

Net ionic equations, titration and redox

AP Chemistry · Lesson

Quick answer: A net ionic equation shows only the species that change, leaving out spectator ions. Precipitation, acid-base and redox reactions can all be written this way. Titration uses a balanced equation and $n = cV$ to find unknown concentrations, and redox reactions are tracked by oxidation numbers, where oxidation is loss of electrons.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 4

How do you write a net ionic equation?

Definition

A **net ionic equation** shows only the species that actually change in a reaction in solution. **Spectator ions** are ions present on both sides, unchanged, and are left out.

Follow three steps. First write the balanced molecular equation with states. Then split every soluble ionic compound (aqueous) and every strong acid or base into ions, but keep solids, liquids, gases and weak electrolytes (such as CH_3COOH) whole. Finally cancel the spectators.

Ion	Compounds are...	Main exceptions
Group 1 ions, NH_4^+ , NO_3^- , CH_3COO^-	soluble	none
Cl^- , Br^- , I^-	soluble	Ag^+ , Pb^{2+} , Hg_2^{2+}
SO_4^{2-}	soluble	Ba^{2+} , Pb^{2+} , Sr^{2+} , Ca^{2+} (slightly)
CO_3^{2-} , PO_4^{3-} , S^{2-} , OH^-	insoluble	group 1, NH_4^+ (and $\text{Ba}(\text{OH})_2$)

Worked example 1

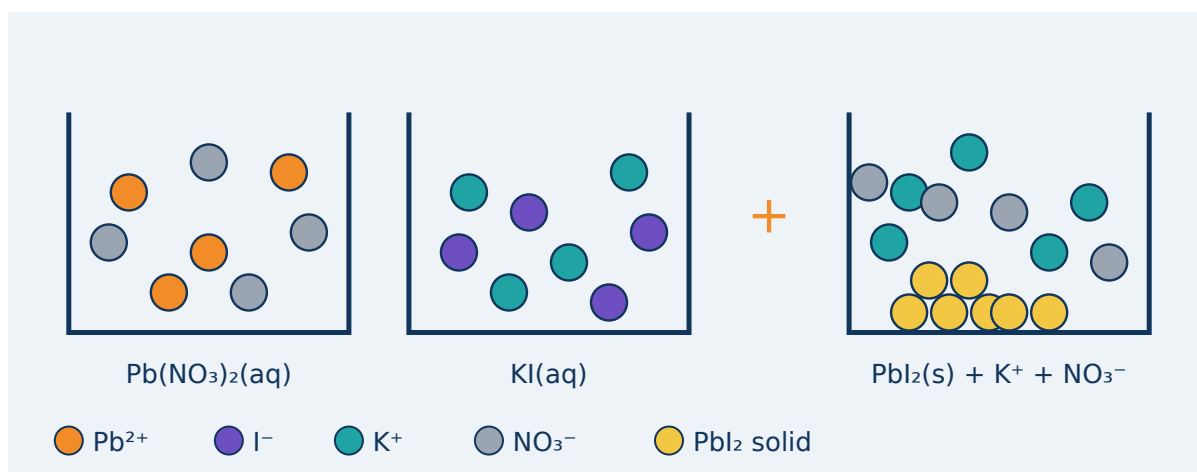
Lead nitrate and potassium iodide solutions are mixed. Write the net ionic equation.

Molecular: $\text{Pb}(\text{NO}_3)_2(\text{aq}) + 2\text{KI}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) + 2\text{KNO}_3(\text{aq})$

Ionic: $\text{Pb}^{2+} + 2\text{NO}_3^- + 2\text{K}^+ + 2\text{I}^- \rightarrow \text{PbI}_2(\text{s}) + 2\text{K}^+ + 2\text{NO}_3^-$

Cancel K^+ and NO_3^- :

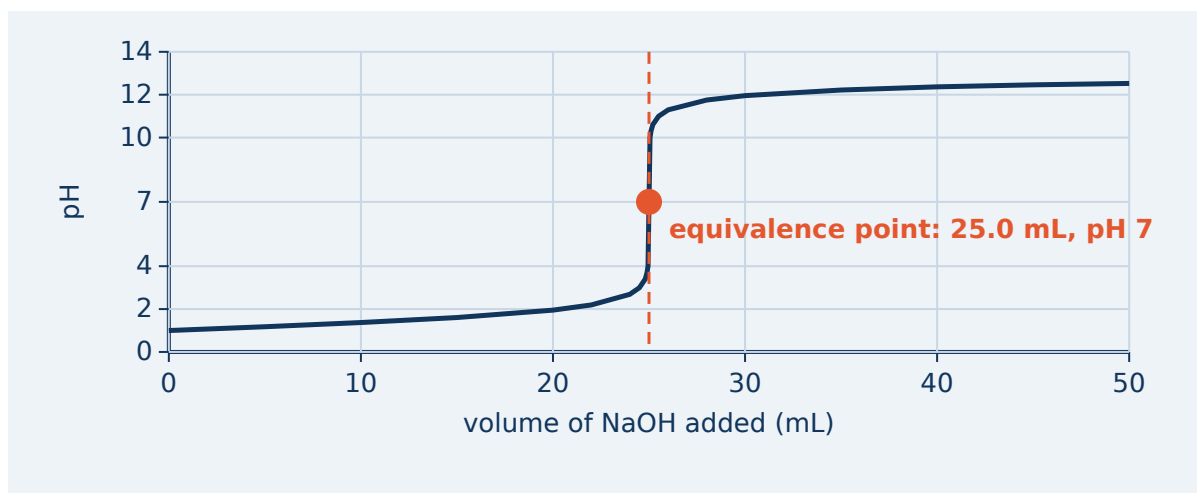
$\text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(\text{s})$



Mixing the two solutions: Pb^{2+} and I^- combine into solid PbI_2 ; K^+ and NO_3^- are spectator ions.

How does a titration find an unknown concentration?

In a **titration** a solution of known concentration (the titrant) is added from a burette to a measured volume of the unknown until the reaction is just complete, the **equivalence point**. An indicator that changes colour near the equivalence point marks the **end point**. For a strong acid and a strong base the equivalence point is at pH 7, and phenolphthalein or bromothymol blue both change colour within the steep part of the curve.



Strong acid with strong base: a sharp pH jump marks the equivalence point.

Formula

$n = c \times V$ (mol = mol/L $\times$ L); at equivalence $n(\text{titrant}) \times a = n(\text{analyte}) \times b$
 where a and b are the coefficients of analyte and titrant from the balanced equation.
 Convert mL to L (divide by 1000) or work in mmol.

Worked example 2

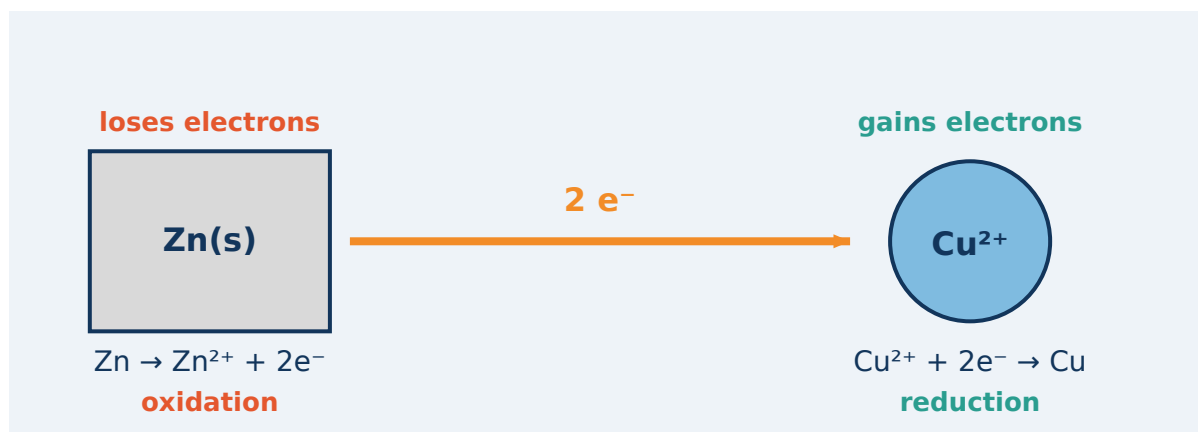
Kofi in Accra finds that 25.00 mL of hydrochloric acid needs 21.40 mL of 0.1000 M NaOH.
 $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. Find $c(\text{HCl})$.

$$n(\text{NaOH}) = 0.02140 \times 0.1000 = 2.140 \times 10^{-3} \text{ mol} = n(\text{HCl}) \quad (1 : 1)$$

$$c(\text{HCl}) = 2.140 \times 10^{-3} / 0.02500 = \mathbf{0.0856 \text{ mol/L}}$$

What are oxidation and reduction?

Oxidation is loss of electrons and a rise in oxidation number; **reduction** is gain of electrons and a fall in oxidation number. They always occur together as a redox reaction. The species that is oxidised is the **reducing agent**; the species that is reduced is the **oxidising agent**.



Zinc reduces Cu^{2+} by giving it two electrons; Zn is the reducing agent, Cu^{2+} the oxidising agent.

Rule for oxidation numbers	Examples
Atoms in an element are 0	Zn, O_2 , Cu are all 0
A monatomic ion equals its charge	Cu^{2+} is +2, Cl^- is -1
O is usually -2, H is usually +1	in H_2O : H +1, O -2
The sum equals the overall charge	Mn in MnO_4^- : $x + 4(-2) = -1$, so $x = +7$

Worked example 3

Identify what is oxidised in $\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu(s)}$.

Zn goes from 0 to +2 (loses 2e^-), so Zn is oxidised and is the reducing agent. Cu goes from +2 to 0, so **Cu^{2+} is reduced and is the oxidising agent.**

Common mistake

Do not split a precipitate, a gas or a weak acid into ions. For example, CH_3COOH stays as CH_3COOH in an ionic equation, while HCl is written as H^+ and Cl^- . Also check that the net ionic equation has balanced charge, not only balanced atoms.

Lina's tip

Remember OIL RIG: oxidation is loss, reduction is gain. For a titration, convert volume to moles first, then use the ratio in the balanced equation. The ratio is the bridge.

Key points to remember

- Split soluble ionic compounds and strong acids or bases into ions; keep solids, gases and weak electrolytes whole.
- Solubility: group 1, NH_4^+ , NO_3^- and CH_3COO^- salts are soluble; most CO_3^{2-} , PO_4^{3-} , S^{2-}

and OH^- salts are not.

- Titration: $n = cV$; use the mole ratio of the balanced equation at equivalence.
- Oxidation: loss of electrons, oxidation number rises; reduction: gain, number falls.
- Limiting reagent gives the theoretical yield; percent yield = $\text{actual/theoretical} \times 100$.

Net ionic equations, titration and redox: frequently asked questions

What is a spectator ion?

A spectator ion is present in the solution before and after a reaction and does not change. In the reaction of silver nitrate with sodium chloride, Na^+ and NO_3^- are spectators and only Ag^+ and Cl^- react.

Why do we use net ionic equations?

They show the real chemical change and the particles that react. Different salts can give the same net ionic equation, such as all neutralisations of strong acids with strong bases, which are written $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$.

What is the difference between the end point and the equivalence point?

The equivalence point is when exactly stoichiometric amounts have reacted. The end point is when the indicator changes colour. A good indicator is chosen so that the two are very close.

How do I find the oxidation number of an element in a compound?

Apply the rules in order: elements are 0, monatomic ions equal their charge, O is usually -2 and H is usually $+1$, and the sum of all numbers equals the overall charge of the species.

Why is a rough titration done first?

The rough titration shows the approximate volume at the end point. In the careful titrations you add the titrant quickly to just before that volume and then drop by drop, giving results that agree within 0.10 mL.