Distillation

Thermometer

85°C

Water + Ethanol

Bunsen Burner

Condenser tube

Faucet Water

“Pure” Ethanol

Bunsen Burner
Chemistry – Unit 4 Worksheet 1

1. Identify the separation techniques pictured below. Which technique would be useful to separate a mixture of sand and salt? Of salt and water?

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

3. Draw particle representations for the following:

<table>
<thead>
<tr>
<th>A mixture of iron and sulfur</th>
<th>A compound of iron and sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Particle representation" /></td>
<td><img src="image" alt="Particle representation" /></td>
</tr>
</tbody>
</table>

4. Explain why a magnet can separate iron atoms from the mixture but not from the compound.

So… The compound has unique properties that are different than the elements alone.
5. Consider the four containers below.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
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a. Which of these are mixtures? **B + D**

b. Which contain only compounds? **A + C**

6. Consider the four containers below.

<p>| | | | |</p>
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<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

a. Which of these are mixtures? **None**

b. Which contain only compounds? **B + C**

8. Which of the containers in #7 contain a gas? **A**

   a liquid **B**

   a solid **D**
2 hydrogen : 1 oxygen

- Explosive

Hydrogen

Support Flame

Water Vapor

Oxygen

- Does Neither

-
Avogadro’s Hypothesis

In Unit 2, you learned that the pressure of a gas is proportional to the Kelvin temperature \((P \propto T)\), when the volume and number of particles is held constant. Now consider equal volumes of two gases at the same temperature (in the figures below, the sphere in the upper corner of the box is a thermometer bulb).

**Part 1**

1. What is reasonable to conclude about the number of gas particles in each container if the pressure and temperature is the same in both containers?

   Avogadro reached this same conclusion building on the work of Gay-Lussac, who first noted that gases (at the same \(T\) and \(P\)) reacted in simple integer volume ratios. His hypothesis made it possible to deduce the formulas of compounds formed when these gases react.

   You have seen evidence that two volumes of hydrogen gas react with one volume of oxygen gas (at the same \(T\) and \(P\)) to produce water. The conclusion that two molecules of hydrogen combine with one molecule of oxygen to form water works only if we assume that each volume of gas contains the same number of particles.

2. Represent molecules of hydrogen and oxygen in the containers below. React these molecules to form water molecules, leaving no leftover gas.
What do the H, O, and 2 in the chemical formula tell us about the composition of water?

\[ \text{Water is made from } \ 2 \text{ Hydrogens} + 1 \text{ Oxygen} \]

3. In like manner, represent particle diagrams that account for the fact that one volume of hydrogen combines with one volume of chlorine to form hydrogen chloride. What do you suppose is the formula of hydrogen chloride?

4. Represent the reaction in which one volume of nitrogen gas reacts with three volumes of hydrogen gas to form ammonia. What is the formula for ammonia?

Part 2

Chemists occasionally found that one volume of gas A reacted with one volume of gas B to produce two volumes of gaseous product. Early chemists like Gay-Lussac were unable to account for this behavior of gases. Avogadro's key contribution was that he reasoned that the molecules of some gaseous elements must contain two atoms.

5. Consider the reaction between hydrogen and chlorine. Two volumes of hydrogen chloride are formed. Sketch particle diagrams consistent with Avogadro's Hypothesis to represent this reaction. Explain why hydrogen and chlorine molecules that have only one atom each cannot account for the observed behavior.
6. When two volumes of hydrogen gas react with one volume of oxygen gas, two volumes of gaseous water are formed. Modify the diagram you made for #2 to represent molecules of hydrogen, oxygen and water in this reaction.

Explain why molecules of oxygen must have an even number of atoms.

Can't divide an odd number by two

7. Two volumes of nitric oxide react with one volume of oxygen gas to form two volumes of a reddish-brown gas. Deduce the formula of this gas and sketch particle representations of its molecules.
Chemistry – Unit 4 Worksheet 3

Use the following information about the masses of elements in each pair of compounds to help you suggest formulas that account for these ratios.

1. Compounds of carbon and oxygen

   Compound A: 57.1 g O / 42.9 g C
   Compound B: 72.7 g O and 27.3 C

a. Determine the value of the ratio \( \frac{\text{mass O}}{\text{mass C}} \) in each compound. \( \frac{1.33}{2.66} \)

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

   CMP A is double the oxygen as CMP B
   CMP A = \( \frac{4}{3} \)   CMP B: \( \frac{8}{3} \)

c. Express these ratios as improper fractions.

d. 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.

<table>
<thead>
<tr>
<th>Hypothesis 1</th>
<th>Hypothesis 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atoms of C and O have the same mass</td>
<td>Atoms of O are heavier than C atoms by the ratio in compound A.</td>
</tr>
<tr>
<td>A [C_3O_4]</td>
<td>A [CO]</td>
</tr>
<tr>
<td>B [C_3O_8]</td>
<td>B [CO_2]</td>
</tr>
</tbody>
</table>
2. Compounds of copper and oxygen

Compound A: 79.9 g Cu / 20.1 g O

Compound B: 88.8 g Cu / 11.2 g O

a. Determine the value of the ratio $\frac{\text{mass Cu}}{\text{mass O}}$ in each compound. $\frac{398}{792}$

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

Cmp B ratio is double compared to cmp A.

\[ \frac{A}{B} = \frac{91}{B} \]

Cmp B ratio is double compared to cmp A.

Express these ratios as improper fractions.

c. Express these ratios as improper fractions.

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<tbody>
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</table>

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</tr>
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<tbody>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

Which hypothesis seems more reasonable to you? Justify your answer.

Hypothesis 2 seems difficult to fit 8 atoms around a single atom.
Use the hypothesis you have chosen to suggest formulas for the following pairs of compounds.

3. **Compounds of copper and chlorine**
   
   **Compound A:** 35.9 g of Cl / 64.1 g of Cu
   **Compound B:** 52.8 g of Cl / 47.2 g Cu
   
   a. Determine the value of the ratio \( \frac{\text{mass Cl}}{\text{mass Cu}} \) in each compound. \( A \boxed{0.561} B \boxed{1.12} \)

   b. How does the mass ratio for compound B compare to that in compound A?
      
      Mass ratio for Cmp B is double

   c. What are the simplest formulas for compounds A and B? Explain your reasoning.
      
      \( \text{CuCl} \) and \( \text{CuCl}_2 \) The ratio of \( \frac{\text{Cl}}{\text{Cu}} \) is twice as much

4. **Compounds of iron and chlorine** *(be careful!)*
   
   **Compound A:** 56.0 g of Cl / 44.0 g of Fe
   **Compound B:** 65.6 g of Cl / 34.4 g of Fe
   
   a. Determine the value of the ratio \( \frac{\text{mass Cl}}{\text{mass Fe}} \) in each compound. \( A \boxed{1.27} B \boxed{1.91} \)

   b. 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 atoms in each of the two compounds?
      
      \[
      \frac{\text{Cmp B}}{\text{Cmp A}} = \frac{1.91}{1.27} = 1.50 = \frac{3}{2} \text{ Cl atoms for every } 1 \text{ Fe atom}
      \]

   c. What would be the formulas of the two compounds, assuming that each compound contains one atom of Fe?
      
      \( \text{FeCl}_3 \) and \( \text{FeCl}_2 \)
Chemistry – Unit 4 Worksheet 4

Answer the following questions on your own piece of paper. Be sure to show all mathematical work and reasoning and use complete sentences in explanations.

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 200.0 g sample of the sugar found in corn syrup. This sample contains 80.0 g 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.

4. A 1.0 g sample of hydrogen reacts completely with 19.0 g of fluorine to form a compound of hydrogen and fluorine.
   a. What is the percent by mass of each element in the compound?
   b. What mass of hydrogen would be present in a 50.0 g sample of this compound?
   c. Justify your answer to b.

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

Mass ratios are constant across the same compounds.
6. 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.
   a. Determine the ratio of the mass of oxygen to the mass of hydrogen in each of the compounds.
   b. Why are the compounds not the same?
   c. What is significant about these mass ratios?
   d. If compound I is water, what could be the formula of compound II?

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

<table>
<thead>
<tr>
<th>Analysis Data of Nitrogen &amp; Oxygen Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
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</table>

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

8. Explain how the examples in questions 6 and 7 help to illustrate the Law of Multiple Proportions.
Chemistry – Unit 4 Test-a

Write the letter(s) of the word(s) or phrase(s) that match the definition.

1. This substance consists of two or more elements in a fixed mass ratio.
   a. element
   b. compound
   c. mixture
   d. pure substance

2. This substance cannot be broken down by physical or chemical means.
   a. element
   b. compound
   c. mixture
   d. pure substance

3. The composition of this substance is variable; its physical properties depend on the composition.
   a. element
   b. compound
   c. mixture
   d. pure substance

4. Electrolysis can be used to separate this substance.
   a. element
   b. compound
   c. mixture
   d. pure substance

5. This substance can be either homogeneous or heterogeneous.
   a. element
   b. compound
   c. mixture
   d. pure substance
Write the letter of the box whose contents best match the description.

6. a mixture of molecules
7. atoms of a pure metal
8. molecules of an element
9. a solid compound
10. a mixture of elements

11. Sketch a graph of temperature vs. time for the heating of a mixture of methanol and ethanol. The b.p. of methanol is 65°C and that of ethanol is 78°C.

12. Describe how you could use the information in the graph you sketched for Q 11 to separate a mixture of methanol and ethanol.

If you heat the mixture to 65°C, the methanol will boil away while the ethanol remains, this being separated.
13. Sketch a particle diagram representing a mixture of hydrogen and oxygen gases. Sketch a particle diagram for the compound formed when these gases react. Describe how these diagrams are different.

![Diagram of mixture and compound]

As a compound they form a chemical bond due to having an unshared amount of electrons making the compound \( \text{H}_2\text{O} \).

14. Suppose that one volume of gas A combined with two volumes of gas B to form one volume of product when measured at the same pressure and temperature. Sketch particle diagrams for molecules of gas A, gas B and the product; assume gases A and B are monatomic.

![Particle diagrams]

15. If the gases in Q 14 were diatomic, how many volumes of the gaseous product would be formed? Explain.
16. Nitrogen and oxygen form several compounds. Two of these have the following mass composition.

Compound A: 63.6 g of N and 36.4 g of O
Compound B: 46.7 g of N and 53.3 g of O

a. Determine the value of the ratio $\frac{\text{mass N}}{\text{mass O}}$ in each compound. A $\frac{18}{9}$ B $\frac{18}{9}$

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

It's twice as big

c. 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.

\[ \text{Cmp A: } \text{N}_2\text{O} \quad \text{Cmp B: } \text{NO} \]