Net Ionic Equations

Video Workbook with Dr. B.

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In **Net Ionic Equations** the soluble ionic compounds are split apart into their ions. We then cross spectator ions and only the substances that reacted/changed are shown.

To be successful:

- You must be able to balance equations, determine the charges on ions, and determine solubility.
- Watch the video Intro to Net Ionic Equations.
- Do the 20 practice problems below and check your work! Watch the video solutions if you're stuck.

Key Videos

- Intro to Net Ionic Equations
- Net Ionic Equations Practice
- Spectator Ions
- Finding the Charge on Ions
- Solubility Chart and Rules

Steps for Writing Net Ionic Equations

1. Write the balanced **molecular equation**.
2. Write the state (*s*, *l*, *g*, *aq*) for each substance.
3. Split soluble compounds into ions (the **complete ionic equation**).
4. Cross out spectator ions on both sides of the complete ionic equation.
5. Write the remaining substances for the **net ionic equation**.

Step 1: Balance the Equation

The first step is to balance the molecular equation.

For example: $2NaOH + CuSO_4 \rightarrow Na_2SO_4 + Cu(OH)_2$

If you need help with balancing:

- How to Balance Equations in Five Easy Steps
- Balancing Equations with Polyatomic ions

Step 2: Write the States

Use the solubility rules or solubility chart to write the states for ionic compounds in water.

- *Soluble* ionic compounds are aqueous (*aq*).
- *Insoluble* ionic compounds are solid (*s*).

For example:

$2NaOH\,(aq) + CuSO_4\,(aq) \rightarrow Na_2SO_4\,(aq) + Cu(OH)_2\,(s)$

$NaOH\,(aq)$: Rule 1, 6 $\quad$ $Na_2SO_4\,(aq)$: Rule 1, 5
$CuSO_4\,(aq)$: Rule 5 $\quad$ $Cu(OH)_2\,(s)$: Rule 6*

Rules on the right are the most common ones. →

*When a substance is ***slightly soluble,*** we treat it as a solid (*s*) in net ionic equations.

Solubility Rules

Salts of:

1. Group I elements (Li^+, Na^+, K^+, Cs^+, Rb^+) are soluble.
2. NH_4^+ (Ammonium ion) are soluble.
3. the nitrate ion (NO_3^-) are generally soluble.
4. of Cl^-, Br^-, and I^- are soluble.
   Exceptions Ag^+, Pb^{2+}, and $(Hg_2)^{2+}$
5. most sulfates are soluble.
   Exceptions: Ba^{2+}, Ca^{2+}, Pb^{2+}, Ag^+, Sr^{2+}
6. most hydroxide salts are only slightly soluble.
   Exceptions: NH_4^+, Li^+, Na^+, K^+
7. most carbonates (CO_3^{2-}) are insoluble.
   Exceptions: Group 1 and NH_4^+

Top rules supersede any lower rules.

Practice with Solubility Rules

Determine whether the following ionic compounds are soluble or insoluble in water.

$CuCl_2$, KOH, $CaCO_3$, $Al_2(SO_4)_3$,

PbI_2, NH_4Br, $(NH_4)_2CO_3$, $Mg(NO_3)_2$

$CuCl_2$ Soluble $\quad$ PbI_2 Insoluble
KOH Soluble $\quad$ NH_4Br Soluble
$CaCO_3$ Insoluble $\quad$ $(NH_4)_2CO_3$ Soluble
$Al_2(SO_4)_3$ Soluble $\quad$ $Mg(NO_3)_2$ Soluble

Strong Acids and Bases

are considered soluble (*aq*).

Strong Acids:
HCl, HBr, HI, HNO_3, H_2SO_4, $HClO_4$

Strong Bases:
$LiOH$, $NaOH$, KOH, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$

These are worth memorizing!

Note

Weak Acids and Bases are usually soluble but only ***partially*** dissociate into their ions. For example, CH_3COOH will be (*aq*).

Step 3 : Split apart soluble ionic compounds.

Careful, small mistakes in this step can cause big problems later!

We use our knowledge of the charges on ions, and solubility to split apart soluble ionic compounds.

$$2NaOH\ (aq) + CuSO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + Cu(OH)_2\ (s)$$

$2NaOH: \ 2Na^+ + 2OH^-$ $\qquad$ $Na_2SO_4: \ 2Na^+ + SO_4^{2-}$

$CuSO_4: \ Cu^{2+} + SO_4^{2-}$ $\qquad$ $Cu(OH)_2$: Do not split! It is a solid.

We end up with the **complete ionic equation**:

$$2Na^+(aq) + 2OH^-(aq) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq) + Cu(OH)_2\ (s)$$

Important: We do not split apart solids (*s*), liquids (*l*), or gases (*g*), or molecular compounds.

When we have a coefficient, that is multiplied by the entire compound. $2NaOH = 2Na^+ + 2OH^-$

When we have a subscript, it means we have that number of the ion. $Na_2SO_4 = 2Na^+ + SO_4^{2-}$

To be successful you must be able to quickly find the charge on ions.

Practice: Split the following compounds into ions (if necessary):

$2NaCl\ (aq)$, $CaCl_2\ (aq)$, $H_2O\ (l)$, $CO_2\ (g)$, $MgCO_3\ (s)$, $NH_4Cl\ (aq)$, $Na_2CO_3\ (aq)$, $2AgNO_3\ (aq)$

Answers

$2NaCl: \ 2Na^+ + 2Cl^-$ $\qquad$ $MgCO_3$: do not split solids (*s*)

$CaCl_2: \ Ca^{2+} + 2Cl^-$ $\qquad$ $NH_4Cl \ : \ NH_4^+ + Cl^-$

H_2O : do not split liquids (*l*) $\qquad$ $Na_2CO_3 \ : \ 2Na^+ + CO_3^{2-}$

CO_2 : do not split gases (*g*) $\qquad$ $2AgNO_3 \ : \ 2Ag^+ + 2NO_3^-$

Two important notes:

- weak acids and bases are often soluble, but we do not split them into ions (they only partially break apart into ions). $CH_3COOH\ (aq)$ and $NH_3\ (aq)$ are the main examples.
- If a substance is listed as *slightly soluble* (ss) we consider it insoluble.

Step 4: Cross out spectator ions.

Spector ions are ions that are on both sides of the equation. This means they did not change.

For example:

$\cancel{2Na^{+}(aq)} + 2OH^{-}(aq) + Cu^{2+}(aq) + \cancel{SO_4^{2-}(aq)} \longrightarrow \cancel{2Na^{+}(aq)} + \cancel{SO_4^{2-}(aq)} + Cu(OH)_2(s)$

This leaves us with the **net ionic equation**: $Cu^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Cu(OH)_2(s)$

Step 5: Check to see that atoms and charge balance.

For the net ionic equation: $Cu^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Cu(OH)_2(s)$

Atoms are balanced: 1 Cu, 2 O, and 2 H atoms on both side of the equation.
Charge is balanced: 2+ and 2(1-) = 0 in the reactants. No/zero charge in the products.

You can watch a video for the entire process of writing the net ionic equation for $NaOH + CuSO_4$.

Practice (write balanced net ionic equations include the stated of all substances)

1. $Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$
2. $HCl + NaOH \longrightarrow NaCl + H_2O$
3. $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$
4. $Pb(NO_3)_2 + KI \longrightarrow KNO_3 + PbI_2$
5. $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + NaCl$
6. $KI + Na_2CO_3 \longrightarrow K_2CO_3 + NaI$
7. $FeCl_3 + NaOH \longrightarrow Fe(OH)_3 + NaCl$
8. $AgNO_3 + Cu \longrightarrow Cu(NO_3)_2 + Ag$
9. $HNO_3 + Ca(OH)_2 \longrightarrow Ca(NO_3)_2 + H_2O$
10. $Ba(NO_3)_2 + Na_2SO_4 \longrightarrow BaSO_4 + NaNO_3$
11. $Pb(NO_3)_2 + Na_2CO_3 \longrightarrow PbCO_3 + NaNO_3$
12. $CH_3COOH + KOH \longrightarrow CH_3COOK + H_2O$
13. $Na + H_2O \longrightarrow NaOH + H_2$
14. $Fe + CuSO_4 \longrightarrow Cu + FeSO_4$
15. $Na_2CO_3 + Ca(NO_3)_2 \longrightarrow NaNO_3 + CaCO_3$
16. $NaHCO_3 + HCl \longrightarrow NaCl + CO_2 + H_2O$
17. $H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$
18. $Pb(NO_3)_2 + NaCl \longrightarrow PbCl_2 + NaNO_3$
19. $NH_3 + CH_3COOH \longrightarrow NH_4CH_3COO$
20. $KCl + NaNO_3 \longrightarrow KNO_3 + NaCl$

Answers Below

1. $Zn\,(s) + Cu^{2+}\,(aq) \rightarrow Zn^{2+}\,(aq) + Cu\,(s)$ (video)
2. $H^{+}\,(aq) + OH^{-}\,(aq) \rightarrow H_2O\,(l)$ (video)
3. $Ag^{+}\,(aq) + Cl^{-}\,(aq) \rightarrow AgCl\,(s)$ (video)
4. $Pb^{2+}\,(aq) + 2I^{-}\,(aq) \rightarrow PbI_2\,(s)$ (video)
5. $Ba^{2+}\,(aq) + SO_4^{2-}\,(aq) \rightarrow BaSO_4\,(s)$ (video)
6. $KI\,(aq) + Na_2CO_3\,(aq) \rightarrow K_2CO_3\,(aq) + NaI\,(aq)$ (video)
7. $Fe^{3+}\,(aq) + 3OH^{-}\,(aq) \rightarrow Fe(OH)_3\,(s)$ (video)
8. $2Ag^{+}\,(aq) + Cu\,(s) \rightarrow Cu(NO_3)_2\,(aq) + 2Ag\,(s) \rightarrow$ (video)
9. $H^{+}\,(aq) + OH^{-}\,(aq) \rightarrow H_2O\,(l)$ (video)
10. $Ba^{2+}\,(aq) + SO_4^{2-}\,(aq) \rightarrow BaSO_4\,(s)$ (video)
11. $Pb^{2+}\,(aq) + CO_3^{2-}\,(aq) \rightarrow PbCO_3\,(s)$ (video)
12. $CH_3COOH\,(aq) + OH^{-}\,(aq) \rightarrow CH_3COO^{-}\,(aq) + H_2O\,(l)$ (video)
13. $Na\,(s) + H_2O\,(l) \rightarrow Na^{+} + OH^{-}\,(aq) + H_2\,(g)$ (video)
14. $Fe\,(s) + Cu^{2+}\,(aq) \rightarrow Cu\,(s) + Fe^{2+}\,(aq)$ (video)
15. $CO_3^{2-}\,(aq) + Ca^{2+}\,(aq) \rightarrow CaCO_3\,(s)$ (video)
16. $HCO_3^{-}\,(aq) + H^{+}\,(aq) \rightarrow CO_2\,(g) + H_2O\,(l)$ (video)
17. $H^{+}\,(aq) + OH^{-}\,(aq) \rightarrow H_2O\,(l)$ (video)
18. $Pb^{2+}\,(aq) + 2Cl^{-}\,(aq) \rightarrow PbCl_2\,(s)$ (video)
19. $NH_3\,(aq) + CH_3COOH\,(aq) \rightarrow NH_4^{+}\,(aq) + CH_3COO^{-}\,(aq)$ (video)
20. $KCl\,(aq) + NaNO_3\,(aq) \rightarrow KNO_3\,(aq) + NaCl\,(aq)$ (video)

If your time is extremely limited, watch these videos:

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- Net Ionic Equations Practice
- Spectator Ions
- Finding the Charge on Ions
- Solubility Chart and Rules

Report errors and suggestions to DrB@breslyn.org

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