

Chemical Reactions

<http://video.google.com/videoplay?docid=-2134266654801392897&q=chemistry+sodium>

Themes for this subject:

1. If a system, molecule, or ionic compound is not stable, how will it change to become more stable?
2. The answer to question #1 is quite dependent on the specific environmental surroundings of the system, molecule, *etc.*.
3. We will not be able to reach completely satisfying answers to all of your questions on this subject, but try to master the basic patterns. *Be patient!*
Look at an example: Rxn. of Cu^{2+} with Al:

Write an equation describing the rxn.: _____ + _____ \rightarrow _____ + _____

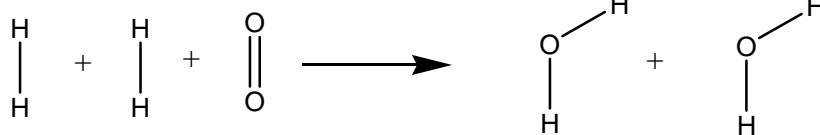
I. What is chemical change & how do we describe it?

A. This is simple if we are looking at covalent compounds: Any change involving forming or breaking covalent bonds is a chemical change.

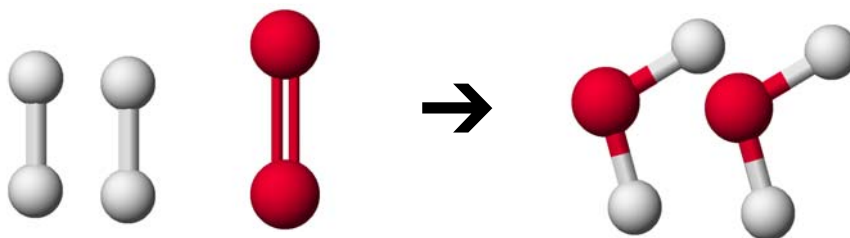
1. Example: Rxn. of hydrogen and oxygen to form water:

chemical equation: $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$

structurally expanded:



ball & cylinder



The old single bonds between the H atoms and the double bonds between the O atoms are broken and new single bonds between the H and O atoms are formed.

2. Would evaporation of water, $\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(g)$, be a chemical change?
Y or N

If no, what type of change is this? _____

3. Would precipitation of glucose in tea, $\text{C}_6\text{H}_{12}\text{O}_6(aq) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(s)$
be a chemical change? Y or N

If no, what type of change is this? _____

B. The picture is a little more complex when we look at ionic compounds

1. Is NaCl dissolving in water, $\text{NaCl}(s) \rightarrow \text{NaCl}(aq)$ a chemical change?
Y or N. *Yes.* Ionic bonds in the salt ($\text{NaCl}(s)$) are broken when the salt dissolves. New interactions form between Na^+ and Cl^- ions & H_2O when the aqueous solution ((aq)) forms.

2. Is NaCl melting, $\text{NaCl}(s) \rightarrow \text{NaCl}(l)$ a chemical change? Y or N
Basically, *No.* Though a given (l) Na^+ may interact w/ a different set of Cl^- ions than it was in the (s) state, it is still interacting with Cl^- ions. (*A phase change is a physical change.*)

3. Is reaction of ionic copper II ($\text{Cu}^{2+}(aq)$) with elemental aluminum ($\text{Al}(s)$) a chemical change? Y or N

Expand your thoughts? _____

Aside: Balancing equations

1. A balanced equation has the same number of atoms of each element on the product side as on the reactant side. Charge must also be conserved.

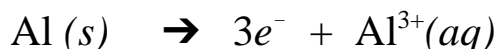
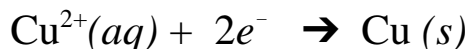
2. You must establish the molecular/ionic formulas of the products first, then balance. (This assumes you know the formulas of reactants.)

3. There are a number of ways to balance equations. Some people like to start with the element present in largest amount in one of the compounds. However, this is not always the most efficient way.

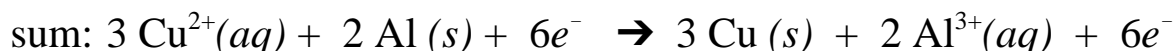
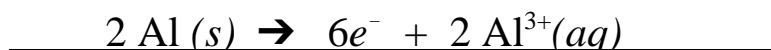
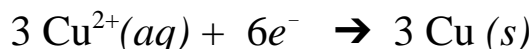
Net unbalanced ionic equation: $\text{Cu}^{2+}(\text{aq}) + \text{Al}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Al}^{3+}(\text{aq})$

How do you know that reaction is not balanced? _____

What is the best way to balance it? Half-reactions are one way:



You need to have the same number of e^{-} on each side, so multiply the copper equation by 3 and the aluminum equation by 2:



You can now cancel out the e^{-} because there is an equal number of e^{-} on each side. This gives a balanced net ionic equation of:



4. Finally, the issue of full balanced equations vs. net ionic balanced equations (the relates to lab for this week).

a) If the salt of copper (II) above was the chloride salt, you could also write this in *full balanced equation* form as:



b) Realize that the Cl^{-} ions are just sitting around in the solution “doing nothing.” They do not change at all during the reaction. Ions that behave this way are sometimes called “*spectator ions*.”

c) I recommend concern w/ the issue raised in b) above only after you get a good grip on the net ionic equation approach.

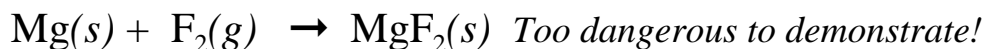
II. Is it easier to understand rxns if we classify them?

Yes!!! There are millions of chemical rxns. If don't put them into categories, there is no way we can keep track of them.

A. General chemistry categories:

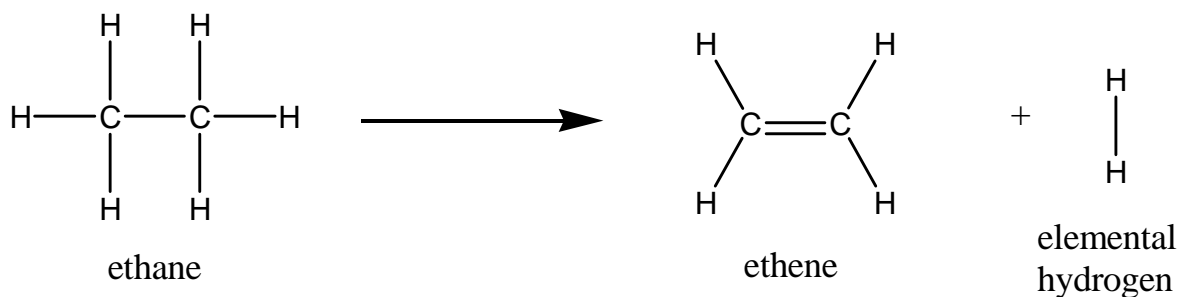
1. **Combination** rxns.: $A + B \rightarrow AB$

This is two separate species coming together to form one compound:



2. **Decomposition** rxns.: $AB \rightarrow A + B$

One thing falling apart (decomposing) to give you two things. Dehydrogenation (removal of H from) ethane is an example:



3.

Replacement rxns (This view is not my favorite!)

Single replacement rxns.: $A + BC \rightarrow B + AC$

Find rxn above that fits pattern: A = _____ B = _____ C = _____

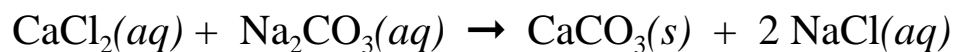
Which component is the spectator ion? _____

The *net ionic equation* is another way to write this. More detail???

Double replacement rxns.: $AB + CD \rightarrow AD + BC$

This applies to ionic precipitation rxns. written as *full balanced equations*.

a) Let's look at the rxn. of $\text{CaCl}_2(aq)$ with $\text{Na}_2\text{CO}_3(aq)$:

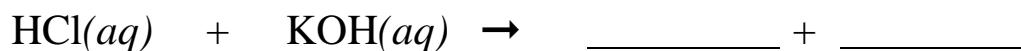


What 2 ions don't change during the rxn.? _____ & _____

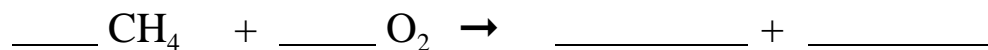
To answer this you must be able to picture *(aq)* in your mind.

Can you write a net ionic equation for the above rxn?

b) Acid-base neutralization rxns.: (*Key: See the H^+ and OH^- !!!*)



4. **Combustion** (Special category)



a) What are the products?

b) Then balance.

c) Does your car/motorcycle/private jet run any rxns like this?

d) Is this rxn important in modern industrial societies?

T. Boone Pickens?

e) Does your body run any rxns like this?

B. Further comments on oxidation-reduction reactions (*Combustion rxns?*)

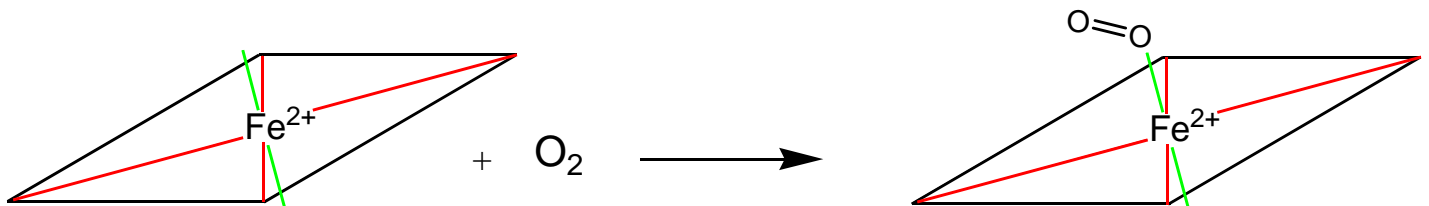
1. By definition:

- a) Oxidation occurs when an atom, ion, or molecule:
 - i) loses e^-
 - ii) loses H atom equivalents
 - iii) gains oxygen
- b) Reduction occurs when an atom, ion, or molecule:
 - i) gains e^-
 - ii) gains H atom equivalents
 - iii) loses oxygen

2. If you can keep track of e^- , H atom equivalents, & O, it's easier to understand bunches of chemistry (batteries, corrosion, hemoglobin function, and energy metabolism, *etc.*).

3. The oxidation state of a compound often alters its function. Ex:
hemoglobin (Hb) binds O_2 efficiently when its heme Fe is Fe^{2+} :

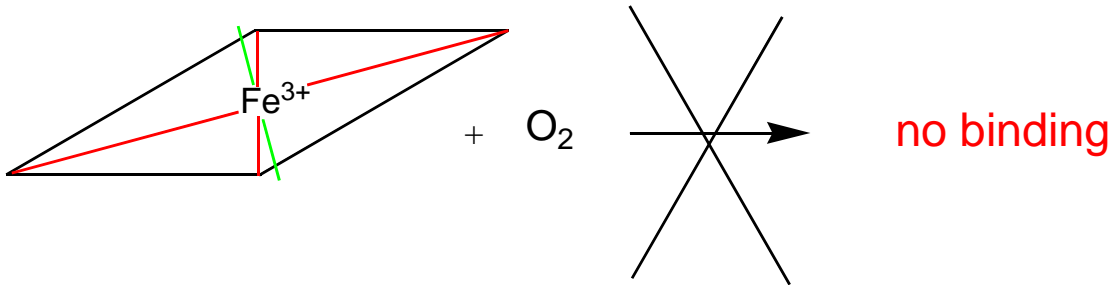
Oxygen binding to heme Fe in normal (Fe^{2+}) Hb



Because we living in an oxidizing environment (Are we aerobes?) heme Fe is oxidized (rate?) from +2 to +3. Resulting Hb is ***methemoglobin (metHb)***. It doesn't carry O_2 .



Oxygen does not bind to heme Fe in Fe^{3+} (met-Hb)



In normal Hb the oxidation rate is quite slow. (metHb < 1%)

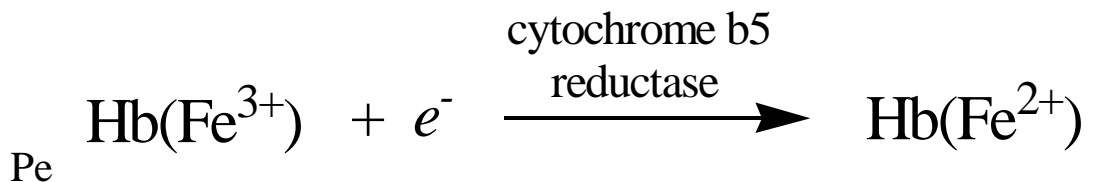
There is more than one way for a patient to have problems with the rate of Fe^{2+} oxidation of their Hb(Fe).

<http://www.nlm.nih.gov/medlineplus/ency/article/000562.htm>

- a) One way: mutation in the beta (β) chain of Hb that makes the heme Fe more readily oxidized. (Hb has 2 α & 2 β chains.) This condition is Type I methemoglobinemia. See:

<http://ghr.nlm.nih.gov/condition=methemoglobinemiabetaglobintype>

- b) We live in an oxidizing environment. We need O_2 ; we also need to repair the damage it does to us. Even if you don't have Type I methemoglobinemia, your Hb(Fe) is still occasionally oxidized to the Fe^{3+} when it releases oxygen. You have an enzyme (cytochrome b5 reductase) to convert the Hb back to the Fe^{2+} state, so you are relatively healthy:



People lacking functional cytochrome b5 reductase have Type II methemoglobinemia. See:

<http://emedicine.medscape.com/article/204178-overview>

- c) There are yet other types of methemoglobinemia, but they are even more rare, and we won't consider them.

III. Why do chemical changes occur? ($G\Delta$)

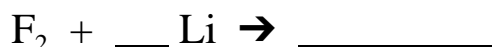
A. We have two goals as we try to answer this question. We want to be able to make predictions about:

1. is a compound likely to change in a given environment, and
2. if it is going to change, what products are most likely to form.

B. A good initial way to try to make a prediction about a specific reaction is to look at patterns with structurally related chemicals. Example: Similar reactivity of halogens.

1. Cl_2 gas reacts vigorously with Na metal: $\text{Cl}_2 + 2 \text{Na} \rightarrow 2 \text{NaCl}$

2. Can you make a prediction regarding what would happen if you mixed F_2 gas and Li metal?



Thanks, Mendeleev!!!

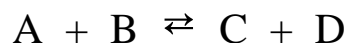
C. As you understand more, you can often make accurate predictions about reactions that are quite different than the ones you have previously studied. We will not be able to reach this level in CHM 109.

D. Energy concerns: $\Delta G = \Delta H - T\Delta S$

1. We have been considering change as though it is an all or nothing process. It is both more accurate & useful to look at it quantitatively. Not, "Will there ...?", but "How much ...?"

Should we try some atomic accounting? re. Equilibrium.

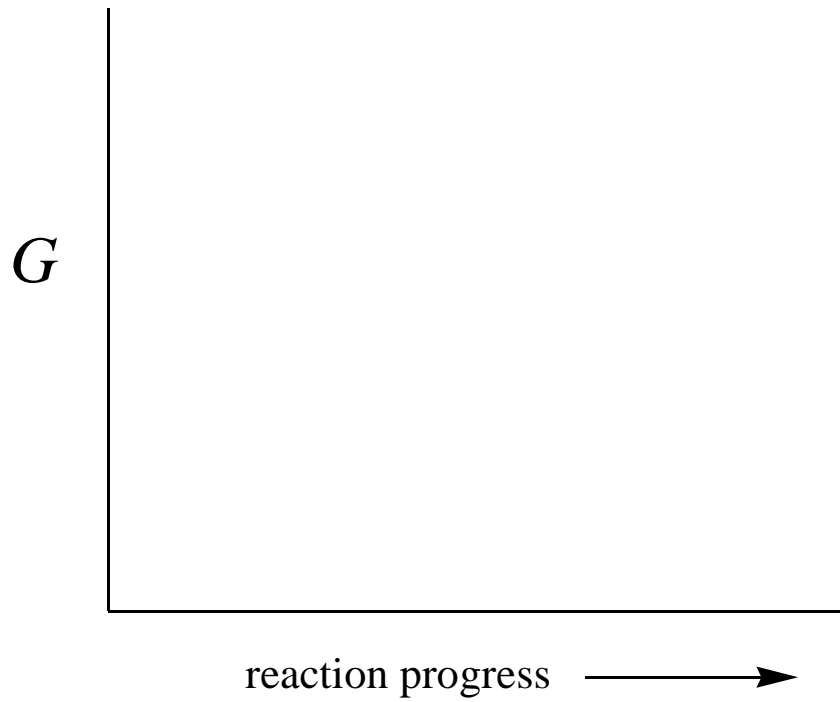
2. Related to this, to this point we have been considering all reactions to proceed only in the forward direction. Actually, at least mathematically all are at least partially reversible. That is, the forward & reverse rxns both usually proceed at the same time:



3. The ΔG in the Gibbs' Free Energy Equation is mathematically related to "How much change will there be?"

4. Most students find that *reaction coordinate diagrams* improve their understanding of these issues. Let's look at some reaction coordinate diagrams for different values of ΔG :

- a) The relative heights of products and reactant on the G axis tells us whether the reactants will mostly change to form products or mostly stay as reactants. (Does water naturally flow uphill or downhill?)
- b) The height of the hill connecting the reactant and product plateaus is related to the inherent speed (rate constant) of the rxn. (Does it take longer to walk from the 2nd floor of the smith Building to the 4th floor or to walk from the base to the top of Mt. Mitchell?)



IV. Chemical Rxn. items we 'll consider in the future

- A. Stoichiometry
- B. Kinetics
- C. Equilibrium
- D. Acid-base rxns.