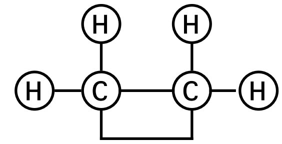
CHAPTER 21 | ETHENE (ETHYLENE)

ETHENE HAS BEEN KNOWN for quite some time. Alexander Crum Brown of Scotland correctly proposed its structure in 1864. His structure showed the carbon atoms forming two bonds to each other.



In Chapter 14 we described the differences in structure and bonding in the three hydrocarbon compounds with a C_2 base, ethane, ethene and ethyne.

Ethene is a colorless, flammable gas with a pungent odor that occurs naturally in ripening fruit and is found at low levels in natural gas deposits. Ethene also goes by its common name ***ethylene***, and the latter is widely used in industry.

Ethene is a gas under standard conditions. Its melting point is -169 ^oC and boiling point is -103.7 ^oC. Ethene is slightly soluble in water; at 25 ^oC, 110 mL C_2H_4 dissolve per L of water.

There are over 500 published methods for preparing ethene.[1] In this chapter we describe the preparation of ethene by two different methods. The most familiar involves the dehydration of ethanol with sulfuric acid.[2]

$$CH_3CH_2OH(l) + H_2SO_4(l) \rightarrow C_2H_4(g) + H_2SO_4{\cdot}H_2O(l)$$

An important method by which vast quantities of ethene are produced in the petroleum industry is the ***cracking process*** by which high molecular mass hydrocarbons are heated to form shorter hydrocarbons.

1 ***Encyclopedia of Hydrocarbon Compounds***, J. E. Faraday
2 Gattermann-Wieland, ***Praxis des organischen Chemikers***, 40th ed, Berlin, 1961

One of the most important uses of ethene is as the reagent used to make ***polyethylene***, perhaps the most common plastic in use today.

Suitability

Both advanced chemistry (2^{nd} year) high school and university-level chemistry students, with the skills listed below, have a suitable background to do these experiments. All of the experiments could be performed as a sequence of classroom demonstrations designed to show several important properties of ethene and organic compounds. Experiments 1 and 6 are the most suited for student-use in a laboratory situation.

Experiment 1. Thermal cracking of polyethylene — an alternative preparation of ethene
Experiment 2. Going bananas!
Experiment 3. Reaction with bromine-water
Experiment 4. Ethene reacts with potassium permanganate
Experiment 5. Flammability of ethene
Experiment 6. Ethene rockets
Experiment 7. Solubility of ethene in alcohol and Henry's law
Experiment 8. Ethene reactions with chlorine

Experiment 1 shows how ethene can be produced from polyethylene. The reaction is pertinent to recycling, petroleum cracking, and bonding. Experiment 2 demonstrates one of the important uses for ethene — ripening fruit. Alkenes are reactive organic molecules. The double bond can be brominated or oxidized as demonstrated in Experiments 3 and 4, respectively. Experiment 5 shows the flammable nature of ethene. Experiment 6 is another rocket experiment and the fourth one so far in this book. Comparisons of the various fuel mixtures should start becoming evident. Experiment 7 explores the ability of organic solvents to dissolve organic compounds, with implications for spray can propellants. Experiment 8 is the most intriguing. Depending on the initial energy added to the reaction mixture, two dramatically different results are obtained. In one case, the reaction progresses slowly to give dichloroethane. Under slightly different conditions, soot and hydrochloric acid are formed instead.

Background skills required

Students should be:

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

The preparation of ethene by either the thermal method or by the alternative method (Experiment 1) takes 30 minutes to set up, perform and clean up by one familiar with the thermal method from experience with the previous chapters.

Experiments 2 and 8 are demonstrations that require overnight to do. All of the rest take only a few minutes to perform if the necessary materials are available. Experiment 3 requires bromine-water and Experiment 6 requires oxygen. The instructor should prepare these reagents before the laboratory session. Oxygen can be prepared in a gas bag (Chapter 5).

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 on the next page. Prepare bromine-water for Experiment 3 (Appendix D) and a gas-bag of oxygen for Experiment 6 (Chapter 5).

Gas reaction catalyst tube

Two interesting reactions involving ethene and the Gas Reaction Catalyst Tube were given in Chapter 18. Refer to these catalytic oxidation experiments for ethene:

B. Oxidation of ethene with air
D. Hydrogenation of ethene

Website

This chapter is available on the web at website:

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

Instructions for your students

GENERATING ETHENE[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

Ethene has low toxicity. It is flammable and care must be taken to avoid unintentional contact with sparks or open flames. Ethene forms explosive mixtures with air between the ranges of 3 - 30% ethene.

Chemical caution: sulfuric acid

Concentrated sulfuric acid is an exceptionally dangerous chemical that causes severe chemical burns upon contact. If contact with the acid is suspected, wash area with plenty of water. Contact with the eyes may cause permanent damage and possible blindness. Wash the eyes with plenty of water and seek immediate medical attention.

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 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

[1] Content for this chapter first appeared as "Microscale Gas Chemistry, Part 13. Experiments with Ethene" Mattson, B. M., Hulce, M., Fujita, J., Anderson, M. P., Catahan, R., Bansal, M., Khandhar, P., Mattson, A., Rajani, A., Worth, L., Obendrauf, V., ***Chem13 News***, **277**, September, 1999.

MAKING ETHENE

Ethene is generated by the Thermal Method, described in detail in Chapter 19 and summarized here. The two chemicals to be heated together are concentrated sulfuric acid and anhydrous ethanol.

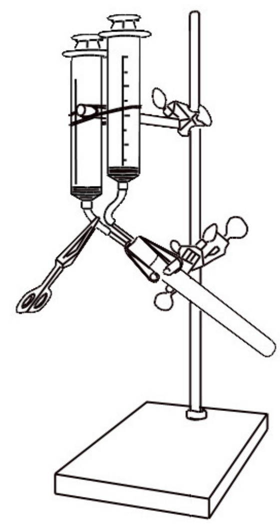
Chemicals required for each preparation

1 mL concentrated sulfuric acid
1 mL ***anhydrous*** ethanol

This quantity of reagents will produce approximately 60 mL of $C_2H_4(g)$. The production of gas is quite fast and requires very little heat. The reaction is:

$$CH_3CH_2OH(l) + H_2SO_4(l) \rightarrow C_2H_4(g) + H_2SO_4{\cdot}H_2O(l)$$

1. Wear your safety glasses!



2. Check the plunger and barrel

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

3. Measure out the liquid reagents

Add 1 mL of each reagent together in 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

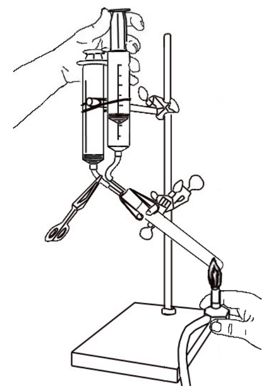
A small Bunsen burner is necessary for this reaction. More heat is required than was the case in the preparation of carbon monoxide in the previous chapter.

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

Step A. Collect air and gas in first syringe

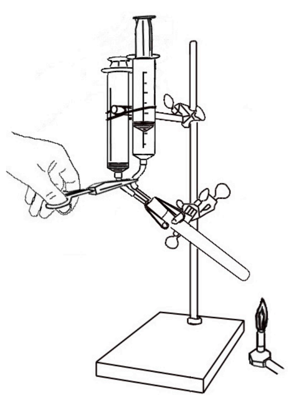


The first of the gas collected is mostly air originally present in the test tube. Hold the heat source with one hand while assisting the movement of the plunger with the other. This maneuver works well with two individuals working together. **Caution**: Do not crimp the tubing!

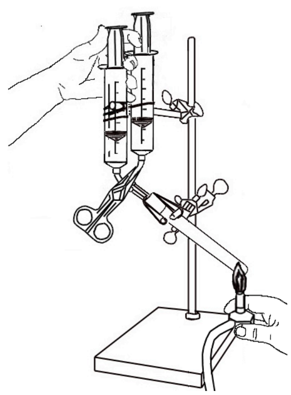
Gently heat while accumulating at least 20 mL waste. Help the plunger upward — maintain reduced pressure. Gas soon will be produced and the plunger of the syringe should begin to move. It may be necessary to assist the sliding movement of the plunger up the barrel of the syringe during the reaction. Continue to heat while gently assisting the plunger's movement.

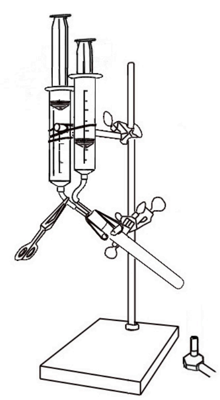
Step B. Collect the gas

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



move hemostat





left tube clamped shut

Step C. Stop heating

Switch the pinch clamp back to the tubing connected to the pure gas collection syringe and remove the heat source (right figure, above). ***WARNING:*** Never simultaneously pinch both tubes!

While holding the plunger slightly outward in order to establish slightly reduced pressure, remove the tubing from the gas collection syringe and immediately cap it with a syringe cap. 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. The plunger may move inward as the apparatus cools.

10. Collecting multiple samples (optional)

It is possible to collect two or more syringes full of $C_2H_4(g)$. Simply replace the "clamped-off" syringe with a clean, dry empty syringe. Switch the hemostat and continue heating. When multiple syringes of ethene are being collected, the sulfuric acid/alcohol solution will become increasingly dark. Stop the reaction before the mixture becomes black in color.

11. Washing the gas

The ethene-filled syringes usually contain 30 - 40% diethyl ether vapors as a by-product of the reaction. Diethyl ether is conveniently removed by "washing" the gaseous products with water in which it is slightly soluble. To do this, draw 10 mL distilled water into the syringe without discharging any gas, cap the syringe and shake the water to dissolve the ether inside the syringe. Remove the cap and discharge the water but not any of the gas. The discharged water will smell like ether. The syringe(s) should now contain about 35 - 40 mL $C_2H_4(g)$.

12. Disposal

Unwanted samples of $C_2H_4(g)$ including the contents of the waste syringe can be discarded in a fume hood or out of doors. While ethene has a low toxicity, its odor is unpleasant so discharging the gas into the room is not recommended. The liquid remaining in the test tube is partially hydrated H_2SO_4 which can be diluted by adding about 10 mL water to the test tube and treated as acidic wastes.

Teaching tips

1. Keep the system under reduced pressure at all times — avoid popping stoppers!
2. The yield of ethene is limited by the formation of diethyl ether from a competing reaction. Washing the gas with water, as described, removes much of the diethyl ether.

Questions

1. Why must anhydrous ethanol be used?
2. Why does diethyl ether dissolve in water better than ethene?
3. What does the gas smell like?
4. Concentrated sulfuric acid is a powerful desiccant — a chemical that removes water. In this reaction, sulfuric acid removes water from ethanol. How does the formula for ethanol and ethene compare? What is the difference — what is missing from the ethene?

EXPERIMENTS WITH ETHENE

EXPERIMENT 1. THERMAL CRACKING OF POLYETHYLENE — AN ALTERNATIVE PREPARATION OF ETHENE

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)

Chemicals

3 – 5 g polyethylene (may be obtained from a plastic milk jug)

Suitability

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

Applications, Topics, Purpose

organic chemistry, petroleum cracking, household chemicals, chemical reactions, recycling plastics, chemical bonding

Instructions

In this experiment, polyethylene is heated until it melts and decomposes to smaller molecules including ethene. The apparatus is the same as was used in the generation of ethene in the previous section. Obtain 3-g ***low-density*** polyethylene from a milk jug, food storage bags, disposable pipet, etc. Be certain that the plastic chosen is indeed polyethylene. Cut the sample into small pieces so they fit into the test tube. Gently heat the polyethylene until it melts. Continue gentle heating and follow the 3-step procedure described above. Avoid excess heating. If the melted polyethylene becomes too hot, a dense white cloud will form above the liquid surface and the molten polyethylene will darken. If this cloud makes it into the syringe, it will condense to a butter-like solid inside the syringe.

Washing the Gas

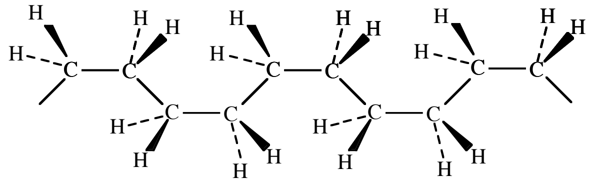
Washing the gas with water is not effective — impurities are all organic alkenes with similar properties to ethene and are insoluble in water.

Teaching tips

1. Unwanted samples of $C_2H_4(g)$ including the contents of the waste syringe can be discarded in a fume hood or out of doors. While ethene has a low toxicity, its odor is unpleasant so discharging the gas into the room is not recommended. Allow the polyethylene to solidify in the test tube. Dispose of the test tube in the trash.
2. The ethene-filled syringes obtained in this way contain other alkene hydrocarbons as by-products of the cracking reaction.
3. A buttery substance that may make its way into the syringes is a mixture of short chain alkenes that are solids at room temperature.

Questions

1. A segment of polyethylene is shown below. It continues in a polymeric chain. Break it apart in places to show that various alkenes can be formed. Create double bonds, if necessary, so that all carbon atoms are formed to have four bonds.



EXPERIMENT 2. GOING BANANAS!

Equipment

Thermal Method Equipment (see list)
bananas, two greenish
gallon ziplock bags, two

Chemicals

C_2H_4(g), 30 mL

Suitability

classroom demonstration

Applications, Topics, Purpose

household foods, food shipping and processing

Instructions

Ethene is used to ripen bananas and citrus fruits. Many fruits emit ethene as they ripen naturally. Place each piece of fruit in a separate bag and seal shut with plenty of air inside. One piece of each fruit will serve as the control. To the other bag, add 30 mL ethene by simply discharging the gas into the bag and resealing the bag. Check the bags over the next hours and days.

Teaching tips

1. Other fruits, especially citrus, work well too.

Questions

1. Why do fruit shippers like to ship green fruit instead of ripe fruit?
2. Would the fruit in the bag without the ethene eventually ripen?

Experiment 3. Reaction with bromine-water

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)
glass disposable pipet

Chemicals

$C_2H_4(g)$, 30 mL
aqueous bromine solution (See Appendix D)
sodium bisulfite solution, $NaHSO_3(aq)$, 1 M
universal indicator

Suitability

high school chemistry lab, university lab, and classroom demonstration

Applications, Topics, Purpose

organic chemistry, characteristic reaction of alkenes, fundamental organic reaction types

Instructions

Prepare a small quantity of bromine-water as instructed in Appendix D. Use of a fume hood is recommended when working with bromine-water. Connect the tubing to a glass disposable pipet that will be used to bubble ethene through the bromine-water solution. Connect the other end of the tubing to an ethene-filled syringe. Add 10 mL bromine-water to the test tube. Slowly discharge the ethene just above the surface of the bromine-water. Stopper the test tube and shake. The reaction between aqueous bromine and ethene is:

$$C_2H_4(g) + Br_2(aq) + H_2O(l) \xrightarrow{catalyst} CH_2BrCH_2OH(aq) + HBr(aq)$$

After the red color has faded, add 5 – 10 drops of universal indicator to the solution. The pH of the reaction mixture decreases by more than two pH units. The reaction can be slow and is catalyzed by the glass surface.

Excess aqueous bromine solution can be treated with 1 M $NaHSO_3(aq)$ until the color disappears and then safely discarded down the drain.

Teaching tips

1. Destroy all excess bromine-water solutions as per the Instructions (last paragraph)
2. Note: The reaction can be slow and is catalyzed by the glass surface.
3. Provide a chart of indicator color vs. the corresponding pH to your students.

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

Questions

1. Sketch the stick structure for ethene and 2-bromoethanol.
2. When there is no water around (such as when a non-aqueous solvent is used), bromine reacts with ethene (and any alkene) to form 1,2-dibromoethene. Sketch this molecule.
3. How might bromine-water be used to estimate the purity of a gas sample that is known to contain both ethane and ethene?

EXPERIMENT 4. ETHENE REACTS WITH POTASSIUM PERMANGANATE

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)

Chemicals

C_2H_4(g), 30 mL
$KMnO_4$, 0.25 g pulverized

Suitability

high school lab, university lab, and classroom demonstration

Applications, Topics, Purpose

organic chemistry, chemical properties of gases, oxidation reactions, household chemicals

Instructions

Prepare a solution of $KMnO_4$ by dissolving 0.25 g pulverized $KMnO_4$ in 30 mL water. Stir thoroughly because $KMnO_4$ dissolves slowly. The solution contains 1.6 mmol $KMnO_4$ and is intensely deep purple. Draw the $KMnO_4$ into the syringe containing the ethene. Cap the syringe and shake the syringe to mix reagents. The volume of gaseous ethene will decrease as the reaction proceeds. The reaction produces water-soluble ethanediol, commonly called ***ethylene glycol*** and sold as anti-freeze. Permanganate is converted into insoluble brown MnO_2.

$$2\ KMnO_4 + 3\ C_2H_4(g) + 4\ H_2O(l) \rightarrow 2\ MnO_2(s) + 3\ CH_2OHCH_2OH(aq) + 2\ KOH(aq)$$

Teaching tips

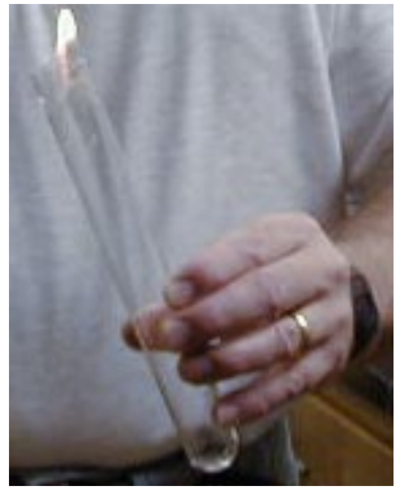
1. MnO_2 is a mineral (pyrolusite) commonly found in nature and is an important ore of manganese.
2. Ethylene glycol is poisonous and has a sweet flavor that dogs like. For that reason safer antifreezes, such as propylene glycol, are now available.
3. Disposal of syringe contents (MnO_2 and ethylene glycol) down the drain with plenty of water is recommended. Discoloration of the syringe can be removed with 1 M HCl(aq).

Questions

1. What color change occurred during the reaction?
2. Why did the volume of ethene decrease?
3. What properties of the product, ethylene glycol, make it more soluble in water than ethene?
4. What is the functional group that was added to the ethene during the reaction?

EXPERIMENT 5. FLAMMABILITY OF ETHENE

Equipment



Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)
large test tube (22 x 200 mm) with suitable rubber stopper
candle
matches

Chemicals

C_2H_4(g), 90 mL (from two syringes full)
limewater

Suitability

classroom demonstration

Applications, Topics, Purpose

Combustion, organic chemistry, chemical properties of gases

Instructions

Use water displacement to fill a large test tube (22 x 200 mm) with ethene from one or more syringes. Stopper the test tube underwater. Remove the test tube from the water and position with the open end up. Darken the room and ignite the gas with a burning candle. Ethene will burn down the test tube with an attractive blue flame that sometimes looks like a descending ring of fire. Tilt the test tube back and forth. This allows air to enter and the blue ring can be made to move up and down the test tube. Unlike ethyne, ethene does not form soot as it burns. After the flame goes out, inspect the test tube. It will be hot to the touch. Test the contents of the test tube for CO_2(g) by adding 10 mL lime water to the test tube and shaking the contents.

Teaching tips

1. You may hold the test tube with your hand, but avoid the top half which will become hot.

Questions

1. Balance the reaction for the combustion reaction.
2. How does oxygen (air) get into the test tube to sustain the reaction?
3. How would the combustion differ if the ethene were in the beaker instead of the test tube?

EXPERIMENT 6. ETHENE ROCKETS

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)
piezoelectric sparker (Appendix C)
extra large body polyethylene disposable pipets
extra small test tubes

Chemicals

$C_2H_4(g)$, 30 mL
$O_2(g)$, 30 mL (Chapter 4)
limewater, 3 mL

Suitability

high school lab, university lab, and classroom demonstration

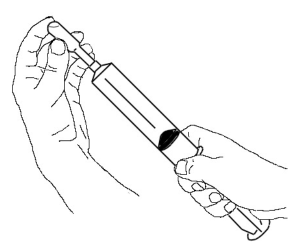
Applications, Topics, Purpose

kinetics, stoichiometry of reactions, activation energy, explosive mixtures, rocketry, types of chemical reactions, energy and chemical change, chemical reactions

Instructions

On several previous occasions (the first time was while studying oxygen), you filled and launched rockets using the method you will use here. You may want to review this procedure that is provided Experiment 3 of Chapter 4 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 in a plastic cup.

Remove the cap from the O_2-filled syringe and slip the water-filled pipet rocket over the syringe fitting. Bubble the $O_2(g)$ into the pipet rocket until it is about half full. Next, complete the water-displacement with $C_2H_4(g)$ until the rocket is nearly filled. Leave some water in the pipet stem.



Position the rocket over the wire of the igniter. If necessary, draw more water into the stem. Trigger the igniter and the rocket will fly 5 m or more. The reaction is:

$$C_2H_4(g) + O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$$

Immediately collect the rocket and test for the presence of carbon dioxide inside by filling the rocket half-full with water and adding a few drops of limewater.

Teaching tips

1. A step-by-step color photo sequence on filling and launching rockets is available at our website.

Questions

1. Describe your experimental observations for this reaction.
2. What were the results of the limewater test of the gaseous reaction products present in the recovered rocket?
3. Consider the overall results/impressions of the entire class when answering this question. Compare the results of the ethene-oxygen rocket with the other rockets we have tried so far: hydrogen-oxygen, ethyne-oxygen, hydrogen-chlorine and carbon monoxide-oxygen.
4. Why do these rocket reactions require a spark to initiate? Explain your answer using a reaction profile and a suitable energy of activation.

EXPERIMENT 7. SOLUBILITY OF ETHENE IN ALCOHOL AND HENRY'S LAW

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)

Chemicals

C_2H_4(g), 30 mL
ethanol, 30 mL

Suitability

university lab and classroom demonstration

Applications, Topics, Purpose

organic chemistry, solubility in non-aqueous solvents, Henry's law

Instructions

Ethene is slightly soluble in water; one volume of C_2H_4 dissolves in nine volumes of water at 25 ^oC. In alcohol, however, two volumes of C_2H_4 dissolve in one volume of alcohol. In this experiment, we will dissolve an equal volume of ethene in ethanol.

Draw 30 mL ethanol into the syringe containing 30 mL ethene. Cap the syringe and push the plunger inward. The ethene will slowly dissolve into the alcohol. In order to get all of the ethene to dissolve, gently shake the syringe while forcefully pushing the plunger inward. Once dissolved, the plunger can be pulled outward and the solution will effervesce — ethene will be released in a profusion of bubbles. The process can be repeated.

Teaching tips

1. This sort of phenomenon is used in spray canisters that use hydrocarbon propellants.

2. Discard all samples properly. Do not pour down the drain and do not store in a closed container — the ethene must be allowed to escape.

Questions

1. Describe the dissolving process and the role of gently agitating the mixture.

2. Describe the effervescing process. How does this apply to what happens when pressurized spray cans are discharged?

3. Plot solubility of a gas (y-axis) vs. pressure (x-axis). This is Henry's law.

EXPERIMENT 8. ETHENE REACTIONS WITH CHLORINE

Equipment

Microscale Gas Chemistry Kit
Thermal Method Equipment (see list)
large test tube (22 x 200 mm)
ring stand and clamp to support the test tube
20 cm or larger diameter balloon (Part A)
small burner or lighter (Part B)
tongs (Part B)

Chemicals

C_2H_4(g), 60 mL for each experiment
Cl_2(g), 55 mL chlorine (Chapter 16)
universal indicator solution
Ag^+(aq) (0.25 g $AgNO_3$/ 10 mL water)
10 cm length of magnesium ribbon (Part B)

Suitability

classroom demonstration

Applications, Topics, Purpose

organic chemistry, reaction mechanism, reaction pathway

Instructions

For each part of this experiment you will need 60 mL ethene in a single syringe. To do obtain this, combine ethene from two syringes by transferring the gas through a 2 cm length of tubing.

Part A.

1,2-Dichloroethane is a solvent used to dissolve fats, oils, greases, gums, and even rubber. Equip both the Cl_2-filled syringe and the C_2H_4-filled syringe with separate pieces of tubing. Position both tubes in the bottom of the test tube. Simultaneously discharge both gases into the test tube. This provides for maximum mixing of the two gases. Equip the top of the test tube with the balloon. Clamp the test tube in a vertical position with balloon up. Within a few minutes the balloon will begin to inflate inside the test tube (you may need to guide the balloon into the test tube with a blunt object such as a stirring rod). Within the first few seconds of the reaction you should notice the formation of a cloudy aerosol due to $C_2H_4Cl_2$. This aerosol condenses to a few drops of liquid on the sides and bottom of the test tube. The reaction is:

$$C_2H_4(g) + Cl_2(g) \rightarrow C_2H_4Cl_2(l)$$

Next, remove the balloon and lay the test tube on its side in a fume hood for a few minutes. This allows unreacted chlorine to dissipate. Waft your hand past the mouth of the test tube and towards your nose. Dichloroethane has a characteristic sweet smell. Alternatively, if you leave the balloon in place overnight, it will "inflate" inside with test tube — very impressive! The rubber will be tight against the glass and most of the way to the bottom of the test tube.

Part B.

Equip both the Cl_2-filled syringe and the C_2H_4-filled syringe with separate pieces of tubing. Position both tubes in the bottom of the test tube. Simultaneously discharge both gases into the test tube. Without delay, ignite the magnesium ribbon with the burner and hold it inside the test tube. This will initiate a quite different reaction between ethene and chlorine, this one producing soot and HCl:

$$C_2H_4(g) + 2\ Cl_2(g) \rightarrow 4\ HCl(g) + 2\ C(s)$$

Various amounts of soot will be produced. Add water to the test tube and test the pH using universal indicator solution. Finally, test for chloride with $Ag^+(aq)$.

Teaching tips

1. In Part A, consider doing the alternative version of the experiment. The sweet odor of dichloroethane can be detected at that time.
2. Discard all samples without handling.
3. Provide a chart of indicator color vs. the corresponding pH to your students.

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

Questions

1. Describe the two reactions that were investigated (Parts A and B).
2. What might cause the same two chemicals to react in such remarkably different ways? Consider the differences in reaction conditions/procedures.
3. As a follow-up to Question 2, sketch a reaction profile diagram for both of the reactions studied. How do they differ? Does this explain the observed results?

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 21. Experiments with ethene

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
Bunsen burner	1	5	10
large test tube (22 x 200 mm) with suitable rubber stopper	2	10	20
piezoelectric sparker*	1	5	10
extra large body polyethylene disposable pipets	1	5	10
small test tubes	3	15	30
tongs	1	5	10

* Appendix C

Materials required

Item	For demo	For 5 pairs	For 10 pairs
matches or a lighter	1	1	1
3 – 5 g polyethylene	a	a	a
candle	1	5	10
matches	1	5	10
20 cm or larger diameter balloon	1	5	10
bananas, two greenish	2	demo	demo
gallon ziplock bags	2	demo	demo

a. may be obtained from a plastic milk jug

Chemicals required

Item	For demo	For 5 pairs	For 10 pairs
sulfuric acid, concentrated	10 mL	50 mL	100 mL
absolute ethanol	10 mL	50 mL	100 mL
limewater	5 mL	25 mL	50 mL
hydrogen peroxide, H_2O_2, 6%	10 mL	50 mL	100 mL
potassium iodide, KI	0.5 g	1 g	2 g
potassium permanganate, $KMnO_4$	0.25 g	-	-
aqueous bromine solution*	1 mL	5 mL	10 mL
sodium bisulfite solution, $NaHSO_3(aq)$, 1 M	5 mL	25 mL	50 mL
universal indicator	2 mL	10 mL	20 mL
chlorine, $Cl_2(g)$	a	a	a
silver nitrate, $AgNO_3$	0.25 g	-	-
ethanol	30 mL	demo	demo
magnesium ribbon	10 cm	demo	demo

* Appendix D

a. prepare chlorine by one of the methods described in Chapter 16