9E Absorption

How is color used in chemistry?

Many chemical reactions, including photosynthesis, are dependent on light for energy. Light implies color, and all of the colors we create for clothes, paints, art, and everything else come from chemistry. This investigation will take a look at how color is created in inks and dyes.

Materials

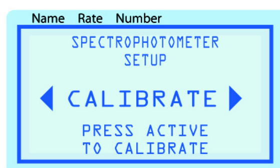
- 4 12 mm test tubes
- 100 ml graduated cylinder
- Test tube holders
- Food coloring
- Droppers
- Probe system
- 5 Cuvettes

Part 1: Calibrating

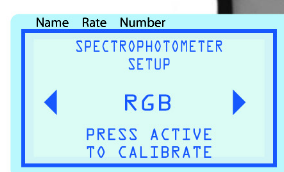
A spectrophotometer measures the absorbtion of light of different colors when the light passes through matter, such as a colored solution. The one you will use measures three colors, red, green, and blue.

To be accurate, the spectrophotometer must be calibrated every time it is used. Calibration tells the instrument what is 100% transmission, or perfectly clear.

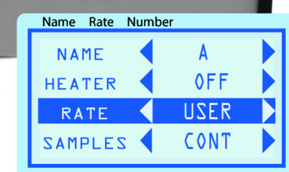
Put a cuvette of clear water in the spectrophotometer



Press ACTIVE, select CALIBRATE and press ACTIVE again. This calibrates the spectrophotometer setting water as 100%.



select RGB and press ACTIVE again. This selects the spectrophotometer and makes it the active sensor

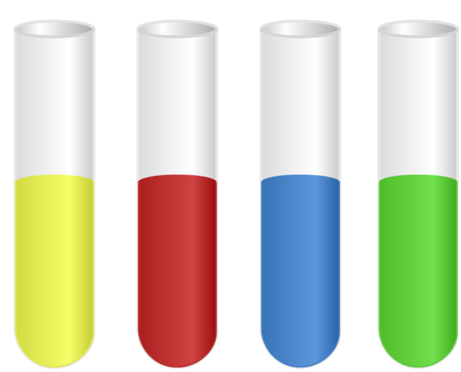


Press SETUP then set RATE = USER and SAMPLES = CONT This sets the CLS to measure when you hit START/STOP

Part 2: Setting Up

1. Measure 50 mL of water into a graduated cylinder.
2. Prepare a colored solution (red, green, yellow, or blue) with one drop of dye in 50 ml of water.
3. Measure about 15 ml into a small test tube and make a grease pencil mark on the tube to record the level.
4. Repeat for all four colors of dye.

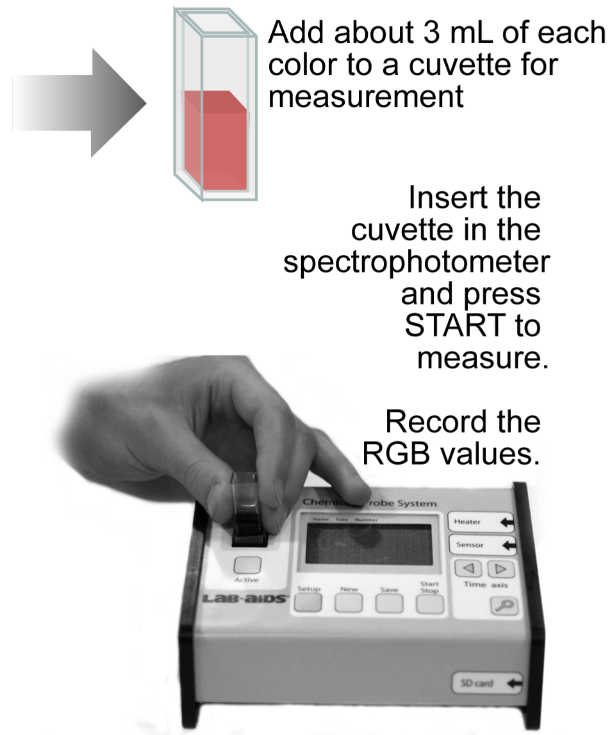
Add 1 drop each of red, green, blue, and yellow color to a test tube full of water



Yellow **Red** **Blue** **Green**

Part 3: Creating color

White light is a mixture of all colors. To a human eye "all colors" means read, green, and blue since our retina only has sensors for those three colors. That means when we see the color RED, reflected from someone's sweater, the blue and green have been absorbed, leaving only the red to be reflected into our eye.



1. Insert a cuvette of each of the four colors into the spectrophotometer. Measure and record the RGB absorption for each color.

Table 1: Color RGB Data

Color	R	G	B
Red			
Green			
Blue			
Yellow			

Part 4: Things to think about

a. Do the solutions emit light, or do we see them only because of transmitted or reflected light?

b. What makes the color?

c. Suppose you add one more drop to each of the vials. What will this do to the RGB values? Try it and see what happens.

d. One of the colors is a mixture of two others. See if you can determine which one is the mixture and present experimental evidence that supports your claim.

9A Oxidizers and Colors

What are the purpose of bleaching agents?

The molecules that create color, whether purposeful dyes or accidental stains, canbe changed through chemical reactions. When the molecules change, the color does too.

Materials

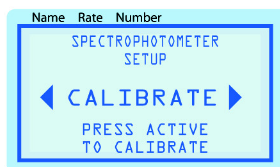
- 4 12 mm test tubes
- 100 ml graduated cylinder
- Test tube holders
- Food coloring
- Droppers
- Probe system
- 5 Cuvettes
- Chlorine bleach
- Hydrogen peroxide

Part 1: Calibrating

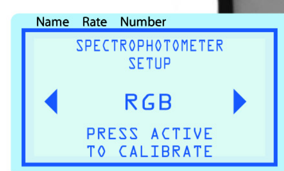
A spectrophotometer measures the absorbtion of light of different colors when the light passes through matter, such as a colored solution. The one you will use measures three colors, red, green, and blue.

To be accurate, the spectrophotometer must be calibrated every time it is used. Calibration tells the instrument what is 100% transmission, or perfectly clear.

Put a cuvette of clear water in the spectrophotometer



Press ACTIVE, select CALIBRATE and press ACTIVE again. This calibrates the spectrophotometer setting water as 100%.



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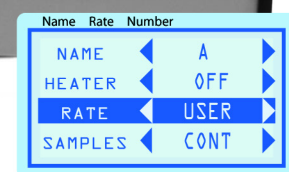
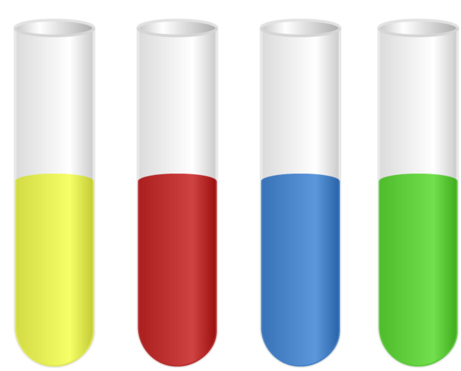


Press SETUP then set RATE = USER and SAMPLES = CONT This sets the CLS to measure when you hit START/STOP

Part 2: Setting Up

1. Measure 50 mL of water into a graduated cylinder.
2. Prepare a colored solution (red, green, yellow, or blue) with one drop of dye in 50 ml of water.
3. Measure about 15 ml into a small test tube and make a grease pencil mark on the tube to record the level.
4. Repeat for all four colors of dye.

Add 1 drop each of red, green, blue, and yellow color to a test tube full of water



Yellow **Red** **Blue** **Green**

Part 3: Baseline data

1. Insert a cuvette of each of the four colors into the spectrophotometer. Measure and record the RGB absorption for each color. This will be the baseline data to evaluate changes against

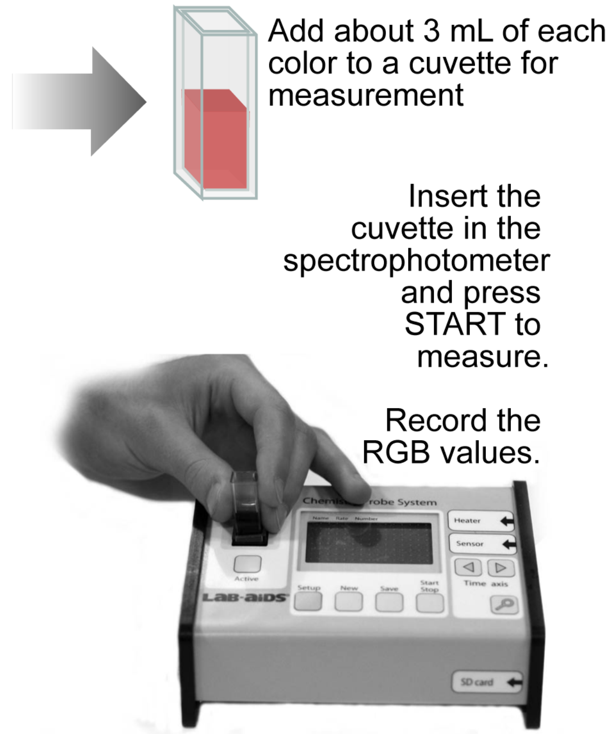


Table 1: Color RGB Data

Color	R	G	B
Red			
Green			
Blue			
Yellow			

Part 4: Reactions

2. Measure 2 ml into a cuvette.
3. Plase the cuvette in the spectrophotometer. Use the eye dropper to add drops of hydrogen peroxide. Swirl the mixture around and see if the color goes away.
4. Keep adding drops until the transmission of the MOST ABSORBED color rises to 95% .
5. Record the number of drops it took to make the solution 95% clear.
6. Empty the cuvette tube, rinse it out and repeat the experiment with the chlorine bleach.
7. Repeat the experiment with another color.

Table 2: Drops to remove color from solution

Color	Drops of hydrogen peroxide	Drops of chlorine bleach

Part 5: Things to think about

a. What makes the color?

b. Propose some possible explanations for what happened to the dye that made the color when you added the hydrogen peroxide or bleach.

c. Did each color behave the same way? What does that suggest about the different colors?

d. Is this a chemical change or a physical change? What evidence can you write down to support you claim?

Part 6: A chemical mystery

1. One of the colors is a mixture of two others. See if you can determine which one is the mixture and present experimental evidence that supports your claim.

Part 7: Doing the math

Like recipes, chemistry often requires exact proportions of ingredients. Volume is an important measuring technique.

1. Propose a way to measure the volume of a single drop of the food color (in mL).
2. Carry out your measurement using water (its much less messy)
3. Calculate the percentage of food color (by volume) in the 50 mL solution you made.
4. As a percentage (by volume) how much bleach or hydrogen peroxide does it take to remove the color? For example if the solution was 1% food color, you may have had to add 2% bleach.
5. Suppose you doubled the percentage of food color. HOw much bleach or hydrogen peroxide would it take to clear the solution?
6. Try the experiment from step (5).

g.

4A Inside the Atom

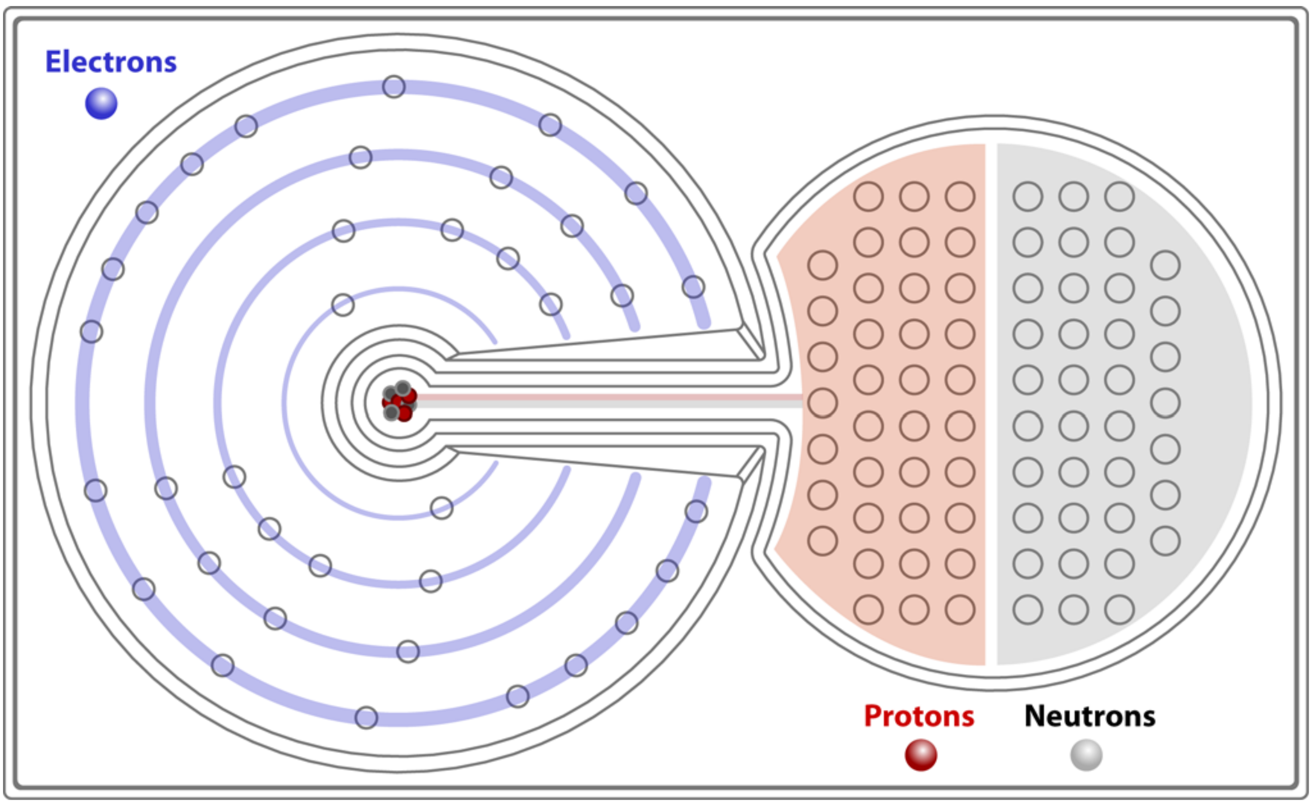
What is inside an atom?

People once though atoms were the smallest possible particles of matter. Then we discovered even smaller particles inside atoms! The structure of the atom is the underlying reason nearly all the properties of matter we experience are what they are.

Materials

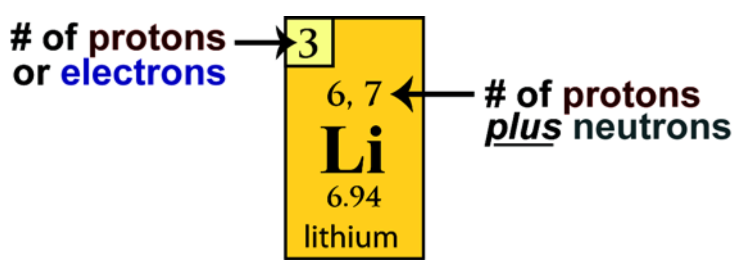
- Atom Model

Part 1: Setting up



The Atom Model represents the particles inside an atom and how they are arranged.

1. Find the element lithium (Li) on the periodic table.
2. Use the colored marbles to build a lithium atom.



Part 2: Thinking about the atom

a. What is the number of protons or electrons called?

b. In the lithium atom, what are the numbers 6 and 7 called?

c. Why do some elements have more than one number above the symbol? What are the variations in this number called?

Part 3: Atom Building

Each group will build an isotope of the same element.

a. How many of each isotope have been built in the class?

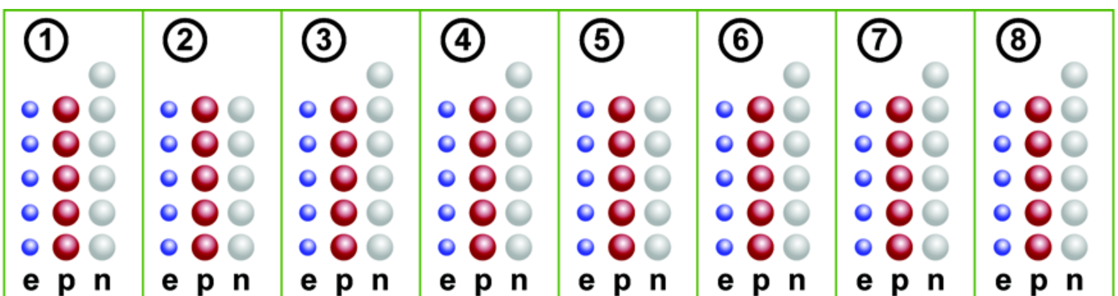
b. What is the average atomic mass for the class?

A game that simulates the periodic table of elements.

1. The winner of the game is the first player to use all their marbles.
2. Each player should start with the following particles:
   6 blue marbles (electrons)
   5 red marbles (protons)
   5 white marbles (neutrons).
3. Each player takes turns adding 1 - 5 marbles, but not more than 5. The marbles may include any mixture of electrons, protons, and neutrons.
4. Marbles played in a turn are added to the marbles already in the atom.
5. If you add marbles that make an atom NOT shown on the periodic table you have to take your marbles back and lose your turn.
6. A player can take from the bank INSTEAD of taking a turn. The player can take as many marbles, and of as many colors as they need. HINT: take few marble but choose the colors wisely.

Part 4: Problems to solve

One class has 8 different groups. Each group makes its own version of an atom of the same element.



	1	2	3	4	5	6	7	8
Individual atomic mass								

a. What element were the students building?

b. Fill in the atomic mass of each of the 8 atoms

c. Calculate the average atomic mass for the class.

d. How does your average compare with the average atomic mass listed on the periodic table? Is it more than the average mass listed in the table, less than, or about the same?

e. What must be different about the natural abundance of the two different isotopes compared to what was built in this class.

Reduced Periodic Table

(first four rows)

Key

Atomic number	Mass numbers of stable isotopes	Element symbol	Average atomic mass	Element name
6	12, 13	C	12.01	carbon

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 1,2 H 1.01 hydrogen																	2 3, 4 He 4.00 helium
3 6,7 Li 6.94 lithium	4 9 Be 9.01 beryllium											5 10, 11 B 10.81 boron	6 12, 13 C 12.01 carbon	7 14, 15 N 14.01 nitrogen	8 16, 17, 18 O 16.00 oxygen	9 19 F 19.00 fluorine	10 20, 21, 22 Ne 20.18 neon
11 23 Na 22.99 sodium	12 24, 25, 26 Mg 24.31 magnesium											13 27 Al 26.98 aluminum	14 28, 29, 30 Si 28.09 silicon	15 31 P 30.97 phosphorus	16 32, 33, 34 36 S 32.07 sulfur	17 35, 37 Cl 35.45 chlorine	18 36, 38, 40 Ar 39.95 argon
19 39, 41 K 39.10 potassium	20 40, 42, 43 44, 46, 48 Ca 40.08 calcium	21 45 Sc 44.96 scandium	22 46, 47, 48 49, 50 Ti 47.88 titanium	23 51 V 50.94 vanadium	24 50, 52, 53 54 Cr 51.00 titanium	25 55 Mn 54.94 chromium	26 54, 56, 57 58 Fe 55.85 iron	27 59 Co 58.93 cobalt	28 54, 56, 57 58 Ni 58.69 nickel	29 63, 65 Cu 63.55 copper	30 64, 66, 67 68, 70 Zn 65.39 zinc	31 69, 71 Ga 69.72 gallium	32 70, 72, 73 74, 76 Ge 72.61 germanium	33 75 As 74.92 arsenic	34 74, 76, 77 78, 80, 82 Se 78.95 selenium	35 79, 81 Br 79.90 bromine	36 78, 80, 82 83, 84, 86 Kr 83.80 krypton

4B Valence

Why is the periodic table shaped the way it is?

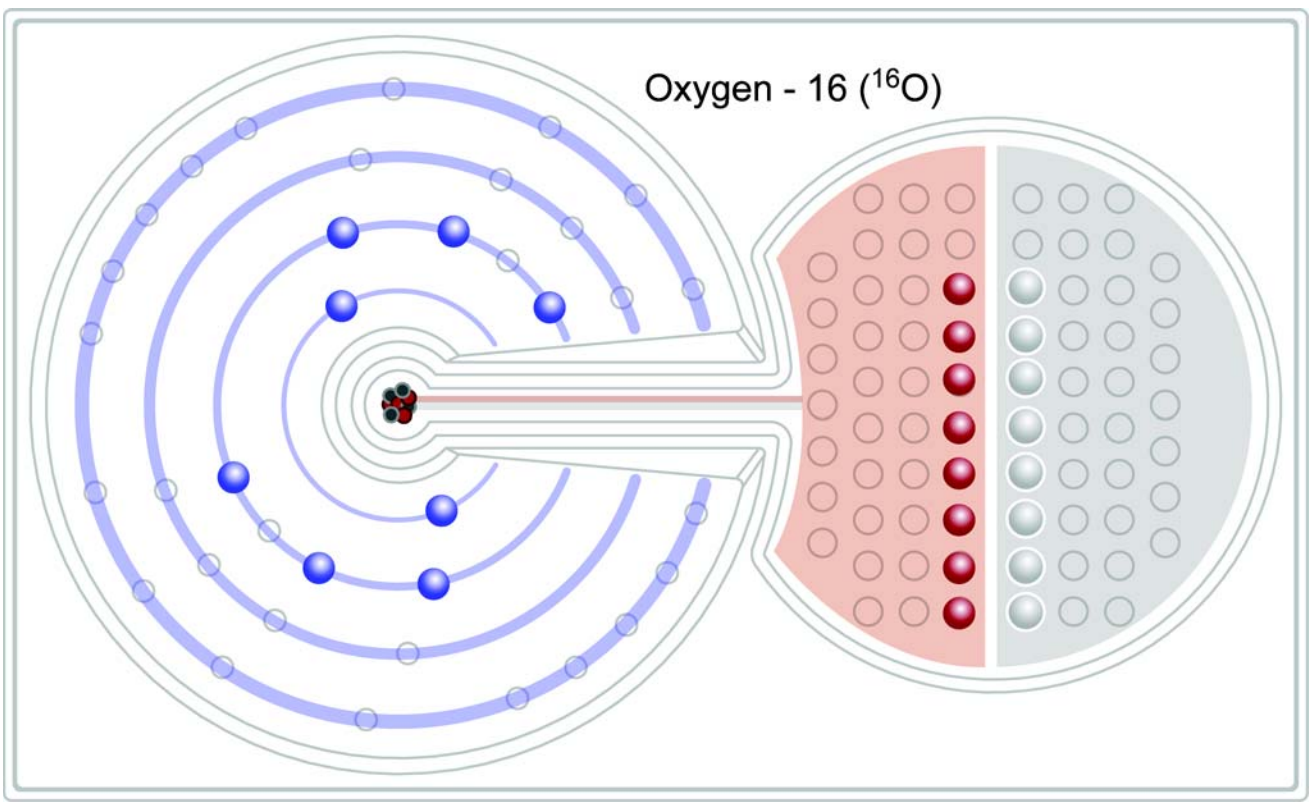
Once people started being able to isolate pure sample of eachelement, curious patterns started to emerge. The element beryllium combined with twice as much oxygen as lithium. Magnesium also combined with twice as much oxygen as lithium, and twice as much as with sodium and potassium too. In fact, lithium, sodium, and potassium all behaved similar to each other and different from other elements. Beryllium, magnesium, and calcium were similar to each other and different from the rest of the elements. What was the explanation for why certain "groups" of elements were chemically similar to each other?

Materials

- Atom Model

Part 1: Setting up

Build an oxygen atom as shownn the diagram below.



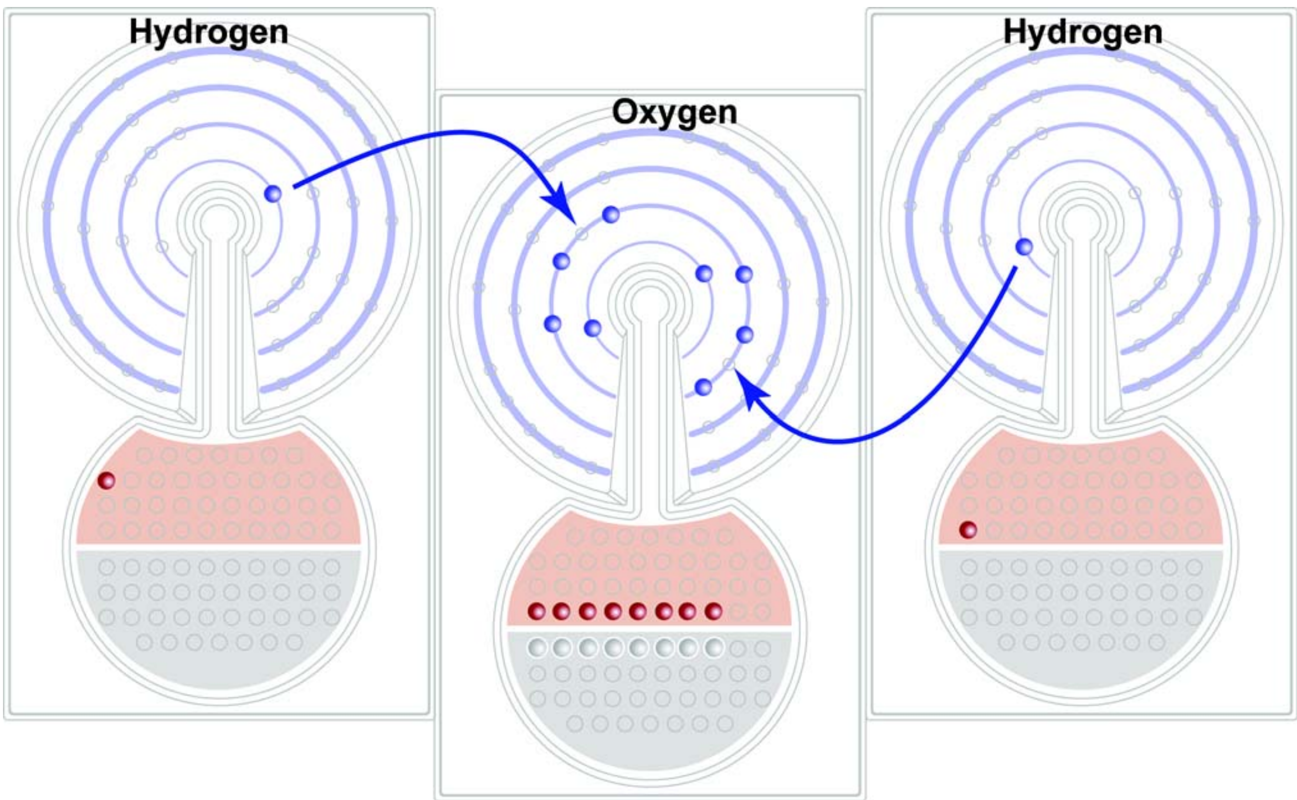
Part 2: What makes oxygen act like oxygen?

a. The overall energy in an atom is LOWEST when all its shells of electrons are either completely filled or completely empty. What can an oxygen atom do to achieve this preferred state?

b. Which of the two choices do you think lowers the energy of an oxygen atom the most?

Part 3: Chemical bonding

Make two hydrogen atoms and put them on either side of the oxygen atom.



a. Use what you did (and the diagram) to explain why the chemical formula for water is H_2O and not H_3O or H_3O_2 or some other combination.

Part 4: Valence

Chemical bonds between atoms involve only the electrons in the outer, unfilled shells. These electrons are called *valence electrons* because they are so important.

1. Build two different atoms that each have 3, 3, 2, 4, 7, and 8 valence electrons.

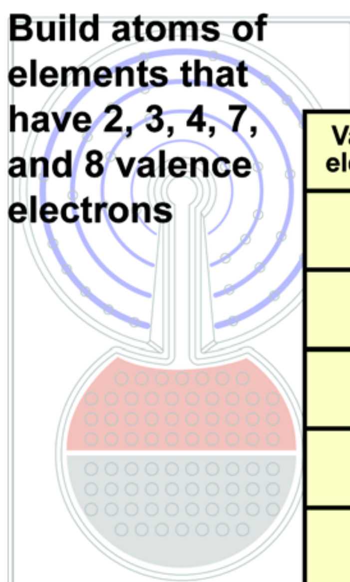
Answer questions a-d for each atom you built.

a. What elements are they?

b. Would they be likely to accept or give up electrons to make bonds?

c. Where on the periodic table are they?

d. Predict how each would combine with hydrogen and with oxygen.



Valence electrons	Element
3	
3	
2	
4	
7	
8	

4D Periodic Table Riddles

This atom can make up to three bonds with other atoms and has 14 particles in the nucleus ***005***	This atom has its second energy level completely filled. Its mass number is odd (not even). ***007***
Add 8 protons, 9 neutrons and 9 electrons. What element is this atom? ***006***	This radioactive atom has 6 electrons but 8 neutrons! ***012***
This atom has 3 electrons in the third energy level. What is it? Its mass number is twice its atomic number plus 1. ***025***	This atom has 3 stable isotopes and four electrons in its outer shell. The mass number is twice the atomic number. ***031***
There are two ways to build the nucleus of this atom and one of them has less neutrons than protons! Build the lighter isotope. ***040***	This atom has only one stable isotope and has five electrons in the third energy level. ***036***
This element has an average atomic mass of 6.94 but this atom actually has 4 neutrons in its nucleus. ***019***	This atom has one electron less than it needs for a full shell and a mass number of 36, its radioactive too. ***010***

19A Nuclear Reactions

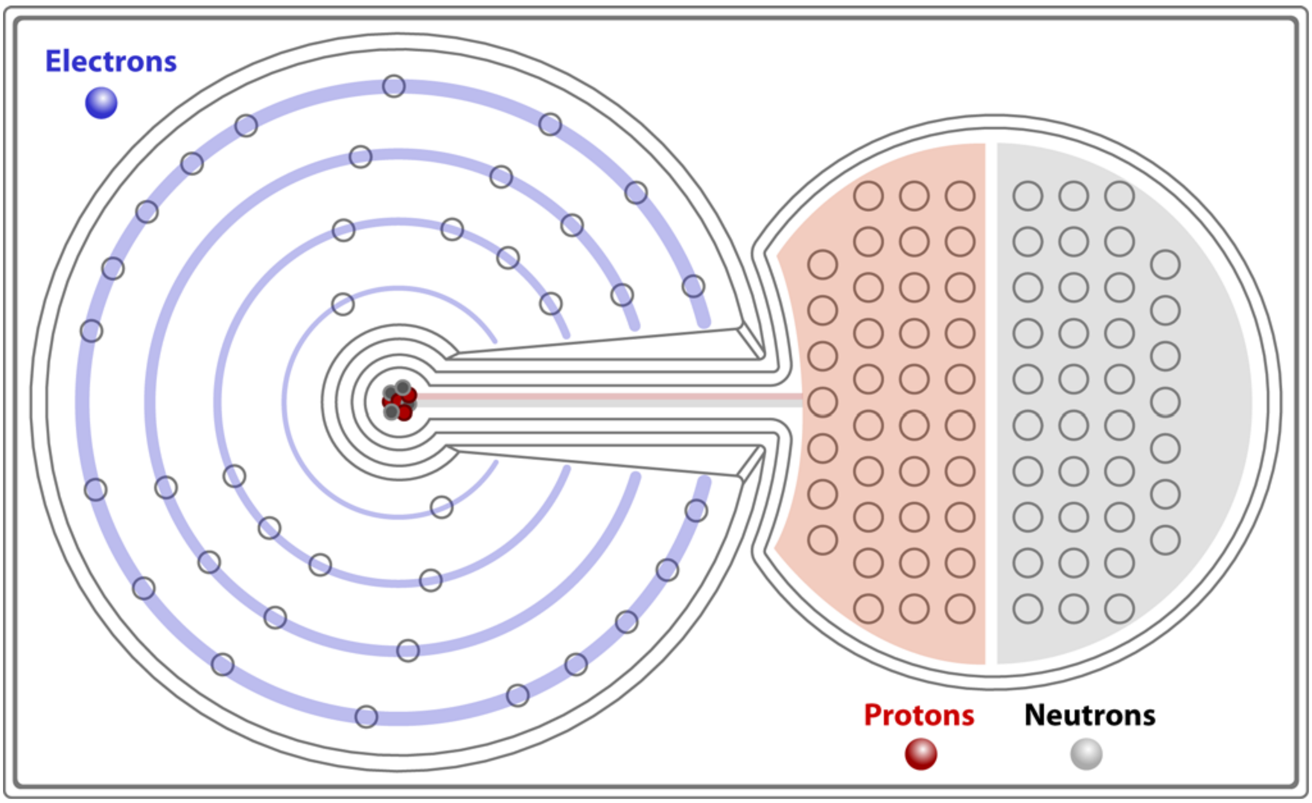
What is radioactivity?

It would be pretty astounding to see a bus suddenly change into two trucks and a car. But something equally strange goes on every second in the world of atoms. For example, an atom of carbon-14 suddenly turns into nitrogen-14! Or a uranium nucleus suddenly ejects a helium nucleus and changes into the element thorium. Both changes are examples of *radioactivity.*

Materials

- Atom Model

Part 1: Beta decay



The Atom Model represents the particles inside an atom and how they are arranged.

1. Build an atom of carbon-14 (^{14}C).
2. Take a single neutron and replace it with a proton and an electron. What element is left now?

Part 2: The beta decay reaction

a. Write down a reaction that represents the transformation you created in Part 1

b. The reaction releases a lot of energy. Discuss where the energy goes.

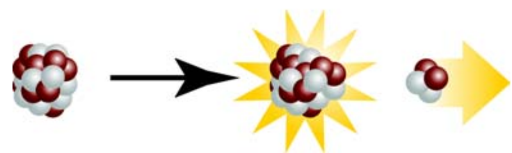
c. How does beta decay change the atomic number? How does it change the mass number?

d. Create a beta decay reaction that LEAVES the isotope neon-20. Write the reaction down.

Part 3: Alpha decay

In alpha decay, a heavy nucleus ejects a helium-4 nucleus. For example, when uranium-238 undergoes an alpha decay, it becomes thorium-234. Uranium has 92 protons and thorium has only 90.

$$^{238}_{92}\mathrm{U} \xrightarrow{\alpha} {}^{234}_{90}\mathrm{Th}$$



a. Create an alpha decay that LEAVES a stable isotope. Build the starting and ending isotopes.

b. Write the reaction down.

Part 4: Half life and probability

Radioactive decay reactions occur spontaneously. While youcan never predict when any single atom will decay, you CAN predict the average decay rate for a large collection of atoms. The time it takes for 50% (1/2) of the atoms in any given radioactive sample to decay is called the half life. The half life for carbon-14 is 5,700 years. That means half the carbon 14 atoms turn into nitrogen-14 atoms every 5,700 years.

1. Unroll 50 pennies from the wrapper. Mark one penny with a black circle on both sides.
2. Lay all the pennies heads-up on the table. Heads represents carbon-14. At the beginning you have 50 atoms of C-14.
3. Put the pennies in a cup and shake the cup, covering it with your hand to prevent the pennies from falling out. Shake the cup and let the pennies fall on the table.
4. Count the number of heads and tails. Record the number in the second column of the table. Each tail represents one atom that has turned into nitrogen-14.
5. Remove all the “tails-up” pennies. Put the remainder (heads-up - or still carbon) pennies back in the cup and shake again.
6. Repeat the shaking, spilling, and counting until you have no pennies left.

Part 5: Thinking about what you did

a. What happened to the number of “carbon” atoms over time?

b. Graph the number of carbon atoms versus time assuming that each shake of the cup represented the passage of 5,700 years.

c. Do the same graph for the total of all the groups in the class. Use averages so the class graph fits on the same 0-50 vertical scale as your individual graph. Wht do you notice?

d. What can you say about when the circle-marked penny changes? Can you predict it with any certainty?

e. What can you say about the average number of carbon atoms over time?

2A The Chemical Formula

What is a chemical formula and how is it used?

Paper, glass, plastic,metal, skin, leaves, its all matter and its all made out of the same 92 ingredients. In fact, only six elements make up most of everything around us. How does such incredible variety come from only a few elements? Well, think about at a dictionary. How do so many words come from only 26 letters? The answer for matter is very similar and the chemical formula is how we "spell" all the different kinds of matter with the same few elements.

Materials

- atomic model kit
- calculator
- periodic table

Part 1: Setting up your model

Look at the molecule building set. Assign colors to the different "atoms" and write the identifications down in the table on the right. Make sure you have at least the followiong four: carbon, oxygen, hydrogen, and nitrogen.

a. One color in particular should be assigned to a specific element. Why?

	Element
black	
red	
white	
green	
yellow	
blue	
purple	

Part 2: Making some models and "spelling" them

1. Pick any four atoms. Use the "bonds" to connect them.
2. Draw in the diagram below for the "molecule" you have made.
3. Use the yellow and blue boxes to work out the chemical formula for your molecule.
4. Write the completed fomula on the line.

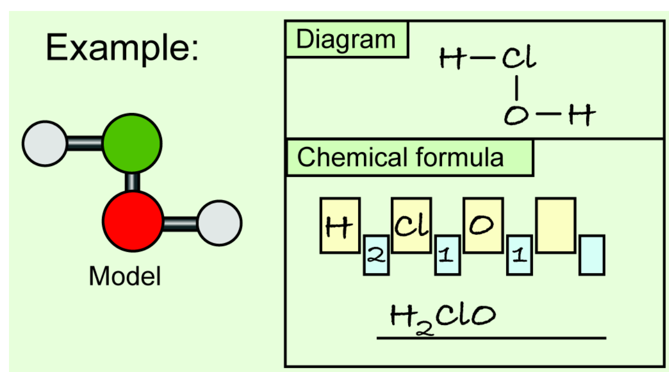


Diagram	Chemical formula
	Write element symbols in yellow boxes Write how many of that element are in your molecule in blue boxes ______________________

Part 3: Using 4 different elements, build molecules with 6 and 8 atoms.

Diagram

Chemical formula

Write element symbols in yellow boxes

Write how many of that element are in your molecule in blue boxes

Diagram

Chemical formula

Write element symbols in yellow boxes

Write how many of that element are in your molecule in blue boxes

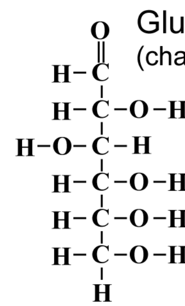
Part 4: Reflecting on what we learned

a. How many total atoms are in the glucose molecule?

b. Write the chemical formula for glucose.

c. Methane has the chemical formula CH_4. Draw a possible chemical diagram for a methane molecule. HINT: Carbon makes 4 bonds with other atoms.

d. Write a chemical formula for a molecule that has 4 hydrogen atoms, 2 carbon atoms, and 2 oxygen atoms.



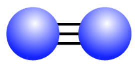
Glucose (chain form)

Part 5: Rules for bonding atoms

In most situations, elements tend to form a specific number of bonds when they make molecules. For example, each carbon atom needs to make 4 bonds, a nitrogen atom needs to make 3 and an oxygen atom needs to make 2. This is one of the most important ways the elements are different from each other. They are different BECAUSE they form different numbers of bonds with other elements.

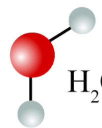
Molecules can have single bonds, double bonds, and even triple bonds! Here are some examples of each.

A nitrogen molecule has 1 triple bond



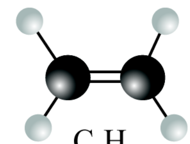
N_2

The oxygen atom in a water molecule makes 2 single bonds



H_2O

The carbon atoms in an ethylene molecule make 1 double bond between them



C_2H_4

Let's reassign the colors and set up the rules for bonding a few elements

		Element	Number of bonds
	black	carbon	4
	red	oxygen	2
	white	hydrogen	1
	green	chlorine	1
	yellow	sulfur	2
	blue	nitrogen	3
	purple	sodium	1

1. Build one possible structure for each of the following molecules. Make sure you follow the rules for how many bonds connect each atom.
2. Draw a possible structure diagram for each molecule you build. There may be many possible sttructures for each molecule!
3. Leave the line labels "formula mass" blank until the next step

HNO_3 **Formula mass** __________	Diagram
$C_3H_3O_2$ **Formula mass** __________	Diagram

C_6H_6 **Formula mass** ____________	Diagram
CH_3OH **Formula mass** ____________	Diagram
H_2SO_4 **Formula mass** ____________	Diagram

Part 6: The formula mass

- Each atom has mass.
- The masses are different for atoms of different elements.
- Each molecule must also have a mass that depends on both its chemical formula and the mass of its individual atoms.

The chart is now expanded to include the average masses of each atom in atomic mass units. An atomic mass unit is roughly equal to the mass of a single hydrogen atom. Carbon is about 12 times as heavy as hydrogen, oxygen about sixteen times as heavy and so on.

		Element	Number of bonds	Avg. atomic mass (amu)
	black	carbon	4	12.0
	red	oxygen	2	16.0
	white	hydrogen	1	1.01
	green	chlorine	1	35.5
	yellow	sulfur	2	32.1
	blue	nitrogen	3	14.0
	purple	sodium	1	23.0

a. Use your diagrams and chemical formulas to calculate the mass of each of the molecules you built. Write the values in under the chemical formulas.

8A Conservation of mass

When something reacts, where does it go?

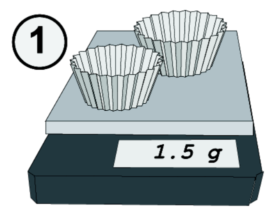
You probably know what happens when you combine vinegar and baking soda. There is a fizzy reaction as the sodium bicarbonate inthe baking soda reacts with the acetic acid in the vinegar. This investigation will take a deeper look atthis interesting experiment and uncover some of the basic laws of chemistry in the process.

Materials

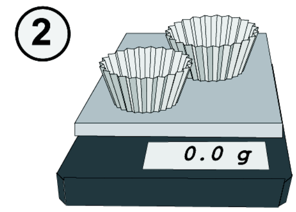
- baking soda
- vinegar
- 2 sealable plastic bags
- 3 foil baking cups
- balance
- Probe System with temperature probe

Part 1: The open system

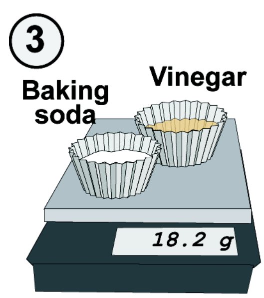
1. Set two foil cups on the balance and record the mass.
2. Tare the balance with both cups on it. Put 5-10 grams of baking soda in one cup and record the mass in Table 1 below.
3. Put 10 - 20 grams of vinegar in the other foil cup and record the total mass of reactants (baking soda + vinegar) in Table 1 below.
4. Add all of the vinegar to the cup full of baking soda. Place the empty vinegar cup back on the balance to properly account for its mass.
5. Watch the mass on the balance and record it every 10 seconds for a minute while the reaction is going.



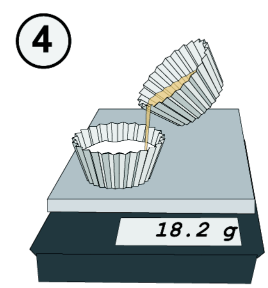
Start with 2 empty cups



Tare balance



Add baking soda and vinegar



Mix and record mass every 10 seconds

Table 1: Masses for open system

	Mass (g)
2 foil cups (before tare)	
Balance reading after tare (with 2 empty cups)	
Balance reading after adding baking soda	
Balance reading after adding vinegar	
Balance reading 10 seconds after mixing	
20 seconds after mixing	
30 seconds after mixing	
40 seconds after mixing	
50 seconds after mixing	
60 seconds after mixing	

Part 2: Think about it

a. What happened to the total mass in the open system as the reaction occured?

Part 3: Analysis

The chemical formula for baking soda is $NaHCO_3$. The active ingredient in vinegar is Acetic acid, or $HC_2H_3O_2$. The three products are sodium acetate $NaC_2H_3O_2$, water (H_2O) and carbon dioxide (CO_2).

a. Use the diagram (below) to calculate the formula mass for each chemical.

b. Write in the actual mass of baking soda and of vinegar you used in Part 1 (the open system).

c. Assume the vinegar is 5% acetic acid. How many grams of acetic acid did you begin with?

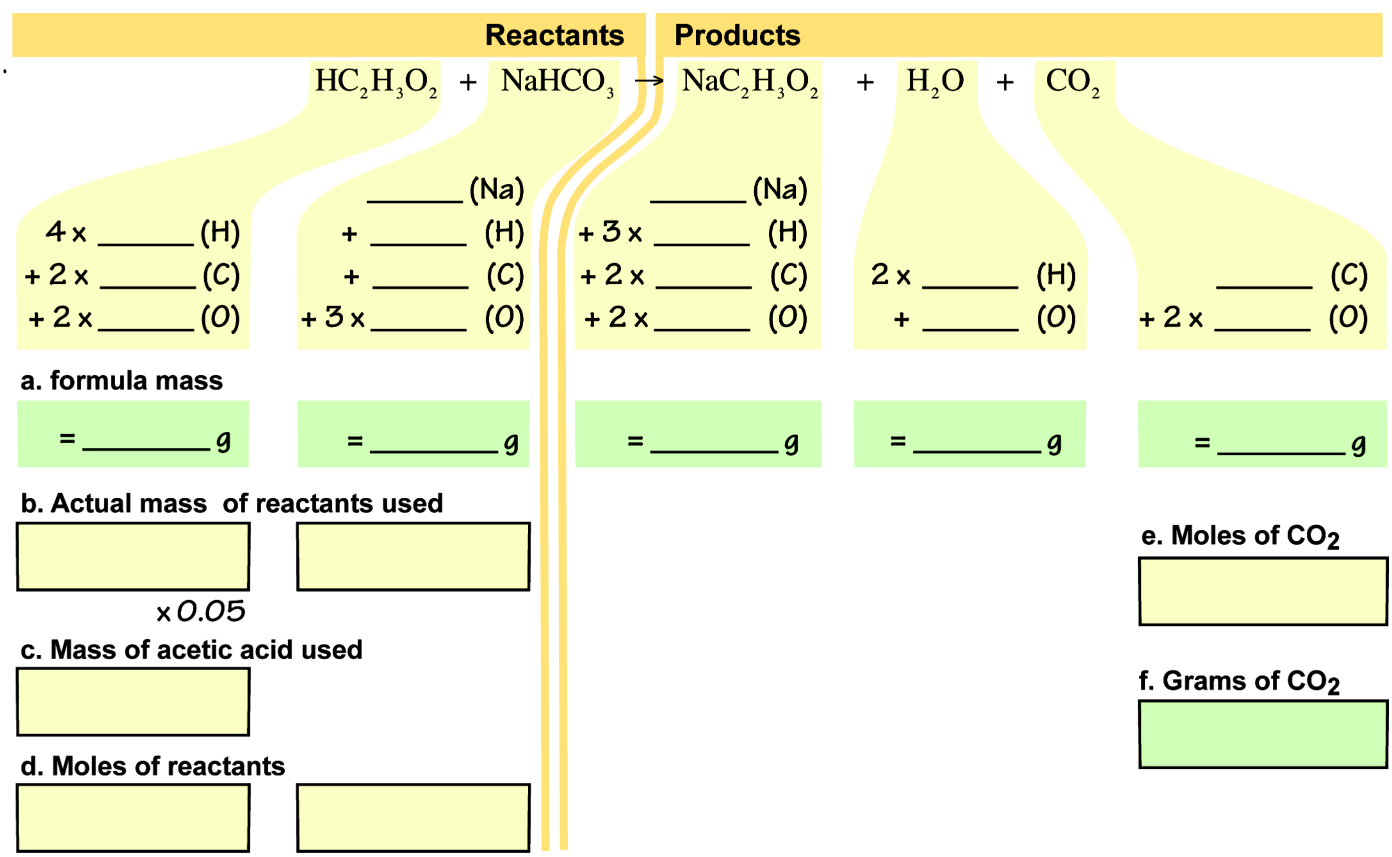
d. Calculate the number of moles of baking soda and acetic acid you started with. Which was the limiting reactant, the baking soda or the acetic acid?

e. How many moles of CO_2 should the reaction have produced?

f. Calculate the mass of the CO_2 produced? This is the mass that should have been "lost" in the open system since the CO_2 gas escapes.

g. Does the amount of CO_2 produced by the reaction explain the decrease in mass you observed in the open system?

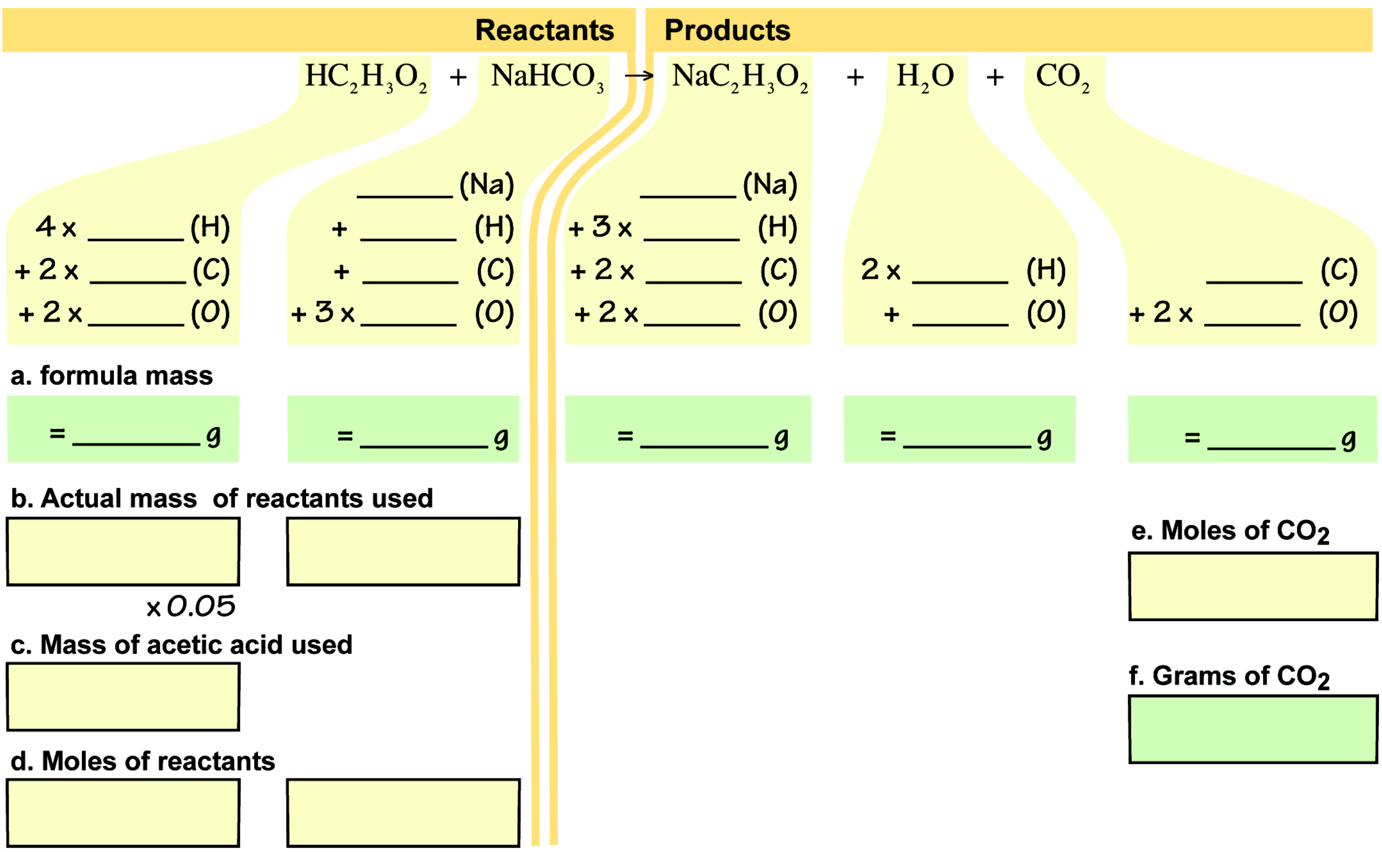
h. Propose an explanation for any difference between what you observed and what your calculations predict.



Part 4: Limiting reactants

a. Did all of the reactants in Part 3 get used? Why or why not?

b. Suppose you wanted to completely react 10 grams of baking soda. How much vinegar do you need? Use the diagram to calculate it.



c. How much CO_2 is prodced by your reaction?

d. Do the actual reaction and see if you get the amount you expected.

Part 5: Planning a reaction

a. Suppose you want to make 10 grams of CO_2. How much baking soda and vinegar do you need?

b. Do the reaction and see if it comes out as you expect.

Part 6: Energy

Almost all chemical reactions either give off or absorb energy. For example, suppose you have a reaction that combines chemicals A and B to make chemicals C and D. The reaction is written:

$$A + B \rightarrow C + D$$

If the reaction is ***exothermic***, or gives off energy, the equation is written to show energy on the *product side*, because energy is given off.

$$A + B \rightarrow C + D + \text{energy} \qquad \text{(exothermic reaction)}$$

If the reaction is ***endothermic***, it absorbs energy, and we can write the energy on on the *reactant side* because it takes an input of energy to make the reaction happen.

$$\text{energy} + A + B \rightarrow C + D \qquad \text{(endothermic reaction)}$$

a. How many moles of sodium bicarbonate are in 20 grams baking soda?

b. How many moles of acetic acid do you need to react with 20 grams of sodium bicarbonate?

c. If vinegar is only 5% acetic acid, how many grams of vinegar do you need to completely react with 20 grams of baking soda?

Part 7:

1. Weigh out the correct amount of vinegar to react with 20 g of baking soda.
2. Put 20 grams of baking soda in a foam cup.
3. Tare the balance and add enough water to saturate the baking soda. Record the temperature of the mixture. Record the mass of water you add. The water does not participate in the reaction, but is there to help get a good temperature measurement.
4. Quickly add the vinegar and stir gently with the temperature probe.
5. When the reaction is complete, record the temperature every ten seconds for one minute.

Part 8: What happens?

a. What happened to the temperature of the products? Was it warmer, colder, or about the same temperature as the reactants?

b. Is this an exothermic or endothermic reaction? How do you know?

c. The specific heat of water is 4.18 joules per gram. Assume all the heat was absorbed by the water. The mass of water is the mass you added tothe baking soda plus the mass of vinegar (mostly water). How much energy was exchanged in the reaction?

d. Calculate the energy per mole of sodium bicarbonate. Do this by dividing the energy you just calculated by the number of moles of $NaHCO_3$ in 20 grams.

e. Write down the balanced reaction including the energy per mole.