
To quickly summarize:

1. The solubility of a compound is **decreased** when an ion which is the same as one of the ions in the compound (*common ion*) is present or added.
2. The solubility of compounds containing the **carbonate** (CO_3^{2-}) ion can be **increased** by adding an **acid**. The H^+ ions from the acid react with the carbonate (CO_3^{2-}) forming carbonic acid ($\text{H}_2\text{CO}_{3(\text{aq})}$) which decomposes into water and $\text{CO}_{2(\text{g})}$. In this way the $[\text{CO}_3^{2-}]$ is decreased in the solubility equilibrium for the original compound, the equilibrium shifts toward the side with the ions, and the solid dissolves more.
3. The solubility of a compound can be **increased** by adding a solution that will form a precipitate with one of the ions in the compound. This will decrease the concentration of that ion, causing the equilibrium to shift to the ion side and dissolve the solid.

1. Briefly explain what is meant by the *common ion effect*.

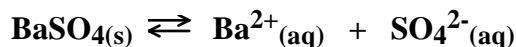
A compound of low solubility forms two ions in a saturated solution. The addition of either of these two ions (from a compound or solution with an ion in common) will decrease the solubility of the compound with low solubility.

2. Name two compounds (not just ions) that can *decrease* the solubility of $\text{BaSO}_{4(\text{s})}$ and explain why each one of them works.

Any compound that contains either Ba^{2+} ions or SO_4^{2-} ions (other than BaSO_4) would work.

Examples could be barium nitrate ($\text{Ba}(\text{NO}_3)_2$) or sodium sulphate (Na_2SO_4).

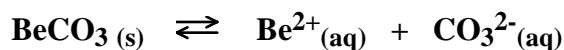
Looking at the equilibrium equation for BaSO_4 dissolving:



Increasing either $[\text{Ba}^{2+}]$ or $[\text{SO}_4^{2-}]$ will cause the equilibrium to shift left and form more solid BaSO_4 . (Thus decreasing its solubility.)

3. Name a substance (not just an ion) which could *increase* the solubility of $\text{BeCO}_3(\text{s})$. Explain why this substance works.

The solubility equilibrium for BeCO_3 is:



Adding any substance which will decrease either $[\text{Be}^{2+}]$ or $[\text{CO}_3^{2-}]$ will shift this equilibrium to the right and increase the solubility of BeCO_3 .

One way would be to find a solution which would form another precipitate with one of these ions.

Looking at the solubility table, the following ions could form a precipitate with Be^{2+} ions: OH^- , PO_4^{3-} or SO_3^{2-} . (Notice that we can't use carbonate. I hope you can see why not!)

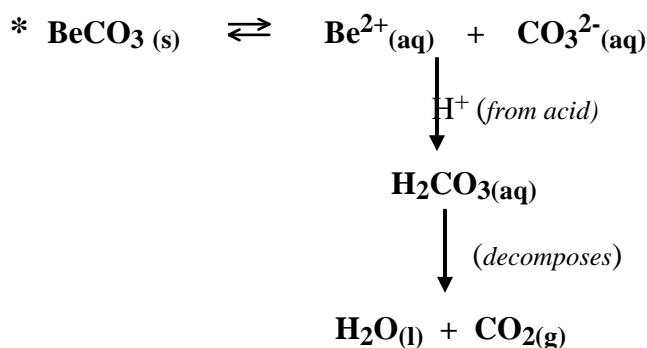
So 3 suitable compounds could be: NaOH , Na_3PO_4 or Na_2SO_3 .

As an example, the OH^- ions from NaOH would precipitate with the Be^{2+} ions in the BeCO_3 equilibrium, forming $\text{Be}(\text{OH})_2(\text{s})$ and decreasing the $[\text{Be}^{2+}]$. This shifts the equilibrium to the right, increasing the solubility of $\text{Be}(\text{OH})_2(\text{s})$.

There are two ways we could decrease the $[\text{CO}_3^{2-}]$:

One way would be to add an acid (eg. HCl , H_2SO_4 , HNO_3). As we have found before, adding an acid to an equilibrium with carbonate (CO_3^{2-}) ions will donate

H^+ ions which will join the carbonate to form carbonic acid, which will then decompose to give carbon dioxide and water:



As shown above, the H^+ ions combine with CO_3^{2-} ions to form carbonic acid (H_2CO_3), which decomposes to water and carbon dioxide.

Since, in the process, the $[\text{CO}_3^{2-}]$ is decreased, the top (*) equilibrium will shift to the right, *increasing* the solubility of $\text{CaCO}_3(\text{s})$.

Another way to decrease the $[\text{CO}_3^{2-}]$ is to add a compound with an ion which would form another precipitate with it.

Checking the solubility table, some ions that precipitate with carbonate are any ions other than alkali, NH_4^+ , or H^+ ions. So there are many possibilities.

They could include Ag^+ , Pb^{2+} , Cu^+ , Ca^{2+} , Sr^{2+} , Ba^{2+} , Mg^{2+} and many others.

Some possible compounds containing these ions could be:

AgNO_3 , $\text{Pb}(\text{NO}_3)_2$, CuNO_3 , $\text{Ca}(\text{NO}_3)_2$, $\text{Sr}(\text{NO}_3)_2$, $\text{Ba}(\text{NO}_3)_2$, $\text{Mg}(\text{NO}_3)_2$

As an example, the Ag^+ ions from AgNO_3 would precipitate with the CO_3^{2-} ions in the BeCO_3 equilibrium, forming $\text{Ag}_2\text{CO}_3(\text{s})$ and decreasing the $[\text{CO}_3^{2-}]$. This shifts the equilibrium to the right, increasing the solubility of $\text{Be}(\text{OH})_2(\text{s})$.

4. Silver sulphate is a white precipitate with low solubility. When a solution of ammonium sulphide ($(\text{NH}_4)_2\text{S}(\text{aq})$) is added, the white precipitate slowly dissolves and a black precipitate forms on the bottom. Using equilibrium equations and clear explanations, indicate what happened here.

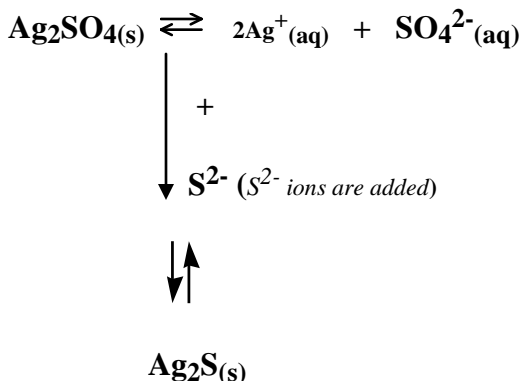
The equilibrium equation for the white precipitate (silver sulphate) is:



Ammonium sulphide ($(\text{NH}_4)_2\text{S}$) is a highly soluble compound which releases ammonium (NH_4^+) ions and sulphide (S^{2-}) ions to the solution. NH_4^+ ions are spectators in this case.

If you check the solubility table, you will see that sulphide (S^{2-}) will precipitate with silver (Ag^+) ions in the solution, forming the black precipitate silver sulphide ($\text{Ag}_2\text{S}(\text{s})$).

This will cause a decrease in the $[\text{Ag}^+]$, shifting the above equilibrium to the right, causing the white $\text{Ag}_2\text{SO}_4(\text{s})$ to dissolve.



<i>Equilibrium</i>	<i>Added Reagent</i>	<i>Effect on Solubility</i>	<i>Explanation</i>
SrSO ₄	Ba(NO ₃) _{2(aq)}	Increase	The Ba ²⁺ from the barium nitrate will precipitate the SO ₄ ²⁻ ion from the SrSO ₄ equilibrium, forming BaSO ₄ . Decreasing the [SO ₄ ²⁻] will cause the SrSO ₄ equilibrium to shift to the ion side, thus dissolving the solid.
Ag ₂ S	AgNO _{3(aq)}	Decrease	The Ag ⁺ ion from the silver nitrate is a common ion to the Ag ⁺ from the Ag ₂ S equilibrium. The increased [Ag ⁺] causes the Ag ₂ S equilibrium to shift toward the solid side and decrease the solubility of Ag ₂ S
SrCO ₃	HNO _{3(aq)} (nitric acid)	Increase	The H ⁺ ions from the acid react with the carbonate (CO ₃ ²⁻) ions from the SrCO ₃ equilibrium, forming carbonic acid (H ₂ CO ₃). The carbonic acid decomposes into carbon dioxide and water. The decreased [CO ₃ ²⁻] in the SrCO ₃ equilibrium causes a shift toward the ion side, thus increasing the solubility of SrCO ₃ .
AgBr	Pb(NO ₃) _{2(aq)}	Increase	The Pb ²⁺ from the lead nitrate will precipitate the Br ⁻ ion from the AgBr equilibrium, forming PbBr ₂ . Decreasing the [Br ⁻] will cause the AgBr equilibrium to shift to the ion side, thus dissolving the solid.
PbCl ₂	KCl _(aq)	Decrease	The Cl ⁻ ion from the potassium chloride is a common ion to the Cl ⁻ from the PbCl ₂ equilibrium. The increased [Cl ⁻] causes the PbCl ₂ equilibrium to shift toward the solid side and decrease the solubility of PbCl ₂
Be(OH) ₂	NaCl _(aq)	no effect	The NaCl has no common ions to the Be(OH) ₂ and neither the Na ⁺ nor the Cl ⁻ forms any precipitates with either of the ions from Be(OH) ₂
PbCO ₃	HCl _(aq)	Increase	The H ⁺ ions from the acid react with the carbonate (CO ₃ ²⁻) ions from the PbCO ₃ equilibrium, forming carbonic acid (H ₂ CO ₃). The carbonic acid decomposes into carbon dioxide and water. The decreased [CO ₃ ²⁻] in the PbCO ₃ equilibrium causes a shift toward the ion side, thus increasing the solubility of PbCO ₃ . - or- The Cl ⁻ from the HCl will precipitate the Pb ²⁺ ion from the PbCO ₃ equilibrium, forming PbCl ₂ . Decreasing the [Pb ²⁺] will cause the PbCO ₃ equilibrium to shift to the ion side, thus dissolving the solid.
CuI	CaI _{2(aq)}	decrease	The I ⁻ ion from the calcium iodide is a common ion to the I ⁻ from the CuI equilibrium. The increased [I ⁻] causes the CuI equilibrium to shift toward the solid side and decrease the solubility of CuI.
Ag ₂ CO ₃	Na ₂ S _(aq)	increase	The S ²⁻ from the Na ₂ S will precipitate the Ag ⁺ ion from the Ag ₂ CO ₃ equilibrium, forming Ag ₂ S. Decreasing the [Ag ⁺] will cause the Ag ₂ CO ₃ equilibrium to shift to the ion side, thus dissolving the solid.
Ca ₃ (PO ₄) ₂	K ₂ SO _{4(aq)}	increase	The SO ₄ ²⁻ from the K ₂ SO ₄ will precipitate the Ca ²⁺ ion from the Ca ₃ (PO ₄) ₂ equilibrium, forming CaSO ₄ . Decreasing the [Ca ²⁺] will cause the Ca ₃ (PO ₄) ₂ equilibrium to shift to the ion side, thus dissolving the solid.

The Common Ion Effect and Altering Solubility

1. Briefly explain what is meant by the *common ion effect*.
2. Name two compounds (not just ions) that can *decrease* the solubility of $\text{BaSO}_{4(s)}$ and explain why each one of them works
3. Name a substance (not just an ion) which could *increase* the solubility of $\text{BeCO}_{3(s)}$. Explain why this substance works.
4. Silver sulphate is a white precipitate with low solubility. When a solution of ammonium sulphide ($(\text{NH}_4)_2\text{S}_{(aq)}$) is added, the white precipitate slowly dissolves and a black precipitate forms on the bottom. Using **equilibrium equations** and clear explanations, indicate what happened here.

5. The following table shows some compounds with low solubility in the left column. In column 2, a solution (reagent) is added. In column 3, indicate whether the solubility of the compound on the left will be increased, decreased or not affected. In column 4, give a brief explanation for your answer. You don't need to include equilibrium equations in your explanations in this case.

<i>Equilibrium</i>	<i>Added Reagent</i>	<i>Effect on Solubility</i>	<i>Explanation</i>
SrSO ₄	Ba(NO ₃) ₂ (aq)		
Ag ₂ S	AgNO ₃ (aq)		
SrCO ₃	HNO ₃ (aq) (nitric acid)		
AgBr	Pb(NO ₃) ₂ (aq)		
PbCl ₂	KCl(aq)		
Be(OH) ₂	NaCl(aq)		
PbCO ₃	HCl(aq)		
CuI	CaI ₂ (aq)		
Ag ₂ CO ₃	Na ₂ S(aq)		
Ca ₃ (PO ₄) ₂	K ₂ SO ₄ (aq)		