Chemical Properties of CO$_2$ and Other Chemical Reactions

**Introduction:**
Carbon dioxide was the first gas to be described as a discrete substance in about 1640, by Jan Baptist van Helmont who observed that when he burned charcoal in a closed vessel some charcoal had been transmuted into an invisible substance he termed a "gas" or "wild spirit".

The properties of carbon dioxide were studied more thoroughly in the 1750s by Joseph Black. He found that limestone (calcium carbonate) could be heated to yield a gas he called "fixed air."

Carbon dioxide has many uses. It is used in fire extinguishers, carbonated soft drinks, refrigerants (dry ice), to cool loaded rail cars, and as the propellant in aerosol cans. The density of CO$_2$ (g) is 1.80 g/L at 25 ºC and standard pressure (air is only 1.18 g/L).

**Procedure:**

*Preparation of CO$_2$ (g).*
Obtain a 250 ml Erlenmeyer flask with a side-arm and a rubber stopper sized to fit the mouth. Clamp the flask to a ring stand and attach a short piece of rubber hose to the side-arm. Run the hose to the underside of the pneumatic trough. Make sure the rubber hose on the wall of the trough hangs over a sink. (See set-up below). Fill the trough ½ full of water.
Obtain a gas-collecting bottle and fill it to the brim with water. Place a glass square on top of the bottle – check for air bubbles in the bottle. If no bubbles, turn the water-filled bottle upside down (while holding the glass square firmly on the mouth of the bottle) and place it underneath the surface of the water in the pneumatic trough. Remove the glass square while keeping the mouth of the water-filled bottle under water. The water should remain in the bottle.

Remove the stopper and add two scoops of sodium bicarbonate (baking soda) to the bottom of the side-arm flask.

Use your graduated cylinder and measure out about 75 ml of 5% acetic acid (white vinegar). Add the acid to the side-arm flask and quickly replace the stopper. Gas should begin to bubble in the pneumatic trough out of the hole in the bottom. Slide one of your water-filled bottles over the hole and collect the gas until bubbles start to come out from the mouth of the bottle. Slide the second bottle over the hole and collect another bottle of gas. If you run out of gas, add more vinegar and baking soda to the side-arm flask.

While still under water, slide the glass squares over the mouths of both bottles and turn the bottles right-side up. Set the bottles on the lab bench. Do not remove the glass squares until you are ready to test the chemical reactions of CO₂.

**Chemical Reactions:**

Not every chemical will react with every other chemical. However, when a chemical reaction does occur there are observable physical clues that indicate to us that a change has indeed taken place. The following events are measurable or visible indicators that a chemical reaction has occurred:

1. Gas production (bubbles appear)
2. Solid formation (an insoluble solid, called a precipitate, forms)
3. Color change
4. Temperature change (a reaction that produces heat or gets hot is exothermic, a reaction that absorbs heat or gets cold is endothermic)
**Gases:**
When a gas is formed from a chemical reaction we may be able to identify it by observing its color and flammability.

The following is a list of the identifying properties of some common gases. Use it to prove the identity of gases that may be produced in your reactions:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide, CO$_2$</td>
<td>Colorless, odorless, and not flammable at all. Large amounts will actually put out a flame so it is used as the gas in standard fire extinguishers.</td>
</tr>
<tr>
<td>Hydrogen, H$_2$</td>
<td>Colorless, odorless, but highly flammable. When a burning splint comes in contact with a test tube of hydrogen it gives a “pop” sound when the gas ignites.</td>
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<tr>
<td>Oxygen, O$_2$</td>
<td>Colorless and odorless. Is necessary for any combustion reaction to occur. If present it will increase the flammability of other substances. A glowing splint will burst into flame in the presence of oxygen.</td>
</tr>
</tbody>
</table>

### Physical & Chemical Reactions of CO$_2$ (g).

Take one of the bottles of CO$_2$ that you made and set it next to a Bunsen burner. Light a wood splint until it has a good flame on it, then slide off the glass square while plunging the burning splint into the glass bottle. If the flame burns brighter, then O$_2$ is probably present. If the flame causes a popping (or barking) noise, then H$_2$ is probably present. If the flame goes out, then CO$_2$ is definitely present since this gas does not support combustion. Record you findings on the Report Form.

Obtain about 20 ml of saturated Ca(OH)$_2$ (calcium hydroxide) solution and add it to the second bottle of CO$_2$ by sliding off the glass square slightly and pouring the solution into the bottle. Cover the bottle with the glass square and shake the contents for about 5 minutes (while holding the glass square firmly on the mouth of the bottle). Formation of a very fine white residue indicates the formation of calcium carbonate (CaCO$_3$). Record you findings on the Report Form.
**Copper(II) Sulfate + Sodium hydroxide**

Place about 5 mL of 0.5 M CuSO₄ solution into a clean test tube. Add about 5 ml of 0.5 M NaOH solution. Note the results on your report form.

**Copper(II) Sulfate Solution.**

Place 20 drops of 0.1 M CuSO₄ solution into a clean test tube. Add drop-wise 1 M NH₃ (NH₄OH) solution, mixing the contents after each drop. Continue to add until the color changes. Note the new color and the number of drops of 1 M NH₃ added and record on your report sheet. To this mixture, add drop-wise 1 M HCl (NOT concentrated) solution until the color changes back to pale blue. Note the results on your report form.

**Yeast and Hydrogen Peroxide.**

Add about ¼ to ½ teaspoon of baking yeast to a large test tube (10-12 inches long). Clamp the test tube vertically on a ring stand. Add about 10-20 ml of 3% hydrogen peroxide. As soon as possible, test the flammability of the gas using a burning wood splint. Try blowing out the splint and quickly putting it near the mouth of the test tube. Results?

**Ammonium Dichromate + Heat.**

Clamp a large dry test tube (10-12 inches long) vertically to a ring stand. Add about ½ teaspoon of the orange solid, ammonium dichromate to the test tube. Tickle the bottom of the test tube with a Bunsen burner until the solid just starts to react (you’ll know when), then quickly remove the burner and let the solid react by itself. Write your results on the Report Form. Place the product in the Chromium waste container as it is very toxic.
Exothermic and Endothermic Reactions:

To two of your largest test tubes, add 5 ml of water to each. Place your thermometer into each to record the initial temperatures (rinse between each recording or use your thermometer for one test tube and your lab partner’s thermometer for the other test tube). Into one of the tubes add about \( \frac{1}{2} \) teaspoon of calcium chloride (CaCl\(_2\)). Into the second test tube add about \( \frac{1}{2} \) teaspoon of ammonium nitrate (NH\(_4\)NO\(_3\)). Stir both solutions with separate stirring rods. Let the solutions sit for about 5 minutes. Record the final temperature of each solution.

Copper + Silver nitrate.

Place a shiny clean Copper penny or piece of clean copper metal into a large test tube or your smallest beaker. Add about 3 mL of 0.1 M Silver Nitrate (AgNO\(_3\)). Watch and wait and record your observations on the report sheet. Observe the tube again after about 20 minutes and record your observations. Dispose of waste from this reaction in a designated Silver Waste container.

Potassium Iodide + Lead(II) Nitrate.

Add about \( \frac{1}{8} \) teaspoon of KI to a 150 ml or 250 ml beaker. Add to the solid 200 ml of very hot water (90°C) and stir. Likewise, add about \( \frac{1}{8} \) teaspoon of Pb(NO\(_3\))\(_2\) to a second 150 ml or 250 ml beaker. Add to this solid 200 ml of very hot water (90°C) and about 5 drops of 3M HC\(_2\)H\(_3\)O\(_2\) (3 molar acetic acid). Pour both solutions into a large flask or beaker. Results? Pour off most of the liquid that forms leaving the solid behind into a large Erlenmeyer flask. Heat the liquid to near boiling (90°C), and then allow the solution mixture to cool to room temperature (you can run cold water over the flask in the sink to hurry up this cooling). Results?

Aluminum and Hydrochloric acid.

Add a small piece of Aluminum foil or shavings (Al) to your largest test tube and place the test tube in your test tube rack. Pour 5 mL of 6M HCl (6 molar hydrochloric acid) into the test tube and let the test tube sit until a reaction is observed. Test the flammability of the gas using a burning wood splint. You may have to concentrate any gas by placing a rubber stopper (loosely) in the mouth of the test tube before testing the gas. Results?
Report for Carbon Dioxide and Chemical Reactions Experiment:

Questions: Preparation of \( \text{CO}_2 \) (g).

1. Amounts of reactants used and product made:

| Approximate amount of sodium bicarbonate used to fill the collection flasks with gas. | _____ scoops sodium bicarbonate |
| Approximate about of acetic acid used to fill the collection flasks with gas. | _________mL acetic acid |

2. Circle the formula of the gas generated from the reaction of sodium bicarbonate and acetic acid.

\[
\text{NaHCO}_3 + \text{HC}_2\text{H}_3\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{NaC}_2\text{H}_3\text{O}_2
\]

3. How long did it take to fill the collection flask with gas?

4. What happened when you plunged the burning splint into the first glass bottle?

5. Did you get a fine residue in the second glass bottle with saturated \( \text{Ca(OH)}_2 \)?
**Copper(II) Sulfate + Sodium Hydroxide**

Circle all of the following that are true about this mixture:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction occurred

Describe observations characteristic to this reaction.

**Copper(II) Sulfate + Ammonia**

Circle all of the following that are true about this mixture:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction occurred

No. of drops of NH₃ __________

Describe observations characteristic to this reaction.

**Yeast + Hydrogen Peroxide**

Circle all of the following that are true about this mixture:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy
- E. Temperature lowers or energy absorbed
- N. No reaction occurs

Identity of gas produced

= ____________________

Give evidence for the identity of any gas produced.

**Ammonium Dichromate + Heat**

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction

Describe observations characteristic to this reaction.

**Calcium Chloride + Water**

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction

Initial Temp ________

Final Temp ________
### Ammonium Nitrate + Water

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction

<table>
<thead>
<tr>
<th>Initial Temp</th>
<th>Final Temp</th>
</tr>
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<tbody>
<tr>
<td></td>
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</table>

Describe observations characteristic to this reaction.

### Copper + Silver Nitrate

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction

The gray solid produced is

### Potassium Iodide + Lead(II) Nitrate

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or energy released
- E. Temperature lowers or energy absorbed
- F. No reaction

Describe the solid that formed when the solution mixture cooled.

### Aluminum + Hydrochloric Acid

Circle all of the following that are true about this reaction:
- A. Gas production
- B. Solid formation
- C. Color change
- D. Temperature rises or light energy released
- E. Temperature lowers or energy absorbed
- F. No reaction.

**Identity of gas produced**

= ________________

Give evidence for the identity of the gas produced.