III.2. CALCULATING SOLUBILITY AND ION CONCENTRATIONS

Once the mass of a substance present in 1 L of a solution has been experimentally measured, it is straightforward to calculate the solubility of the substance.

EXAMPLE: It is experimentally found that 1 L of saturated $AgBrO_3(aq)$ contains 1.96 g of $AgBrO_3$. What is the **molar solubility** of $AgBrO_3$; that is, the solubility expressed in moles per litre?

$$[AgBrO_3] = 1.96\ \frac{g}{L} \times \frac{1\ mol}{235.8\ g} = \mathbf{8.31 \times 10^{-3}\ M}$$

EXAMPLE: The molar solubility of PbI_2 is 1.37×10^{-3} M. Express this value in grams per litre.

$$\text{Solubility (g/L)} = 1.37 \times 10^{-3}\ \frac{mol}{L} \times \frac{461.0\ g}{1\ mol} = \mathbf{0.632\ \frac{g}{L}}$$

> **A "Calculator Interlude":**
> When entering "1.37×10^{-3}" into your calculator, don't forget that the "EXP" or "EE" key on your calculator stands for "***10 to the power of***". The sequence of keystrokes needed to enter "1.37×10^{-3}" is:
>
> 1.37 EXP +/– 3
> or 1.37 EE +/– 3 .

EXAMPLE: Experimentally it is found that 250 mL of saturated $CaCl_2$ contain 18.6 g of $CaCl_2$ at 20°C. What is the molar solubility of $CaCl_2$?

$$[CaCl_2] = \frac{18.6\ g}{0.250\ L} \times \frac{1\ mol}{111.1\ g} = \mathbf{0.670\ M}$$

Note: Assume all solutions are at a temperature of 25°C unless otherwise indicated.

EXERCISES:

8. Aluminum fluoride, AlF_3, has a solubility of 5.59 g/L of solution at 20°C. Express this solubility in moles per litre.
9. Lead (II) chloride, $PbCl_2$, has a solubility of 0.99 g/100.0 mL of solution at 20°C. Calculate the molar solubility of $PbCl_2$.
10. The molar solubility of $MgCO_3$ is 1.26×10^{-3} M at 25°C. Express this value in grams per litre.
11. The molar solubility of Ag_2CO_3 is 1.2×10^{-4} M at 25°C. Express this value in grams per 100.0 mL.

12. Chromium (VI) oxide, $CrO_3(s)$, has a solubility of 92.6 g in 150.0 mL of solution at 0°C. Calculate the molar solubility of CrO_3.

13. Silver chlorite, $AgClO_2$, has a molar solubility of 0.014 M at 25°C. What mass of $AgClO_2$ is contained in 50.0 mL of saturated $AgClO_2$?

14. Manganese (II) chloride, $MnCl_2$, has a molar solubility of 5.75 M at 0°C. If 125 mL of saturated $MnCl_2$ is evaporated to dryness, what mass of $MnCl_2$ will be left?

15. A chemistry student was assigned the task of determining the solubility of potassium chloride, KCl. She added an excess of solid KCl to water, stirred, and let the solution sit overnight. The next day, she pipetted a 25.00 mL portion of the saturated solution into a pre–weighed evaporating dish, determined the combined mass, carefully boiled off the water present, allowed the residue to cool and re–determined the mass of the evaporating dish and residue. The data obtained is given below.

temperature of solution	= 22.5°C
mass of evaporating dish	= 54.87 g
mass of solution and evaporating dish	= 84.84 g
mass of residue and evaporating dish	= 62.59 g

Calculate:

a) the mass of 25.00 mL of the solution.
b) the mass of KCl in 25.00 mL of solution.
c) the mass of water in 25.00 mL of solution.
d) the mass of KCl which can dissolve in 100.0 g of water at 22.5°C.
e) the molar solubility of KCl, expressed in moles of KCl per litre of solution.

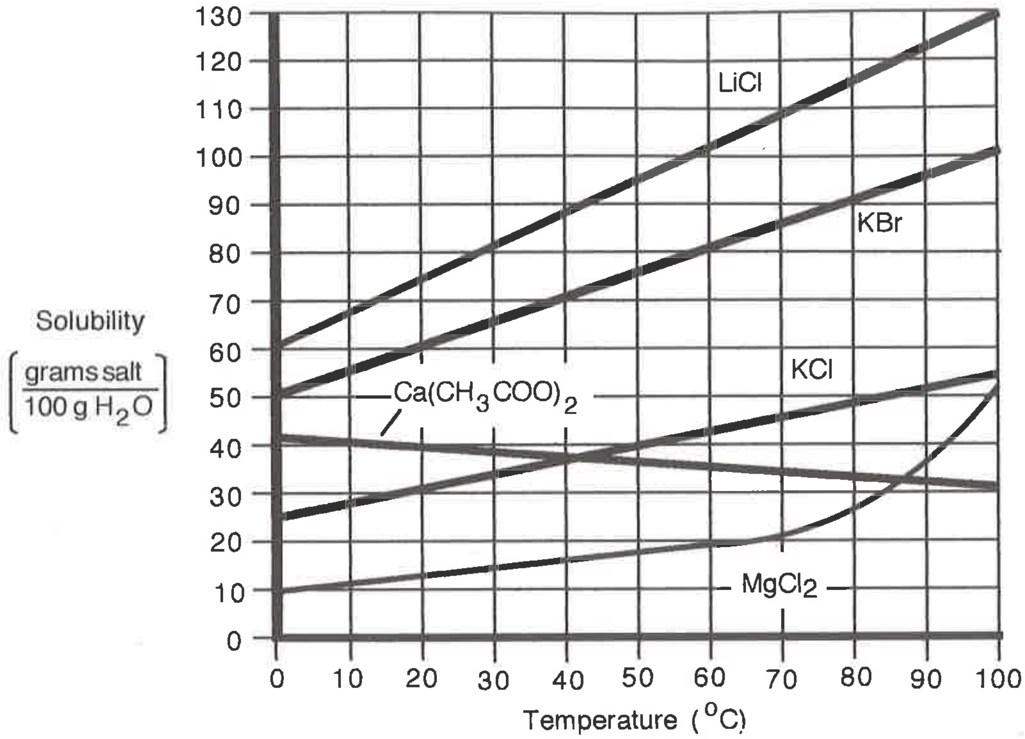
16. The following data was obtained when a saturated solution of aqueous ammonium sulphate, $(NH_4)_2SO_4(aq)$, was poured into a beaker and evaporated to dryness.

temperature of solution	= 25°C
volume of solution used	= 70.0 mL
mass of beaker	= 87.23 g
mass of original solution and beaker	= 147.42 g
mass of beaker and dried $(NH_4)_2SO_4$	= 104.08 g

Calculate:

a) The mass of the solution.
b) The mass of ammonium sulphate in the solution.
c) The mass of water in the solution.
d) The mass of ammonium sulphate which could be dissolved in 100.0 g of water.
e) The molar concentration of the ammonium sulphate solution.

17. Examine the following diagram:



a) Which salt is the most soluble at 60°C?

b) If you put 40 g of KCl into 100 g of water at 90°C, will you be able to form a saturated solution? Explain your answer.

c) If you heat a saturated solution of calcium acetate, $Ca(CH_3COO)_2$, from 20°C to 80°C, what will you observe?

d) If you put 20 g of $MgCl_2$ into 100 g of water at 20°C and gradually heat the solution, what will you observe?

e) If you dissolve 90 g of both KBr and LiCl in 100 g of water at 90°C and then cool the mixture to 10°C, which salt will form crystals first?

f) A solution contains 20 g of KCl and 20 g of KBr in 100 g of water at 20°C. If the solution is left open to the air, which salt will form crystals first as the water evaporates?

g) Make a general statement regarding the change in solubility of LiCl(s) with a change in temperature. What does this imply about shifting the equilibrium:

$$LiCl(s) \rightleftharpoons Li^+(aq) + Cl^-(aq)$$

when the temperature is increased? Is the dissolving of LiCl(s) an endothermic or exothermic process?

h) Is the dissolving of $Ca(CH_3COO)_2(s)$ endothermic or exothermic?

Having performed calculations relating to the solubility of a salt, a review of calculations involving the concentrations of ions in solution should be beneficial. Since a salt will dissociate into ions when it dissolves, you must be able to calculate the concentrations of all the ions in the solution.

EXAMPLE: When 1 mol of Na_3PO_4 is dissolved and diluted to a total volume of 1 L, one finds

	$Na_3PO_4(s)$	$\longrightarrow$	$3\,Na^+(aq)$	+	$PO_4^{3-}(aq)$
moles of particles (in 1 L):	1 mol	$\longrightarrow$	3 mol	+	1 mol
molar concentration:	1 M	$\longrightarrow$	3 M		1 M

Note that the final solution has: $[Na^+] = 3$ M and $[PO_4^{3-}] = 1$ M and **NO** particles of Na_3PO_4 in the final solution; all of the Na_3PO_4 present has dissociated into ions.

EXAMPLE: What is the concentration of all the ions present in a saturated solution of Ag_2CO_3 having a concentration of 1.2×10^{-4} M?

The calculation is based on the amount of Ag_2CO_3 which has actually dissolved.

	$Ag_2CO_3(s)$	$\longrightarrow$	$2\,Ag^+(aq)$	+	$CO_3^{2-}(aq)$
so that	1 mol	$\longrightarrow$	2 mol	+	1 mol

It can be seen that if $[Ag_2CO_3]_{DISSOLVED} = 1.2 \times 10^{-4}$ M, then:

$$[CO_3^{2-}] = \mathbf{1.2 \times 10^{-4}\ M}$$

and
$$[Ag^+] = \frac{1.2 \times 10^{-4}\ \text{mol } Ag_2CO_3}{\text{L}} \times \frac{2\ \text{mol } Ag^+}{1\ \text{mol } Ag_2CO_3}$$

$$= 2.4 \times 10^{-4}\ \frac{\text{mol } Ag^+}{\text{L}} = \mathbf{2.4 \times 10^{-4}\ M}\ .$$

You also must be able to calculate the dilution occuring when solutions of ions are mixed with water or each other, as illustrated in the next example.

EXAMPLE: If 5.0 mL of 0.020 M Cl^- is added to 15.0 mL of 0.012 M Br^-, what is the molarity of the Cl^- and Br^- ions in the mixture?

The 5.0 mL of chloride solution is diluted by the 15.0 mL of liquid contained in the bromide solution, and vice versa. Recall that **dilution calculations** are performed as follows:

$$[\text{SUBSTANCE}]_{\text{DILUTED}} = [\text{SUBSTANCE}]_{\text{OLD}} \times \frac{\text{OLD VOLUME}}{\text{DILUTED VOLUME}}$$

so that
$$[Cl^-]_{DILUTED} = 0.020\ \text{M} \times \frac{5.0\ \text{mL}}{(5.0 + 15.0)\ \text{mL}} = \mathbf{0.0050\ M}$$

and
$$[Br^-]_{DILUTED} = 0.012\ \text{M} \times \frac{15.0\ \text{mL}}{(5.0 + 15.0)\ \text{mL}} = \mathbf{0.0090\ M}\ .$$

***EXERCISES*:**

18. Calculate the concentration of all the ions in each of the following solutions.
    a) 0.25 M $FeCl_3$
    b) 1.5×10^{-3} M $Al_2(SO_4)_3$
    c) 12.0 g of $(NH_4)_2CO_3$ in 2.50 L
    d) 0.41 g of $Ca(OH)_2$ in 500 mL of aqueous solution
    e) 2.50 g of KBr in 150 mL of aqueous solution

19. a) Write an equation showing the equilibrium in a saturated solution of lead (II) bromide, $PbBr_2$.
    b) The solubility of $PbBr_2$ is 0.844 g/100 mL. What is its molar solubility?
    c) Calculate the concentrations of Pb^{2+}(aq) and Br^- (aq) in a saturated solution of $PbBr_2$.

20. Calculate the concentration of all the ions present when
    a) 25.0 mL of water is added to 20.0 mL of 0.35 M Fe^{3+}.
    b) 50.0 mL of 0.25 M Ag^+ is mixed with 100.0 mL of 0.10 M NO_3^-.
    c) 15.0 mL of 6.5×10^{-5} M Cu^{2+} is mixed with 40.0 mL of 3.2×10^{-3} M Cl^-.
    d) 55.0 mL of 0.185 M $MgCl_2$ is mixed with 25.0 mL of 4.8×10^{-2} M $CaBr_2$.
    e) 95.0 mL of 8.65×10^{-4} M $Al(NO_3)_3$ is mixed with 15.0 mL of 7.50×10^{-6} M Ag_2SO_4.
    f) 50.0 mL of 0.200 M $CaCl_2$ is mixed with 50.0 mL of 0.200 M NaCl.
    g) 25.0 mL of 0.360 M NH_4Br is mixed with 75.0 mL of 0.160 M $(NH_4)_2SO_4$.
    h) 10.0 mL of 0.100 M $Ba(NO_3)_2$ is mixed with 40.0 mL of 0.300 M $AgNO_3$.

III.3. PREDICTING THE SOLUBILITY OF SALTS

This section examines some of the general rules for predicting the solubility of salts and uses a Solubility Table to predict whether a specific salt is soluble in water.

First, let's establish what is meant when a salt is said to be "SOLUBLE" or to have a "LOW SOLUBILITY".

Strictly speaking, nothing is INSOLUBLE in water. For example, glass dissolves to an extremely small extent in water. Normally, the amount of glass which dissolves in water can be NEGLECTED and glass is said to have a **NEGLIGIBLE SOLUBILITY** in water.

Some compounds may dissolve SLIGHTLY, such that the amount which dissolves is extremely small but cannot be neglected. Such a substance is said to have **LOW SOLUBILITY.** For example, lead (II) chloride, $PbCl_2$, has a low solubility in water, but the amount which dissolves cannot always be neglected. For example, the small amount of Pb^{2+} ion present in saturated $PbCl_2$(aq) is toxic if swallowed.

Now the problem is: when has a compound dissolved to a sufficient extent that you cannot say it has LOW SOLUBILITY? This is like asking: "What is the least amount of money you need in order to be RICH?" All that can be done is to set an ***arbitrary value***.

***Definition*:** A substance is said to have **LOW SOLUBILITY** if a saturated solution of the substance is less than 0.1 M.

17. (a) LiCl

(b) The solution won't be saturated because at 90°C about 50 g of KCl dissolves in 100 g of water.

(c) As you heat the $Ca(CH_3COO)_2$ solution, more precipitate forms because the solubility decreases as temperature increases.

(d) Initially some of the $MgCl_2(s)$ dissolves. Then, as the temperature increases, more of the solid dissolves; by about 70°C the last of the solid dissolves.

(e) Initially all the solid is dissolved but as the temperature decreases to 10°C the KBr forms crystals first. As the temperature decreases, KBr's solubility starts at about 97 g at 90°C (unsaturated solution) but by about 75°C the solubility drops to about 90 g (saturated solution) and at temperatures lower than 75°C the solution deposits the excess KBr in the form of crystals.

(f) Since KCl has a lower solubility (about 30 g/100 g H_2O) than does KBr (about 60 g/100 g H_2O), the KCl solution becomes saturated first when the water evaporates and KCl forms crystals first.

(g) The solubility of LiCl increases with an increase in temperature. This implies the equation

$$LiCl(s) + heat \rightleftharpoons Li^+(aq) + Cl^-(aq)$$

shifts to the product side when temperature is increased and is ENDOTHERMIC.

(h) The dissolving of $Ca(CH_3COO)_2(s)$ is exothermic. As temperature is increased the solubility decreases, which implies that heat is on the product side of the dissolving reaction.

$$Ca(CH_3COO)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2\,CH_3COO^-(aq) + heat$$

18. (a) $[Fe^{3+}] = 0.25\ M$, $[Cl^-] = 0.75\ M$

(b) $[Al^{3+}] = 3.0 \times 10^{-3}\ M$, $[SO_4^{2-}] = 4.5 \times 10^{-3}\ M$

(c) $[(NH_4)_2CO_3] = \frac{12.0\ g}{2.50\ L} \times \frac{1\ mol}{96.0\ g} = 0.0500\ M$, so $[NH_4^+] = 0.100\ M$ and $[CO_3^{2-}] = 0.0500\ M$

(d) $[Ca(OH)_2] = \frac{0.41\ g}{0.500\ L} \times \frac{1\ mol}{74.1\ g} = 0.011\ M$, so $[Ca^{2+}] = 0.011\ M$ and $[OH^-] = 0.022\ M$

(e) $[KBr] = \frac{2.50\ g}{0.150\ L} \times \frac{1\ mol}{119.0\ g} = 0.140\ M$, so $[K^+] = [Br^-] = 0.140\ M$

19. (a) $PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,Br^-(aq)$

(b) $[PbBr_2] = \frac{0.844\ g}{0.100\ L} \times \frac{1\ mol}{367.0\ g} = 2.30 \times 10^{-2}\ M$

(c) $[Pb^{2+}] = 2.30 \times 10^{-2}\ M$, $[Br^-] = 4.60 \times 10^{-2}\ M$

20. (a) $[Fe^{3+}] = 0.35\ M \times \frac{20.0\ mL}{45.0\ mL} = 0.16\ M$

(b) $[Ag^+] = 0.25\ M \times \frac{50.0\ mL}{150.0\ mL} = 0.083\ M$, $[NO_3^-] = 0.10\ M \times \frac{100.0\ mL}{150.0\ mL} = 0.067\ M$

(c) $[Cu^{2+}] = 6.5 \times 10^{-5}\ M \times \frac{15.0\ mL}{55.0\ mL} = 1.8 \times 10^{-5}\ M$

$[Cl^-] = 3.2 \times 10^{-3}\ M \times \frac{40.0\ mL}{55.0\ mL} = 2.3 \times 10^{-3}\ M$

(d) $[MgCl_2] = 0.185\ M \times \frac{55.0\ mL}{80.0\ mL} = 0.127\ M$, so $[Mg^{2+}] = 0.127\ M$, $[Cl^-] = 0.254\ M$

$[CaBr_2] = 4.8 \times 10^{-2}\ M \times \frac{25.0\ mL}{80.0\ mL} = 1.5 \times 10^{-2}\ M$, so $[Ca^{2+}] = 1.5 \times 10^{-2}\ M$

$[Br^-] = 3.0 \times 10^{-2}\ M$

(e) $[Al(NO_3)_3] = 8.65 \times 10^{-4}\ M \times \frac{95.0\ mL}{110.0\ mL} = 7.47 \times 10^{-4}\ M$

so: $[Al^{3+}] = 7.47 \times 10^{-4}\ M$, $[NO_3^-] = 2.24 \times 10^{-3}\ M$

$[Ag_2SO_4] = 7.50 \times 10^{-6}\ M \times \frac{15.0\ mL}{110.0\ mL} = 1.02 \times 10^{-6}\ M$

so: $[Ag^+] = 2.05 \times 10^{-6}\ M$, $[SO_4^{2-}] = 1.02 \times 10^{-6}\ M$

(f) $[CaCl_2] = 0.200\ M \times \frac{50.0\ mL}{100.0\ mL} = 0.100\ M$; $[Ca^{2+}] = 0.100\ M$ and $[Cl^-]_{\#1} = 0.200\ M$

$[NaCl] = 0.200\ M \times \frac{50.0\ mL}{100.0\ mL} = 0.100\ M$; $[Na^+] = 0.100\ M$ and $[Cl^-]_{\#2} = 0.100\ M$

$[Cl^-]_{total} = 0.200\ M + 0.100\ M = 0.300\ M$

(g) $[NH_4Br] = 0.360\ M \times \frac{25.0\ mL}{100.0\ mL} = 0.0900\ M$; $[NH_4^+]_{\#1} = 0.0900\ M$ and $[Br^-] = 0.0900\ M$

$[(NH_4)_2SO_4] = 0.160\ M \times \frac{75.0\ mL}{100.0\ mL} = 0.120\ M$; $[NH_4^+]_{\#2} = 0.240\ M$ and $[SO_4^{2-}] = 0.120\ M$

$[NH_4^+]_{total} = 0.0900\ M + 0.240\ M = 0.330\ M$

(h) $[Ba(NO_3)_2] = 0.100\ M \times \frac{10.0\ mL}{50.0\ mL} = 0.0200\ M$; $[Ba^{2+}] = 0.0200\ M$ and $[NO_3^-]_{\#1} = 0.0400\ M$

$[AgNO_3] = 0.300\ M \times \frac{40.0\ mL}{50.0\ mL} = 0.240\ M$; $[Ag^+] = 0.240\ M$ and $[NO_3^-]_{\#2} = 0.240\ M$

$[NO_3^-]_{total} = 0.0400\ M + 0.240\ M = 0.280\ M$

21. (a) low solubility (b) soluble (c) low solubility (d) soluble (e) low solubility (f) soluble (g) soluble (h) low solubility (i) soluble (j) low solubility

22. (a) AgBr is a precipitate (b) no precipitate (c) $Al(OH)_3$ is a precipitate (d) PbI_2 is a precipitate (e) $BaSO_4$ is a precipitate (f) no precipitate

23. (a) $BaSO_4$ has a very low solubility, so that the $[Ba^{2+}]$ is very low and hence there is little toxicity. (What can't dissolve, can't poison you.)
(b) AgBr also has a very low solubility: a saturated solution at 18°C has a silver ion concentration of 69 parts per billion (69 g per 10^6 L of water). Ag^+ ion is toxic to micro–organisms at concentrations as low as 10 parts per billion, yet is harmless to humans at such low concentrations.

24. (a) $Pb(NO_3)_2$ and NaCl (b) $AgNO_3$ and NaBr (c) $Cr(NO_3)_3$ and Na_2S (d) $Sr(NO_3)_2$ and Na_2SO_4

25. (a) $MgS(aq) + Sr(OH)_2(aq) \longrightarrow Mg(OH)_2(s) + SrS(aq)$; $Mg(OH)_2(s)$ has a low solubility

$Mg^{2+}(aq) + S^{2-}(aq) + Sr^{2+}(aq) + 2\ OH^-(aq) \longrightarrow Mg(OH)_2(s) + Sr^{2+}(aq) + S^{2-}(aq)$

$Mg^{2+}(aq) + 2\ OH^-(aq) \longrightarrow Mg(OH)_2(s)$

(b) $CuBr_2(aq) + Pb(NO_3)_2(aq) \longrightarrow PbBr_2(s) + Cu(NO_3)_2(aq)$; $PbBr_2(s)$ has a low solubility

$Cu^{2+}(aq) + 2\ Br^-(aq) + Pb^{2+}(aq) + 2\ NO_3^-(aq) \longrightarrow PbBr_2(s) + Cu^{2+}(aq) + 2\ NO_3^-(aq)$

$Pb^{2+}(aq) + 2\ Br^-(aq) \longrightarrow PbBr_2(s)$

(c) all products soluble

(d) $Ba(NO_3)_2(aq) + Li_2SO_4(aq) \longrightarrow BaSO_4(s) + 2\ LiNO_3(aq)$; $BaSO_4(s)$ has a low solubility

$Ba^{2+}(aq) + 2\ NO_3^-(aq) + 2\ Li^+(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s) + 2\ Li^+(aq) + 2\ NO_3^-(aq)$

$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

(e) $2\ K_3PO_4(aq) + 3\ CuCl_2(aq) \longrightarrow Cu_3(PO_4)_2(s) + 6\ KCl(aq)$; $Cu_3(PO_4)_2(s)$ has a low solubility

$6\ K^+(aq) + 2\ PO_4^{3-}(aq) + 3\ Cu^{2+}(aq) + 6\ Cl^-(aq) \longrightarrow Cu_3(PO_4)_2(s) + 6\ K^+(aq) + 6\ Cl^-(aq)$

$3\ Cu^{2+}(aq) + 2\ PO_4^{3-}(aq) \longrightarrow Cu_3(PO_4)_2(s)$

(f) $3\ (NH_4)_2SO_3(aq) + Al_2(SO_4)_3(aq) \longrightarrow Al_2(SO_3)_3(s) + 3\ (NH_4)_2SO_4(aq)$;
$Al_2(SO_3)_3(s)$ has a low solubility.

$6\ NH_4^+(aq) + 3\ SO_3^{2-}(aq) + 2\ Al^{3+}(aq) + 3\ SO_4^{2-}(aq) \longrightarrow Al_2(SO_3)_3(s) + 6\ NH_4^+(aq) + 3\ SO_4^{2-}(aq)$

$2\ Al^{3+}(aq) + 3\ SO_3^{2-}(aq) \longrightarrow Al_2(SO_3)_3(s)$

(g) $3\ AgNO_3(aq) + Na_3PO_4(aq) \longrightarrow Ag_3PO_4(s) + 3\ NaNO_3(aq)$; $Ag_3PO_4(s)$ has a low solubility.

$3\ Ag^+(aq) + 3\ NO_3^-(aq) + 3\ Na^+(aq) + PO_4^{3-}(aq) \longrightarrow Ag_3PO_4(s) + 3\ Na^+(aq) + 3\ NO_3^-(aq)$

$3\ Ag^+(aq) + PO_4^{3-}(aq) \longrightarrow Ag_3PO_4(s)$

(h) all products soluble

(i) $CoSO_4(aq) + Li_2CO_3(aq) \longrightarrow CoCO_3(s) + Li_2SO_4(aq)$; $CoCO_3(s)$ has a low solubility.

$Co^{2+}(aq) + SO_4^{2-}(aq) + 2\ Li^+(aq) + CO_3^{2-}(aq) \longrightarrow CoCO_3(s) + 2\ Li^+(aq) + SO_4^{2-}(aq)$

$Co^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CoCO_3(s)$

(j) $2\ Fe(NO_3)_3(aq) + 3\ MgS(aq) \longrightarrow Fe_2S_3(s) + 3\ Mg(NO_3)_2(aq)$; $Fe_2S_3(s)$ has a low solubility.

$2\ Fe^{3+}(aq) + 6\ NO_3^-(aq) + 3\ Mg^{2+}(aq) + 3\ S^{2-}(aq) \longrightarrow Fe_2S_3(s) + 3\ Mg^{2+}(aq) + 6\ NO_3^-(aq)$

$2\ Fe^{3+}(aq) + 3\ S^{2-}(aq) \longrightarrow Fe_2S_3(s)$

(k) $BeSO_4(aq) + (NH_4)_2CO_3(aq) \longrightarrow BeCO_3(s) + (NH_4)_2SO_4(aq)$; $BeCO_3(s)$ has a low solubility

$Be^{2+}(aq) + SO_4^{2-}(aq) + 2\ NH_4^+(aq) + CO_3^{2-}(aq) \longrightarrow BeCO_3(s) + 2\ NH_4^+(aq) + SO_4^{2-}(aq)$

$Be^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow BeCO_3(s)$

(l) $MgSO_4(aq) + Sr(OH)_2(aq) \longrightarrow Mg(OH)_2(s) + SrSO_4(s)$; both products have low solubility.

$Mg^{2+}(aq) + SO_4^{2-}(aq) + Sr^{2+}(aq) + 2\ OH^-(aq) \longrightarrow Mg(OH)_2(s) + SrSO_4(s)$; (net and complete)

26. The salt must be **soluble** so as to obtain a sufficiently high concentration of the anion to be added.

27. (a) Ag^+, Ba^{2+}, Pb^{2+} or Ca^{2+} (b) Sr^{2+}

28. You cannot differentiate between Ag^+ and Pb^{2+}. Any anion which will precipitate Ag^+ will also precipitate Pb^{2+}, and vice versa. (However, other information such as colour of the precipitate can eventually lead to differentiation.)

29. Analyze for solubility.

	Cl^-	SO_4^{2-}	S^{2-}	OH^-	PO_4^{3-}
Al^{3+}	—	—	ppt	ppt	ppt
Ag^+	ppt	ppt	ppt	ppt	ppt

Precipitate the Ag^+ with NaCl or Na_2SO_4. Then precipitate the Al^{3+} with Na_2S, NaOH or Na_3PO_4.