Chemistry 1

Volume 3

Worksheet 2

Calculating Ion Concentrations in Solutions

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1. What is the concentration of lithium ions in a 1.45 M solution of Li_3PO_4?

2. What is the concentration of NO_3^- in a 0.65 M solution of barium nitrate?

3. When $CaCl_2$ is dissolved in water, the resulting concentration of Cl^- is 0.15 M. What was the concentration of the original solution?

4. 1.00 L of a 0.25 M solution of $CdCl_2$ was mixed with 1.00 L of a 0.10 M solution of LiCl. What is the concentration of cadmium, lithium, and chlorine ions in the mixed solution?

5. A solution was obtained by dissolving 1.1 g $NaCl$ and 0.25 g $MgCl_2$ in 0.50 L of water. What is the concentration of Cl^- in the final solution?

6. What is $[OH^-]$ when 0.66 g $NaOH$ is dissolved in 150 mL water?

7. NaCl and LiCl were dissolved in a solution, and the final [Cl^-] is 0.15 M. If the original [NaCl] was 0.10 M, what was the original concentration of LiCl?

8. How many moles of strontium chloride were used to create a 0.15 L solution where $[Cl^-]$ = 0.88 M?

9. A chemist wants a final solution of 0.16 M $[Br^-]$ with a volume of 0.150 L created from a 0.55 M LiBr solution. What volume of the original solution should be diluted to obtain this concentration?

10. **Challenge:** What is the total ion concentration in a solution created by dissolving 0.55 g $LiNO_3$ in 1.5 L water?

Answer Key

1. What is the concentration of lithium ions in a 1.45 M solution of Li_3PO_4?

   Step 1:

   Write the balanced equation for the dissolution:

$$Li_3PO_4\ (s) \xrightarrow{H_2O\ (l)} 3\ Li^+\ (aq) + PO_4^{3-}\ (aq)$$

   Step 2:

   For every 1 mole of Li_3PO_4, 3 moles of Li+ are formed. Use this as the conversion factor to calculate the Li^+ concentration from the original solution molarity.

$$\frac{1.45\ \cancel{mol\ Li_3PO_4}}{1\ L} \times \frac{3\ mol\ Li^+}{1\ \cancel{mol\ Li_3PO_4}} = 4.35\ M\ Li^+$$

   Correct answer: 4.35 M Li^+

2. What is the concentration of NO^{3-} in a 0.65 M solution of barium nitrate?

   Step 1:

   Write the balanced equation for this process:

$$Ba(NO_3)_2\ (s) \xrightarrow{H_2O\ (l)} Ba^{2+}\ (aq) + 2\ NO_3^-\ (aq)$$

   Step 2:

   Convert moles of $Ba(NO_3)_2$ into moles of NO_3^- using the conversion factor of 1 mole of $Ba(NO_3)_2$ for every 2 moles NO_3^-.

$$\frac{0.65\ \cancel{mol\ Ba(NO_3)_2}}{1\ L} \times \frac{2\ mol\ NO_3^-}{1\ \cancel{mol\ Ba(NO_3)_2}} = 1.3\ M\ NO_3^-$$

   Correct answer: 1.3 M NO_3^-

Rev 9/29/2020

3. When $CaCl_2$ is dissolved in water, the resulting concentration of Cl^- is 0.15 M. What was the concentration of the original solution?

Step 1:
Write a balanced equation for this process:

$$CaCl_2\,(s) \xrightarrow{H_2O\,(l)} Ca^{2+}\,(aq) + 2\,Cl^-\,(aq)$$

Step 2:
Convert [Cl-] to [$CaCl_2$] using the molar ratio from the equation above.

$$\frac{0.15\ \cancel{mol\ Cl^-}}{1\ L} \times \frac{1\ mol\ CaCl_2}{2\ \cancel{mol\ Cl^-}} = 0.075\ M\ CaCl_2\ \text{solution}$$

Correct answer: 0.075 M $CaCl_2$ solution

11. 1.00 L of a 0.25 M solution of $CdCl_2$ was mixed with 1.00 L of a 0.10 M solution of LiCl. What is the concentration of cadmium, lithium, and chlorine ions in the mixed solution?

Step 1:

Write the balanced equations for the dissolution of each of the ionic compounds.

$$CdCl_2\,(s) \xrightarrow{H_2O\,(l)} Cd^{2+}\,(aq) + 2\,Cl^-\,(aq)$$

$$LiCl\,(s) \xrightarrow{H_2O\,(l)} Li^+\,(aq) + Cl^-\,(aq)$$

Step 2:

Use the molar ratio of the original ionic compounds to ions to calculate the concentration of the individual ions in their starting solution.

$CdCl_2$:

$$\frac{0.25\ \cancel{mol\ CdCl_2}}{1\ L} \times \frac{1\ mol\ Cd^{2+}}{1\ \cancel{mol\ CdCl_2}} = 0.25\ M\ Cd^{2+}$$

$$\frac{0.25\ \cancel{mol\ CdCl_2}}{1\ L} \times \frac{2\ mol\ Cl^-}{1\ \cancel{mol\ CdCl_2}} = 0.50\ M\ Cl^-$$

LiCl:

$0.10\ \cancel{mol\ LiCl}$ / $1\ L$	$1\ mol\ Li^{+}$ / $1\ \cancel{mol\ LiCl}$	$= 0.10\ M\ Li^{+}$

$0.10\ \cancel{mol\ LiCl}$ / $1\ L$	$1\ mol\ Cl^{-}$ / $1\ \cancel{mol\ LiCl}$	$= 0.10\ M\ Cl^{-}$

Since you have 1.00 L of each solution, the concentration of ions is also the number of moles of each ion:

$0.25\ M\ Cd^{2+} = 0.25\ mol\ Cd^{2+}$
$0.050\ M\ Cl^{-} = 0.050\ mol\ Cl^{-}$
$0.10\ M\ Li^{+} = 0.10\ mol\ Li^{+}$
$0.10\ M\ Cl^{-} = 0.10\ mol\ Cl^{-}$

Step 3:
Since there are two sources of Cl^{-}, add these together to get the total moles of Cl^{-}.

$Cl^{-} = 0.10\ mol + 0.50\ mol = 0.60\ mol\ Cl^{-}$

Step 4:
Divide each value of moles by the volume of the new solution (2.00 L).

$$[Cl^{-}] = \frac{0.60\ mol}{2.00\ L} = 0.30\ M$$

$$[Cd^{2+}] = \frac{0.25\ mol}{2.00\ L} = 0.13\ M$$

$$[Li^{+}] = \frac{0.10\ mol}{2.00\ L} = 0.050\ M$$

Correct answers: $[Cl^{-}] = 0.30\ M$; $[Cd^{2+}] = 0.13\ M$; $[Li^{+}] = 0.050\ M$

4. A solution was obtained by dissolving 1.1 g NaCl and 0.25 g $MgCl_2$ in 0.50 L of water. What is the concentration of Cl^{-} in the final solution?

   Step 1:

   Write balanced equations for the processes:

   $NaCl\ (s) \xrightarrow{H_2O\ (l)} Na^{+}\ (aq) + Cl^{-}\ (aq)$

$MgCl_2\ (s) \xrightarrow{H_2O\ (l)} Mg^{2+}\ (aq) + 2\ Cl^-\ (aq)$

Step 2:

Use the masses and the molar masses of NaCl and $MgCl_2$ to calculate moles of each and use the molar ratio

$$\frac{1.1\ \cancel{g\ NaCl}}{} \left| \frac{1\ mol\ NaCl}{58.44\ \cancel{g\ NaCl}} \right| = 0.019\ mol\ NaCl$$

$$\frac{0.25\ \cancel{g\ MgCl_2}}{} \left| \frac{1\ mol\ MgCl_2}{95.211\ \cancel{g\ MgCl_2}} \right| = 0.0026\ mol\ MgCl_2$$

Step 3:

Calculate the molarity of the original solutions.

Molarity = $\frac{0.019\ mol\ NaCl}{0.50\ L}$ = 0.038 M NaCl

Molarity = $\frac{0.0026\ mol\ MgCl_2}{0.50\ L}$ = 0.0052 M $MgCl_2$

Step 4:

Use the molar ratio from the balanced equations to calculate $[Cl^-]$ from each salt.

$$\frac{0.038\ \cancel{mol\ NaCl}}{1\ L} \left| \frac{1\ mol\ Cl^-}{1\ \cancel{mol\ NaCl}} \right| = 0.038\ M\ Cl^-$$

$$\frac{0.0052\ \cancel{mol\ MgCl_2}}{1\ L} \left| \frac{2\ mol\ Cl^-}{1\ \cancel{mol\ MgCl_2}} \right| = 0.010\ M\ Cl^-$$

Add these two values together to get the total $[Cl^-]$ in the final solution.

Correct answer: $[Cl^-]$ = 0.048 M

5. What is $[OH^-]$ when 0.66 g NaOH is dissolved in 150 mL water?

Step 1:

The balanced equation for this process is:

$$NaOH\ (s) \xrightarrow{H_2O\ (l)} Na^+\ (aq) + OH^-\ (aq)$$

Step 2:

Calculate the moles of NaOH using the molar mass of NaOH (39.99 g/mol).

0.66 g ~~NaOH~~	1 mol NaOH	= 0.017 mol NaOH
	39.99 ~~g NaOH~~	

Step 3:

Convert 150 mL to L and calculate the molarity of NaOH.

150 ~~mL~~	1 L	= 0.15 L
	1,000 ~~mL~~	

Molarity = $\frac{0.017\ mol\ NaOH}{0.15\ L}$ = 0.11 M

Step 4:

Convert molarity of NaOH to $[OH^-]$ using the molar ratio from the balanced equation.

0.11 ~~mol NaOH~~	1 mol OH^-	= 0.11 M OH^-
1 L	1 ~~mol NaOH~~	

Correct answer: $[OH^-]$ = 0.11 M

6. NaCl and LiCl were dissolved in a solution, and the final $[Cl^-]$ is 0.15 M. If the original [NaCl] was 0.10 M, what was the original concentration of LiCl?

Step 1:

Write out balanced equations for both processes.

$$NaCl\ (s) \xrightarrow{H_2O\ (l)} Na^+\ (aq) + Cl^-\ (aq)$$

$$LiCl\ (s) \xrightarrow{H_2O\ (l)} Li^+\ (aq) + Cl^-\ (aq)$$

Step 2:

Calculate $[Cl^-]$ from the NaCl using the original molarity of the NaCl solution.

$$\frac{0.10\ \cancel{\text{mol NaCl}}}{1\ \text{L}} \times \frac{1\ \text{mol Cl}^-}{1\ \cancel{\text{mol NaCl}}} = 0.10\ \text{M Cl}^-$$

Step 3:

Since we know the final concentration of Cl^- and the amount of Cl^- that came from NaCl, we can determine how much of the Cl^- came from LiCl by just subtracting these two numbers.

0.15 M – 0.10 M = 0.05 M Cl^-

Step 4:

Calculate the molarity of LiCl by using the molarity of Cl^-.

$$\frac{0.05\ \cancel{\text{mol Cl}^-}}{1\ \text{L}} \times \frac{1\ \text{mol LiCl}}{1\ \cancel{\text{mol Cl}^-}} = 0.05\ \text{M LiCl}$$

Correct answer: 0.05 M LiCl

7. How many moles of strontium chloride were used to create a 0.15 L solution where $[Cl^-]$ = 0.88 M?

Step 1:

The balanced equation is:

$$SrCl_2\ (s) \xrightarrow{H_2O\ (l)} Sr^{2+}\ (aq) + 2\ Cl^-\ (aq)$$

Step 2:

0.88 $\cancel{\text{mol } Cl^-}$ / 1 L	1 mol $SrCl_2$ / 2 $\cancel{\text{mol } Cl^-}$	= 0.44 M $SrCl_2$

Step 3:

$$0.44\ M\ SrCl_2 = \frac{moles\ SrCl_2}{0.15\ L} = 0.066\ moles\ SrCl_2$$

Correct answer: 0.066 moles $SrCl_2$

8. A chemist wants a final solution of 0.16 M [Br-] with a volume of 0.150 L created from a 0.55 M LiBr solution. What volume of the original solution should be diluted to obtain this concentration?

Step 1:
Write the balanced equation for this process:

$$LiBr\ (s) \xrightarrow{H_2O\ (l)} Li^+\ (aq) + Br^-\ (aq)$$

Step 2:

Calculate the moles of LiBr in the final solution. Since moles don't change during a dilution, this is also the moles of LiBr in the original solution.

0.16 $\cancel{\text{mol Br}}$ / 1 $\cancel{L}$	0.150 $\cancel{L}$	1 mol LiBr / 1 $\cancel{\text{mol Br}}$	= 0.024 mol LiBr

Step 3:

Calculate the volume using the calculated moles of LiBr and the molarity of the original solution (0.55 M).

Rev 9/29/2020

0.55 M = $\frac{0.024\ mol\ LiBr}{volume}$

Volume = 0.044 L solution

Correct answer: 0.044 L original LiBr solution.

Rev 9/29/2020

9. **Challenge:** What is the total ion concentration in a solution created by dissolving 0.55 g $LiNO_3$ in 1.5 L water?

Step 1:
Write the balanced equation for this process.

$LiNO_3$ (s) $\xrightarrow{H_2O\ (l)}$ Li^+ (aq) + NO_3^- (aq)

Step 2:
Calculate the number of moles $LiNO_3$ in 0.55 g

0.55 ~~g $LiNO_3$~~	1 mol $LiNO_3$	= 0.0080 mol $LiNO_3$
	68.946 ~~g $LiNO_3$~~	

Step 3:
Calculate the molarity of the solution.

Molarity = $\frac{0.0080\ mol\ LiNO_3}{1.5\ L}$ = 0.0053 M $LiNO_3$

Step 4:
Use the molar ratio to calculate the concentration of the individual ions in solution.

0.0053 ~~mol $LiNO_3$~~	1 mol Li^+	= 0.0053 M Li^+
1 L	1 ~~mol $LiNO_3$~~	

0.0053 ~~mol $LiNO_3$~~	1 mol NO_3^-	= 0.0053 M NO_3^-
1 L	1 ~~mol $LiNO_3$~~	

Step 5:

Add [Li+] and [NO_3-] to get the total ion concentration.

Total ion concentration = 0.0053 M + 0.0053 M = 0.0106 M

Correct answer: 0.0106 M