ANSWER KEY. In the complete ionic equations, spectator ions are crossed out in gray.

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Net Ionic Equations

AP Chemistry | Topic 4.2 | ANSWER KEY

Part A. Each reaction gives the reactants and products, including the precipitate. Write the balanced molecular, complete ionic, and net ionic equations with states of matter, then list the spectator ions.

AP solubility rule. Always soluble (aq): any compound containing Na^+, K^+, NH_4^+, or NO_3^-. **Everything else:** AP does not expect you to memorize any other solubility rules. When a solid forms, the question names it or shows it as (s) in an equation. **Splitting into ions:** only (aq) strong electrolytes split. Solids, liquids, gases, and weak acids stay together.

1. When solutions of calcium chloride and sodium carbonate are mixed, a white precipitate of calcium carbonate forms. The unbalanced equation is:

$$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + NaCl(aq)$$

Molecular equation:

$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$

Complete ionic equation:

$Ca^{2+}(aq) + \cancel{2Cl^-(aq)} + \cancel{2Na^+(aq)} + CO_3^{2-}(aq) \rightarrow CaCO_3(s) + \cancel{2Na^+(aq)} + \cancel{2Cl^-(aq)}$

Net ionic equation:

$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

Spectator ions: Na^+ and Cl^-

$CaCO_3(s)$ is given as the solid, so it stays together. NaCl(aq) contains Na^+ (always soluble), so it splits into ions. Balance with a 2 in front of NaCl. Charge check: (+2) + (−2) = 0 on both sides.

2. Aqueous iron(III) chloride is mixed with aqueous sodium hydroxide. The products are solid iron(III) hydroxide, which appears as a reddish-brown precipitate, and aqueous sodium chloride.

Molecular equation:

$FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$

Complete ionic equation:

$Fe^{3+}(aq) + \cancel{3Cl^-(aq)} + \cancel{3Na^+(aq)} + 3OH^-(aq) \rightarrow Fe(OH)_3(s) + \cancel{3Na^+(aq)} + \cancel{3Cl^-(aq)}$

Net ionic equation:

$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

Spectator ions: Na^+ and Cl^-

Iron(III) is Fe^{3+}, so the formulas are $FeCl_3$ and $Fe(OH)_3$. $Fe(OH)_3(s)$ is given as the solid and stays together. The 3 in front of OH^- carries into the net ionic equation: (+3) + 3(−1) = 0.

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Part B. AP-Style Free Response

Show the balanced equation and include states of matter where asked. Answer each explanation in one to three sentences.

3. A student dissolves solid sodium phosphate, Na_3PO_4, in water. The student then mixes the solution with aqueous magnesium nitrate, $Mg(NO_3)_2$. A white precipitate of magnesium phosphate, $Mg_3(PO_4)_2(s)$, forms, and sodium nitrate remains in solution.

(a) Write a balanced equation for dissolving $Na_3PO_4(s)$ in water.

$$Na_3PO_4(s) \rightarrow 3Na^+(aq) + PO_4{}^{3-}(aq)$$

(b) Write the balanced net ionic equation for the formation of the precipitate.

$$3Mg^{2+}(aq) + 2PO_4{}^{3-}(aq) \rightarrow Mg_3(PO_4)_2(s)$$

Molecular: $3Mg(NO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(s) + 6NaNO_3(aq)$

(c) Identify the spectator ions.

Na^+ and $NO_3{}^-$

(d) Show that your equation in part (b) conserves charge.

Reactants: $3(+2) + 2(-3) = +6 - 6 = 0$. Product: $Mg_3(PO_4)_2$ is neutral, so 0. The total charge is 0 on both sides.

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4. When aqueous silver nitrate, $AgNO_3$, is mixed with aqueous potassium chromate, K_2CrO_4, a red-brown precipitate of silver chromate, $Ag_2CrO_4(s)$, forms. A student writes the following net ionic equation.

$$Ag^+(aq) + CrO_4{}^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

(a) Identify what is wrong with the student's equation. Justify your answer using conservation of atoms and charge.

It is not balanced. There is 1 Ag on the left but 2 Ag in Ag_2CrO_4. The charge on the left is $(+1) + (-2) = -1$, but the solid on the right has a charge of 0.

(b) Write the correct balanced net ionic equation.

$$2Ag^+(aq) + CrO_4{}^{2-}(aq) \rightarrow Ag_2CrO_4(s)$$

(c) Write the balanced molecular equation for the reaction.

$$2AgNO_3(aq) + K_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2KNO_3(aq)$$

(d) The student then mixes $K_2CrO_4(aq)$ with $NaNO_3(aq)$, and no change is observed. Use the AP solubility rule to explain why no net ionic equation can be written.

Any new combination, KNO_3 or Na_2CrO_4, contains K^+, Na^+, or $NO_3{}^-$, so it is always soluble. No solid forms, so every ion is a spectator. Nothing is left after canceling, so there is no reaction.

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