Using Scientific Methods

Course
Forensic Science

Unit I
Safety & Scientific Method

Essential Question
How can scientific methods help solve everyday problems?

TEKS
§130.295(c)(6)(A)(B)(C)(D)

Prior Student Learning
- *Lab Safety*
- *Scientific Method*

Estimated Time
3 ½ hours total
- *30 min. lecture on metric and dimensional analysis*
- *50 min. conversion worksheet*
- *20 min. lecture on properties*
- *50 min. lab*
- *20 min. lecture on reaction types*
- *30 min. quiz*

Rationale
The ability to use scientific methods is a critical skill in problem solving and forensic science. An investigator will use scientific methods to analyze evidence, determine what happened at a crime scene, and to narrow down a suspect pool.

Objectives
The student will be able to:
1. Demonstrate conversions of measurements from English to International System (SI) units.
2. Distinguish between physical and chemical properties.
3. Determine the elements within a compound or mixture.
4. Identify the four types of chemical reactions.

Engage
Do an Internet search for the following video: Fortune Teller Fish Amy Toy. Have the students watch the video. Then have them work in pairs and discuss how they would use scientific methods to figure out how the fortune fish works. You can find these fortune teller fish at many local party or toy shops. (An alternative to the video would be to give each pair of students a fortune teller fish and ask them to use scientific methods to figure it out.) Give a disclaimer for the students to not destroy the fish, so you can reuse them year after year. Use the Discussion Rubric for assessment.

Key Points
I. The Metric System
- A. The worldwide standard for measurements
- B. All measurements have two parts
  1. A number
  2. Units
- C. Based on multiples of ten
- D. Basic Units
  1. Length = meter
  2. Volume = liter
  3. Mass = gram
  4. Time = second
  5. Temperature = Kelvin
- E. Other Units
  1. Area = m^2
  2. cm^3 = mL (volume)
- F. Metric Prefixes
  1. Smaller
     a) Deci = 1/10
     b) Centi =1/100

c) Milli = 1/1000
d) Micro = 1/1,000,000
e) Nano =1/1,000,000,000

2. Larger
   a) Deka = 10
   b) Hecto = 100
   c) Kilo = 1000

G. Examples
   1. Centimeter = 1/100 of a meter
   2. Milligram = 1/1000 of a gram
   3. Kiloliter = 1000 liters

H. Remember
   1. King Henry Died by drinking chocolate milk
   2. Kilo, hecto, deka base deci, centi, milli

II. Dimensional Analysis (the Factor-Label Method)

A. Steps
   1. Write down the given measurement
   2. Create one or more expressions of 1 using the following
      a) Put the given unit in the denominator (bottom) of the conversion
      b) Put the unit you want to convert to in the numerator (top)
      c) Remember (as in the example below), there are 100cm in 1m; therefore 100cm/1m = 1
   3. Cancel the redundant units (those in both the denominator and the numerator) and solve for the desired unit

B. Example
   1. Convert 3.60 meters to inches
      a) $\frac{100cm}{1m} = 1$
      b) $\frac{1in}{2.54cm} = 1$
   2. $3.60m \times \frac{100cm}{1m} \times \frac{1in}{2.54cm} = ?$
   3. $3.60\cancel{m} \times \frac{100\cancel{cm}}{1\cancel{m}} \times \frac{1in}{2.54\cancel{cm}} = ?$
   4. $\frac{3.60 \times 100 \times 1in}{2.54} = 141.7in$ $(360 \div 2.54 = 141.7)$

III. Physical Properties

A. Observed with the senses and can be determined without destroying the object
B. Examples are color, shape, mass, length, odor, density, melting point, and boiling point

IV. Chemical Properties

A. Indicate how a substance reacts with something else
B. The substance is changed while the chemical property is observed
C. Examples are iron rusting, food digesting, marshmallows burning

V. Types of Reactions (Rxns)
A. Synthesis Rxns
1. Two or more substances combine to form a more complex substance
2. A + B → AB
3. For example, $4Al + 3O_2 \rightarrow 2Al_2O_3$*
*1 product formed
B. Decomposition Rxns
1. One substance breaks down to form two or more simpler substances
2. AB → A + B
3. For example, $2CaCO_3$* → $2CaO + 2CO_2$
*1 reactant
C. Single Replacement Rxns
1. One substance is replaced in its compound by another substance
2. A + BC → AC + B
3. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$
4. $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$
D. Double Replacement Rxns
1. Ions of two compounds exchange places to form two new compounds
2. AB + CD → AD + CB
3. For example, $BaCl_2 + Na_2SO_4 \rightarrow 2NaCl + BaSO_4$

Activities

1. Metric Conversions Worksheet. Have students use the steps of dimensional analysis that they learned in the Using Scientific Methods computer-based presentation to convert between English and Metric measurements. Use the Metric Conversion Worksheet Key for assessment.

2. White Powder Lab. Have students analyze 10 unknown powders to determine their identity using the White Powder Lab. They will use scientific method and observations of physical and chemical properties to make these determinations. Have the students complete the data chart and flowchart on the 10 Unknown Solids – Data Sheet. Answers will vary based on how you choose to set up the lab. Make a key after you assign numbers to the chemicals. The Cooperative Teams Rubric may also be used for assessment.

3. Reactions Worksheet. Have students use their knowledge of the types of

chemical reactions from the Using Scientific Methods computer-based presentation to determine the types of reactions on the Reactions Worksheet. Use the Reactions Worksheet Key for assessment.

Assessments
Conversion Quiz and Key
Metric Conversion Worksheet Key
Reactions Worksheet Key
Chemical Reactions Tree Map Key
Cooperative Teams Rubric
Discussion Rubric

Materials
Using Scientific Methods computer-based presentation
Metric Conversion Worksheet and Key
Calculators
White Powder Lab
- 10 Unknown Solids – Data Sheet
- Boric acid, H_3BO_3
- Sodium Chloride, NaCl
- Calcium carbonate, $CaCO_3$
- Calcium sulfate, $CaSO_4$
- Sodium hydroxide, NaOH
- Cornstarch
- Sodium carbonate, Na_2CO_3
- Sucrose, $C_{12}H_{22}O_{11}$
- Sodium bicarbonate, $NaHCO_3$
- Magnesium sulfate, $MgSO_4$
- Iodine tincture, 6 drops
- Sodium hydroxide solution, 0.2M, 18 drops
- Isopropyl alcohol solution, 12mL
- White vinegar, 4mL
- Phenolphthalein solution,1%
- Deionized water
- 10 Test tubes, 13x100mm
- Stirring rod
- Ring stand & ring
- Test tube rack
- Graduated cylinder, 10mL
- 250mL beaker
- Marking pen
- Bunsen burner

Reactions Worksheet and Key
Unknowns Lab
- Unknowns Lab Teacher notes

- Unknowns Lab Handout
- Vinegar
- Baking Soda
- Alum
- Overhead Transparencies
- Plastic beral pipettes

Chemical Reactions Tree Map and Key

Resources

Saferstein, Richard. *Forensic Science: An Introduction*. New Jersey: Pearson Prentice Hall, 2008.

Do an Internet search for the following video: Fortune Teller Fish Amy Toy

Accommodations for Learning Differences

For reinforcement, students will use their notes on types of chemical reactions to fill in the Chemical Reactions Tree Map. Use the Chemical Reactions Tree Map Key for assessment.

For enrichment, students will perform the Unknowns Lab. Teacher notes are included with materials and setup directions. When setting up, make a key of your unknowns in order to assess students.

State Education Standards

Texas Essential Knowledge and Skills for Career and Technical Education

§130.295. Forensic Science (One Credit).

(6) The student analyzes the evidence collected from a crime scene using scientific methods. The student is expected to:

(A) demonstrate conversions of measurements between English and International System (SI) of units;

(B) distinguish between physical and chemical properties of matter using the periodic table;

(C) determine the elements within a compound or mixture;

(D) identify the four types of chemical reactions;

College and Career Readiness Standards

I. Nature of Science: Scientific Ways of Learning and Thinking

A. Cognitive skills in science

4. Rely on reproducible observations of empirical evidence when constructing, analyzing, and evaluating explanations of natural events and processes.

C. Collaborative and safe working practices

1. Collaborate on joint projects.

Name_____Date_____

Conversion Quiz

Use the table to complete the following conversions.

12 inches = 1 foot	100 centimeters = 1 meter	1 yard = 3 feet
1 mile = 5280 feet	1 minute = 60 seconds	1 inch = 2.54 centimeters
1 gallon = 4 quarts	60 minutes = 1 hour	1 quart = 2 pints
1 liter = 1.06 quarts	1000 milligrams = 1 gram	1 pound = 16 ounces
1 pound = 454 grams	100 centigrams = 1 gram	1 kilometer = 1000 meters
1 kilogram = 1000 grams		

1) Convert 1.25 miles to meters.

2) Convert 3.65 centimeters to kilometers.

3) Convert 2.54 inches to meters.

4) Convert 3.5 gallons to liters.

5) Convert 3.95 centimeters to miles.

Conversion Quiz Key

1) 2011.68m
2) 3.65×10^{-5}km
3) .06m
4) 13.21L
5) 2.45×10^{-5} miles

Name_____ Date_____

Metric Conversion Worksheet

Change the measurement in the blank to the unit in brackets. Show your work and box the answer. Pay attention to significant figures. You must use the conversion units below:

12 inch = 1 ft.	1 yard = 3 feet	1 mile = 5280 feet	1 inch = 2.54 centimeter
1 gallon = 4 quarts	1 quart = 2 pints	1 liter = 1.06 quarts	1 pound = 16 ounces
1 pound = 454 grams	100 centigrams = 1 gram	1 kilogram = 1000 grams	1 kilometer = 1000 meters
1 minute = 60 seconds	60 minutes = 1 hour	100 centimeters = 1 meter	1000 milligrams = 1 gram

1. First down and *10.0 yards* to go. [meter]

2. *5ft. 2in.* ,eyes of blue. [meter]

3. Give him *an inch (1.0in)* [centimeter] and he'll take *a mile (1.0mi)* . [meter]

4. I'll have a *quarter-pounder (0.25lb)* . [gram]

5. *10.00 gallon* hat. [liter]

6. A journey of *1000 miles* begins with one step. [meter]

7. *8.0 second* ride. [hour]

8. *100.0 yard* dash. [centimeter]

Metric Conversion Worksheet Key

1. 9.14 m
2. 1.6 m
3. 2.54 cm and 1609.34 m
4. 113.5g
5. 37.74 L
6. 1,609,344 m
7. .0022 hr
8. 9144 cm

White Powder Lab

Introductions

In this lab we will identify 10 unknown substances by following a qualitative analysis flow chart. We will also use a variety of chemical and physical tests to identify 10 common household substances, all of which are white solids.

Background

The process of determining the identities of unknown substances is called qualitative analysis. Qualitative analysis schemes are generally summarized in a flow diagram, like the one shown below. A flow diagram is designed with procedural steps on the vertical lines, the possible test results on the horizontal lines, and the resulting identifications in the boxes.

Qualitative analysis procedures include physical tests as well as chemical tests. The physical tests in this lab are melting point determination and solubility in water or in alcohol. The chemical reactions or tests in this lab are with iodine, vinegar, sodium hydroxide, and phenolphthalein. All of the chemical tests involve either formation of a precipitate (solid), color change, or evolution of gas bubbles.

Materials Needed

Unknown Samples (in alphabetical order)

Boric acid, H_3BO_3	Magnesium sulfate, $MgSO_4$	Sodium Chloride, NaCl
Calcium carbonate, $CaCO_3$	Sodium bicarbonate, $NaHCO_3$	Sodium hydroxide, NaOH
Calcium sulfate, $CaSO_4$	Sodium carbonate, Na_2CO_3	Sucrose, $C_{12}H_{22}O_{11}$
Cornstarch		

Chemicals/Test Reagents

Iodine tincture, 6 drops	Sodium hydroxide solution, 0.2 M, 18 drops	Isopropyl alcohol solution, 12mL
White vinegar, 4mL	Phenolphthalein solution,1%, 1mL	Deionized water

Equipment:

Test tubes, 13x100mm, 10	Stirring rod	Ring stand and ring
Test tube rack	Graduated cylinder, 10mL	250mL beaker
Marking pen	Bunsen burner	

Pre-Lab Notes

The steps of the procedure written below correspond to the qualitative analysis flow chart provided. As each step is followed, record detailed observations of your results in the data table you have created in your lab book.

Examine the flow chart that has been provided. The numbers 1 – 13 are provided next to some of the possible results. Write the corresponding number in your data table as you go through the flow chart. For example, if unknowns A, B, And C are water-insoluble (which is result #1) and unknowns D – J are water-soluble then write a "1" by A, B, and C and record "Insoluble in H_2O," and for D – J record "Soluble" in H_2O" on your data sheet.

Procedure

1. Label 10 test tubes A – J with a marking pen and place the tubes in a test tube rack.
2. Place a **small scoop** of each of the 10 unknown substances, A – J, into the appropriate test tube (*Note*: the results will be affected if you use too much of a sample).
3. Add approximately 5mL of deionized water to each tube (*Note*: this can be efficiently accomplished by measuring 5mL once using a 10mL graduated cylinder. Pour the 5mL of water into test tube A and then add water to each of the 9 remaining tubes to the same height of the liquid in tube A).
4. a. Stir the contents of each tube with the stirring rod. Be sure to rinse the stirring rod with deionized water between tubes.

   b. Record observations of which substances are soluble and which are insoluble in water. Remember to record both the result (#1) as well as the written observation (*Note*: some soluble solids may take longer to dissolve than others). Only three of the unknowns – cornstarch, calcium sulfate, and calcium carbonate – will not readily dissolve in water and are considered insoluble.

5. Following the flow chart, take the three tubes containing the insoluble substances from step 4, and add 2 drops of iodine tincture to each. Two of the tubes will show no reaction with iodine and will be an orange-brown color. The contents of one tube will turn a deep blue color. The deep blue color is a starch-iodine complex which positively indicates ***cornstarch***.

6. a. Dispose of the contents of the two tubes that did not react with iodine. Rinse out the tubes. Prepare fresh tubes of these two unknowns by placing a small scoop of the solid into the appropriate tube. **Do not add water**.

   b. Add approximately 10 drops of vinegar to these two tubes and note whether gas bubbles are produced. The evolution of carbon dioxide gas positively identifies ***calcium carbonate***. The remaining solid must be ***calcium sulfate***. Record the numbers and observations.

7. The other seven solids are water soluble. To each of the seven tubes from step 4, add 3 – 4 drops of phenolphthalein solution. Two of the unknowns, sodium hydroxide and sodium carbonate, dissolve in water to produce alkaline solutions basic enough to give a bright pink color upon addition of phenolphthalein. Do not be concerned with precipitate (solid) formation or a faint pink color at this point.

8. a. Dispose of the contents of the two tubes that tested positively in step 7. Rinse out the tubes. Prepare fresh tubes of these two unknowns by placing a small scoop into the appropriate tube. Do not add water.

   b. Add approximately 10 drops of vinegar to each tube and note whether gas bubbles are produced. The evolution of carbon dioxide gas positively identifies ***sodium carbonate***. The remaining solid must be ***sodium hydroxide***.

9. a. Dispose of the contents of the tubes containing the five solids that remain to be identified. Rinse out the tubes. Prepare fresh tubes of these five unknowns by placing a small scoop into the appropriate tube.

   b. Add 5mL of distilled or deionized water to the five tubes and stir as in step 4 to dissolve the solids.

10. Add 3 drops of 0.2M NaOH to each tube. All of the tubes should remain clear except one which gives a white precipitate. This white precipitate positively identifies ***magnesium sulfate***, which forms an insoluble hydroxide upon addition of sodium hydroxide.

12. a. Dispose of the contents of the tubes containing the four solids that remain to be identified. Rinse out the tubes. Prepare fresh tubes of these four unknowns. Do not add water.

    b. Add approximately 10 drops of vinegar to each tube and note whether gas bubbles are produced. The evolution of carbon dioxide gas positively identifies ***sodium bicarbonate***.

13. a. Dispose of the contents of the three remaining tubes. Rinse out the tubes and prepare fresh tubes of these three unknowns. Do not add water.

    b. Add approximately 5mL of isopropyl alcohol to each tube. Stir the contents of each tube to attempt to dissolve the solids. Of the three solids, only boric acid dissolves readily in alcohol; thus, this test is a positive identification for ***boric acid***.

14. a. Dispose of the contents of the two remaining tubes. Rinse out the tubes. Prepare fresh tubes of these two unknowns. Do not add water.

    b. Hold each tube with a test tube holder and heat it gently with a Bunsen burner. The solid in one tube will turn brown, smell sweet, and begin to melt in 1–2 minutes. **Cease heating the tube once you have determined that the contents are changing**. Place the hot test tube on the lab top. Do not place it in the plastic test tube rack. This change is an indication that the material has a low melting point and that it is ***sucrose***. The other solid will not change as it is heated. This indicates that the solid has a high melting point and is ***sodium chloride***.

Name_____ Date_____

10 Unknown Solids – Data Sheet

All observations must include a number (see your flow chart) and the result. For example: 1-not soluble.

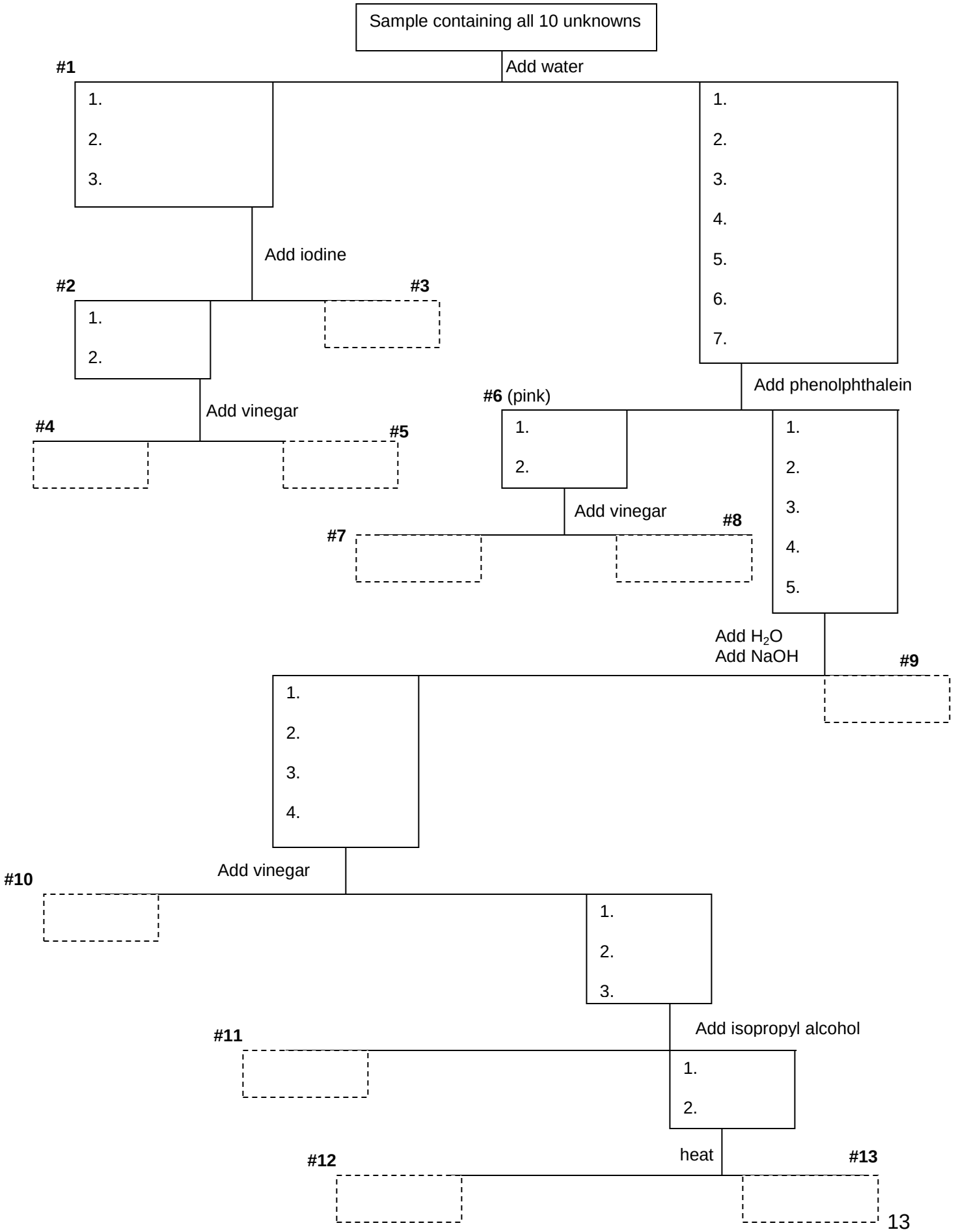
Unknown Set _____	Observations	Identity
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

During the lab

1. Make sure you record your unknown set number in your lab write-up.
2. Record all observations in the chart and identify the substance in your flow chart. As you work, you should use the A – J designations. When you get to a dashed box, identify the unknown (for example: A = NaCL).

Post-lab

1. Identify each of your unknowns (you may do this in your data chart).
2. Identify each of the observations in the numbered steps as physical or chemical.



Name_____Date_____

Reactions Worksheet

Identify the type of reaction for each of the following:

1. $Al + O_2 \rightarrow Al_2O_3$

2. $HgO \rightarrow Hg + O_2$

3. $NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$

4. $Fe + CuCl_2 \rightarrow FeCl_2 + Cu$

5. $Pb(NO_3)_2 + K_2CrO_4 \rightarrow PbCrO_4 + KNO_3$

6. $H_2 + N_2 \rightarrow NH_3$

7. $KClO_3 \rightarrow KCl + O_2$

8. $Mg + HCl \rightarrow H_2 + MgCl_2$

9. $Fe + O_2 \rightarrow Fe_2O_3$

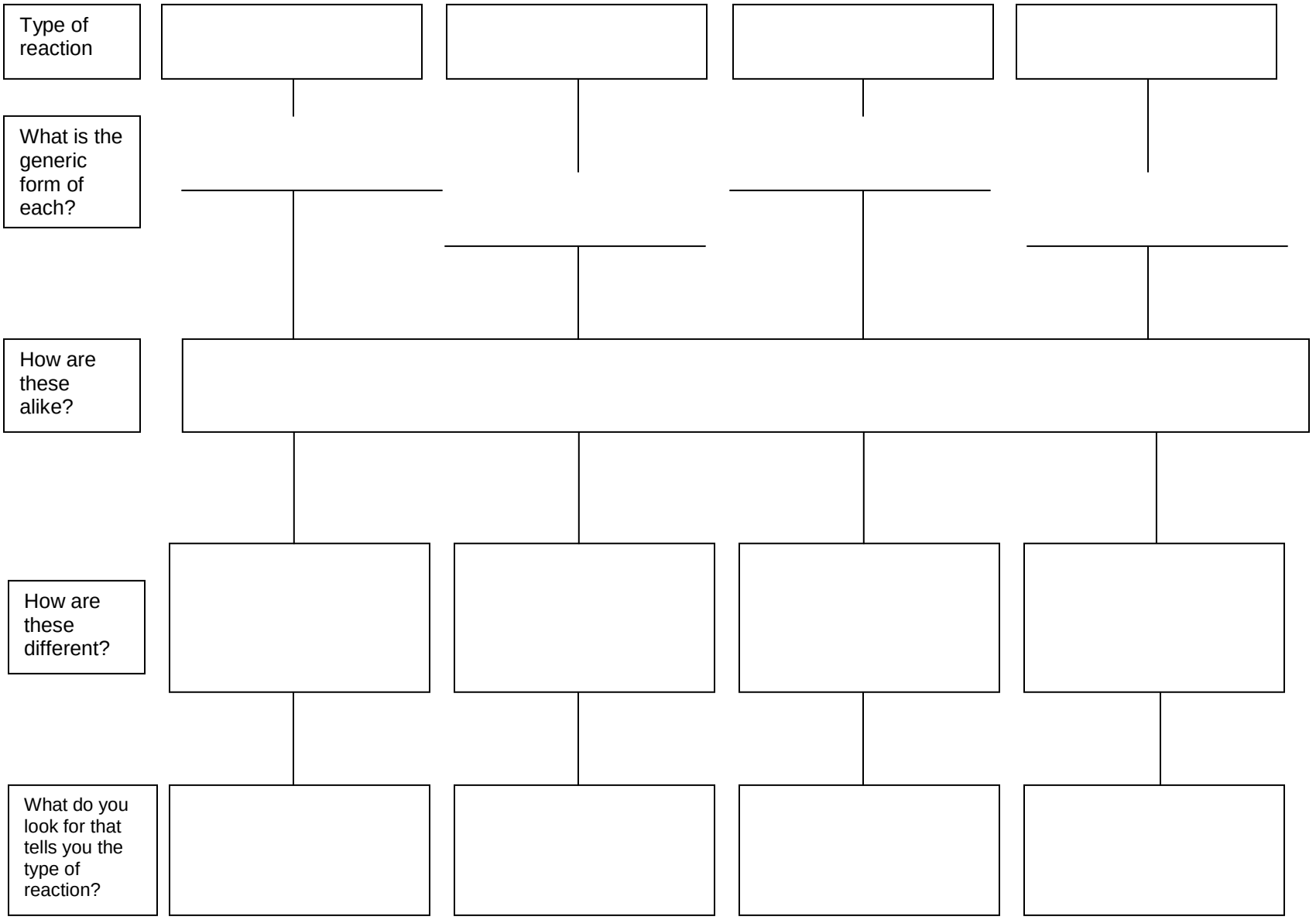
10. $3Mg + N_2 \rightarrow Mg_3N_2$

Reactions Worksheet Key

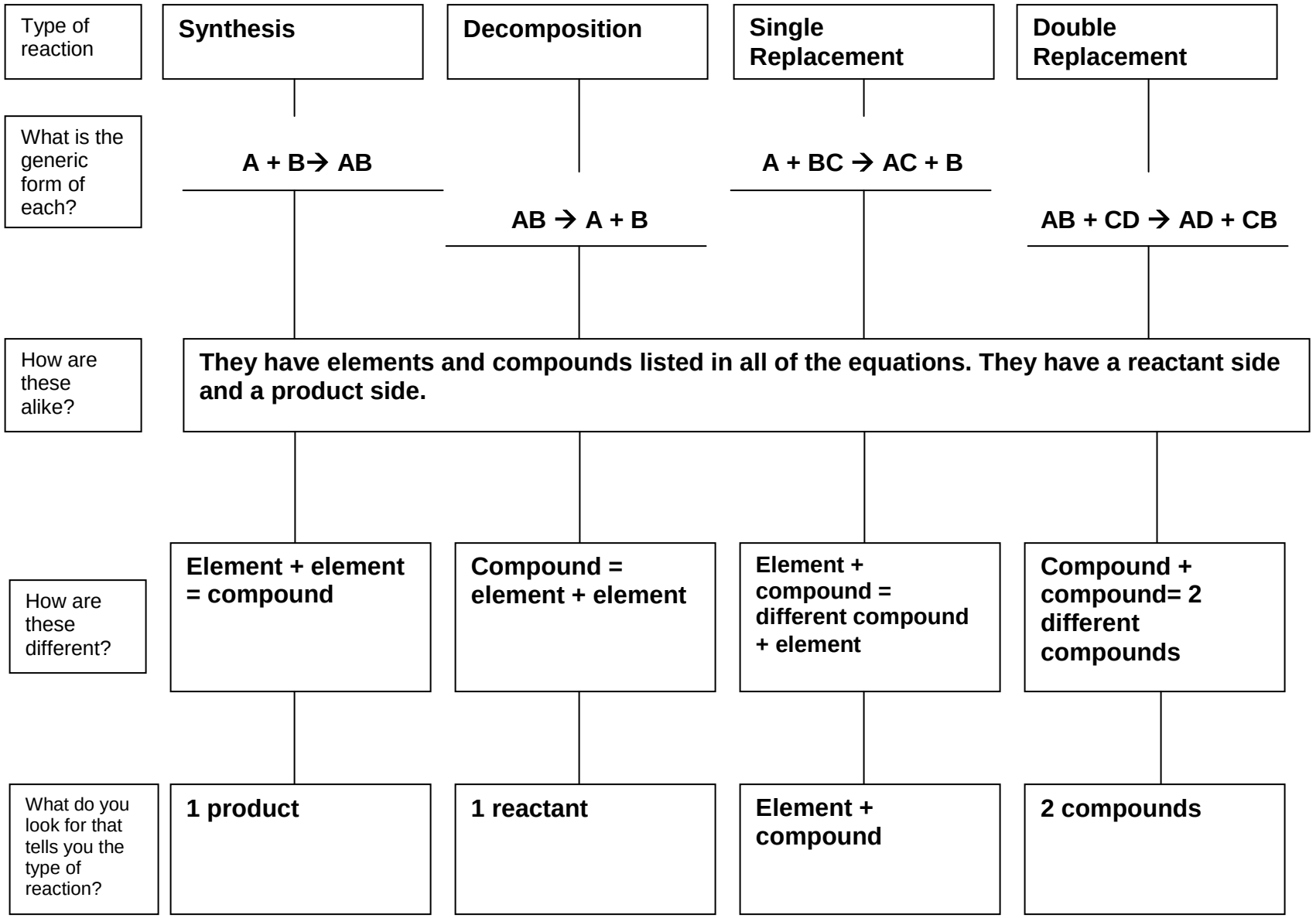
1. Synthesis
2. Decomposition
3. Double Replacement
4. Single Replacement
5. Double Replacement
6. Synthesis
7. Decomposition
8. Single Replacement
9. Synthesis
10. Synthesis

Name_____ Date_____

Chemical Reactions Tree Map



Chemical Reactions Tree Map Key



Unknowns Lab Teacher Notes

Set up 6 pipettes in a ziploc bag for each lab group.

Have 2 pipettes of each of the following solutions:

- Vinegar (dilute with a little water)
- Baking soda solution (1 tablespoon of baking soda in 200mL of water)
- Alum solution (find alum at the grocery store in the spice section) (1 teaspoon of alum in 200mL of water

Label 3 of the pipettes with letters (example: A,B,C, etc.)

Label 3 of the pipettes with numbers (example: 1,2,3, etc.)

Cut an overhead transparency into 4 squares. Put 2 squares in the ziploc bags with the 6 pipettes

One of the students will get the letters and one will get the numbers.

Students will not talk during the lab. They can communicate by "texting" each other on white notebook paper.

Students should make observations about what they see when they mix the chemicals together and drop some on the transparency squares.

They should observe the following

	Vinegar	Baking Soda	Alum
Vinegar	X	Bubbles	No reaction
Baking soda	Bubbles	X	White precipitate
Alum	No reaction	White precipitate	X

Make yourself a Key to refill the pipettes and for grading. When you fill your pipettes, put your chemicals in a beaker labeled with X, Y, and Z so that you can refill quickly during and between classes and the students will not know what the actual chemicals are. A sample key is given below:

X – Vinegar

Y – Baking Soda

Z – Alum

1 – X	A – Z
2 – Y	B – X
3 – Z	C – Y
4 – X	D – Y
5 – Y	E – X
6 – Z	F – Z

Students should write up their procedure using the scientific method and include a key of which pipette numbers match which letters in their group.

Unknowns Lab

1. Determine which lettered pipette matches which numbered pipette. NO TOUCHING. NO TASTING.
2. You will be working with your partner who is sitting in front of you.
3. You are not allowed to talk to each other, but you may “text” each other using the white paper.
4. When you have figured out the matches, write a report using the scientific method. Make sure to identify your matches in your report.

Name: _____ Date:_____

Cooperative Teams Rubric

Objectives	4 pts. Excellent	3 pts. Good	2 pts. Needs Some Improvement	1 pt. Needs Much Improvement	N/A	Pts.
Participates in group discussions						
Encourages others to join the conversation						
Maintains the pace of the discussion to achieve goals						
Shares ideas and thoughts						
Offers constructive criticism and recommendations						
Credits others for their contributions and ideas						
Empathizes with others						
Requests input from others to reach an agreement						
Expresses ideas and thoughts						
Total Points (36 pts.)						

Comments:

Name_____ Date_____

Discussion Rubric

Objectives	4 pts. Excellent	3 pts. Good	2 pts. Needs Some Improvement	1 pt. Needs Much Improvement	N/A	Pts.
Participates in group discussion						
Encourages others to join the conversation						
Keeps the discussion progressing to achieve goals						
Shares thoughts actively while offering helpful recommendations to others						
Gives credit to others for their ideas						
Respects the opinions of others						
Involves others by asking questions or requesting input						
Expresses thoughts and ideas clearly and effectively						
Total Points (32 pts.)						

Comments: