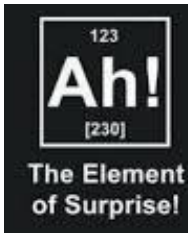
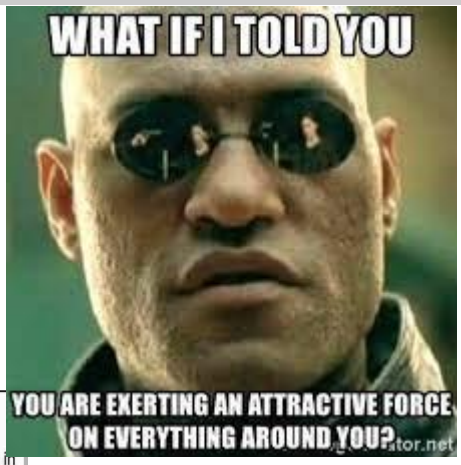
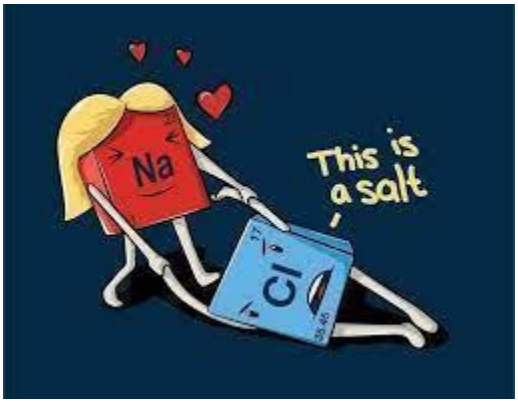
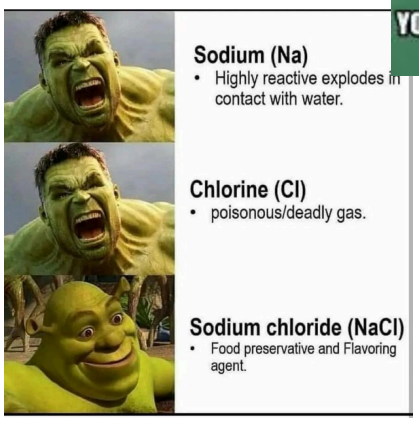
UNIT 3: WHAT MAKES THINGS STICK?



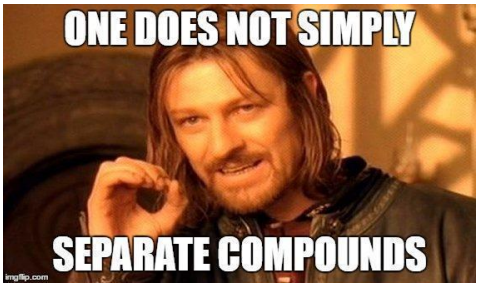


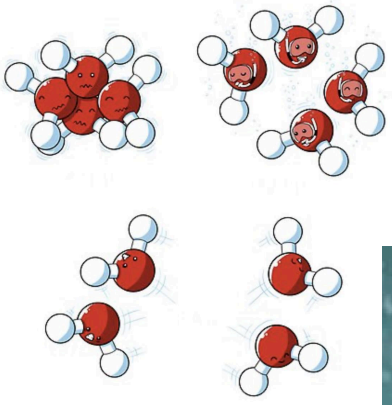


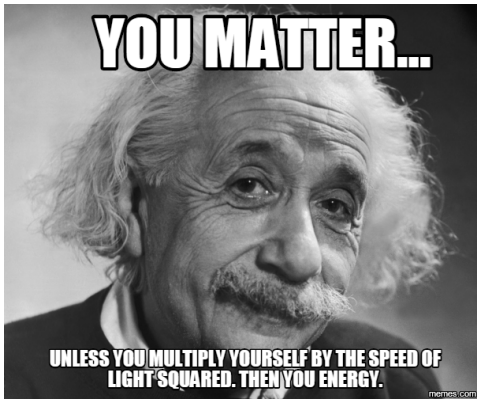


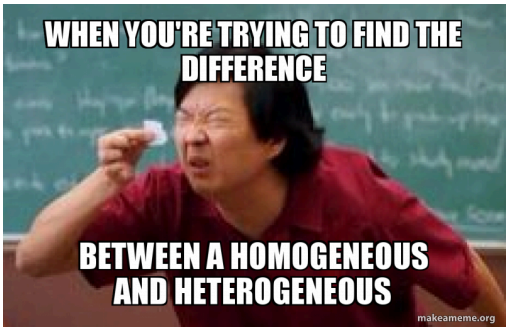












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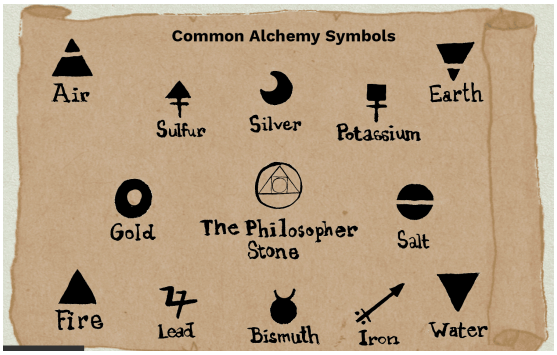
The Gold Obsession: Alchemy and the Search for Gold



Imagine if you could take an ordinary metal like lead and turn it into pure gold. you could be rich! For centuries, this dream was at the heart of a mysterious and ancient practice known as alchemy. Practiced across ancient Egypt, China, India, and medieval Europe, alchemy was a blend of science, philosophy, magic, and mysticism. But one goal united many alchemists: the quest to create gold from base metals, a process known as transmutation.

Alchemists believed that all matter was made of four basic elements: earth, air, fire, and water. They thought that if they could discover the right balance or "purify" a substance, they could change it into something more valuable, like turning lead into gold. They spent years heating, mixing, and distilling substances, hoping to uncover the mythical philosopher's stone, a legendary substance said to have the power to transform any metal into gold and grant eternal life.



Hennig Brand lived in the 17th century and was a keen alchemist. He used the wealth brought to him by his first wife to pursue his hunt for the Philosopher's Stone. Brand's big idea was that urine could be used to produce silver. So Brand took urine and boiled it down. This left some solid residue that Brand could work with. He added this to a furnace and heated it red hot. Suddenly a luminous cloud of fumes formed and a liquid poured out that caught fire. When this liquid was captured and covered it glowed for hours with a green light. Brand had discovered the element Phosphorous. To get around 120 grams of phosphorus Brand had to boil down over 5,000 litres of urine!

Most alchemists kept secret lab notebooks in code (see above) so no other person could recreate their work, for fear it would be stolen.

Some alchemists claimed to be able to produce valuable gold from other metals. Many stories include those of '"alchemists" who claimed if a person brought a mass of gold the alchemist could double it. After a whizz bang show, smoke would clear, and the alchemist would make off with the patrons gold! Others brought items that looked like gold and swapped out the gold brought by patrons for the fool's gold.

Kings, Queens, Popes, and Emperors have all poured fortunes into alchemy. Throughout history the lure of creating precious metals from nowhere has been a powerful one for those in power. But when the alchemists inevitably failed they often found themselves with an angry and vengeful patron. One punishment for alchemists was to hang them on a scaffold gilded with gold to show the fruits of their false promises. Henry IV of England issued a law in 1404 called "The Act Against Multiplication." This was not a law against mathematics but one that banned alchemy. The multiplication in question was the multiplication of precious metals. The worry was that if someone found out how to make gold or silver it would make the crown's currency worthless. In 1317 Pope John XXII issued a decree called Spondent Pariter that banned alchemy. The pope called alchemy "The Crime of

Falsification." If an alchemist claimed to have made a precious metal then they would be fined the weight of that metal in gold.

While many people today think of alchemy as the badly designed effort to turn lead into gold, it was actually much more than this. Alchemists made all sorts of materials for commerce, including medicines, pigments, metallic alloys, perfumes and cosmetics. In working with these materials, the alchemists learned an enormous amount about the nature of matter and how different materials could be isolated and combined. They handed this knowledge down to modern science. Alchemists invented experimental techniques (distillation, for example) and laboratory tools (funnels, flasks, cupels, etc.) still used by chemists today. They were also the first to isolate certain metals, including antimony, arsenic and zinc. By the 1600s, scientists like Robert Boyle began to move away from the mystical ideas of alchemy. He believed in testing ideas through experiments and careful observation, laying the foundation for modern chemistry. Over time, the idea of turning lead into gold was replaced by the desire to understand the true nature of matter. In the end, alchemists never found the philosopher's stone or made gold from cheap metals. But their obsession with transformation inspired centuries of scientific exploration. Their golden dream may have been impossible, but it led to something even more valuable: the birth of modern science.

1. What were the four elements of alchemy? Are they still our elements today?

2. Identify one discovery that alchemists made that is still relevant today.

3. Explain one reason why alchemists used symbols in their lab notebooks.

Elements and Compounds Demo

SEP: Construct and an Explanation CCC: Models

4. Watch the iron and sulfur demonstration https://www.youtube.com/watch?v=hFaxkBYuH2o and write qualitative observations:

5. Model the difference between the iron and sulfur before and after heating:

Before	After

6. Explain what you think happened at the particle level that would result in your observations.

Classifying Matter Activity 1

SEP: Obtaining Information CCC: Patterns

Directions: For each sample of matter, record qualitative observations and data from the cards.

	Symbol	Name	Phase	MP	BP	Malleability	Ductility	Luster
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								



1. The matter at station 1 showed both larger and smaller samples of the same material. Did your observations vary based on sample size?

2. Draw particle models to demonstrate a large sample and a smaller sample of the matter at lab station 1.

3. Use evidence from this activity to support your claim: can any of these samples be broken down into smaller samples and change properties?

4. Based on your answer to the question above, would you classify these materials as elements or compounds? Provide reasoning to support your answer.

5. Scientists often classify sets of things that are similar in order to find patterns, make connections, and ultimately make predictions. Based on the properties, Sort the samples into two groups. Then describe the characteristic properties of each group.
   Group 1: _____ **Group 2:** _____.

6. Scientists initailly classified these samples into two groups based on their properties: metals and nonmetals. Do any of your groups match with the metal classification? Explain your answer and label the groups with their new title.

7. Observe the properties of silicon, as demonstrated by your teacher. Record observations below.

8. What classification would silicon have? Explain your choice.

9. To solve this, scientists created a third category called **metalloids**. Based on your observations, what are the properties of a metalloid?

10. On the periodic table of elements, what numbered groups do you find:
    a. metals b. nonmetals c. metalloids

Elements Check Your Understanding

SEP: Interpreting Data CCC: Patterns

The 18 columns on the periodic table are "Groups" of elements with similar properties. The 7 rows are "Periods" which have "periodic" properties (properties that form repetition patterns).

1. Which three groups of the Periodic Table contain the most elements classified as metalloids?
   a. 1, 2, and 13 b. 2, 13, and 14 c. 14, 15, and 16 d. 16, 17, and 18

2. On the Periodic Table, an element classified as a semimetal (metalloid) can be found in
   a. Period 6, Group 15 b. Period 2, Group 14
   c. Period 3, Group 16 d. Period 4, Group 15

3. Which element is malleable and ductile?
   a. S b. Si c. Ge d. Au

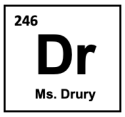
4. Which characteristics describe most solid nonmetals?
   a. They are malleable and have metallic luster.
   b. They are malleable and lack metallic luster.
   c. They are brittle and have metallic luster.
   d. They are brittle and lack metallic luster.

5. The element arsenic has the properties of
   a. metals, only
   b. nonmetals, only
   c. both metals and nonmetals
   d. neither metals nor nonmetals

6. A student examines a sample of pure Germanium and notes that it has a shiny, metallic luster. The student concludes that silicon must be classified as a metal. Which additional test would provide the strongest evidence to refute the student's claim?
   a. observing if the sample reflects light
   b. measure the melting point of the substance
   c. strike the sample with a mallet to see if it is malleable or brittle

7. A student investigates an unknown element located along the stair-step line on the periodic table. When placed in a simple circuit at room temperature, a bulb glows dimly. When the element is warmed gently with a heat lamp, the bulb glows noticeably brighter. Which classification and atomic-level explanation best account for this observation?

8. A materials engineer tests four unknown solid elements for use in a flexible heating element that must conduct electricity efficiently without shattering when bent. Based on the data below, which sample should the engineer select? Justify your response.
   Sample W: Dull gray solid; shatters when struck with a hammer; poor electrical conductor.
   Sample X: Silvery solid; flattens into a thin sheet when hammered; high electrical conductivity.
   Sample Y: Shiny brittle solid; conducts electricity moderately well only when heated.
   Sample Z: Yellow solid; crumbles easily under pressure; does not conduct electricity.

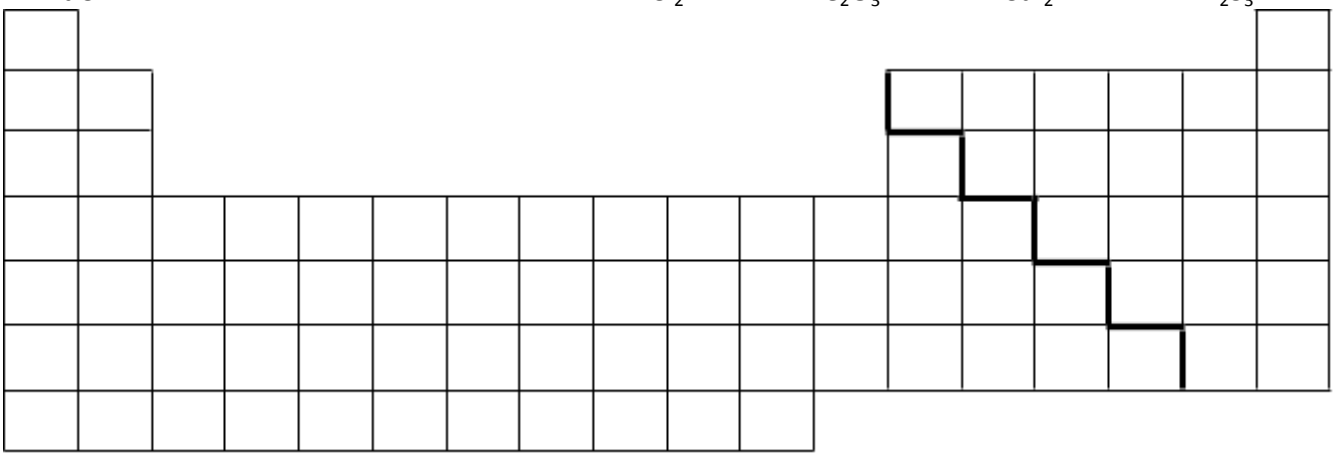


Types of Compounds Think Tank

SEP: Analyzing Data CCC: Patterns

MODEL #1: For each of the following substances, place the symbol of the first element in its spot on the periodic table using red ink. Then, place the symbol of the second element in the substance in its spot on the periodic table using black ink.

NaCl LiBr KF $ZnCl_2$ Fe_2O_3 CuI_2 Al_2S_3

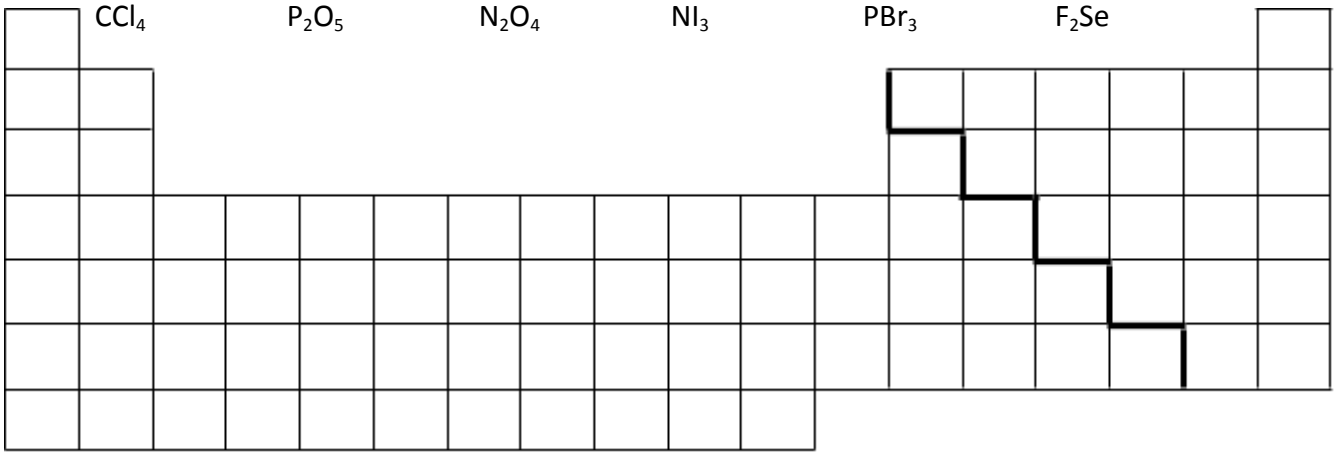


1. Where are all the first elements located on the periodic table (red symbols)?Based on your knowledge about the periodic table, what "classification" would you give these elements? Metal or Nonmetal?

2. Where are all the second elements located on the periodic table (black symbols)? Based on your knowledge about the periodic table, what "classification" would you give these elements?

MODEL #2: Repeat the process used in Model 1.

CCl_4 P_2O_5 N_2O_4 NI_3 PBr_3 F_2Se



3. Where are all the first elements located on the periodic table (red symbols)? What "classification" would you give these elements?

4. Where are all the second elements located on the periodic table (black symbols)? What "classification" would you give these elements?

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5. Model 1 substances are called ionic compounds and Model 2 substances are called covalent particles. Write a simple rule that will allow you to classify compounds as ionic or covalent on the basis of what you have learned from the model.

6. Did the subscripts (the little numbers shown in the compound formulas) provide any insight into determining whether a substance is ionic or covalent? Why or why not?

7. Fill in the following tables identifying the type of element present in the substance. Use "M" for metal, and "NM" for non-metal.

Formula	1ST Element (M or NM)	2ND Element (M or NM)	Ionic or Covalent?
NaBr			
SF_6			
$CoBr_2$			
BaS			
NO_2			
C_6H_6			
$CrCl_3$			
CO_2			
MnO_2			
$PbCl_2$			
OF_2			

8. What did you notice about the second element in each compound?

9. How do chemists write chemical formulas?

metal then nonmetal nonmetal then metal

Bonds Activity

SEP: Analyzing and Interpreting Data CCC: Patterns

Focus Question: What conductivity and solubility properties does household bleach have?

Pre-Activity Questions:

1. Under what conditions will the light bulb light?

2. Does pure water light the light bulb? Why?

Procedure: Your teacher will demonstrate several qualitative properties of various compounds. As tests are performed, record the results in your data table.

Chemical	Phase (S, L, or G?)	Melting point (ºC)	Initial Conductivity	Solubility (Y or N?)	Aqueous conductivity
Salt		801			
Sugar		186			
Oil		-33			
Acetone		-95			
Baking soda		50			
Starch		none			
Vinegar		16			
Rock Salt		772			

Analysis Questions:

1. Salt is known as sodium chloride and is an **ionic** substance because it contains a metal (sodium) and a nonmetal (chlorine). It is not always easy to determine the types of elements in a compound based on the name. Summarize the properties of sodium chloride that were tested in the activity which make it **ionic**.

2. Based on the properties you listed in question 1, record 3 other substances used in this activity that are **ionic**.

3. The substances that are not ionic in this activity are **covalent**. List the 4 remaining chemicals and explain their common properties.
    a. Substances:

    b. Properties:

4. Water is a **polar** compound because its structure is asymmetrical (it seems that there are two distinct and different sides of the molecule). Covalent substances that dissolve in water are also considered polar. Determine which 2 **covalent** substances that we tested are polar.

5. The rest of the **covalent** compounds are **nonpolar**. List the remaining 2 **covalent** substances and explain why they are **nonpolar**.

6. The melting points of the **ionic** compounds are much higher than those of the **covalent** compounds. What does this imply about the strength of ionic and covalent bonds?

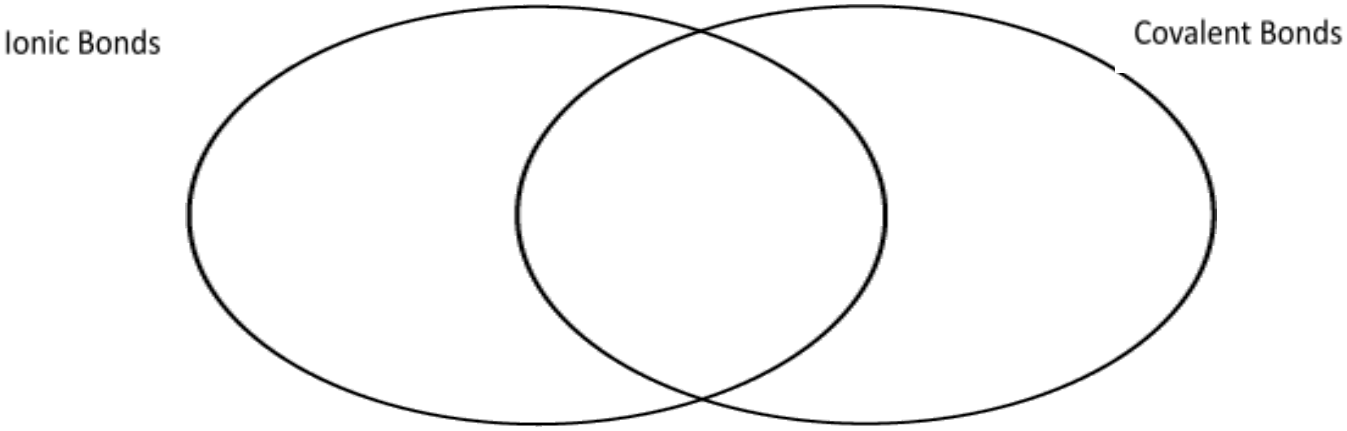
7. Explain in terms of particles why **ionic** compounds can conduct electricity while **covalent** compounds cannot.

8. Construct a claim that answers the Focus question: “What conductivity and solubility properties does household bleach have?” Bleach is an ionic substance. Provide evidence that supports your claim. Use your reasoning skills to explain why your evidence is relevant.

Types of Bonds Check Your Understanding

SEP: Analyzing and Interpreting Data CCC: Patterns

1. Complete the Venn diagram below with properties of ionic and Covalent Bonds:



2. Use information in the table below to identify each compound as Ionic or Covalent Compounds.

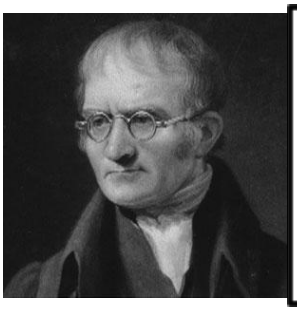
Compound	Phase	Conductivity as a pure solid	Conductivity as a liquid	Melting Point	Ionic or Covalent
A	solid	no	yes	1049°C	
B	solid	no	no	223°C	
C	liquid	no	no	20°C	
D	solid	no	yes	378°C	
E	liquid	no	no	-94°C	
F	solid	no	yes	650°C	

3. The major components distributed throughout the ocean that makes the ocean taste "salty" are NaCl, $MgCl_2$, and CaS. Explain what types of bonds and properties these substances have.

4. Waves and tides mix the ocean water together constantly , however, if oil is spilled in the ocean it does not mix well. What bonds must the oil have?

Dalton's Formulas of Compounds Part I Think Tank

SEP: Analyzing and Interpreting Data CCC: Patterns



Law of Definite Proportions: Every chemical compound contains fixed and constant proportions (by mass) of its constituent elements. Although many experimenters had long assumed the truth of the principle in general, the French chemist Joseph-Louis Proust first accumulated conclusive evidence for it in a series of researches on the composition of many substances, especially the oxides of iron (1797). The principle was then concretely formulated by the English chemist John Dalton in his chemical atomic theory (1808).

1. Table sugar is a compound known as sucrose. Sucrose is composed of the elements carbon, hydrogen, and oxygen. Analysis of a 20.0 g of sucrose from a bag of sugar finds that the sugar is composed of 8.44 g of carbon, 1.30 g of hydrogen, and 10.26 g of oxygen.
    a. Express, as fractions, the ratio of the mass of each element to the total mass of the sample.

    b. Using these ratios, calculate the percent composition by mass of each element in the compound.

2. A similar chemical analysis is performed on a 500.0 g sample of the sugar isolated from a sample of pure sugar cane. Analysis shows this sample contains 211.0 g of carbon, 32.5 g of hydrogen, and 256.5 g of oxygen.
    a. Determine the percent composition by mass of each element in the sugar cane sample.

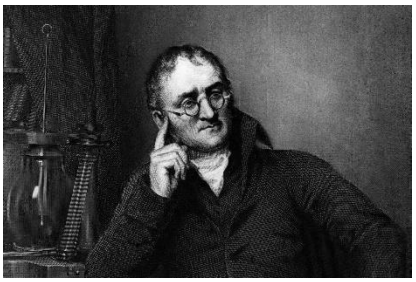
    b. Could the sugar in this sample be sucrose? Justify your conclusion.

3. A similar chemical analysis is performed on a 200.0g sample of the sugar found in corn syrup. This sample contains 80.0g of carbon, 13.3 g of hydrogen and 106.7 g of oxygen.
    a. Determine the percent composition by mass of each element in the sugar cane sample.

    b. Could the sugar in corn syrup be sucrose? Justify your conclusion.

Dalton's Formulas of Compounds Part II Think Tank

SEP: Using Mathematics CCC: Patterns



Law of multiple proportions: When two elements combine with each other to form more than one compound, the masses of one element that combine with a fixed mass of the other are in a ratio of small whole numbers. The law was announced in 1803 by the English chemist John Dalton, and its confirmation for a wide range of compounds.

Use the following information about the masses of elements in each of the compounds to help you suggest formulas that account for these ratios. For each trial Dalton would keep the mass of carbon fixed and identify how much oxygen completely reacted (with nothing left over).

Trial	Mass of Carbon **Used**	Mass of Oxygen **Added**	Mass of Oxygen **Left over**	Mass of Oxygen **Reacted**	**Ratio:** $\frac{\text{mass O}}{\text{mass C}}$
A	1.00g	10.00g	8.67g		
B	1.00g	10.00g	7.34g		
C	2.00g	10.00g	7.34g		
D	2.00g	10.00g	4.68g		
E	27.3g	100.00g	27.30g		
F	27.3g	100.00g	63.70g		
G	42.9g	200.00g	142.90g		
H	42.9g	200.00g	85.90g		

1. Calculate the mass of Oxygen that reacted in each Trial.
2. Reduce all of the compound data to a decimal ratio of mass O/mass C.
3. Dalton concluded that there are two types of compounds formed between carbon and oxygen. What evidence from your work aligns with his conclusion?

4. Express these two compound ratios as improper fractions and label them with O and C.

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5. Dalton identified two hypotheses for why the C and O reacted in these ratios. For each hypothesis, sketch particle diagrams for the compounds of A and B that account for these mass ratios. Write the formula for the compound in each diagram.

	Hypothesis 1	**Hypothesis 2**
	Particles of C and O have the same mass	Particles of O are heavier than C particles by the ratio in compound A.
	A	A
	B	B

6. Based on your knowledge of density and mass, which hypothesis seems correct?

7. Is this relationship between Carbon and Oxygen qualitative or quantitative? How is this different from other work done during this time of alchemy?

Dalton continued his work with Copper and Oxygen shown below.

Trial	Mass of Copper used	Mass of Oxygen reacted	Ratio: $\frac{\text{mass Cu}}{\text{mass O}}$
A	10.00g	2.50g	
B	10.00g	1.25g	
C	80.0g	20.0g	
D	80.0g	10.0g	

8. How many types of compounds are formed between Cu and O?

9. Using the hypothesis selected above, what are the formulas of the two new compounds identified?

More work is done with nitrogen and oxygen, shown below.

Trial	Mass of Nitrogen used	Mass of Oxygen reacted	Formula
A	14.0g	8.00g	
B	14.0g	16.0g	NO
C	14.0g	24.0g	
D	14.0g	32.0g	
E	14.0g	40.0g	

10. Identify the pattern of mass that reacted with Nitrogen. Can any of these be the same compound?

11. How many compounds of Nitrogen and Oxygen did he form?

12. If trial B represents NO how do the masses of individual N and O atoms compare?

13. Identify the other formulas of the compounds in the chart above.

Dalton's Formulas Check Your Understanding

SEP: Using Mathematics CCC: Patterns

Dalton identified two different compounds of copper chloride:
Compound A: 35.9 g of Cl / 64.1 g of Cu
Compound B: 52.8 g of Cl / 47.2 g Cu

1. Determine the value of the ratio $\frac{\text{mass Cl}}{\text{mass Cu}}$ in each compound. A _____ B _____

2. How does the mass ratio for compound B compare to that in compound A?

3. What are the simplest formulas for compounds A and B? Explain your reasoning.

Dalton identified two different compounds of iron chloride:
Compound A: 56.0 g of Cl / 44.0 g of Fe
Compound B: 65.6 g of Cl / 34.4 g of Fe

4. Determine the value of the ratio $\frac{\text{mass Cl}}{\text{mass Fe}}$ in each compound. A _____ B _____

5. The ratios you determined in step (a) give the mass of Cl that combines with 1 g of Fe in each compound. To determine how the mass of Cl in compound B compares to the mass of Cl in compound A for the same amount of Fe, divide these ratios and express the answer as an improper fraction. What does this fraction tell you about the *number* of Cl particles in each of the two compounds?

6. What would be the formulas of the two compounds, assuming that each compound contains one particle of Fe?

A 1.0 g sample of hydrogen reacts completely with 19.0 g of fluorine to form a compound of hydrogen and fluorine.

7. What is the percent by mass of each element in the compound?

8. What mass of hydrogen would be present in a 50 g sample of this compound? Justify your answer.

9. Explain how the previous examples help to illustrate the Law of Definite Proportions.

Two compounds of hydrogen and oxygen are tested. Compound I contains 15.0 g of hydrogen and 120.0 g of oxygen. Compound II contains 2.0 g of hydrogen and 32.0 g of oxygen.

10. Determine the ratio of the mass of oxygen to the mass of hydrogen in each of the compounds.

11. How do we know these are not the same compounds?

12. What is significant about these mass ratios?

13. If compound I is water, what could be the formula of compound II?

Nitrogen and oxygen combine to form a variety of compounds. The following data were collected for three different compounds of nitrogen and oxygen:

Analysis Data of Nitrogen & Oxygen Compounds	
Compound	Mass of Nitrogen that combines with 1.00 g of Oxygen
A	1.750 g
B	0.8750 g
C	0.4375 g

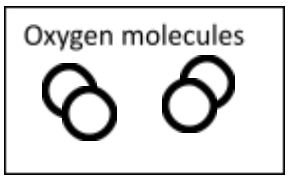
14. Additional evidence shows that the formula of compound B is NO. Sketch particle diagrams of particles of all three compounds. Justify your representations above.

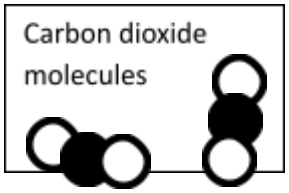
Types of Particles Think Tank

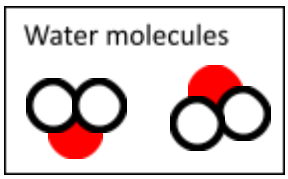
SEP: Models CCC: Patterns

1. John Dalton defined an **atom** as a one singular particle, the smallest form of matter that retains its physical and chemical properties. Would atoms represent elements or compounds?

2. A **molecule** is defined as two or more atoms combined together in a fixed ratio (preferably with covalent bonds) that can be decomposed into smaller atoms. The molecule has different physical and chemical properties than the individual atoms.
   a. Observe examples of molecules below. Decide if these represent examples of elements or compounds.







   b. Using the examples above as evidence, would molecules represent elements or compounds?

3. A collection of sodium (Na) particles are lustrous, malleable, ductile, and conduct electricity. A collection of chlorine (Cl_2) particles are green, poisonous, gaseous, and do not conduct electricity. If combined, the sodium and chlorine bond to create sodium chloride, NaCl, also known as household salt.
   a. Draw models to represent the before and after particle diagrams of sodium and chlorine reacting to form table salt. Label each diagram as elements, compounds, atoms, and/or molecules.

Sodium	Chlorine	Table Salt

   b. Did the particles retain the same physical and chemical properties as they changed from sodium and chlorine to salt? Defend your answer with evidence.

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Sticky Tape Activity

SEP: Develop and Use Models CCC:Structure and Function

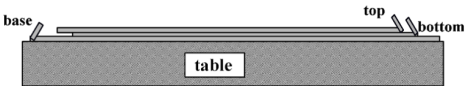
Focus Question: So far we know that elements combine in fixed ratios but what holds them together?

Pre-Activity Questions:

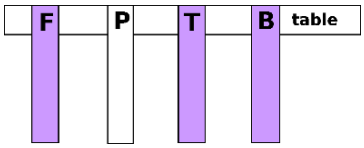
1. John Dalton's model of the atom was known as the "billiard ball model" because he defined atoms as tiny indivisible spherical objects that cannot be divided any further. Draw his model of the atom.

2. What characteristic might be added to Dalton's model to allow it to explain, at the particle level, static electricity?

3. What evidence do you have that the behavior of electrical forces varies among metals, nonmetals, and metalloids?



Part 1: Measure an approximately 15 cm length of transparent tape. Make a handle on one end by folding under the first 1 cm of tape, sticky side to sticky side. Place this tape flat on the lab table, sticky side down. This is the base tape. Measure a second approximately 15 cm length of transparent tape, make a handle as before, and place this tape on top of the base tape, sticky side down, with the handle at the opposite end from the handle on the base tape. Label this tape "B" for bottom tape using a pen or a permanent marker. Attach a third similarly prepared strip of tape onto the bottom tape. The handle for the third tape should be at the same end as the bottom (B) tape. Label this tape "T" for top tape. Repeat steps 1 through 3 above twice, placing the second set of tapes about 5 cm from the first set.



Obtain 2 pieces of aluminum foil and 2 pieces of paper. Hang 1 piece of foil and 1 piece of paper from the edge of the table using tape (see illustration). Keep other paper and foil to the side, on your table. Peel one set of T and B tapes from its base tape, keeping the T and B tapes together. Run your finger down the non-sticky side and then quickly peel the T and B tapes apart. Hang the T and B tapes next to the hanging foil and paper on the edge of the table. Repeat with the other set of tapes (peel T and B together from the base tape and then peel T and B apart). Keep this second T tape in one hand and the B tape in another.

4. **Foil to Foil.** Investigate the interactions between these two substances by approaching the hanging piece of foil with the other piece of foil held in one hand. Does foil have strong forces of attraction or repulsion with other foil?
5. **Paper to Paper.** Repeat the foil process but with paper. Does paper have strong forces of attraction or repulsion with other paper?
6. **Foil and Paper.** Use this same approach to investigate interactions between the two different substances. Does paper have strong forces of attraction or repulsion with foil?
7. Initially, what evidence do we have to support Dalton's model of the atom?

8. **Top tape:** Holding a Top tape in one hand, observe how the top tape behaves around the hanging top tape and bottom tape. Record observations below:
   Top Tape: Bottom Tape:

9. **Bottom tape:** Holding a Bottom tape in one hand, observe how the top tape behaves around the hanging top tape and bottom tape. Record observations below:
   Top Tape: Bottom Tape:

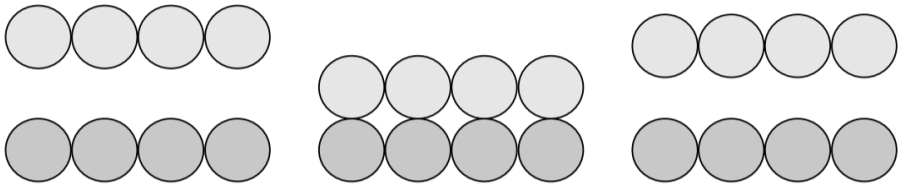
10. What evidence did we gather after we pulled the tape apart that refutes Dalton's model of the atom?

11. We know that opposite charges attract and like repel.
    a. How might something become charged?

    b. What might neutral mean in terms of charged particles?

    c. At a tape manufacturing company, the tape is produced in one long layer and later coiled on top of one another in the dispensers. In the initial manufacturing, the tape in one layer is neutral. What action made the tape gain charges?

12. On a whiteboard draw a model at the particle level of the two pieces of tape as they are layered. "Before adhesion" is the initial manufactured tape, "in contact" is when it is coiled in the dispense. "Seperated" represents after the tape was separated into top and bottom tape. Be sure that your model accounts for conservation of mass and charge. Then draw a consensus model below.



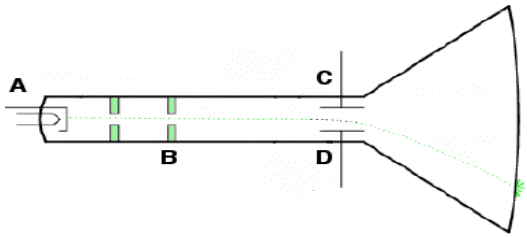
13. Explain the interaction of the two Top tapes in terms of attractive and repulsive forces and electrical charges.

14. Explain the interaction of the two Bottom tapes in terms of attractive and repulsive forces and electrical charges.

15. Explain the interaction of the Top tape and Bottom tape in terms of attractive and repulsive forces and electrical charges.

Part 2: Thomson's Model and Sticky Tape: ***Watch the video on Thompson's Model before you move on to Part 2.***

Let's see how we can use Thomson's model to explain the behavior of the sticky tape when we made our tape stacks. A diagram of the cathode ray tube is represented below. **A** is the anode, which is the negative terminal. **B** are the alignment rods to control the path of the subatomic particle that Thompson discovered. **C** is a negative magnetic plate and **D** is a positive magnetic plate.



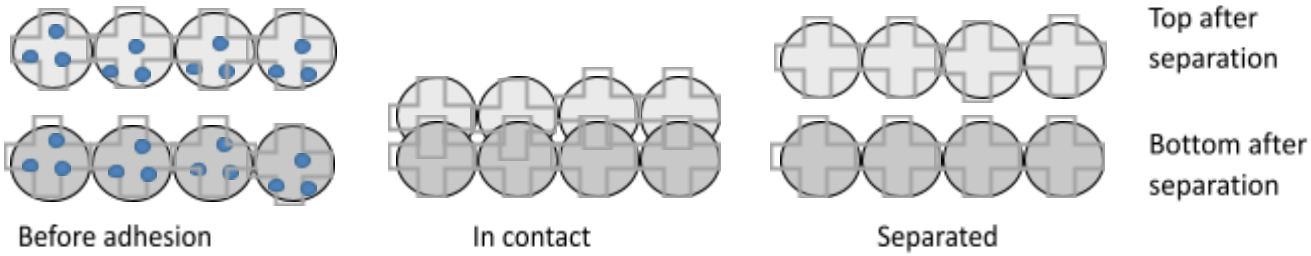
1. Based on your knowledge of chemistry, label the charges of **A**, **C** and **D** as positive or negative on the diagram. Then label the subatomic particle that is coming from the source, **A**.
2. Which subatomic particle was identified during the cathode ray tube experiment?

3. What is the charge of that subatomic particle?

4. If the atom is neutral, what additional charge must be in the atom besides the charge of the subatomic particle you identified above?

5. Which charges are able to move in an atom? Which are stationary?

6. On a whiteboard re-draw a model at the particle level of the two pieces of tape as they approach one another. Be sure that your model accounts for conservation of mass and charge.

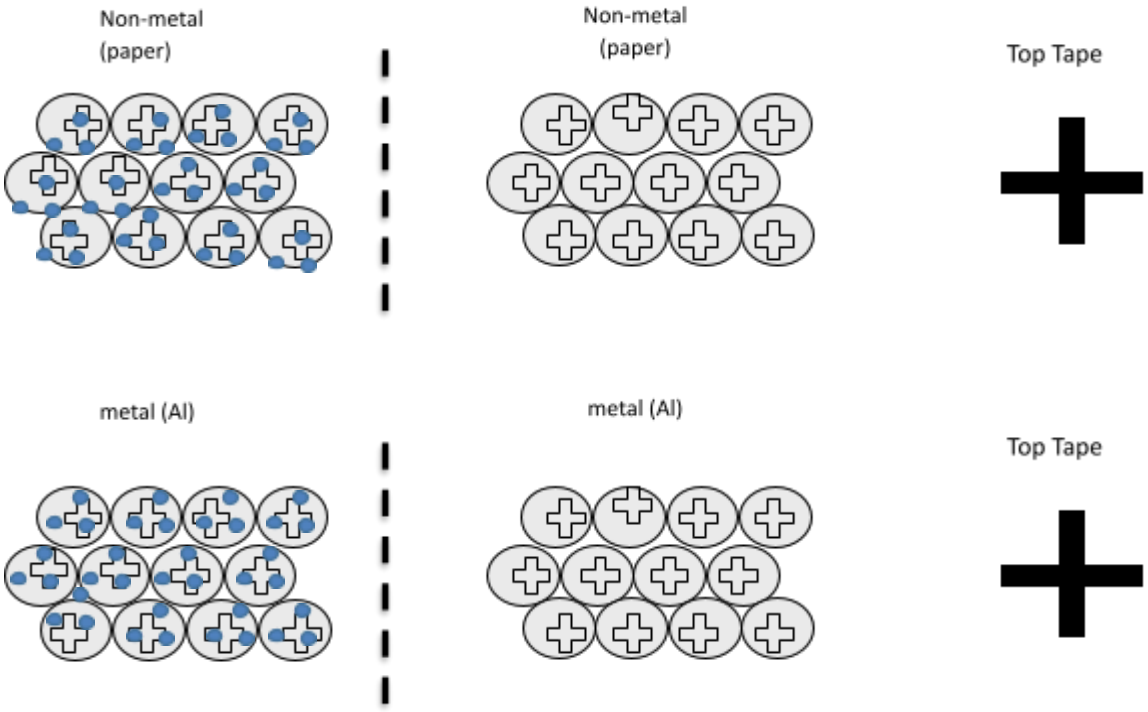


7. Explain your model in terms of movement of particles, attractive, and repulsive forces.

8. **Top tape with Paper and Foil:** Holding a Top tape in one hand, observe how the top tape behaves around the hanging paper and foil. Record observations below.
   Paper: Foil:

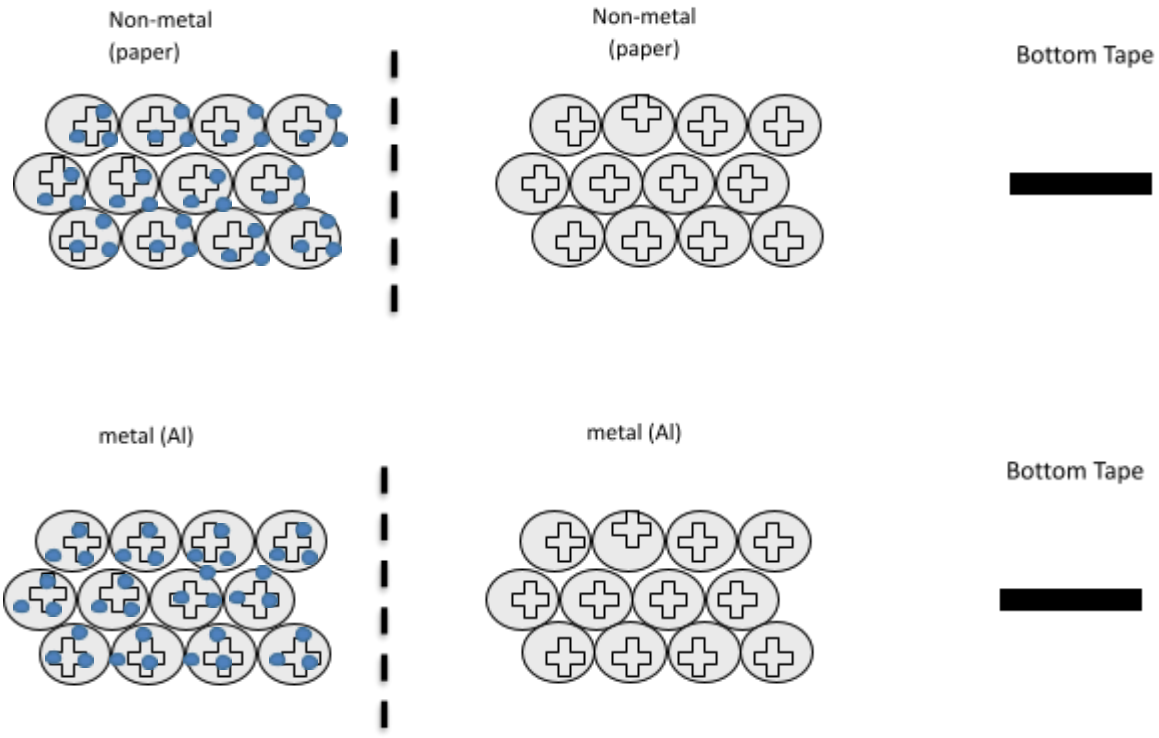
9. **Bottom tape with Paper and Foil:** Holding a Bottom tape in one hand, observe how the top tape behaves around the hanging paper and foil. Record observations below.
   Paper: Foil:

10. Several atoms from the paper and foil are drawn below. The ones on the left have no charged object near them. The ones on the right are next to a top tape (+ charge). Now draw the electrons in each atom to show their arrangements when a charged object is brought near. Consider how attractive each paper and foil was with the top tape.



11. Explain why these arrangements of electrons would produce the observed attractions.

12. Repeat your drawings above but for the negative bottom tape.



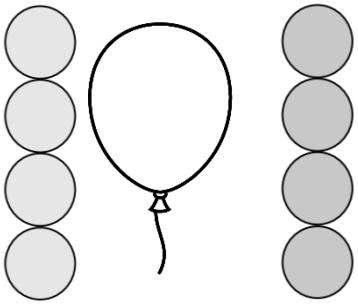
13. Explain why these arrangements of electrons would produce the observed attractions.

<u>Part 3: Balloon</u> Rub a balloon on your shirt or hair provided by your instructor to develop an electrical charge on the balloon. Investigate the interactions between the balloon and the paper and foil.

1. What happened to the balloon's charge before and after it was rubbed on the shirt/hair?

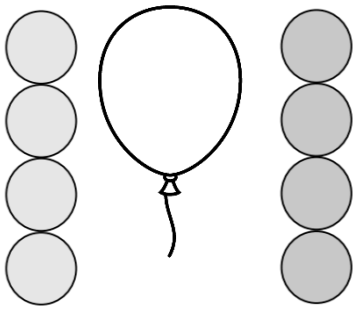
2. Student A hypothesized the balloon was positively charged when rubbed on their shirt. Draw how the balloon would interact with each tape by placing the charges in the balloon and tape. Explain the charges you selected.

   Top Tape Bottom Tape <u>Explain:</u>



3. Student B hypothesized the balloon was negatively charged when rubbed on their shirt. Draw how the balloon would interact with each tape by placing the charges in the balloon and tape. Explain the charges you selected.

Top Tape Bottom Tape Explain:

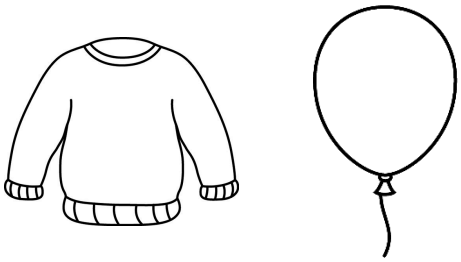


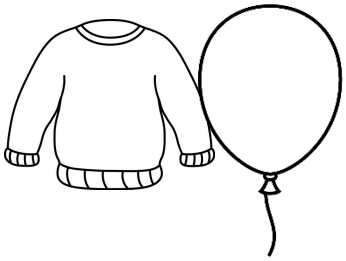
4. Based on your answer above, what charge did the balloon accrue as it was rubbed on a shirt?

5. Go to https://phet.colorado.edu/en/simulations/balloons-and-static-electricity and view the simulation. Choose "show all charges' and one balloon.

a. Rub the balloon on the sweater and describe what happens to the charges.

b. Draw a before and after model below:





c. Bring the balloon towards the wall and describe what happens to the charges.

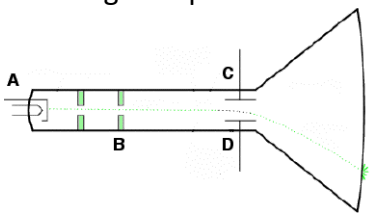
Thomson Model of the Atom: Think Tank Problems

SEP: Develop and Use Models CCC:Structure and Function

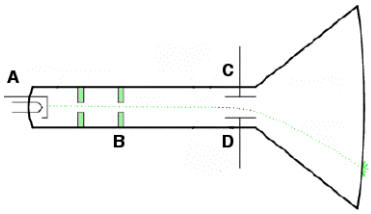


J. J. Thomson performed experiments in 1897 with cathode rays in an attempt to understand electricity – which was still a mystery in the late 1800s. State the conclusions Thomson drew from each of his famous cathode ray experiments:

1. **First Experiment**: Thomson turned on the cathode ray tube and observed a beam moving away from the negative plate (A) towards the positive plate. Label the positive and negative plates. Then draw a beam traveling across the tube to the other end.

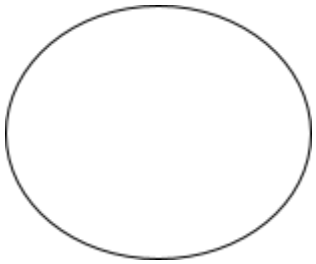


2. **Second Experiment**: Thomson repeated the experiment but brought a negative charge near point C and a positive charge near point D. Label those points and draw the direction of the ray that passed through the tube.



3. **Third Experiment**: Thomson did some careful measurements on how much the path of the cathode ray was bent in a magnetic field and how much energy they carried. He identified the ray to have no mass. What does that imply about the mass of each of the small particles inside that ray? Is the ray considered matter? What is wrong with this discovery?

4. **Thomson's Atomic Model**: From these experiments, Thomson developed the model of the atom known as the *Plum Pudding* model. Complete the atom drawing below to illustrate Thomson's plum pudding model. Explain how this fits with his observations.



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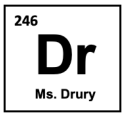
Ionic Compounds Think Tank Problems

SEP: Analyzing And Interpreting Data CCC: Patterns

Dalton determined that compounds form from individual atoms of elements in very specific and quantifiable whole number ratios. We will now examine the patterns that exist for the ratios in which these elements combine in order. Write the formula and draw **one formula unit** for each compound.

		a.	b.	c.	d.	e.	f.
1.	Atoms involved	1 lithium 1 fluorine	1 lithium 1 chlorine	2 lithium 1 oxygen	2 lithium 1 sulfur	3 lithium 1 nitrogen	3 lithium 1 phosphorus
	formula						
	particle diagram						
2.	Atoms involved	1 sodium 1 fluorine	1 sodium 1 chlorine	2 sodium 1 oxygen	2 sodium 1 sulfur	3 sodium 1 nitrogen	3 sodium 1 phosphorus
	formula						
	particle diagram						
3.	Atoms involved	1 magnesium 2 fluorine	1 magnesium 2 chlorine	1 magnesium 1 oxygen	1 magnesium 1 sulfur	3 magnesium 2 nitrogen	3 magnesium 2 phosphorus
	formula						
	particle diagram						
4.	Atoms involved	1 calcium 2 fluorine	1 calcium 2 chlorine	1 calcium 1 oxygen	1 calcium 1 sulfur	3 calcium 2 nitrogen	3 calcium 2 phosphorus
	formula						
	particle diagram						
5.	Atoms involved	1 gallium 3 fluorine	1 gallium 3 chlorine	2 gallium 3 oxygen	2 gallium 3 sulfur	1 gallium 1 nitrogen	1 gallium 1 phosphorus
	formula						
	particle diagram						
6.	Atoms involved	1 aluminum 3 fluorine	1 aluminum 3 chlorine	2 aluminum 3 oxygen	2 aluminum 3 sulfur	1 aluminum 1 nitrogen	1 aluminum 1 phosphorus
	formula						
	particle diagram						

7. What patterns do you find in the formulas of the compounds formed?
    a. Is there a relationship between question 1 and 2?



b. Is there a relationship between columns a and b?

c. What other relationship pairs are present?

8. Lithium and sodium are known as alkali metals because they react similarly. What other elements may react in the same ratios and Li and Na?

9. Magnesium and Calcium are known as alkaline earth metals because they react similarly. What other elements may react in the same ratios and Mg and Ca?

10. Fluorine and chlorine are known as halogens because they react similarly. What other elements may react in the same ratios and F and Cl?

11. Based on these patterns, predict the formulas of the compounds formed by the ions below and draw one formula unit.

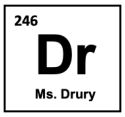
Atoms involved	**Ratio of ions in compound**					
	___ potassium ___ fluorine	___ potassium ___ chlorine	___ potassium ___ oxygen	___potassium ___ sulfur	___potassium ___ nitrogen	___potassium ___ phosphorous
formula						
Particle diagram						

Atoms involved	**Ratio of ions in compound**					
	___ beryllium ___ iodine	___ cesium ___ bromine	___ beryllium ___ selenium	___cesium ___ tellurium	___boron ___ iodine	___ cesium ___ phosphorous
formula						
Particle diagram						

12. How does a neutral atom become a positive ion (an atom with positive charge)?

13. How does a neutral atom become a negative ion (an atom with negative charge)?

14. Recall metals conduct electricity in all phases. Is this because the electrons were mobile or stationary?

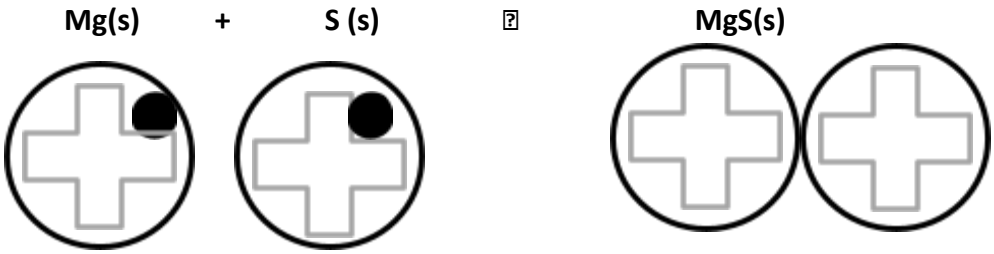


15. In ionic compounds, the metal particles tend to form positively charged ions (cations), while non-metal particles tend to form negatively charged ions (anions). However, when these same metal and non-metal particles are combined to form compounds they do not conduct electricity as solids. Use your evidence to explain why ions may conduct in the liquid phase and not in the solid phase. Draw a model to help your explanation.
16. Are all cations equal but oppositely charged from all anions? Use the ratio of metals to nonmetals observed in question 1 to help you answer this question.

17. Make the generalizations you can about the charge of the ions formed by elements in groups 1, 2, 13, 15, 16, and 17 based on the ratio of atoms in each of the compounds they form.

Hydrogen 1 H							Helium 2 He
	2A	3A	4A	5A	6A	7A	
Lithium 3 Li	Beryllium 4 Be	Boron 5 B	Carbon 6 C	Nitrogen 7 N	Oxygen 8 O	Fluorine 9 F	Neon 10 Ne
Sodium 11 Na_2S	Magnesium 12 Mg	Aluminum 13 Al	Silicon 14 Si	Phosphorus 15 P	Sulfur 16 Na_2S	Chlorine 17 Cl	Argon 18 Ar
Potassium 19 K	Calcium 20 Ca	Gallium 31 Ga	Germanium 32 Ge	Arsenic 33 As	Selenium 34 Se	Bromine 35 Br	Krypton 36 Kr

18. Complete the models below to show how neutral atoms transfer of electrons to form neutral compounds. Include the charges of the ions in the model of the compound. add additional models to show conservation of mass.



19. Create your own models to show how table salt is formed from Na and Cl_2.

Oxidation Numbers Check Your Understanding

SEP: Using Mathematics and Computational Thinking CCC: Patterns

Assign oxidation numbers to each element in the following:

1.	NaCl	Na___	Cl___	12.	CsF	Cs____	F____
2.	Fr_2S	Fr___	S___	13.	KCl	K ____	Cl____
3.	Rb_2O	Rb___	O ___	14.	K_2O	K ____	O____
4.	CaO	Ca ___	O___	15.	LiI	Li ____	I____
5.	KI	K___	I___	16.	NaBr	Na ____	Br____
6.	AlP	Al___	P___	17.	$BaBr_2$	Ba___	Br___
7.	$MgCl_2$	Mg___	Cl___	18.	Al_2O_3	Al___	O___
8.	BeO	Be____	O____	19.	RaTe	Ra___	Te___
9.	Na_3P	Na___	P___	20.	Ga_2Se_3	Ga___	Se___
10.	SrF_2	Sr____	F ____	21.	Ca_3N_2	Ca___	N___
11.	$AlCl_3$	Al____	Cl____	22.	SrI_2	Sr___	I___

23. What similarities do all first elements have in common above?

24. What similarities do all second elements have in common above?

25. For each of the following, determine the charge and group of unknown element M.
    MCl_2 MS M_2O_3 MF_3 MP M_3N

26. For each of the following, determine the charge and group of unknown element X.
    LiX Na_2X CaX K_3X Mg_3X_2 AlX

27. What is the name given to all metals with a +1 oxidation state?

28. What is the name given to all metals with a +2 oxidation state?

29. What is the name given to all nonmetals with a -1 oxidation state?

30. If an element is not bonded, what is the charge?

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REDOX Reactions Think Tank Problems

SEP: Using Mathematics and Computational Thinking CCC: Cause and Effect

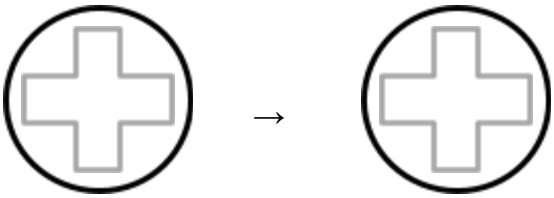
A redox reaction is a reaction in which electrons are transferred from one element to another. The reaction involves at least two elements, one that will give up an electron, and one that will receive that electron. The term redox comes from two words, "reduction" and "oxidation." If something is oxidized, it "burns" in oxygen, as shown below:

$$\mathbf{Mg(s) + O(g) \rightarrow Mg^{+2} + O^{-2} \rightarrow MgO(s)}$$

1. What are the charges of Magnesium and Oxygen before the reaction takes place?

2. What can be said about the amount of positive charge and negative charge inside the atoms of Magnesium and Oxygen reactants?

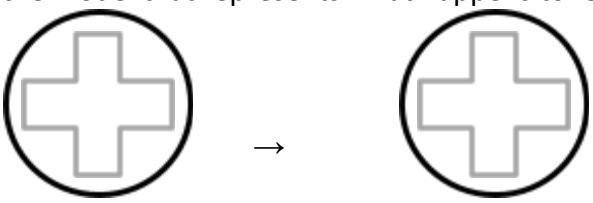
3. Complete the model that represents what happens to Mg when it changes into the Mg^{+2} ion.



4. Mg was **"oxidized"** by the oxygen. What is the definition of oxidation in terms of
   a. charge:

   b. electrons:

5. Complete the model that represents what happens to O when it changes into the Mg^{-2} ion.



6. O was **"reduced"** by the magnesium. What is the definition of reduction in terms of
   a. charge:

   b. electrons:

A simple way to remember this is to remember that **LEO the lion goes GER**.

LEO = loss of electrons is oxidation.

GER = gain of electrons is reduction.

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A half reaction shows either the oxidation or reduction portion of a redox equation including if the electrons are gained or lost. A reduction half reaction shows an atom or ion gaining one of more e^-:

$O + 2e^- \rightarrow O^{-2}$ **Notice that the e^- is on the left.**

An oxidation half reaction shows an atom or ion losing one or more e-:

$Mg \rightarrow Mg^{2+} + 2\ e^-$ **Notice that the e^- is on the right.**

7. What do all of these oxidation number changes have in common? Do they increase or decrease? Do they represent oxidation or reduction?

   $F^0 \rightarrow F^{-1}$ $N^0 \rightarrow N^{-2}$ $Cr^{+5} \rightarrow Cr^0$ $Mn^{+7} \rightarrow Mn^0$ $Fe^{+2} \rightarrow Fe^0$

8. What do all of these oxidation number changes have in common? Do they increase or decrease? Do they represent oxidation or reduction?

   $Cr^0 \rightarrow Cr^{+4}$ $Mn^0 \rightarrow Mn^{+7}$ $F^{-1} \rightarrow F^0$ $N^{-3} \rightarrow N^0$ $O^{-2} \rightarrow O^0$

9. For the following examples, determine if they represent oxidation or reduction.

   a. $3e^- + Cr^{+3} \rightarrow Cr$
   b. $5e^- + Mn^{+5} \rightarrow Mn$
   c. $Mg^{+2} + 2e^- \rightarrow Mg$
   d. $K \rightarrow e^- + K^{+1}$
   e. $2e^- + Cu^{+2} \rightarrow Cu$
   f. $Al \rightarrow Al^{+3} + 3e^-$
   g. $Li^+ + e^- \rightarrow Li$
   h. $S^{-2} \rightarrow 2e^- + S$

10. For the following examples, add in the e- to balance the charge.

    a. $Cr^{+5} \rightarrow Cr$
    b. $Mn \rightarrow Mn^{+7}$
    c. $Ca^{+2} \rightarrow Ca$
    d. $Rb \rightarrow Rb^{+1}$
    e. $P \rightarrow P^{-3}$
    f. $S \rightarrow S^{-2}$
    g. $N^{-3} \rightarrow N$
    h. $Te^{-2} \rightarrow Te$

11. In these full reactions, indicate which element is being oxidized, and which is being reduced.

    a. $Cr + Fe^{2+} \rightarrow Cr^{2+} + Fe$

    b. $4F + 2O^{2-} \rightarrow 4F^{-1} + O_2$

12. In these full reactions, add oxidation numbers and indicate which element is being oxidized, and which is being reduced.

    a. $Li_2O \rightarrow Li + O_2$

    b. $Cl_2 + KBr \rightarrow KCl + Br_2$

13. In the following examples, provide evidence that either supports or denies that electrons have been transferred during the reaction:

    a. $2Ca + O_2 \rightarrow 2CaO$

    b. $2LiCl + CaO \rightarrow CaCl_2 + Li_2O$

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Activity Series Activity

SEP: Carrying Out Investigations CCC: Patterns

Focus Question: Are all metals equally reactive?

Pre-activity Questions:

1. When a pure metal atom reacts, do they tend to undergo oxidation or reduction? Explain in terms of electrons.

2. Write a balanced half reaction for an magnesium atom becoming an magnesium ion.

Procedure: Go to https://teachchemistry.org/classroom-resources/metals-in-aqueous-solutions-simulation and click activity one. Test each metal in the solutions and record R for a reaction and NR for no reaction. Record any observation about the reaction that you observe.

	Mg^{+2} solution	Zn^{+2} solution	Cu^{+2} solution	Ag^{+1} solution
Mg				
Zn				
Cu				
Ag				

Post-activity Questions:

1. Did the metals react in a solution of the same metal? For example, did Zn react in Zn^{+2} solution? Explain why this pattern exists in terms of transferring electrons.

2. Explain what is happening between the Mg metal and the Zn^{+2} solution that is causing a chemical change to be observed.

3. Rank the metals in order from least reactive to most reactive and explain your ranking.

4. Provide evidence that demonstrates how electrons have been transferred between the silver solution and zinc metal.

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Spontaneous Reactions and Activity Series Formulas Think Tank Problems

SEP: Asking Questions CCC: Cause and Effect

Iron is one substance which is used in abundance on the ship. A ship is continuously in contact with water and moisture-laden winds which makes it highly susceptible to corrosion (rust).

1. Write the oxidation half reaction for metallic iron becoming iron (II) ion.

2. What happens to the phase of iron as it rusts?

3. What happens to the mass of iron remaining on the boat as it rusts?



It is for this reason **sacrificial anodes** are used to protect the parent material. Another metal, such as zinc, is drilled into the ship to oxidize instead of the iron. The anode is the metal electrode where oxidation takes place.

4. Why would zinc be placed as the sacrificial anode? What does that mean the zinc will do?

5. Provide evidence that zinc will exchange electrons as a sacrificial anode in an iron boat.

6. Compare the location and reactivity of zinc and iron on the activity series.

7. What other metals could be used as a sacrificial anode on an iron boat?

8. What metals could be used as a sacrificial anode on an aluminum boat?

9. Why would the sacrificial anode need to be replaced after a few years?

10. When storing jewelry, do not place gold and silver jewelry near aluminum and other "cheaper" jewelry in an environment known to have high humidity. Explain your answer.

Activity Series**

Most Active	Metals	Nonmetals	Most Active
	Li	F_2	
	Rb	Cl_2	
	K	Br_2	
	Cs	I_2	
	Ba		
	Sr		
	Ca		
	Na		
	Mg		
	Al		
	Ti		
	Mn		
	Zn		
	Cr		
	Fe		
	Co		
	Ni		
	Sn		
	Pb		
	H_2		
	Cu		
	Ag		
Least Active	Au		Least Active

**Activity Series is based on the hydrogen standard. H_2 is *not* a metal.

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Formulas of Binary Ionic Compounds Think Tank Problems

SEP: Communicating Information CCC:Patterns

Look at the formulas and corresponding names of various ionic compounds. What naming rules can you infer with these examples?

Sodium fluoride	**NaF**	**Calcium iodide**	**CaI_2**
Lithium chloride	**LiCl**	**Magnesium bromide**	**$MgBr_2$**
Potassium Bromide	**KBr**	**Aluminum oxide**	**Al_2O_3**
Cesium Iodide	**CsI**	**Beryllium Phosphide**	**Be_3P_2**

1. What type of element is always written first in the formula?
2. What type of element is always written second in the formula?
3. How many elements are present in these compounds?
4. How do all of these names end?
5. Did the subscripts influence the names of the formulas?
6. Based on your knowledge of chemistry so far, where do the subscripts come from?

Formulas of Binary Ionic Compounds Check Your Understanding

7. Name the following compounds:

a. NaF _____ f. NaH _____

b. $MgCl_2$ _____ g. K_3P _____

c. Al_2O_3 _____ h. MgO _____

d. MgI_2 _____ i. Li_2Te _____

e. H_2O _____ j. $AlCl_3$ _____

8. Give the formula for the following compounds. One is provided for you.

	Cation charge	Anion Charge	Formula
Sodium chloride	Na^{+1}	Cl^{-1}	NaCl
Potassium oxide			
Lithium nitride			
Calcium bromide			
Magnesium sulfide			
Beryllium nitride			
Aluminum fluoride			
Aluminum oxide			

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RedOx Reaction Check Your Understanding

SEP: Using Mathematics and Computational Thinking CCC: Cause and Effect

1. In an oxidation-reduction reaction, reduction is defined as the
   (1) loss of mass (3) loss of electrons
   (2) gain of mass (4) gain of electrons

2. When a neutral atom undergoes oxidation, the atom's oxidation state
   (1) decreases as it gains electrons
   (2) decreases as it loses electrons
   (3) increases as it gains electrons
   (4) increases as it loses electrons

3. In a redox reaction, there is a conservation of
   (1) mass, only
   (2) both mass and charge
   (3) neither mass nor charge

4. In any redox reaction, the substance that undergoes reduction will
(1) lose e- & have a decrease in oxidation number
(2) lose e- & have an increase in oxidation number
(3) gain e- & have a decrease in oxidation number
(4) gain e- & have an increase in oxidation number

5. Given the reaction:

$$Mg(s) + 2\ H^+(aq) + 2\ Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq) + H_2(g)$$

Which species undergoes oxidation?
   (1) Mg(s) (3) $Cl^-(aq)$
   (2) $H^+(aq)$ (4) $H_2(g)$

6. Given the redox reaction:

$$Cr^{3+} + Al \rightarrow Cr + Al^{3+}$$

As the reaction takes place, there is a transfer of
   (1) electrons from Al to Cr^{3+}
   (2) electrons from Cr^{3+} to Al

7. Given the redox reaction:

$$2\ Fe^{3+} + 3\ Zn \rightarrow 2\ Fe + 3\ Zn^{2+}$$

As the reaction takes place, there is a transfer of electrons
   (1) from Fe^{3+} to Zn
   (2) from Zn to Fe^{3+}
   (3) from Zn^{2+} to Fe
   (4) from Fe to Zn^{2+}

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8. Circle the electrons in the half-reactions below and identify as oxidation or reduction.

(a) $Br_2 + 2\ e^- \rightarrow 2\ Br^-$

(b) $Na \rightarrow Na^+ + e^-$

(c) $Ca^{2+} + 2e^- \rightarrow Ca$

(d) $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$

(e) $Na^+ + e^- \rightarrow Na$

(f) $S^{2-} \rightarrow S + 2e^-$

(g) $Cu^{2+} + 2\ e^- \rightarrow Cu$

(h) $Fe \rightarrow Fe^{2+} + 2\ e^-$

(i) $Mn^{7+} + 7\ e^- \rightarrow Mn^0$

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9. Complete the half-reactions below by ADDING in electrons to the correct side in order to equalize charge (show conservation of charge).

(a) $Fe^{2+} \rightarrow Fe^{3+}$
(b) $K \rightarrow K^{+}$
(c) $Sn^{4+} \rightarrow Sn$
(d) $Cr^{6+} \rightarrow Cr$
(e) $Mn^{3+} \rightarrow Mn$
(f) $Cr \rightarrow Cr^{3+}$
(g) $Cl^{7+} \rightarrow Cl$

10. Which half-reaction correctly represents oxidation?

(1) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^{-}$
(2) $Fe^{2+}(aq) \rightarrow Fe(s) + 2e^{-}$
(3) $Fe(s) + 2e^{-} \rightarrow Fe^{2+}(aq)$
(4) $Fe^{2+}(aq) + 2e^{-} \rightarrow Fe(s)$

11. Given the balanced ionic equation:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Which equation represents the oxidation half-reaction?

(1) $Zn(s) + 2e^{-} \rightarrow Zn^{2+}(aq)$
(2) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$
(3) $Cu^{2+}(aq) \rightarrow Cu(s) + 2e^{-}$
(4) $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$

12. Which half-reaction equation represents the reduction of a potassium ion?

(1) $K^{+} + e^{-} \rightarrow K$
(2) $K + e^{-} \rightarrow K^{+}$
(3) $K^{+} \rightarrow K + e^{-}$
(4) $K \rightarrow K^{+} + e^{-}$

13. Given the equation:

$$2\ Al + 3\ Cu^{2+} \rightarrow 2\ Al^{3+} + 3\ Cu$$

The reduction half-reaction is

(1) $Al \rightarrow Al^{3+} + 3e^{-}$
(2) $Cu^{2+} + 2e^{-} \rightarrow Cu$
(3) $Al + 3e^{-} \rightarrow Al^{3+}$
(4) $Cu^{2+} \rightarrow Cu + 2e^{-}$

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14. Base your answers to the questions below on the following redox reaction, which occurs in a battery.

$$Zn + Cr^{3+} \rightarrow Zn^{2+} + Cr$$

(a) Write the half-reaction for the reduction that occurs.

(b) Write the half-reaction for the oxidation that occurs.

(c) Which species loses electrons and which species gains electrons?

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15. The outer structure of the Statue of Liberty is made of copper metal. The framework is made of iron. Over time, a thin green layer (patina) forms on the copper surface.

(a) When copper oxidized to form this patina layer, the copper atoms became copper(II) ions (Cu^{2+}). Write a balanced half-reaction for this oxidation of copper.

(b) Where the iron framework came in contact with the copper surface, a reaction occurred in which iron was oxidized. Explain in terms of chemical reactivity why iron was oxidized.

Matter Activity

SEP: Obtaining Information CCC: Patterns

	Common Name	Chemistry Name	Chemistry Formula	Additional Observations	Homogeneous or Heterogeneous	Particle Diagram
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						

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Analysis Questions:

1. Which of the samples observed were elements?

2. How could you tell a sample is an element based on names and formulas?

3. How could you tell a sample is an element based on particle diagrams?

4. Which of the samples observed were compounds?

5. How could you tell a sample is a compound based on names and formulas?

6. How could you tell a sample is a compound based on particle diagrams?

7. Why are elements and compounds considered **pure substances**?

8. Which of the samples observed were mixtures?

9. How could you tell a sample is a mixture based on names and formulas?

10. How could you tell a sample is a mixture based on particle diagrams?

11. What is the only classification that can be heterogeneous?

12. How do you know the difference between a homogeneous and heterogeneous mixture?

13. Did phases help you decide if something was an element, compound, or mixture?

Intermolecular Forces of Attraction Lab

SEP: Constructing Explanations CCC: Cause and Effect

Focus Question: We now know how elements stick together to form compounds but, how do other materials stick together?

Pre-lab questions:

1. Define intermolecular forces (IMF) of attraction.

2. Which phase implies the substance has the most IMFs?

3. Explain polarity in terms of charges and attraction.

4. Look at the following options to draw water particle diagrams. Which could show that the water is "polar"? Explain your answers.



5. Explain the rule of "like dissolves like" in terms of polar and nonpolar substances.

Procedure/Data: You must write down observations, data, and models from each lab station and complete that station's questions. **Clean up each lab station before going to the next station.**

1. In a petri dish, pour enough water to fill the left half of the dish. Fill the other side with mineral oil. Place one drop of food dye to the oil side. Then move that small bubble over to the water side.
    a. Record qualitative observations:

    b. Are the oil and dye attractive or repulsive?

    c. Are the water and dye attractive or repulsive?

    d. In terms of polarity, why doesn't the water and oil mix well?

    e. In terms of polarity, why does the food dye dissolve in one solvent and not the other?

2. In a petri dish, add water until it is half full. Sprinkle pepper on the top of the water. Notice and write down if the pepper is sinking or floating. Add a few drops of liquid detergent (soap).
    a. Record qualitative observations:

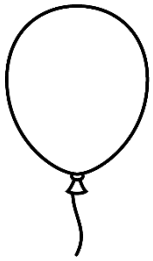
    b. Consider the fact that pepper is generally more dense than water and should sink. What does that imply about the strength of the intermolecular forces of attraction between water particles? Are they strong or weak?

    c. Explain what happened to the forces of attraction between water molecules when the detergent was added? Did they break or strengthen? How do you know?

    d. Make a claim to predict the polarity of the pepper flakes. Explain your claim.

3. Run the water in the faucet on a very low setting. Rub a balloon on someone in your group's clothing. Bring the balloon near the stream of water without getting the balloon wet.
    a. Record qualitative observations:

    b. Create a model to describe your observations of the balloon before it was rubbed, and the balloon after rubbing near the water.





    c. In terms of charges and charged particles, what happened when you were rubbing the balloon on your clothes?

    d. In terms of polarity and charges, why was the water attracted to the balloon?

4. Using a dropper, count and record how many drops of water fit on the head of a penny without spilling over. Repeat using mineral oil instead of water.
    a. Record qualitative observations:

    b. Which liquid has stronger intermolecular forces of attraction? Explain your claim.

    c. The detergent (soap) can be added to water and dropped onto a penny. Predict if the soapy water would accrue more drops, less drops, or the same number of drops on the penny than water and oil. Explain your answer.

5. In a petri dish, add acetone until about 1/3 of the dish is full. Then place in a piece of Styrofoam.
    a. Record qualitative observations:

    b. Normally styrofoam cups can be used to hold hot coffee/tea and other water based drinks. Is the styrofoam polar or nonpolar? Explain your choice.

    c. Is the acetone polar or nonpolar? Explain your choice.

6. Fill both beakers with approximately 25mL of water. In beaker 1 add one scoop of NH_4Cl and feel the outside of the beaker. In beaker 2 add one scoop of NaOH and feel the outside of the beaker.
    a. Record qualitative observations:

    b. In terms of heat, explain what type of reaction occurred when NH_4Cl dissolved in water.

    c. Were more forces broken or formed when NH_4Cl dissolved in water? Draw a model to explain your claim:

    d. In terms of heat, explain what type of reaction occurred when NaOH dissolved in water.

    e. Were more forces broken or formed when NaOH dissolved in water? Draw a model to explain your claim:

Separating a Mixture Lab

SEP: Designing Solutions CCC: Cause and Effect

Task: You will be given a mixture of sand and salt. Your task is to design a method of separating the sand and salt to quantitatively determine the percent of sand and the percent of salt in the mixture.

Materials: Sand and salt mixture**,** beaker, flask, graduated cylinder, funnel, filter paper, hot plate, electronic balance, magnet, ruler.

Procedure: As a team, write a step-by-step procedure that you will use to separate the mixture. Consider the fact that you just need the sand separated from the salt but they can be mixed with other substances. Have your teacher approve your procedure before you perform your experiment.

Data: Record relevant observations and measurement (be sure to include the mass of the original mixture and the mass of the sand and salt separately.)

Analysis:

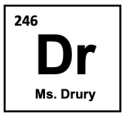
1. How well did your procedure work for separating the sand from salt? Explain.

2. Would you change anything about your procedure or how you carried it out that could improve your results?

3. What test(s) could you do to ensure the separated materials are purely sand and purely salt?

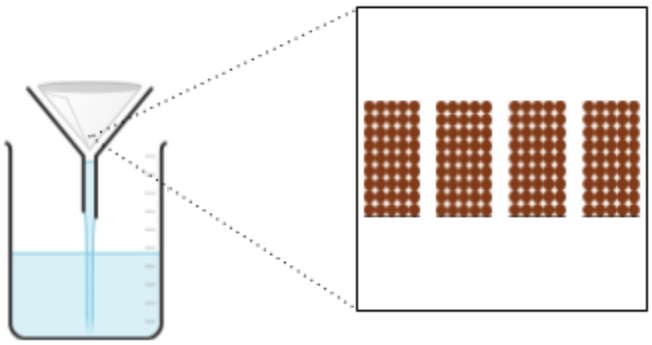
4. Calculate the percent of sand and salt in the mixture.
   a. Sand: b. Salt:

5. Explain why the salt did not have to be purified (completely alone) in order to solve for the mass and mass percentages of the sand and salt.

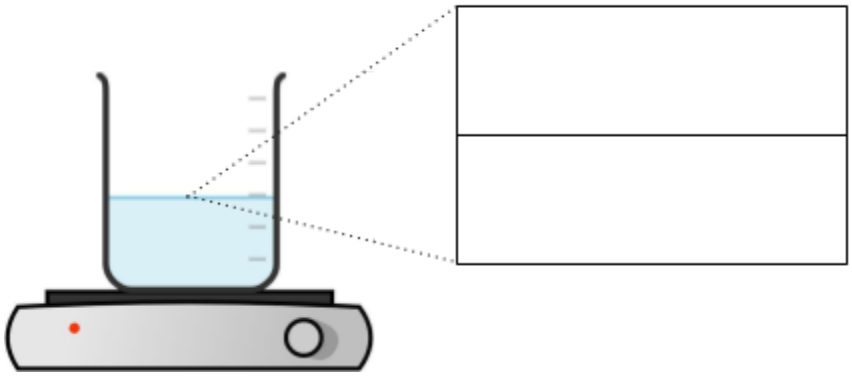




6. The left side of the diagram below shows the setup that one student used to separate the sand from the salt. The right side of the diagram shows a magnified view of the filter paper and the space just above and just below it. You can see the small holes (pores) in the filter paper that allows for fluid and small particles to pass through. In their procedure, the student added water to the sand and salt mixture. Then they poured mixture into the funnel with the filter paper. Complete the particle model in the magnified view of the sample using the key provided.



7. The left side of the diagram below shows the process that one student group used to purify the salt. As the diagram shows, the students heated a beaker of salt and water on a hot plate. The right side of the diagram is incomplete. It is designed to show a magnified view of the boundary between the liquid and vapor phases of the water. Fill in the right side of the diagram to represent water and salt particles just above and below the boundary.

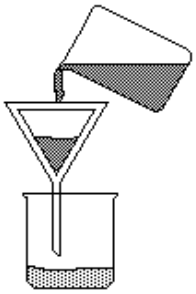


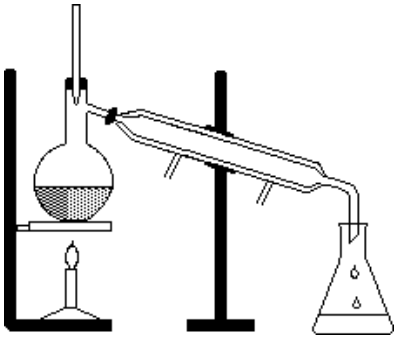
Mixtures Think Tank

SEP: Designing Solutions CCC: Cause and Effect

1. Solutions have two major components: the **solvent,**which is the larger amount of the mixture and does the dissolving and the **solute,** which is the smaller amount in the mixture and gets dissolved. Describe the difference between solutes and solvents in a solution using an example.

2. Read the separation techniques pictured below. Label which technique would be useful to separate a mixture of sand and salt and which technique would separate salt and water.
   Filtration: separates by particle size and solubility **Distillation: separates by boiling point**





3. Explain why the technique at left would not be effective in separating a mixture of salt and sugar.

4. Draw particle representations for the following:

A mixture of iron and sulfur	A compound of iron and sulfur

5. Explain why a magnet can separate iron particles from the mixture but not from the compound.

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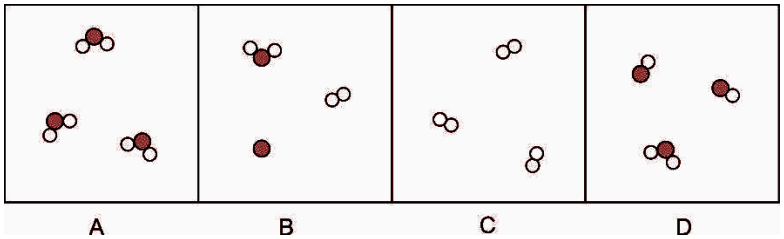
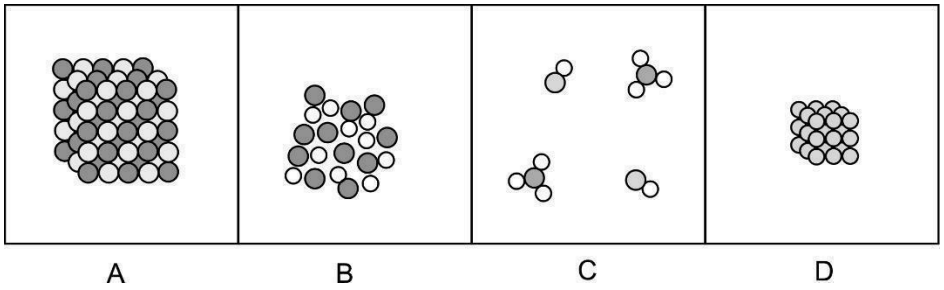
6. Consider the four containers below.



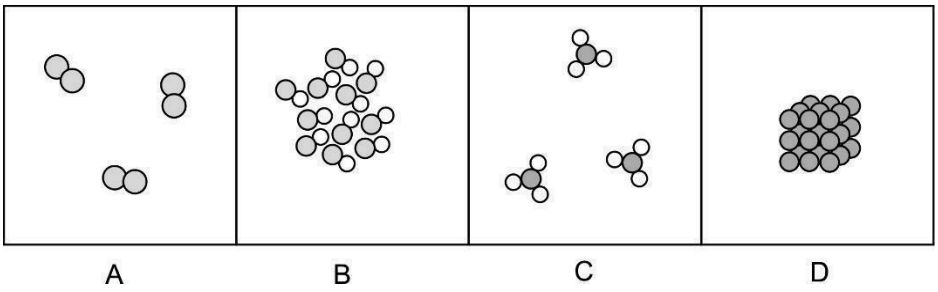
a. Which of these are mixtures? _____ pure substances? _____
b. Which contain only compounds? _____ only elements _____

7. Consider the four containers below.



a. Which of these are mixtures? _____ pure substances? _____
b. Which contain only compounds? _____ only elements _____
c. How many formula units of each compound are shown in container c?

8. Consider the four containers below.



a. Which of these are mixtures? _____ pure substances? _____
b. Which contain only compounds? _____ only elements _____
c. How many formula units are shown in container C?

9. Which of the containers in #8 contain gas? _____ a liquid? _____ a solid? _____

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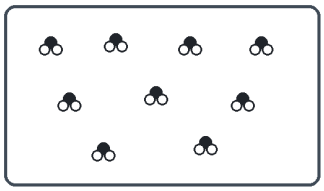
Particle Diagram Practice

SEP: Modeling CCC: Patterns

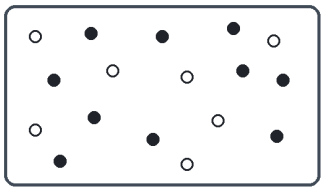
Directions: Classify each particle diagram. Write the correct letter on the line below each box.

A = Element B = Compound C = Mixture of elements D = Mixture of compounds E = Mixture of elements and compounds

Model key: Each circle represents an atom. Different colors represent different elements. Touching atoms are bonded.



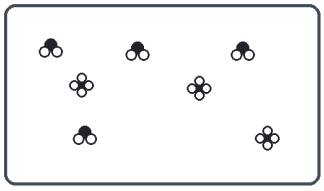
1. _____



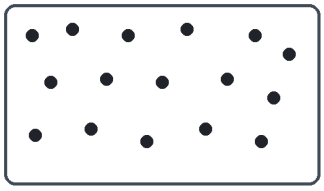
2. _____



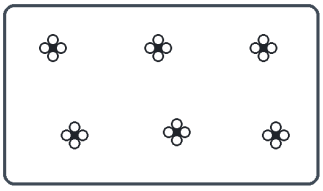
3. _____



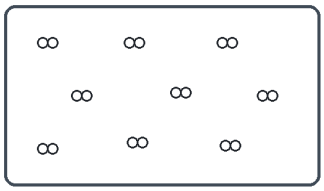
4. _____



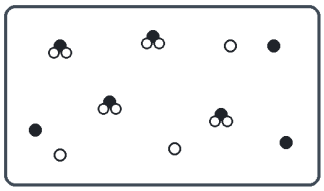
5. _____



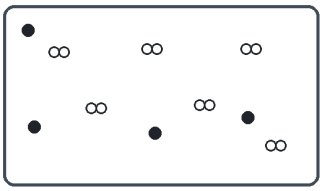
6. _____



7. _____



8. _____



9. _____

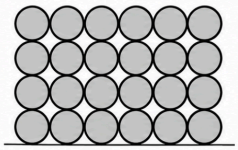
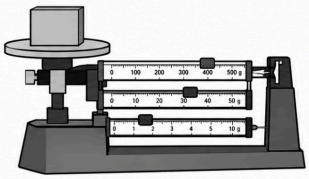
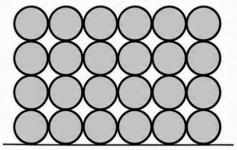
10. Go back to each diagram and label the particles as atoms or molecules.

Physical and Chemical Changes Think Tank

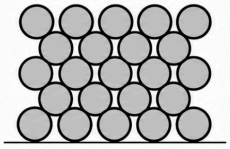
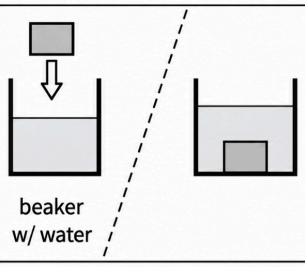
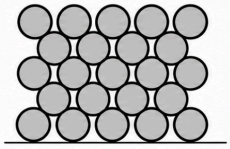
SEP: Modeling CCC: Patterns

Substances are known by their ***physical properties*** and ***chemical properties***.

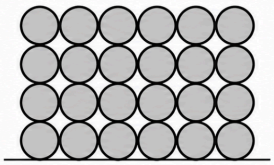
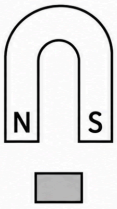
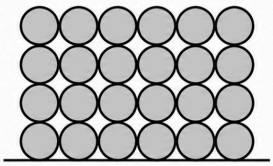
Example 1: Mass is a ***physical property.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum (This is a particle drawing of the block.)		 Block of aluminum *mass* = 307 g

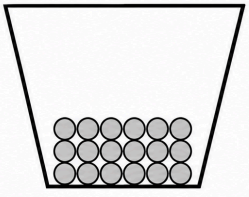
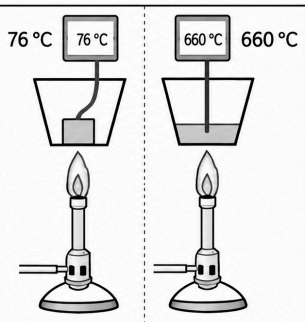
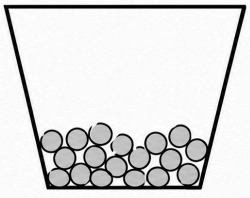
Example 2: Volume is a ***physical property.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum	 beaker w/ water	 Block of aluminum *Volume* = 114 mL

Example 3: Magnetism is a ***physical property.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum		 Block of aluminum Magnetic = No

Example 4: Melting point is a ***physical property*** associated with a ***physical change.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum in a crucible		 Liquid aluminum in a crucible Melting point = 660 °C

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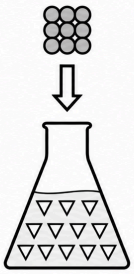
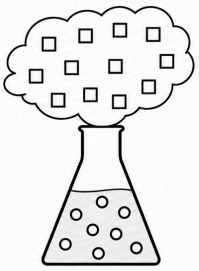
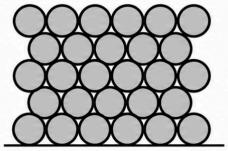
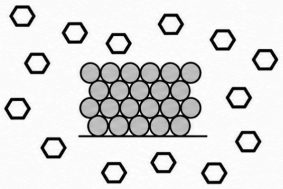
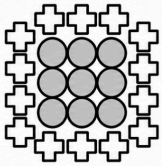
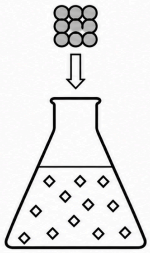
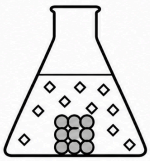
Example 5: Reactivity with acid is a ***chemical property*** associated with a ***chemical change.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum	 Flask with acidic solution	 Reactive Hydrogen gas and flask with solution of aluminum ions

Example 6: Reactivity with oxygen is a ***chemical property*** associated with a ***chemical change.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum	 Block of aluminum exposed to oxygen	 Reactive Block of aluminum with shiny coating

Example 7: Reactivity with water is a ***chemical property*** associated with a ***chemical change.***

Before the property is measured	Measuring the property	After the property is measured
 Block of aluminum	 Flask with water	 Unreactive Flask with block of aluminum in water

Questions*:*

1. Make a list of the **physical properties** that are identified in the Model. What are the common features of **physical properties** represented in the Model (aside from the fact that they all involve aluminum)?

2. Make a list of the **chemical properties** that are identified in the Model. What are the common features of **chemical properties** represented in the Model (aside from the fact that they all involve aluminum)?

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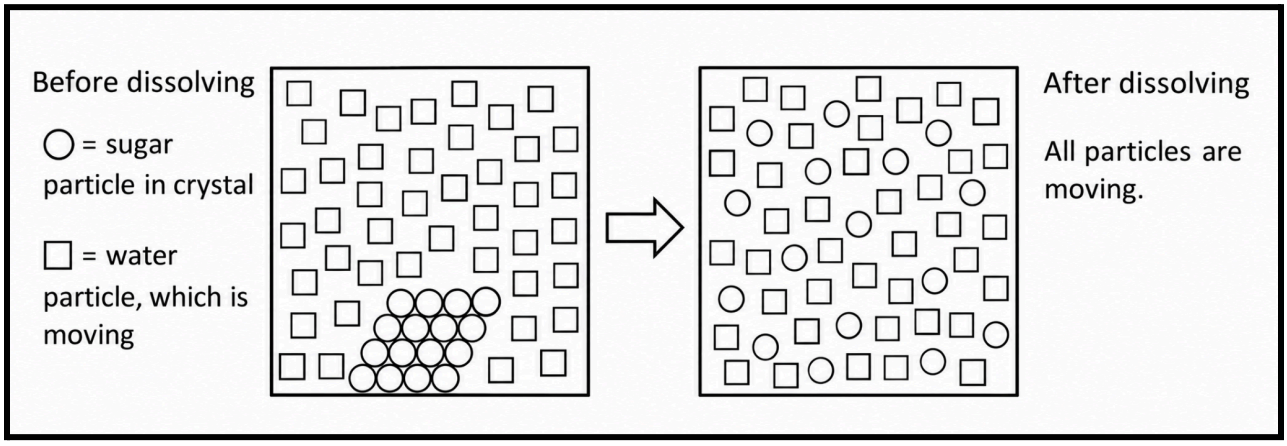
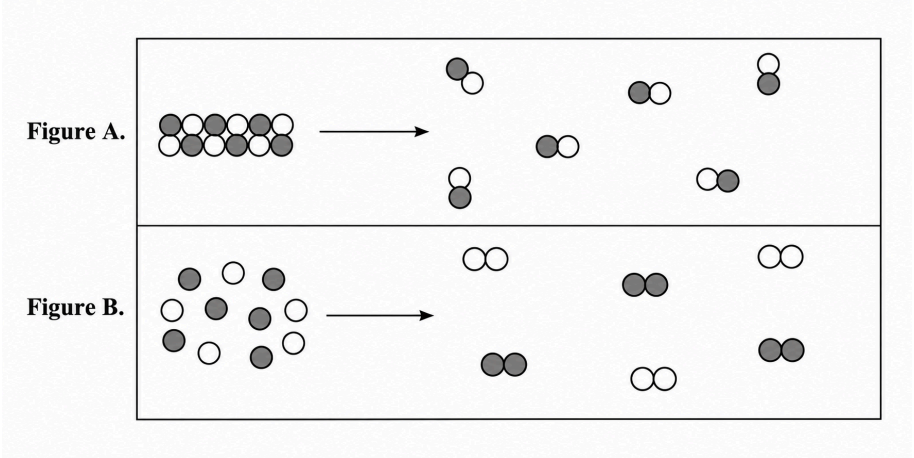
3. How do the **chemical properties** differ from the **physical properties**?

4. Below is a representation of the ***solvation*** process (*e.g.*, water dissolving a sugar crystal). Is the ability of one compound dissolving into another a **physical property** or a **chemical property**? Explain.



5. Which of the following statements about phosphorus describe **physical properties**? Which describes **chemical properties**? Briefly explain your choice.
   a. Phosphorus is never found free in nature. For example, phosphorus catches fire spontaneously in air by reacting with oxygen.
   b. Phosphorus melts at 44.1°C.
   c. Phosphorus can be stored under water
   d. Phosphorus dissolves in carbon disulfide

6. Answer the following questions and briefly explain your reasoning in each case. Which figure(s) represents a physical change?Which figure(s) represents a chemical change?



Distillation and Electrolysis Lab

SEP: Carrying Out an Investigation CCC: Energy and Matter

Background Information: **Intermolecular forces** are attractions between molecules and are responsible for many physical properties including the melting point and boiling point of a substance. It is relatively easy to change the strength of intermolecular forces via physical changes. Intermolecular forces are weakened or strengthened during phase changes. **Intramolecular forces**, also known as chemical bonds, hold atoms together in a compound and generally require more energy to overcome. In this activity, we will use identification techniques to determine gases evolved in various changes. From that evidence, we will determine if the changes that occurred were due to intermolecular or intramolecular forces.

Part 1: Identification of common gases evolved in lab investigations.

Read the following information about testing procedures used to identify an unknown gas. Then answer the questions that follow.

> Several gases can easily be generated in the laboratory. These include carbon dioxide, hydrogen, oxygen, chlorine, ammonia, and water vapor. To test for the presence of carbon dioxide, a burning wood splint brought near the gas will be extinguished. To test for the presence of Hydrogen gas, a burning wood splint will make a "pop" noise. Oxygen gas near a burning wood splint, that has recently been extinguished, will re-light. The presence of ammonia or chlorine is usually noticed by a sharp odor. Ammonia can also be tested with red litmus paper, which will turn blue in the presence of ammonia. The chlorine gas can be tested with blue litmus paper that will turn red or starch-iodine paper, which will turn a dark blue or black color. Water vapor will extinguish a flame much like carbon dioxide, and it will also turn cobalt chloride paper from blue to pink.

1. Which gases can be tested using a burning wood splint? How will you differentiate between the gases?

2. Which gases can be tested using test papers? How will you differentiate between the gases?

Part 2: Distillation of Soda

Materials: large and small beaker, graduated cylinder, stopper, colored soda (such as root beer, no sprite), aluminum foil, crushed ice, beaker tongs, cobalt chloride paper, and hot plate.

Pre-Activity Questions:

1. Is soda a pure substance or a mixture? Provide evidence in your answer.

2. Make a prediction about what will happen as the soda boils over the hot plate in a closed container. Draw a model of your prediction below.

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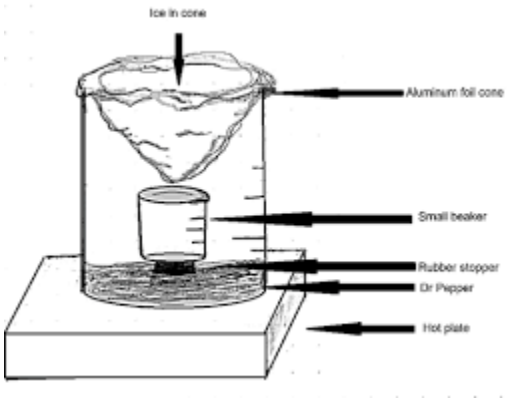
Procedure:



1. Measure 50.0mL of soda in a graduated cylinder. Pour into the large beaker.
2. Mass the small dry beaker.
3. Place a rubber stopper in the large beaker to create a platform for the smaller beaker. Place the smaller beaker on the rubber stopper. Ensure the small beaker is still dry.
4. Make a "cold finger" by creating a cone of aluminum with no holes. Place it so the tip of the cone is hanging just above the small beaker, the top of the cone is covering the rim of the large beaker. Cover the large beaker with the aluminum to prevent vapors from escaping the large beaker as it boils.
5. Place crushed ice in the cone to fill the cone.
6. Place the entire set up on the hot plate and allow the soda to boil until the ice melts on the cold finger. Do not add more ice. Make observations about the color, volume, and phase changes occurring in the set up.
7. Once the ice has melted, remove the set up from the hot plate using beaker tongs.
8. **IMMEDIATELY** Test the vapors with a burning wood splint.
9. Test the vapors from the boiling liquid with cobalt chloride paper.
10. When, cooled, measure the mass of liquid collected in the smaller beaker
11. Pour the new liquid into a cylinder to measure the volume.

Data and Observations:

Post Activity Questions:

1. Calculate the mass of the new liquid collected.

2. Calculate the density of the new liquid.

3. Identify a vapor formed when the soda was distilled. Provide evidence to support your claim.

4. What is the identity of the liquid in the small beaker? Provide evidence to support your claim.

5. Amend your prediction in the pre-activity question: what occurred as the soda was distilled? Re-draw your model.

Part 3: Electrolysis of Water

Materials: clear plastic cup, two metal thumb tacks, 9 volt battery, distilled water, baking soda, plastic pipettes, scissors, wood splints, and lighter.

Pre-Activity Question: Predict what will happen as electricity is conducted through water (with the help of salt) in a closed container.

Procedure**:**

1. Place two metal thumb tacks through the bottom of a small plastic cup so the points of the tacks are pointing up into the cup. The thumb tacks should be spaced the same as the tall terminals on the 9V battery.
2. Pour water into the plastic cup to fill approximately ¾ of the way.
3. Add baking soda to the water and stir.
4. Cut two plastic pipettes near the tip, to allow the tip to have a wider opening.
5. Fill the pipettes with the baking soda water
6. Invert the full pipettes into the water one over each thumbtack. Do not allow any air bubbles into the pipettes. One student should hold the pipettes in the cup.
7. Place the cup over the 9V battery so the terminals touch the tacks. Record observations as the changes occur.
8. Once a significant amount of gas has formed in the pipettes, cut the tip of one pipette and test the gas formed with a burning wood splint. Do this quickly (but carefully!) so that the gas formed doesn't disperse into the air. Record observations.
9. Repeat the previous step with the other pipette and record observations.



Observations:

Post Activity Questions:

1. What is the identity of the gas(es) formed in the electrolysis? Provide evidence to support your claim.

2. Based on the chemical formula of water, why did more hydrogen gas form than oxygen gas?

3. Amend your prediction in the pre-activity question: What occurred as electricity was conducted through the water? Re-draw your model.
   Macroscopic: Microscopic:

4. Explain the major differences between distillation and electrolysis:



	Distillation	Electrolysis
Physical or chemical change?		
Evidence of previous answer:		
Changes in the intramolecular or intermolecular forces?		
Reasoning for previous answer:		
Determined qualitatively or quantitatively?		

Matter Check Your Understanding

1. Matter that is composed of two or more different elements chemically combined in a fixed proportion is classified as
   (1) a compound (2) an element (3) a mixture (4) a solution

2. A compound differs from an element in that a compound
   (1) is homogeneous
   (2) has a definite composition
   (3) has a definite melting point
   (4) can be decomposed by a chemical reaction

3. A compound differs from a mixture in that a compound always has a
   (1) homogeneous composition
   (2) maximum of two elements
   (3) minimum of three elements
   (4) heterogeneous composition

4. A heterogeneous material may only be
   (1) an element (2) a compound (3) a pure substance (4) a mixture

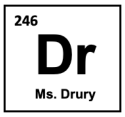
5. Which statement is an identifying characteristic of a mixture?
   (1) a mixture can consist of a single element
   (2) a mixture can be separated by physical means
   (3) a mixture must have a definite composition by weight
   (4) a mixture must be homogeneous

6. Which must be a mixture of substances?
   (1) solid (2) liquid (3) gas (4) solution

7. Which substance can be decomposed by chemical means?
   (1) aluminum (2) octane (3) silicon (4) xenon

8. Which substance cannot be broken down by a chemical reaction?
   (1) ammonia (2) argon (3) methane (4) water

9. Two substances, A and Z, are to be identified. Substance A cannot be broken down by a chemical change. Substance Z can be broken down by a chemical change. What can be concluded about these substances?
   (1) Both substances are elements.
   (2) Both substances are compounds.
   (3) Substance A is an element and substance Z is a compound.
   (4) Substance A is a compound and substance Z is an element.



10. Which terms are used to identify pure substances?
    (1) an element and a mixture
    (2) an element and a compound
    (3) a solution and a mixture
    (4) a solution and a compound

11. Two different samples decompose when heated. Only one of the samples is soluble in water. Based on this information, these two samples are
    (1) both the same element
    (2) two different elements
    (3) both the same compound
    (4) two different compounds

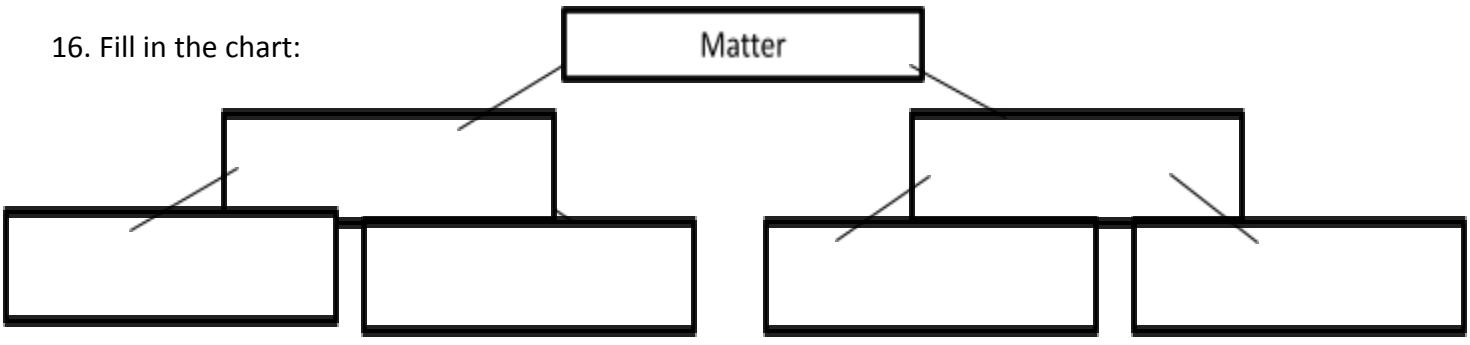
12. Tetrachloromethane, CCl_4, is classified as a
    (1) compound because the particles of the elements are combined in a fixed proportion
    (2) compound because the particles of the elements are combined in a proportion that varies
    (3) mixture because the particles of the elements are combined in a fixed proportion
    (4) mixture because the particles of the elements are combined in a proportion that varies

13. Why does all my milk say "homogenized' on the label? What does that imply?

14. Your friend wants to get all "gunk" out of the tap water at home and decides to use filter paper and a funnel to separate the water out because he wanted "filtered water." Will this work?

15. The liquor store carries triple distilled vodka. What does triple distilled mean?

16. Fill in the chart:



Matter and Redox Assessment Task



Performance Expectation: HS-PS1-12: Use evidence to illustrate that some chemical reactions involve the transfer of electrons as an energy conversion occurs within a system.

Background Information: Portable hand warmers used in winter sports or emergency kits generate heat when exposed to air. The chemical reaction inside involves iron oxidizing as shown in the following reaction: $Fe_{(s)} + O_{2\,(g)} \rightarrow Fe_2O_{3\,(s)}$. Iron oxide, also known as rust, is the chemical produced when iron and oxygen react with one another. This oxidation-reaction is exothermic.

Scenario: You've joined the product development team at Hot Hands®, a company that specializes in outdoor safety gear. Your task is to help explain the science behind iron-based hand warmers to new customers and engineers. These devices rely on an oxidation-reduction reaction that transforms chemical energy into thermal energy.

Assessment Task: Write an explanation that addresses the following prompts. Use scientific reasoning and evidence from the chemical reaction to support your claims.

1. Identify the classification of each species in the reaction and provide a justification.

Species	Classification (element, compound, homogeneous mixture, heterogenous mixture)	Justification
Fe		
O_2		
Fe_2O_3		

2. Create a particle model that illustrates how the energy was released in the reaction. Be sure to include both the reactants and products in your model.

3. Is the reaction a physical or chemical change? Justify your choice with scientific reasoning.

4. A student makes a claim that the conversion of iron ions is oxidation. Identify evidence from the passage above and your knowledge of chemistry to agree or disagree with this claim.

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5. Why is this redox reaction particularly useful in portable devices like hand warmers? Consider both energy output and practicality.

6. If oxidation of iron (rusting) is an exothermic process, why don't we usually notice any heat given off when rust forms on everyday objects?

7. What might engineers do to increase the rate of this chemical reaction in a hand warmer so that heat is produced more quickly and efficiently? What constraints do they have?

Return to the Study of Alchemy



Recall that ancient alchemists believed they could transmute metals to create lucrative gold and elixirs for long life free of disease. One such example is a Polish-born alchemist, known as Sendivogius, who arrived in Prague sometime in the 1590s. Sendivogius' great feat took place in 1604, when he boiled mercury (known then as "quicksilver") and a red liquid made from a red powder turning it to "gold". In alchemy, the mysterious red powder needed to transmute metals was often called "Red Lion" (aka the Philosopher's Stone, which is needed to transform base metal into gold). It was a combination of mercury and sulfur also known as vermillion red or cinnabar. Everyone wanted the secret, and Sendivogius was often on the run from cutthroats. We now know that vermillion red/cinnabar/red lion is HgS, a toxic red powder.

1. What are the oxidation states of mercury and sulfur in HgS?

2. When mercury and sulfur changes from elemental to the compound HgS, what evidence is there that electrons have transferred during this change?

3. Using the CER format, use evidence from this unit's labs and activities to argue if Sendivogius could have created gold from those materials. Be sure to include the following key vocabulary words and concepts. You may also choose to add particle models and graphs to your reasoning.
   - element
   - metal
   - nonmetal
   - metalloid
   - compound
   - ionic bond
   - covalent bond
   - plum pudding model (Thomson)
   - oxidation numbers
   - redox reaction
   - reduction
   - oxidation
   - physical changes
   - chemical changes
   - distillation
   - electrolysis

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