Activity 16 - Synthesis and Qualitative Analyses of Gases[1]

Goals

- Carry out chemical reactions that produce gases.
- Employ indicators to assist in the detection of gases.
- Deduce the identity of unknown gases by examining the chemical reactions of the reactants used to generate them.

Pre-Lab Lecture Questions. *Answer these questions on a separate sheet using complete sentences.*

1. What is the difference between a gas, a liquid and a solid at the molecular level?
2. What is observed when two solutions are mixed and a gas is produced?
3. Give the names and formulas for three gases that are part of our everyday lives.
4. What gas is the major component of air? Give its name and formula.
5. What gases are responsible for acid rain and where do they come from?
6. What experimental difficulties arise when the products of your chemical reactions include gases?
7. What is the chemical formula for bleach?

Concepts to Review

Indicators of Chemical Change
Nomenclature
Writing Chemical Equations

Introduction

We are swimming in a vast solution of gases as we move through our daily lives. Our bodies need oxygen from the atmosphere to live and we generate carbon dioxide as an end product of metabolism. Marsh gas or methane is also a natural product of the decomposition of biological matter. One of the most obvious visual evidences of chemical change is the production of bubbles-insoluble gases moving through a liquid sample.

The generation of gases is fundamental to all chemistry, both “natural” and industrial. The combustion of fossil fuels produces sulfur dioxide and the oxides of nitrogen. Both of these oxides are implicated as sources of pollution, with the nitrogen oxides being responsible for the brown haze we see and both of them reacting with atmospheric moisture to produce acid rain. Even something that can be a “natural product” (carbon dioxide) may cause environmental problems such as the greenhouse effect when its concentrations are unusually high.

In this lab you will mix six different combinations of reactants in the presence of four different indicators. The chemistry for each of the reactions includes both double displacement reactions (acid/base) and oxidation-reduction reactions. Similarly the chemical changes in the indicator drops include both double displacement and oxidation-reduction reactions. You are not expected to analyze or deeply understand the mechanism of the reactions but you are expected to make careful observations. Take a moment to identify the composition of the indicators. How are they similar? How are they different? A critical experimental concern in this experiment is that your products are gases and must be contained in order to be identified. Read through the experimental procedure carefully before beginning the lab.

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[1] Adapted from: Waterman, E. L. *Chemistry: Small-Scale Chemistry Laboratory Manual;* Addison-Wesley/Prentice-Hall, Inc.: Upper Saddle River, New Jersey, 2002; pp 103-110.

Safety

Act in accordance with the laboratory safety rules of Cabrillo College.
Wear safety glasses at all times.
Avoid contact with all chemical reagents and dispose of reactions using appropriate waste containers.
Use microburets to dispense reagents in such a way that they do not make contact with other drops on the reaction surface.
Return any contaminated microburets to your instructor.

Materials:

Reagent Central chemicals include both indicator reagents and reactants:

Indicators	Chemical Reactants (center stage)	
Potassium iodide (KI)	Hydrochloric acid (HCl)	Sodium hydrogen sulfite ($NaHSO_3$)
KI + starch		Sodium nitrite ($NaNO_2$)
Bromthymol Blue indicator (BTB)		Sodium hydrogen carbonate ($NaHCO_3$)
KI + starch + sodium hypochlorite (NaOCl)		Sodium hypochlorite (NaOCl) "bleach"
	Acidic potassium permanganate ($KMnO_4$ + HCl)	Hydrogen peroxide (H_2O_2)
	Sodium hydroxide (NaOH)	Ammonium chloride (NH_4Cl)

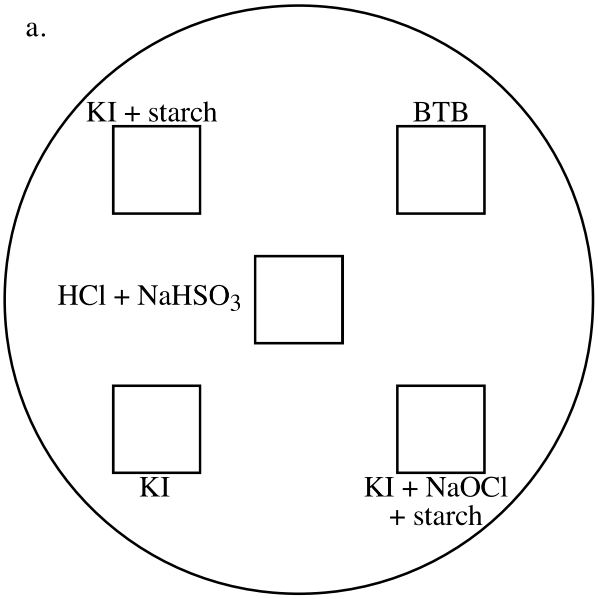
Equipment: Clear plastic cups Labtop reaction surface

Experimental Procedure

1. Insert your experimental page under your reaction surface such that the circles are visible. Place 1 drop of each indicator solution in the squares near the inside edge of each circle as depicted on your Experimental Template. When you are ready to make observations, mix 1 drop of each reactant (HCl + something else) in the center of each circle, and cover the entire circle with a cup. Be sure the cup does not touch any of the solutions.
2. Continue to observe the reactions in the center and in the indicator drops for few minutes, recording anything you see in your laboratory notebook and/or data page. Take care to notice any differences between the bubbles (size, how quickly they disappear, position), recording everything you see. Remember, "no visible change" or "no reaction" is an observation, a potentially important piece of evidence.
3. After all the reactions have gone to completion, neutralize the central reactions with a few drops of NaOH; clean the reaction surface thoroughly with a *damp* paper towel and then dry it. Clean the cups with a *dry* paper towel to absorb any stray moisture. Repeat this process to assure a clean surface for the next two reactions.
4. Continue onto the next experimental template and complete Steps 1-3 for the last two reactions.
5. Devise a method of detection for carbon dioxide gas. This is found in exhalations, as carbon dioxide is a waste byproduct of metabolism. Carbon dioxide combines with water to form carbonic acid. Test your method using any of the indicators available. Record your results.

Reaction Template 1: Insert this page into the labtop.

a.



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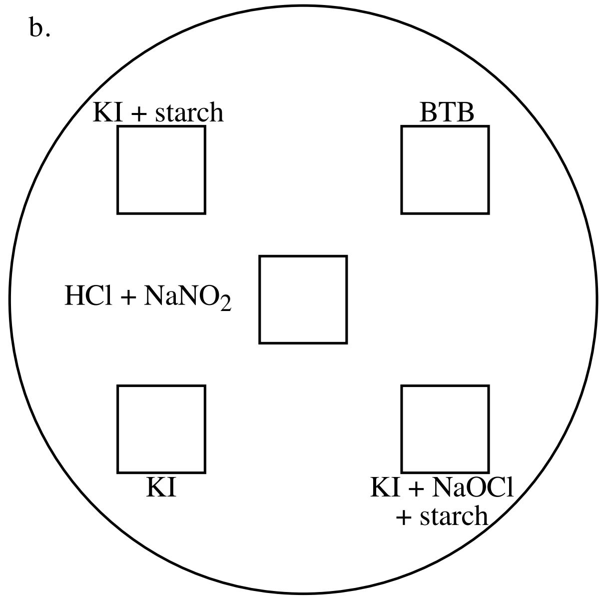

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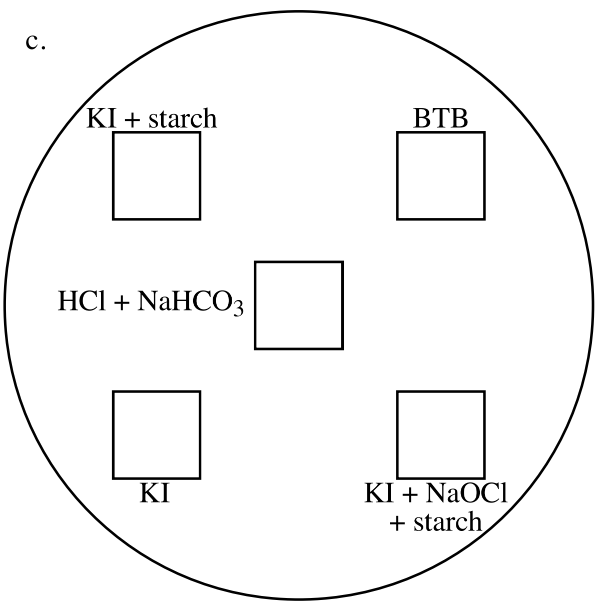
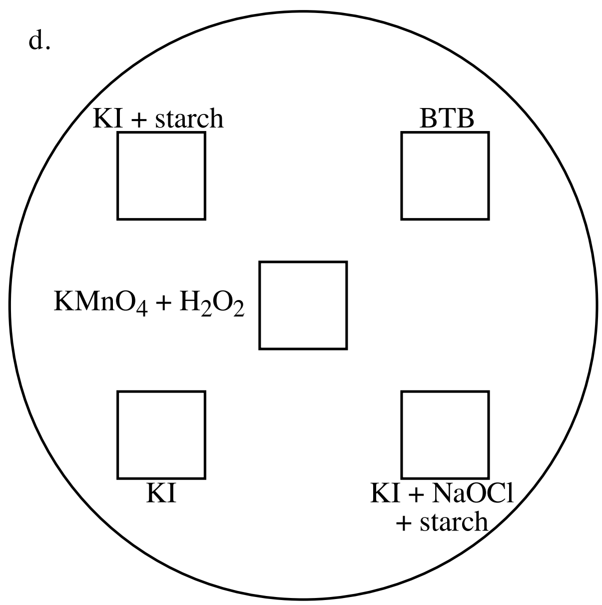
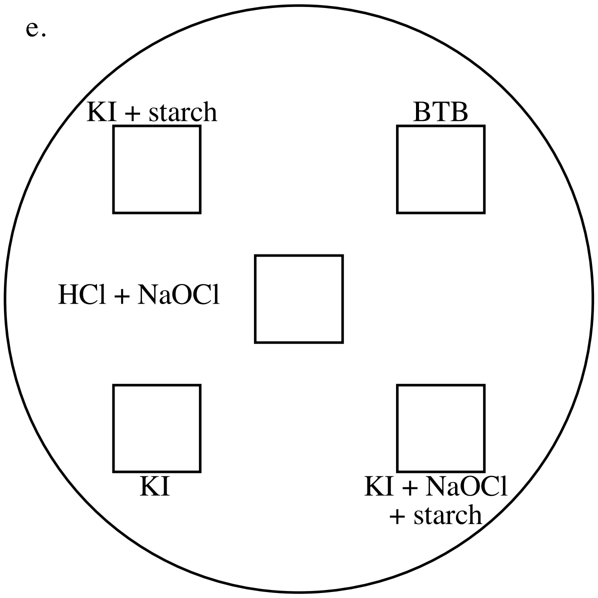
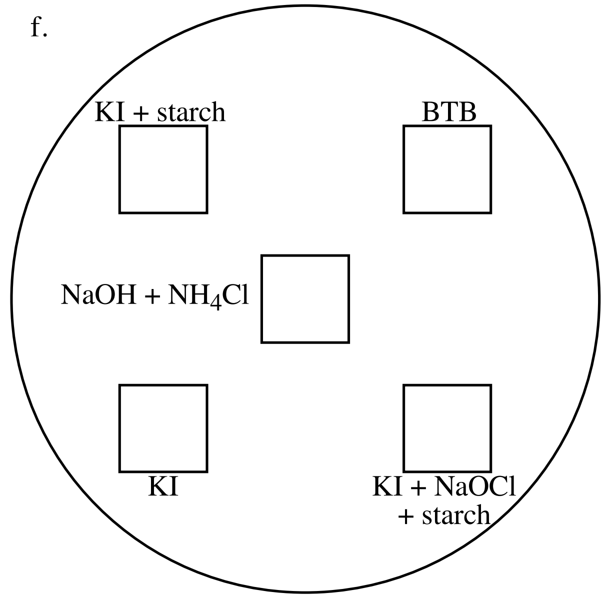


d.



Reaction Template 2: Insert this page into the labtop.





Cleaning Up

Avoid contamination by cleaning up in a way that protects you and your environment. Carefully clean the plastic cups by wiping them with a dry paper towel. Clean the small-scale reaction surface by absorbing the contents onto a paper towel, rinsing the reaction surface with a damp paper towel, and drying it. Dispose of the paper towels in the wastebasket. Wash your hands thoroughly with soap and water.

Activity 16 - Synthesis and Qualitative Analysis of Gases

Name____________________________

Section____________ **Date**_______

Experimental Data: Observations of Gases

Complete the following table by recording any observed changes. Write "NVR" for no visible reaction.

MIXTURE	Bubbles? (describe)	BTB (green)	KI + starch (colorless)	KI + NaOCl + Starch (black)	KI (colorless)
a. HCl + $NaHSO_3$					
b. HCl + $NaNO_2$					
c. HCl + $NaHCO_3$					
d. $KMnO_4$ + H_2O_2					
e. HCl + NaOCl					
f. NaOH + NH_4Cl					

1. What is the physical evidence that mixtures (a-f) produced gases?

2. Are all the gases the same? Explain your answer using specific physical evidence from your experiment.

3. Given the word equations that describe all of the chemical reactions in this experiment, write and balance a chemical equation to describe the formation of each gas produced. **The letter of each word equation corresponds to the letter in the Experimental Data table**. Only ions will have charges in formula.

   a) Sodium hydrogen sulfite reacts with hydrochloric acid to produce sulfur dioxide gas, water, and sodium chloride.

   b) Sodium nitrite reacts with hydrochloric acid to produce nitrogen monoxide gas, water, sodium chloride, and sodium nitrate.

      – Nitrogen monoxide from the above reaction reacts with oxygen gas in the air to produce nitrogen dioxide.

   c) Sodium hydrogen carbonate reacts with hydrochloric acid to produce carbon dioxide gas, water, and sodium chloride.

   d) Five moles of hydrogen peroxide react with 2 moles of permanganate ion and 6 moles of hydrogen ion to produce oxygen gas, manganese (II) ion and water. Make sure you balance the product side of the equation without changing the number of moles of reactants.

   e) Chlorine gas, water and sodium chloride *are produced* when hydrochloric acid is added to sodium hypochlorite.

   f) Sodium hydroxide reacts with ammonium chloride to produce ammonia gas, water and sodium chloride.

4. Given the word equations below, write and balance chemical equations to describe each reaction of a gas with an indicator or *the water present in the indicator solution*. **The letter of each word equation corresponds to the letter in the Experimental Data table.** Only ions will have charges.

   a) Sulfur dioxide gas reacts with water to produce sulfurous acid ($H_2SO_3(aq)$). (Hint: This is a combination reaction.)

      – Sulfur dioxide also reacts with iodine and water to form iodide ion, sulfate ion and hydrogen ion.

b) Nitrogen dioxide gas reacts with water in the indicator to produce nitric acid ($HNO_3(aq)$) and nitrous acid ($HNO_2(aq)$).

c) Carbon dioxide combines with water to form carbonic acid ($H_2CO_3(aq)$).

e) Chlorine reacts with iodide ion to form iodine and chloride ion.

f) Ammonia gas reacts with water to produce ammonium hydroxide.

5. **Review** the indicator changes in your experimental data table and the reactions written in Problem 4. *When you answer the following questions, you are drawing conclusions from what you saw and the chemical equations in the previous questions.*

   a) What one of the three chemicals is responsible for the dark color associated with the KI/NaOCl/starch indicator mixture?

   b) What is the color of BTB in the presence of an "acid"? Explain. Look at the names of products given on the previous page for help here.

   c) What is the color of BTB in a solution produced by bubbling ammonia through water? Explain.

6. Describe the method used to detect carbon dioxide in the breath. Include your results.

7. Return to the two equations under 3b, and equation 4b. Use these three equations together to explain your observations for reaction b between hydrochloric acid and sodium nitrite.