Balancing Equations

We all know that matter cannot be created or detroyed by chemical reaction, or at least that is what the book tells us. This is true...in a way.

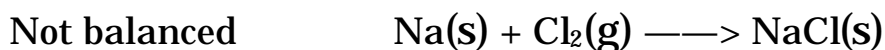Almost everyone has seen the expression

$$E = mc^2$$

it even appears in several Warner Brothers cartoons. Everyone likes to ignore this relationship but what it means is that the amount of matter and energy of the reactants has to equal the amount of matter and energy of the products.

In chemical reactions the amount of mass gained or lost due to energy conversions is so small that we do not worry about it. The problem is just making sure our chemical equation is not creating matter from nothing.

The good news is that it is simple to balance an equation. If 12 carbons go into the reaction then 12 carbons MUST come out of the reaction. It is that simple.

The bad news is that balancing equations is rarely simple, and it is all trial and error. There is no formula to use to balance every equation.
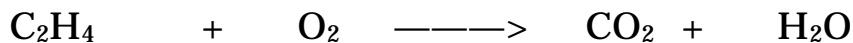
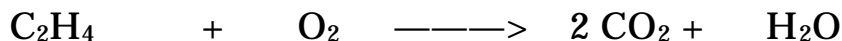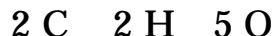So, you just start going. Balance the following:

Not balanced

$$Na(s) + Cl_2(g) \longrightarrow NaCl(s)$$

1 Na 2 Cl's   1 Na, 1Cl

Balanced

$$2\ Na_{(s)} + Cl_{2(g)} \longrightarrow 2\ NaCl_{(s)}$$

2 Na's, 2 Cl's   2 Na's, 2 Cl's

$$C_2H_4 \quad + \quad O_2 \quad \longrightarrow \quad CO_2 + \quad H_2O$$

For a combustion reaction sometimes it is easiest to start with the carbons

2 C   4 H   2 O   C   2 H   3 O

$$C_2H_4 \quad + \quad O_2 \quad \longrightarrow \quad 2\ CO_2 + \quad H_2O$$

$$2\,C \quad 4\,H \quad 2\,O \qquad\qquad 2\,C \quad 2\,H \quad 5\,O$$

still not balanced
balance the H's

$$C_2H_4 \quad + \quad O_2 \quad \xrightarrow{\hspace{1cm}} \quad 2\,CO_2 + \ 2\,H_2O$$

$$2\,C \quad 4\,H \quad 2\,O \qquad\qquad 2\,C \quad 4\,H \quad 6\,O$$
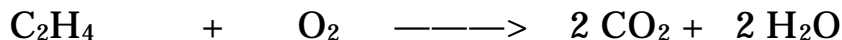
Now use the O_2 to balance the number of O's...

$$C_2H_4 \ + \ 3\,O_2 \quad \xrightarrow{\hspace{1cm}} \quad 2\,CO_2 \ + \ 2\,H_2O$$
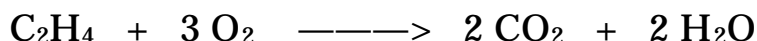
A hint to balance double displacement reactions

$$Ba(NO_3)_2 + \ Fe_2(SO_4)_3 \xrightarrow{\hspace{1.5cm}} BaSO_4 + \ Fe(NO_3)_3$$
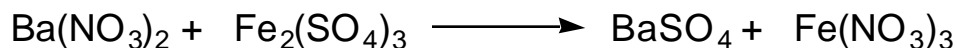
treat polyatomic ions as whole entities.

There is no need to count the number of nitrogens, sulfurs and oxygens on each side; simply count the number of *nitrates* and *sulfates*.

$$Ba(NO_3)_2 + \ Fe_2(SO_4)_3 \xrightarrow{\hspace{1.5cm}} BaSO_4 + \ Fe(NO_3)_3$$
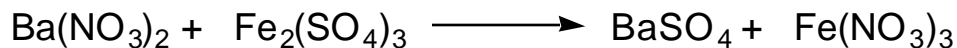
1 Ba, 2 nitrates, 2 Fe's, and 3 sulfates   1 Ba, 3 nitrates, 1 Fe, and 1 sulfate

need 2 Fe on product side so multiply $Fe(NO_3)_2$ by 2

$$Ba(NO_3)_2 + \ Fe_2(SO_4)_3 \xrightarrow{\hspace{1.5cm}} BaSO_4 + 2\,Fe(NO_3)_3$$
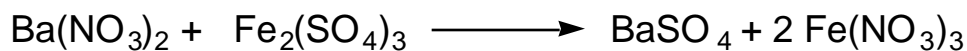
1 Ba, 2 nitrates, 2 Fe's, and 3 sulfates   1 Ba, 6 nitrates, 2 Fe, and 1 sulfate

nitrates do not balance so multiply $Ba(NO_3)_2$ by 3

$$3\,Ba(NO_3)_2 + \ Fe_2(SO_4)_3 \xrightarrow{\hspace{1.5cm}} BaSO_4 + 2\,Fe(NO_3)_3$$
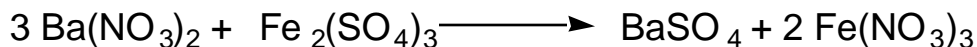
3 Ba's, 6 nitrates, 2 Fe's, and 3 sulfates   1 Ba, 6 nitrates, 2 Fe's, and 1 sulfate

now Ba does not balance multiply $BaSO_4$ by 3

$$3\,Ba(NO_3)_2 + Fe_2(SO_4)_3 \xrightarrow{\hspace{1.5cm}} 3\,BaSO_4 + 2\,Fe(NO_3)_3$$
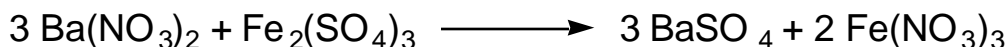
3 Ba's, 6 nitrates, 2 Fe's, and 3 sulfates   3 Ba's, 6 nitrates, 2 Fe's, and 3 sulfates

Stoichiometry

The difference between a recipe and a balanced equation is that a recipe tells you how much flour you need in terms of someting you can measure.

3.25 cups of flour, 2.125 cups of water, 1.25 tsp salt.

Chemical equations relate numbers of atoms or moles.

2 moles of Na, 1 mole of Cl_2

So, for equations to be useful they have to be related to a quatity we can measure like grams.

$$2 Na + Cl_2 ---> 2 NaCl$$
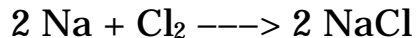
Typically the question starts with "How many grams of Na are needed to completely consume 3.49 g of Cl_2.

The only way an amount of Na can be related to Cl is through the balanced equation!

The balanced equation relates moles of Na to moles of Cl_2.

So, to relate Na to Cl_2

Cl_2 must be converted from g to moles using molar mass.

3.49 g Cl_2 x $\underline{\text{1 mol } Cl_2}$ = 0.04922 mol Cl_2
            70.906 g Cl_2

1 mol Cl_2 = 2 x 1 mol Cl = 2 x 35.453 g = 70.906 g

Moles of Cl_2 can be converted to
moles of Na using the balanced equation.

0.04922 mol Cl$_2$ x $\underline{\text{2 mol Na}}$ = 0.09844 mol Na
1 mol Cl$_2$

Moles of Na can be converted to grams of Na
using the molar mass.

0.09844 mol Na x $\underline{\text{22.990 g Na}}$ = 2.26 g Na
1 mol Na

1 mol Na = 22.990 g Na

Now you know that you need to add 2.26 g Na to 3.49 g Cl$_2$ to get this recipe to work; however, I would not advise doing this!

The problem could also be solved in one step:

3.49 g Cl$_2$ ~~g Cl$_2$~~ x $\underline{\text{1 mol Cl}}$~~mol Cl~~$_2$ x $\underline{\text{2 mol N}}$~~mol N~~a x $\underline{\text{22.99 g Na}}$ = 2.26 g Na
70.906 g Cl~~g Cl~~$_2$ 1 mol Cl~~mol Cl~~$_2$ 1 mol N ~~mol N~~a