CHAPTER 23 NITROUS OXIDE

NITROUS OXIDE IS A COLORLESS GAS WITH A SLIGHTLY SWEET ODOR. It is the least reactive of all the nitrogen oxides at normal temperatures — it does not even react with the halogens. At higher temperatures it functions as an oxidant. Nitrous oxide is a very minor constituent of the Earth's atmosphere and represents 0.00005% by volume of the atmosphere.

The official IUPAC name for nitrous oxide, N_2O, is dinitrogen oxide. Like many substances, N_2O has a common name, "nitrous oxide" which is so widely used that most people refer to the gas by this name. The gas was discovered by Joseph Priestley and described in his 1772 paper titled ***Observations on Different Kinds of Air***. In this paper, he called the gas "nitrous air diminished". It is also referred to as simply "nitrous" or "laughing gas" and is the chemical subject of the famous caricature of a program at the Royal Institution in 1802 (shown in figure).

James Gillray's 1802 caricature of a lecture at the Royal Institution titled, "New Discoveries in Pneumaticks: or, an Experimental Lecture on the Power of Air." (Reproduced courtesy of the Library and Information Centre, Royal Society of Chemistry.)

Nitrous oxide is prepared by the thermal decomposition of ammonium nitrate in the temperature range 170 – 260 ^oC. Nitrous oxide soluble in fats/oils, which coupled with the fact that N_2O is a condensable gas, makes the gas an ideal propellant for whipping cream. Nitrous oxide is used as an inhalation anesthetic and analgesic.

Nitrous oxide has a melting point -90.81 ^oC and a boiling point -88.46 ^oC. The density of $N_2O(g)$ is 1.799 g/L at 25 ^oC and 1 atm. It has a density that is 1.52 times greater than that of air. Nitrous oxide is fairly soluble in water. Under standard conditions, 56.7 mL of $N_2O(g)$ will dissolve per 100 mL of water. It is also very soluble in alcohols, ether, fats, oils and sulfuric acid.

Suitability

All of the experiments could be performed as a sequence of classroom demonstrations designed to show several important properties of nitrous oxide. All of the experiments are suitable for student-use in the laboratory by advanced high school or university-level chemistry students. Of the six experiments given, Experiment 4 is most suited as a demonstration because it is messy (uses vegetable oil). Experiment 5 involves burning magnesium and thus makes another good candidate for a classroom demonstration. Individuals attempting these experiments should be experienced with the simpler syringe/gas techniques. The experiments included in this chapter are:

Experiment 1. Wooden splint test for nitrous oxide
Experiment 2. Nitrous oxide forms explosive mixtures with hydrogen
Experiment 3. Nitrous oxide rockets
Experiment 4. Solubility in water and oil
Experiment 5. Magnesium burns in nitrous oxide
Experiment 6. Enlarged candle flame of nitrous oxide

Most of the eleven experiments with nitrous oxide can be used to address topics such as physical and chemical changes, energy and chemical change, writing balanced chemical equations, properties of N_2O, chemical reactivity of N_2O, and oxidation-reduction reactions. Experiments 1 and 6 specifically address the ability of nitrous oxide to function as an oxidant, much like oxygen. Experiments 2 and 3 demonstrate that nitrous oxide forms explosive mixtures with hydrogen. Nitrous oxide is used as a propellant in whipping cream dispensers because it is quite soluble in fats. This will be seen in Experiment 4. Experiment 5 gives one more example of the ability of nitrous oxide to function as an oxidant at elevated temperatures.

Background skills required

Students should be:

- ❖ able to manipulate syringes from previous experience with the In-Syringe method.
- ❖ familiar with the Thermal Method.

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❖ understand fundamental concepts of high school chemistry so that observations can be interpreted.

Time required

If nitrous oxide is provided from a cartridge/gas bag, these experiments can be conducted rather quickly — Experiments 1, 2, 3 and 6 could accomplish by students in a single laboratory period. Experiments 4 and 5 could be presented as a classroom demonstration.

Before students arrive: Assemble the equipment required

Generating gases by the Thermal Method requires the Microscale Gas Chemistry Kit as well as the special "Thermal Method Equipment" listed in Chapter 19. If nitrous oxide is being provided by the cartridge method, the dispensing equipment must be constructed.

Alternative method for preparing nitrous oxide: Boiling water bath method

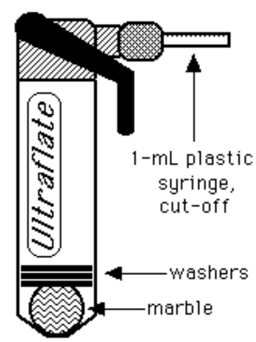
Samples of N_2O (g) can be prepared using a boiling water bath. Before starting, prepare a hot water bath at a continuous boil. In a small clean test tube, measure out 0.05 g NaCl and 1.0 g NH_4NO_3. Measure out 5 mL of 6 M HNO_3 and add to the test tube. Gently swirl the mixture until all of solid is completely dissolved. Transfer mixture to a small weighing dish. Lubricate the black rubber diaphragm of a 60 mL syringe and draw the liquid mixture from the weighing dish. Cap the syringe and place in boiling hot water bath. It will take about 20 - 30 minutes to completely fill a syringe with N_2O by this method.

Alternative method for preparing nitrous oxide: Cartridge Method

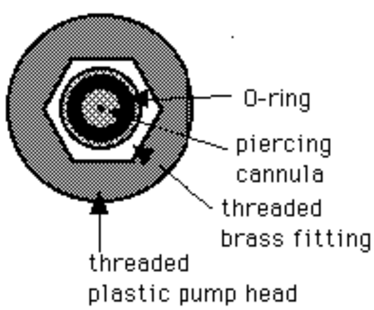
Samples of N_2O (g) can be prepared using a boiling water bath. The cartridge method, developed by the late Viktor Obendrauf, requires a little more initial effort, but provides for a very inexpensive and reliable method for quickly dispensing N_2O(g). One dispenser is adequate for an entire laboratory class of students. Nitrous oxide is sold as a propellant for whipping cream. Each nitrous cartridge contains approximately 7 g (160 mmol) N_2O — enough to fill over 60 syringes with 60 mL N_2O(g). The "nitrous" cartridges are shaped similar to CO_2-cartridges used for inflating bicycle tires, but they are a bit shorter and the connection tip is wider. For those two reasons, the bicycle tire pump must be modified slightly in order to accept nitrous cartridges.

Equipment needed for the cartridge method

- Nitrous oxide cartridges, available from restaurant supply houses ("Cream Charger" cartridges (UPC 85355 00088) are available from iSi North America, Inc., Telephone 1-800-211-9608)
- CO_2-bicycle tire pump (The carbon dioxide cartridge bicycle tire pump (sold as "Ultraflate") is available from bicycle supply stores for about $20. You may purchase the Ultraflate (UPC 08162 02410) from Innovations in Cycling, Inc., Tucson, AZ, 1-520-295-3936.)
- a glass marble (15 mm dia)
- 5 washers (18 mm dia washers)
- Dremel tool
- tubing, 3 cm length
- 1 mL plastic disposable syringe



Because the overall length of the CO_2 cartridge is longer than the N_2O cartridge, a glass marble plus a few washers (we use several washers with a combined thickness of 8 mm) are placed in the pump body as shown in the figure at right. Next, the inner threads of the brass head-piece need to be removed with a Dremel tool so that the wider nitrous connection top will fit into the head. Use caution not to damage either the piercing cannula or the O-ring at the base of the threads during the thread-removal procedure. This work area is shown in the figure below. When installing the cartridge, use care to not over-tighten the dispenser head which could damage the rubber O-ring. Using the modified dispenser is easy. A 3 cm length of a plastic 1 mL syringe barrel is inserted into the tire-valve fitting of the dispenser forming a gas-tight fit. A short length of tubing is slipped over the cut-off syringe and the dispenser is ready for use. This tubing can connect directly to the syringe fitting of a syringe to be filled with the gas. Pulling back on the handle for just a brief instant is enough to fill a syringe with 60 mL $N_2O(g)$.



Gas chromatography can be used to compare these two methods along with the thermal method described in the next section. The gas chromatograms of N_2O produced by the three methods is shown in the figure below.

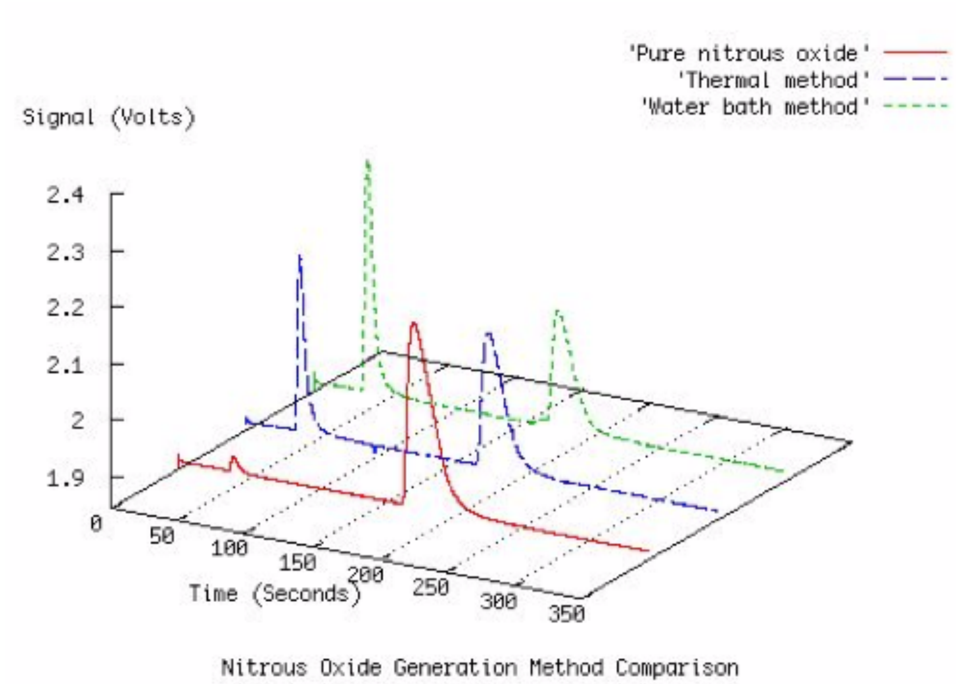
Gas bags

If nitrous oxide is being provided via cartridges, the use of a gas bag to store and dispense the gas is convenient. See Chapter 5.

Gas reaction catalyst tube

Three interesting reactions involving methane and the Gas Reaction Catalyst Tube were given in Chapter 18. Refer to these catalytic experiments:

H. Decomposition of nitrous oxide
I. Nitrous oxide and ammonia
J. Nitrous oxide and carbon monoxide



Comparative gas chromatograms of N_2O produced by microwave (top), thermal (middle) and cartridge (bottom) methods. The peaks at t = 40 s are due to air.

Website

This chapter is available on the web at website:

http://mattson.creighton.edu/Microscale_Gas_Chemistry.html

Instructions for your students

For classroom use by teachers. Copies of all or part of this document may be made for your students without further permission. Please attribute credit to Professors Bruce Mattson and Mike Anderson of Creighton University and this website.

GENERATING NITROUS OXIDE[1]

General Safety Precautions

Always wear safety glasses. Gases in syringes may be under pressure and could spray liquid chemicals. Follow the instructions and only use the quantities suggested.

Toxicity

Nitrous oxide has relatively low toxicity. All gases except for oxygen are potential asphyxiants. The anesthetic and analgesic effects of nitrous oxide are not noticed when working with small quantities of gas.

Equipment

The following "Thermal Method Equipment" is used to generate gases by the Thermal Method. It is the same equipment that was used to produce HCl(g) in Chapter 19. You will also need the basic Microscale Gas Chemistry kit (Chapter 1)

18 x 150 mm test tube (in addition to the one in the Microscale Gas Chemistry Kit)
two-hole #1 stopper fitted with two short lengths (2 cm) of glass tubing
two pieces of tubing, 1/8-inch (3.175 mm) ID, 5 cm length
pinch clamp or hemostat
ring stand and a suitable clamp to hold test tube
wooden dowel or aluminum rod, 1 cm diameter x 15 cm length with suitable clamp
three heavy duty rubber bands
small Bunsen burner
matches or a lighter
balance capable of measuring to 0.01 g

MAKING NITROUS OXIDE

Traditionally, nitrous oxide is made by the thermal decomposition of ammonium nitrate at temperatures between 170 - 260 ºC.[2] This method was developed by the French chemist Claude Louis Berthollet in 1785 and has been widely used ever since. Unfortunately, the method poses a potential explosion risk from overheating ammonium nitrate. Here we follow a less familiar method that gives excellent results and poses no risk of explosion. Gently heating a dilute nitric acid solution of ammonium nitrate in the presence of a small amount of chloride gives almost pure N_2O.[3] The reaction is:

$$NH_4NO_3(aq) \rightarrow N_2O(g) + 2\ H_2O(l)$$

[1] Content for this chapter first appeared as "Microscale Gas Chemistry, Part 18. Experiments with Nitrous Oxide," Mattson, B., Sullivan, P., Fujita, J., Pound, K., Cheng, W., Eskestrand, S., Obendrauf, V., ***Chem13 News***, **299**, January, 2002.
[2] Archibald, E. H., ***The Preparation of Pure Inorganic Substances***, pg 246, Wiley, New York, 1932.
[3] Cotton, F. A., Wilkinson, G., ***Advanced Inorganic Chemistry, Fourth Edition***, pg.,423, Wiley, New York, 1980.

Chemicals required for each preparation

5 mL 6 M HNO_3

1 g NH_4NO_3

0.05 g NaCl

1. Wear your safety glasses!

2. Check the plunger and barrel

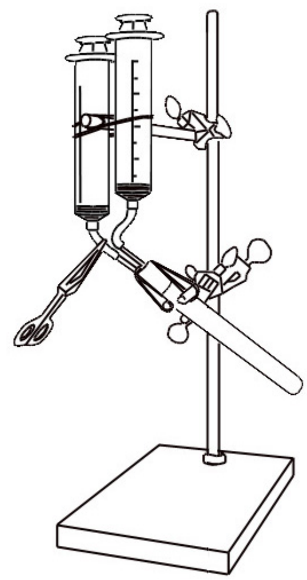
Make sure the syringe plunger moves easily in the syringe barrel. If it does not, try another combination of plunger and barrel.

3. Measure out the reagents

Add 5 mL 6 M HNO_3(aq), 1 g NH_4NO_3(s) and 0.05 g NaCl(s) to the 18 x 150 mm test tube.

4. Assemble the apparatus

The fully assembled apparatus is shown. Start by clamping the test tube in position at a 45º angle.



5. Secure the stopper in the test tube

Insert the rubber stopper firmly and snugly into the test tube. The stopper is held in place with a rubber band. The rubber band should be taut.

6. Position the syringes

Clamp the wooden dowel or aluminum rod in position about 15 cm above the lower clamp that holds the test tube. The two syringes are held in position by rubber bands around the dowel/rod. The use of rubber bands is preferable to using clamps because it is easier and faster to removed/replaced syringes.

7. Burner

A small Bunsen burner is necessary for this reaction. More heat is required than was the case in the preparation of carbon monoxide in the previous chapter.

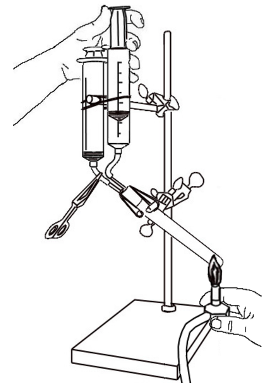
8. Hemostat/pinch clamp

A hemostat or pinch clamp is used to pinch closed the left rubber tube.

9. Perform the reaction in three steps

Nitrous oxide is generated by the following 3-step maneuver.

Step A. Collect air and gas in first syringe

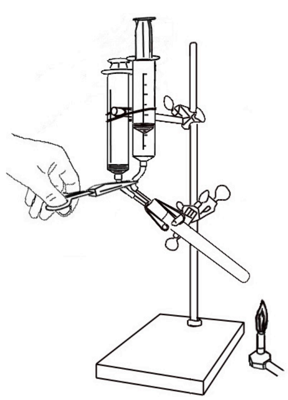


The first of the gas collected is mostly air originally present in the test tube. Hold the heat source with one hand while assisting the movement of the plunger with the other. This maneuver works well with two individuals working together. **Caution**: Do not crimp the tubing!

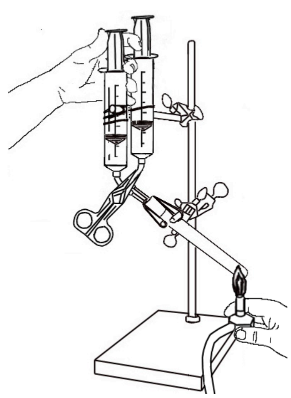
Gently heat the mixture in the test tube with the cool part of the flame. Bubbles of N_2O soon will appear. Establish a gentle rate of N_2O production by waving the flame back-and-forth across the test tube in order to produce a steady stream of tiny bubbles. Important: N_2O is produced as tiny bubbles in the solution. This occurs at a temperature of about 80 ^oC. Larger bubbles attributed to boiling water and/or production of NO(g) will occur if the solution is overheated. Avoid producing large bubbles. The plunger of the Waste syringe should begin to move. It may be necessary to assist the sliding movement of the plunger up the barrel of the syringe during the reaction. Continue to heat while gently assisting the plunger's movement. Within 5 minutes the volume of gas in the syringe will be 25 - 30 mL. This gas is mostly air originally present in the test tube.

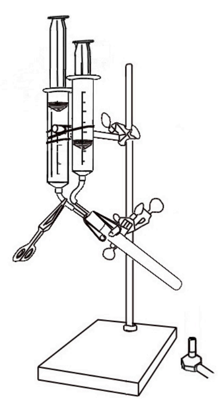
Step B. Collect the gas

After 25 - 30 mL of air/N_2O has been collected in the Waste syringe, switch the location of the pinch clamp to the other tube so that relatively pure N_2O(g) can be accumulated in the syringe labeled "N_2O". Continue to collect N_2O(g) over the next 10 minutes — until at least 50 - 55 mL has been collected in the N_2O-syringe. This entire process of careful heating to only produce tiny bubbles will take about 20 minutes. (If you intend to collect multiple syringes full of N_2O, replace the Waste syringe with another clean, dry syringe while you are waiting for the gas to accumulate during this step.)



move hemostat





left tube clamped shut

Step C. Stop heating

Switch the hemostat back to the tubing connected to the N_2O-syringe and remove the heat source. WARNING: Never simultaneously pinch both tubes!

10. Collecting multiple samples (optional)

It is possible (and probably desirable) to replace the $N_2O(g)$ syringe with a clean, dry syringe, and repeat Steps 2 and 3; two syringes full of $N_2O(g)$ can be collected in this fashion. As each N_2O-filled syringe is removed from the apparatus, cap the syringe with a syringe cap. After two syringes full of N_2O have been collected, allow the apparatus to cool.

11. Washing the gas

It is unnecessary to wash the samples of $N_2O(g)$; they can be used as collected.

12. Disposal

Unwanted $N_2O(g)$ samples can be safely discharged into the fume hood or out of doors.

Teaching tips

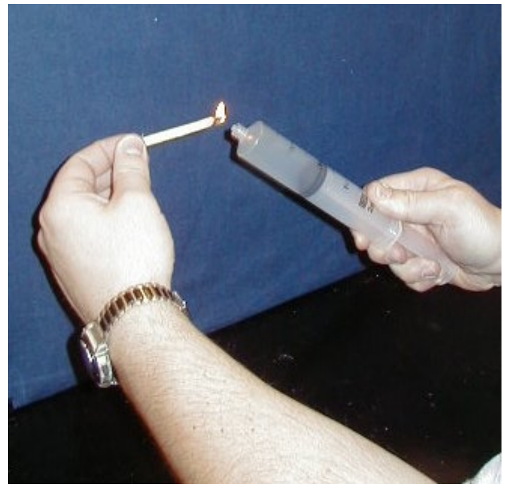
1. Keep the system under reduced pressure at all times — avoid popping stoppers!
2. The easiest method for producing syringe-filled samples of nitrous oxide is the "cartridge method" followed by the boiling water bath method, both described in this section.

Questions

1. How many moles of $N_2O(g)$ can be expected if 5 mL 6 M $HNO_3(aq)$, 1 g $NH_4NO_3(s)$ and 0.05 g $NaCl(s)$ are used in the reaction? Comment on the role of these three reagents. Refer to the balanced equation given above.
2. Referring to Question 1, what volume (in mL) of $N_2O(g)$ is expected if the temperature is 298 K and standard pressure?
3. How does the rate of $N_2O(g)$ formation compare to other gases made by the thermal method?

EXPERIMENTS WITH NITROUS OXIDE

EXPERIMENT 1. WOODEN SPLINT TEST FOR NITROUS OXIDE



Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)
wooden splint
match or lighter
glass pipet

Chemicals

$N_2O(g)$, 60 mL

Suitability

advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

combustion, oxidizing agents, energy and chemical change, chemical formulas, properties of N_2O, chemical reactivity of N_2O

Instructions

Nitrous oxide is the only common gas, other than oxygen, that will ignite a glowing splint. Remove the syringe cap and set it aside. Connect the syringe to a glass pipet with a short length of tubing. Ignite and then blow out the wooden splint. While the splint is still glowing, discharge a few mL of N_2O directly onto the red embers. The splint will re-ignite. Option: Fill a large test tube with $N_2O(g)$ using a 15 cm length of tubing attached to the N_2O-filled syringe. Poke the glowing splint into the test tube of $N_2O(g)$ and it will re-ignite.

Teaching tips

1. Nitrous oxide does not support combustion nearly as well as oxygen, but it is the only other common gas besides oxygen to do so.
2. Practice with the N_2O-syringe/glowing splint. It does not work every time.

Questions

1. What other gas was tested with the glowing-splint test?
2. How is nitrous oxide's ability to support combustion used in the "real world"?
3. Imagine methane being oxidized to water vapor and carbon dioxide by nitrous oxide. Write and balance the chemical equation that takes place.
4. How does nitrous oxide differ from oxygen in terms of its oxidizing ability?

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Experiment 2. Nitrous oxide forms explosive mixtures with hydrogen

Equipment

Microscale Gas Chemistry Kit

Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)

match or lighter

Chemicals

$N_2O(g)$, 10 mL

$H_2(g)$, 10 mL, Chapter 3

3% soap solution, 10 mL

Suitability

advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

explosive mixtures, energy and chemical change, writing balanced chemical equations, classifying chemical changes, chemical reactivity of N_2O, volume-volume relationships (law of combining volume), oxidation-reduction

Instructions

Prepare a syringe full of hydrogen. Transfer 10 mL of each $N_2O(g)$ and $H_2(g)$ to a clean syringe. Bubble some of the N_2O/H_2 mixture through a 3% soap solution in a plastic weighing dish. Ignite the mixture with a match. This should produce a loud bang.

Teaching tips

1. These two gases form an explosive mixture. Do not store the gas mixture and do not make more than 20 mL total volume.
2. Avoid sparks (including static electricity) and flames in the vicinity of the gas mixture.

Questions

1. Given that the products of the reaction are nitrogen and water, write and balance the chemical equation that takes place in this experiment.
2. Use a table of ΔH_f values to calculate ΔH_{rxn} for the chemical equation determined in the previous problem.
3. Suppose 10 mL $N_2O(g)$ and 8 mL $H_2(g)$ were combined in a syringe. Which is the limiting reagent?
4. Continuing with Question 3, assuming room temperature and standard pressure, and that all of the gas was used to make bubbles, what amount of heat would be released during the reaction?

EXPERIMENT 3. NITROUS OXIDE ROCKETS

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)
piezoelectric sparker, (See Appendix C)
"rockets" (cut-off disposable plastic pipets)
small test tubes

Chemicals

$N_2O(g)$, 60 mL
$CH_4(g)$, 10 mL, from natural gas or Chapter 22
$H_2(g)$, 20 mL, Chapter 4

Suitability

advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

rocketry, explosive mixtures, energy and chemical change, writing balanced chemical equations, classifying chemical changes, chemical reactivity of N_2O, volume-volume relationships (law of combining volume), oxidation-reduction

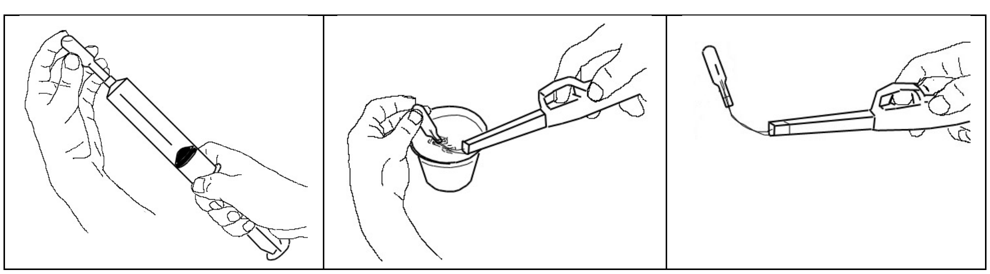
Instructions

This experiment is similar to numerous "pipet rocket" experiments we have described throughout this series, starting with Chapter 4, Oxygen. You may want to review this procedure that is provided on page 68 and again in Appendix C. Fill the pipet rockets completely with water and store them open-end down in test tubes filled with water. Stand the test tubes upright by placing them in a cup.

Part A. CH_4/N_2O Rocket

Transfer 10 mL CH_4 and 40 mL N_2O to a single syringe. Displace water in a water-filled "rocket" (left figure, below). Slip the pipet over a piezoelectric sparker, draw some water into the stem (center figure) and ignite the gas mixture with a spark (right figure). The rocket will fly over 5 m. An especially bright light accompanies the detonation. The reaction is:

$$4\ N_2O(g) + CH_4(g) \rightarrow 4\ N_2(g) + 2\ H_2O(g) + 2\ CO_2(g) \qquad \Delta H = -1131\ kJ$$



Part B. H_2/N_2O Rocket

Transfer 10 mL H_2 and 10 mL N_2O to a single syringe. Repeat the procedure described in Part A. The detonation is louder than the analogous reaction between methane and nitrous oxide.

Teaching tips

1. A step-by-step color photo sequence on filling and launching rockets is available at our website.
2. Try the reaction with the lights for added effect.
3. As a courtesy to others, tell students inform everyone in the room before they launch their rockets.
4. Award prizes for the rockets traveling the greatest distances.
5. The objective of the experiment is to illustrate that nitrous oxide and hydrogen (or methane) combustion reactions liberate energy and can perform useful work. The idea of stoichiometric ratios of N_2O to H_2 (or CH_4) can also be demonstrated.
6. Discuss and compare how the two fuel/oxidant mixtures performed.

Questions

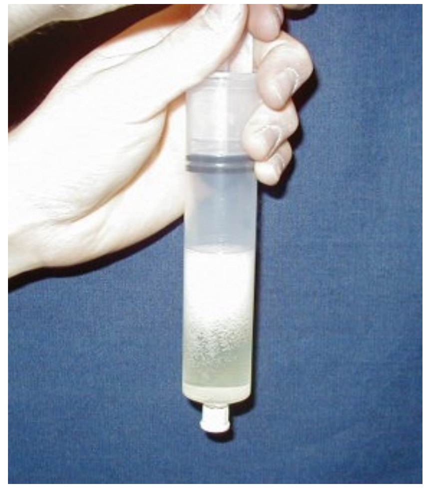
1. How far, in meters, did each fuel/oxidant mixture propel the rocket? Which works better, the N_2O/H_2 or the N_2O/CH_4 mixture?
2. Why did you use 10 mL CH_4 + 40 mL N_2O in Part A, but only 10 mL N_2O and 10 mL H_2 In Part B?
3. List the other fuel mixtures that you have used for rocketry experiments so far.
4. Would N_2O and O_2 make a reasonable fuel mixture for a rocket?

EXPERIMENT 4. SOLUBILITY IN WATER AND OIL

Equipment

Microscale Gas Chemistry Kit

Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)



Chemicals

$N_2O(g)$, 20 mL

vegetable oil, 40 mL

Suitability

advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

matter, classification of matter (homogeneous/heterogeneous solutions), physical and chemical changes, solutions, the dissolving process, solution equilibrium

Instructions

Part A. Solubility in water

Nitrous oxide is fairly soluble in water. Almost 60 mL N_2O will dissolve in 100 mL water. Fill a syringe with 20 mL N_2O. While the cap is still removed, draw in 40 mL water. This is more than enough water to dissolve all of the gas at 25 ^oC. Allow the syringe to stand overnight. By morning, almost all (>90%) of the N_2O will have dissolved. The solution process can be considerably hastened by positioning the syringe with its cap resting on the countertop and pressing firmly downward. Over the course of several minutes much of the gas will go into solution. Next, remove the gas from solution by pulling the plunger outward to the 60 mL mark and hold it there. Tap the syringe firmly on its side and bubbles of N_2O will swirl out of solution.

Part B. Solubility in oil

Repeat the experiment using vegetable oil instead of water as the solvent. N_2O is much more soluble in vegetable oil than it is in water.

Teaching tips

1. This experiment takes overnight.
2. The effervescence step (when the plunger is pulled outward to create a reduced pressure) is quite spectacular with vegetable oil.

Questions

1. When nitrous oxide dissolved in water, was a homogeneous or heterogeneous solution formed? What about when nitrous oxide in vegetable oil?
2. Why would nitrous oxide dissolve in water? Why would it dissolve in vegetable oil?

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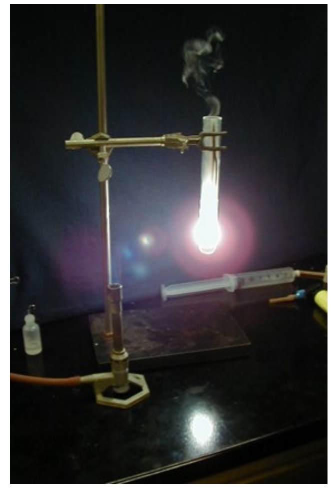
Experiment 5. Magnesium burns in nitrous oxide

Equipment



Microscale Gas Chemistry Kit
Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)
test tube, large (25 x 200 mm)
ring stand and clamp
lighter

Chemicals

$N_2O(g)$, 60 mL
3 cm length of magnesium ribbon
sand, 5 g
phenolphthalein indicator, 1 mL

Suitability

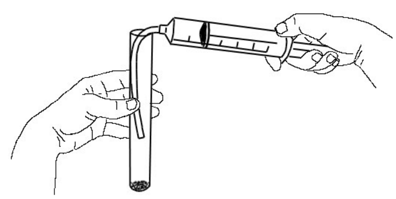
advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

combustion, energy and chemical change, writing balanced chemical equations, classifying chemical changes, chemical reactivity of N_2O, oxidation-reduction

Instructions

Add sand to a large test tube to a depth of 1 – 2 cm in order to protect the bottom of the test tube from the hot burning magnesium. Generate a syringe full of $N_2O(g)$. Equip the syringe with a 15 cm length of tubing and slowly discharge all 60 mL of the gas just above the surface of the sand as shown in the figure. The gas is 37% heavier than air and will displace air upward. Support in a vertical position with the aid of a ring stand.



Form a 3 cm length of magnesium ribbon into a loose coil. Using tongs to hold the magnesium, ignite the magnesium with the flame of a Bunsen burner and immediately drop the burning magnesium into the test tube. The Mg ribbon will burn brightly white at first and then turned orange as the N_2O nears depletion. A white cloud of $MgO(s)$ will form in the test tube. Allow the test tube to cool, then dump out the sand and unreacted Mg into a beaker. Add 30 mL water and a few drops of phenolphthalein indicator solution to the test tube. Stopper and shake the contents of the test tube. The white suspension of MgO will slowly turn to a pink suspension as MgO slowly hydrolyses to form $Mg(OH)_2$.

Teaching tips

1. Nitrous oxide is not as good an oxidant as oxygen at normal temperatures, but at elevated temperatures it is a reactive, powerful oxidant.
2. Avoid prolonged viewing of burning magnesium. Ultraviolet radiation is produced.

Questions

1. Balance the reaction that has occurred in this experiment.
2. Classify this reaction by type (acid-base, precipitation, oxidation reduction, etc.)
3. Does magnesium react better with air or nitrous oxide?
4. Does magnesium react better with oxygen or nitrous oxide?

EXPERIMENT 6. ENLARGED CANDLE FLAME OF NITROUS OXIDE

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)
birthday candle
long glass stir rod
tape
matches or lighter
test tube, large (25 x 200 mm)

Chemicals

$N_2O(g)$, 60 mL
$O_2(g)$, 60 mL

Suitability

advanced high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

combustion, oxidizing agents, energy and chemical change, chemical formulas, properties of N_2O, chemical reactivity of N_2O

Instructions

Joseph Priestley described the combustion of a candle in nitrous oxide as enabling the candle to burn with an "enlarged flame." As the discoverer of oxygen, he was familiar with the dazzling combustion of a candle in the presence of oxygen. These were the only two gases known to Priestley that could facilitate combustion. In this experiment, we shall compare air, oxygen and nitrous oxide as oxidants for a candle.

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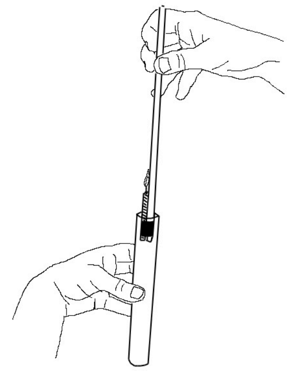
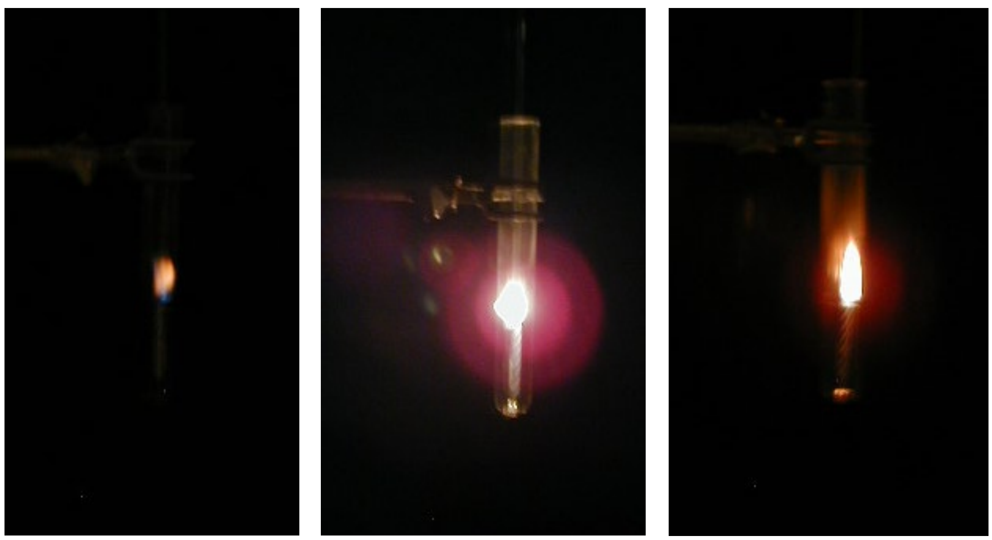
Tape a birthday candle to a long glass stir rod as shown in the figure. Ignite the candle and quickly lower it to the bottom of a large test tube. It will burn for a few seconds and then go out due to lack of oxygen.



Generate a syringe full of $N_2O(g)$ and with the aid of a 15 cm length of tubing and slowly discharge all 60 mL of the gas just above the bottom of the test tube as was done in the previous experiment. Ignite the candle and lower it to the bottom of the test tube into the $N_2O(g)$. It will burn much longer than in air and will burn with an enlarged flame as described by Priestley. Repeat the candle experiment with $O_2(g)$ and notice the differences in the abilities of the two gases to support combustion.



Left: Candle burning in air; Center: Candle burning in O_2; Right: Candle burning in N_2O:

Teaching tips

1. Insert all three candles in their respective test tubes all at the same time for comparison purposes.
2. Oxygen is a better oxidizing agent than nitrous oxide, but nitrous oxide works much better than air.

Questions

1. Compare your observations for these three gases, air, oxygen, and nitrous oxide.
2. In which test tube did the candle burned the longest? The next longest?
3. Is nitrous oxide a fuel or an oxidant?
4. Complete: (a) Air is to candle wax as nitrous oxide is to (methane, oxygen); (b) Nitrous oxide is to oxygen as hydrogen is to (methane, air).

Clean-up and storage.

At the end of the experiments, clean the syringe parts, caps and tubing with water. Rinse all parts with distilled water if available. Be careful with the small parts because they can easily be lost down the drain. **Important:** Store plunger out of barrel unless both are completely dry.

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SUMMARY OF MATERIALS AND CHEMICALS NEEDED FOR CHAPTER 23. EXPERIMENTS WITH NITROUS OXIDE

Equipment required

Item	For demo	For 5 pairs	For 10 pairs
Microscale Gas Chemistry Kit (See Chapter 1)	1	5	10
Thermal Method Equipment*	1	5	10
top-loading balance	1	2 - 3	3 – 5
pipet, glass Pasteur	2	10	20
wooden splint	1	5	10
piezoelectric sparker	1	2 - 3	3 - 5
extra large body polyethylene disposable pipets	1	5	10
small test tubes	3	15	30
large test tube (22 x 200 mm)	1	5	10
long glass stir rod	3	15	30

* Thermal Method Equipment (if $N_2O(g)$ is to be prepared by Thermal method)
** See Appendix C

Materials required

Item	For demo	For 5 pairs	For 10 pairs
matches or a lighter	1	1	1
birthday candles	3	15	30
sand	5 g	25 g	50 g
tape	1 roll	-	-
vegetable oil	40 mL	demo	demo

Chemicals required

Item	For demo	For 5 pairs	For 10 pairs
nitric acid, 6 M HNO_3*	25 mL	125 g	300 g
ammonium nitrate, NH_4NO_3*	5 g	25 g	50 g
sodium chloride, NaCl	0.5 g	2.5 g	5 g
3% dish soap solution	10 mL	50 mL	100 mL
hydrochloric acid, 2 M HCl(aq)	5 mL	25 mL	50 mL
magnesium ribbon	10 cm	50 cm	100 cm
natural gas, methane, CH_4(g)**	60 mL	300 mL	600 mL
phenolphthalein indicator	1 mL	5 mL	10 mL
hydrogen peroxide, 3% H_2O_2	5 mL	25 mL	50 mL
potassium iodide, KI	0.5 g	2.5 g	5 g

* This is enough for several preparations of nitrous oxide. These chemicals are not needed if the cartridge method is used

** use lab gas if available, or see Chapter 22 to prepare CH_4(g)

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