^{-3}\ \text{mol} \end{aligned}$$

Molar mass, *M*, of $Ca(OH)_2(s)$:

$$\begin{aligned} M_{Ca(OH)_2} &= 1M_{Ca} + 2M_{O} + 2M_{H} \\ &= 1(40.08\ \text{g/mol}) + 2(16.00\ \text{g/mol}) + 2(1.01\ \text{g/mol}) \\ &= 74.1\ \text{g/mol} \end{aligned}$$

Mass, *m*, of $Ca(OH)_2(s)$:

$$\begin{aligned} m_{Ca(OH)_2} &= n \times M \\ &= 1.260 \times 10^{-3}\ \cancel{\text{mol}} \times 74.1\ \text{g}/\cancel{\text{mol}} \\ &= 0.09336\ \text{g} \\ &= 0.093\ \text{g} \end{aligned}$$

The mass of the calcium hydroxide is 0.093 g.

b. acetic acid
Volume conversion:

$$\begin{aligned} \text{volume of } CH_3COOH(aq) \text{ solution} &= 50\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.050\ \text{L} \end{aligned}$$

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

$$\begin{aligned} c \times V &= \frac{n}{\cancel{V}} \times \cancel{V} \\ n &= c \times V \end{aligned}$$

Substitution to calculate the amount in moles, *n*, of $CH_3COOH(aq)$:

$$\begin{aligned} n_{CH_3COOH} &= c \times V \\ &= 4.0\ \text{mol}/\cancel{\text{L}} \times 0.050\ \cancel{\text{L}} \\ &= 0.20\ \text{mol} \end{aligned}$$

Molar mass, M, of CH_3COOH (s):

$$M_{CH_3COOH} = 2M_C + 2M_O + 4M_H$$
$$= 2(12.01 \text{ g/mol}) + 2(16.00 \text{ g/mol}) + 2(1.01 \text{ g/mol})$$
$$= 60.06 \text{ g/mol}$$

Mass, m, of CH_3COOH(s):

$$m_{CH_3COOH} = n \times M$$
$$= 0.20 \cancel{\text{mol}} \times 60.06 \text{ g/}\cancel{\text{mol}}$$
$$= 12.012 \text{ g}$$
$$= 12 \text{ g}$$

The mass of acetic acid is 12 g.

c. ammonium phosphate
volume of $(NH_4)_3PO_4$(aq) = 5.31 L

Formula for molar concentration:

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

Rearranged formula to solve for the amount in moles:

$$c \times V = \frac{n}{\cancel{V}} \times \cancel{V}$$
$$n = c \times V$$

Substitution to calculate the amount in moles, n, of $(NH_4)_3PO_4$(aq):

$$n_{(NH_4)_3PO_4} = c \times V$$
$$= 0.675 \text{ mol/}\cancel{\text{L}} \times 5.31 \cancel{\text{L}}$$
$$= 3.584 \text{ mol}$$

Molar mass, M, of $(NH_4)_3PO_4$(s):

$$M_{(NH_4)_3PO_4} = 3M_N + 12M_H + 1M_P + 4M_O$$
$$= 3(14.01 \text{ g/mol}) + 12(1.01 \text{ g/mol}) + 1(30.97 \text{ g/mol}) + 4(16.00 \text{ g/mol})$$
$$= 149.12 \text{ g/mol}$$

Mass, *m*, of $(NH_4)_3PO_4(s)$:

$$\begin{aligned} m_{(NH_4)_3PO_4} &= n \times M \\ &= 0.675\ \cancel{\text{mol}} \times 149.12\ \text{g}/\cancel{\text{mol}} \\ &= 100.656\ \text{g} \\ &= 101\ \text{g} \end{aligned}$$

The mass of ammonium phosphate is 101 g.

Check Your Solution
The masses seem reasonable and the units have cancelled correctly. The answers show the correct number of significant digits.

46. Practice Problem (page 381)
Calculate the molar concentrations of the ions in each solution.
a. 18 g of sodium sulfate, $Na_2SO_4(s)$, dissolved in 210 mL of solution
b. 15 g of ammonium phosphate, $(NH_4)_3PO_4(s)$, dissolved in 98 mL of solution
c. 20 mg of calcium phosphate, $Ca_3(PO_4)_2(s)$, dissolved in 1.7 L of solution

What Is Required?
You need to determine the molar concentrations of the ions in three solutions.

What Is Given?
You know the masses and volumes of the three solutions:
a. $Na_2SO_4(s)$: m = 18 g; V = 210 mL
b. $(NH_4)_3PO_4(s)$: m = 15 g; V = 98 mL
c. $Ca_3(PO_4)_2(s)$: m = 20 mg; V = 1.7 L

Plan Your Strategy
Where necessary, convert the mass of solute from milligrams to grams: 1 mg = 1×10^{-3} g
Where necessary, convert the volume of solution from millilitres to litres: 1 mL = 1×10^{-3} L
Determine the molar mass of each solute.
Determine the mass of each solute using the relationship $n = \dfrac{m}{M}$.
Calculate the molar concentration using the relationship $c = \dfrac{n}{V}$.
Write the dissociation equation for each compound and use the mole ratio in this balanced equation to calculate the concentration of each ion.

Substitution of calculated data to determine the volume, V, of the solution:

$$\begin{aligned} V &= \frac{n}{c} \\ &= \frac{0.12076\ \cancel{\text{mol}}}{0.555\ \cancel{\text{mol}}/\text{L}} \\ &= 0.21758\ \text{L} \\ &= 0.218\ \text{L} \end{aligned}$$

The volume of the sodium carbonate solution is 0.218 L.

Check Your Solution
The correct units have been used and the answer correctly shows three significant digits. The calculated answer seems reasonable.

50. Practice Problem (page 381)
Zinc oxide, $ZnO(s)$, has a solubility of 0.16 mg/100 mL in water at 30°C. Find the molar concentration of a saturated solution of zinc oxide at 30°C.

What Is Required?
You need to determine the molar concentration of a zinc oxide solution.

What Is Given?
You know the solubility of the zinc oxide: 0.16 mg/100 mL of solution

Plan Your Strategy
Convert the solubility from mg/100 mL to g/L:
1 mg = 1×10^{-3} g
1 mL = 1×10^{-3} L
Determine the molar mass of $ZnO(s)$.

Calculate the amount in moles of the $ZnO(s)$ using the relationship $n = \frac{m}{M}$.

Calculate the molar concentration of the solution using the relationship $c = \frac{n}{V}$.

Act on Your Strategy
Solubility conversion:

$$\frac{0.16\ \cancel{\text{mg}} \times 1 \times 10^{-3}\ (\text{g}/\cancel{\text{mg}})}{100\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ (\text{L}/\cancel{\text{mL}})} = 0.0016\ \text{g/L}$$

Molar mass, *M*, of ZnO(s):

$$\begin{aligned} M_{ZnO} &= 1M_{Zn} + 1M_{O} \\ &= 1(65.38 \text{ g/mol}) + 1(16.00 \text{ g/mol}) \\ &= 81.38 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of ZnO(s):

$$\begin{aligned} n_{ZnO} &= \frac{m}{M} \\ &= \frac{0.0016 \cancel{\text{g}}}{81.38 \cancel{\text{g}}\text{/mol}} \\ &= 1.966 \times 10^{-5} \text{ mol} \\ &= 2.0 \times 10^{-5} \text{ mol} \end{aligned}$$

Molar concentration, *c*, of the solution:

$$\begin{aligned} c &= \frac{n}{V} \\ &= \frac{2.0 \times 10^{-5} \text{ mol}}{1 \text{ L}} \\ &= 2.0 \times 10^{-5} \text{ mol/L} \end{aligned}$$

The molar concentration of the zinc oxide solution is 2.0×10^{-5} mol/L.

Check Your Solution

The concentration would be expected to be low given the low solubility. The answer seems reasonable and the units have cancelled correctly. The answer correctly shows two significant digits.