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Topic 4.3: Representations of Reactions

Revision Notes · AP Chemistry

UNIT 4 · CHEMICAL REACTIONS

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Three Representations of the Same Reaction

One reaction can be represented at three levels, and exam questions move between them. The macroscopic level is what is observed in the lab: a solid forming, a colour fading, bubbles rising.

The symbolic level is the balanced chemical equation. Its coefficients state the mole ratio of reactants and products, and its state symbols record the phases. It cannot depict molecular-level arrangements: where particles are, how they are grouped, or what they touch.

The particulate level draws the particles themselves. A diagram shows which species are present before and after, how atoms are grouped into molecules or ions, and what is left over. Its counts are a scaled sample: they carry ratios, never amounts in moles.

Each level shows information the others hide, so a complete answer often needs more than one.

The Atom Count Never Changes

Compare any before-and-after pair of boxes atom by atom. The total of each element is identical on the two sides; if it is not, the diagram is wrong, however neat it looks.

What changes is the connections. Bonds in the reactants break, atoms regroup, and new substances form: H_2 and O_2 molecules go in, H_2O molecules come out. Same atoms, new arrangements, new properties: that regrouping is what makes the change chemical.

Charge is conserved in the same way. A box that starts with dissolved ions carrying a total charge must end with the same total charge, split between product ions, leftover ions and any neutral solid.

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If the after box holds exactly the same particles, in the same groupings, merely mixed, then no reaction has taken place. Mixing without regrouping is a physical change.

Drawing What Is Actually in the Beaker

A dissolved ionic compound is drawn as separated ions spread among the water molecules. Joined Na^+ and Cl^- pairs describe the solid lattice, not the solution.

A dissolved covalent compound is drawn as intact molecules dispersed among the water. Sugar molecules move apart as they dissolve, but the bonds inside each molecule do not break and no ions appear.

A strong acid is drawn fully split: only H^+ and the anion appear, with no intact acid molecules anywhere. A weak acid is drawn the opposite way round: mostly intact molecules, with just a few H^+ and anions among them.

A precipitate is drawn as a cluster: its ions locked together in a regular lattice, out of the solution. Drawing the solid product as ions spread evenly through the liquid contradicts its being a solid.

Spectator ions can be drawn two ways. Kept in the picture, still separated after the reaction, they give the diagram form of the complete ionic equation. Deleted, they leave the picture form of the net ionic equation, showing only the species that change. Both are correct; they answer different questions.

From Coefficients to Particle Counts

The coefficient ratio in the equation is the particle ratio in every correct diagram. For $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$, the smallest faithful drawing uses 2 Al atoms and 3 Cu^{2+} ions before, and 2 Al^{3+} ions and 3 Cu atoms after; any whole-number multiple of those counts represents the same reaction.

Charge makes the same point: the 3 Cu^{2+} ions carry +6 in total before, and the 2 Al^{3+} ions carry +6 after. The aluminium atoms decrease as copper atoms form; nothing simply swaps places.

In a neutralisation diagram the change is H^+ and OH^- particles merging into H_2O molecules, while Na^+ and Cl^- sit unchanged on both sides. For $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ the key feature is reciprocal: zinc atoms become ions as copper ions become atoms, one for one.

Diagrams can also annotate electrons moving from one particle to another, which is the clearest picture of a redox change. The oxidation-number bookkeeping behind that picture belongs to Topic 4.9.

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Leftovers: Reading the Limiting Reactant From a Diagram

Run a diagram in rounds. Each round consumes reactant particles in the coefficient ratio and forms product particles in the same ratio. Continue until one reactant is used up: that reactant is the limiting reactant, and it alone sets how much product the picture can show.

Particles of the other reactant that remain are drawn unchanged in the after box: they are the excess reactant, left because its partner ran out, not product and not an error.

Full calculations with masses, moles and limiting reactants belong to Topic 4.5. The skill here is counting: what is used, what is made, and what is left.

Worked Examples

Example 1: Hydrogen burning, with oxygen left over. The equation is $2H_2 + O_2 \rightarrow 2H_2O$. A before box holds 4 H_2 molecules and 3 O_2 molecules. In the 2 to 1 ratio, the 4 H_2 consume exactly 2 O_2 and form 4 H_2O, so H_2 is limiting. The after box holds 4 H_2O molecules and 1 unchanged O_2 molecule. Check: hydrogen 8 atoms on both sides; oxygen 6 before, and 4 in the water plus 2 in the leftover O_2 after.

Example 2: A precipitate, with and without spectators. Solutions are mixed so the combined box holds 3 Ag^+, 3 Cl^-, 3 Na^+ and 3 NO_3^- ions, all separated. After the reaction, the 3 Ag^+ and 3 Cl^- are locked together as a cluster of 3 AgCl units, while the 3 Na^+ and 3 NO_3^- remain separated: that is the complete ionic picture of $Ag^+ + Cl^- \rightarrow AgCl$. Delete the unchanged Na^+ and NO_3^- and the same event is drawn as 3 Ag^+ and 3 Cl^- becoming the cluster alone.

Example 3: Zinc in excess over copper ions. A box holds 3 Zn atoms as a solid block and 2 Cu^{2+} ions in solution, with 2 SO_4^{2-} ions spectating. The ratio in $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ is 1 to 1, so only 2 Zn atoms can react. The after box holds 1 Zn atom still in the block, 2 Zn^{2+} ions in solution, 2 Cu atoms deposited, and the 2 SO_4^{2-} untouched. Charge check: the solution carries +4 from the Cu^{2+} before and +4 from the Zn^{2+} after.

Traps That Cost Marks in Topic 4.3

Drawing dissolved salt as joined pairs. A soluble ionic compound exists in solution as separated ions. Pairs and clusters belong to the solid.

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Splitting a molecular solute. Sugar and glucose dissolve as intact molecules. A diagram showing their atoms or ions separately describes a reaction that never happened.

Strong and weak acids drawn the same way. A strong acid shows no intact molecules; a weak acid shows mostly intact molecules with a few ions. Swapping the two pictures reverses the chemistry.

Drawing the precipitate spread out. A solid product is a bonded cluster in one place. Ions drawn evenly through the liquid are still dissolved ions.

Quietly changing the atom count. Adding an atom to finish a molecule, or dropping a leftover particle, breaks conservation. Every atom in the before box must be findable in the after box.

Assuming every particle reacts. When one reactant is in excess, its leftover particles stay in the after box unchanged. Counting them as product overstates what formed.

Treating spectators as part of the change. Spectator ions are present on both sides because they do nothing. A diagram may keep them or omit them, but they never join the product cluster.

Key Relationships to Remember

- Three representations, one reaction: macroscopic observations, the symbolic equation and the particulate diagram each show information the others hide
- Coefficients in the balanced equation fix the particle ratio in every correct diagram, at any scale
- Atoms of each element, and total charge, are identical in the before and after boxes; only the connections between atoms change
- New groupings of the same atoms mean new substances; identical particles before and after mixing means no reaction occurred
- Dissolved ionic compounds are drawn as separated ions, dissolved molecular compounds as intact molecules, and a precipitate as a clustered lattice
- Strong electrolytes are drawn fully split; weak electrolytes mostly intact with a few ions
- Keeping spectator ions gives the diagram form of the complete ionic equation; omitting them gives the diagram form of the net ionic equation
- The limiting reactant is the one used up first; leftover particles are drawn unchanged, and the product count follows the limiting reactant

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