Combining Volumes of Gases: NO and O₂

Description: Gay-Lussac’s law of combining volumes is demonstrated by the reaction of nitric oxide (NO) with oxygen (O₂) to generate NO₂.

Materials:
- O₂ gas
- NO gas
- Food coloring
- 2 1-L round bottom flasks
- 1 2-L Erlenmeyer flask
- Tubing, stoppers, clamps (see diagram)

Procedure:

1. Fill one flask with O₂ gas and the other with NO gas and seal the flasks until the demonstration is to be performed. See step 2 for NO generation. Continue setup as depicted in the figure below (Shakhashiri, 169). Fill the Erlenmeyer with water and add food coloring. Use a syringe to pull water through the tubing that will run between the Erlenmeyer and the round bottom that will have oxygen in it. Clamp it so that the water does not drain from the tubing. Also clamp the tubing that will run between the two gases. Once tubing is setup attach the gas filled flasks to the tubing apparatus by inverting the flasks, removing their stoppers and replacing with the stopper/tubing setup.

2. NO (g) can be generated by the reaction of Cu turnings with 8.0 M nitric acid in a fume hood. Place 17 g of copper turnings in a 500 mL Erlenmeyer flask and seal the flask with a stopper and glass funnel as shown below (Shakhashiri, 169). The stem of the funnel should be placed close to the bottom of the flask. Add 50 mL of 8.0 M HNO₃ slowly through the funnel. NO gas will be produced but will immediately react with oxygen in the flask to generate NO₂ (brown). Allow this gas to be released into the fume hood. Once the brown NO₂ gas is no longer observed, begin collecting NO in the 1-L flask. This is accomplished by filling the 1-L flask with water and inverting it in a large evaporating dish also filled with water. Push the rubber tubing into the flask and the NO
produced from the Erlenmeyer flask will displace the water inside the 1-L flask (shown below).

3. To begin, unclamp the tubing in between NO and O$_2$. A brown gas will be observed in the tubing and in the NO flask. Remove the clamp between the water and the oxygen. As the reaction proceeds, water will replace the void created by the consumed gas. The NO$_2$ generated will dissolve in the water. Water flow will decrease towards the end of the reaction but can be steadied by raising the height of the Erlenmeyer flask. At the end of the demonstration, the O$_2$ flask should be filled while the NO flask will be half-filled.

**Discussion:** The product of the reaction of these two colorless gases (NO and O$_2$) is a brown gas, NO$_2$ which readily dissolves in water. The consumption of gas creates a vacuum in the flasks which is filled by water from the Erlenmeyer flask. The stoichiometry of the reaction is indicated by the amounts of water that are introduced into each flask.

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2 \text{ NO (g)} + \text{ O}_2 \text{ (g)} \rightarrow 2 \text{ NO}_2 \text{ (g)}
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Although the “O$_2$” flask is completely filled with water, the reaction consumes NO and O$_2$ in a ratio of 2:1. The excess O$_2$ is introduced into the NO flask as water fills the “O$_2$”flask. This can be confirmed by placing a glowing wooden splint near the mouth of the flask.
Safety: Wear proper protective equipment including gloves and safety glasses when preparing and performing this demonstration. Concentrated solutions of acids and bases (>2 M) can irritate the skin and cause burns. When diluting concentrated acids, add the acid to the water to avoid spattering. NO is readily oxidized in air to generate NO$_2$. NO$_2$ is extremely toxic and lethal even at concentrations as low as 200 ppm. Inhalation may result in delayed but severe pulmonary irritation. Preparation of NO should be performed in a fume hood and the demonstration should be performed in a well ventilated area.

Disposal: Any residual NO should be oxidized to NO$_2$ and dissolved in water. The contents can be flushed down the drain.

References:
