ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 4.2: Net Ionic Equations

Revision Notes · AP Chemistry

UNIT 4 · CHEMICAL REACTIONS

On ExamFitter.com: Topic 4.2 Quiz · Topic 4.2 Worksheet · Unit 4: All Topics · AP Chemistry Home

Three Levels of the Same Equation

Most reactions in this unit happen in water, between species that are already dissolved. One reaction can be written at three levels of detail, differing in how much of what is present they show.

The **molecular equation** writes every substance as a complete formula: $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$. It records what was mixed and what formed, but it hides the fact that the dissolved compounds exist as separated ions.

The **complete ionic equation** splits every soluble ionic compound into its ions: $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$. Only strong electrolytes marked (aq) split; AgCl is a solid, so it stays a formula.

The **net ionic equation** deletes the ions that appear unchanged on both sides: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$. What survives is the actual chemical change, the formation of the solid from two dissolved ions.

What Splits Into Ions and What Stays Whole

A strong electrolyte dissociates completely in water, so in a complete ionic equation it is written as its separate ions. Three groups qualify: soluble ionic salts such as NaCl and KNO_3, strong acids, and strong bases.

The strong acids to know are HCl, HBr, HI, HNO_3, H_2SO_4 and $HClO_4$; the strong bases are the Group 1 hydroxides, such as NaOH and KOH, together with $Ba(OH)_2$. Each exists entirely as ions.

A weak electrolyte ionizes only slightly, so it is written as an intact formula. Acetic acid stays $CH_3COOH(aq)$ and ammonia stays $NH_3(aq)$: most of their particles never become ions.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

A nonelectrolyte forms no ions at all. Glucose dissolves as whole $C_6H_{12}O_6$ molecules, never split.

Solids, pure liquids and gases keep their formulas, not being separated into ions: AgCl(s), $H_2O(l)$, $CO_2(g)$ and Zn(s) are all written whole. Water is always $H_2O(l)$, never H^+ and OH^-.

Polyatomic ions travel as single units. Sulfate stays SO_4^{2-} and nitrate stays NO_3^-; they are never broken into atoms of sulfur, nitrogen and oxygen.

Predicting Precipitates: Solubility Anchors in Action

When two solutions mix, the ions can pair up in new combinations. Whether anything happens depends on whether one new pairing is insoluble: if it is, those ions lock together and leave the solution as a precipitate.

The anchor rules from Topic 3.10 are applied, not re-derived. All nitrates are soluble, and all Group 1 and ammonium salts are soluble, so Na^+, K^+, NH_4^+ and NO_3^- almost always end up as spectators.

Chlorides are soluble except AgCl and $PbCl_2$. Sulfates are soluble except $BaSO_4$ and $PbSO_4$. Carbonates and sulfides are insoluble except those of Group 1 and NH_4^+, so $CaCO_3$ and CdS precipitate while Na_2CO_3 and $(NH_4)_2S$ dissolve.

If both possible products are soluble, every ion stays dissolved and no reaction occurs, and there is no net ionic equation to write.

Spectator Ions and the Route to the Net Equation

A spectator ion is an ion that appears identically on both sides of the complete ionic equation. It is dissolved before the reaction and dissolved after it, chemically untouched.

Four steps lead to the net ionic equation. First, write the balanced molecular equation with state symbols. Second, split only the strong electrolytes marked (aq), keeping everything else whole. Third, cancel every species appearing unchanged on both sides. Fourth, check what remains: atoms of every element must balance, and so must charge.

Charge balance is the check students skip: in $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ the left side sums to zero, +2 with -2, matching the neutral solid. A net equation whose charges do not match is wrong, however tidy it looks.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

One Net Equation Behind Many Reactions

Strong acid with strong base always reduces to the same net equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$. HCl with NaOH and HNO_3 with KOH have different spectators, but the change itself, hydrogen ions and hydroxide ions forming water, is identical.

If the acid is weak, it stays whole and appears in the net equation itself: $CH_3COOH(aq) + OH^-(aq) \rightarrow CH_3COO^-(aq) + H_2O(l)$. Splitting the acetic acid would invent ions that barely exist.

Acid with a dissolved carbonate gives $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$. The gas escapes, and its leaving drives the reaction to completion.

A reactive metal in acid gives $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$, with the acid's anion, such as Cl^-, as spectator. Zinc atoms hand electrons to the hydrogen ions, which is why the metal dissolves and hydrogen bubbles off; the bookkeeping of those electrons belongs to Topic 4.9.

These families share a pattern: a reaction in solution goes ahead when it removes ions from solution, by forming a precipitate, a gas, or water. If none of these forms, the ions simply stay mixed.

Worked Examples

Example 1: Barium chloride with sodium sulfate, at all three levels. Molecular: $BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$. Complete ionic: $Ba^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2Na^+(aq) + 2Cl^-(aq)$, six ion units on the left. The $2Na^+$ and $2Cl^-$ appear unchanged on the right, so four of the six units are spectators and cancel. Net ionic: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$, its left side summing to zero charge, +2 with -2.

Example 2: Lead(II) nitrate with potassium iodide. Molecular: $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$, the yellow precipitate. The complete ionic equation holds seven ions on the left: one Pb^{2+}, two NO_3^-, two K^+ and two I^-. Potassium and nitrate cancel, four spectator ions, leaving $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$. The charge check is +2 + 2(-1) = 0, and the iodine atoms balance only because of the coefficient 2 in front of I^-.

Example 3: A mixing that is not a reaction. Solutions of KNO_3 and NaCl are mixed. Swapping the partners would give KCl and $NaNO_3$, both soluble. Written out, the complete ionic equation has the same four ions, K^+, Na^+, NO_3^- and Cl^-, on both sides, so everything cancels: no precipitate, no gas, no water formed, no reaction.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Traps That Cost Marks in Topic 4.2

Splitting whatever is written (aq). Only strong electrolytes split. $CH_3COOH(aq)$ and $NH_3(aq)$ are aqueous but weak, so they stay whole; splitting them is the most common error in this topic.

Splitting a solid, liquid or gas. $AgCl(s)$, $CaCO_3(s)$, $H_2O(l)$ and $CO_2(g)$ never appear as ions, even alongside dissolved ions that do split.

Cancelling a species that changes form. In the acid and carbonate reaction, CO_3^{2-} on the left and CO_2 on the right are not the same species, so nothing about them cancels; the carbonate is consumed, not spectating.

Forgetting the charge check. $Pb^{2+} + I^- \rightarrow PbI_2$ fails twice: the iodine atoms do not balance, and the charges sum to +1 on the left against a neutral solid. Coefficients must fix both counts together.

Breaking up a polyatomic ion. Writing SO_4^{2-} as separate sulfur and oxygen particles invents species that do not exist. The whole ion moves, hydrates and precipitates as one unit.

Writing spectators as if they reacted. $Na^+(aq) + NO_3^-(aq) \rightarrow NaNO_3(aq)$ describes nothing happening. Ions that stay dissolved are deleted from the net equation, not paired up.

Assuming every mixture reacts. When all possible products are soluble, the correct conclusion is no reaction. An empty net ionic equation is an answer, not a failure.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Key Relationships to Remember

- Three levels, one reaction: the molecular equation shows formulas, the complete ionic equation shows every dissolved ion, and the net ionic equation shows only species that change
- Split only strong electrolytes in solution: soluble ionic salts, strong acids and strong bases; weak electrolytes, nonelectrolytes, solids, liquids and gases stay intact
- Polyatomic ions such as NO_3^-, SO_4^{2-} and CO_3^{2-} move and react as single units and are never split into atoms
- A spectator ion appears unchanged on both sides of the complete ionic equation and is cancelled; what remains must balance for atoms and for charge
- Solubility anchors decide precipitation: nitrates and Group 1 and ammonium salts stay dissolved; AgCl, $PbCl_2$, $BaSO_4$, $PbSO_4$, most carbonates and most sulfides precipitate
- The same net equation covers a whole family: $H^+ + OH^- \rightarrow H_2O$ for every strong acid and strong base pairing, and $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$ for acid with a dissolved carbonate
- Reactions in solution proceed when ions are removed as a precipitate, a gas, or water; if every product stays dissolved, no reaction occurs

Continue Revising

Topic 4.2 Quiz: Net Ionic Equations

Topic 4.2 Worksheet

Unit 4: All Topics

© 2026 ExamFitter.com · Free AP Chemistry revision notes