“Atoms, Colors, and Changes in Our Chemical World!”
a General Chemistry Experience

By Joseph Topczewski
8/4/16 – v1.2

Session Goals:

1. Provide a demonstration of fundamental concepts and principles in chemistry
2. Provide a connection between macroscopic matter and atomic theory
3. Provide a connection between chemical concepts and everyday experiences

Activities

Activity #1 – Dry ice in water – color change and pH indicator

Desired Learning outcomes:

1. Visitors will be engaged by the bubbling flask
2. Visitors will recognize one sign of a chemical reaction (color change)
3. Visitors will be exposed to the concept of ocean acidification

Materials:

1. Large Erlenmeyer flask (2.5L or 5L optimal) or other sizable glass vessel (punch pitcher)
2. Purified water (enough to half fill flask)
3. Foam insulating container for dry ice transport and storage
4. Several pounds of dry ice crushed into small to medium chunks (**CAUTION:** dry ice is a cryogenic material and can cause severe freezer burns. It should only be handled with proper protective gloves and tongs)
5. Insulated gloves
6. Screwdriver or other instrument to break up dry ice
7. Small amount of Bromothymol Blue as pH indicator (CAS# 76-59-5)
8. Large volume (2 L) of a concentrated solution (3 M) of NaOH in water (**CAUTION:** concentrated base is caustic and can cause severe chemical burns. This solution should be handled only by Market Science “staff”. In case of exposure rinse thoroughly with running water.)
9. Other large display materials to be eye catching (models, microscopes, etc.)

Lesson:

Note: This is intended to be an eye catching display to lure participants to the booth. It is recommended that it be clearly visible in the center of the booth.

Set up: Fill the flask half full of water and add a ***very*** small amount of bromophenol blue. (Note: a small amount of indicator goes a long way and if the color is too faint more can be added after set up is complete). Add several small pieces of dry ice and the solution should begin to "smoke" and bubble as well as turn yellow as it acidifies.

Activity: As participants approach the booth they should see the bubbling beaker and may ask "what is that?" or "what is going on here?" These are great lead in questions to introduce Market Science and the chemistry booth. If the participants are interested, the Market Science staff can talk for a second about chemistry and chemical reactions. Then they can add some NaOH to the yellow colored beaker – this should basify the solution for a few seconds and lead to a color change from yellow to blue and then back to yellow as more CO_2 dissolves. A brief comment on color change being a sign of a chemical reaction and pH can be followed with an invitation to participate in the other Market Science activities. Furthermore, a comment can be made on ocean acidification and how CO_2 causes the color change (see below).

Activity #2 – Visible signs of a chemical reaction

Desired Learning outcomes:

1. Visitors will recognize signs of a chemical reaction (precipitation and gas evolution)
2. Visitors will recognize that reactions can alter the state of matter (solution to solid to gas)
3. Visitors will draw a connection between the provided chemical reactions and observations

Materials:

1. Large volume (2 L) of $CaCl_2$ in water (0.5 M)
2. Large volume (2 L) of Na_2CO_3 in water (0.5 M)
3. Large volume (2 L) of citric acid in water (1 M)
4. Clear plastic cups (1-4 oz styrene medicine cup – Note: better to get **clear** cups without ridges or frosted look – graduated is OK)
5. Plastic eye droppers (purchased in stockroom)
6. Handout describing the reactions, ocean acidification & $CaCO_3$ in biology
7. Packing tape to hold down handout signs

Lesson:

Note: Completion of the lesson will take about 3-5 min. This activity is best for people who have already engaged one of the other activities and are committed to finish.

Step 1: Participants are asked if they "want to do some chemistry this morning?" If so, they are invited to take a dropper full of $CaCl_2$ solution (colorless) and add it to the cup/vial. They then are asked to make a guess as to what will happen when they add Na_2CO_3 solution (colorless) to the cup/vial? Both are colorless clear solutions in water so – "nothing" will be a common answer or perhaps they will expect a color change. This is an opportunity to describe what a chemical reaction may look like – solids form, things dissolve, colors change, gases form etc. Then participants can mix the two solutions to observe the following precipitation reaction (1):

(1) $Na_2CO_3\,(aq) + CaCl_2\,(aq) \rightarrow NaCl\,(aq) + CaCO_3\,(s)$

If the solutions are concentrated enough, a gelatinous white goo of $CaCO_3$ will form almost instantly (less concentrated solutions will form a white solid or hazy suspension). Participants can then be directed to the handout showing the equation (1) and can discuss for a few seconds what the connection is between a chemical formula and their observations. Participants can then exit the lesson or participate in step 2.

Step 2: Participants can continue with a second chemical step. They will be invited to add a dropper full of citric acid solution (colorless) to the cup/vial containing the results from Step 1. Before they add the solution, they should be asked for a guess as to what will happen. Based on the results from step 1, more solid forming may be a common guess or some may think the process will reverse and a clear solution will form. Then participants can slowly mix the solution to observe the following gas evolution reaction (2):

(2) $CaCO_3$ (s) + citric acid (aq) → CO_2 (g) + H_2O (l) + CaCitrate (aq)

The mixing of an acid with the carbonate will cause the evolution of gas upon stirring and the resulting solution will be clear if enough citric acid is used. Participants can then be directed to the handout showing the equation (2) and can discuss for a few seconds what the connection is between a chemical formula and their observations. Participants can then be instructed to look at handouts on ocean acidification and coral/sea life that uses carbonate in shells and structures. Participants are then invited to engage in one of the other activities or to visit the Market Science booth next week.

Activity #3 – Ideal Gases… air is made of molecules!

Desired Learning outcomes:

1. Visitors will recognize that air is made of atoms or molecules
2. Visitors will recognize that gases follow set properties

Materials:

1. Party balloons (enough for each participant plus extra ~250-300)
2. Foam insulating container for LN2 and balloon to be stored in.
3. Several liters of liquid nitrogen (**CAUTION:** liquid nitrogen is a cryogenic material and can cause severe freezer burns. It should only be handled with proper protective gloves and should avoid all contact with skin.) (**CAUTION:** transporting or storing liquid nitrogen in an enclosed space can cause asphyxiation due to oxygen depletion. Liquid nitrogen should always be moved in a compartment separate from the driver or passengers.)
4. Long metal tongs

Lesson:

Step 1: Ask participants to blow up a balloon (Not too full – just small to medium). While they are doing this, ask them what they are adding into the balloon. “Air” or “Breath” will be common answers which should be followed with the question what is air made of? This would give an opportunity to say that air is made mostly of nitrogen (~78%) and oxygen (~21%) with smaller contributions from water, argon, and CO_2. Before the balloon is tied off, we should ask participants to relate what happened when they breathe more air into the balloon with what happens when air is let out of the balloon. This may seem obvious – but it is actually Avogodro's law $V_1/n_1 = V_2/n_2$ (V is volume and n is moles gas). Would this same observation hold true with other gases?

We can then ask participants if they think all gases behave the same. If they have the balloon ready we can then ask what will happen if we squeeze the balloon a little (not too much or it will pop). Will it get larger or smaller? This then can be related to Boyle's law $P_1V_1=P_2V_2$ and that the math is not complex it just says that if you squeeze harder the balloon gets smaller (and they probably won't be because they cannot act on the balloon in a uniform manner so the balloon will likely just squeeze into odd shapes). If participants are not impressed, we can ask what they think will happen to the balloon once dunked into liquid nitrogen?

Step 2: Charles's law. We can ask to borrow the participant's balloon and ask what will happen when dunked in liquid notrogen. Then submerge the balloon in LN2 using tongs. The balloon should shrink. We can then ask what happened and what they think will happen next. This can lead to a discussion of Charles's law $V_1/T_1=V_2/T_2$ which means that gases shrink when they get cold. While this discussion is going on, the balloon should begin to warm up to temp and expand back to its original size. We can then ask what other objects might do? As we know and can explain by demonstration (dunk a veggie from the market or a penny or something into the liquid nitrogen), only gases have this property to shrink so much when cold! The participant can then be invited to keep their balloon (after it warms up and all of the LN2 is gone).

Activity #4 – Cleaning with (weak) Acids

Desired Learning outcomes:

1. Participants have fun with redox chemistry
2. Participants recognize the use for chemistry in daily life
3. Participants learn principles of experimentation

Materials:

1. Several hundred old crusty pennies (1 or 2 per participant)
2. Table salt
3. Citric acid (homebrew store or amazon sells this)
4. Several gallons of clean water (to rinse pennies)
5. Several small shallow bins or dishes (to clean pennies in)
6. Baking soda and dish soap

Lesson:

Set up: mix the salt and citric acid to be 2:1 salt : citric acid as a solid (Salt is just used to cut the amount of citric acid needed and to increase ionic strength of water). Add enough water to make a concentrated solution/paste. Add a little bit of the solution to each of the penny cleaning dishes. (or add the solid to the dishes followed by water). Note: each mixture should be able to clear many pennies but may need occasional refreshing.

Step 1: Ask participants if they would like to clean a penny with chemistry? If so, they can be challenged to find the scuzziest grossest penny in the pile and then attempt to clean it. While they are picking their penny, we can explain how chemistry can be used in all kinds of things. They then can dunk the penny into the solution of citric acid and use their finger to swish it around. The penny should brighten in a few seconds. They then can rinse the penny in clean water which should also clean their fingers (citric acid is relatively benign but we should still rinse it off).

Step 2: Participants can then keep the penny and move onto another activity – or they can try to experiment with another penny? If they experiment, they should be asked to try the same thing in clean water? Or in soapy water? In citric acid solution that is diluted way down (over 1:10 dilution)? Or in a solution that is mixed with baking soda (neutralized)? This should give the participants a taste for experimentation and illustrate that some things only work under certain conditions (concentration and pH). Participants who try and fail to clean the penny under one or more other conditions can clean the penny back in the original conditions and show reproducibility as well as keep a second penny.

NOTE: cross contamination is a problem. When kids want to move the penny from bin to bin to bin, they tend to move citric acid with them. This then contaminates the other bins and the plain water then can clean the penny (no so impressive when just water does it). Be on the lookout for cross contamination and change the solution if it becomes an issue.

Activity #5 – Slime!

Desired Learning outcomes:

1. Who needs to learn anything? Let's make SLIME!

Materials:

1. Diluted Elmer's glue (polyvinyl acetate glue)
2. Green food coloring (added to glue to make slime appeal – could use other colors too)
3. Several larger plastic cups for mixing color
4. Borax (sodium borate) solution
5. Cups for mixing (could be same as used in Activity #2 on reactions)
6. Plastic eye droppers
7. Bags to take the slime home in…so it does not get stuck in the car seat…

Setup:

Mix food coloring into the glue before use. If there are enough large cups, one cup for each color can be prepared

Lesson:

Step 1: Ask people if they want to make slime (parental approval might be a good idea). If so, invite the participant to add some diluted glue into a cup and then add some borax. Then ask them to stir. The solutions should go lumpy in a few seconds to make a slime. They then get to take the slime home. The reaction is a cross linking between the glue (polyvinyl acetate) and borate after partial hydrolysis to polyvinyl alcohol.

Optional Handouts

Spectroscope instructions and Pattern:
https://pantherfile.uwm.edu/awschwab/www/specweb.htm
https://www.store.acs.org/eweb/ACSTemplatePage.aspx?site=ACS_Store&WebCode=storeItemDetail&parentKey=a62366d1-8877-42e8-a3f8-e423f874fdaf
https://www.store.acs.org/eweb/ACSTemplatePage.aspx?site=ACS_Store&WebCode=storeItemDetail&parentKey=422219b9-5492-49c9-9351-09d3c7e45612

Add a test for if foods are acidic or basic for next year…

Trivia Questions

1) What are some visible signs of a chemical reaction?
    a. Color change, gas evolution, precipitation, (heat evolution or cooling don't count – these can happen without chemistry sadly…)

2) The movement of _____________ is responsible for all chemical reactions.
    a. Electrons

3) We (animals) are made mostly of what four elements?
    a. Carbon, hydrogen, oxygen, and nitrogen

4) What two elements are liquids at room temperature in elemental form?
    a. Mercury and bromine

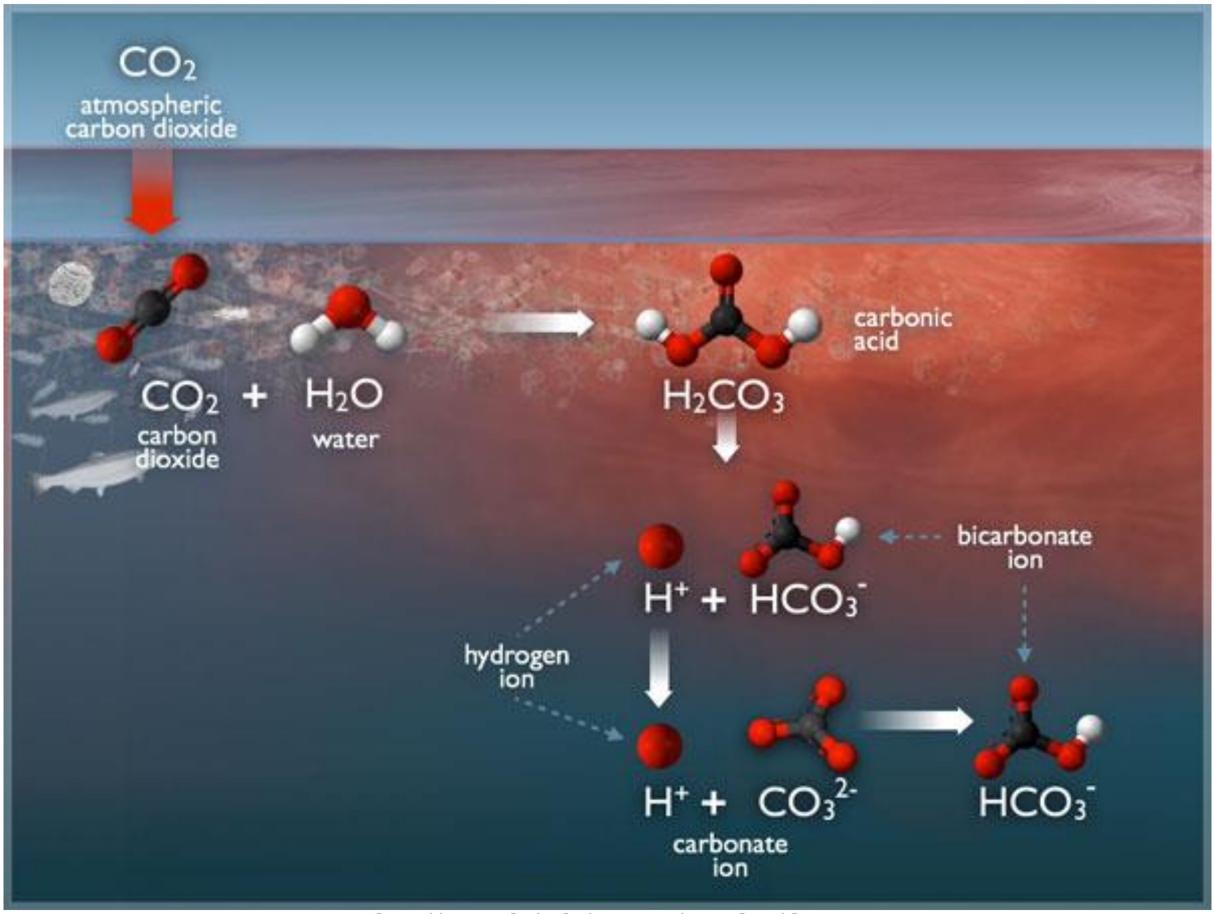
5) Can you name one common household acid, base, and oxidizer?
    a. Acid = citric acid, lactic acid (sour milk), or acetic acid (viniger); Base = ammonia (NH_4OH), lime ($Ca(OH)_2$), washing soda (Na_2CO_3), backing soda ($NaHCO_3$); Oxidizer = bleach ($NaClO$), hydrogen peroxide

6) What are the three most abundant components of air? How much of each?
    a. Air consists of nitrogen (~78%), oxygen (~21%), Argon (~1%), and many other gases as trace components (< ½%)

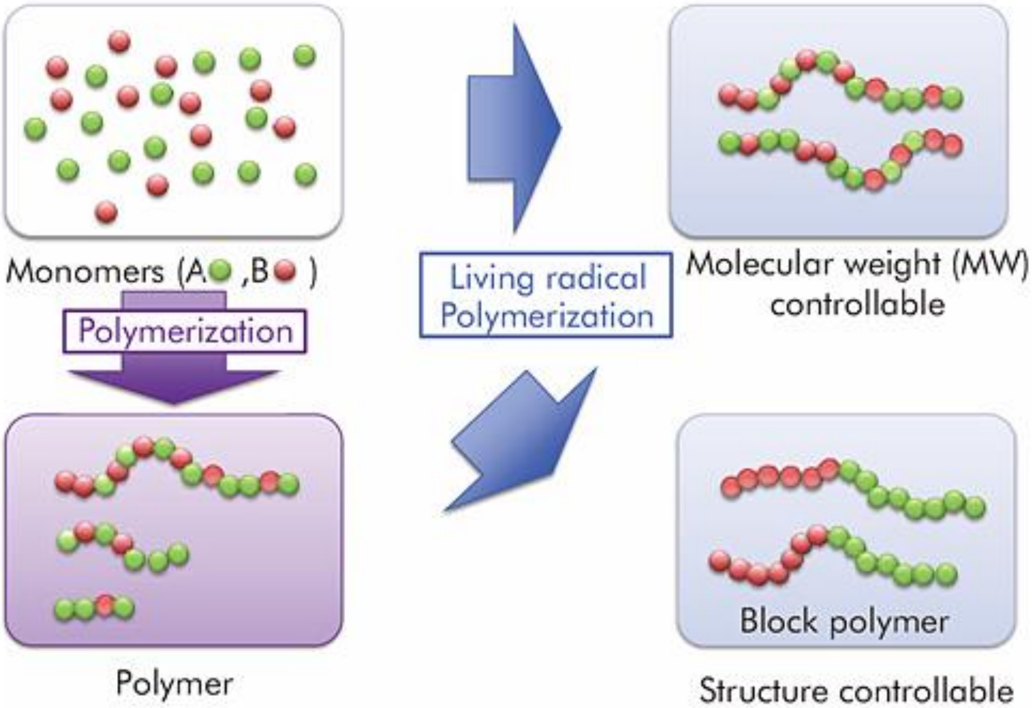
7) Chemistry is commonly called the __________ science because chemistry is fundamentally important to physics, biology, geoscience, ecology, and medicine.
    a. Chemistry is the "Central Science"

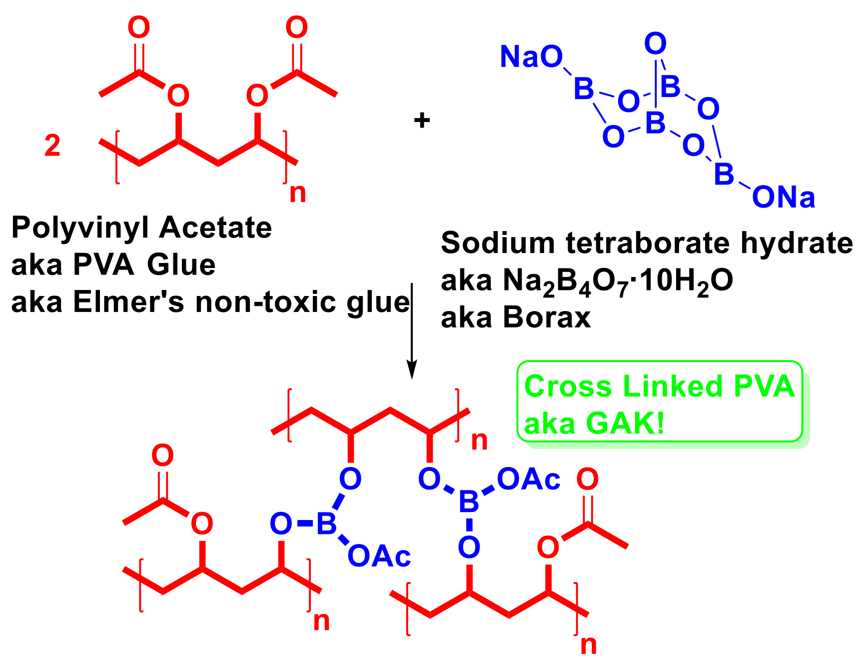
Recommended citation for this lesson plan:

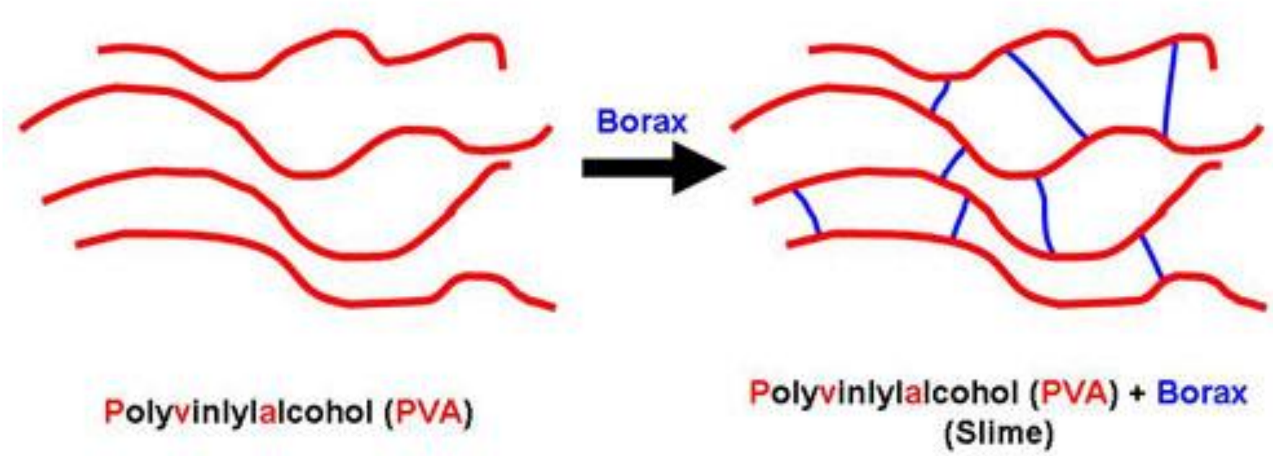
Topczewski, Joseph. 2016. Atoms, Colors, and Changes in Our Chemical World! A General Chemistry Experience . marketsci.org



http://www.whoi.edu/OCB-OA/page.do?pid=112076

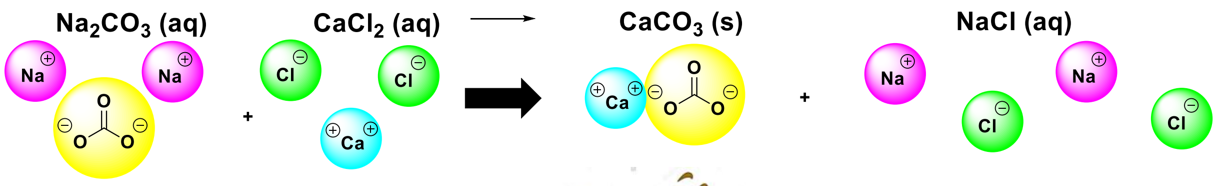

Monomers (A ,B)
Polymerization
Polymer
Living radical Polymerization
Molecular weight (MW) controllable
Block polymer
Structure controllable


2
n
+
NaO
B
O
O
B
O
B
O
O
B
ONa
Polyvinyl Acetate
aka PVA Glue
aka Elmer's non-toxic glue
Sodium tetraborate hydrate
aka $Na_2B_4O_7{\cdot}10H_2O$
aka Borax
Cross Linked PVA
aka GAK!
OAc
OAc

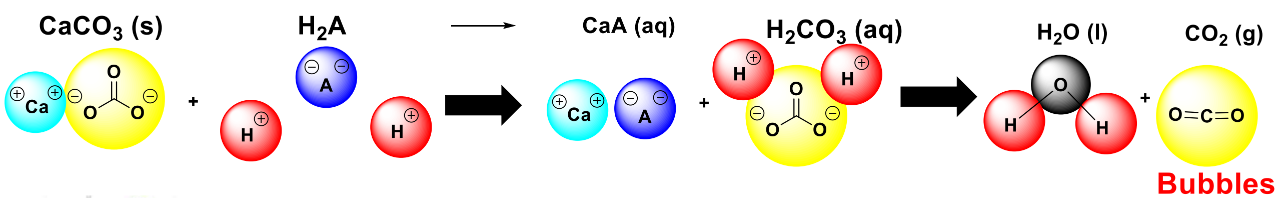


https://www.otsukac.co.jp/en/products/chemical/lr-polymer/
http://www.chemicalconnection.org.uk/chemistry/topics/view.php?topic=5&headingno=5

An Ion is just a charged atom or molecule.
Water, especially the ocean, is full of disolved ions.
Sometimes two or more ions react.



I make my shell through this reaction!
Most of my shell is made of $CaCO_3$!
But, my shell can react too...



My shell can be disolved by acids.
The formation of HCO_3 or H_2CO_3 is damaging to sea life like me and coral.
H_2CO_3 is unstable and gives of CO_2 and water
When you mix baking soda and vinegar this is
the reaction that makes bubbles.