Net Ionic Equations

Do all reactant species participate in a reaction?

Why?

If you were to attend a sporting event on any random weekend you would find there are two types of people in attendance—players and spectators. Although both are important in their own right, they have different functions. This is also the case in chemical reactions. Although a species may be shown in a chemical reaction, it might only be a spectator. In other words it does not actually participate in the breaking and forming of chemical bonds that define the chemical reaction.

Model 1 – Three Reactions

1. Consider the three reactions in Model 1.
   a. Which beakers in the model contain solid, insoluble substances?
      1C, 2A, 2C, 3A, 3C
   b. What evidence is provided in the model to show that these substances are solids?
      The solids are shown as atoms touching. The circles are very close together in a regular pattern.
c. Which beakers in the model contain solutions of ionic substances?

1A, 1B, 1C, 2B, 2C, 3B, 3C

d. What evidence is provided in the model to show that these substances are ionic compounds?

*Outside of the water they are solids, but when they go into the water, the ions divide as the substance dissolves.*

2. Which of the reactions in Model 1 produces a gas?

*Reaction 3 produces a gas.*

3. Three reactions are provided below. Indicate which reaction in Model 1 corresponds to each reaction below. Discuss with your group members the evidence you used from Model 1 to match the reactions, and be prepared to support your choices to the class. Do not assume the reactions are stoichiometric. That is, one reactant may be present in excess.

\[
\begin{align*}
\text{Zn (s) + 2HCl (aq) } & \rightarrow \text{ ZnCl}_2 (aq) + \text{H}_2 (g) \quad \text{Reaction 3} \\
\text{Zn (s) + Cu(NO}_3)_2 (aq) & \rightarrow \text{ Zn(NO}_3)_2 (aq) + \text{Cu (s)} \quad \text{Reaction 2} \\
\text{Zn(NO}_3)_2 (aq) + \text{Na}_2\text{CO}_3 (aq) & \rightarrow \text{ ZnCO}_3 (s) + 2\text{NaNO}_3 (aq) \quad \text{Reaction 1}
\end{align*}
\]

4. For each of the reactions in Model 1, write a complete sentence that describes the specific chemical change that occurred.

*Reaction 1: A zinc carbonate precipitate was formed from zinc and carbonate ions in solution.*

*Reaction 2: A single replacement reaction between zinc and copper ions produced solid copper.*

*Reaction 3: Formation of gaseous hydrogen from the single replacement of hydrogen by zinc.*

5. In each of the reactions in Model 1, there are ions present in the solutions that do not participate in the chemical reaction. In other words, they exist in the same form both before and after the reaction. These substances are called **spectator ions**. Identify the spectator ions for each reaction.

*Reaction 1: Na\(^{+}\) \(\text{NO}_3^{-}\)*

*Reaction 2: \(\text{NO}_3^{-}\)*

*Reaction 3: Cl\(^{-}\)*

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**Model 2 – Writing a Reaction Three Ways**

<table>
<thead>
<tr>
<th>Molecular Equation</th>
<th>Zn (s) + Cu(NO(_3)_2 (aq) \rightarrow Zn(NO(_3)_2 (aq) + Cu (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic Equation</td>
<td>Zn (s) + Cu(^{2+}) (aq) + 2NO(_3^{-}) (aq) \rightarrow Zn(^{2+}) (aq) + 2NO(_2^{-}) (aq) + Cu (s)</td>
</tr>
<tr>
<td>Net Ionic Equation</td>
<td>Zn (s) + Cu(^{2+}) (aq) \rightarrow Zn(^{2+}) (aq) + Cu (s)</td>
</tr>
</tbody>
</table>

6. Consider the equations in Model 2.

a. Which equation represents the ionic substances as bonded together in the solution?

*The molecular equation represents the ionic substances as bonded together in solution.*
b. Which equation represents the ionic substances as separate ions in solution?

*The ionic equation represents the ionic substances as separate ions in solution.*

c. Which of the two equations from parts a and b is a better representation of how the species take part in the reaction?

*The ionic equation is a better representation of what is actually happening in the reaction.*

7. Compare the net ionic equation in Model 2 to the other two equations.

a. What chemical species is missing in the net ionic equation?

*The nitrate ions are missing in the net ionic equation. These ions were spectator ions.*

b. Explain why it is valid to remove this species from the equation.

*The nitrate ion did not change during the reaction. It was the same charge and phase after the reaction as it was before the reaction. It does not take part in a chemical reaction, or a chemical change.*

8. Work as a group to write a definition for a net ionic equation.

*The net ionic equation is an equation that denotes the species that take an active part in a chemical reaction. The spectator ions are removed from the equation.*

9. Write ionic and net ionic equations for the remaining reactions in Model 1.

a. Molecular Equation

\[ \text{Zn(s)} + \ 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g) \]

Ionic Equation

\[ \text{Zn(s)} + 2\text{H}^{+}(aq) + 2\text{Cl}^{-}(aq) \rightarrow \text{Zn}^{2+}(aq) + 2\text{Cl}^{-}(aq) + \text{H}_2(g) \]

Net Ionic Equation

\[ \text{Zn(s)} + 2\text{H}^{+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{H}_2(g) \]

b. Molecular Equation

\[ \text{Zn(NO}_3)_2(aq) + \text{Na}_2\text{CO}_3(aq) \rightarrow \text{ZnCO}_3(s) + 2\text{NaNO}_3(aq) \]

Ionic Equation

\[ \text{Zn}^{2+}(aq) + 2\text{NO}_3^{-}(aq) + 2\text{Na}^{+}(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{ZnCO}_3(s) + 2\text{Na}^{+}(aq) + 2\text{NO}_3^{-}(aq) \]

Net Ionic Equation

\[ \text{Zn}^{2+}(aq) + \text{CO}_3^{2-}(aq) \rightarrow \text{ZnCO}_3(s) \]

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**Read This!**

When writing an ionic or net ionic equation for a reaction you must consider what species will divide into ions in solution. For example, strong acids like hydrochloric acid or sulfuric acid will be represented as ions, but weak acids remain mostly in molecular form so these are not divided. Similarly, only soluble ionic substances are represented as separate ions in solution. If the substance is insoluble, it remains written in the molecular form.
10. Write a molecular, ionic and net ionic equation for the reaction between acetic acid and sodium hydroxide.

\textit{Molecular Equation:} \[ \text{CH}_3\text{COOH} \text{(aq)} + \text{NaOH} \text{(aq)} \rightarrow \text{NaCH}_3\text{COO} \text{(aq)} + \text{H}_2\text{O} \text{(l)} \]

\textit{Ionic Equation:} \[ \text{CH}_3\text{COOH} \text{(aq)} + \text{Na}^+ \text{(aq)} + \text{OH}^- \text{(aq)} \rightarrow \text{Na}^+ \text{(aq)} + \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}_2\text{O} \text{(l)} \]

\textit{Net Ionic Equation:} \[ \text{CH}_3\text{COOH} \text{(aq)} + \text{OH}^- \text{(aq)} \rightarrow \text{CH}_3\text{COO}^- \text{(aq)} + \text{H}_2\text{O} \text{(l)} \]

11. Write a molecular, ionic and net ionic equation for the reaction between solid magnesium carbonate and sulfuric acid.

\textit{Molecular Equation:} \[ \text{MgCO}_3 \text{(s)} + \text{H}_2\text{SO}_4 \text{(aq)} \rightarrow \text{MgSO}_4 \text{(s)} + \text{H}_2\text{O} \text{(l)} + \text{CO}_2 \text{(g)} \]

\textit{Ionic Equation:} \[ \text{MgCO}_3 \text{(s)} + 2 \text{H}^+ \text{(aq)} + \text{SO}_4^{2-} \text{(aq)} \rightarrow \text{MgSO}_4 \text{(s)} + \text{H}_2\text{O} \text{(l)} + \text{CO}_2 \text{(g)} \]

\textit{Net Ionic Equation:} \[ \text{MgCO}_3 \text{(s)} + 2 \text{H}^+ \text{(aq)} + \text{SO}_4^{2-} \text{(aq)} \rightarrow \text{MgSO}_4 \text{(s)} + \text{H}_2\text{O} \text{(l)} + \text{CO}_2 \text{(g)} \]
Extension Questions

12. Choose either Question 10 or 11, and draw a picture representing the reaction at the atomic level.

   ![Chemical reaction diagram]

   *Acetic acid
   *Sodium hydroxide

   *This drawing illustrates Question 10.*

13. Is the law of conservation of mass obeyed in net ionic reactions? Support your answer with evidence from this activity.

   *Yes, the law of conservation of mass is obeyed in net ionic reactions. For example, in the equation*
   
   \[ \text{CH}_3\text{COOH}^{\text{(aq)}} + \text{OH}^{\text{−}}^{\text{(aq)}} \rightarrow \text{CH}_3\text{COO}^{\text{−}}^{\text{(aq)}} + \text{H}_2\text{O} \]

   *both sides of the reaction have two carbon atoms, four hydrogen atoms and three oxygen atoms.*

14. In molecular equations, all substances are written as neutral, but in net ionic equations several of the species have charges. Is charge conserved in a net ionic equation? Support your answer with evidence from this activity.

   *Yes, charge is conserved in net ionic equations. For example in the equation*
   
   \[ \text{Zn}^{\text{(s)}} + 2\text{H}^{\text{+}}^{\text{(aq)}} \rightarrow \text{Zn}^{2\text{+}}^{\text{(aq)}} + \text{H}_2^{\text{(g)}} \]

   *the total charge on the left side of the equation is 2+, and the total charge on the right side of the equation is 2+.*

15. What are the advantages and disadvantages to using a net ionic equation to represent a chemical change rather than a molecular equation?

   *Advantages include representing only the species in the reaction that are part of the chemical change. This makes it easier to identify the bonds being broken and formed in the reaction. A net ionic equation is also shorter to write.*

   *Disadvantages include not representing the ions that may be present in the beaker that may interfere with isolation of a product or use of a product in subsequent reactions.*