Chemistry 11

Solution Chemistry II

Name:
Date:
Block:

1. **Ions in Solutions**
2. **Solubility Table**
3. **Separating Ions**

Ions in Solutions

Ionization Equation

- Represents the salt breaking apart into ions.
  - $NaCl_{(aq)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$
- If the salt were $CaCl_2$.
  - $CaCl_{2\,(aq)} \rightarrow Ca^{2+}_{(aq)} + 2\,Cl^{-}_{(aq)}$

*keep polyatomic ions together!

Practice:	
1. $KOH \rightarrow K^{+} + OH^{-}$	5. $Pb(IO_3)_2 \rightarrow Pb^{2+} + 2\,IO_3^{-}$
2. $SrCl_2 \rightarrow Sr^{2+} + 2\,Cl^{-}$	6. $Mg(OH)_2 \rightarrow Mg^{2+} + 2\,OH^{-}$
3. $NH_4NO_3 \rightarrow NH_4^{+} + NO_3^{-}$	7. $BaCO_3 \rightarrow Ba^{2+} + CO_3^{2-}$
4. $Ag_2CrO_4 \rightarrow 2\,Ag^{+} + CrO_4^{2-}$	8. $(NH_4)_2SO_3 \rightarrow 2\,NH_4^{+} + SO_3^{2-}$

Calculating Concentration

- Mole ratios represent the relative amounts of ions in solution.

$NaCl_{(aq)}$	$\rightarrow$	$Na^{+}_{(aq)}$	+	$Cl^{-}_{(aq)}$
1.0 M		1.0M		1.0M

$CaCl_{2\,(aq)}$	$\rightarrow$	$Ca^{2+}_{(aq)}$	+	$2\,Cl^{-}_{(aq)}$
1.0 M		1.0M		2.0M

x2

Practice:

1. 0.25 M KOH $\rightarrow K^+ + OH^-$
   0.25M   0.25M

2. 0.75 M $SrCl_2$ $\rightarrow Sr^{2+} + 2Cl^-$
   0.75M   1.5M
   ×2

3. 0.20 M NH_4NO_3 $\rightarrow NH_4^+ + NO_3^-$
   0.20M   0.20M

4. 0.45 M Ag_2CrO_4 $\rightarrow 2Ag^+ + CrO_4^{2-}$
   0.90M   0.45M
   ×2

5. 0.60 M $Pb(IO_3)_2$ $\rightarrow Pb^{2+} + 2IO_3^-$
   0.60M   1.2M
   ×2

6. 0.011 M $Mg(OH)_2$ $\rightarrow Mg^{2+} + 2OH^-$
   0.011M   0.022M
   ×2

7. 0.45 M $BaCO_3$ $\rightarrow Ba^{2+} + CO_3^{2-}$
   0.45M   0.45M

8. 0.50 M $(NH_4)_2SO_3$ $\rightarrow 2NH_4^+ + SO_3^{2-}$
   1.0M   0.50M
   ×2

Ionization + Dilution

$V_2 = 25.0\ mL$

✓ A 15.0 mL sample of 3.0 M HCl was added to 10.0 mL of 2.0 M $CaCl_2$. Calculate the concentration of each ion in the solution. Assume no reaction occurs *($[H^+]$ = 1.8 M $[Cl^-] = \cancel{2}.4$ M $[Ca^{2+}]$ = 0.80M)*
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[HCl]

$$C_1V_1 = C_2V_2$$
$$(3.0M)(15.0mL) = (C_2)(25.0mL)$$
$$C_2 = \frac{(3)(15)}{(25)}$$
$$= 1.8M = [HCl]$$

[$CaCl_2$]

$$C_1V_1 = C_2V_2$$
$$(2.0M)(10.0mL) = (C_2)(25.0mL)$$
$$C_2 = \frac{(2)(10)}{(25)}$$
$$= 0.80M = [CaCl_2]$$

$HCl \rightarrow H^+ + Cl^-$
1.8M   1.8M   1.8M

$CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$
0.80M   0.80M   1.6M
×2

$$\boxed{\begin{aligned} [H^+] &= 1.8M \\ [Ca^{2+}] &= 0.80M \\ [Cl^-] &= 1.8M + 1.6M = 3.4M \end{aligned}}$$

Practice 1.
What are the concentrations of both ions in a 3.00 M solution of H_3PO_4? *([H^+] = 9.00M [PO_4^{3-}] = 3.00M)*

$H_3PO_4 \rightarrow 3H^+ + PO_4^{3-}$
3.00M 9.00M 3.00M

Practice 2.
What is the sodium ion concentration when 250.0 mL of water is added to 125.5 mL of a 3.21 M solution of sodium phosphate? *([Na^+] = 3.21M)*

$C_1 = 3.21M$
$V_1 = 125.5mL$
$C_2 = ?$
$V_2 = 375.5mL$

$C_1V_1 = C_2V_2$
$(3.21M)(125.5mL) = (C_2)(375.5mL)$
$C_2 = 1.07M$

$Na_3PO_4 \rightarrow 3Na^+ + PO_4^{2-}$
1.07M 3.21M 1.07M
×2

$\boxed{[Na^+] = 3.21M}$

Practice 3.
$V_2 = 80.0mL$
Determine the concentration of each ion when 45.0 mL of 7.20 M magnesium sulphate is mixed with 35.0 mL of 0.900 M ~~magnesium hydroxide~~. *([Mg^{2+}] = 4.44M [SO_4^{2-}] = 4.05M. [OH^-] = 0.788M)*

$[MgSO_4]$
$C_1V_1 = C_2V_2$
$(7.20M)(45.0mL) = (C_2)(80.0mL)$
$C_2 = 4.05M = [MgSO_4]$
$MgSO_4 \rightarrow Mg^{2+} + SO_4^{2-}$
4.05M 4.05M 4.05M

$[Mg(OH)_2]$
$C_1V_1 = C_2V_2$
$(0.900M)(35.0mL) = (C_2)(80.0mL)$
$C_2 = 0.394M = [Mg(OH)_2]$
$Mg(OH)_2 \rightarrow Mg^{2+} + 2OH^-$
0.394M 0.394M 0.788M

$\boxed{[Mg^{2+}] = 4.44 \quad [SO_4^{2-}] = 4.05M \quad [OH^-] = 0.788M}$

Practice 4.
What is the molar concentration of each ion in solution resulting from mixing 55.0 mL of 0.15 M potassium hydroxide with 75.0 mL of 0.25 M potassium sulphate? *([K^+] = 0.34M [OH^-] = 0.063M [SO_4^{2-}] = 0.14M)*

$[KOH]$
$C_1V_1 = C_2V_2$
$(0.15M)(55.0mL) = C_2(130.0mL)$
$C_2 = 0.063M$
$KOH \rightarrow K^+ + OH^-$
0.063M 0.063M 0.063M

$[K_2SO_4]$
$C_1V_1 = C_2V_2$
$(0.25M)(75.0mL) = C_2(130.0mL)$
$C_2 = 0.14M$
$K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$
0.14M 0.28M 0.14M
×2

$\boxed{[K^+] = 0.34M \quad [OH^-] = 0.063M \quad [SO_4^{2-}] = 0.14M}$

<u>Ions in Solutions Worksheet</u>

Solubility Table

When some ions are combined, they create a solid → they are NOT soluble (will form a precipitate)

SOLUBLE → Dissolves in water; aqueous
LOW SOLUBILITY → Does not dissolve in water; solid (ppt)

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Practice:

1. Classify the following salts as being soluble or having low solubility in water:
   a. Sodium phosphate
      soluble
   b. Aluminum hydroxide
      low solubility
   c. * Copper (II) chloride
      soluble
   d. Calcium sulphate
      low solubility
   e. Iron (II) sulphide
      low solubility
   f. Strontium hydroxide
      soluble
   g. Zinc bromide
      soluble
   h. Cesium sulphite
      soluble
   i. Potassium chromate
      soluble

ionic compound

2. Write the formula for the following:
   a. A salt containing carbonate that is soluble
      CO_3^{2-}
      Li_2CO_3, Na_2CO_3, H_2CO_3 . . .
   b. A salt containing sulphate with low solubility
      Ag_2SO_4, $CaSO_4$, $BaSO_4$ . . .
   c. A cation that forms a salt with low solubility with both chloride and sulphate ions
      Ag^+ or Pb^{2+}
   d. An anion that forms soluble salts with all cations
      NO_3^-

Types of chemical equations:

Formula Equation: shows the chemical formulas of the compounds and their states.

$$2\ KI_{(aq)} + Pb(NO_3)_{2\ (aq)} \rightarrow 2\ KNO_{3\ (aq)} + \boxed{PbI_{2\ (s)}}$$ → low solubility

Complete Ionic Equation: shows the soluble salts represented in their dissociated form.

$$\cancel{2K^+_{(aq)}} + 2I^-_{(aq)} + Pb^{2+}_{(aq)} + \cancel{2NO_3^-{}_{(aq)}} \rightarrow \cancel{2K^+_{(aq)}} + \cancel{2NO_3^-{}_{(aq)}} + PbI_{2\ (s)}$$

Net Ionic Equation: shows only the ions that take part in the reaction. Ions that are the same on both sides of the equation are called **spectator ions.**

$$Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2\ (s)}$$

Practice: (Formula Equation)

1. Write the formula for the precipitate that forms when the following solutions are mixed:

a. BaS and $MgSO_4$

$$BaS_{(aq)} + MgSO_{4\ (aq)} \rightarrow \boxed{BaSO_{4(s)}} + MgS_{(aq)}$$

b. NH_4OH and $FeBr_2$

$$2NH_4OH_{(aq)} + FeBr_{2\ (aq)} \rightarrow 2NH_4Br_{(aq)} + \boxed{Fe(OH)_{2\ (s)}}$$

c. H_3PO_4 and $ZnCl_2$

$$2\ H_3PO_{4\ (aq)} + 3\ ZnCl_{2\ (aq)} \rightarrow 6\ HCl_{(aq)} + \boxed{Zn_3(PO_4)_{2\ (s)}}$$

d. K_2CO_3 and $CrSO_4$

$$K_2CO_{3\ (aq)} + CrSO_{4\ (aq)} \rightarrow K_2SO_{4\ (aq)} + \boxed{CrCO_{3\ (s)}}$$

e. MnI_2 and $Sr(OH)_2$

$$MnI_{2\ (aq)} + Sr(OH)_{2\ (aq)} \rightarrow \boxed{Mn(OH)_{2\ (s)}} + SrI_{2\ (aq)}$$

(F) (C) (N)

2. Write a formula equation, complete ionic equation and net ionic equation for the following reactions:

a. Strontium hydroxide and silver nitrate

F: $Sr(OH)_{2(aq)} + 2AgNO_{3(aq)} \rightarrow Sr(NO_3)_{2(aq)} + \boxed{2AgOH_{(s)}}$

C: $\cancel{{Sr^{2+}}_{(aq)}} + 2{OH^-}_{(aq)} + 2{Ag^+}_{(aq)} + \cancel{2{NO_3^-}_{(aq)}} \rightarrow \cancel{{Sr^{2+}}_{(aq)}} + \cancel{2{NO_3^-}_{(aq)}} + \boxed{2AgOH_{(s)}}$

N: $2{OH^-}_{(aq)} + 2{Ag^+}_{(aq)} \rightarrow 2AgOH_{(s)}$

b. Magnesium sulphide and zinc chloride

F: $MgS_{(aq)} + ZnCl_{2(aq)} \rightarrow MgCl_{2(aq)} + \boxed{ZnS_{(s)}}$

C: $\cancel{{Mg^{2+}}_{(aq)}} + {S^{2-}}_{(aq)} + {Zn^{2+}}_{(aq)} + \cancel{2{Cl^-}_{(aq)}} \rightarrow \cancel{{Mg^{2+}}_{(aq)}} + \cancel{2{Cl^-}_{(aq)}} + \boxed{ZnS_{(s)}}$

N: ${Zn^{2+}}_{(aq)} + {S^{2-}}_{(aq)} \rightarrow ZnS_{(s)}$

c. Sodium carbonate and barium sulphide

F: $Na_2CO_{3(aq)} + BaS_{(aq)} \rightarrow Na_2S_{(aq)} + \boxed{BaCO_{3(s)}}$

C: $\cancel{2{Na^+}_{(aq)}} + {CO_3^{2-}}_{(aq)} + {Ba^{2+}}_{(aq)} + \cancel{{S^{2-}}_{(aq)}} \rightarrow \cancel{2{Na^+}_{(aq)}} + \cancel{{S^{2-}}_{(aq)}} + \boxed{BaCO_{3(s)}}$

N: ${Ba^{2+}}_{(aq)} + {CO_3^{2-}}_{(aq)} \rightarrow BaCO_{3(s)}$

d. $(NH_4)_2S_{(aq)} + FeSO_{4(aq)} \rightarrow$

F: $(NH_4)_2S_{(aq)} + FeSO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)} + \boxed{FeS_{(s)}}$

C: $\cancel{2{NH_4^+}_{(aq)}} + {S^{2-}}_{(aq)} + {Fe^{2+}}_{(aq)} + \cancel{{SO_4^{2-}}_{(aq)}} \rightarrow \cancel{2{NH_4^+}_{(aq)}} + \cancel{{SO_4^{2-}}_{(aq)}} + \boxed{FeS_{(s)}}$

N: ${Fe^{2+}}_{(aq)} + {S^{2-}}_{(aq)} \rightarrow FeS_{(s)}$

e. $H_2SO_{3(aq)} + CaCl_{2(aq)} \rightarrow$

F: $H_2SO_{3(aq)} + CaCl_{2(aq)} \rightarrow 2HCl_{(aq)} + \boxed{CaSO_{3(s)}}$

C: $\cancel{2{H^+}_{(aq)}} + {SO_3^{2-}}_{(aq)} + {Ca^{2+}}_{(aq)} + \cancel{2{Cl^-}_{(aq)}} \rightarrow \cancel{2{H^+}_{(aq)}} + \cancel{2{Cl^-}_{(aq)}} + \boxed{CaSO_{3(s)}}$

N: ${Ca^{2+}}_{(aq)} + {SO_3^{2-}}_{(aq)} \rightarrow CaSO_{3(s)}$

f. Copper (II) sulphate + H_2SO_3

F: $CuSO_{4(aq)} + H_2SO_{3(aq)} \rightarrow \boxed{CuSO_{3(s)}} + H_2SO_{4(aq)}$

C: ${Cu^{2+}}_{(aq)} + \cancel{{SO_4^{2-}}_{(aq)}} + \cancel{2{H^+}_{(aq)}} + {SO_3^{2-}}_{(aq)} \rightarrow \boxed{CuSO_{3(s)}} + \cancel{2{H^+}_{(aq)}} + \cancel{{SO_4^{2-}}_{(aq)}}$

N: ${Cu^{2+}}_{(aq)} + {SO_3^{2-}}_{(aq)} \rightarrow CuSO_{3(s)}$

Separating Ions

Example:

A solution may contain the ions Ca^{2+}, Sr^{2+} and Zn^{2+}. How would you precipitate the ions out of solution individually? Describe your answer using a flow chart.

- All are cations - therefore an addition of an anion will precipitate out these cations.
- "Low solubility" – means will precipitate out.

1. Which anion will precipitate just one of the ions out first?

   S^{2-}

   a. Which ions are left?

   Ca^{2+} Sr^{2+}

2. Which anion will precipitate just one of the two ions left?

   OH^- will create a ppt with Ca^{2+}

3. Which anion will precipitate out the last ion left?

   Sr^{2+}

   SO_4^{2-} will create a ppt with Sr^{2+}

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Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Ca^{2+}, Sr^{2+}, Zn^{2+}

① Add $Na_2S_{(aq)}$

Ca^{2+}, Sr^{2+} | $ZnS_{(s)}$ ppt

② Add $NaOH_{(aq)}$

Sr^{2+} | $Ca(OH)_{2\,(s)}$ ppt

③ Add $Na_2SO_{4\,(aq)}$

$SrSO_{4\,(s)}$ ppt

Practice:

1. For each of the following solutions, describe a process to individually remove each ion. Be sure to list the compounds that you add in order, and the method of removing the precipitate. You may wish to use a flow chart.

a. Ag^+ Ba^{2+} and Be^{2+}

① Add $NaI_{(aq)}$

$AgI_{(s)}$ ppt

Ba^{2+}, Be^{2+}

② Add $Na_2SO_{4(aq)}$

$BaSO_{4(s)}$ ppt

Be^{2+}

③ Add $NaOH_{(aq)}$

$Be(OH)_{2(s)}$ ppt

b. Br^-, SO_4^{2-} and S^{2-}

① Add $Ca(NO_3)_{2(aq)}$

$CaSO_{4(s)}$ ppt

Br^-, S^{2-}

② Add $Ra(NO_3)_{2(aq)}$

$RaS_{(s)}$ ppt

Br^-

③ Add $AgNO_{3(aq)}$

$AgBr_{(s)}$ ppt

c. OH^-, PO_4^{3-} and S^{2-}

① Add $Sr(NO_3)_{2(aq)}$

$Sr_3(PO_4)_{2(s)}$ ppt

OH^-, S^{2-}

② Add $Mg(NO_3)_{2(aq)}$

$Mg(OH)_{2(s)}$ ppt

S^{2-}

③ Add $Al(NO_3)_{2(aq)}$

$Al_2S_{3(s)}$ ppt

d. Cr^{3+}, Ca^{2+} and Mg^{2+}

① Add $Na_2S_{(aq)}$

$CrS_{(s)}$ ppt

Ca^{2+}, Mg^{2+}

② Add $Na_2SO_{4(aq)}$

$CaSO_{4(s)}$ ppt

Mg^{2+}

③ Add $NaOH_{(aq)}$

$Mg(OH)_{2(s)}$ ppt

Separating Ions Worksheet