A few examples of precipitation and acid/base:

* Transition metals DO NOT change their charge in exchange reactions!

$$CaCl_2(aq) + 2\,Ag^{*}NO_3(aq) \longrightarrow 2\,AgCl(s) + Ca(NO_3)_2(aq)\ \checkmark$$

Ca^{2+} Cl^- Ag^+ NO_3^-

this reaction is driven by the precipitation of INSOLUBLE (solid) AgCl!

$$H_3PO_4(aq) + 3\,NaOH(aq) \longrightarrow 3\,H_2O(l) + Na_3PO_4(aq)\ \checkmark$$

H^+ PO_4^{3-} Na^+ OH^-

This reaction is driven by the formation of WATER MOLECULES!

$$KCl(aq) + NaNO_3(aq) \longrightarrow \sout{KNO_3(aq) + NaCl(aq)}$$ NO REACTION

K^+ Cl^- Na^+ NO_3^-

We do not form either an insoluble ionic compound or a molecule like water. There is no driving force here, therefore NO REACTION.

$$Ca(NO_3)_2(aq) + Na_2CO_3(aq) \longrightarrow 2\,NaNO_3(aq) + CaCO_3(s)$$

Ca^{2+} NO_3^- Na^+ CO_3^{2-}

This reaction is driven by the precipitation of INSOLUBLE calcium carbonate!

OXIDATION / REDUCTION CHEMISTRY

- Precipitation reactions involve ions pairing up, but the ions themseves are not formed in precipitation reactions. Precipitation reactions (and quite a few others) start with pre-existing ions.

... but ions have to be produced somehow - through a chemistry that involves the transfer of electrons.

- OXIDATION/REDUCTION chemistry ("REDOX" chemistry) involves transfer of electrons and can make ions.

$$2Al(s) + 3Br_2(l) \rightarrow 2AlBr_3(s)$$

Elemental, metallic aluminum. Uncharged! Al^{0}

Aluminum cation Al^{3+}

These are called "half-reactions"

$$Al \rightarrow Al^{3+} + 3e^-$$

electron

oxidation: loss of electrons

$$Br_2 + 2e^- \rightarrow 2Br^-$$

reduction: gain of electrons

- oxidation and reduction always occur together. In other words, we can't just make free electrons using oxidation without giving them somewhere to go.

- Many of the types of reactions that you might have heard of before are actually redox reactions!

- SINGLE REPLACEMENT reactions

$$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$$

$$Cu \rightarrow Cu^{2+} + 2e^-$$ oxidation

$$2Ag^+ + 2e^- \rightarrow 2Ag(s)$$ reduction

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

- COMBUSTION reactions (burning)

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

$$2Mg(s) \rightarrow 2Mg^{2+} + 4e^-$$ oxidation

$$O_2(g) + 4e^- \rightarrow 2O^{2-}$$ reduction

REDOX LANGUAGE

"oxidizer"

- "Oxidation" is loss of electrons, but an OXIDIZING AGENT is something that causes ANOTHER substance to lose electrons. An oxidizing agent is itself reduced during a redox reaction.

- "Reduction" is gain of electrons, but a REDUCING AGENT is something that causes ANOTHER substace to gain electrons. Reducing agents are themselves oxidized during a redox reaction.

$$2\overset{0}{Al}(s) + 3\overset{0}{Br_2}(l) \rightarrow 2\overset{+3}{Al}\overset{-1}{Br_3}(s)$$

Aluminum is OXIDIZED during this process. We say that metallic aluminum is a REDUCING AGENT!

Bromine is REDUCED during this process. We say that bromine is an OXIDIZING AGENT!

* Strong oxidizers (oxidizing agents) can cause spontaneous fires if placed into contact with combustibles (safety issue!).

* Reactive metals tend to be REDUCING AGENTS, while oxygen-rich ions like NITRATES tend to be OXIDIZING AGENTS. HALOGENS (Group VIIA) also tend to be OXIDIZING AGENTS

CHEMICAL CALCULATIONS - RELATING MASS AND ATOMS

$$\_\ Na_2CO_3 + \underline{2}\,HCl \rightarrow \_\ H_2O + \_\ CO_2 + \underline{2}\,NaCl$$

Chemical equations are written and balanced in terms of ATOMS and MOLECULES

- While chemical equations are written in terms of ATOMS and MOLECULES, that's NOT how we often measure substances in lab!

- measurements are usually MASS (and sometimes VOLUME), NOT number of atoms or molecules!

CHEMICAL CALCULATIONS CONTINUED: REACTIONS

- Chemical reactions proceed on an ATOMIC basis, NOT a mass basis!

- To calculate with chemical reactions (i.e. use chemical equations), we need everything in terms of ATOMS ... which means MOLES of atoms

$$2\,Al(s) + 3\,Br_2(l) \longrightarrow 2\,AlBr_3(s)$$

coefficients are in terms of atoms and molecules!

2 atoms Al = 3 molecules Br_2 = 2 formula units $AlBr_3$

2 mol Al = 3 mol Br_2 = 2 mol $AlBr_3$

- To do chemical calculations, we need to:
  - Relate the amount of substance we know (mass or volume) to a number of moles
  - Relate the moles of one substance to the moles of another using the equation
  - Convert the moles of the new substance to mass or volume as desired

$$2Al(s) + 3Br_2(l) \longrightarrow 2AlBr_3(s)$$

* Given that we have 25.0 g of liquid bromine, how many grams of aluminum would we need to react away all of the bromine?

(1) Convert grams of bromine to moles: Need formula weight Br_2: $2 \times 79.90 = 159.80$

$159.80\ g\ Br_2 = mol\ Br_2$

$$25.0\ g\ Br_2 \times \frac{mol\ Br_2}{159.80\ g\ Br_2} = 0.15645\ mol\ Br_2$$

(2) Use the chemical equation to relate moles of bromine to moles of aluminum

$2\ mol\ Al = 3\ mol\ Br_2$

$$0.15645\ mol\ Br_2 \times \frac{2\ mol\ Al}{3\ mol\ Br_2} = 0.10430\ mol\ Al$$

(3) Convert moles aluminum to mass: Need formula weight Al: 26.98

$26.98\ g\ Al = mol\ Al$

$$0.10430\ mol\ Al \times \frac{26.98\ g\ Al}{mol\ Al} = \boxed{2.81\ g\ Al}$$

You can combine all three steps on one line if you like!

(1) $154.80\ g\ Br_2 = mol\ Br_2$ (2) $2\ mol\ Al = 3\ mol\ Br_2$ (3) $26.98\ g\ Al = mol\ Al$

$$25.0\ g\ Br_2 \times \frac{mol\ Br_2}{154.80\ g\ Br_2} \times \frac{2\ mol\ Al}{3\ mol\ Br_2} \times \frac{26.98\ g\ Al}{mol\ Al} = 2.81\ g\ Al$$

(1) (2) (3)

Things we can do:

If we have ...	... and we need ...	Use ...
MASS	MOLES	FORMULA WEIGHT
SOLUTION VOLUME	MOLES	MOLAR CONCETRATION (MOLARITY)
MOLES OF A	MOLES OF B	BALANCED CHEMICAL EQUATION

Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 grams of sodium carbonate to moles. Use FORMUAL WEIGHT.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00 M).

① Na_2CO_3: Na - 2 x 22.99
C - 1 x 12.01
O - 3 x 16.00

$105.99\,g\ Na_2CO_3 = mol\ Na_2CO_3$

$$25.0\,g\ Na_2CO_3 \times \frac{mol\ Na_2CO_3}{105.99\,g\ Na_2CO_3} = 0.2358713086\ mol\ Na_2CO_3$$

② $2\ mol\ HCl = mol\ Na_2CO_3$

$$0.2358713086\ mol\ Na_2CO_3 \times \frac{2\ mol\ HCl}{mol\ Na_2CO_3} = 0.4717426172\ mol\ HCl$$

113 Example:

How many milliliters of 6.00M hydrochloric acid is needed to completely react with 25.0 g of sodium carbonate?

$$2HCl(aq) + Na_2CO_3(s) \longrightarrow H_2O(l) + CO_2(g) + 2NaCl(aq)$$

1 - Convert 25.0 grams of sodium carbonate to moles. Use FORMUAL WEIGHT.
2 - Convert moles sodium carbonate to moles HCl. Use CHEMICAL EQUATION.
3 - Convert moles HCl to volume HCl solution. Use MOLARITY (6.00 M).

(3) 6.00 mol HCl = L

$$0.4717426172 \text{ mol HCl} \times \frac{L}{6.00 \text{ mol HCl}} = 0.07862376953 L \text{ HCl solution}$$

We have the volume (0.0786 L), but we need to convert to mL to fully finish the problem.

$mL = 10^{-3} L$

$$0.07862376953 L \times \frac{mL}{10^{-3} L} = \boxed{78.6 \text{ mL of } 6.00 M \text{ HCl}}$$

42.081 g/mol 53.064 g/mol

$$4\,C_3H_6 + 6\,NO \longrightarrow 4\,C_3H_3N + 6\,H_2O + N_2$$

propylene acrylonitrile

Calculate how many grams of acrylonitrile could be obtained from 651 g of propylene, assuming there is excess NO present.

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1 - Convert 651 grams of propylene to moles. Use FORMULA WEIGHT.
2 - Convert moles propylene to moles acrylonitrile. Use CHEMICAL EQUATION.
3 - Convert moles acrylonitrile to grams acrylonitrile. Use FORMULA WEIGHT.

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(1) $42.081\,g\ C_3H_6 = mol\ C_3H_6$ (2) $4\,mol\ C_3H_6 = 4\,mol\ C_3H_3N$

(3) $53.064\,g\ C_3H_3N = mol\ C_3H_3N$

$$651\,g\ C_3H_6 \times \underbrace{\frac{mol\ C_3H_6}{42.081\,g\ C_3H_6}}_{(1)} \times \underbrace{\frac{4\,mol\ C_3H_3N}{4\,mol\ C_3H_6}}_{(2)} \times \underbrace{\frac{53.064\,g\ C_3H_3N}{mol\ C_3H_3N}}_{(3)} = \boxed{821\,g\ C_3H_3N}$$