NI · Net ionic equations

Completed notes

Goals: Write a dissolved ionic compound as its ions. Write a net ionic equation and name the spectator ions. Check a net ionic equation for atoms and charge.

Slide 1 of 5 · Which substances are written as ions?

An ionic compound dissolved in water breaks into its ions. This is called **dissociation**.

Split only an ionic compound or a strong acid marked **(aq)**.

A solid, a liquid or a gas stays **whole**.

The subscript on an ion becomes its **coefficient**. A polyatomic ion such as SO_4^{2-} stays together.

Example. Given: $Na_2SO_4(aq)$. Write the ions in the water, with the number of each ion. Then say which of $AgCl(s)$, $KBr(aq)$ and $H_2O(l)$ is split into ions.

1. $Na_2SO_4(aq) \rightarrow 2Na^+(aq) + SO_4^{2-}(aq)$.

2. The subscript 2 on Na becomes the coefficient 2. SO_4^{2-} stays together.

3. Only $KBr(aq)$ is split: $K^+(aq)$ and $Br^-(aq)$.

4. $AgCl(s)$ is a solid and $H_2O(l)$ is a liquid. They stay whole.

Try it. Given: $Al_2(SO_4)_3(aq)$. Write the ions in the water, with the number of each ion. Then say which of $CaCl_2(aq)$, $Zn(s)$ and $CO_2(g)$ is split into ions.

1. $Al_2(SO_4)_3(aq) \rightarrow 2Al^{3+}(aq) + 3SO_4^{2-}(aq)$.

2. Check the charge: $2(+3) + 3(-2) = 0$.

3. Only $CaCl_2(aq)$ is split: $Ca^{2+}(aq)$ and $2Cl^-(aq)$.

4. $Zn(s)$ is a solid and $CO_2(g)$ is a gas. They stay whole.

Slide 2 of 5 · From a full equation to a net ionic equation

The **total ionic equation** shows every dissolved ionic compound as separate ions.

An ion that is the same on both sides did not change. It is a **spectator ion**.

Cancel the spectator ions. What is left is the **net ionic equation**.

Check a net ionic equation for atoms and for **charge**.

Example. Given: $Mg(s) + 2AgNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + 2Ag(s)$. Write the total ionic equation and the net ionic equation. Name the spectator ion.

1. Total ionic: $Mg(s) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow Mg^{2+}(aq) + 2NO_3^-(aq) + 2Ag(s)$.

2. $2NO_3^-(aq)$ is on both sides. Cancel it. The spectator ion is NO_3^-.

3. Net ionic: $Mg(s) + 2Ag^+(aq) \rightarrow Mg^{2+}(aq) + 2Ag(s)$.

4. Check: Mg 1 and Ag 2 on each side. Charge: +2 and +2.

5. Mg goes 0 → +2: oxidized. Ag^+ goes +1 → 0: reduced.

Try it. Given: $Zn(s) + Cu(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Cu(s)$. Write the total ionic equation and the net ionic equation. Name the spectator ion.

1. Total ionic: $Zn(s) + Cu^{2+}(aq) + 2NO_3^-(aq) \rightarrow Zn^{2+}(aq) + 2NO_3^-(aq) + Cu(s)$.

2. $2NO_3^-(aq)$ is on both sides. Cancel it. The spectator ion is NO_3^-.

3. Net ionic: $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$.

4. Check: Zn 1 and Cu 1 on each side. Charge: +2 and +2.

5. Zn goes 0 → +2: oxidized. Cu^{2+} goes +2 → 0: reduced.

Slide 3 of 5 · Method: how to write a net ionic equation

Step 1. Write the **balanced** equation with states.

Step 2. **Split** every ionic compound or strong acid marked (aq) into its ions.

Step 3. **Cancel** ions that are the same on both sides. They are spectator ions.

Step 4. Write what is left, with the lowest whole numbers.

Step 5. Check **atoms** and **charge** on both sides.

Example. Magnesium metal is put in silver nitrate solution. Magnesium nitrate solution and silver metal form. Use the five steps to write the net ionic equation.

1. Step 1. $Mg(s) + 2AgNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + 2Ag(s)$.

2. Step 2. $Mg(s) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow Mg^{2+}(aq) + 2NO_3^-(aq) + 2Ag(s)$.

3. Step 3. Cancel $2NO_3^-(aq)$ from each side.

4. Step 4. $Mg(s) + 2Ag^+(aq) \rightarrow Mg^{2+}(aq) + 2Ag(s)$.

5. Step 5. Mg 1 and Ag 2 on each side. Charge: +2 and +2.

Try it. Given: $Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$. Use the five steps to write the net ionic equation.

1. Step 1. The equation is balanced: Cu 1, Ag 2, N 2 and O 6 on each side.

2. Step 2. $Cu(s) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2NO_3^-(aq) + 2Ag(s)$.

3. Step 3. Cancel $2NO_3^-(aq)$ from each side.

4. Step 4. $Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$.

5. Step 5. Cu 1 and Ag 2 on each side. Charge: +2 and +2.

Slide 4 of 5 · Your turn: aluminium in copper(II) chloride solution

To count an ion, multiply the **coefficient** by the subscript.

$3CuCl_2(aq)$ gives $3Cu^{2+}(aq)$ and **6**$Cl^-(aq)$.

Two chloride ions are written $2Cl^-$. Each one has a charge of **1−**.

The charge on each side of a net ionic equation must be **equal**.

Example. Given: $2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Cu(s)$. Write the total ionic equation and the net ionic equation. Name the spectator ion.

1. Total ionic: $2Al(s) + 3Cu^{2+}(aq) + 6Cl^-(aq) \rightarrow 2Al^{3+}(aq) + 6Cl^-(aq) + 3Cu(s)$.

2. $6Cl^-(aq)$ is on both sides. Cancel it. The spectator ion is Cl^-.

3. Net ionic: $2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$.

4. Check: Al 2 and Cu 3 on each side. Charge: 3(+2) = +6 and 2(+3) = +6.

5. Al is oxidized. Cu^{2+} is reduced.

Try it. Given: $2Al(s) + 3Pb(NO_3)_2(aq) \rightarrow 2Al(NO_3)_3(aq) + 3Pb(s)$. Write the total ionic equation and the net ionic equation. Name the spectator ion.

1. Total ionic: $2Al(s) + 3Pb^{2+}(aq) + 6NO_3^-(aq) \rightarrow 2Al^{3+}(aq) + 6NO_3^-(aq) + 3Pb(s)$.

2. $6NO_3^-(aq)$ is on both sides. Cancel it. The spectator ion is NO_3^-.

3. Net ionic: $2Al(s) + 3Pb^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Pb(s)$.

4. Check: Al 2 and Pb 3 on each side. Charge: 3(+2) = +6 and 2(+3) = +6.

5. Al is oxidized. Pb^{2+} is reduced.

Slide 5 of 5 · A net ionic equation is not always redox

A solid product is written **whole**. It is not split into ions.

A net ionic equation shows what **changed**.

A reaction is redox only if at least one **oxidation number** changes.

Ions can join into a solid with **no** electrons transferred.

Example. Given: $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$. Write the net ionic equation. Is it a redox reaction? Explain.

1. Split the three dissolved compounds. $PbI_2(s)$ stays whole.

2. K^+ and NO_3^- are on both sides. They are the spectator ions.

3. Net ionic: $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$. Charge: 0 and 0.

4. Lead is +2 before and after. Iodine is −1 before and after.

5. No oxidation number changes, so it is not a redox reaction.

Try it. Given: $CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$. Write the net ionic equation. Is it a redox reaction? Explain.

1. Split the three dissolved compounds. $CaCO_3(s)$ stays whole.

2. Na^+ and Cl^- are on both sides. They are the spectator ions.

3. Net ionic: $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$. Charge: 0 and 0.

4. Calcium stays +2, carbon stays +4 and oxygen stays −2.

5. No oxidation number changes, so it is not a redox reaction.

NI · Worked practice

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1. Given: $K_3PO_4(aq)$. Write the ions it forms in water, with the number of each ion.

$K_3PO_4(aq) \rightarrow 3K^+(aq) + PO_4^{3-}(aq)$. The subscript 3 on K becomes the coefficient 3. PO_4^{3-} is one ion and stays together. Check the charge: $3(+1) + (-3) = 0$.

2. Given: $Ni(s) + Pb(NO_3)_2(aq) \rightarrow Ni(NO_3)_2(aq) + Pb(s)$. Write the total ionic equation and the net ionic equation. Name the spectator ion.

Use Method: how to write a net ionic equation. Total ionic: $Ni(s) + Pb^{2+}(aq) + 2NO_3^-(aq) \rightarrow Ni^{2+}(aq) + 2NO_3^-(aq) + Pb(s)$. Cancel $2NO_3^-(aq)$. The spectator ion is NO_3^-. Net ionic: $Ni(s) + Pb^{2+}(aq) \rightarrow Ni^{2+}(aq) + Pb(s)$. Check: Ni 1, Pb 1 and a charge of +2 on each side.

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3. Given: $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$. HCl(aq) is a strong acid. Write the net ionic equation and name the spectator ion.

Total ionic: $Zn(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow Zn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$. Cancel $2Cl^-(aq)$. The spectator ion is Cl^-. Net ionic: $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$. Check: Zn 1, H 2 and a charge of +2 on each side.

4. Given: $Cl_2(g) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(s)$. Write the net ionic equation. Then say what is oxidized and what is reduced.

Total ionic: $Cl_2(g) + 2K^+(aq) + 2I^-(aq) \rightarrow 2K^+(aq) + 2Cl^-(aq) + I_2(s)$. Cancel $2K^+(aq)$. Net ionic: $Cl_2(g) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(s)$. Check: Cl 2, I 2 and a charge of −2 on each side. I^- goes $-1 \rightarrow 0$, so it is oxidized. Cl goes $0 \rightarrow -1$, so Cl_2 is reduced.

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5. Given: $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$. Write the net ionic equation. Is it a redox reaction? Explain.

Total ionic: $Ba^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2Na^+(aq) + 2Cl^-(aq)$. Cancel $2Na^+(aq)$ and $2Cl^-(aq)$. Net ionic: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$. The charge is 0 on each side. It is not a redox reaction. Barium stays +2, sulfur stays +6 and oxygen stays −2, so no oxidation number changes.

6. A student writes this total ionic equation for $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$: $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow Ag^+(aq) + Cl^-(aq) + Na^+(aq) + NO_3^-(aq)$. Then the student cancels everything. Find the mistake and write the correct net ionic equation.

The student split AgCl(s). It is a solid, so it stays whole. Correct total ionic: $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$. Cancel $Na^+(aq)$ and $NO_3^-(aq)$. Net ionic: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$. The charge is 0 on each side.

NI · Worked practice

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7. Challenge: Given: $3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$. $HNO_3(aq)$ is a strong acid. Write the total ionic equation and the net ionic equation. How many nitrate ions are spectator ions?

Total ionic: $3Cu(s) + 8H^+(aq) + 8NO_3^-(aq) \rightarrow 3Cu^{2+}(aq) + 6NO_3^-(aq) + 2NO(g) + 4H_2O(l)$. There are $8NO_3^-$ on the left and $6NO_3^-$ on the right. Cancel 6 from each side. Six nitrate ions are spectator ions, and $2NO_3^-$ stay on the left. Net ionic: $3Cu(s) + 8H^+(aq) + 2NO_3^-(aq) \rightarrow 3Cu^{2+}(aq) + 2NO(g) + 4H_2O(l)$. Check: Cu 3; H 8; N 2; O 6. Charge: $+8 - 2 = +6$ and $+6$.