Chemical reactions are described using chemical equations

Reactants $\xrightarrow{\text{magic}}$ Products

(starting material) (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 how much in units of moles

(x) tells state of matter

solid = s

liquid = l

gas = g

aq = aqueous (dissolved in water)

* All atoms in reactants must also be in products
* All chemical equations must be balanced

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

L	R
2 H	2 H
2 O	1 O – Uh oh – not balanced

To balance – adjust stoichiometric coefficients ONLY

Never change chemical formula

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

L	R
2 H	4 H – Crap
2 O	2 O

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

L	R
4 H	4 H ✓ Balanced
2 O	2 O

* Always balance equations before use

$C_2H_6O_{(e)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(e)}$

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

↕ same

$2C_2H_6O_{(e)} + 6O_{2(g)} \rightarrow 4CO_{2(g)} + 6H_2O_{(e)}$

↕ same

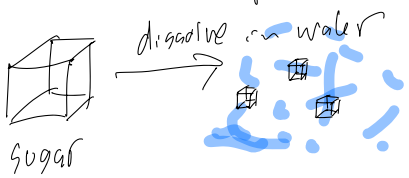
$\frac{1}{2}C_2H_6O_{(e)} + \frac{3}{2}O_{2(g)} \rightarrow CO_{2(g)} + \frac{3}{2}H_2O_{(e)}$

Aqueous chemistry (stuff dissolved in water)

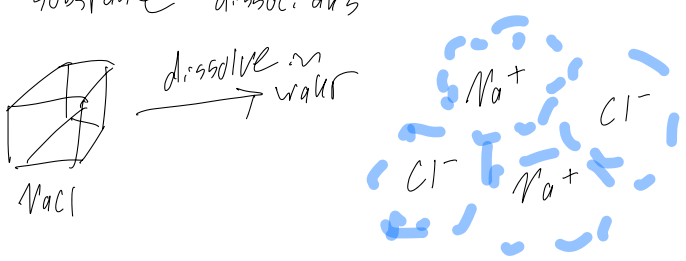
solute – is the substance dissolved in the solvent

solvent – is what the solute is dissolved in

Molecular substance like sugar dissolved in water yields sugar molecules dissolved in water



Ionic substance dissolved in water yields aqueous <u>ions</u> because the ionic substance dissociates



each ion is solvated by a bunch of water molecules

soluble compounds will dissolve

insoluble compounds will not dissolve

For ionic compounds there are guidelines that help predict solubility

Ions that lead to soluble ionic compounds → Na^+, K^+, NH_4^+, NO_3^-, Cl^-, Br^-, I^-

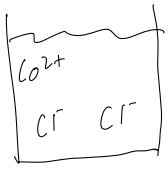
SO_4^{-2}, F^- (sometimes)

Ions that lead to insoluble ionic compounds → CO_3^{-2}, PO_4^{-3}, S^{-2}, O^{-2}
CrO_4^{-}, $C_2O_4^{-2}$, OH^-

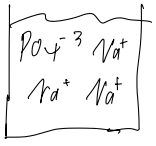
* But if cation is Na^+, K^+, NH_4^+ compound will be soluble

Precipitation reactions – start with 2 separate solutions – each containing soluble ionic compound dissolved in water
– combine solutions to form an insoluble ionic compound that "precipitates"

$CoCl_2(aq)$



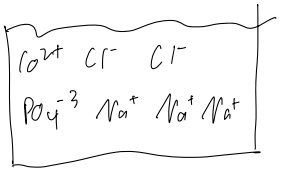
$Na_3PO_4(aq)$



$CoCl_2(s) \rightarrow Co^{2+}_{(aq)} + 2Cl^-_{(aq)}$

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

↓ combine



→ insoluble ionic compound will form and precipitate

We could make
$CoCl_2$ – soluble
$NaCl$ – soluble
Na_3PO_4 – soluble
$Co_3(PO_4)_2$ – must be the precipitate

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

* $Co^{2+} : Cl^-$ must always be 1:2
* $PO_4^{-3} : Na^+$ must always be 1:3

$3CoCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Co_3(PO_4)_2 + 6NaCl_{(aq)}$

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

overall/total ionic equation

Cl^-, Na^+ are spectator ions in this equation

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

$Co_3(PO_4)_2 + 6\,NaCl_{(aq)}$

Net ionic equation — w/out spectator ions

Acids/Base

Acids give away H^+ ions

Bases take H^+ ions

Acids and bases are dissolved in and react with water

HCl is a gas in its pure form

"Hydrochloric acid" results from dissolving HCl(g) in water and then having it react with water

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

↑ will give H^+ to water

this is the corrosive thing

↑ "hydronium"

HCl is a strong acid → all $HCl_{(aq)}$ will react w/ H_2O to make $H_3O^+_{(aq)}$

CH_3COOH (acetic acid) is a weak acid

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

Most $CH_3COOH_{(aq)}$ does not react

↑ acetate

"equilibrium" only some of reactants become products and most remain as reactants

Strong acids

HCl HNO_3

H_2SO_4

$H_2SO_{4(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$

Weak base – react with water, takes H^+ from water

$$NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

NH_3: weak base

OH^-: hydroxide – melts face

strong bases usually are ionic compounds w/ OH^- anion

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

$$SB + H_2O \rightarrow SB\,H^+ + OH^-(aq)$$

Acid / Base

$$HSO_4^-(aq) + H_2O \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$$

Base / Acid

$$HSO_4^-(aq) + H_2O \rightleftharpoons H_2SO_4(aq) + OH^-(aq)$$

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oxidation / reduction reactions involve electron transfer

oxidation: loss of e^- ; reduction: gain of e^-

ox + red always come as a team – conservation of electrons

$$Cu(s) + Ag^+(aq) \rightarrow Ag(s) + Cu^{2+}(aq)$$ ← not balanced for charge

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

Cu gives up $2e^-$ to become Cu^{2+}

Ag^+ gained e^- to become $Ag(s)$

Cu oxidized to Cu^{2+}

Ag^+ reduced to Ag

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$$ – ox/red happening here also – How do we tell??

Use oxidation numbers to figure out if ox/red reactions are happening

ON rules

ON of pure elements = 0

ON of monoatomic ions = charge

When I, Br, Cl, F are in compounds ON = -1 almost always

When O in compounds ON = -2 almost always

When H in compounds ON = +1 almost always

Sum of ON in compound = 0

Sum of ON in polyatomic ion = charge

Determine ON of all atoms

Are there any changes in ON going from reactants → products

$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$

(4 × +1) = +4, 0, (2 × -2) = -4, 2 × +1 = +2, -2

C was oxidized $-4 \rightarrow +4$

O was reduced $0 \rightarrow -2$

H was neither $+1 \rightarrow +1$