Chemical reactions described w/ chemical equation

Reactants (starting material) $\xrightarrow{\text{Magic}}$ Products (what you end up with)

$$a A_{(x)} + b B_{(x)} \longrightarrow c C_{(x)} + d D_{(x)}$$

A, B, C, D are chemical formulas

a, b, c, d are stoichiometric coefficients – tells us how much – in moles

(x) tells state/phase

could be solid, liquid, gas, aqueous = dissolved in water

↓ s ↓ ℓ ↓ g ↓ aq

* all atoms that we start with have to accounted for at the end
* all chemical equations must be balanced

$H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(\ell)}$ Is it balanced? NO

L	R
2H	2H
2O	1O

* Balance by changing stoichiometric coefficients
* DO NOT change chemical formulas

$H_{2(g)} + O_{2(g)} \longrightarrow \underline{2} H_2O_{(\ell)}$

L	R
2H	4H
2O	2O

$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$ — Balanced

L	R
4H	4H
2O	2O

* Always balance equations before use

$C_2H_6O(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell)$

equiv to $2C_2H_6O(\ell) + 6O_2(g) \rightarrow 4CO_2(g) + 6H_2O(\ell)$

equiv to $\frac{1}{2}C_2H_6O(\ell) + \frac{3}{2}O_2(g) \rightarrow 2CO_2(g) + \frac{3}{2}H_2O(\ell)$

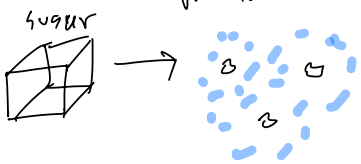
L	R
2C, 6H, 3O	1C, 2H, 3O
2C, 6H, 3O	2C, 2H, 5O
2C, 6H, 3O	2C, 6H, 7O
2C, 6H, 7O	2C, 6H, 7O

Aqueous chemistry (stuff dissolved in water)

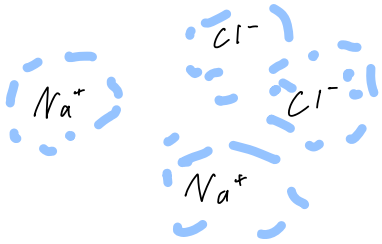
solute – substance dissolved in the solvent

solvent – what solute is dissolved in

Molecular compound (sugar) dissolved in water – molecules of sugar dispersed in water



Ionic compound (NaCl) dissolved in water – dissociates into ions



each ion is "solvated" by a bunch of water molecules

Some ionic compound are soluble, some are insoluble

$NaNO_3$ dissolves to give $Na^+_{(aq)}$ and $NO_3^-{}_{(aq)}$

↑ does not break up further

$C_6H_{12}O_{6(s)} \rightarrow C_6H_{12}O_{6(aq)}$

$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$Ca(NO_3)_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2NO_3^-{}_{(aq)}$

solubility of ionic compounds is based on composition

Ions that lead to soluble compounds

$Na^+, K^+, NH_4^+, NO_3^-, Cl^-, Br^-, I^-$

SO_4^{2-}, F^- (sometimes)

Ions that lead to insoluble

$CO_3^{2-}, PO_4^{3-}, S^{2-}, O^{2-}$

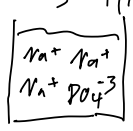
$CrO_4^-, C_2O_4^{2-}, OH^-$

Na^+, K^+, NH_4^+ with will be soluble

Precipitation reaction - start with 2 separate solutions of soluble ionic compounds
- Mix and form insoluble compound that precipitates

$CoCl_{2(aq)}$

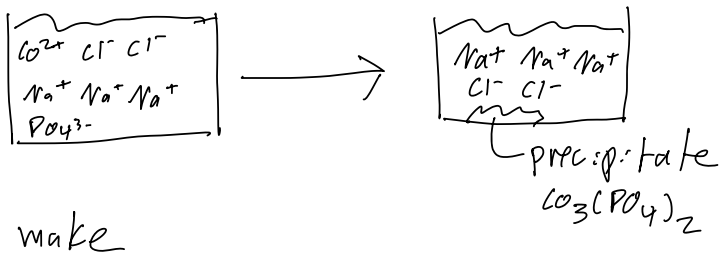
$Na_3PO_{4(aq)}$



$CoCl_{2(s)} \rightarrow Co^{2+}_{(aq)} + 2Cl^-_{(aq)}$

$Na_3PO_{4(s)} \rightarrow 3Na^+_{(aq)} + PO_4^{3-}_{(aq)}$

combine the 2 solutions



We could make

$CoCl_2$ – soluble
$NaCl$ – soluble
Na_3PO_4 – soluble
$Co_3(PO_4)_2$ – must be precipitate

Na^+, Cl^- are spectator ions

$$3\,Co^{2+}_{(aq)} + \cancel{2}^{6}\,Cl^-_{(aq)} + \cancel{3}^{6}\,Na^+_{(aq)} + 2\,PO_4^{3-}_{(aq)} \rightarrow Co_3(PO_4)_{2(s)} + 6\,Na^+_{(aq)} + 6\,Cl^-_{(aq)}$$

* Co^{2+} and Cl^- always have to be 1:2

* Na^+ and PO_4^{-3} always have to be 3:1

$$3\,Co^{2+}_{(aq)} + 6\,Cl^-_{(aq)} + 6\,Na^+_{(aq)} + 2\,PO_4^{3-}_{(aq)} \rightarrow Co_3(PO_4)_{2(s)} + 6\,Cl^-_{(aq)} + 6\,Na^+_{(aq)}$$

overall or total ionic equation

$$3\,Co^{2+}_{(aq)} + 2\,PO_4^{3-}_{(aq)} \rightarrow Co_3(PO_4)_{2(s)}$$ – net ionic eq. w/out spectator ions

Acid/Base reactions

Acids give away H^+ ions

Bases take H^+ ions

Acids + Bases react w/ water

$HCl_{(g)}$ – pure form of hydrogen chloride

Hydrochloric acid is what you get when $HCl_{(g)}$ mixes + reacts w/ water to make $HCl_{(aq)}$

$$HCl_{(aq)} + H_2O_{(\ell)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

↑ hydronium

HCl is a strong acid → all $HCl_{(aq)}$ reacts w/ water to make $H_3O^+_{(aq)}$

Acetic acid (CH_3COOH) is a weak acid
– only a small fraction will react w/ water to make H_3O^+

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

↑ acetate ion

indicates an equilibrium process – not all reactants turn into prod as opposed to a reaction that goes to completion →

Bases take H^+

$$NH_{3(aq)} + H_2O_{(\ell)} \rightarrow NH_4^+_{(aq)} + OH^-_{(aq)}$$

↑ ammonia

↑ ammonium

↑ hydroxide

Strong bases are often ionic compounds w/ OH^-

$NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Water can act as acid or base

HCO_3^- can also act as acid or base

$HCO_3^-{}_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_3O^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

Acid Base

$HCO_3^-{}_{(aq)} + H_2O_{(\ell)} \rightleftharpoons H_2CO_3{}_{(aq)} + OH^-_{(aq)}$

Base Acid

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oxidation / reduction reactions involve transfer of electrons

losing e^- gaining e^-

must always have ox and red together to conserve e^-

$Cu_{(s)} + Ag^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + Ag_{(s)}$

Ag^+ got e^- Red

Cu lost e^- ox

- Not balanced b/c of charge
- Need to balance for charge

$Cu_{(s)} + 2Ag^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$

Cu is being oxidized to Cu^{2+} (each losing $2e^-$)

Ag^+ is being reduced to Ag (each gaining $1e^-$)

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$ — This involves ox/red but we can't tell!

Keep track of "oxidation numbers" to figure out if we have ox/red

ON rules

ON of pure elements = 0
ON of monoatomic ions = charge
ON of I, Br, Cl, F in compounds = −1 almost always
ON of O in compounds = −2 almost always
ON of H in compounds = +1 almost always
Sum of ON in compound = 0
Sum of ON in polyatomic ion = charge

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$

−4 ; +1×4 ; 0 ; +4 ; −2×2 ; 2×+1 ; −2

C went from −4 → +4 – oxidation – loss of e^-
H went from +1 → +1
O went from 0 → −2 – reduction – gain of e^-

$2Fe(s) + \overset{0}{O_2} \rightarrow Fe_2O_3$

0 ; 0 ; +3×2 ; −2×3