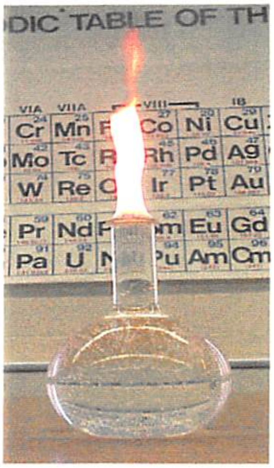
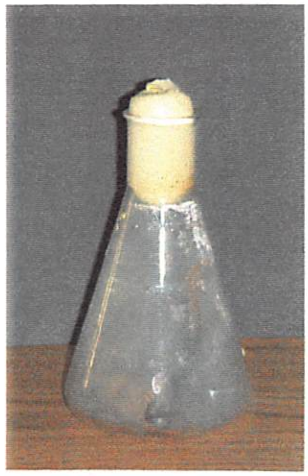
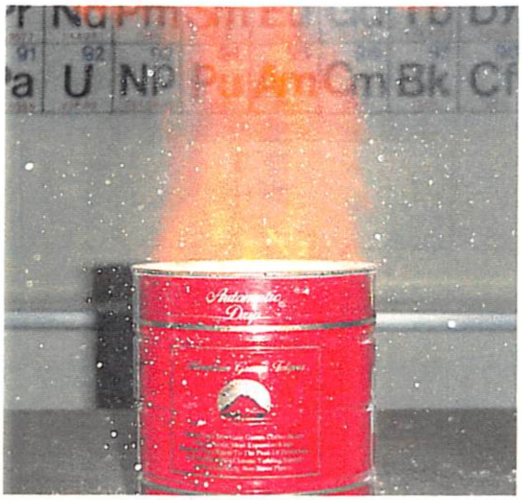


A Repertoire of Chemical Demonstrations

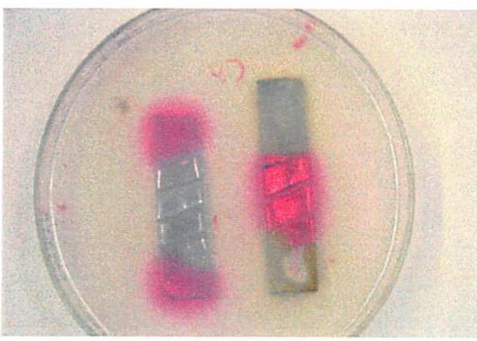


Joel Minderhoud

Published by

The Federation of Protestant Reformed Schools

1999




A Repertoire of Chemical Demonstrations

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Preface

This project began as discussions among teachers at a Teacher's Convention a year ago. Some junior high teachers said that they had difficulty from time to time, depending on the topic at hand, coming up with ways to teach the children about chemical and physical phenomena. They had difficulty explaining some of the content, and had more difficulty yet, coming up with demonstrations or activities for the students to do which would further enhance their understanding of the concepts. Furthermore, many of these schools lacked "high-tech" or "expensive" chemicals in which to do any demonstrations. The task, which I was given, was to develop and share demonstrations which teach basic fundamental chemical and physical concepts without the need for "high-tech" and "expensive" tools. What I have developed are 27 demonstration/activities in a variety of areas for teachers to use to help explain chemical and physical phenomena.

These 27 demonstrations have been broken into 6 sections:

a.) Chemical/Physical Changes
b.) Chemical/Physical Properties
c.) Water and Its Properties
d.) Corrosion
e.) Acids/Bases/Indicators
f.) Gases and Pressure

Each section is preceded by a brief general description as to how the Reformed believer should understand these concepts. This should not be understood that "perspective" is isolated from the "practical". Rather, the Reformed perspective must come out in all subjects each day. To write this perspective into each demonstration write-up would result in plenty of over-lap and repetition. To avoid this, an introductory section with the common ideas which could be applied to each of the demonstrations, precedes each section. This, of course, is just a small beginning in terms of the depth of the perspective. Much more work needs and can be done to apply Reformed principles to the chemical and physical content. In a desire to help our teachers with this I have included in Appendix 3, Professor Hanko's work on the Principles of Education as they pertain to the Sciences.

Each demonstration write-up consists of concepts that can be taught, materials needed, set-up and demonstration procedures, questions to discuss with the students, and detailed explanations as to how and why the demonstration worked. It is my hope that the questions and explanations have been written in a manner that the junior high students can understand. Without teaching that age group, it is difficult to know for certainty what kinds of questions they may have. Hopefully, the questions and explanations will be understandable to every teacher, who then can use the information in a way that their students can understand it.

It is my hope that this manual can be used by the Protestant Reformed teachers to better instruct the covenant seed in the "fear of the Lord". May it be used by teachers and students that the "man of God may be perfect, thoroughly furnished unto all good works" (II Timothy 3:17). May God's blessing rest upon this work that the child of God may grow in true understanding and wisdom of God. May he grow closer in fellowship with God. May he exercise his calling as king under Christ, using the creation and all its powers in the service of his covenant God. May he understand that this calling to serve God in all that he does, is for the benefit of the church. May he understand that this creation will be destroyed, and therefore, he must always be looking and seeking for the "heavenly", "spiritual" kingdom of God. To God be given all the glory and honor.

Section 1 - Chemical and Physical Changes

How should the Reformed believer understand the concepts involved with chemical reactions?

Certainly the idea is present that in order to have a chemical reaction or for a chemical change to occur something has to undergo a radical and complete change. The product in the end of a chemical reaction is completely different than the material with which the chemist began.

First of all the student must understand, as with all things, that God is the creator and has made the beautiful and intricate creation. We bow before His greatness and marvel at all His works; including the chemical reactions. Psalm 97: 1ff we read,

> The Lord reigneth: let the earth rejoice; let the multitude of isles be glad thereof.
> Clouds and darkness are round about him: righteousness and judgement are the habitation of his throne.
> A fire goeth before him, and burneth up his enemies round about.
> His lightnings enlightened the world; the earth saw, and trembled.
> The hills melted like wax at the presence of the Lord, at the presence of the Lord of the whole earth.
> The heavens declare his righteousness, and all the people see his glory. . . . .
>
> For thou, Lord, art high above all the earth; thou art exalted far above all gods.

God is sovereign. He is in control of all things. The physical and chemical phenomena are in his hand. We bow before the almighty and utter "How great thou art".

Secondly, the idea of chemical and physical changes brings to mind passages of Scripture which speak of gold and silver being "purified" by the fire.

Isaiah 1:25 "And I will turn my hand upon thee, and purely purge away thy dross, and take away all thy tin".

Malachi 3:2,3 "But who may abide the day of his coming? And who shall stand when he appeareth? For he is like a refiner's fire, and like a fullers' soap; And he shall sit as a refiner and purifier of silver: and he shall purify the sons of Levi, and purge them as gold and silver, that they may offer unto the Lord an offering in righteousness".

Fire, a common element in many chemical and physical reactions, is given in the Scripture as that which "purifies". Fire purifies elements and makes them to be clean and pure – without impurity. God gives us this picture to show us how we shall be completely purged of all our sin.

Related to this idea is that in Chemistry we see things "change". The item(s) with which we began are radically different when we are finished with them. This is seen in the "Charcoal Sausage" or "The Grain Elevator Explosion" demonstrations. Is the same not true for the believer? Are we not radically changed? We are changed in two ways. On this earth we already are changed. We no longer have a hard heart but our heart has been softened. We have been given a heart of flesh. "And I will give them one heart, and I will put a new spirit within you; and I will take the stony heart out of their flesh, and will give them an heart of flesh: that they may walk in my statutes, and keep mine ordinances, and do them; and they shall be my people, and I will be their God" (Ezekiel 11:19, 20). We are no longer spiritually dead, but we are spiritually alive. Secondly, we know that our earthy bodies cannot inherit the "spiritual" so we must be transformed. "Behold, I show you a mystery; we shall not all sleep, but we shall all be changed, in a moment, in the twinkling of an eye, at the last trump; for the trumpet shall sound, and the dead shall be raised incorruptible, and we shall be changed" (I Corinthians 15:51,52).
In these ways we experience change, just as things upon this earth experience chemical and physical changes.

Not only is fire used to show God's preservation and purification of his people, but it also is used in Scripture to show God's judgment upon sin and the wicked. "Upon the wicked he shall rain snares, fire and brimstone, and an horrible tempest: this shall be the portion of their cup" (Psalm 11:6). "Then the Lord rained upon Sodom and Gomorrah brimstone and fire from the Lord out of heaven" (Genesis 19:24). "But the day of the Lord will come as a thief in the night; in the which the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also and the works that are therein shall be burned up" (II Peter 3:10).

When we read these Bible passages with our students it becomes evident that the Lord hates sin and the wicked sinner. God will destroy sin and the sinner with fire as he did to the 250 men that offered incense in the matter with Korah, Dathan, and Abiram (Numbers 16:35). It behooves us to teach the students that this world will be utterly destroyed with fire in the end. We are not to store up earthly possessions, for they will be utterly destroyed. We are not to look for an earthly kingdom, for the earth will be utterly destroyed. We are not to try to "save the earth" with the environmentalist because we are going to have to live here forever. No, the world will be destroyed. We must, of course, be good stewards of the gifts and creation that the Lord has entrusted unto us, but we ought not expect to live here forever.

In conclusion, we see that chemical and physical reactions are under the sovereign reign and control of God. As we study the reactions we are humbled and stand in awe of our Creator God. We further are reminded that we too shall change on the last day. We shall receive our glorified bodies. We already now experience change. We have been called out of darkness into God's marvelous light. We are reminded as we study reactions and fire that God will judge the wicked with fire and destroy them and the earth. God shall create a new heavens and a new earth for his chosen people.

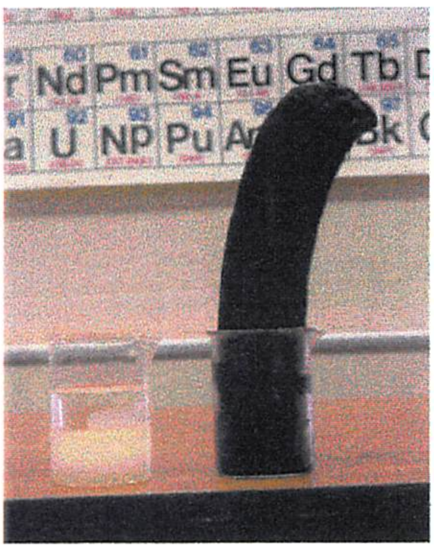
"The Charcoal Sausage" or "The Dehydration of Sugar"

Chemical Topic or Concept:
- Physical and Chemical Changes
- Types of Reactions (Exothermic)

Materials:
- Two 150 ml beakers, 2 glass stirring rods (optional)
- 100ml of sugar crystals
- 50 ml of concentrated sulfuric acid
- 50 ml of water

Cautions:
- Sulfuric Acid fumes are produced and are harmful.
- This activity should be done outside or in a fume hood.
- Sulfuric acid is extremely corrosive.

Procedure:
1. Fill each beaker with 50 ml of sugar.
2. Add 50 ml of water to the first beaker and stir.
3. Add 50 ml of the concentrated sulfuric acid to the second beaker and stir.
4. Wait and make observations.



Questions:
1. What are the differences in the two liquids that combined with the sugar?
2. What are the contents of Beaker # 1?
   What are the contents of Beaker # 2?
   Are the contents in each case the same as they were originally?
3. What is the difference in the two processes?
4. In which of the two beakers could we get sugar back again as plain sugar?
5. How can we recognize the difference between physical and chemical changes?

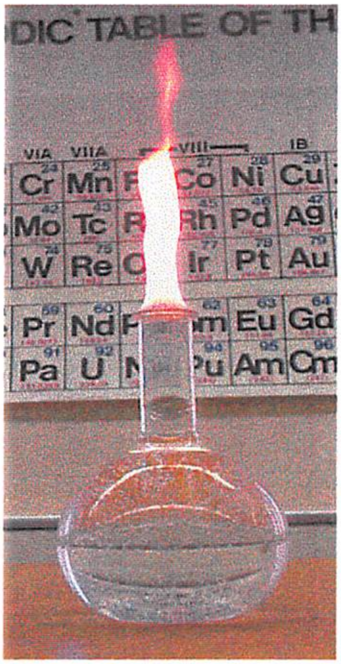
Explanations:

In the first beaker, where the sugar was mixed with water, a **physical change** took place. *The components mixed, but nevertheless, retained their properties.* There still was sugar and water in the beaker – no new substances formed. We could separate the mixture back into its original parts with a variety of procedures (filter, distillation (collect the water that boils off)).

In the second beaker, a **chemical change** took place in which the sugar and sulfuric acid reacted so that the hydrogen and oxygen atoms that are within the sugar molecule were "pulled" off the carbons, turning the sugar into a column of black carbon and producing water vapor from the hydrogen and oxygen atoms. Fumes of water vapor and sulfuric acid vapor, with a large amount of heat, were produced in this reaction as well. *These new products have different properties than the sugar and sulfuric acid had had originally.* It is impossible to retain the original sugar and sulfuric acid back from this column of charcoal, so we recognize this as a chemical change.

Reference: Liem, Tik L. Invitation to Science Inquiry. El Cajon, CA: Science Inquiry Enterprises, 1989. P. 135.

Burning Water



Chemical Topic or Concept:

- Density
- Combustion
- Chemical changes
- Observation and Problem solving

Materials:

- Water
- Beaker, flask, bottle etc.
- Flammable liquid which is less dense than water, such as, hexane, Coleman fuel, lighter fluid etc.
- Matches, lighter
- Fire extinguisher

Cautions:

- Make sure flask does not tip over!!
- Make sure a fire extinguisher is in hand!
- Make sure other flammable liquids are not open nearby.
- Make sure the liquid you use is less dense than water. Try this the day before and be sure to see two distinct layers.

Procedure:

1. Place a little bit (5 ml) of a flammable, less dense than water, liquid in the bottom of a flask before class starts. Students will not see the liquid on the bottom of the beaker.

2. As the class begins and as you begin the lecture, fill the beaker with water from out of the tap. The less dense liquid will rise to the top, but should be so small an amount that the two distinct layers are not visible or distinguishable to the students.

3. Light a match and light the "water"

4. Observe and see student amazement.

Questions:

1. Predict why the water appears to have gone on fire.

2. Does water burn?

3. What liquids do you know burn?

4. Of the liquids named in # 3, which liquids are less dense than water (will float on water)?

5. When fighting a fire created by gasoline burning, is it wise to try to get the fire out with water from a fire hose? Why not? What should be used instead?

Explanations:

1. The water appears to have gone on fire, but we know that water does not burn, but is used to extinguish most fires. Therefore, what was burning must have been something else. The teacher either had somehow put another liquid which burns, or some other chemical into the water which was really doing the burning.

2. No.

3. Alcohol, acetone, gasoline, lighter fluid . . .

4. Gasoline, lighter fluid. Alcohol and acetone are usually miscible (mix) with water to some degree. They probably wouldn't be great choices for this demonstration because they would not float to the top necessarily. They probably would be found as bubbles throughout the liquid. You could try this and see if it works.

5. Gasoline fires should be fought with fire blankets, and fire extinguishers (powder) which smother the fire, rather than water which will only spread the fire and allow the fire to burn on top of the water layer.

References:

Paul Groves (ICE, Berkley, 1987),
Lee Marek (Chem Team 8)
Richard Willis, Kennebunk High School, Grandvalley State University Presentation,1991
Woodrow Wilson Conference, Grandvalley State University, Allendale, MI, 1991

Absorption of Heat and the "Non-Burning Paper Cup"

Chemical Concept or Topic:
- Combustion
- Heat absorption
- Water properties

Materials:
- Flame, Bunsen burner or candle
- Paper cup
- Water

Procedure:

1. The goal of this demonstration is to show the student that in order for something to burn it needs to reach a specific temperature. Paper ignites and burns at 451 °F. (One could at this time bring up the book Fahrenheit 451 by Ray Bradbury).

2. Obtain a paper cup (or make your own). Place it above a flame and observe.

3. Obtain a paper cup (or make your own) and fill it with water. Place it above a flame and observe.

Questions:

1. Does the paper cup ignite when it has water in it? Why not?

2. What property of water is important in this demonstration, as it is the water, which prevents the cup from igniting?

Explanations:

1. The paper cup, which is empty immediately, ignites when it is placed above the flame. The paper cup, which is filled with water, does not ignite when it is placed above the flame. The reason for this difference is attributed to the presence of the water. The water absorbs the heat given off by the flame. It absorbs so much heat that the paper can not achieve the temperature necessary for it to ignite. If left long enough above the flame, the water in the cup could boil and yet the cup would not ignite. As long as the paper, which is in contact with the flame, has water touching it, it will not ignite. This is because of the tremendous amount of heat that a molecule of water can absorb.

2. The heat capacity (or ability to hold heat) is the property of water that is so important in this demonstration. Water can absorb 4.184 J of energy per degree Celsius per gram of water. That is; if one had one gram of water and raised the temperature of that water by one degree Celsius, then it is said that the water will have absorbed 4.184 J of energy. This demonstration further emphasizes the fact that things can not burn unless they reach their "critical" temperature.

3. One sees God's providential hand at work here too. God ordained and now governs even the properties of water so that lakes absorb much heat and have a "moderating effect" on climate. We are reminded here again of a purpose of water. Water, in Scripture, is preserving and destructive in nature. God saved His people with the Flood, and destroyed the world with the same Flood. God saved His people by having them walk through the Red Sea on dry ground, and destroyed obstinate Pharaoh and all his host in that same Red Sea. When we observe the properties of water in Creation, such as, that water absorbs heat energy and "preserves" the paper cup from burning we are reminded

of how God used water in the Old Testament. This study of water reminds us of God's workings in history, of His preservation of His people and of His destruction of the wicked. May we be reminded of these things and give God all glory and honor as we study these things in Science.

Reference: Woodrow Wilson Conference. Grand Valley State University. Allendale, MI: 1991.

The "Non-Burning" Dollar Bill

Chemical Concept or Topic:

- Combustion
- Observations
- Volatile Liquids

Materials:

- Dollar Bill (paper towel if you are cheap)
- 50% Alcohol-Water mixture
- Match
- Tongs
- Beaker

Cautions:

1. Alcohol is very flammable. Containers and beakers with the alcohol in it should be closed and kept far away from sources of fire and heat.
2. A fire extinguisher should be kept nearby.
3. Alcohol can be very harmful to the eyes. Wear eye-protection.

Procedure:

1. Before class prepare a 50% Alcohol-Water mixture by placing 50 ml of water and 50 ml of isopropyl alcohol (ethanol or methanol can be substituted) in a beaker. Stir and mix it well.
2. When class begins take out a one-dollar bill. Soak the dollar bill in the alcohol-water mixture.
3. With a pair of tongs take the dollar bill out of the solution and let it drip off a bit.
4. Ignite the dollar bill with a match or lighter.
5. The alcohol should burn off and the dollar bill should not ignite. If it appears that the dollar bill is beginning to ignite, stamp it out.

Questions:

1. Explain why the dollar bill did not ignite and yet we observed flames.
2. Why did the teacher use a water and alcohol mixture, compared to a pure alcohol solution?

Explanations:

1. The dollar bill did not ignite even though we observed flames because it had been soaked in an alcohol-water mixture. The alcohol burned before the dollar bill could. However, a lot of heat was given off by the burning of the alcohol. This heat could be enough to bring the dollar bill to its ignition temperature (451 degrees Fahrenheit). However, much of the heat is given off to the air. After the heat is given off to the surrounding air there may still be enough heat being given off by the burning alcohol to ignite the dollar bill. This is why water was used with the alcohol. Water has a tremendous ability to absorb heat energy. Any heat that may have been able to ignite the dollar bill was absorbed by the water. One could test to see if this is accurate by using a 100% alcohol solution. I would not recommend using a dollar bill, but would suggest a paper towel. The alcohol will burn furiously and will give off much heat to the atmosphere, but will also give

enough heat to the paper towel to bring it to its ignition temperature. The paper towel will be charred at the end of the demonstration.

2. Water is used with the alcohol rather than a pure 100 % alcohol solution for two main reasons. Pure alcohol would burn violently and be too great of a hazard. Secondly, the water is very important in keeping the dollar bill from reaching its ignition temperature, because the water absorbs a lot of heat energy.

References:

Shakhashiri, Bassam Z. **Chemical Demonstrations Volume 1**. Madison, Wisconsin: The University of Wisconsin Press, 1983.

Veltkamp, Pamela. **Dordt College General Chemistry**. Sioux Center, IA: 1991-1992.

Reaction Rates and "The Grain Elevator Explosion"

Chemical Concept and Topic:

- Surface Area and Reaction Rates
- Chemical Reactions
- Exothermic Reactions
- Everyday life applications

Materials:

- One large coffee can with a lid
- One 4 foot section of rubber tubing
- One plastic funnel
- One medium sized candle
- One plastic "film" container
- A few spoonfuls of powdered sugar

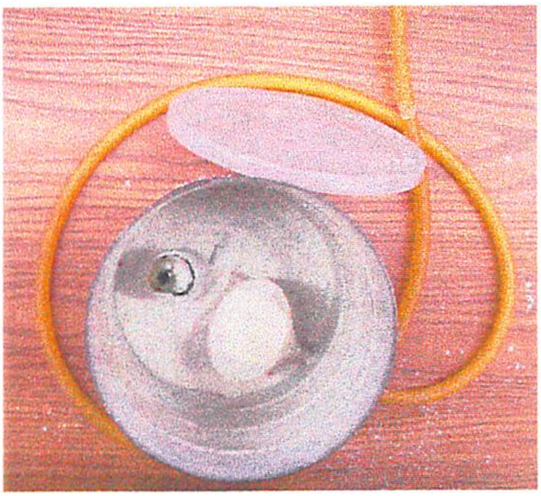


Figure 1.

Set-up Procedure:

1. Drill a ½ inch or a 3/8 inch diameter hole into the bottom of the side of the coffee can.

2. Slide the hose through the hole. Connect the hose to the end of the funnel. Pull any slack hose inside the coffee can out of the can through the hole.

3. With some caulking (I actually use "play-dough" and it has worked well) cover around the hole so that there are no air gaps between the hose and the edges of the hole.

Demonstration Procedure:

1. Place one or two spoonful of powdered sugar into the funnel. Make sure that the powdered sugar lies over top of the hole in the funnel.

2. Light a candle and place it directly in front of the funnel. (See Figure 1.)

3. Turn out the classroom lights and close the blinds.

4. Un-tangle the rubber hose and be prepared to blow into the hose.

5. Very quickly, place the lid on the coffee can and make sure it sealed well, step back a stride or two, and blow one long large breath of air into the hose.

6. Observe. The results should occur in dramatic fashion. (See Figure 2.)

Figure 2.

Questions:

1. What happens to a sugar cube when you try to burn it? Try it.

2. What accounts for the fact that powdered sugar in the coffee can got a lot different result than a pile of powdered sugar or a sugar cube would have had?

3. What is surface area?

4. What is the relationship between surface area and reaction rates?

Explanations:

1. When one tries to burn a pile of powdered sugar or a sugar cube, the sugar will burn and turn black but it does so in a very slow and difficult manner.

2. The powdered sugar in the coffee can was blown into the air inside the coffee can. As this happened the particles of sugar were spread apart from each other and the "surface area" of the sugar was increased. This permitted each particle of sugar to burn simultaneously, producing a large ball of fire.

3. Surface area refers to the amount of area of a particle that is exposed to the flame or other chemicals in which it needs to react. In a sugar cube, 3 cm by 3 cm by 3 cm, all the sugar particles are packed into a cube so that the amount of sugar actually "exposed" to the air is only the sugar particles that are on the edge of the cube. All the inner particles are not "exposed". The actual surface area of this cube would be: 6 sides times 9 cm^2 (area per face) = 54 cm^2

   If the cube would be crushed and every single sugar crystal was set on a table next to another sugar crystal, the surface area (the amount of sugar exposed to the air) would dramatically increase.

4. A reaction will occur more quickly if the reactants have a greater surface area. In this case, the powdered sugar was forced to increase its surface area, because the demonstrator blew the particles into the air. This increased surface area increased the rate of reaction and a violent reaction was observed.

5. This demonstration can be applied to everyday life. Grain elevators receive grain from the farmers. This grain is stored in the grain elevator. As the grain is unloaded from the farmer into the grain elevator the grain is moved around so much that a lot of grain dust forms. The surface area of the grain is increased greatly. Therefore, a cigarette or an electrical spark in a grain elevator acts like the candle in our demonstration and ignites the grain dust. This results in a rapid burning of the grain dust, forming a huge fireball and a costly explosion.

Reference: Zwart, John. Physics Department Dordt College. Sioux Center, IA, 1992.

Reaction Rates and the "Light Stick"

Chemical Concept or Topic:
- Reaction rates and the effect of temperature

Materials:
- Two or more Cyalume (trade mark) light sticks. These can be purchased for about $ 2.00 each at most hardware or sporting good stores.
- Two large beakers
- Hot water
- Ice water

Procedure:

1. Place a beaker of hot water and cold water at the front of class.

2. Bend a light stick until the inner container snaps. This allows the inner reactants to mix. Intense light is given off, depending on the temperature of the water.

3. Place one light stick into the cold water and the other into the hot water. Another possibility is to just use one light stick and continue to transfer it from hot to cold and make observations.

Questions:

1. In which beaker does the light stick glow the brightest?

2. What affect does temperature have on the amount of light that is produced? Explain.

3. Give some "everyday life" examples of the kinds of chemical reactions that occur inside this light stick.

4. These light sticks, or smaller versions thereof, are advertised for use as fishing lures. The light stick is supposed to glow and attract fish. In Washington State, many of the rivers have water temperatures between 2 ° C and 6 ° C. Would it be helpful to have light sticks attached to the fishing lure in these rivers?

Explanations:

1. The light stick glows brightest in the hot water.

2. Temperature is directly related to the brightness of the light stick. The hotter the temperature, the brighter the light. This is because as the water is warmed it contains more kinetic energy than the cold water. This allows the chemicals inside the light stick to receive more kinetic energy, to move faster, to have more collisions, and therefore, to speed up the reaction. As the reaction between the chemicals speeds up, more light is produced because more molecules are reacting.

3. Fireflies and other animals and plants have chemical reactions that occur within them, which has the production of light as a product.

4. These light sticks would not be helpful in the cold waters of Washington State because the temperatures are so cold that the light sticks will barely give any light at all.

Reference: Thompson, Ron. Making Your Biology/Life Science Instruction The Best It Can Be. Institute for Educational Development, Medina, WA: 1998.

Section 2 - Chemical and Physical Properties

How should the Reformed believer understand the physical properties of matter?

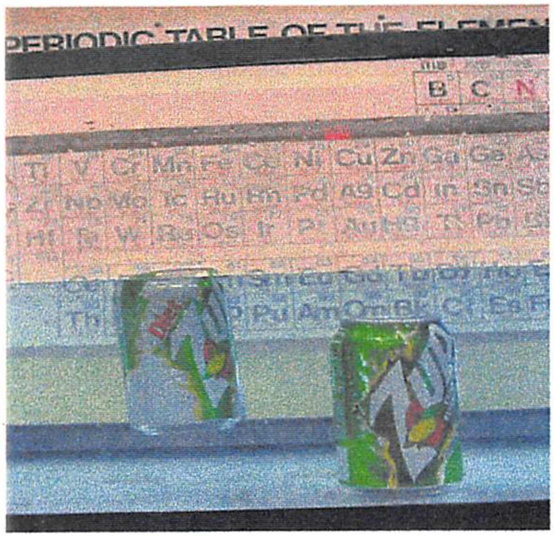
This section deals with physical characteristic properties of matter. These properties of matter are properties that do not depend on how much of the substance there is present, but on the nature of the substance. These properties help scientists and others determine the difference between two different substances. In this section, primarily the property of density is considered.

Characteristic properties help us identify matter. Density is an important property because it also helps in distinguishing between different substances. We learn from this that God has ordained great diversity in the creation. When one studies botany, zoology, microbiology and the other fields of biology it is not very difficult to see that God created within the creation a vast number of different kinds of creatures. This is so very true also in Chemistry. In Organic chemistry one can study the vast amount of different kinds of compounds that can be made from the carbon atom as the fundamental element. In nuclear chemistry one can study the man different parts of the atom. In all of these aspects of Science one truly can see the complexity and diversity in the creation.

Density is used to distinguish typically between different solids or different liquids. Some solids look similar but can be distinguished because of their densities. The Scriptures speak of this diversity in describing different stones that were placed in the breastplate of judgment. Similarly, Revelation speaks of the foundations of the walls of the New Jerusalem being garnished with all manner of precious stones. In both of these cases there are twelve stones. In Exodus, the twelve stones refer to the twelve tribes of Israel. "And thou shalt set in it settings of stones, even four rows of stones: the first row shall be sardius, a topaz, and a carbuncle; this shall be the first row. And the second row shall be an emerald, a sapphire, and a diamond. And the third row a ligure, an agate, and an amethyst. And the fourth row a beryl, and an onyx, and a jasper: they shall be set in gold in their inclosings. And the stones shall be with the names of the children of Israel, twelve, according to their names, like the engravings of a signet; every one with his name shall they be according to the twelve tribes" (Exodus 28:17-21). "And the foundations of the wall of the city were garnished with all manner of precious stones. The first foundation was jasper; the second, sapphire; the third, a chalcedony; the fourth, an emerald; the fifth, sardonyx; the sixth, sardius; the seventh, chrysolite; the eighth, beryl; the ninth, a topaz; the tenth, a chrysoprasus; the eleventh, a jacinth; the twelfth, an amethyst" (Revelation 21:19-20). Twelve is a number used in the Scriptures to speak of the complete number of God's people. Within that complete number are all different kinds of people. "And they sung a new song, saying, Thou art worthy to take the book, and to open the seas thereof; for thou wast slain, and hast redeemed us to God by thy blood out of every kindred, and tongue, and people, and nation" (Revelation 5:9). Furthermore, Scripture speaks of the church as the body of Christ which has many members (I Corinthians 12). As we study in the Sciences, physical properties show us the diversity of things which have been created. This diversity is seen in the creation as a picture to us of the many members which make up the body of Christ.

Density has practical applications. Without substances having different densities and different physical and chemical properties, matter would look the same and would all mix together. By virtue of the different physical and chemical properties that God has created, there are different objects and creatures.

Pop Can Density



Chemical Topic or Concept:

- Density
- Contents of pop
- Everyday life applications
- Difference between sugar and aspartame

Materials:

- Regular pop
- Diet pop
- Aquarium
- Water, preferably colored

Procedure:

1. Fill the aquarium about ¾ full of water.
2. Add food coloring to water if desired.
3. Place a regular can of pop into the water. It will rest on the bottom of the aquarium
4. Place a diet can of pop into the water. It will float in the water.

Questions:

1. Why do you think the diet pop floats and the regular pop does not float?
2. What is the fundamental difference between regular and diet pop?
3. What does this difference between the two types of pop have to do with density?

Explanations:

1. Some students may argue that the cans are different shape or size. This may have some effect. Occasionally dented cans will not float. However, the main reason for the one floating and the other not must be found in the fundamental difference between the two pops.

2. The fundamental difference between the two cans is that regular pop contains "high fructose corn syrup, and/or sugar" and the diet pop contains "aspartame – the sweetener". Other minor differences are that the regular pop contains "sodium citrate" while diet pop contains "potassium citrate (slightly heavier compound)" and an extra preservative "potassium benzoate".

3. The main difference is that regular pop's second most abundant ingredient is sugar forms, while diet pop contains lower down on the ingredient list a sweetener called aspartame. The two compounds have similar taste, but different effects on the body. Furthermore, regular pop that contains more sugar than diet pop contains aspartame, makes regular pop to be a heavier substance per volume. Thus, regular pop is denser than diet pop and should sink to the bottom of the aquarium. This demonstration leads the student to once again understand density and to inquire as to the fundamental differences between regular and diet pop.

Reference: Herr, Norman and James Cunningham. **Chemistry Activities with Real-life Applications.** New York: The Center for Applied Research in Education, 1999.

Density of Water

Chemical Topic or Concept:

- Density
- Diffusion
- Problem Solving

Materials:

- Hot water
- Cold water (ice water)
- Food coloring
- 4 cups/containers with no pour spout
- 2 or more 4 X 5 index cards

Set-up Procedure:

1. Boil water. Also, pour ice into another bucket and add water, to make ice cold water.

2. Fill two cups with hot water and two cups with cold water. (This should be done only a very short time before class begins. You do not want the two different temperature waters to come to equilibrium.

3. Make one of the two hot cups colored with food coloring.

4. Make one of the two cold cups colored with food coloring.

5. Put the cup with clear hot water and the cup with clear cold water on the demonstration table.

6. Place a few 4 X 5 index cards on top of the colored hot water and the colored cold water cups. One at a time, quickly flip the cups with index cards on them and place the colored hot water on top of the cup with clear cold water. Quickly flip the colored cold water cup and place it on top of the cup with the clear hot water. **Make sure that hot is on top of cold and cold is on top of hot.** (See Figure 1.)

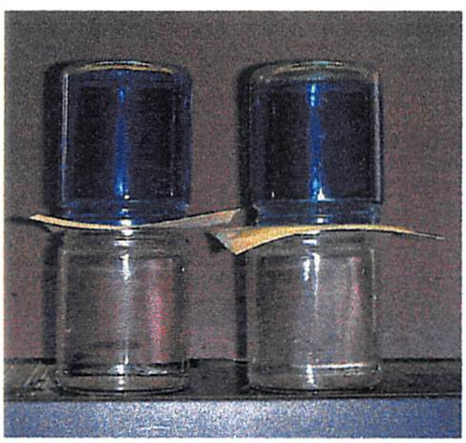


Figure 1: Before Demonstration

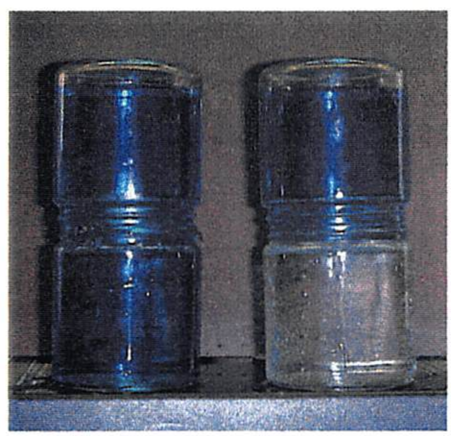


Figure 2: After Demonstration

Demonstration Procedure:

1. A variety of interactions could occur with students prior to pulling the 4 X 5 cards.

For example:

a.) They could be asked to predict what will happen and why.

b.) Students could be engaged in a discussion about density and then anticipate what will happen in the demonstration.

c.) Students could be explained how the demonstration has been set up, to see if they have a fundamental understanding of density.

d.) And the like.

2. Simply pull out the 4 X 5 cards **CAREFULLY** and them observe.

Questions:

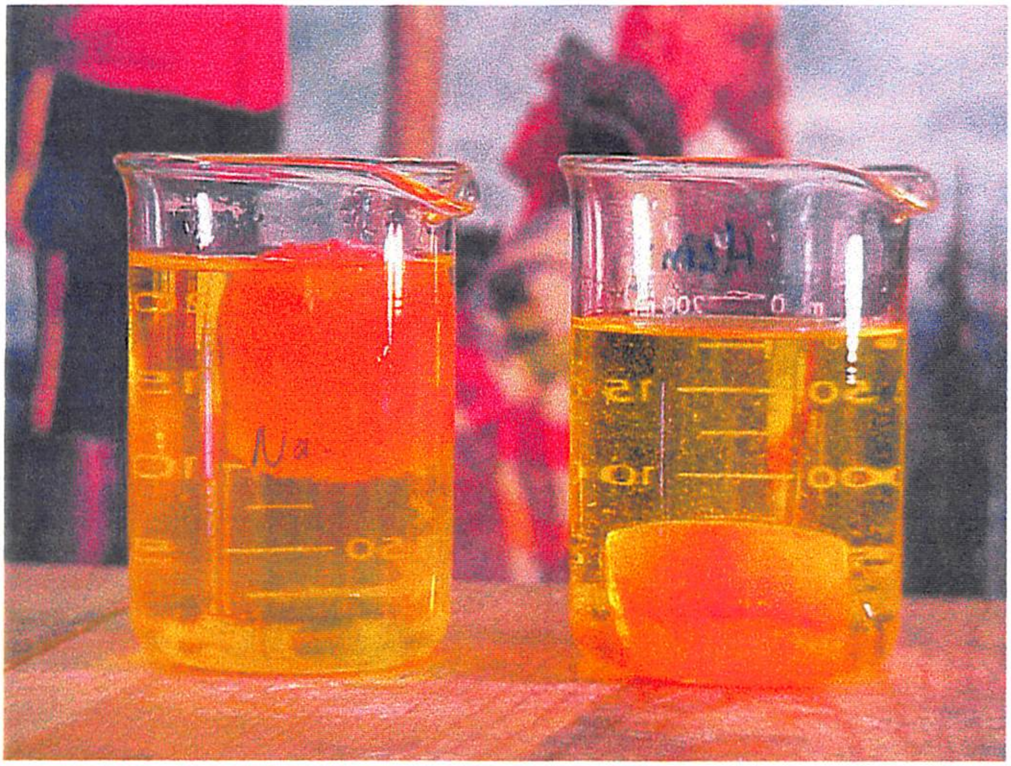
1. Define density.
2. Is hot water more or less dense than cold water? Explain your reasoning.
3. Define diffusion.
4. In the two liquids that mixed, what did the mixing process look like? Describe it.
5. If the two sets of beakers sat long enough, would they eventually look the same? Explain your reasoning.

Explanations:

1. Density is that intensive property of matter (does not matter how much of it you have) which indicates the ratio of the mass of the matter to the amount of space that it takes up. Substances with a low ratio of mass to volume will float on top of substances with a higher ratio of mass to volume.
2. Hot water would be less dense than cold water because the molecules in hot water have more kinetic energy than the average cold water molecule, and therefore, will spread further from neighboring hot water molecules. Since they spread out more, the hot water will have less mass per a given volume (because less molecules will be present in a defined volume because they have spread out) than the cold water. Therefore, hot water is defined as less dense than cold water
3. Diffusion is the spontaneous mixing of two substances with each other due to their random motion. Since the hot water on the bottom is less dense than the cold water on top, the hot water rose and the cold water sank, causing the two substances to mix together or to diffuse.
4. The liquids swirled around in what appeared to be something like circular patterns.
5. Eventually the two sets of beakers will look the same. That is because the hot water will lose its heat to the environment outside of the beaker (air will absorb heat) and the cold water will gain heat from the environment. Eventually both sets of beakers will come to an equilibrium temperature and will thoroughly mix with each other.

Reference: Woodrow Wilson Conference. Grandvalley State University, Allendale, MI: 1991.

Does Ice Always Float?



Chemical Concept or Topic:

- Density of liquids
- States of matter and density
- Hydrogen bonding

Materials:

- Ice cubes of water; colored preferred
- 2 beakers
- Water
- Alcohol

Set-up Procedure:

1. Make colored ice cubes by dropping a drop of food coloring into the water before putting the water into the ice-cube tray.

2. Before class, set up a beaker with water and a beaker with alcohol. Make sure both are filled to the same level.

Demonstration Procedure:

1. A discussion about the relative density of ice compared to water could precede this activity.

2. Take an ice cube from the tray and place it in the beaker with water. It floats.

3. Take an ice cube and place it in the beaker with alcohol. It sinks.

4. Explain the discrepancy.

Questions:

1. Why does ice float on water? Is this the opposite of what you would expect?

2. Does the solid form of all substances float on the liquid form? Explain

3. Why did the ice cube in the one beaker float and the other sink?

Explanations:

1. Solid water (ice) floats on liquid water. This is the opposite of what you would expect. It would make sense that the solid form would sink because solids tend to be denser. The molecules in solids tend to have less kinetic energy than do the molecules in the liquid form. Therefore, the molecules in a solid will have more opportunity to be attracted to one and another, and therefore, they "group" closer together. Solids are typically more dense than their liquid counterpart, and therefore, sink when mixed with the liquid. This does not happen with water. This is because as the liquid water cools to near freezing (4 ° C) the water's density changes. At this point the molecules move very slowly and are attracted to each other. However, as they "group" together, they do so in an organized fashion. The "hydrogen bonds" that exist between the molecules, and the molecular shape of water itself, act together to make the water molecules bond in an organized hexagonal pattern. This is the most efficient way of "packaging" water molecules. When water "groups" into these hexagonal patterns, there is empty space between the molecules, which makes the frozen water to be less dense than the liquid form. In this case, because of the hexagonal pattern made as water freezes, its solid form takes up more space (less dense) than the liquid form. Thus, solid water floats on liquid water.

2. This situation, outlined above, does not happen with any other substances. It is unique only to water. We see here God's providence. Water makes up a majority of the human body, of the earth, and of the atmosphere. In order for the world to continue to exist, God originally created, and now governs and upholds, all things so that they work for the sake of the elect. Without the density of water changing at 4 ° C and becoming less in the solid form, plant, animal, and human life would be considerable different. God created this world with a design and with laws. These laws must be obeyed for life to exist.

3. In this demonstration, the beakers contained different liquids. When the solid form of water was placed in the liquid form of water, the ice floated. When the solid form of ice was placed in the liquid alcohol, the ice sank, because water is more dense (whether it is in the ice or liquid form) than alcohol.

Reference: Woodrow Wilson Conference. Grand Valley State University. Allendale, MI: 1991.

Isotopic Pennies

Chemical Concept or Topic:

- Isotopes
- Nature of pre-1982 and post-1982 pennies
- Algebra
- Use of triple beam or electronic balances

Materials:

- 50 or so pre-1982 pennies
- 50 or so post-1982 pennies
- Empty black film canisters
- Electronic Balance or Triple beam balance
- Calculator

Set-up Procedure:

1. Place ten pennies in a black film canister. Find out the ratio of pre-1982 pennies to post-1982 pennies in the canister. On a piece of paper, record the ratio and the number of the canister. Mark the canister with a number or a letter or some code.

2. Continue to fill film canisters as in # 1. Try to make a wide variety of ratios of pre-1982 to post-1982 pennies. Make sure to record the canister number and its ratio of pennies.

3. Find an average weight for a post-1982 penny and for a pre-1982 penny. Record this information. Do the same for an "empty" canister and lid.

4. Close all the canisters and place them in a place where the students can have easy access to them.

Student Procedure:

1. Students are to be instructed to obtain a film canister and to find its mass.

2. They are to be told that the canister contains ten pennies. Some might be pre-1982 pennies and some may be post-1982 pennies. They should be told or should understand that pre-1982 pennies and post-1982 pennies have different masses. They are not to look inside the canisters.

3. Students should record the canister number and the total mass of the canister and pennies.

4. At this point the teacher can either give them the predetermined average post-1982 penny mass and the average pre-1982 penny mass, or the teacher can provide the students with some extra loose pennies and have them determine the average masses for each type.

5. The teacher can either tell the students the average mass of an empty film canister and lid, or give them a few loose canisters and lids and have them determine the average mass of a film canister and lid.

6. The goal of the assignment is for the students to determine, using algebra, what the contents of the container are. What is the ratio of post-1982 pennies to pre-1982 pennies?

Information:

1. The average mass of a pre-1982 penny is about 3.08 grams.

2. The average mass of a post-1982 penny is about 2.50 grams.

3. The average mass of an "empty" film canister and lid is about 7.10 grams.

4. Pre-1982 pennies are basically pure copper and post-1982 pennies are zinc metal with a thin layer of copper covering.
Pre-1982 pennies are pure copper with a density of 8.9 g/ml.
1982 pennies are an alloy of 99.2% zinc and 0.8% copper.
Post-1982 pennies are an alloy of 97.5% zinc and 2.5% copper, with a density of 7.1g/ml.

Avoid using 1982 pennies in this activity. Strictly, keep to post and pre-1982 pennies.

5. An algebraic equation that can be determined by the students if they think about it long enough, or can be given to them by the teacher, that will aid them in determining the contents of the container is as follows:

Let X = the number of pre-1982 pennies.
Let 10- X = the number of post-1982 pennies.
Then:

X (3.08 grams) + (10 – X) (2.50grams) = (Weight of canister and pennies) – (7.1 grams; the weight of one film canister and lid)

For Example, I massed a canister and lid with 10 pennies (3 pre-1982 and 7 post-1982) and found the mass to be 33.87 grams. From this I can calculate the number of pre-1982 pennies and the number of post-1982 pennies.

a.) X (3.08 grams) + (10 – X)(2.50 grams) = 33.87 grams – 7.1 grams

b.) 3.08 X + 25.0 – 2.50 X = 26.77 grams

c.) .58 X = 1.77 grams

d.) X = 3.05 pennies

The results indicate that I must have had 3.05 pre-1982 pennies and 6.95 post-1982 pennies. Obviously, you cannot have partial pennies and these numbers are so close to 3 and 7 respectively, that I predict that I had 3 pre-1982 pennies and 7 post-1982 pennies. I was correct.

6. What does this have to do with chemical isotopes?

Isotopes are atoms with the same number of protons (therefore the same element) but a differing number of neutrons (therefore a different mass).

In Creation, it is determined, for example that, 78.7 % of Magnesium has 12 neutrons, that 10.13% of Magnesium has 13 neutrons, and that 11.17 % of Magnesium has 14 neutrons. These are the three isotopes of Magnesium. Methods for determining the isotopic nature of chemical elements are not very different than what we do in this activity.

Consider the black canister. It represents a lump of a certain element. We know its mass. We know the total number of sub-particles (the total number of pennies). From this information we can determine how many of those sub-particles are pre-1982 pennies (protons) and how many are post-1982 pennies (neutrons). Although this is a greatly simplified version of how chemists determine the ratio of neutrons to protons, it does give the student some understanding as to how one can figure these things out. Students usually have many questions yet, and many can not be answered. Let them understand and appreciate the difficulty in determining these kinds of things.

References:

Woodrow Wilson Conference. Grand Valley State University. Allendale, MI: 1996.

Herr, Norman and James Cunningham. Chemistry Activities with Real-life Applications. New York: The Center for Applied Research in Education, 1999.

Sherman, Allan, Sharon Sherman and Leonard Russikoff. Basic Concepts of Chemistry. New Jersey: Houghton Mifflin Company, 1984.

Section 3 - Water and Its Properties

How should the Reformed believer understand the concepts related to water and its properties?

Water is an amazing substance. It has many unique properties. Which of the properties are most important is a difficult question to answer. The main properties of water are its unique ability to decrease its density as it becomes a solid (opposite of all other substances whose densities increase as they become solids), its ability to dissolve many substances within itself, and the fact that it remains liquid from 0 ° C to 100 ° C. Its other properties include its remarkable ability to exhibit strong surface tension, its tremendous heat capacity, and its ability to pass through semi-permeable membranes easily (osmosis).

God created water for distinct purposes and functions within the creation. Each creature in the creation has distinct place in which it is to occupy and serves a distinct purpose in which it glorifies God. Furthermore all creatures are related to the other creatures.

God created laws in the creation. Laws have been created for water. These laws give water the properties which we observe. Without these laws water could not serve the purpose for which God created it. We too, are given laws. In disobedience to these laws we experience death. In the obedience of these laws we experience life.

Water makes up a huge portion of the creation. It is a major component in man. It is a major component of the earth. Much of the atmosphere is water vapor. God created water with the properties which we observe so that our life could exist. In God's providence he continues to uphold and govern the creation. Therefore, God continually, by the word of his power, commands water to have a lighter density in the solid form than in the liquid form. Without this, water would freeze and sink to the bottom of lakes destroying plant and animal life. By God's providence, he gives water a polar nature so that it can dissolve many ionic compounds. As a result of this, many solutions can be made which serve man. By God's providence, he gives to water an ability to absorb much heat, so that lakes may have a moderating affect on climate. This moderating affect of climate gives different regions of the world different climates and different weather. We quickly see how God directs all things. All things in the creation are related to each other. We see the intricate design of God in the creation. We see God's immutability, as these laws do not change from day to day. This constancy allows us to observe and predict things in the creation. Truly, "the heavens declare the glory of God; and the firmament showeth his handiwork. Day unto day uttereth speech, and night unto night showeth knowledge." (Psalm 19:1,2).

Water is given in the Scriptures also to teach us about God's preservation of His people and His judgement upon the wicked.

God uses water to preserve His people. God saved Noah and his family by the flood. God saved the Israelites by leading them by a mighty hand and an outstretched arm through the midst of the Red Sea. God healed Naaman from leprosy by having him wash seven times in the Jordan river. Leprosy was a picture in the Old Testament of spiritual death. Naaman was healed of his leprosy (given "spiritual life") by washing with water. Baptism pictures the washing away of our sin. Christ is the living water. He who drinks "Christ" lives. (John 4:14).

Water purifies. "Then washed I thee with water; yea, I thoroughly washed away thy blood from thee, and I anointed thee with oil" (Ezekiel 16:10) and "Let us draw near with a true heart in full assurance of faith, having our hearts sprinkled from an evil conscience, and our bodies washed with pure water" (Hebrews 10:22). "Husbands, love your wives, even as Christ also loved the church, and gave himself for it; that he might sanctify and cleanse it with the washing of water by the word, that he might present it to himself a glorious church, not having spot, or wrinkle, or any such thing; but that it should be holy and without blemish" (Ephesians 5:25-27).

Scripture speaks of the man of God as being like a tree planted by the water's side (Psalm 1:3) or as a green olive tree in the house of God (Psalm 52:8, Psalm 92:12,13). God speaks that the child of God grows spiritually when he hears and studies the word of God, just as a plant grows which is watered. "And the Lord shall guide thee continually, and satisfy thy soul in drought, and make fat thy bones; and thou shalt be like a watered garden, and like a spring of water, whose waters fail not" (Isaiah 58:11).

Scripture also speaks of water in terms of God's judgment upon the world. God destroyed the world with the Flood. God destroyed obstinate Pharaoh and all his host in the Red Sea. Floods, storms and tempestuous seas are uses of water in judgment. "Save me, O God; for the waters are come in unto my soul. I sink in deep mire, where there is no standing: I am come into deep waters, where the floods overflow me" (Psalm 69:1). See Psalm 18 and Isaiah 30:20.

Therefore, when we teach the children about water and its properties we must clearly indicate that God has created all things. We indicate that God daily upholds and governs all things, even the "insignificant" properties of water for the sake of the elect. Furthermore, we are reminded that water is a picture of the salvation and purification of God's people and that it is a picture of the judgment and destruction of the wicked.

Surface Tension of Water

Chemical Topic or Concept:

- Properties of water
- Surface Tension
- Prediction

Materials:

- 1 container (transparent) – no spout
- water
- pennies

Procedure:

1. Fill a container as full to the top as you can without spilling and without allowing surface tension to be observed. (See Figure 1).

2. Ask students to predict how many pennies can be added before the water spills over the edge.

3. Student responses vary but usually land in the 10-20 area.

4. Begin dropping pennies into the water. This does take some practice and technique in order to avoid splashing or violent waves. I find that dropping the pennies only millimeters from the water's surface, and doing so from as close to the edge of the container as possible allows for the easiest method of getting pennies into the water without spillage.

5. Continue to add pennies one at a time until the water level rises and begins to "pile-up" over top of the container's top. The students will begin to see the water "hanging" and will get excited and come running to get a closer look. They are surprised at the amount of pennies that can be added, as well as the remarkable God-designed and governed property of surface tension. (See Figure 2).

6. When water begins to drip over the edge of the container, then you are done. A healthy discussion of surface tension now ensues.

Figure 1. Before Adding Pennies

Figure 2. After Adding 27 Pennies

Questions:

1. Why did the water continue to rise higher and higher and not drip over the edge?

2. What is surface tension? Explain it in terms of bonding between the water molecules.

3. What are some everyday life phenomena that are related to the surface tension of water?

4. What is divine providence? Why is it of comfort to you?

5. What are some ways in which God's providence is revealed in the creation, particularly in terms of surface tension of water, or in terms of other properties of water?

Explanations:

1. Water did not drip over the edge immediately when the first one or two pennies were added because of the property water has called surface tension. (In this demonstration 27 pennies caused the water to drip. I can usually get 40 to 50 pennies, but it does matter on what kind of container is used and how full the water is to start. It is more impressive if more pennies can go into the container).

2. Surface tension is that property of water by which individual water molecules "cling" to neighboring water molecules. Water molecules are called polar molecules because they have an unequal sharing of the total 10 electrons in the molecule. Oxygen, when bonded with two hydrogens, will have two sets of electrons (4 total electrons) which are not involved in bonding. This causes oxygen to have a high density of electrons around it, making it to have a high density of negative charge around it. Oxygen being partially negatively charged because of this high density of electrons, is attracted to hydrogens of other water molecules. These hydrogens do not have many electrons near them, and so they tend to be partially positively charged. This makes for strong forces of attraction to occur between the hydrogens of one water molecule and oxygens of other water molecules. This is called hydrogen bonding. It is a strong type of bond between molecules and is the chemistry behind why water has such intense surface tension.

3. Everyday phenomena related to surface tension would include: water bugs walking on water, spherical drops of rain and other drops of water, etc.

4. The Heidelberg Catechism, Question and Answer 27 and 28 give the answer as to what is divine providence and its benefit to God's people. Providence is the "almighty and everywhere present power of God; whereby, as it were by his hand, he **upholds and governs,** (all things) . . . .so that . . . . **all** things come, not by chance, but by his fatherly hand". Providence teaches us to be "patient in adversity; thankful in prosperity; and that in all things . . .we place our firm trust in our faithful God and Father, that nothing can separate us from his love; since all creatures are so in his hand, that without his will they cannot so much as move".

5. Surface tension, capillary action, density of ice, viscosity of liquids, high heat capacity of water, and water's universal solvent nature are uniquely tied to the hydrogen bond. Therefore, water rising up the roots to the tops of the tallest trees (capillary action), ice floating on lakes preserving animal and plant life below from being destroyed (density of ice), water's moderating effect on climate (high heat capacity), the plethora of solutions that can be made because water is the solvent; chicken soup, kool-aid, latex paints, pop, etc., and the like are everyday life applications of hydrogen bonding the basis for surface tension. All of this is ordained, upheld, and governed by our Heavenly Father who directs all these things for our profit.

Reference: Taylor, Dave. **Calvin Christian School.** Winnipeg, MB, **CANADA,** 1986 or 1987.

Polymer Chemistry and "Diapers"

Chemical Concept or Topic:

- Osmosis
- Polymers
- "Everyday-life" Applications

Materials:

- Beaker with water (yellow food coloring added for special effects)
- Diapers
- Sodium polyacrylate (optional)
  Flinn Scientific sells it for $4.80 for 25 grams (W0012)

Procedure:

1. I often begin this demonstration by using the sodium polyacrylate. If you do not have this chemical, the demonstration can be just as good for teaching about osmosis as with the chemical. I would begin with placing a gram of sodium polyacrylate in the bottom of a Styrofoam cup. I would fill the cup half full with water and talk to the students for a minute. (This allows the sodium polyacrylate time to absorb the water). I then turn the cup upside down. The water does not pour out. The students are surprised and we pass the cup with "gel" (water absorbed into the sodium polyacrylate) around the room for students to see what happened. We discuss how that happened.

2. We do a second demonstration which shows that same "foreign" chemical in an "everyday-life" setting. I pull out of my briefcase a diaper. (With two diaper-clad children in the house, I have learned to always be prepared for those "accidents"). On the counter is a large beaker (1-liter) of water (colored yellow if you want). I have two students come and hold the diaper wide open for me. I ask how much of the liter can the diaper hold? I proceed to fill the diaper with a liter of water. The diaper still does not leak.

3. Both the diaper and the chemical sodium polyacrylate demonstrate the concept of osmosis.

Questions:

1. What is osmosis?

2. What does osmosis have to do with diapers absorbing water?

3. Why do diapers leak sometimes?

Explanations:

1. Osmosis is the movement of water across a semi-permeable membrane from areas of low solute concentration to areas of high solute concentration.

2. The diaper contains a chemical like sodium polyacrylate. Sodium polyacrylate is a chemical that consists of very long carbon chains that are bonded together with sodium atoms found in the center of the molecule.

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C-C-C-C-C-C-C-C-C-C-C-C-C- Na-C-C-C-C-C-C-C-C-C-C-C-C-C-C-
C-C-C-C-C-C-C-C-C-C-C-C-C-Na-C-C-C-C-C-C-C-C-C-C-C-C-C-C-
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When a water molecule approaches a sodium polyacrylate molecule it is "drawn" to the center of the molecule where all the sodium atoms are found. This is because on the "inside" of the molecule there appears to be a high concentration of sodium compared to the low concentration of sodium on the "outside" of the molecule. Thus, water is "pulled" into the molecule in order to reduce this apparent sodium atom concentration difference. More and more water is pulled into the molecule until the ratio of sodium atoms to water molecules is so small that the amount of sodium on the "inside" of the molecule is considered "negligible". It takes a lot of water to do this and that is why sodium polyacrylate is advertised to absorb up to 800 times its own weight. This demonstration is a good demonstration to use to show students what polymers are, how they are used in everyday-life situations, and how osmosis works.

3. Diapers fail sooner than they did in this demonstration because of the contents of urine. Urine contains salts. The more concentrated the urine, the more salt it contains. Therefore, if a child urinates, the child will place "water" into the diaper, but also salts. Since there are now salts on the "outside" of the sodium polyacrylate molecule, it will not be necessary for the sodium polyacrylate to absorb as much water as before in order to "balance" the salt on the inside and outside of the molecule. Thus, the child who urinates in the diaper will not be able to have as much urine absorbed as we had pure water absorbed. This is why diapers will leak. The more concentrated the urine, the sooner the diaper will leak.

Reference:

Woodrow Wilson Conference. Grand Valley State University. Allendale, MI: 1996.

Boiling Water in a Syringe

Chemical Topic or Concept:
- Boiling of Water
- Change of State
- Vapor Pressure

Materials:
- Warm water
- 20 ml syringe (needle removed)
- small cork

Procedure:

1. "Suck" 15 ml of warm water (70 °C) into a 20 ml syringe.
2. Seal the syringe tip with your thumb or with a small cork.
3. Pull back on syringe plunger.
4. Observe.

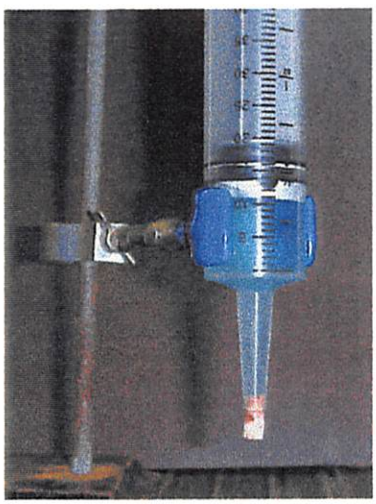


Figure 1. Set-up

Figure 2. Notice bubbles at bottom and top.

Questions:

1. When the syringe plunger was pulled back, what did you observe? Explain why you think what you observed occurred.
2. What does it mean when we say "water boils"? Define "boiling".
3. Did the water in the syringe boil?
4. If you used cold water (20°C) would the water boil when you pull back the syringe?
5. In Colorado, those who live in the mountains must follow different cooking instructions than those who cook at or near sea-level. Explain why that is.
6. Explain whether it will take more or less time to boil an egg in Denver than it will in Grand Rapids. Why?

Explanations:

1. When the syringe plunger is pulled out, one should observe the water begin to bubble. If the syringe is pulled out far enough it should come to a rolling bubble as it does when water boils in a pan on the stove. The difference here is that the water is boiling but the temperature of the water is only about 70°C.

2. "Boiling" occurs in a liquid when the liquid's vapor pressure equals atmospheric pressure. Between liquid molecules there are bonds. These bonds break when the liquid gains enough kinetic energy to break loose. The molecule will then escape and become a vapor. All liquids "lose" molecules to the vapor state at basically any temperature. Some liquids, such as alcohols, have high vapor pressures, meaning that a lot of the liquid molecules have escaped into the vapor state. This implies that the bonds between alcohol molecules is relatively weak compared to other liquids which have a lower vapor pressure.

   Since these liquid molecules escape into the vapor state they are often right above the container from which they left. Some of the vapor molecules will return to the liquid and return to the liquid state, because they are "knocked" back into the liquid by the atmospheric molecules hitting them. However, the more heat that is applied to the liquid the more molecules escape into the vapor state. When enough liquid molecules escape and form vapor so that the vapor pressure pushing up on the atmosphere is equal to the atmospheric pressure pushing down on the liquid, the liquid is said to have reached its boiling point. At this point it is easier for molecules to escape from the liquid state to the vapor state because they are not hindered by the atmospheric pressure, because the atmospheric pressure has to "contend with" the vapor pressure.

   With this definition of boiling, it is easy to conclude that water does not necessarily have to be hot (100°C) in order to "boil". If the atmospheric pressure can be reduced, then the liquid will not have to work as hard to counteract atmospheric pressure, and thus, the water will be able to "boil" at a lower temperature.

3. In this demonstration, since the syringe plunger was pulled back, the "atmospheric pressure" within the syringe was reduced (because molecules of air had more space to fill, they could not hit the water surface with the same amount of pressure), and the water attained to the boiling point without reaching 100°C. Therefore, we say that the water did truly boil in the syringe. The bubbles at the surface and forming at the bottom of the syringe, indicate that the water was boiling.

4. If we used cold water instead of hot water the water probably would not boil, unless we had such a large syringe that could be pulled very far back, really reducing the "atmospheric pressure" in the syringe. Warm water was used because, it had a large vapor pressure, which was not too far away from being equal to the "atmospheric pressure".

5. "Coloradians" have different cooking instructions than "Grand Rapidsters" because those in Colorado experience a higher altitude, and thus, a lower atmospheric pressure than those at sea-level.

6. In Denver it will take more time to boil the egg than it does in Grand Rapids. This is true because since Denver has a lower atmospheric pressure than Grand Rapids, its water will boil at a lower temperature (95°C on normal pressure) than water boils in Grand Rapids. Thus, the egg will receive less heat than the egg in Grand Rapids. In Grand Rapids it is necessary to boil the egg for 5 minutes to get a certain degree of "doneness" to the egg. In Denver it will be necessary to boil that egg for more than 5 minutes to give it the heat that it needs to reach the same degree of "doneness" that occurs in Grand Rapids.

Reference: Woodrow Wilson Conference, 1991 at Grandvalley State University.

Water and Alcohol Mixtures and "The Amazing Air Bubble"

Chemical Topics or Concepts:
- Observation skills
- Prediction and Problem Solving
- Solutions and Solubility, miscibility
- Density
- Hydrogen Bonding
- Vapor pressures

Materials:
- Test tubes - classroom quantity
- Corks to fit the holes in the test tubes.
- Yellow and Blue food coloring
- Ethanol or Methanol
- 20-30 thin stem pipettes

Set-up Procedure:

1. Make about 1 liter of water solution by adding 10 –15 drops of yellow food coloring.
2. Make about 1 liter of alcohol solution by adding 10-15 drops of blue food coloring.
3. Place half of the pipettes into the water solution and the other half into the alcohol solution.
4. Place the test tubes with corks in an easily accessible place for the students.

Student Instructions:

1. **Goal: To place an equal amount of yellow and blue liquid into the same test tube, with no air bubbles in the test tube and keeping the liquids the same color.** Place both the yellow and blue liquid into the test tubes. The only requirements are that you must fill the tube completely full so that when you put the cork into the test tube there is no air bubble, and that you use ½ blue liquid and ½ yellow liquid.
2. Repeat the procedure as many times as you like and be ready to share your observations in about 15 minutes.

Explanations:

1. When alcohol and water mix the resulting volume of the two solutions is less than the total of the individual volumes. In this case "one plus one" does not equal two. The reason for this decrease in volume can be attributed to the hydrogen bonds which develop between the alcohol molecules and the water molecules (See "Surface Tension of Water" to see a further explanation of hydrogen bonding). This hydrogen bond pulls the molecules really close to each other and the small water molecules will fit nicely in the spaces between the alcohol molecules.
2. If students added the blue (alcohol) liquid to their test tube first and then added the yellow (water) to that test tube, they would find immediately that the color turns green as the heavier (more dense) yellow water sinks to the bottom and "dissolves" into the alcohol on the way down, making the solution green.
3. If the students added the yellow (water) liquid first and then placed the blue (alcohol) liquid on second, they should observe that two distinct layers are formed. The more dense yellow water solution will stay on the bottom and the blue alcohol mixture will "float" on top of the water.

4. If the students have the blue on bottom and the yellow on top, have them invert the test tube. What they will notice is that the color changes to green and that the test tube warms up and that an "air" bubble appears. This bubble is a result of the volume decrease when two liquids mix. What is the composition of that "air" bubble? The "air" bubble is probably very little "air". Initially, it is a vacuum, due to the liquid molecules coming closer together when they dissolved, but for the most part, once the liquids have mixed, the "air" bubble is water and alcohol vapor. (See "Boiling Water in a Syringe" for an explanation of vapor pressure). Every liquid "loses" some of its molecules to the vapor state, even at room temperature. Alcohol "loses" its liquid molecules to the vapor state much more quickly than water does. This "air" bubble is primarily alcohol and water molecules which have "escaped" to the vapor state.

5. The warming of the test tube indicates that the process of mixing alcohol and water is an exothermic reaction. As the molecules come closer together and form hydrogen bonds, they release extra energy that is released in the form of heat energy.

Reference: Woodrow Wilson Conference. Grandvalley State University. Allendale, MI: 1996.

Section 4 - Corrosion

How should the Reformed believer understand the concepts involved with corrosion?

The topic of corruption ought to bring to mind many teachings of Scripture. When the Reformed teacher teaches students about "rust" and "corrosion", he should take time to discuss what Scripture says about corruption.

a.) As a result of the Fall, sin and "corruption" entered into the Creation, bringing forth physical death.

Romans 8:20-22 "for the creature was made subject to vanity, not willingly, but by reason of him who hath subjected the same in hope, because the creature itself also shall be delivered from the bondage of corruption into the glorious liberty of the children of God. For we know that the whole creation groaneth and travaileth in pain together until now."

Genesis 3:19b "for dust thou art, and unto dust shalt thou return"

b.) Sin, itself, is called "corruption".

Isaiah 38:17 "Behold, for peace I had great bitterness: but thou hast in love to my soul **delivered it from the pit of corruption**: for thou hast **cast all my sins behind thy back**".

2 Peter 2: 12 "But these, as natural brute beasts, made to be taken and destroyed, speak evil of the things which they understand not; and shall utterly perish in their own corruption (sin)".

c.) As a result of sin, man is totally depraved. His nature is totally corrupt and will bring forth only sin and corruption, unless changed by the Holy Spirit. Sin brought spiritual death.

Psalm 53:1 "The fool hath said in his heart, There is no God. Corrupt are they, and have done abominable iniquity: there is none that doeth good".

Matthew 7:17,18 "Even so every good tree bringeth forth good fruit; but a corrupt tree bringeth forth evil fruit. A good tree cannot bring forth evil fruit, neither can a corrupt tree bring forth good fruit".

I Cor. 15: 21-22 "For since by man came death, by man came also the resurrection of the dead. For as in Adam all die, even so in Christ shall all be made alive".

d.) We are called to live as pilgrims and strangers. This is because we seek a spiritual kingdom – not an earthly physical kingdom. Therefore, we are commanded to store up "spiritual" treasures where moth and rust do not destroy, rather than to store up "physical/earthly" treasures where moth and rust do destroy.

Matthew 6:19-21 "Lay not up for yourselves treasures upon earth, where moth and rust doth corrupt, and where thieves break through and steal: but lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt, and where thieves do not break through nor steal".

e.) This gives us great hope that we shall be delivered to glory where there will be no sin, death, and corruption.

Rev. 21: 4 "And God shall wipe away all tears from their eyes; and there shall be no more death, neither sorrow, nor crying, neither shall their be any more pain: for the former things are passed away".

I Cor 15:51ff "Behold, I show you a mystery; We shall not all sleep, but we shall all be changed, in a moment, in the twinkling of an eye, at the last trump; for the trumpet shall sound, and the dead shall be raised incorruptible, and we shall be changed. For this corruptible must put on incorruption, and this mortal must put on immortality . . . .O death, where is thy sting? O grave, where is thy victory? The sting of death is sin; and the strength of sin is the law. But thanks be to God, which giveth us the victory through our Lord Jesus Christ."

As we bring forth the concepts in Chemistry about how metals undergo corrosion, it is a timely opportunity to once again bring forth the truths of Scripture about how we have been corrupted by sin, both physically and spiritually, how the whole creation suffers and is corrupted by sin, and how we shall be finally changed so that we are incorruptible, without sin, without blemish, like our Lord Jesus Christ.

Be sure that the students do not misunderstand us here. Do not let them think that metals just have some surface tarnishing or corrosion, and therefore, man is not totally depraved. Remind them that we are spiritually dead apart from grace. True it is that when metal corrodes it still is metal. True it is, that when man sinned he still was man (Belgic Confession of Faith, Article 14 "corrupt in all his ways, he hath lost all his excellent gifts, which he had received from God, and only retained a few remains thereof, (that he is still a moral, rational creature – the pinnacle of Creation)), but nevertheless, man is totally corrupt apart from the renewing grace of God. Do not allow any common grace to wiggle its way in here.

Corrosion

Chemical Concept or Topics:

- Corrosion
- Oxidation and Reduction
- Chemical reactions
- Chemical equations and compounds

Materials:

- Iron nails
- Petri dishes
- Agar-Agar solution
- Phenolphthalein solution
- Strips of zinc and copper metal
- Sandpaper

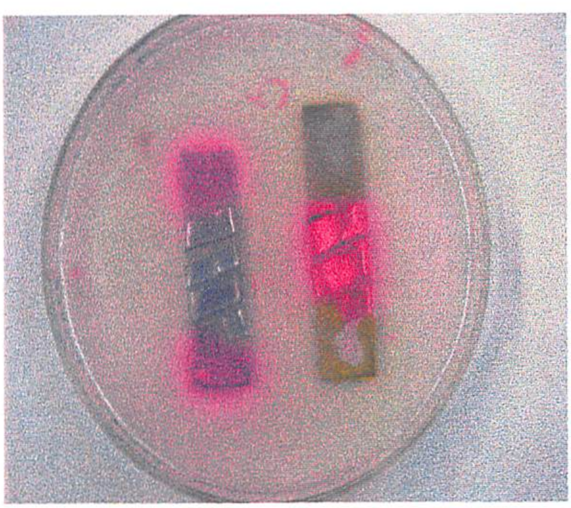
Procedure:

1. Prepare 200 ml of agar-agar solution. Measure out a mass of 2.0 grams of powdered agar-agar. Heat 200 ml of water to boiling. Remove the water from the heat and add the agar-agar powder slowly while constantly stirring. Once the agar has dissolved, add 5 drops of phenolphthalein solution (Figure 1) or 5 drops of bromothymol blue (Figure 2).

2. Take two nails (or strips of pure iron) and wrap them in the strips of metal. One nail should be wrapped with zinc metal and the other nail wrapped with copper metal. Place these two wrapped nails into a petri dish. Be sure the nails do not touch. (The zinc and copper metals should be rubbed down and cleaned with sandpaper before they are wrapped around the nails). Make sure the nails are not galvanized or have some other type of coating. The idea is to use **iron.**

3. Slowly pour the agar-agar solution into the petri dishes to a depth of about 0.5 cm above the nails and metals.

4. Allow the petri dishes to remain untouched for a day or two. From time to time make observations. At the end of the next day and then at the end of the second day make and record observations.



Questions:

1. What changes did you observe in the petri dish? Why did the color changes occur where they did?

2. In which nail did the iron of the nail corrode?

3. Why did the iron nail corrode in the one situation and not in the other?

4. Explain "corrosion" or "rust" in an electrochemical point of view.

5. What does the "pink" color (if phenolphthalein was used) indicate?

Figure 1. Using Phenolphthalein as indicator.
Iron wrapped in zinc is on the left and iron wrapped in copper is on the right.

6. What is a cathode and what is an anode?

7. What is oxidation?

Explanations:

1. As can be seen in Figure 1, the iron strip which is wrapped in copper corroded. Pink color is found around the copper strip and the iron can be seen to be turning orange-yellow. This is only after 5 hours. More corrosion would be visible days later. The second strip of iron is not corroded. Pink is found on the iron and nothing by the zinc strip. The color changes occurred where they did as a result of the corrosion.

In the strip of iron wrapped with copper the iron corroded. Iron metal oxidizes faster or more easily than does the copper. It is said that the iron is oxidized and the copper is reduced. What is happening is that the iron is losing electrons and the copper is gaining electrons. The copper is considered the cathode in this case and the iron is considered to be the anode. The iron metal loses electrons and turns into an iron ion according to this equation:

$$Fe_{(s)} \rightarrow Fe^{+2} + 2e^{-} \quad \text{Equation 1.1}$$

These two electrons travel through the iron metal to the copper. At the copper there is water and oxygen which take the two electrons and use them to form hydroxide ions as in Equation 1.2:

$$\tfrac{1}{2} O_{2\,(g)} + H_2O_{(l)} + 2e^{-} \rightarrow 2\,OH^{-} \quad \text{Equation 1.2}$$

This excess of OH^{-} produced causes the solution next to the copper to be pink. Hydroxide ions (OH^{-}) make a solution to be basic which turns pink in the presence of phenolphthalein.

What ultimately happens in the case of the iron metal wrapped with copper is that the iron metal loses two electrons which are used by water and oxygen to make hydroxide ions. It is evident that the hydroxide ions are formed at the copper surface because of the pink that exists around the copper. The iron ions that are formed react with oxygen and water to form "rust" as is seen in Equation 1.3:

$$Fe^{+2} + \tfrac{1}{2} O_{2\,(g)} + H_2O_{(l)} \rightarrow Fe(OH)_2\,(s) \quad \text{Equation 1.3}$$

This $Fe(OH)_2$ (s) combines with a second molecule of $Fe(OH)_2$ (s) in the presence of oxygen to form iron(III)oxide (the more common form of rust) and water.

$$2\,Fe(OH)_2\,(s) + \tfrac{1}{2} O_{2\,(g)} \rightarrow Fe_2O_3\,(s) + 2H_2O_{(l)} \quad \text{Equation 1.4}$$

Thus iron "rusts" and the copper does not react with anything.

In the other situation in which iron is wrapped with zinc the opposite occurs. In this case zinc is oxidized faster or more easily than the iron and therefore it undergoes a very similar reaction as did the iron in the last example. Here zinc loses two electrons and forms a Zn^{+2} ion. On the surface of the iron the same reaction occurs as did on the copper. Water and oxygen combine with the two electrons to make hydroxide ions, which turn the solution next to the iron surface pink. In this case the zinc is considered to be the anode and the iron is considered to be the cathode.

This has very practical implications. The auto industry and boating industry have used this idea to prevent automobiles and the steel hulls of ships from rusting. Water is a crucial component to act as a medium to transfer electrons. Iron metal will not "rust" when it is in dry air. So these industries, knowing that zinc, aluminum, and magnesium oxidize or "rust" faster and more easily than iron, place these metals adjacent to the steel so that these metals will "rust" before the iron does.

2. The iron of the nail which is covered with copper corroded.

3. See number 1.

4. See number 1.

5. The pink color indicates that hydroxide ions are produced. This indicates a chemical reaction has occurred. The location of the pink indicates that the metal nearest to it was producing the hydroxide ions, and therefore, was the metal "gaining" electrons. This metal which "gained" electrons is said to have been "reduced" while the metal which "lost" the electrons is said to have been "oxidized" or "rusted" or "corroded".

6. The cathode is the place in an electrochemical cell **to where** the electrons travel. The anode is the place in an electrochemical cell **from where** the electrons came.

7. Oxidation is the "loss of electrons". It is usually comparable to "rusting" or "corroding" because the metal loses electrons, turns into an ion, and therefore, there are less "metal" atoms around. Thus the metal is said to have corroded.

References:

Heath Chemistry. D.C. Heath and Company, 1987.

Foundations of Chemistry. Holt, Rinehart, Winston. Toronto, Ontario: 1978.

Section 5 - Acids/Bases/Indicators

How should the Reformed believer understand the concepts related to acids/bases/indicators?

When we study the acids and bases the complexity and beauty of the creation awe us. Acid and base reactions are found in so many "every-day" life situations, from the need for a constant pH in our blood, to acid-indigestion, to vinegar and baking soda reactions, we see that God has created these things in the Creation for a purpose. Each reaction has its very own purpose according to God's will. In God's providential care He governs these reactions so that life can be sustained on this earth. In the human blood, just a small deviation from the pH level could prove to be fatal. God governs these tiny buffer reactions in the blood that we may continue to live and bring glory to God.

Acids and bases are also corrosive and caustic. This again brings us back to the idea discussed in the section earlier on corrosion. We see again how sin is corrosion. We see how we are both physically and spiritually corrupt and dead because of sin. As we see the corrosive nature of acids and bases we are reminded to look at creation and ourselves and see the corruptive effects of sin.

Indicators serve the purpose of "indicating" or "showing" the observer whether or not the solution is acidic or basic. When we study how indicators work and "show" us and give us valuable information about a solution, we are reminded that God has given us "signs" by which to discern the condition of man and society and of Christ's return. "The Pharisees also with the Sadducees came, and tempting desired him that he would show them a sign from heaven. He answered and said unto them, When it is evening, ye say, It will be fair weather: for the sky is red. And in the morning, It will be foul weather today: for the sky is red and lowering. O ye hypocrites, ye can discern the face of the sky; but can ye not discern the signs of the times?" (Matthew 16:1-3). We are reminded that although it is interesting to study the indicators and the signs and information that that gives us about solutions, it is far more important that we spend time reading and studying the "signs of the times".

When we study acids, bases and indicators may we see the corruption that has come upon the earth and man because of our sin. May we also be reminded to look at the signs of the times and every be watching for our Lord's return. To God be given all the glory.

Acid/Base Reactions: The "Breath Activated" Demonstration

Chemical Topic or Concept:

- Acid/base reactions
- Indicators
- Effects of CO_2 on acid/base solutions
- Problem Solving

Materials:

- 2 bottles, or flasks
- 2 stoppers or corks
- Classroom quantity of straws
- Slightly basic solution
- Indicators:
  a.) Phenyl red
  – pH change 8.2 Red, 6.8 yellow
  b.) Bromothymol blue
  -pH change: 7.6 Blue, 6.0 yellow

Figure 1.

Set-up Procedure:

1. Fill each bottle about ½ full with a slightly basic solution (pH of 8.5). This can be done by adding NaOH to water. Basically, this could be done quantitatively, but is not necessary here. Simply, you need the one bottle to be red and the other to be blue as in Figure 1.

2. Add to bottle a.) a few drops of Phenyl red indicator solution. Swirl and mix the bottle well. If the solution is not red, add more NaOH to the bottle.

3. Add to bottle b.) a few drops of Bromothymol blue indicator solution. Swirl and mix. If the solution is not blue add more NaOH to the bottle.

4. Stopper the bottles. This demonstration can be saved from year to year. Each year just add the correct solution (NaOH) to get the correct starting color and proceed with the demonstration.

Figure 2.

Demonstration Procedure:

1. Give each student a straw. Tell them to make sure they remember which end goes in their mouth and which end goes in the solution. **Students should be warned not to "suck" any liquid into their mouths, should not let the liquid splatter them, and should not get solution in their mouth at all.**

2. Give the blue bottle from Figure 1 to the boys and the red bottle from Figure 1 to the girls. Have a race. Tell the students to blow in to the bottles with their straws (make bubbles – but not too

vigorously or they will be sprayed by the liquid). Once they blow into the bottle, they should stopper the bottle, shake it up, and pass it to their neighbor. They should keep their straw in case they get another turn. Everyone should get a turn at blowing into the bottle. The team whose liquid undergoes the most radical change (don't tell them what happened) wins. With experience, you can "fix" the winner by making one bottle be far more basic than the other. The one that is closer to the acid point will turn colors first. I usually set it up so that the girls win, but later in the class conclude that that must have happened because girls are "full of hot air anyway". Everyone gets a good laugh.

3. Save the bottles for next year. This is what is nice about this demonstration. It takes a little work to get it set up, but then it is reusable each year with a minimal 5 minutes of preparation.

Questions:

1. What happened to the liquid in each bottle? Be specific.
2. Predict what you think was the cause of the color change.
3. When you exhale, what do you actually breathe out?
4. Explain the process of respiration?
5. When you breathed out into the bottle, what was causing the solution to turn color?
6. How could you get the solutions back to the original colors?

Explanations:

1. In bottle a.) the color changed form red to orange and eventually to a bright yellow.
   In bottle b.) the color changed from blue to dark green to light green to yellow.

2. The color change occurred because of an acid/base reaction. The solution was originally basic and contained an indicator which in bottle a.)'s case caused the liquid to be red in color and another indicator which in bottle b.)'s case caused the liquid to be blue in color. As we breathed into the bottles, we added carbon dioxide to the solution. We know from experience that pop is acidic. (Test it with pH paper). Pop which has lost its "fizz" is not as acidic as it was with the "fizz". Carbon dioxide makes pop "fizzy". Therefore, if we add carbon dioxide to our bottles we should expect the pH to change towards the acidic end. In fact, we added so much carbon dioxide that we changed the pH from 8.5 to about 7.0, in bottle a.)'s case, and from 7.6 to 6.0 in bottle b.)'s case. This resulted in the observed color changes.

3. When you exhale you breathe out carbon dioxide gas. Most students will fail to recognize that one breathes out much more than just CO_2. If this were not the case, it would be impossible to help someone with mouth-mouth resuscitation, because all you would do be doing would be blowing CO_2 into their mouth. Students must leave with the idea that one breathes out CO_2, O_2, N_2 and a variety of other minor gases.

4. Respiration is the chemical process in the body by which one turns forms of glucose into energy by burning the glucose in the presence of oxygen to produce energy and carbon dioxide and water.

5. Breathing out carbon dioxide caused the liquid to turn colors. This could be further tested by setting up a carbon dioxide generator (antacid tablet in water), an oxygen generator (hydrogen peroxide and manganese dioxide (catalyst)) or a hydrogen generator (zinc and hydrochloric acid).

Test each of these gases with the bottles and see which of them produces the same results as when you breathed into the bottles.

6. The solutions can be brought back to the original color by adding some sodium hydroxide. This is nice to do in front of the students because as you add a few drops and swirl, the color turns to the original color, but then falls back to a shade of yellow, orange or green. This demonstrates the concept of equilibrium. The system continues to switch colors until it reaches a state of equilibrium. As you continue to add sodium hydroxide (NaOH) the color will eventually reach the original color. Furthermore, this is nice to do the next day in front of the students because it sets up the demonstration for next year.

Reference: Veltkamp, Pamela. **Dordt College General Chemistry.** Dordt College, Sioux Center, IA, 1991.

Alka-Seltzer and Temperature

Chemical Topic or Concept:

- Solubility of gases
- Temperature relationships to solubility
- Reaction Rates
- Acid-Base Neutralizations and Indicators

Materials:

- Alka-Seltzer tablet	- Balance
- 3 – 250 ml beakers	- 3 medium sized test tubes
- 10 ml graduated cylinder	- bromthymol blue indicator
- 1 M NaOH	- Hot plate/Bunsen burner
- Ice	- pipettes

Procedure:

1. Place 150 ml of water into each of the beakers.

2. Place one beaker as a control, one beaker in an ice bath, and a third on a hot plate.

3. Weigh out two 1.0 gram samples of Alka-Seltzer tablets.

4. When the beaker on the hot plate reaches a temperature of about 80 °C, remove it from the heat. Also remove the other beaker from the ice bath. Place 3 ml of bromthymol blue indicator into each of the three beakers. The color should be a bright blue – add a drop or two of NaOH to the beaker if the water is not blue. (Bromthymol blue indicator can be made by placing 0.04 grams of bromthymol blue indicator powder in 100 ml of water). (See Figure 1. Control is on the left, ice cold water in the middle, and hot on the left)

Figure 1: Before Alka-Seltzer (Control, cold, hot)

Figure 2. During Alka-Seltzer (Control, cold, hot)

5. Simultaneously drop each tablet into the hot and cold beakers of water. Make observations. (See Figure 2)

6. When the Alka-Seltzer stops bubbling, note the appearance of the liquids in each beaker. (See Figure 3)

7. Remove 10 ml samples from each beaker and place it in a test tube.

8. Add drops of NaOH to the samples from the hot and the cold beakers of water, until their colors correspond with the color of the water from the control. Record the number of drops of NaOH used for each test tube.

Figure 3. After the Alka-Seltzer reacted (control, cold, hot)

Questions:

1. In which beaker did the tablet dissolve faster? Why did it do that?

2. In which beaker was there a more distinct color change?

3. What do the color changes signify?

4. To which test tube was more NaOH added?

5. What does the result of # 4 mean?

6. Which liquid, the hot or the cold, dissolves more gas? How do you know?

Explanations:

1. The tablet dissolves much faster in the hot water than in the cold water. It does that because the molecules of the hot water are moving faster than the molecules of the cold water, and thus, they make more collisions with the Alka-Seltzer tablet resulting in it dissolving very quickly.

2. The cold water underwent a more significant color change. The cold water turned from a dark blue to a yellow color, while the hot water turned from a light blue to a bluish-green color (although that does not seem so evident in Figure 3, that is what happened, and should happen).

3. The color changes are significant. Students may not know enough about indicators and the color changes at this point, but bromthymol blue indicator is a commonly used indicator in the Sciences. It is an indicator which has a blue color when it is in solutions which are basic and has a yellow color when it is in solutions which are acidic. The color changes in this demonstration indicate that the cold water turned from a basic solution (blue colored) to an acidic solution (yellow color), while the hot water moved in the direction of basic to acidic, but never reached a distinctly acidic point (green colored liquid is a mixture of blue and yellow – it became a solution whose acidity level was near neutral)

   The acidic nature of the cold water solution is a result of the carbon dioxide that was a product of the Alka-Seltzer tablet dissolving. As the carbon dioxide is produced it dissolved in the cold water. Dissolved carbon dioxide in water makes a solution to be acidic (see discussion about this in "Acid/Base Reactions: The "Breath Activated" Demonstration). It is apparent from the color changes alone that the cold water must dissolve more carbon dioxide than hot water does. This would correspond with our "every-day life" experience as one considers pop. Warm pop does not taste good because it is warm and not very refreshing, but also because it has lost its "fizz" or its dissolved carbon dioxide. Cold pop is refreshing and still maintains its "fizz". It dissolves more carbon dioxide than does warm pop.

4. More NaOH must be added to the cold water than needs to be added to the hot water. This is because the cold water is more acidic than the hot water. This confirms our conclusions from #3.

5. This result of adding more NaOH to the cold water than the hot water means that the cold water is more acidic than the hot water. This is a result of more carbon dioxide being able to dissolve in a cold liquid than in a hot liquid. This teaches about the solubility of gases. Most substances have a solubility that gets better with increased temperature, but gases are the opposite. As the temperature increases, the solubility of a gas in a liquid decreases.

6. The cold water dissolves more gas. The reasons for this have been stated in # 3, and # 5.

Reference: Chem Fax # 33.00. **Flinn Scientific Inc.** P.O.Box 219, Batavia, Illinois, 60510; 1995.

Acid/Base Reactions and "Cabbage Indicator"

Chemical Concept or Topic:

- Indicators
- Acid / Base Reactions
- "Everyday-life" applications

Materials:

- One head of Red Cabbage
- Large beaker
- Hot plate or stove
- Various Household items
  - Baking Soda
  - Soda Pop
  - Toilet bowl cleaner
  - Dishwasher detergent
  - Laundry detergent
  - Apple juice
  - Vinegar
  - Window washing fluid
  - Drain cleaner
  - Milk
  - Ammonia
  - Etc

Set-up Procedure:

1. Using a knife and a cutting board, cut up a head of red cabbage. Place the small slices into a beaker of water (1 liter) or into a pan. Boil the cabbage for 10 minutes. Allow the contents to cool and then pour the contents through a strainer and collect the liquid. This is your indicator.

2. You are ready to do the demonstration, however, it is more effective if one sets up a pH – buffer system prior to testing the household items. Make a solution of pH 1.00, 2.00, 3.00, 4.00, 5.00, 6.00, 7.00, 8.00, 9.00, 10.00, 11.00, and 12.00. This can be done by taking a pH buffer kit (Flinn Scientific, Catalog, AP1300 $21.00 for enough pH 4.00, 7.00, 10.00 to do this demonstration 20 to 30 times.) and diluting various pH liquids to make a new pH liquid. For example, pH 4.00 is ten times more acidic than pH 5.00. Take 10 ml of pH 4.00 and dilute it with 90 ml (total 100 ml) of water and you will have 100 ml of a pH 5.00 solution. Use 1 ml of pH 4.00 and 99 ml of water to make 100 ml of a pH 6.00 solution. Use pH 7.00 solution in a similar fashion to make pH 8.00 and pH 9.00. Use pH 10.00 solution to make pH 11.00 and 12.00. Use a 0.1 Molar HCl (pH 1.00) to make the pH 2.00 and pH 3.00 solutions.

3. Once the pH standard solutions are made, take a small amount of them (10 ml) (store the rest of future years) and add to them a few milliliters of the cabbage juice indicator. This should give you a nice spectrum of colors (See Appendix 1 for charts and tables regarding this) which you can use to compare the household items to.

Demonstration Procedure:

1. Take 10 ml of a household sample and add to it 5 ml of cabbage indicator juice.

2. Compare the color to the pH standards or to the chart in Appendix 1.

3. Any household item which is a solid (powdered detergents) should be mixed with water and permitted to dissolve before testing it.

4. You may desire to make "pH paper" with this cabbage indicator. Simply, take filter paper and soak it in a concentrated solution of cabbage juice. Remove the paper after a few hours and hang the paper from a clothesline or string to dry. Once the paper is dry, cut it into strips, and use it as you please to test the pH of various solutions.

Questions:

1. Explain how cabbage juice works as an indicator for pH?

2. Which household items are acidic and which are basic?

3. What is pH?

Explanations:

1. "Each year millions of tourists travel to the woods of New England, upstate New York, Wisconsin and Canada to witness the appearance of brilliant autumn colors. Sugar maples, red oaks, sumac, birch, and other trees and shrubs turn from green to bright red, orange and yellow. The short, cool days of autumn bring an end to the production of chlorophyll (the green light-gathering pigment). As chlorophyll gradually breaks down, the colors of the more stable carotenoid (yellow-orange) and anthocyanin (red/blue/purple) pigments become visible." (Herr and Cunningham, p. 526)

   The anthocyanins are responsible for the reds and purplish colors of autumn. They are also found in summer leaves of plants such as red cabbage, red lettuce, red plum; flowers such as, roses, geraniums, dark pansies; fruit such as, cherries, red apples, grapes, tomato, plum; roots such as, beets and radishes; bulbs such as, red onion and petioles, such as, rhubarb. These anthocyanins are water-soluble and dissolved in the cell sap. If the cell sap of a leaf is acidic then the anthocyanins show a red color. If the cell sap is less acidic then the anthocyanins appear purple.

   Cabbage juice contains anthocyanins. As the cabbage juice is exposed to different pH solutions the anthocyanins show a different color. Very acidic solutions will turn the anthocyanins to a red color. Neutral solutions will result in a purplish color. Basic solutions will appear in the green-yellow region of color. Therefore, it is possible to determine a solution's pH on the basis of the color it causes the anthocyanin pigments in red cabbage juice to turn.

2. The household items vary in pH. Most detergents are basic. Most foods are acidic. See Appendix 1 for a listing of some regular household items and their estimated pH.

3. pH is a scale which helps scientists determine how acidic or basic a solution is. Ultimately the pH scale is an indication of how much hydrogen ion there is present in a solution. The hydrogen ion makes a solution to be acidic. The more hydrogen ion that there is present in a solution the closer the pH value is to 0. The less hydrogen ion that there is present in a solution the closer the pH value is to 14. Therefore, solutions whose pH value is 7 are said to be neutral. Solutions whose pH is below 7 are acidic. Those with a pH value greater than 7 are basic.

Reference:

Herr, Norman and James Cunningham. Chemistry Activities with Real-life Applications. New York: The Center for Applied Research in Education, 1999.

Section 6 - Gases and Pressure

How should the Reformed believer understand the concepts related to gases and pressure?

First of all, it can be seen as we study the gases that God governs and upholds all things, even the motion of the gas molecules. One of the points of the Kinetic Molecular Theory of Gases is that gases travel in rapid, **random**, straight-line motion. Although we may observe that gases move rapidly and in straight-lines and that they tend to have no pattern to their travel (random), we certainly understand that even the **molecules' path is ordained by God from before eternity**. "We believe that the same God, after he had created all things, did not forsake them, or give them up to fortune or chance, but that he rules and governs them according to his holy will, so that nothing happens in this world without his appointment:" (Belgic Confession of Faith, Article 13). "Praise ye the Lord. . . .Praise the Lord from the earth, ye dragons, and all deeps: Fire, and hail; snow, and vapour; stormy wind fulfilling his word;" (Psalm 148:7,8).

Secondly, in the study of gases we see that God's word is effectual. God's word never returns void. It accomplishes his purpose. Just as God commands the snow, the storms, and the wind (movement of gases) and they obey, so too God's word causes man to repent or hardens his heart. "For as the rain cometh down, and the snow from heaven, and returneth not thither, but watereth the earth, and maketh it bring forth and bud, that it may give seed to the sower, and bread to the eater: so shall my word be that goeth forth out of my mouth; it shall not return unto me void, but it shall accomplish that which I please, and it shall prosper in the thing whereto I sent it" (Isaiah 55:10,11). "He sendeth forth his commandment upon earth: his word runneth very swiftly. He giveth snow like wool: he scattereth the hoarfrost like ashes. He casteth forth his ice like morsels: who can stand before his cold? He sendeth out his word, and melteth them: he causeth his wind to blow, and the waters flow." (Psalm 147:15-18). God sends out his word. The gases obey and move as God commands them. As we study gases and see their movement, we know that God's will is effectual.

Thirdly, the wind (movement of gases) is used in Scripture as a picture of the Holy Spirit. Ezekiel, in the valley of the dry bones, prophesied as he was commanded, and the bones came together. "And when I beheld, lo, the sinews and the flesh came up upon them, and the skin covered them above: but there was no breath in them. Then said he unto me, Prophesy unto the wind, prophesy, son of man, and say to the wind, thus saith the Lord God; come from the four winds, O breath, and breathe upon these slain, that they may live. So I prophesied as he commanded me, and the breath came into them, and they lived, and stood up upon their feet, an exceeding great army." (Ezekiel 37:8-10). "And when he (Jesus) had said this, he breathed on them, and saith unto them, Receive ye the Holy Ghost:" (John 20:22). "And suddenly there came a sound from heaven as of a rushing mighty wind, and it filled all the house where they were sitting . . . . and they were all filled with the Holy Ghost . ." (Acts 2:2,4). "The wind bloweth where it listeth, and thou hearest the sound thereof, but canst not tell whence it cometh, and whither it goeth: so is every one that is born of the Spirit" (John 3:8). God sends the Holy Spirit wherever He pleases. The Holy Spirit is powerful and irresistible. When we study the gases, the gas laws, and pressure we are awe-struck by the power and majesty of gases and of the wind. It is a good opportunity to remind the students of the power of the Holy Spirit. It is a good opportunity to remind them that as God sends the wind wherever he pleases, so too, God sends His Spirit, and "breathes" the Spirit upon whom he desires. Again, we see that God is sovereign over all things, even salvation. Man does not choose God. Man does not invite God into his heart. God "breathes" His Spirit into whom he desires.

Fourthly, we see the practical purposes behind why God made gases. Gases serve a purpose in God's creation. They are necessary so that man can "breathe" and have life. Furthermore, as gases are formed by "evaporation" there is cleansing occurring. Water can be contaminated in its liquid form, but when the water evaporates and is made into a gas, it is purified from the contamination. Thus, God always provides for His creation, and for the elect, a source of fresh water. In the gases, we see God's providential hand.

We also see other attributes of God displayed as we study gases. By virtue of the fact that we can make predictions about the behavior of the gases, we learn that the Creation is orderly. The scientist often speaks that the gases move randomly. However, even in this we see order. God designed the creation in an orderly fashion. Most of these demonstrations, show the concepts relating to Boyle's law. The fact that we can observe that as pressure increases, volume decreases, we see that this is based upon God's immutability. Since God does not change (Malachi 3:6 "For I am the LORD, I change not; therefore ye sons of Jacob are not consumed"), his laws for the creation do not change. Therefore, what we observe today, is observed tomorrow. This is not to mean that we fall into the trap of Uniformitarianism (See Appendix 3). We understand that the creation is radically different due to the Flood and the Curse. However, at this time, we do see that the creation runs in an orderly fashion.

Furthermore, we see the intricate design of the creation and the interrelatedness of the parts of the creation. When we study the gases we see how all living creatures need oxygen and/or carbon dioxide. We see the cycles that God governs and upholds so that the living creatures may live and work to the glory of God. We see how the gases are related to the liquids and solids. In all of this we see that God truly is worthy of all praise and glory.

The gases are an important part of the creation. As we study them we are encouraged again to see the order, intricacy, and beauty of the creation. We see God directing and upholding and governing all things, even the very tiny gas molecules. We see that God's will is effectual and that His word never returns void. We are reminded as we see gases, and the wind, that these are pictures for us of the Holy Spirit and His work. May these things be brought out in our teaching of the gases.

Pressure: Balloon on a Bed of Nails

Chemical Topic or Concept:

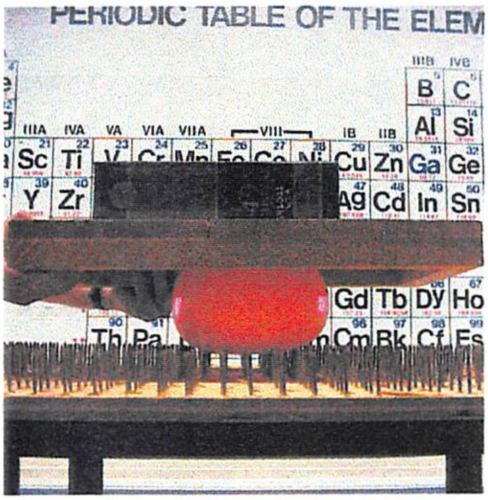
- Pressure –definition

Materials:

- Piece of plywood
- Several hundred nails
- Balloon
- Big Books

Set-up Procedure:

1. Obtain a piece of plywood (about 3 feet by 3 feet)
2. Hammer nails into the plywood. Nails should be about 1 inch apart.
3. **Keep "bed-of-nails" locked up. Warn students to behave around it. It could be a very dangerous activity.**



Demonstration Procedure:

1. Lay the bed-of-nails on a flat level surface.

2. Blow up a balloon to about ½ size.

3. Rest the balloon on the bed-of-nails.

4. Lay another small piece of plywood (2 feet square) On top of the balloon.

5. Steady the plywood with your hands, but try to let the weight of the board rest on the balloon.

6. Have a student lay the thickest book you have access to on top of the board. Again you will need to steady the board with your hands, but you should let the weight rest on the balloon as much as possible.

Questions:

1. Why does a balloon pop when you hit it with a single pin, but it did not pop when it was resting on a "bed-of-nails" with weight on it?

2. How many nails was the balloon "exposed" to?

3. What is pressure? Define it.

4. How does the definition of pressure, help understand how this demonstration worked?

5. Does the amount in which the balloon is inflated have any affect on the "pop-ability" of the balloon? Explain. Try some different scenarios.

Explanations:

1. The balloon pops with a single pin and not with a "bed-of-nails" because although the force of the balloon hitting the pin or hitting the nails is the same, the force hitting the nails is spread over a greater area than it is with the pin, reducing the amount of force

each nail experiences. Thus, since each nail experiences (or applies) a smaller amount of force on the balloon than the pin does, the balloon will not pop when it rests on many nails.

2. The number of nails that the balloon is exposed to will differ from situation to situation.

3. Pressure is defined as the amount of force per area.

4. As was stated earlier, since pressure is force per area, and the force (weight of balloon) is the same whether it rests on a single pin or on a dozen nails, the area on which it rests differs. The more area it rests on, the less pressure the balloon experiences from the nails. Thus, the balloon will not pop, even when we add extra weight, so long that weight is distributed over much area.

5. Certainly, the amount in which the balloon is filled has an affect on its "pop-ability". We recommend only filling the balloon about ½ full. This allows the walls of the balloon to be thicker and able to withstand pressure better than if it was completely full.

Reference: Teachworth, Martin. The Science Teacher, September 1994, pp. 55-56.

Marshmallow in Syringe

Chemical Concept or Topic:

- Pressure and Vacuums
- Kinetic Molecular Theory of Gases

Materials:

- 10 ml syringe
- Mini-marshmallow

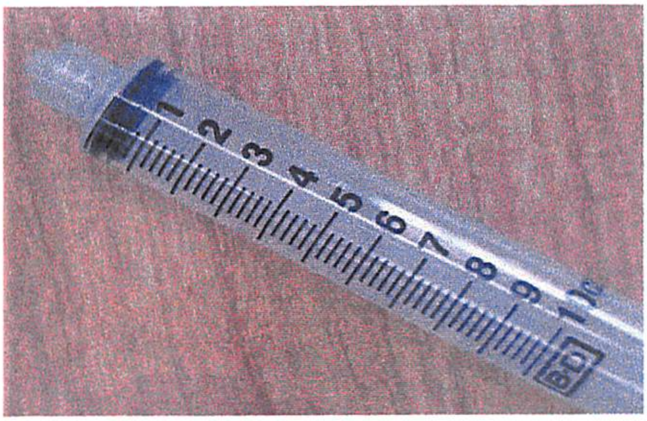


Figure 1.

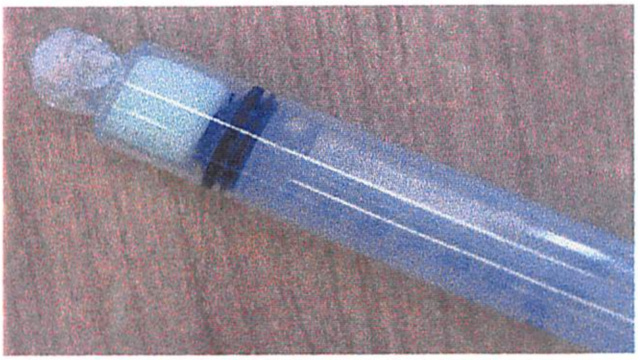


Figure 2.

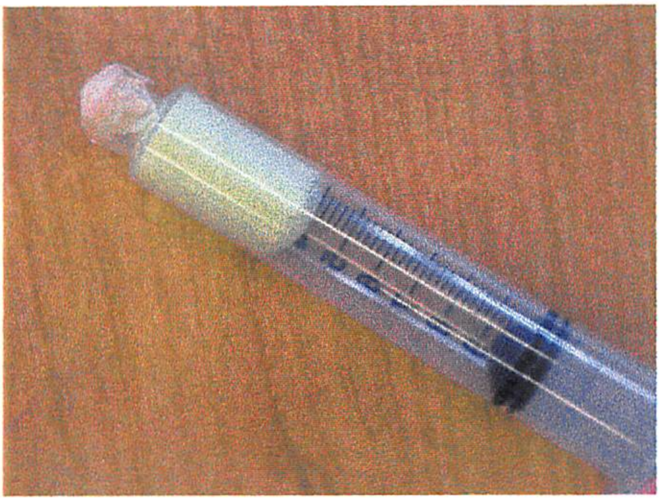


Figure 3.

Procedure:

1. Obtain a 10 ml syringe.
2. Remove the needle.
3. Remove the "plunger"
4. Place a mini-marshmallow into the syringe.
5. Replace the "plunger" (See Fig. 2)
6. Seal the tip with masking tape or by melting the tip with a candle or a match.
7. Once the syringe is air-tight, pull back on the "plunger" and watch the marshmallow expand (Fig 3).
8. Release the "plunger" and make Observations.

Questions:

1. Why is it so hard to pull the "plunger" back once the tip has been sealed?

2. Why does the marshmallow expand?

3. What happens to the marshmallow when you release the "plunger"? Explain.

4. Explain the marshmallow expansion in terms of the Kinetic Molecular Theory of Gases.

Explanations:

1. It is difficult to pull back on the syringe because the pressure on the outside of the plunger is greater than on the inside as you pull it out, and so it is being "pushed" back in. This is the resistance you feel.
2. The marshmallow expands because the tiny air bubbles inside the marshmallow are enlarged because they experience less

pressure. As the "plunger" is pulled out, the air molecules in the syringe are permitted to occupy more space. They hit the marshmallow with less frequency and force than they used to because they are more spread out. This permits the air molecules trapped as air bubbles inside the marshmallow to move around more and therefore the air bubbles inside the marshmallow expand. The marshmallow, consequently, also expands.

3. As you release the "plunger" the marshmallow shrinks, and in fact, shrinks to a smaller size than it did originally. This is because as the marshmallow expanded, some of the air bubbles got so large they burst through the marshmallow. As the "plunger" returns to its original spot the pressure that the marshmallow experiences increases, causing it to shrink. However, since some of the air bubbles actually burst, there are less air molecules inside it than there were originally, causing there to be a pressure differential, making the marshmallow shrink.

4. One of the five points of the Kinetic Molecular Theory of Gases is that ideal gases travel in rapid, random straight line motion. This means that molecules experience a mean-free path, i.e. an average distance free of collisions. As the "plunger" is pulled out, the mean-free path of the molecules increases. Since they travel a longer distance before a collision the marshmallow will consequently receive less collisions than it did originally. Thus, it is permitted to enlarge.

Reference: Flinn Scientific Inc. **The Expanding Marshmallow.** Publication number 10073, Catalog number: AP1732, 1993.

Pressure and PVC

Chemical Topic or Concept:

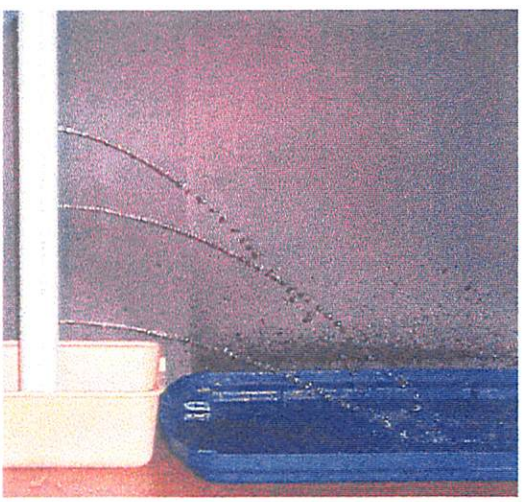
- Pressure and depth of water
- Gravity and parabolic trajectory
- Problem solving and Prediction

Materials:

- 1 inch or 2 inch diameter PVC pipe (3 feet long)
- Appropriate cap for one end of PVC pipe
- 3 corks, the size of holes in the pipe
- water
- tubs to catch water
- paper towels

Procedure:

1. Obtain a 1 inch diameter PVC pipe about 3 feet long.
2. Drill 3 holes (1/4 inch) in three different locations along the same vertical line. Drill one hole about six inches down from the top of the tube and another hole about 6 inches up from the bottom of the tube. Drill a third hole exactly in the center of the tube.
3. Place the corks in the holes.
4. Fill the tube with water.
5. Ask students to predict from which hole the water will shoot the farthest.
6. Have a student pull the plugs and hold the tube to keep it from tipping.
7. Continually pour water into the top to maintain a constant water level as close to the top of the PVC pipe as you can.
8. Observe.
9. Consult your hypothesis and explain why it was correct or why it was incorrect.



Questions:

1. What determines the pressure with which the water shoots out of the holes?
2. Does gravity (or height) play a role? How?
3. Based on your answers above, which of the three holes should shoot the farthest?
4. What if another tube, 3 inches in diameter (but otherwise exactly the same – holes drilled the same size and in the same locations) was placed next to this tube, and the corks were removed at the same time, would the 3 inch diameter PVC pipe shoot the water further than the 1 inch diameter PVC pipe?

Explanations:

1. Fluid pressure is determined by the depth of the liquid. Simply, water at a deeper level will experience greater pressure than water at a shallower level. This is one's experience when one swims in a pool. Two or three feet under water does not cause one's ears to pop, but at a depth of seven or eight feet one may begin to experience his/her ears popping.

2. Gravity also plays a role in this demonstration. All objects will experience a parabolic flight when they are shot out of the tube. Those that shoot from a greater height will land further from the base of the PVC pipe than those that shoot near the bottom. From this perspective one would have predicted that the PVC pipe hole at the top would cause the water to shoot the farthest.

3. In reality the hole drilled exactly at the middle of the PVC pipe will get the maximum distance. Water from this hole will experience a good amount of pressure due to its depth, and it will have a decent trajectory due to its height.

4. Regardless of the diameter of the tube, if all other conditions are the same, then the water will shoot exactly the same distance as in the 1 inch diameter tube. This can be explained by thinking about swimming in a pool versus swimming in the ocean. Regardless of where you are swimming when you go down to a *depth* of eight feet or so, then your ears pop. Pressure is dependent upon the depth of the water, not the volume of the water. In this situation, if the holes are drilled at the same heights with the same diameters, it does not matter what the volume of water is above the holes, the water will shoot the same distance because the pressure is dependent only upon how *high* the water is above it. Try it!!

Reference: Zwart, John. Dordt College Physics Department. 1994.

Pressure: Egg into the Bottle

Chemical Concept or Topic:
- Atmospheric Pressure
- Chemical reactions
- Kinetic Molecular Theory of Gases

Materials:
- Boiled eggs (2 or 3 in case of accidents)
- Narrow necked bottle or flask
- Matches, paper

Procedure:

1. Place the boiled egg (shell removed) on top of the bottle (Figure 1).
2. Question students to see if they can think of a way of getting the egg into the bottle without causing it to break.
3. Students may try to push it with their hands but quickly see that that is futile.
4. If they do not come up with the procedure, tell them you can do it with a match and a piece of paper.
5. Remove the egg from the top of the bottle, momentarily.
6. Light the match and start burning a piece of paper.

Figure 1

Figure 2

Figure 3

7. Throw the piece of burning paper into the bottle and place the egg on top of the bottle.

8. Observe the flame go out shortly thereafter, the egg beginning to be "sucked" into the bottle (Figure 2) and finally the entire egg, with minimal damage, in the bottle (Figure 3).

Questions:

1. How is the burning piece of paper and the fact that the egg gets "sucked" into the bottle related?

2. Does the egg really get "sucked" into the bottle? Explain the procedure in a more scientific fashion.

3. Propose a method for getting the egg out of the bottle, without causing damage to the egg.

Explanations:

1. Most commonly the relationship between the egg going into the bottle and the burning piece of paper is misunderstood. Students, and teachers sometimes, explain this phenomena by saying that the burning paper uses up the oxygen in the "closed" bottle (closed because egg seals the top); and therefore, there is a lack of oxygen molecules in the bottle, resulting in a pressure difference between the inside and outside of the bottle, forcing the egg to get "pushed" into the bottle. This is incorrect. The proper response is that the burning paper heats up the inside of the bottle, causing the air molecules on the inside of the bottle to gain kinetic energy and therefore "escape" the bottle. This leaves the pressure differential that causes the egg to get pushed into the bottle. The reason the other answer is incorrect is because as the burning paper uses up the oxygen, it replaces those molecules with carbon dioxide molecules and water vapor. Therefore, there is really no significant gain or loss of molecules from a chemical standpoint.

2. The egg is not "sucked" into the bottle. In reality it is "pushed". What has happened is that there has been a pressure differential between the inside and the outside of the bottle, resulting in the air molecules outside the bottle hitting the egg with more force per area than the air molecules on the inside, resulting in the egg being literally "pushed" into the bottle.

3. Possible methods of getting the egg out of the bottle would be to:

   a.) Turn the bottle upside down and cause the egg to seal with the inner edge of the bottle. Heat the bottle with a Bunsen burner until the molecules on the inside of the bottle have enough energy to "push" the egg back out.

   b.) A more humorous way is to flip the bottle upside down and press your lips on the bottle mouth. Blow, with one large breath-full of air, into the bottle and then quickly adjust the bottle so that the egg seals with the inner edge of the mouth of the bottle. If you add enough air and seal the inside quickly enough, you should have been able to create a large enough pressure differential to force the egg out. The students enjoy watching the teacher turn blue in the face blowing on the bottle.

Reference: Taylor, Dave. **Calvin Christian School.** Winnipeg, MB, **CANADA:** 1986 or 1987.

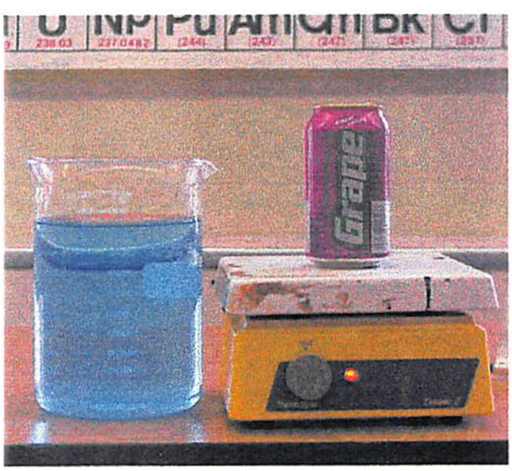
Atmospheric Pressure and the "Collapsing Pop Can"

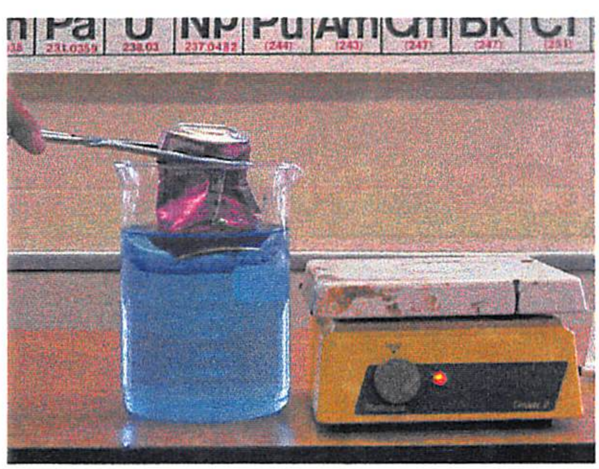
Chemical Topic or Concept:
- Atmospheric Pressure
- Kinetic Molecular Theory of Gases
- Prediction/Observations

Materials:
- Used pop can
- Heating source (hot plate, bunsen burner, or the like)
- Large Beaker or transparent bucket
- Water
- Tongs

Cautions:
- Make sure you wait until there has been plenty of steam coming out of the pop can before you procede to cause it to implode.
- Pop can can be quite warm. Be careful

Procedure:
1. Put a few milliters (10) of water into the pop can.
2. Place the pop can on the hot plate. Begin heating it.
3. Meanwhile, set up a large beaker with water. The beaker should be almost full with the water.
4. Wait until the pop can emitts steam for a few minutes.
5. Grab the pop can with a set of tongs.
6. Quickly invert the pop can above the water and lower it into the water. You need to do this quickly to make a good seal with the water.
7. Make observations. The pop can should implode nearly immediately.





Questions:

1. List your observations.
2. Why was it necessary to heat the water in the pop can?
3. What could account for the implosion of the pop can? Explain your reasoning. Connect your answer to your observations as much as possible.
4. When the pop can was pulled out of the water, what did you observe? Give logical explanations for this observation.
5. List the five main points of the Kinetic Molecular Theory of Gases.
6. What does this demonstration teach you about the Kinetic Molecular Theory of Gases?

Explanations:

1. Water is added to the pop can so that the demonstrator can see the condensed water vapor (steam) rise out of the pop can. This gives the demonstrator an idea that the air in the pop can has been warmed sufficiently.

2. The pop can implodes because as the water inside the pop can was heated the water began to vaporize. This vaporization indicates that the air molecules had been increasing in their average kinetic energy. Therefore, the molecules of the air needed more space to move. Since the pop can was open on top, the molecules "escaped" out of the can. The pop can contained less air molecules at this point than it did originally. When the pop can is inverted into the water, the water makes a seal with the lip of the can. No air molecules can enter or exit the can. Very rapidly the air molecules lose kinetic energy because the can has been lifted off of the hot plate and has been placed in cool water. Since they lost kinetic energy they do not need to occupy as much space as they had previously. Thus, they come closer to each other. By doing so, there is a lack of molecules inside the pop can to provide an equal amount of pressure as is being exerted on the outside of the can by the air molecules that surround the pop can. These air molecules pound on the side of the pop can with approximately a pressure of 15 lbs/in^2. This pressure on the outside of the pop can is greater than the internal pressure and the pop can implodes. As this occurs the external air pressure also pushed on the surface of the water and forced some of it up into the "semi-vacuum" inside of the pop can. This difference in external and internal pressure accounts for both the water rising into the pop can and the pop can collapsing.

3. The five points of the Kinetic Molecular Theory of Gases are these:

   a.) Ideal gases consist of infinitely small particles. This means ideal gases technically take up no space.
   b.) Ideal gas molecules travel in rapid, random, straight-line motion.
   c.) Ideal gas molecules experience perfectly elastic collisions (no lose of energy) with each other and the walls of the container.
   d.) Ideal gases experience no attractive forces between each other or the walls of the container.
   e.) The average kinetic energy of the molecules is directly related to the temperature. Therefore as the temperature rises so does the kinetic energy of the molecules.

   This demonstration best demonstrates the 5th point of the Kinetic Molecular Theory of Gases. This is seen by the fact that the molecules speed up, spread out, and left the container. This was due to the fact that the pop can was heated up.

Reference: Woodrow Wilson Conference 1991 at Grand Valley State University.

Atmospheric Pressure and Smaller Tin Cans

Chemical Topic or Concept:
- Atmospheric Pressure
- Kinetic Molecular Theory of Gases

Materials:
- "Empty" Coleman fuel can or the like
- Heating Source - Hot plate or bunsen burner
- 5 gallon bucket of water.

Procedure:

1. Add a half-cup of water to the "empty" Coleman fuel can.
2. Heat the can on a hot-plate.
3. Wait until lots of condensed water vapor (steam) comes out of the can.
4. Remove the can from the heat and quickly close the lid tightly on the can.
5. Place the can aside and let it cool on its own, or for quicker results stick it into a shallow tray with cold water or into a 5 gallon bucket.
6. Observe.

Questions:

1. List your observations.
2. Why was it necessary to heat the water in the tin can?
3. What could account for the implosion of the tin can? Explain your reasoning. Connect your answer to your observations as much as possible.
4. List the five main points of the Kinetic Molecular Theory of Gases.
5. What does this demonstration teach you about the Kinetic Molecular Theory of Gases?

Explanations:

1. Water is added to the tincan so that the demonstrator can see the condensed water vapor (steam) rise out of the tin can. This gives the demonstrator an idea that the air in the tin can has been warmed sufficiently.

2. The tin can implodes because as the water inside the tin can was heated the water began to vaporize. This vaporization indicates that the air molecules had been increasing in their average kinetic energy. Therefore, the molecules of the air needed more space to move. Since the tin can was open on top, the molecules "escaped" out of the can. The tin can contained less air molecules at this point than it did originally. When the tin can is sealed shut with the lid, no more air molecules can enter or exit the can. Very rapidly the air molecules lose kinetic energy because the can has been lifted off of the hot plate and has been placed in cool water. Since they lost kinetic energy they do not need to occupy as much space as they had previously. Thus, they come closer to each other. By doing so, there is a lack of molecules inside the tin can to provide an equal amount of

pressure as is being exerted on the outside of the can by the air molecules that surround the tin can. These air molecules pound on the side of the tin can with approximately a pressure of 15 lbs/in^2. This pressure on the outside of the tin can is greater than the internal pressure and the tin can implodes

3. The five points of the Kinetic Molecular Theory of Gases are these:

a.) Ideal gases consist of infinitely small particles. This means ideal gases technically take up no space.
b.) Ideal gas molecules travel in rapid, random, straight-line motion.
c.) Ideal gas molecules experience perfectly elastic collisions (no lose of energy) with each other and the walls of the container.
d.) Ideal gases experience no attractive forces between each other or the walls of the container.
e.) The average kinetic energy of the molecules is directly related to the temperature. Therefore as the temperature rises so does the kinetic energy of the molecules.

This demonstration best demonstrates the 5th point of the Kinetic Molecular Theory of Gases. This is seen by the fact that the molecules speed up, spread out, and left the container. This was due to the fact that the tin can was heated up.

Reference: Fransen, Ted. **Mennonite Brethern Collegiate Institute.** Winnipeg, MB, **CANADA:** 1990.

Atmospheric Pressure and the 55 gallon drum

Chemical Topic or Concept:
- Atmospheric Pressure
- Kinetic Molecular Theory of Gases

Materials:
- "Empty" 55-gallon drum
- Heating Source - Coleman gas stove
- Several gallons of cold water (dry ice?)

Procedure:

1. Place a few gallons (3-5) of water into the 55 gallon drum.
2. Put the 55 gallon drum on the Coleman gas stove
3. Heat the water for 10 to 15 minutes (or until significant amount of steam comes out of the cap opening).
4. Turn off the stove, and tighten the cap of the 55 gallon drum.
5. Pour ice cold water over the 55 gallon drum. If dry ice is available, place it on the lid of the drum. This is done to help cool the air inside of the drum more quickly.
6. In the few times that I have done this demonstration, it has taken some where between 10 to 15 minutes before the 55 gallon drum collapses all at once with a large thundering noise. Be patient. Also get out of the way because the 55 gallon drum probably will tip over and may still be quite warm.

Questions:

The same questions could be asked for this demonstration as were asked in "Atmospheric Pressure and the 'Collapsing Pop Can'".

You might want to ask why it takes so much longer to collapse the 55 gallon drum than it did to crush the pop can. Some answers would include an analysis of the amount of air in a 55 gallon drum than in a pop can. A 55-gallon drum contains 208 liters of volume (55 gallons times 3.785 liters per gallon), while a pop can only contains 0.355 liters of volume (355 ml). This means that a 55 gallon drum has approximately 585 times the volume that a pop can does. This is a lot more air to cool down. Secondly, a 55 gallon drum is made from different materials than a pop can is. A pop can has relatively thin walls and is made from a soft metal called aluminum. A 55 gallon drum is not made out of aluminum. Therefore, the pressure due to the atmosphere will have a much more immediate effect on the pop can than on the 55 gallon drum.

Teacher Hints:

This demonstration takes about 30 to 45 minutes to do from beginning to end. I usually set it up just before noon hour and begin heating it. Then when noon starts the students can eat their lunch outside and watch. When all the students are gathered around the water inside the 55 gallon drum is boiling and it is time to put on the cap. It still takes about 15 minutes until it collapses. It is a vivid demonstration to do every few years. Most of the student body available at lunch time come and watch.

Reference: Lanning, Gary. **Covenant Christian High School.** Grand Rapids, MI: 1996.

Pressure – "The Potato Gun" and Boyle's Law

Chemical Topic or Concept:

- Boyle's Law
- Kinetic Molecular Theory of Gases
- Enjoyment

Materials:

- One 2-foot long, ½ inch diameter conduit Pipe
- One 3-foot long, 3/8 inch diameter dowel
- Duct-tape
- One 2-inch diameter "metal-washer"
- Potatoes
- Hammer, plumb bob (or something similar)

Cautions: Students enjoy this demonstration, but be careful with the projectiles – do not aim at students, or hold "gun" carelessly as it sometimes misfires. Do not let students use the "gun".

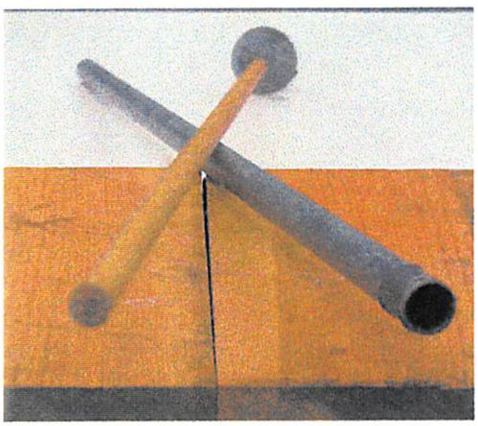


Figure 1

Set-up Procedure:

1. Obtain a 2-foot long, ½ inch diameter piece of conduit pipe. Flare one end of it, with a plumb bob (this is necessary because you want to use this end to get the first piece of potato. When it is flared it will take a piece of potato, slightly larger than the ½ diameter tube, making for a snug fit between potato and conduit walls). Crimp the other end, by hitting it several times with a hammer.

2. Obtain a 3-foot long, 3/8 inch dowel. The dowel needs to be longer in length and just small enough to slide inside the conduit pipe. Take a large "metal-washer" and slide it up the dowel, so that the longer section of dowel is about the same length as the conduit pipe, but no longer than the pipe.

3. Tape the large "metal-washer" in place with the duct-tape. This washer acts as protection for your hand for when you thrust the dowel through the conduit.

Demonstration Procedure:

1. This demonstration can be done at any time, but is best to be done just prior to teaching the relationship between pressure and volume, known as Boyle's Law.

2. Obtain a large potato. I usually use russet potatoes, but I would think any kind would work well.

3. Place the potato on a piece of board on the floor, between your two feet. Steady the potato with your feet and then jam the conduit pipe into the potato (flared end into the potato). Pull the conduit pipe out of the potato and the conduit pipe should have a piece of potato cork inside it.

4. Take your dowel and push the potato cork all the way to the other side (crimped side) of the conduit pipe.

5. Repeat steps # 2 and # 3 to get a second cork into the conduit pipe.

6. Push the second cork up the conduit pipe with the dowel. As you push the second cork closer to the first cork a "ball-of-gas" is trapped between the two corks. This "ball-of-gas" becomes smaller and smaller as the corks get closer and closer, building up pressure.

7. When the second cork is about ½ way up the conduit pipe, the gun is considered "loaded". **At this point be very careful where the gun is pointing at all times.**

8. Go outside, or find a safe spot in the classroom (probably not possible) and set up a target 30-feet away. We usually set pop cans on a table or a desk.

9. Aim at the target and with a firm rapid push, jam the dowel through the conduit pipe. The cork nearest the crimped end will be fired out of the gun. 90% of the time the second cork will remain at the crimped end and not fall out of the gun. This is desired, because all that will need to be done at this point is load another "second" cork into the gun and it will be ready to be fired.

Questions:

1. What is the relationship between pressure and volume?

2. How does the potato gun demonstrate this concept?

Explanations:

1. Pressure and volume are inversely related. This means that as the volume of a gas decreases the pressure that that gas exerts increases.

2. The potato gun demonstrates this concept because there is a section of trapped gas between the two potato corks which gets smaller and smaller as the dowel pushes the "second" cork nearer to the "first" cork. Eventually the pressure being exerted on the "first" cork becomes so great that it is fired out of the "gun". If the potato did not make a good seal with the conduit pipe (either because you did not flare the one end well enough, or you did not take a good "slice" of the potato), then the potato will not fire out of the "gun" but will probably just "spudder" out.

3. Always clean the "gun" out at the end of the demonstration. Old plugs, and potato juices, do not smell or look so nice the next year!!!

Reference: "Weird Science" Group. Woodrow Wilson 1996. Grandvalley State University.

Boyle's Law

Chemical Topic or Concept:

- Relationship between pressure and volume of a gas
- Data collection and observation
- Making graphs and interpreting graphs

Materials: For a classroom quantity of 20:

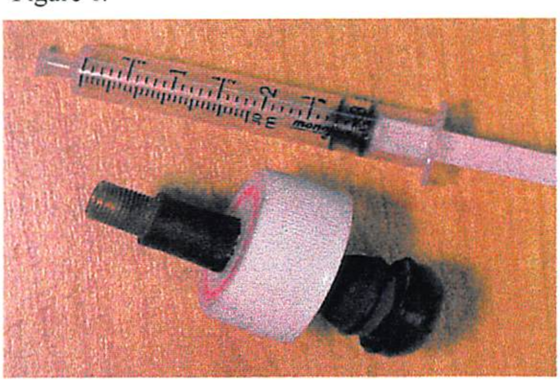
- 20 **one liter** pop bottles. Take the labels off. Make sure they have caps.
- 20 automobile air stems. Easily obtained at any tire-fixing place. The old air stems work great. Just make sure they look in reasonable shape. Get thirty maybe, in case a few don't work.
- 20 syringes. Any size will do, but I find 3 ml fit through the top of the pop bottle the easiest. Make sure the markings on the syringe are readable. Take the needles off of the syringe.
- 20 tire pressure gauges.
- One air compressor or a few bicycle pumps.
- Optional activities: You may want thermometers to monitor temperature during the activity.

Set-up Procedure:

1. Once you have obtained the various materials above, it is necessary to "fix" your bottle caps and syringes.

2. Take the bottle cap and drill a hole through the center of it, slightly larger than the diameter of the tip of the air stem. Take the air stem from the underside of the cap and push it up through the hole. You probably will get the metal top of the air stem through the hole, but then the rubber will get stuck on the edges of the hole. Grab the metal tip with a set of pliers and gently "pull and twist" the air stem up through the cap, until it is about half way through the cap or until it makes a snug fit. You will notice that in most cases the air stem widens toward the bottom. This is important because this will help make an airtight seal with the bottle cap. You do not want any air escaping between the edges of the hole and the air stem. (See Figure 1 below).

Figure 1.



3. To make the syringe measure the effect of air pressure, do the following to it.

Open the syringe to about the 3 ml mark (or whatever is the last marking), but do not open it beyond the last mark or you will not get good readings. (You can "suck" up colored water to aid in reading the syringe later, but air has worked well for me). When the syringe is opened to the spot you want, heat the syringe tip (Top far left of Figure 1) with a candle or Bunsen burner. Immediately push the tip flat on the edge of a table and hold it still until it has cooled. This should make for a sealed airtight tip. It takes some practice and will probably result in the loss of a few syringes, but eventually you will get good airtight syringes.

Experimental Procedure:

1. Once the syringe and bottle cap have been made, place the syringe inside the bottle and twist the bottle cap on firmly. (See Figure 2.)

2. Read and record the volume of the syringe. With the pressure gauge take the pressure of the air inside the bottle. Your pressure gauge will not record any pressure. This does not mean that there is no air pressure in the bottle. This simply means that the air pressure inside the bottle is the same as the atmospheric pressure. You can either have the students assume that the atmospheric air pressure is 15 lbs/in^2, or you can have them find out what it is in your city by checking with the nearest weather station.

Figure 2.

Figure 3.

3. Add air to the bottle with an air compressor or with a bicycle pump. The bottle supposedly can withstand up to 100 lbs/in^2 of pressure. I never add more than 60 lbs/in^2 because this is plenty of air to compress the syringe to about the 1 ml mark. **Always wear safety goggles.**

4. Record the new volume of the syringe. Also take a pressure reading with the pressure gauge. Do not forget to add atmospheric pressure to the pressure gauge reading. (See Figure 3.)

5. Release some air out of the bottle by pressing on the little pin inside the air stem.

6. Record the new volume of the syringe and take another pressure reading.

7. Continue to release air and record volumes and pressures until you have about 6 good readings. Do not let out too much air at any one time or you will not get 6 readings before the internal air pressure once again is equal to atmospheric pressure.

Questions:

1. What happens to the syringe as air is added to the bottle?
2. What happens to the pressure in the bottle as more air is added to the bottle?
3. What is the relationship between pressure and volume in a closed system?
4. On a piece of graph paper graph your data. Plot the pressure on the vertical axis and the volume on the horizontal axis. Connect the points with a smooth curve, not with a dot-to-dot line.

Explanations:

1. Pressure and volume are inversely related. This means that as pressure increases, volume decreases. As pressure decreases, volume increases. For each set of pressure and volume data points, if you multiply volume and pressure, you will find that each set of data points produces the same constant (it should).

2. It is interesting to add a thermometer inside the bottle because at each point in the experiment one can monitor the temperature, the pressure, and the volume. This will give the student a good understanding of the relationships between the three.

Reference: Graham, Tim. **MSTA Conference Detroit MI, 1997.**

A Bibliography of Other Helpful Demonstration Source Books

Beran, Jo. A. Chemistry In the Laboratory: A Study of Chemical and Physical Changes. New York: John Wiley and Sons, 1993.

Herr, Norman and James Cunningham. Chemistry Activities and Real-Life Applications. New York: The Center for Applied Research in Education, 1999.

Lewis, Grace. 1001 Chemicals in Everyday Products. New York: Van Nostrand Reinhold, 1994.

Martin, Marjorie. Science Notes. The Federation of Protestant Reformed Schools, 1985.

Shakhashiri, Bassam Z. Chemical Demonstrations: Volumes 1 – 4. Madison, Wisconsin: The University of Wisconsin Press, 1983.

Tocci, Salvatore. Chemistry Around You: Experiments and Projects with Everyday Products. New York: Prentice Hall, 1985.

Appendix 1

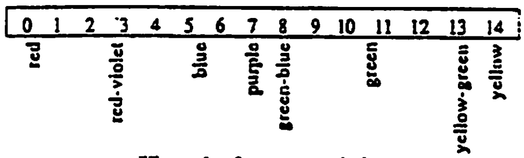
Information in this Appendix has been borrowed from:

Herr, Norman and James Cunningham. Chemistry Activities and Real-Life Applications. New York: The Center for Applied Research in Education, 1999.

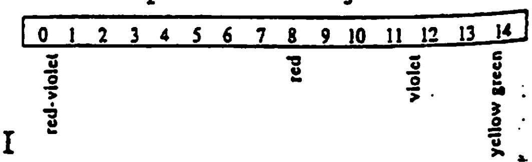
Table 4: Physical and Chemical Changes

	Chemical or Physical	*Evidence and Explanation*
lighting a match	chemical	Light and heat are produced. This occurs when a sesquisulfide of phosphorous is oxidized by the oxygen released when potassium chlorate in the match head decomposes. Also, the wood or paper chars, showing that carbon is produced.
crushing chalk with a mortar and pestle	physical	Chalk (primarily calcium carbonate) is broken into smaller pieces, but retains its chemical identity.
mixing vinegar and crushed chalk	chemical	A gas is produced. Acetic acid reacts with the calcium $CaCO_3(s) + 2HC_2H_3O_2(aq) \rightarrow Ca(C_2H_3O_2)_2(aq) + CO_2(g) + H_2O(l)$
mixing 1 mL of silver nitrate solution with 5 mL of sodium chloride solution	chemical	A precipitate (silver chloride) is formed: $AgNO_3 + NaCl \rightarrow NaNO_3 + AgCl(s)$
bending a Cyalume® light stick (contents)	chemical	Light and a slight amount of heat are produced. A phenyl oxalate ester decomposes in the presence of hydrogen peroxide, transferring energy to a dye molecule which glows as it returns to its ground state.
boiling water	physical	Water vapor will condense to form liquid vapor with exactly the same properties as it had before boiling.
crumple a sheet of	physical	Crumpled paper has the same physical characteristics as paper regular paper.
mixing vinegar and baking soda	chemical	Gas (carbon dioxide) is produced. $NaHCO_3 + HC_2H_3O_2 \rightarrow Na^+ + C_2H_3O_2^- + CO_2 + H_2O$
crush a large crystal of rock candy	physical	The resulting pieces have the same properties (color, taste, etc.) as the original.
dissolving/re-crystallizing sugar	physical	As water evaporates, crystalline sugar will reappear, with the physical properties it had before.
separation of pigments by chromatography	physical	Chromatography separates chemicals, but doesn't change them.

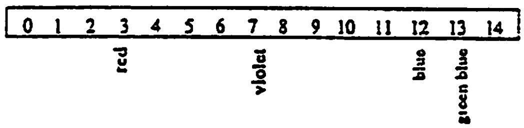
pH scale for red cabbage extract



pH scale for beet juice



pH scale for grape juice



pH red onion juice

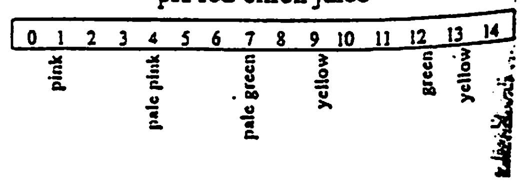


Table 3: pH of Common Substances

pH	*Substance with This pH*
0	hydrochloric acid
1	gastric juices (stomach acids)
2	lemons, vinegar
3	apples, oranges, carbonated soft drinks
4	tomatoes
5	potatoes
6	milk, most bland vegetables
7	pure water, blood. saliva
8	baking soda, eggs
9	
10	Milk of Magnesia
11	ammonia
12	soda ash (sodium carbonate, used to raise swimming pool pH
13	
14	caustic soda (lye, sodium hydroxide based drain cleaner)

Table 4: pH and Anthocyanin Colors

Color	*pH*
cherry red	1–2
cerise	3
plum	4
royal purple	5
blue-purple	6
blue	7
blue-green	8
emerald green	9–10
grass green	10–11
lime green	12–13
yellow	14

DISPOSAL OF CHEMICALS

Regulations: It is important that your school is in compliance with all federal, state, local and district regulations pertaining to the handling, storage and disposal of chemical wastes. Consult your local environmental health and safety specialist regarding the policies and regulations in your school, community and state.

Drain Disposal: The National Research Council's Committee on Hazardous Substances in the Laboratory has published a book entitled *Prudent Practices for Disposal of Chemicals from Laboratories* (National Academy Press; Washington DC). This book provides detailed information regarding the handling of chemical waste. The Committee approves compounds of the following low-toxic-hazard cations and anions for disposal down the drain with excess water in quantities up to 100 g at a time. Any strongly acidic or basic substances should be neutralized before disposal down the drain. Always consult local policies and regulations before disposing of chemical wastes in your laboratory drain.

Low-Toxicity Ions

Low-Toxicity Cations		*Low-Toxicity Anions*	
Al^{3+}	Na^{+}	BO_3^{3-}	OH^{-}
Ca^{2+}	NH_4^{+}	$B_4O_7^{2-}$	I^{-}
Cu^{2+}	Sn^{2+}	Br^{-}	NO_3^{-}
$Fe^{2+,3+}$	Sr^{2+}	CO_3^{2-}	PO_4^{3-}
H^{+}	$Ti^{3+,4+}$	Cl^{-}	SO_4^{2-}
K^{+}	Zn^{2+}	HSO_3^{-}	SCN^{-}
Li^{+}	Zr^{2+}	OCN^{-}	
Mg^{2+}			

Trash Disposal: In most areas, nonhazardous solids can be disposed of in the trash. Liquid wastes are generally not allowed in sanitary landfills and should not be placed in the trash. The following types of solid laboratory waste are generally considered nonhazardous or of low toxicity and may be placed in the trash depending on quantities involved. Always consult local policies before disposing of chemical wastes in the trash.

<u>organic chemicals</u>
naturally occurring α-amino acids and salts
citric acid and its Na, K, Mg, Ca, and NH_4 salts
lactic acid and its Na, K, Mg, Ca, and NH_4 salts
sugars and starches

<u>inorganic chemicals</u>
borates: Na, K, Mg, Ca
carbonates: Na, K, Mg, Ca, Sr, NH_4
chlorides: Na, K, Mg
fluorides: Ca
oxides: B, Mg, Ca, Sr, Al, Si, Ti, Mn, Fe, Co, Cu, Zn
phosphates: Na, K, Mg, Ca, Sr, NH_4
sulfates: Na, K, Mg, Ca, Sr, NH_4

<u>laboratory materials</u> NOT contaminated with hazardous materials: chromatographic paper and absorbents, filter paper, filter aids, glassware, and rubber and plastic protective clothing

COMMON AND INEXPENSIVE SOURCES OF CHEMICALS

Many of the chemicals used in this book may be purchased from the market, drug store, pet store or hardware store at dramatically lower prices than are available through scientific supply companies. We believe that students gain a greater appreciation for the applicability of chemistry to everyday life if they are able to use everyday products to conduct their experiments and investigations. Although the products listed on this page are less expensive, it should be noted that they often contain additives. Most of these additives do not affect the performance of the chemicals, but the instructor should always carefully examine the label to note the percent concentration of the desired substance and adjust the quantities used as necessary. It should also be noted that manufacturers sometimes change the composition of their products, so you should always carefully examine the contents label before purchasing. As with all experiments, the instructor should carefully perform all experiments and test for safety prior to classroom experiments or demonstrations.

Chemical	*Formula*	*Source/Description*
acetic acid	CH_3COOH	Vinegars vary between 4–5.5% acetic acid; more concentrated acetic acid (28%) may be purchased at photography supply stores.
acetone	CH_3COCH_3	Nail polish remover is generally acetone; fiberglass cleaner is also generally made of acetone and is available at boating supply stores.
aluminum	Al	Aluminum foil; aluminum turnings are available as scrap from machine shops.
potassium aluminum sulfate	$KAl(SO_4)_2 \cdot 12H_2O$	Alum is available at most drug stores. It is used as an astringent to shrink mucus membranes.
ammonia	$NH_3(aq)$; NH_4OH	Household ammonia (ammonium hydroxide) is an aqueous solution of ammonia. Note: This often has additives.
ammonium nitrate	NH_4NO_3	Nitrate of ammonia fertilizer is available at most garden supply stores.
amylose	$(C_6H_9O_5)_n$	Cornstarch is available at most markets and is used extensively in cooking.
anthocyanin	$C_{15}H_{11}OCl$	Anthocyanin solution can be prepared by cutting, boiling and filtering red cabbage.
ascorbic acid	$C_6H_8O_6$	Vitamin C tablets sold at the market are primarily ascorbic acid.
bromthymol blue	$C_{27}H_{28}Br_2O_5S$	Aquarium pH test kits often employ bromthymol blue because it changes color in the 6.0–7.6 range.
butane	C_4H_{10}	The lighter fluid in hand-held fire starters or cigarette lighters is usually liquid butane.
calcium carbonate	$CaCO_3$	Chalk, limestone and marble chips are good sources of solid calcium carbonate; some antacids are largely calcium carbonate.
calcium chloride	$CaCl_2$	Much of the road salt (de-icer) used to de-ice roads in cold climates is calcium chloride.

COMMON AND INEXPENSIVE SOURCES OF CHEMICALS *(Continued)*

Chemical	*Formula*	*Source/Description*
calcium hydroxide	$Ca(OH)_2$	Some antacids are primarily calcium hydroxide; slaked lime is calcium hydroxide and is used in lime-softening water treatment and in plastering.
calcium hypochlorite	$Ca(ClO)_2$	Bleaching powder and some swimming pool disinfectants contain calcium hypochlorite. Available from cleaning or swimming pool supply companies.
calcium oxide	CaO	In the past, quicklime was a material plasterers used in making plaster. It is now difficult to obtain from hardware stores.
carbon	C	Charcoal used in cooking, activated charcoal used in fish tank filters and graphite used in pencil leads are good sources of carbon.
carbon dioxide	CO_2	Dry ice is available from party stores, refrigeration supply companies and ice cream companies.
carbonic acid	H_2CO_3	Soda water is simply carbonated water, a dilute solution of carbonic acid.
copper	Cu	Electrical wire, copper pipe, and copper sheeting are available at hardware stores; American pennies (minted 1944–1946, 1962–1982) are 95% copper and 5% zinc.
copper sulfate pentahydrate	$CuSO_4 \cdot 5H_2O$	Basicop® or Bluestone® algaecide used to kill algae and other aquatic pests contain copper sulfate.
ethylene glycol	CH_2OHCH_2OH	Some engine antifreezes are primarily ethylene glycol.
glucose	$C_6H_{12}O_6$	Dextrose (glucose) is available in many drug stores; some specialty throat lozenges are dextrose.
glycerol	$C_3H_8O_3$	Glycerin is an emollient used to soften skin by delaying the evaporation of water. It is available at most drug stores.
gold	Au	Gold jewelry is generally not pure gold. Gold is generally alloyed with other metals to increase strength.
helium	He	Helium can be obtained from party stores or wherever helium balloons are available.
hydrochloric acid	HCl	Muriatic acid (the common name for HCl) is used in swimming pool maintenance. It is also sold as masonry cleaner and is available at the hardware store. Percentage concentrations vary.
hydrogen peroxide	H_2O_2	Hydrogen peroxide antiseptic (3%) is available from the drug store. Clairoxide® hair bleach by Clairol is much more concentrated and is available from beauty supply stores.

COMMON AND INEXPENSIVE SOURCES OF CHEMICALS *(Continued)*

Chemical	*Formula*	*Source/Description*
iodine	I_2	Tincture of iodine, a topical antiseptic used for treating wounds, is a solution of iodine dissolved in ethyl alcohol. It is available at most drug stores.
iron	Fe	Steel wool, iron nails, iron bolts, nuts and screws are good sources of iron. You can get iron filings by dragging a strong magnet through sand.
ferric oxide	Fe_2O_3	Ceramic rust is used to add a red color to pottery and can be purchased at ceramic stores.
kerosene	C_nH_{2n+1} (n = 12 – 16)	Lamp oil or kerosene is sold in the paint departments of most hardware stores.
lead	Pb	Lead shot and lead sinkers are used by fishermen and are available at sporting goods stores.
magnesium hydroxide	$Mg(OH)_2$	Milk of Magnesia is an antacid used to settle sour (acidic) stomachs. Some antacid tablets also contain magnesium hydroxide.
magnesium silicate	$Mg_3Si_4O_{10}(OH)_2$	Talcum powder comes from talc, the softest of all minerals, and is used as a dusting powder for babies. It is available in the body-care section of the drug store.
magnesium sulfate	$MgSO_4 \cdot 7H_2O$	Epsom salt is sold at most drug stores and is used as a laxative or as an anti-inflammatory soak.
methanol	CH_3OH	Methanol is sold as a solvent in paint supply stores under the names "wood alcohol" or "methyl alcohol."
methylene blue	$C_{16}H_{18}ClN_3S$	Methylene blue (Methidote® antiseptic) is used to treat small injured fish and is available at pet stores.
mineral oil	complex mixture of hydrocarbons	Mineral oil is sold in drug stores as an emollient. Some baby oils are essentially mineral oil and fragrance.
nickel	Ni	Pre-1985 Canadian nickels are made of nickel. Note: American "nickels" are composed of 25% nickel and 75% copper.
oxygen	O_2	Portable welding oxygen tanks are available at welding shops and some hardware stores.
paraffin	C_nH_{2n+2} (*n* >19)	Candle wax is made of paraffin. Some grocery stores sell paraffin as a sealant for home canning.
phenolphthalein	$C_{20}H_{14}O_4$	Ex-Lax® laxative contained phenolphthalein prior to 1997. In that year it was determined phenolphthalein might cause cancer, and the ingredients were changed.
phosphoric acid	H_3PO_4	Some pH reducers (available at pet stores) used in fish tanks are simply dilute solutions of phosphoric acid.

COMMON AND INEXPENSIVE SOURCES OF CHEMICALS *(Continued)*

Chemical	*Formula*	*Source/Description*
potassium bitartrate	$KHC_4H_4O_6$	Cream of tartar is available at the market and is used to stabilize delicate foods like meringue toppings and other baked egg-white products.
potassium carbonate	K_2CO_3	Some agricultural supply companies sell potash to farmers who need to increase the potassium content in their soils.
potassium chloride	KCl	Lite Salt® is used as a salt substitute by people who must limit their sodium intake and is available at most markets.
potassium bromide	KBr	Potassium bromide may be purchased from photography stores where it is used in photographic development.
potassium iron (II) hexacyanoferrate (III)	$KFe[Fe(CN)_6]$	Mrs. Stewart's® liquid laundry bluing is used to whiten clothes and may be found in the detergents section of the market.
potassium nitrate	KNO_3	Saltpeter or quick salt is used to cure homemade sausages and corned beef and may be available at some butcher shops.
potassium permanganate	$KMnO_4$	Clearwater® is a solution of approximately 50% potassium permanganate and is used to remove odors and cloudiness from water to be used in aquariums.
propane	C_3H_8	Gas barbecue fuel is generally made of propane and is available at many gasoline stations or picnic supply stores.
2-propanol	$CH_3CHOHCH_3$	Rubbing alcohol (isopropyl alcohol) is a concentrated solution (generally 70%) of 2-propanol and may be found in most drug stores.
silicon dioxide	SiO_2	Quartz sand is relatively pure silicon dioxide and is available at most building supply stores.
silver	Ag	Older non-clad American dimes, quarters, half dollars and silver dollars are 90% silver and 10% copper.
sodium acetate	$NaC_2H_3O_2$	Re-Heater® and other hand-warmers are available at sporting goods stores.
sodium bicarbonate	$NaHCO_3$	Baking soda is pure sodium bicarbonate and may be found in the baking section of the market.
sodium carbonate	Na_2CO_3	Washing soda is used to treat wool fibers and is available at spinning, weaving, and art supply stores.
sodium chloride	NaCl	The table salt used in cooking is sodium chloride. Iodized salt contains a trace of sodium iodide.

COMMON AND INEXPENSIVE SOURCES OF CHEMICALS *(Concluded)*

Chemical	*Formula*	*Source/Description*
sodium hydroxide	$NaOH$	Known also as caustic soda and lye, sodium hydroxide is used in many commercial drain cleaners.
sodium hypochlorite	$NaClO$	Household bleach is generally a 5% solution of sodium hypochlorite.
sodium phosphate	Na_3PO_4	Tri-sodium phosphate, commonly known as TSP, is available at hardware stores and is used to clean walls prior to painting.
sodium tetraborate decahydrate	$Na_2B_4O_7 \cdot 10H_2O$	Borax, such as Twenty Mule Team Borax® Laundry Booster, is sodium tetraborate decahydrate.
sodium thiosulfate	$Na_2S_2O_3$	Photographer's hypo is used in photograph development and is available at photography supply stores.
sucrose	$C_{12}H_{22}O_{11}$	Table sugar is available at grocery stores in large or small bags.
sulfur	S	Flowers of sulfur is sold at some garden stores to treat certain plant diseases.
sulfuric acid	H_2SO_4	Battery acid, also known as oil of vitriol, is sulfuric acid and may be obtained at some auto supply stores.
tungsten	W	The filament in incandescent light bulbs is made of tungsten.
zinc	Zn	Recent American pennies (1982–present) are 97.5% zinc with a 2.5% copper coating.

PREPARATION OF ACID AND BASE STOCK SOLUTIONS

WARNINGS

- Perform all acid dilutions in a fume hood or well ventilated area. Acids can irritate the skin and vapors can damage the eyes and respiratory system. Always wear goggles and lab coat when working with acids and bases.
- When diluting, always add acid to water. Never add water to acid because it may splatter. The heat released in the dilution process may be substantial. A small amount of water in a concentrated acid will heat up and may vaporize and cause splattering. A small amount of acid in water will also heat up, but because the specific heat of water is great and there is so much water, it will not vaporize and will not splatter.
- Cover acid spills with baking soda ($NaHCO_3$, sodium hydrogen carbonate) before wiping up with plenty of water
- Place 500 mL of distilled water in the beaker before mixing.
- Always add the acid or base slowly and stir with a glass rod.
- Add distilled water until 1 L of solution has been reached.
- Only instructors should dilute concentrated acids and bases.

To make:	*Dissolve this in water to make 1 liter solution:*	*To make:*	*Dissolve this in water to make 1 liter solution:*
acetic acid $HC_2H_3O_2$	*glacial acetic acid (17.5 M)*	*aqueous ammonia* NH_3	*concentrated ammonia (15 M)*
5 *M*	286 mL	5 *M*	333 mL
2 *M*	114 mL	2 *M*	132 mL
1 *M*	57 mL	1 *M*	67 mL
0.10 *M*	5.7 mL	0.1 *M*	6.7 mL
hydrochloric acid (HCl)	*concentrated HCl (12 M)*	*sodium hydroxide* NaOH	*sodium hydroxide (pellets or powder)*
6 *M*	500 mL	6 *M*	240 g
2 *M*	167 mL	2 *M*	80 g
1 *M*	83 mL	1 *M*	40 g
0.1 *M*	8.3 mL	0.1 *M*	4.0 g
sulfuric acid H_2SO_4	*concentrated sulfuric acid (18 M)*	*nitric acid* HNO_3	*concentrated nitric acid (16 M)*
2 *M*	111 mL	2 *M*	125 mL
1 *M*	55 mL	1 *M*	63 mL
0.1 *M*	5.5 mL	0.1 *M*	6.3 mL

Appendix 2

Information in this Appendix has been borrowed from:

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Herr, Norman and James Cunningham. Chemistry Activities and Real-Life Applications. New York: The Center for Applied Research in Education, 1999.

APPENDIX 5.1 PROPERTIES OF COMMON ELEMENTS

Element	*Symbol*	*Atomic Mass*	*Common Oxidation States*	*Phase 25°C*	*Color*	*Density g/cm³*
aluminum	Al	27.0	+3	s	silver	2.70
antimony	Sb	121.8	−3,+3,+5	s	silver	6.69
arsenic	As	74.9	−3,+3,+5	s	gray	5.73
barium	Ba	137.3	+2	s	silver	3.51
bismuth	Bi	209.0	+3,+5	s	silver	9.75
bromine	Br	79.9	−1,+1,+3,+5,+7	l	red/brown	3.12
calcium	Ca	40.1	+2	s	silver	1.55
carbon (graphite)	C	12.0	+2,+4,−4	s	blk/clear	2.26
chlorine	Cl	35.5	−1,+1,+3,+5,+7	g	grn/yellow	0.0032
chromium	Cr	52.0	+2,+3,+6	s	silver	7.19
cobalt	Co	59.0	+2,+3	s	silver	8.90
copper	Cu	63.5	+1,+2	s	red	8.96
fluorine	F	19.0	−1	g	yellow	0.0017
gold	Au	197.0	+1,+3	s	yellow	19.3
hydrogen	H	1.0	−1,+1	g	none	0.00009
iodine	I	126.9	−1,+1,+3,+5,+7	s	blue/black	4.93
iron	Fe	55.8	+2,+3	s	silver	7.87
lead	Pb	207.2	+2,+4	s	silver	11.4
magnesium	Mg	24.3	+2	s	silver	1.74
manganese	Mn	54.9	+2,+3,+4,+6,+7	s	silver	7.3
mercury	Hg	200.6	+1,+2	l	silver	13.5
nickel	Ni	58.7	+2,+3	s	silver	8.90
nitrogen	N	14.0	−1,+3,+5	g	none	0.0012
oxygen	O	16.0	−2,−1	g	none	0.0014
phosphorous	P	31.0	+3,+5	s	yellow/red	1.82
platinum	Pt	195.1	+2,+4	s	silver	21.4
potassium	K	39.1	+1	s	silver	0.86
silicon	Si	28.1	+2,+4	s	gray	2.33
silver	Ag	107.9	+1	s	silver	10.5
sodium	Na	23.0	+1	s	silver	0.97
strontium	Sr	87.6	+2	s	silver	2.54
sulfur	S	32.1	−2,+4,+6	s	yellow	2.07
tin	Sn	118.7	+2,+4	s	silver	7.31
titanium	Ti	47.9	+2,+3,+4	s	silver	4.54
tungsten	W	183.8	+6	s	gray	19.3
zinc	Zn	65.4	+2	s	silver	7.13

TEACHER'S SUPPLEMENT:

Element	Atomic Number	
Hydrogen (H)	1	Hydrogen is from the Greek hydro and genes meaning water-former. The sun, stars and the planet Jupiter are almost entirely hydrogen.
		Slide: Sun
Helium (He)	2	Helium was named for the sun, helios (Greek), because it was first discovered in the light coming from the sun. Its name carries the -ium ending characteristic of a metal because it was at first believed to be an alkaline earth metal. (He is $1s^2$ and alkaline earth metals $[Ng]s^2$). When helium was isolated on earth it was quickly apparent that it was far from metallic. There was some pressure to rename it helon, but this effort was defeated and helium retains the -ium ending that reminds us of its history. It is used in blimps and balloons and for producing very low temperatures.
		Slide: Balloons or blimp
Lithium (Li)	3	Lithium is from the Greek word lithos, meaning stone. Compounds of lithium are used to treat gout victims and, in the form of lithium carbonate, manic-depressives.
Beryllium (Be)	4	Beryllium is named for the mineral beryl from which it was first isolated. It was originally named glucium because of a sweet taste similar to glucose. However, it was later found to be a very dangerous poison attacking in particular the optic nerve. Today beryllium is used in rocket nose cones.
Boron (B)	5	Boron is named from the mineral borax with the ending -on copied from carbon. About a million tons of boron compounds are used in industry each year. Boron is best known as borax (Death Valley Days) and in boric acid. In agriculture, it is used as a plant food and weed killer.
		Slide: Box of borax
Carbon (C)	6	Carbon is from the Latin word, carbo, which means charcoal. As diamond and graphite it occurs in pure form in nature. According to thermodynamic theory diamond will, given sufficient time, be converted into the more stable graphite. What does this tell you about the gem on your finger? On the other hand, diamonds are prepared synthetically from graphite at high temperatures and pressures. Consider the effects of P, T, and catalyst on the extent and direction, as well as the rate, of this reaction. Carbon is added to iron to make steel.
		Slide: Charcoal briquettes, diamond ring, pencil

Nitrogen (N)	7	Nitrogen comes from Greek nitron and genes meaning nitre-forming. In French, nitrogen is called azote which means without life. Its compounds include "laughing gas," TNT, fertilizers, and amino acids. 78% of air is nitrogen.
Oxygen (O)	8	Oxygen has swinging singles (electrons that is) and is paramagnetic. Oxygen from oxys and genes means "acid-former." Lavoisier's recognition of the part played by atmospheric oxygen in combustion and respiration may be said to mark the beginning of modern chemistry. Two-thirds of the human body is made up of oxygen.
Fluorine (F)	9	Fluorine is from the Latin fluere meaning "to flow." CaF_2, fluorspar, is used as a flux in metal working. The existence of the element fluorine was suspected for more than a hundred years before it finally was isolated by Henri Moissau in 1886. Ionic fluorides are used to fluoridate drinking water, thus reducing cavities.
		Slide: Crest toothpaste
Neon (Ne)	10	William Ramsay's son is said to have suggested the name for neon for the gas isolated by his father. He called it neos, meaning something new. It is chiefly used in "neon signs."
		Slide: Neon sign
Sodium (Na)	11	Sodium named from the English soda. Its Latin name was natrium which accounts for the symbol Na. Its useful compounds include table salt, baking soda, borax and lye.
		Slide: Boxes of table salt, borax, baking soda, lye
Magnesium (Mg)	12	Magnesium is named after an ancient district in Asia Minor where magnesium ores were common. It is extracted from sea water and salt brines. It is used as a powder or foil in firecrackers, flash bulbs, and bombs.
Aluminum (Al)	13	Aluminum comes from the Latin alumen or alum. Aluminum was first purified by Charles Hall who was a student at Oberlin College in Ohio. A solvent was needed to electrolyze bauxite, and after Hall discovered the correct combination, the price of aluminum fell from $545/lb to about $0.15/lb. While aluminum was still considered an exotic metal, it was used to cap the Washington Monument. Hall later founded the Alcoa Aluminum Company of America. There is an aluminum life-size statue of Charles Hall in the Ketting Science Building at Oberlin College. Aluminum has many uses from toothpaste tubes to airplane wings.
		Slide: Aluminum cans, aluminum foil, house siding, toothpaste tube, aluminum pots and pans
Silicon (Si)	14	Silicon is named from the Latin silex or flint. Sand, largely silicon dioxide, goes into making glass and cement. Pure silicon is used in making many micro-electronic devices.

Phosphorus (P)	15	The name phosphorus comes from phosphoros or light bearer. White phosphorus yellows, then reddens in light, and glows in the dark, hence "phosphorescence." Phosphorus is the major ingredient in "Mata-Rata" a rat poison from Common Sense Chemical Company of Buffalo. Mata-Rata means "death to the rat."
Sulfur (S)	16	Sulfur is from the Latin sulphurum which denoted the Biblical brimstone. Genesis 19:24 talks about the fire and brimstone that rained on Sodom and Gomorrah. Sulfur is used in matches, insecticides, fertilizers, gun powder, and rubber tires. The most important use of sulfur is in manufacturing sulfuric acid of which 40.7 million tons were produced in 1981. It is so important that the amount of it produced each year is a fairly accurate index of industrial prosperity.
		Slide: Matches, tires, fertilizers
Chlorine (Cl)	17	Chlorine is from the Creek chloros meaning grass green. Important chlorine compounds include bleach, disinfectants, and table salt.
		Slide: Table salt, bleach
Argon (Ar)	18	Arcos means neutral or inactive in Greek, and argon was named because of its pronounced lack of reactivity. It was the first noble gas discovered on the earth and is by far the most abundant, constituting about 1% of the atmosphere.
Potassium (K)	19	Potassium was named for the Old English potashes, an impure form of potassium carbonate known to the ancients. The symbol K, if from its Latin name, kalium. Along with nitrogen and phosphorus, potassium is one of the three key chemical elements in fertilizer.
Calcium (Ca)	20	The name calcium comes from the Latin calx or lime. Its presence in our bodies is essential. About two pounds of the human body are calcium compounds, mostly in bones and teeth.
Scandium (Sc)	21	Scandium was named for Scandinavia. It was discovered in 1879 by a Swede, L. F. Nilson, and its properties amply confirmed those predicted by Mendeleev for eka-boron a few years earlier.
Titanium (Ti)	22	Titanium was named for the Titans, the supermen of Greek mythology. Titanium white (TiO_2) is a paint pigment. The metal itself is used in constructing jet aircraft because it is light and strong and can withstand high temperatures. Unlike lead white, titanium white does not blacken in polluted air.
		Slide: A tube of titanium white

Vanadium (V)	23	Vanadium, named after the Scandinavian goddess Vanadia, is found in Venezuelan crude oil. The source of the vanadium in the crude is ancient animals who used vanadium in their oxygen transport systems just as we use the iron in hemaglobin. Vanadium fouls and corrodes boiler tubes by dissolving protective oxides.
Chromium (Cr)	24	Chromium is from the Greek chroma for color. It has the same root as chromatic, chromatography, and Kodachrome. The red chromophore in a ruby is chromium ion.
Iron (Fe)	26	Iren is Old English for ion. The symbol Fe comes from the latin name, ferrum. Iron is the basic ingredient of steel. Making up part of the compound hemoglobin, it carries oxygen in the blood. Surprisingly the iron in "iron fortified cereals" is present in the form of iron filings.
Cobalt (Co)	27	Cobalt comes from the German Kobalt which means evil spirit. Its poisonous ores were treacherous to miners. Cobalt salts give blue color to porcelains, tiles, and enamels. Its alloys are used in jet engines. The permanent magnet used in Walkman headphones is made from a samarium-cobalt alloy which has a high magnetic permeability and is very stable in the presence of external fields. This alloy is superior to others because it can be driven by milliwatt power and has minimum battery drain.
		Slide: Tube of cobalt blue, Walkman headphone
Nickel (Ni)	28	Nickel comes from the German Kupfernickel which means false copper. The durable quality of nickel has made it popular for use in coins. The 5 cent piece is 25% nickel; the rest is copper.
		Slide: Nickel coins
Copper (Cu)	29	Copper comes from the Latin cuprum, which was derived in turn from the ancient name for Cyprus, an island famed for its copper mines. The Statue of Liberty is made from copper. Copper is found in crustacean blue blood. Copper is mixed with zinc to make brass and with tin to make bronze. It is used in electrical wires and for modern plumbing.
		Slides: Pennies, quarters, dimes, plumbing pipes
Zinc (Zn)	30	Zinc was probably named for Zink which is German for tin. Zinc is used as the anodic outer-casing in flashlight batteries and to galvanize steel as a protection against rust.
		Slide: Alkaline battery
Gallium (Ga)	31	Gallium was discovered by a Frenchman, LeCoq de Boisbaudran. He claimed that he named the element after his homeland, Latin Gallia. Actually he pulled a fast one since gallus means a cockerel or young rooster in Latin. Thus LeCoq de Boisbaudran managed to name the element after himself!

Germanium (Ge)	32	Germanium was first isolated in 1886 by the German chemist Car Winkler. Its properties startlingly confirmed those predicted by Mendeleev for eka-silicon. Its principal use is in the manufacture of photovoltaic devices and transistors.
Arsenic (As)	33	Arsenic comes from arsenikos which means valiant or bold in Greek. Noble ladies of France ate trace amounts of arsenic (III) oxide and arsenic (V) oxide to get whiter cheeks (alabaster white), as was then the fashion. They built up a tolerance to it and this came in handy when they felt the need to poison false lovers. Rumor has it that it was fed to princelings by their nurses to build immunity against such a fate. Later it was used to cure syphilis by injecting it into the bloodstream. In 2-3 days all symptoms of syphilis were gone. Unfortunately, in 3-4 days the patient died. Salvarsan, a compound of arsenic, was later used successfully to treat syphilis.
Selenium (Se)	34	Selenium comes from the Greek selene for moon. Selenium is present in anti-dandruff shampoos such as "Selsun Blue" and also in garlic.
		Slide: Selsun Blue shampoo, garlic
Bromine (Br)	35	Bromine is from the Green bromos which means stench. It is used in nerve sedatives, in disinfectants, and in gasoline as a scavenger for lead.
Krypton (Kr)	36	Kryptos means hidden in Greek. Krypton, a rare noble gas, is thus the "hidden one." Cryptography, the deciphering of secret codes, is from the same root. Because radioactive krypton is a by-product of all nuclear reactors, it is used to monitor Soviet nuclear production. The Russian share is found by subtracting the amount that comes from Western reactors from the total in the air.
Rubidium (Rb)	37	Rubidium was first isolated in 1860 from salt brines by Robert Bunsen (of burner fame) and Gustave Kirchhoff. The metal was characterized by the bright ruby-red (Latin rubidus) color which it imparts to a flame. The metal and its compounds have few uses except in specialty glasses.
Strontium (Sr)	38	Strontium was named for the town of Strontian in Scotland, a region where the mineral Strontianite ($SrCO_3$) is common. It is obtained by the electrolysis of fused $SrCl_2$. The metal and its compounds have few uses though it is sometimes employed to impart bright red colors to fireworks.
Yttrium (Y)	39	Yttrium is named for Ytterby, a town in Sweden. Though not generally considered a lanthanide, it shares many of their properties, in particular the dominant +3 oxidation state. It finds use in hot filament lamps and in TV screen phosphors.

Zirconium (Zr)	40	Named from the arabic Zerek, a precious stone known in English as zircon. Crystalline cubic zirconium oxide has a fairly high refractive index and is used in costume jewelry as the "poor person's diamond" though it lacks the hard, high brilliance of diamond. For many years "100%" pure zirconium was advertised and sold. This was later found to contain up to 5% hafnium, zirconium and hafnium having extremely similar properties. Used in photoflash primers, flares and blasting caps due to its strongly exothermic reaction with oxygen. Refractories containing zirconium oxides and silicates are used in crucibles and muffle furnaces.
Niobium (Nb)	41	The element was named by its discoverer columbium since the original ore came from the U.S. Strangely, while the Europeans preferred the name columbium, the Americans preferred niobium after the Greek goddess Niobe, the daughter of Tantalus. Niobium often occurs associated with tantalum.
Molybdenum (Mo)	42	Molybdenum occurs as the sulfide and was early confused with lead metal. The name derives from the Greek molybdos or lead. Quite rare in nature it finds many uses alloyed with other transition metals.
Technetium (Tc)	43	This element is not found in nature but is made artificially, hence its name from the Greek technikos—an art. All known isotopes are radioactive but some are very long-lived and potassium and ammonium pertechnetates (analogous to the permanganates) are rather ordinary, though expensive, materials.
Ruthenium (Ru)	44	The element is named for Ruthenia or Russia. It is found with the other platinum metals and is quite rare. As the metal or in the form of compounds it finds extensive use as a homogeneous and heterogeneous catalyst.
Rhodium (Rh)	45	Aqueous solutions of rhodium are often rose-colored and this gave rise to the name: Greek rhodon, a rose. Rhododendron bushes clearly derive their name from the same root. Like other members of the platinum family it is used in alloys and as a catalyst for a wide variety of inorganic and organic reactions.
Palladium (Pd)	46	Palladium is from the Greek, Pallas. In view of its position in the Periodic Table it should not perhaps be surprising that it occurs in commercial amounts in the world's richest nickeliferous ores, those of Sudbury in Ontario. A noble metal, it is none the less an excellent hydrogenation catalyst when in finely divided form. Hydrogen gas passes through thin palladium thimbles and this property has been adapted for the production of ultra-pure hydrogen.

Silver (Ag)	47	The origin of silver's name was the Latin, argentum. Argentina was named for its numerous silver mines. Silver is one of the best conductors of heat and electricity and is used in coins and jewelry. Sterling is 92.5% silver and 7.5% copper. Silver bromide is the most common light sensitive material used in photography.
		Slide: Silver jewelry
Cadmium (Cd)	48	Cadmium comes from the Green kadmeia which means earth. It is used for plating iron and steel objects, such as screws and bolts, because it does not oxidize readily. Control rods from nuclear reactors are made of cadmium because the metal "soaks up" excess neutrons. The metal is also used in cadmium-nickel (Edison) batteries and in yellow paint. Cadmium oxide is used in making rubber tires.
Tin (Sn)	50	Tin is derived from the Arabic and Sanscrit. The symbol Sn comes from the Latin stannum. At temperatures below 13.2°C, malleable "white" tin slowly changes to powdery "gray" tin. This property known as "tin disease" or "tin pest" was dramatically observed by Siberians who found that in the winter the buttons fell off of their uniforms and their organ pipes crumbled from the vibrating air columns. A "tin can" is actually sheet steel coated with a layer of tin about 0.0005 in thick.
		Slide: Tin cans
Antimony (Sb)	51	Antimony comes from the Latin antimonos "opposed to solitude" because the element is generally found mixed with other elements. The symbol Sb came from Stibium, which means mark, because antimony sulfide was once used as eyeshadow. Jeremiah 4:30 condemns women who painted their eyes with it. The story is told of a monk in France who was studying antimony compounds. He threw out his waste materials which were promptly gobbled up by the hogs at the monastery. Curiously, the hogs thrived and put on weight. The monk noted his poor skinny, malnourished, fellow monks, and he slipped stibnates into their diet. Unfortunately, they all sickened and died. As his self-imposed penance, he toured Europe preaching of the dangerous "anti-monk," in French "anti-moine," which evolved into antimony. Antimony is mixed with lead in automobile batteries and goes into many metal alloys such as pewter.
Iodine (I)	53	Iodine comes from iodes which means violet, the color of its vapor and of certain of its solutions. The radioactive isotope, I-131, is used to detect thyroid problems. Most table salt is iodized because iodine deficiency causes goiter.
		Slide: A box of iodized salt

Xenon (Xe)	54	Xenon means stranger in Greek, xenos. Xenophobe, which is a fear of strangers, is from the same root. Dr. Spinar at South Dakota State University, tells this story: In the late 1950's a high school student came to a friend of Dr. Spinar's to discuss a science project. The student wanted to react Xe with F_2 in a Ni container. When he was told this would not work since it was a noble gas, he changed his project. Dr. Spinar always ended his story by saying he hoped that the student had not found out that he was correct and the expert was wrong.
Barium (Ba)	56	Barium was named from the Greek baros which means heavy or dense. Barium sulfate is used in "medical cocktails" to outline the stomach for x-ray examinations.
Tungsten (W)	74	Tungsten comes from a Swedish word which means heavy stone. The symbol W is from the ore wolframite. It has the highest melting point of any metal, 6170°F (5828°C). It is used in light bulb filaments.
		Slide: Light bulb filaments
Platinum (Pt)	78	Platinum is named from the Spanish platina, which means little silver. It is used in jewelry, delicate instruments, electrical equipment, and catalytic converters. At one time platinum was cheap enough that it was used to adulterate gold.
Gold (Au)	79	Gold's symbol is from the Latin aurum. The Old English word geolo meaning yellow is the origin of the modern name. Gold is plated on the inside of a pipe (waveguide) that is used to transmit microwaves from the transmitter to the dish with no appreciable loss of power. The electroplated layer of gold is so thin that the gold in a wedding ring would plate 100 ft or more of the pipe. Gold is also used for money, jewelry, and dental work.
		Slide: Gold jewelry
Mercury (Hg)	80	The name mercury comes from the planet Mercury. The symbol is from the Greek word hydrargyrum which means liquid silver. Mercury was once used to "cure" syphilis. Mercury salts were also used to make the felt used in beaver fur hats. The men who made the hats were exposed to the mercury and eventually became insane. The Mad Hatter is a famous example. Today mercury is amalgamated with silver to make dental inlays. It is also used in thermometers and barometers, in silent electric switches, and in mercury vapor lights.
		Slides: Thermometer, barometer, mercury vapor lights, the Mad Hatter

Lead (Pb)	82	Lead's symbol is from the Latin word plumbum. Related terms include plumber, plumbing, plumb bob, and plumb line. Upper class Romans stored their wines in lead-glazed pottery vessels. Archaeological evidence indicates that they suffered from lead poisoning, while the lower classes who used unglazed pottery vessels, did not. The rust-inhibiting "red lead" (Pb_3O_4) is used as undercoating on bridges and military vehicles. The "white lead" (basic lead carbonate) formerly used quite commonly in paints causes lead poisoning in children who eat the sweet tasting pieces of peeling paint. Lead acetate was called "sugar of lead" because of its sweet taste. Lead and lead (IV) oxide (PbO_2) are used in storage batteries. Lead as tetraethyl lead is added to gasoline as an antiknock agent. The brilliant yellow lead chromate pigment ($PbCrO_4$) is used to paint the yellow lines on highways.
		Slide: Fishing sinkers, plumb bob, lead-acid battery, leaded regular gasoline pump
Uranium (U)	92	Uranium was named for the planet Uranus. The fissionable isotope U-235 is used in nuclear reactors and the non-fissionable U-238 is used to make plutonium.
Plutonium (Pu)	94	Plutonium was named after the planet Pluto, the planet beyond Neptune. In one World War II war code it was referred to as "copper" and copper itself had to be renamed "honest-to-God copper."

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Ban Dihydrogen Monoxide!

THE INVISIBLE KILLER

Dihydrogen monoxide is colorless, odorless, tasteless, and kills uncounted thousands of people every year. Most of these deaths are caused by accidental inhalation of DHMO, but the dangers of dihydrogen monoxide do not end there. Prolonged exposures to its solid form cause sever tissue damage. Symptoms of DHMO ingestion can include excessive sweating and urination, and possibly a bloated feeling, nausea, vomiting and body electrolyte imbalance. For those who have become dependent, DHMO withdrawal means certain death.

Dihydrogen Monoxide:

- Is also known as hydroxl acid, and is the major component of acid rain.
- Contributes to the green house effect
- May cause severe burns.
- Contributes to the erosion of our natural landscape.
- Accelerates corrosion and rusting of many metals.
- May cause electrical failures and decreased effectiveness of automobile brakes.
- Has been found in excised tumors of terminal cancer patients.

CONTAMINATION IS REACHING EPIDEMIC PROPORTIONS

Quantities of dihydrogen monoxide have been found in almost every stream, lake, and reservoir in America today. But the pollution is global, and the contaminant has even been found in Antarctic ice. DHMO has caused millions of dollars of property damage in the Midwest, and recently California.

Despite the danger, dihydrogen monoxide is often used:

- As an industrial solvent and coolant.
- In nuclear power plants.
- In the production of styrofoam.
- As a fire retardant.
- In many forms of cruel animal research.
- In the distribution of pesticides. Even after washing, produce contaminated by this chemical.
- As additive in certain "junk foods" and other food products.

Companies dump waste DHMO into rivers and the ocean, and nothing can be done to stop them because this practice is *still legal*. The impact on wildlife is extreme, and we cannot afford to ignore it any longer!

THE HORROR MUST STOP

The American government has refused to ban the production, distribution, or use of this damaging chemical due to its "importance to the economic health of this nation." In fact, the navy and other military organizations are conducting experiments with DHMO, and designing multi-billion dollar devices to control and utilize it during warfare situations. Hundreds of military research facilities receive tons of it through a highly sophisticated underground distribution network. Many store large quantities for later use.

IT'S NOT TOO LATE!

Act NOW to prevent further contamination. Find out more about this dangerous chemical. What you don't know can hurt you and others throughout the world. Send email to no dhmo@circus.com, or a SASE to:

Coalition to Ban DHMO
211 Pearl St.
Santa Cruz CZ 95060

Appendix 3

Information in this Appendix has been borrowed from:

Hanko, Professor Herman. Principles of Education. Hope Protestant Reformed Christian School, 1963.

Principles of Education

by

Prof. Herman Hanko

♦ ♦ ♦

Hope Protestant Reformed
Christian School

INTRODUCTION

A school is the character of instruction given in it. It is not the number of pupils, the size and quality of the physical plant, the number of books in its library, the scope or limitations of its curriculum; it is the instruction that is given.

A Christian school is Christian instruction.

Christian instruction means several things, although it means essentially one thing. This one thing is instruction that is based entirely upon the truth of the Word of God. This implies several fundamental principles:

1) This implies that the revelation of God in infallibly inspired Scripture is the sole rule of faith and life. The principle of all truth is to be found in the Word of God. Nothing which is contrary to Scripture and only that which meets the standard of Scripture is Truth.

2)This truth has been developed throughout the ages by the Church of Jesus Christ as that Church has been led into the truth by the Spirit of Truth. Thus the truth of Scripture is the historically Reformed faith developed in the line of the Calvin Reformation and incorporated into the creeds of the Reformed Churches.

3) This truth contains the basic principles of every subject of knowledge. Although the "facts" of history, science, music, etc. can be discovered through a systematic study of God's creation, these facts remain bare facts until they are developed in connection with the truth of the Word of God. In fact, it may be said that they are not "Truth" until they are put into the total framework of Scripture.. This does not mean that the Bible is an additional fact to many other facts. This does not mean that one simply adds to Scripture what is discovered in God's creation. This means rather that every fact of every subject must be based upon, incorporated into, permeated with, explained in the light of, the truth of God in Holy Writ. Scripture is the foundation, the basic structure, the pulse beat and life blood of all knowledge. Only when this is done is education "Christian".

It is to attempt a beginning at this important work that these principles are prepared.

This is to say that we consider this emphatically a beginning. Much work must still be done. Further development must still take place. But this is, we are convinced, the direction that such study should take.

If these principles make the work of our teachers a little easier in the attainment of their calling; if these principles aid our parents in striving towards a school that is truly Christian; if these principles inspire those from our fellowship to go on in this important work; then our efforts, under the blessing of our covenant God, will not have been in vain.

IV. SCIENCE TYPE SUBJECTS

I. Introduction:

A. This paper includes:

1. General principles underlying the study of the natural sciences.

2. Although the social sciences (sociology and psychology would perhaps enter into the general subject, this paper does not treat these subjects.

3. This paper is intended to be a basis for the study of the natural sciences as taught in the grade school where the sciences are not completely differentiated.

B. There is included therefore:

1. A discussion of the relation between the special and general revelation.

2. Some points with respect to the study of the creation.

3. A discussion of the scientific method.

4. Applications to the teaching of this subject.

II. The relation between special and general revelation.

A. This subject is treated here because:

1. The basic premise of the Christian pedagogue is that the knowledge of God is above all else important. Or, to put it a little more exactly, the knowledge of God is the only true knowledge that there is.

a. By the knowledge of God is meant that true and saving knowledge of God which is life eternal.

b. Not to possess this knowledge of God always ends in eternal misery and punishment.

2. This basic premise brings with it some questions that need to be answered.

a. Is there a revelation of God through the creation which is the object of study in the natural sciences.

b. Is it possible to know God through the things that are made? To come to the saving knowledge of God Whom to know is life eternal?

c. If this is not possible, what purpose is there in a study of the creation in all the branches of the natural sciences, and why should a Christian engage in such a study?

B. The original means of revelation was through creation.

1. Adam, in the state of rectitude, knew God through this creation in which he stood; and, seeing God in the handiwork of creation, He loved God with all his heart, and the full strength of his being.

2. This knowlege of God through the things that are made was lost through the fall.

a. For a more detailed discussion of this point, cf. the paper on the language arts.

b. It is sufficient for our purposes here to point out that the curse came upon the creation so that no longer was any speech of God heard but the speech of the curse. Besides, man himself retains only a few remnants of his former powers with which he was endowed at his creation, and has lost, to a considerable extent, the powers to investigate God's handiwork.

3. This does not mean, however, that man lost all the knowledge of God.

a. He can, through the things that are made, know that there is a God, that this God is the sovereign of the universe and that this God ought to be served. Cf. Romans 1:18ff.

b. However, this truth even, as limited as it is, wicked man holds under in unrighteousness. He willingly and consciously corrupts this truth, changes the glory of the incorruptible God into an image like to corruptible man and, by doing so, is without excuse.

c. The conclusion of the matter is therefore that man can never come to a saving knowledge of God through the creation.

1) He cannot construct a natural theology from limitations of the knowledge of God through the works of God. He cannot develop any truth concerning God because of his sin.

2) His worship of idols and ignorant superstitions are not an expression of his sighing and longing after God corrupted by ignorance; rather, all his idols, all his philosophical systems are so many conscious and deliberate attempts to corrupt the truth of God and change His glory to the likeness of the creature.

4. Therefore, although one may speak of a revelation of God through the creation, this must not be construed to mean that man can arrive at any knowledge of God which will lead him to confess that God is the only Lord of heaven and earth who ought to be and is actually served.

C. Considering this, is it possible for the wicked to know anything at all about the creation itself? Can a wicked man come to any conclusions about the nature of the creation about him?

1. In order to answer this question, it is first of all necessary to make a distinction between what may be called "formal knowledge" and "transcendent knowledge."

a. Formal knowledge--This is the purely intellectual knowledge of the bare facts of the creation.

b. Transcendent knowledge--This is a knowledge of the creation which involves not only the intellect, but also the will and the heart, which sees and understands the creation, not merely as an aggregate of facts, but as the handiwork of God and which leads to a deep sense of humility before the majesty of the Most High.

2. The wicked man, apart from regeneration, can come to a formal knowledge of the creation.

a. This means that he is in a position as a rational and moral creature to ascertain facts concerning the creation. He is able to discover the laws which are in the creation and the powers of the creation about him. He is able to determine the way in which trees grow, the laws according to which planets move in their courses, the means of the formation of snow, etc. He is even able to harness the creation's powers and put them to his own use.

B. But, in spite of this,

1) Man, apart from grace, cannot see nor believe God's hand in creation.

2) Even his formal knowledge of creation is more limited that it would have been had man continued to stand in a state of rectitude.

3) That this knowledge which he is able to gain is itself vanity for it has not the true content of the knowledge of God. Presently this creation shall be destroyed with man, and his knowledge of the creation shall perish with him.

4) That even though man is able to harness the creation's powers for his own use, he uses these powers of God's world for sin and to establish his own kingdom of darkness, thus filling the cup of iniquity and becoming ripe for judgment.

D. Is it possible for the regenerated child of God to know the creation?

1. This is certainly the case.

a. In the sense of the formal knowledge of the creation, he is in as good a position as the unbeliever to examine the creation and make it the object of his study, and learn its facts.

b. But also in the sense of transcendent knowledge of creation--the revelation of God through creation--he is also able to see this revelation and respond to it in praise.

2. In this connection, we must notice however:

a. The entire creation, already in Paradise, and even today, was formed by God as a picture of the heavenly. For this reason, there are many signs in creation which are pictures and patterns of the heavenly creation; for this reason our Lord could teach in Parables: "The kingdom of heaven is like unto..." Ps 19

b. This transcendent knowledge of the creation is possible only through Scripture. The Scriptures come to the people of God as the Word of God through Jesus Christ. This Word of God is put into the hearts of God's people by Christ's Spirit. It is only therefore, when the believer stands on the pinnacle of Scripture and surveys the world about him that he can see the handiwork of God which "day unto day uttereth speech and night unto night showeth forth knowledge." Ps. 19:2

c, Even then, the revelation of God in creation is to us different from the revelation of God through creation to Adam.

1) Adam was perfect; the creation was free from the curse. We are imperfect; we see only a cursed world.

2) Adam could not know of the fall and salvation in Christ. This can only be revealed against the background of sin and the curse.

3) But for us who see creation through the spectacles of Scripture, even the material universe speaks to us of the wonder of grace whereby this creation and God's people with it at its head are redeemed and brought into the new creation of heaven.

4) This can be illustrated in many ways:

a) The transformation of a caterpillar to a moth in a cacoon speaks of the wonder of the resurrection through the grave.

b) The barren winter speaks of the curse; the glorious budding of spring speaks of the regeneration of the brute creation.

c) The brilliantly colored sunset gives hope at the dying of the day of another day that shall come--the dawning of an eternal day.

d) Standing on the brink of the colorful Grand Canyon in Arizona, one cannot help but be astounded at the power of the curse that tears the earth open to its bowels. But in the glorious array of color especially in the light of the setting sun, there is the unmistakable language of the power of grace that delivers this sin-cursed world from the bondage of corruption.

3. In conclusion: as far as the formal knowledge of creation is concerned, the worldly scientist is as well equipped or better equipped to investigate the mysteries of creation as the child of God. But he cannot come to the deeper and true knowledge of God through the things that are made.

III. Concerning the creation itself as an object of investigation, there are several points of importance.

A. The creation is an organic unity.

1. The character of this unity.

a. The creation was originally formed by the hand of God with each part of it united to, dependent upon and related with each other part. There was an interrelationship and interdependence in the entire creation between every creature.

b. This was true especially because there were various levels of existence and life.

1) The inorganic creation is the lowest form of existence.

2) The entire world of plants is a higher form of existence, is in fact a form of life. Yet plants are dependent upon and related to the inorganic creation, for they must be connected to the earth in order to live.

3) A higher form of life is to be found in the animal world including fish, fowl, creeping things, insects and animals. It possesses a higher form because it is capable of moving about on the face of the earth, because, especially in the higher forms, it possesses a measure of intelligent life. Yet the whole world of animals is dependent upon the earth through the world of plants.

4) At the pinnacle of creation, united to the things about him and dependent upon them, yet king over them, stood man. His life is a higher life than all, for he possesses a rational moral nature capable of bearing the image of God.

2. This entire unity was disrupted through sin and the consequent curse.

a. The entire creation once stood in harmony with itself and in fellowship with God united to God through the heart of man. But, because man through the fall, was separated from God, the whole creation was separated from God with him and fell under the curse.

b. Thus there is turmoil and confusion in the creation, strife and warfare, so that only a remnant of the original unity remains.

3. This unity is restored in a much higher sense of the word through Jesus Christ who is the Head over all things and unites all things together in perfect harmony in Himself in the new creation to the eternal glory of God.

B. In this connection we must notice that this is all true because of the law of God.

1. The law of God is the will of God which is the full expression of the place which each creature shall occupy in the midst of the creation, how that creature shall be related to the rest of the creation, and through its

proper place, how each creature shall serve the purpose of God and glorify its Maker.

2. Each creature is given a nature that is in perfect harmony with the law for it, that because of its nature it can keep the law, occupy its proper place in God's world, and thus fulfill its purpose.

3. Thus,

   a. The law for the fish is that he swims in the sea.

   b. The law for the bird is that it flies in the heavens.

   c. The law for the tree is that it be planted in the soil.

   d. The law for man is that he eat and drink and breathe in this creation to live, that as image bearer, he love the Lord His God with all his strength and being.

4. Every violation of this law means death. This is true for man not only, but for every other creature. Take a fish out of the water and put him in the air and he will die.

5. Death means therefore that the creature no longer fulfills the purpose of its creation and must be banished by God from the midst of God's world.

C. It is in connection with God's law that a discussion of mathematics enters in.

1. Mathematics in all its forms is basically a means to define and render intelligible the various relationships between the creatures.

2. All mathematics therefore:

   a. Define and describe the characteristics of each creature.

   b. Define and describe the relation in which each creature stands toward every other.

3. The fundamental relationships between the creatures are the relationships of time and space. Although difficult to define, the following is the closest we can come.

   a. Space--The relationship between creatures characterized by distance.

   b. Time--The relationship between creatures characterized by succession of moments.

4. Our mathematical units and units of measurement are arbitrary standards adopted universally in order to define these relationships in some intelligible way. It is however, quite possible that there is inherent in the creation itself an objective standard of measurement, that the closer one comes to this standard, the more accurately one can describe the creature and his relatinnships, and the more intelligible the creation becomes.

IV. The Scientific Method.

A. The scientific method itself is a means to determine facts by the observation of and experimentation with various phenomena through the use of which are formed hypotheses, theories and finally laws.

B. This scientific method is undoubtedly a legitimate tool in the investigation of facts provided that the following limitations are admitted:

1. It can only determine formal truth concerning the creation, never transcendent truth.

2. It is not a method which must be used without bias and prejudice. This is the high sounding plea of the worldly scientist, but is is a figment of the imagination impossible both in theory or in practice. The scientific method is itself based upon various accepted truths which determine and govern its use.

3. There are truths concerning the creation which cannot be ascertained by means of this method.

C. The limitations of the scientific method.

1. There are basic presuppositions which are recorded in Scripture and which are accepted by faith. These presuppositions determine the who of scientific investigation.

2. Some examples of these presuppositions are:

a. That all creation is formed by the Word of God, upheld by this same Word and guided through that Word to its inevitable and final destination.

b. That this Word of God is principally Christ through whom all things were created and by whom all things shall be saved and restored in the coming of His kingdom.

c. That upon this creation and upon man lies the heavy hand of the curse affecting both the subject and the object of scientific investigation.

d. That upon this creation has come the flood which seriously and profoundly changed the entire world so that things do not continue as they were from the beginning of time.

e. That this creation is the scene of the drama of sin and grace enacted according to God's eternal purpose and sovereignly controlled by Him.

3. Thus the scientific method is never a tool by means of which one can explain the origin of the universe, its relation to God and its final purpose.

a. This is important to remember, for it is exactly when this is forgotten that science claims as its legitimate right and by means of the scientific method to determine the origin of things. This inevitably leads to the myriad forms of evolutionism including the so-called period theory.

b. Scripture alone can give us information concerning the origin of creation, its purpose and destination. It is not by means of the scientific method that we learn the origin of the world or the character of creation; it is only "By faith we understand that the worlds were formed by the Word of God so that things which are seen were not made from things which do appear." Hebrews 11:3.

c. Thus the "period theory" must be discarded because,

1) It is based upon the proposition that all things continue as they were from the beginning of creation until now. On the contrary, Scripture teaches us that the curse and the flood wrought changes in this creation of such magnitude that we cannot even form an adequate conception of the character of the creation prior to these catastrophes.

2) It is and must be an outright denial of the creation narrative of Genesis 1.

3) It necessarily leads to a denial of the infallible inspiration of Scripture because it relegates Scripture to a place of subordinate importance. Science is then the ultimate standard of truth, and even Scripture must be measured by the standards of science.

d. We must ever beware that we do not fall victim to the character of the times. Science is exalted to a place of utmost preeminence; the scientist is worshipped as being almost superhuman; the truth is sacrificed on the altar of science to the idol of modern technology and scientific advancement. Our schools must maintain their distinctively Reformed heritage and resist all attempts to destroy it.

V. <u>The purpose of the study of science.</u>

1. Through an investigation of the revelation of God in the things that are made the believer can come to a greater appreciation of the infinite and spledid wonders of the power and majesty of the Most High. Viewing the handiwork of His Creator, he is forced to prostrate himself before the most high majesty of God and utter in sublime wonder the eternal truth, "How great Thou art."

2. The believer must exercise his calling as king under Christ in using this creation and all its powers in the service of God. The one fundamental truth that must be impressed upon the minds and hearts of the covenant seed is the truth that God's people live to serve their Maker.

3. Because the believer knows that presently this creation shall be destroyed, that therefore the kingdom of heaven is

the only reality that shall endure beyond the cataclysm of the end of the ages, he must learn to use all things also in this world for the promotion and extension of this kingdom of Jesus Christ. This kingdom is manifested on this earth in this present age in the church. His life therefore centers in his church, and he has not begun to fulfill his calling until he has learned that all that he does in all God's world must be for the benefit of his church, for in this way he lives to the praise and honor and glory of Him who is Lord over all and who is blessed forever.

The Reformed Witness

of the Protestant Reformed Churches

Reformed Witness/Box 181/Doon, Ia. 51235

THE SCRIPTURE DOCTRINE OF CREATION: UNIFORMITARIANISM

In the last issue of "The Reformed Witness" pamphlet we considered the truth of the perspicuity of Holy Scripture and its relation to the truth of creation. By the perspicuity of Holy Scripture we mean that Scripture is basically clear and plain. The meaning of Scripture is not obscure or clouded. But the meaning of Scripture is plain and understandable to the ordinary believer. The outstanding proof of this is that Scripture is addressed by God to the ordinary believer. That God addresses the Bible to the ordinary believer and intends that the Bible be read by the ordinary believer proves the perspicuity of the Bible.

The theistic evolutionist denies the perspi-cuity of the Bible. He does this especially by his re-interpretation of Genesis 1, and the "days" of Genesis 1. By interpreting the "days" of the creation week in a way other than the plain, literal sense of the word "day", and by doing this for scientific rather than Biblical reasons, the theistic evolutionist overthrows the truth of the perspicuity of Scripture. At the same time he sets himself and his alleged scientific findings above Holy Scripture. From now on our understanding of Scripture is subject to the scientist and the scientist's discoveries. Because of its denial of the perspicuity of Holy Scripture, the Reformed believer rejects the contentions of theistic evolution.

In this issue of "The Reformed Witness" pamphlet we want to look at theistic evolution from the point of view of its dependence on the un-Scriptural principle of "uniformitarianism." One of the basic pre-suppositions of the theory of theistic evolution, as well as the atheistic brand of evolutionary thought, is the principle of uniformitarianism. So critical is the principle of uniformitarianism to the theory of evolution that, it is safe to say, if the principle of uniformitarianism be dis-proved, the whole structure of evolutionary thought falls to the ground.

Although a frightening word in appearance, the idea expressed by the word "uniformitarianism" is not difficult to grasp. Those who hold to the principle of uniformitarianism teach that the same "natural laws" and processes which are at work in the creation today have always been present in the creation and have always operated in exactly the same way. All things have remained basically the same since the beginning. The laws and processes which apply in the world today have continued unchanged from the past until the present. The idea of uniformitarianism has been expressed in the phrase, "The present is the key to the past."

The principle of uniformitarianism comes into play in connection with what is considered to be the main evidence for evolution, the fossil record. One of the strongest evidences for evolution is the fossil record and the great ages which scientists assign to many of the fossils. But in dating fossil remains, scientists presuppose uniformitarianism. Their whole method of dating is built on the presupposition of the principle of uniformitarianism.

The most common method of dating fossils is the radioactive dating method. The most common radioactive dating methods are the uranium method and the carbon-14 method. The uranium method is the basis for the presently accepted idea that the earth is about 4.5 to 5 billion years old. Without going into detail, in radioactive dating a parent substance (for example, uranium) is gradually changed into a daughter substance (for example, lead). This takes place at a fixed rate. Scientists are able to determine how quickly a given amount of radioactive uranium changes into lead. Given this rate of decay, by measuring the relative amounts of uranium and lead in a fossil scientists are able to determine when this process began, and hence, the approximate age of the fossil.

Sounds fool-proof, doesn't it. Most scientists and science teachers have thought so. For over half a century now they have contended that uranium dating in particular has proved the earth to be billions of years old.

But is this method fool-proof? The answer is: No. Apart from many inconsistencies and discrepencies in the methods themselves, there is one basic flaw to all the dating methods. What is that flaw? That flaw is the principle of uniformitarianism. That's not difficult to see. All the dating methods presuppose the principle of uniformitarianism. The uranium method presupposes that radioactive uranium has always turned into lead at exactly the same rate. The carbon-14 method presupposes that carbon-14 has always turned into nitrogen at exactly the same rate. If, for example, at some time in the past uranium decayed into lead at twice the present rate, it would be impossible, using the present rate of decay to determine the correct age of a fossil. The approximations of the scientists would be incorrect.

The theory of evolution rests heavily on the evidence of the fossil record. The dating of the fossil record depends on the principle of uniformitarianism. But is uniformitarianism correct? Have the same natural laws and processes which are at work in the creation today always been present in the creation, and have they always been present in exactly the same way?

The answer of the Bible is: No. The Bible refutes the principle of uniformitarianism. The outstanding passage of Scripture which dis-proves the principle of uniformitarianism is II Peter 3: 3-7. In this passage, the Apostle Peter predicts that in the last days unbelieving scoffers shall arise who will deny the promise concerning Christ's second coming. One of the arguments that these scoffers shall put forward to deny the possibility of Christ's return in judgment is that "... all things continue as they were from the beginning of the creation." These scoffers rest their argument that Christ is not going to come again on the principle of uniformitarianism. Nothing has changed, they say, since the beginning of the world. All things continue today as they ever have.

The Apostle denies this argument of the scoffers. He denies that all things continue the same from the beginning to the end of the world. He does that by appealing to the historical event of the Flood. "For this they willingly are ignorant of, that by the word of God the heavens were of old, and the earth standing out of the water and in the water: whereby the world that then was, being overflowed with water, perished," II Pet. 3: 5,6. The principle of uniformitarianism is dis-proved by the Flood. All things have NOT continued the same since the beginning of the world. The same laws and processes have NOT always been at work in the creation. For at one time, in His just judgment over man's sin, God sent the great catastrophe of the Flood of Noah's day. That was such a catastrophe that changed entirely the earthly creation. Such a radical change was produced by the Flood that the Apostle Peter refers to two different worlds in II Peter 3. He refers to the world before the Flood as "the world that then was", and he refers to the world after the Flood as "the heavens and the earth, which are now." They are, very really, two distinct worlds, so completely different are they.

This great difference between the world before the Flood and the world after the Flood is evident from what the Bible tells us in the Book of Genesis. We'll point to just one evidence of this great change. If you read the geneology recorded in Genesis 5, the geneology of Adam up to the Flood, and Noah's geneology through his son Shem in Genesis 11 it immediately strikes you that the relative ages of the men recorded in Genesis 11 are about half of those recorded in Genesis 5. After the Flood man's life-span was cut in half, a rather drastic change, wouldn't you say! Suddenly after the Flood men are no longer living to be 900 years old and older, but now they are living to be about 450 years old. (By the way, a similar sharp decline in man's age took place after the Tower of Babel.) From this it ought to be clear to us that conditions before the Flood were not the same as those after the Flood. The world before the Flood, and the conditions in that world, were quite different from the world as we know it today.

In the light of the clear teaching of Scripture, the principle of uniformitarianism cannot stand. And if the principle of uniformitarianism cannot stand, the scientific methods of dating the fossil record cannot stand. And if the alleged evidence of the age of the fossil record cannot stand, the main pillar of the theory of evolution falls to the ground.

It is interesting that even the fossil record itself testifies against the principle of uniformitarianism and gives evidence for the Flood. Fossils are not produced by slow uniformitarian processes. To become fossilized a plant or animal must usually have hard parts, such as bone or shell. It must then be buried quickly to prevent decay, most commonly either by volcanic activity or by watery inundation. The evidence of the fossils themselves points to the great catastrophe of the Flood.

Were the fossils and the rocks and the other characteristics of the earth's surface formed slowly over billions of years by the same processes now at work in the earth? Does the principle of uniformitarianism apply? The evolutionist says: Yes. His entire evolutionary theory depends on the principle of uniformitarianism. But the child of God, in the light of the Word of God, rejects the principle of uniformitarianism. And along with his rejection of uniformitarianism goes his rejection of the theory of evolution.

Rev. Ron Cammenga, pastor of
the Hull Protestant Reformed
Church, Hull, Iowa

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