PART 5

OTHER METHODS

Overview to Part 5

PART 5. OTHER METHODS

Chapter 19. The Thermal Method: Making Hydrogen Chloride

Chapter 20. Carbon Monoxide

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In this section, we present five gases that cannot be generated by the In-Syringe Method used in Sections 1 - 3. Instead, we utilize a method that is over two centuries old and involves heating two reagents together and collecting the gas produced. The general idea for this method was first proposed by LeBlanc in the 18th century and described in Wurtz's 1875 ***Dictionary of Chemistry***. We have modified the method to utilize 60 mL syringes for gas collection. The Thermal Method is used to generate hydrogen chloride, carbon monoxide, ethene, methane and nitrous oxide.

In Chapter 24 we introduce yet a third method for gas generation, involving the use of a microwave oven. We have found this method useful for generating ammonia, oxygen, carbon monoxide, sulfur dioxide, methane and hydrogen chloride.

CHAPTER 19

THERMAL METHOD: GENERATING HYDROGEN CHLORIDE

THE FIRST RECORDED PREPARATION of hydrogen chloride dates back 1100 years ago when dilute HCl was prepared by the Arabian alchemist Rhazes. Methods for producing more concentrated forms of the acid were developed over the next three centuries and by 1200 AD, ***aqua regia***, a mixture of concentrated HCl and HNO_3, was being used to dissolve gold. J. L. Glauber was the first to prepare concentrated aqueous HCl in 1648 by heating $ZnCl_2$ and sand in a retort. Because of its reactivity, hydrogen chloride as a compound does not usually occur in nature.

Hydrogen chloride is a colorless gas with a disagreeable, pungent odor. When exposed to moist air, it forms fumes which are an aerosol of hydrochloric acid, HCl(aq). Hydrogen chloride has a melting point of -114.8 ^{o}C and a boiling point of -84.9 ^{o}C.

Hydrogen chloride is extremely soluble in water and forms the familiar hydrochloric acid, HCl(aq). At 0 ^{o}C, 823 g HCl dissolve per L H_2O; this corresponds to 506 volumes HCl per 1 volume water. Concentrated hydrochloric acid is 12 M and is one of only a few common strong acids that dissociate 100% in water:

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

By volume, hydrogen chloride ranks as one of the moat important chemicals produced by volume in modern society. Production follows a variety of pathways that depend on the resources available and the intended use of the product. Where NaCl deposits are available, HCl can be produced with concentrated H_2SO_4 by the ***Leblanc process*** developed in late 1700s:

$$2\ NaCl(s) + H_2SO_4(l) \rightarrow Na_2SO_4(s) + 2\ HCl(g)$$

The ***Hargreaves process***, developed a century later, is similar to the Lablanc process, but it utilizes $SO_2(g)$, H_2O and air instead of H_2SO_4. Because these reagents produce H_2SO_4 with an enormous amount of heat release, the overall reaction with NaCl is exothermic:

$$2\ NaCl(s) + SO_2(g) + H_2O + O_2(g) \rightarrow Na_2SO_4(s) + 2\ HCl(g)$$

Ultrapure HCl is produced by the direct combination of H_2 and Cl_2:

$$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$$

Hydrogen readily burns in an atmosphere of chlorine. The HCl produced in this way can be used in the food industry.

In terms of sheer volume, the largest industrial use of aqueous HCl is the *pickling* of steel — the removal of oxide coating by dipping the metal in HCl(aq). Hydrogen chloride and hydrochloric acid have literally thousands of uses that cover every sector of the chemical and pharmaceutical manufacturing industry. For example, the gelatin industry uses large amounts of HCl to decompose bones used as raw materials. HCl catalyzes the conversion of starch into glucose. Corn starch is converted into artificial maple syrup in this manner.

Suitability

Both advanced chemistry (2^{nd} year) high school and university-level chemistry students, with the background skills listed below, have a suitable background to do these experiments and all are suited for use as classroom demonstrations.

Experiment 1. Formation of an aerosol
Experiment 2. White clouds
Experiment 3. Acid snow?
Experiment 4. Fizzzzz!
Experiment 5. Curdles away
Experiment 6. Levitating paper
Experiment 7. Hydrogen chloride fountain

Experiment 1 is useful in demonstrating the acidic nature of HCl(g) and the formation of an aerosol. Experiment 2 demonstrates the formation of an inorganic salt, ammonium chloride, from a gas-phase acid and base. Experiment 3 demonstrates supersaturation. Both Experiments 4 and 6 pertain to the reaction between carbonates and hydrochloric acid to produce carbon dioxide. Experiment 5 shows how acid can be used to curdle milk. Experiment 7 uses an entire syringe full of HCl(g) to produce a spectacular fountain due to the extreme solubility of HCl(g) in water.

Background skills required

Students should be able to:

- ❖ manipulate syringes from previous experience with the In-Syringe method.
- ❖ measure quantities of reagents using a balance.

- prevent unintentional discharge of gas by using reduced pressure whenever opening the system.
- understand fundamental concepts of high school chemistry so that observations can be interpreted.

Time required

Generating the gas takes some time because the equipment and procedure is unfamiliar. Each experiment takes only a few minutes to perform. One possibility for a two-day treatment of this chapter is: Day 1: Set up the equipment and measure out the reagents necessary to generate HCl(g); Place these chemicals in the test tube. Day 2: Prepare HCl(g) and perform the experiments. Students should be able to perform most of the seven experiments in a single 45 minute laboratory period.

Before students arrive

Solid reagent mixture for hydrogen chloride preparation (optional)

The solid reagent mixture is a 2:1 mass ratio of sodium hydrogen sulfate monohydrate, $NaHSO_4 \cdot H_2O$, and sodium chloride, NaCl. It is convenient to prepare a large quantity of the solid reagent mixture (20 g $NaHSO_4 \cdot H_2O$ + 10 g NaCl) in order to perform several gas preparations. The mixture should be pulverized together with the aid of a mortar and pestle. (During the pulverization, you may notice the faint smell of hydrogen chloride. This is normal.) The mixture should be stored in a tightly sealed glass or plastic bottle. We have also obtained very nice results with a 2:1 mixture of anhydrous sodium hydrogen sulfate and sodium chloride.

Thermal Method Equipment list

Generating gases by the Thermal Method requires the following list of equipment.

Microscale Gas Chemistry Kit (Chapter 1)
18 x 150 mm test tube (in addition to the one in the 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 to hold it to the ring stand
three heavy duty rubber bands
small Bunsen burner
matches or a lighter
marker pen
balance capable of measuring to 0.01 g

Preparation of Hydrogen Chloride in the Microwave Oven

Samples of $HCl(g)$ also can be prepared conveniently in a microwave oven. See Chapter 24 for details.

Website

This chapter is available on the web at website:

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

Instructions for your students

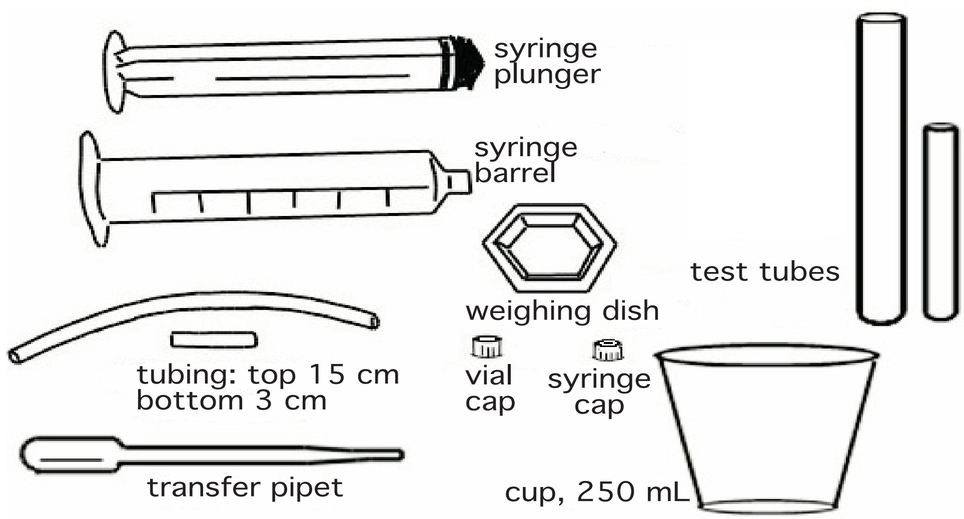
For classroom use by teachers. Copies of all or part of this document may be made for your students without further permission. Please attribute credit to Professors Bruce Mattson and Mike Anderson of Creighton University and this website.

THE THERMAL METHOD
GENERATING HYDROGEN CHLORIDE[1]

Not all gases can be prepared by the In-Syringe method used up until this chapter. The reason is always the same: the two reagents used to prepare the gas need to be heated in order for the reaction to proceed. We cannot heat plastic syringes because they will melt, so we must use a new method, called the ***Thermal Method***. The Thermal method is hardly new — it is over two centuries old! The general idea was first proposed by LeBlanc in the 18th century and described in Wurtz's 1875 ***Dictionary of Chemistry***. We have modified the method to utilize 60 mL syringes for gas collection. The Thermal Method is used to generate hydrogen chloride, carbon monoxide, ethene, methane and nitrous oxide.

Thermal Method Equipment

The Thermal Method requires the equipment pictured below. Much of this equipment is familiar to you because it is found in the Microscale Gas Chemistry Kit that you have used to produce gas samples by the In-Syringe Method.



Equipment not pictured above:

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 to hold it to the ring stand
matches or a lighter
marker pen
balance capable of measuring to 0.01 g

[1] Content for this chapter first appeared as "Microscale Gas Chemistry, Part 11. Experiments with Hydrogen Chloride" Mattson, B. M.; Catahan, R.; Vaitkus, R., ***Chem13 News***, **266**, April, 1998.

MAKING HYDROGEN CHLORIDE

The general strategy of the Thermal Method is to heat two substances together in a test tube. For example, we will generate HCl(g) from sodium hydrogen sulfate and sodium chloride. The steps given below can be used to make all of the gases in this section.

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

Hydrogen chloride has an irritating and unpleasant odor and is toxic. Inhalation of the gas will cause coughing.

Chemicals required for each preparation

sodium hydrogen sulfate, (sodium bisulfate) $NaHSO_4$, anhydrous, 1.1 g (or 1.3 g sodium hydrogen sulfate monohydrate $NaHSO_4 \cdot H_2O$)

sodium chloride, NaCl, 0.7 g

This quantity of reagents will produce approximately 60 mL of HCl(g). The production of HCl is relatively fast , depending on the amount of heat provided. Upon heating this mixture, HCl(g) is produced according to the reaction:

$$NaHSO_4(s) + NaCl(s) \rightarrow HCl(g) + Na_2SO_4(s)$$

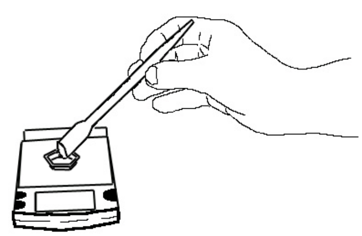
1. Wear your safety glasses!

2. Check the plunger and barrel

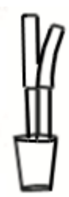
Make sure the syringe plunger moves easily in the syringe barrel. If it does not, try another combination of plunger and barrel.

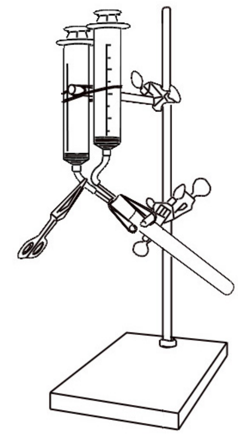
3. Measure out the solid reagents

Measure the solid reagents together into a weighing dish. To make HCl(g), use 1.1 g sodium hydrogen sulfate and 0.7 g sodium chloride (*or 1.3 g sodium hydrogen sulfate monohydrate). Place the chemicals together in the test tube.



4. Assemble the apparatus

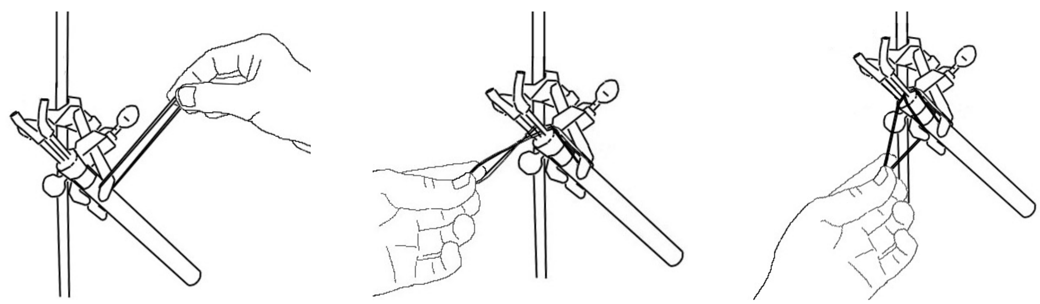




The fully assembled apparatus is shown at right. Start by clamping the test tube in position at a 45º angle. Insert a two-hole stopper equipped with two short lengths of glass tubing (the glass tubing must form an air-tight seal with the stopper). CAUTION! Use extreme caution when inserting glass into the rubber stopper. Lubricate the stopper and glass with alcohol to make it easier. Equip the glass tubes with 3 cm lengths of rubber tubing.

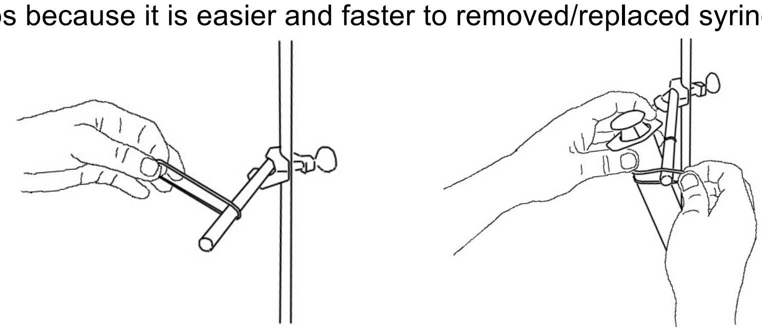
5. Secure the stopper in the test tube

Insert the rubber stopper firmly and snugly into the test tube. The stopper is held in place with a rubber band as shown in the following sequence: (Left) Hook the rubber band around one of the clamp's fingers; (Center) Maneuver the rubber band between the two glass tubes; and (Right) Hook the rubber band onto another clamp finger. The rubber band should be taut.

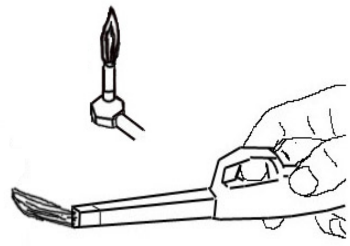


6. Position the syringes

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 as shown below: (Left) Slip two rubber bands (only one shown in figure) over the wooden dowel or aluminum rod; (Right) place the syringe next to the dowel/rod and then slip the rubber band around the syringe and over the dowel/rod; and then repeat with the other syringe. The use of rubber bands is preferable to using clamps because it is easier and faster to removed/replaced syringes.



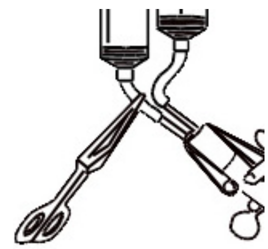
7. Burner



Prepare a burner for use. The amount of heat required depends on the gas being produced. For example, hydrogen chloride requires the use of a small burner. Carbon monoxide requires very little heat — the flame from a butane lighter is sufficient. Read gas-specific instructions carefully.

8. Hemostat/pinch clamp

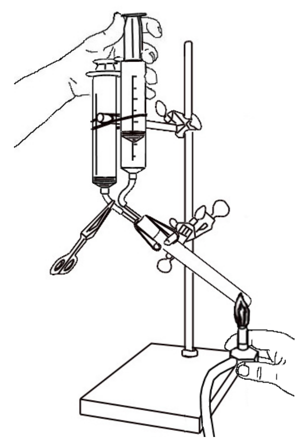
A hemostat or pinch clamp is used to pinch closed the left rubber tube as shown in the close-up figure.



left tube clamped shut

9. Perform the reaction in three steps

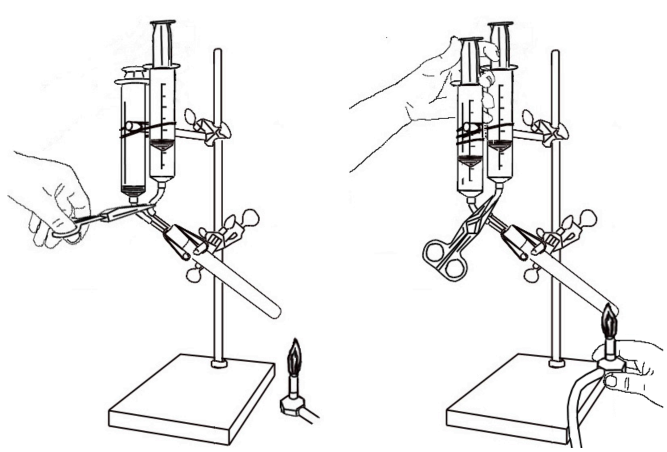
Step A. Collect air and gas in first syringe



The first syringe full of the gas collected is mostly air originally present in the test tube. Hold the heat source with one hand while helping the plunger upward — maintain reduced pressure. Gas soon will be produced and the plunger of the syringe should begin to move. It is 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.

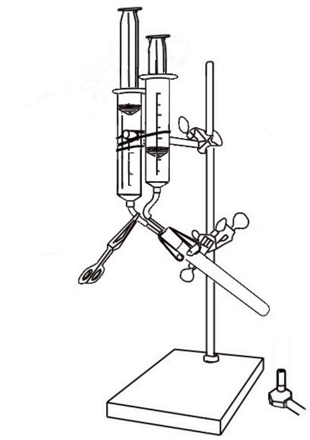
Step B. Collect the gas

After at least 30 mL of waste gas (air) has been collected in the right syringe, switch the location of the pinch clamp (left figure) to the right rubber tube so that relatively pure product gas can be collected in the left syringe. Assist the movement of the plunger as before (right figure). Continue to collect pure gas until at least 50 mL has been collected.



Step C. Stop heating

Switch the pinch clamp back to the tubing connected to the pure gas collection syringe and remove the heat source.



While holding the plunger slightly outward in order to establish a slightly reduced pressure, remove the tube from the gas collection syringe and immediately cap the syringe. The syringe contents are > 95% pure and ready for experiments.

Allow the apparatus to cool. The plunger in the remaining syringe may move outward at first because gas generation may continue for several seconds after the test tube is removed from the flame and then move inward as the apparatus cools.

10. (optional) Collecting multiple samples

If more than the prescribed amounts of reagents were used, it would be possible to collect two or more syringes full of HCl(g). Simply replace the "clamped-off" syringe (the left one in the figure above) with a clean, dry empty syringe. Switch the hemostat and continue heating.

11. Washing the gas is unnecessary

Hydrogen chloride is extremely soluble in water and cannot be washed. However, it is unnecessary to wash gases collected by the thermal method because the gas sample was collected in a clean, dry syringe.

Disposal

Unwanted samples of HCl(g) can be discarded by dissolving in water. The solid remaining in the test tube is Na_2SO_4 can be dissolved in water and discarded down the drain. The test tubes can be reused unless they have been damaged.

Teaching tips

1. This reaction (HCl-generation) tends to cause the rubber stoppers to become slippery. This in turn results in stoppers that tend to pop out of the test tubes. Use of the rubber band helps prevent this problem.
2. Remember: Before switching or removing a syringe, the tubing to that syringe must be pinched closed with the hemostat.
3. ***Never pinch both tubes closed at the same time.*** The moveable plunger provides necessary pressure relief.

Questions

1. How many moles of HCl(g) can be expected if 1.1 g anhydrous $NaHSO_4$ (or 1.3 g $NaHSO_4 \cdot H_2O$) and 0.7 g sodium chloride, NaCl are used in the reaction? Which is the limiting reagent?

2. Referring to Question 1, what volume (in mL) of HCl(g) is expected if the temperature is 298 K and standard pressure?

3. Describe the appearance of the reagents during the heating process.

4. Why did we have to make HCl by this method — and not by the familiar In-Syringe method used up until now?

5. In what form have you encountered HCl before this experiment?

6. Concentrated hydrochloric acid contains 12 moles HCl per liter of solution. Using the ideal gas law, calculate the volume of 12 moles of HCl(g), expressed in L at a temperature of 298 K and standard pressure.

7. Review the balanced equation for the reaction provided in the instructions above. Write a similar one that would occur if sodium bisulfate monohydrate were used instead of anhydrous sodium bisulfate.

EXPERIMENTS WITH HYDROGEN CHLORIDE

Universal indicator pH 8 solution

Experiments 1 and 7 require a slightly basic universal indicator solution. Prepare a solution by mixing 200 mL distilled water plus 20 mL universal indicator solution. Raise the pH to 11 by bubbling through the solution a pipet full of gaseous ammonia taken from the vapors above a solution of concentrated ammonium hydroxide solution. If the solution does not turn violet, repeat one or more times.

Indicator Colors		
pH	**Universal**	**Red Cabbage**
4.0	Red	Red
5.0	Orange Red	Purple
6.0	Yellow Orange	Purple
7.0	Dark Green	Purple
8.0	Light Green	Blue
9.0	Blue	Blue-Green
10.0	Reddish Violet	Green
11.0	Violet	Green
12.0	Violet	Green
13.0	Violet	Green-Yellow
14.0	Violet	Yellow

EXPERIMENT 1. FORMATION OF AN AEROSOL

Equipment

Microscale Gas Chemistry Kit
graduated cylinder, 100 mL
plastic transfer pipet

Chemicals

HCl(g), 40 mL
ammonium hydroxide, concentrated (vapors only used)
universal indicator pH 8 solution (or cabbage juice indicator)

Suitability

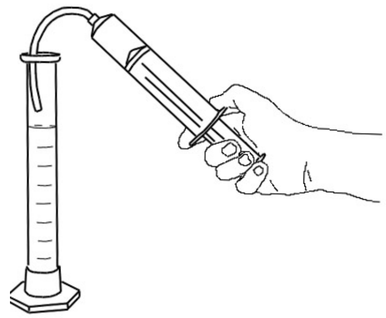
high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

chemical properties of gases, gas density, density of solutions, acidic nature of HCl(g), aerosols

Instructions

Fill a 100 mL graduated cylinder with 90 mL of the universal indicator/pH 8 solution. Remove the syringe cap and attach a 15 cm length of tubing to the HCl(g)-filled syringe. Dispense some of the gas near the surface of the water and notice the production of an acidic solution at the surface. You should also notice two other phenomena. An aerosol cloud of HCl/H_2O is formed above the surface. This is caused by HCl(g) condensing H_2O(g) into an aerosol because of the great affinity of HCl for water. You should also notice that the acidic solution sinks through the column of water and soon the entire contents of the graduated cylinder are the same color (acidic). The "sinking" occurs because the HCl(aq) solution that is produced near the surface is more dense than water and sinks.



Teaching tips

1. The reaction can be conducted using corn syrup instead of water. This creates a very nice longer-lived color-gradient display.
2. Students should compare their results – their colorful display will be quite different from others.
3. A chart of indicator color vs. the corresponding is provided at the beginning of this section.

Questions

1. What happened to the white cloud aerosol that formed above the surface of the water?
2. What indicator color(s) is(are) associated with acidic solution? Neutral solutions? Basic solutions?
3. Why does the red solution sink? Does your explanation involve HCl(g) or HCl(aq)?
4. Did the solution eventually become all red or revert to the pH neutral colors? Why is either answer possible?

EXPERIMENT 2. WHITE CLOUDS

Equipment

Microscale Gas Chemistry Kit
vial, 2 dram (5 mL bottle)
pipet

Chemicals

HCl(g), 10 mL
5 mL HCl(g), 1 – 2 mL concentrated ammonium hydroxide

Suitability

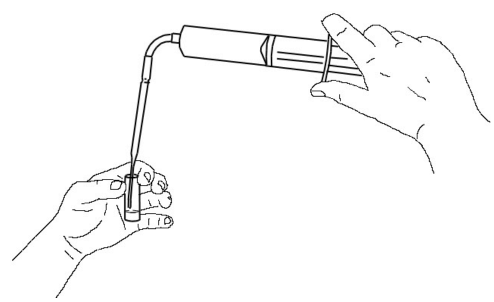
high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

chemical properties of gases, Lewis acids and bases, formation of ionic substances, properties of ionic substances

Instructions

Connect the HCl-syringe to a pipet using tubing. (Note: The tubing fits snugly *inside* the pipet). Pour 1 - 2 mL of concentrated ammonium hydroxide into a vial. Discharge a few mL HCl over the surface of the ammonium hydroxide. The reaction is:



$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

Continue to slowly discharge enough of the HCl so that the white cloud spills over the top of the vial.

Teaching tips

1. Discharge HCl(g) above the surface — there is a natural inclination to discharge the gas below the surface.
2. The white cloud is a solid suspension of ammonium chloride.
3. The reaction occurs between HCl(g) and NH_3(g) that has left the concentrated ammonium hydroxide solution.
4. "Ammonium hydroxide" is an old, but unfortunate name that suggests that the solution contains ionic ammonium hydroxide. It doesn't! Instead, ammonium hydroxide is simply aqueous ammonia solution. Some have suggested to rename the solution "strong ammonia solution."

Questions

1. What is the white cloud that seems to hover above the ammonium hydroxide solution? Is it a solid, liquid or gas? What is its formula?
2. Is the HCl reacting with the fumes above the liquid or with the liquid?
3. What would happen if you discharged enough of the HCl that the white cloud spilled over the top of the vial?
4. What would happen if you connected a syringe of HCl(g) with a syringe of NH_3(g) with a short piece of tubing and allowed the gases to react?

EXPERIMENT 3. ACID SNOW?

Equipment

Microscale Gas Chemistry Kit
vial, 2 dram (5 mL bottle)
pipet
flashlight

Chemicals

HCl(g), 10 mL
3 – 5 mL saturated NaCl(aq)

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

LeChâtelier's principle, saturation, precipitation, chemical equilibria

Instructions

Pour 3 - 5 mL of saturated NaCl(aq), into a vial, making it just over half-full. Discharge a few mL HCl over the surface of the solution and observe what happens just below the surface. The effect is enhanced by using a flashlight to watch the solid NaCl glitter as it falls. The reaction, demonstrating LeChatelier's principle, is:

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

$$Na^+(aq) + Cl^-(aq) \rightleftharpoons NaCl(s)$$

Teaching tips

1. One flashlight is enough for entire class.
2. Discharge HCl(g) *above* the surface — there is a natural inclination to discharge the gas below the surface.

Questions

1. The equilibrium that exists between saturated NaCl and the solid is:

$$NaCl(s) \rightleftarrows Na^+(aq) + Cl^-(aq)$$

   How does LeChatelier's theory predict the formation of more solid NaCl if more chloride is added to the solution?

2. What causes the glittering?

3. How would one prepare a saturated solution of NaCl?

4. How might one redissolve the solid NaCl produced?

EXPERIMENT 4. FIZZZZZ!

Equipment

Microscale Gas Chemistry Kit
vial, 2 dram (5 mL bottle)
pipet

Chemicals

$HCl(g)$, 10 mL
3 - 5 mL saturated $NaHCO_3(aq)$

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

chemical properties of gases, chemical reactions, carbonates, gas solubility, formation of an acid

Instructions

Pour 3 - 5 mL of saturated $NaHCO_3(aq)$, into a vial. Discharge a few mL HCl over the surface of the solution. Listen carefully to the "roar" of the reaction! The reaction is:

$$HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$$

$$HCO_3^-(aq) + H^+(aq) \rightarrow CO_2(g) + H_2O$$

Teaching tips

1. Discharge HCl(g) *above* the surface.

2. The gas bubbling forth from the solution is carbon dioxide.

Questions

1. What causes this reaction to be audible? What difference would occur if a larger vial were used? What difference would occur if you used three vials, each filled to a different level with solution?

2. Combine the two equations given above to produce an overall reaction.

3. What spectator ion is not listed in the above chemical reactions? If the reaction were carried out to completion, what product would remain in the solution?

EXPERIMENT 5. CURDLES AWAY!

Equipment

Microscale Gas Chemistry Kit
vial, 2 dram (5 mL bottle)
pipet

Chemicals

HCl(g), 10 mL
milk, a few mL

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

household chemicals, cheese production

Instructions

Place approximately 1 mL milk in a vial. Discharge a few mL HCl over the surface of the solution. The HCl will curdle the milk. Variant II. Dilute the milk with 5 parts water to 1 part milk before the reaction takes place.

Teaching tips

1. Discharge HCl(g) *above* the surface.

2. The curds are fat globules that come together.

Questions

1. Would skim milk work as well?

2. Milk is an emulsion of homogenized fat suspended in an aqueous phase. What other emulsions are common in the kitchen?

3. Recipes sometimes call for curdled milk. Neither hydrogen chloride nor hydrochloric acid is a foodstuff. What might one use in the kitchen to curdle milk?

EXPERIMENT 6. LEVITATING PAPER

Equipment

Microscale Gas Chemistry Kit
vial, 2 dram (5 mL bottle)
pipet

Chemicals

HCl(g), 10 mL
a disc of office paper (from a punch)

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

chemical properties of gases, chemical reactions, carbonates, gas solubility, formation of an acid

Instructions

Calcium carbonate used as the source of white opaqueness in office paper. High quality paper is up to 40% $CaCO_3(s)$. Place approximately 1 mL water and a paper disc into a vial. Discharge a few mL HCl over the surface of the solution. The HCl will dissolve in the water and react with the office paper, forming bubbles on the surface of the paper. The reaction is:

$$CaCO_{3(s)} + 2\ H^+(aq) \rightarrow Ca^{+2}(aq) + CO_2(g) + H_2O(l)$$

Teaching tips

1. Discharge HCl(g) above the surface.
2. Look for the bubbles forming on the disc of paper — more subtle than previous experiments.
3. Highly opaque office paper can contain over 40% calcium carbonate

Questions

1. What is the component in office paper that causes it to be white?
2. Although it was not measured, does the mass of your paper decrease with the reaction with acid?
3. Would bubbles form on a sheet of notebook paper if a few mL of vinegar were spilled on it?
4. In what form does the calcium end up at the end of the reaction? (You will need the spectator ion for your answer.) Is this substance water-soluble or is it still in the paper?

EXPERIMENT 7. HYDROGEN CHLORIDE FOUNTAIN

Equipment

Microscale Gas Chemistry Kit

Chemicals

HCl(g), 50 mL

universal indicator/pH 8 solution (or cabbage juice)

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

chemical properties of gases, gas solubility, indicators, acidic nature of HCl, gas pressure, atmospheric pressure

Instructions

Pour the universal indicator/pH 8 solution into a 250 mL beaker or plastic cup. Remove the syringe cap from the HCl(g)-filled syringe and ***while holding the plunger firmly in place so that it cannot be drawn inward***, plunge the syringe opening into the cup of water. Keep the syringe's syringe fitting under the surface of the water. Because HCl(g) is so soluble in water, the water is rapidly drawn into the syringe producing a small fountain. Be sure to hold the plunger in place to prevent it from being pulled into the syringe. There is a considerable force pulling the plunger inward.

Teaching tips

1. Students may be surprised with the force trying to pull the plunger inward. There is a tendency to pull the syringe back out away from the "grabbing forces".
2. A chart of indicator color vs. the corresponding is provided at the beginning of this section.

Questions

1. Is this a physical or chemical change?
2. What is the pH of the resulting solution?
3. Explain why there is a fountain effect.
4. What is the gas that remains in the syringe after the reaction?

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.

Summary of Materials and Chemicals Needed for Chapter 19. Experiments with Hydrogen Chloride

Equipment required

Item	For demo	For 5 pairs	For 10 pairs
Microscale Gas Chemistry Kit (See Chapter 1)	1	5	10
18 x 150 mm test tube*	1	5	10
two-hole #1 stopper fitted with two short lengths (2 cm) of glass tubing*	1	5	10
two pieces of tubing, 1/8-inch (3.175 mm) ID, 5 cm length*	2	10	20
pinch clamp or hemostat*	1	5	10
ring stand and a suitable clamp to hold test tube*	1	5	10
wooden dowel or aluminum rod, 1 cm diameter x 15 cm length with suitable clamp to hold to ring stand*	1	5	10
small Bunsen burner*	1	5	10
top-loading balance	1	2 - 3	3 – 5
vial, 2 dm (5 mL bottle)	2	10	20
graduated cylinder, 100 mL	1	5	10
pipet, plastic transfer	1	5	10
pipet, glass Pasteur	1	5	10

* from the list of Thermal Method equipment

Materials required

Item	For demo	For 5 pairs	For 10 pairs
heavy duty rubber bands*	3	15	30
paper punch	1	1	1
flashlight	1	1	1
milk	2 mL	5 mL	10 mL

* from the list of Thermal Method equipment

Chemicals required

Item	For demo	For 5 pairs	For 10 pairs
anhydrous $NaHSO_4$ *	3 g	15 g	30 g
sodium chloride, NaCl	2 g	10 g	20 g
universal indicator solution	10 mL	50 mL	100 mL
concentrated ammonium hydroxide	1 mL	5 mL	10 mL
saturated NaCl **	2 mL	10 mL	20 mL
saturated $NaHCO_3$ ***	2 mL	10 mL	20 mL

* or $NaHSO_4 \cdot H_2O$, 30% more than amount listed

** Add 10 g NaCl to 25 mL water and heat until quite hot and most of the salt dissolves. It does not need to boil. Allow to cool before using.

*** Add 5 g $NaHCO_3$ to 25 mL water and heat until quite hot and most of the salt dissolves. It does not need to boil. Allow to cool before using.

