Reactions of Common Reagents with Everyday Materials[1]

Objective: During this laboratory you will investigate the effects of strong acids, strong bases, and acetone on various materials.

Background: This lab has a two-fold purpose. You will discover the kinds of reactions that different chemicals can have on everyday materials and also see what effects milder versions of these chemicals can have on our environment. Acid rain is much more dilute an acid than the concentrated acids that you will be investigating, but the reactions are often the same, just not as quickly.

Behavior of Strong Acids

Acids are well known to be corrosive substances. The potential hazard of a given acid depends on a number of factors including the ***strength*** and the ***concentration*** of the acid. Acids are most readily defined as proton (H^+) donors or electron pair acceptors. The ease with which an acid donates a proton determines its strength. ***Strong acids*** are extremely reactive and readily lose a proton (H^+) or gain an electron pair. Common examples of strong acids that you will investigate today are nitric acid (HNO_3), sulfuric acid (H_2SO_4), and hydrochloric acid (HCl).

The vast majority of acids are ***weak*** and do not readily lose H^+ or gain electron pairs. Weak acids are commonly used in cooking. For example, vinegar is a 5% (by volume) solution of the weak acid, acetic acid ($HC_2H_3O_2$), while citric acid is the weak acid that gives the tangy taste to lemons.

Acids are usually used as solutions in water and the acid concentration is described using the term ***molarity (M)***. This description can be a bit confusing, however, because *strong* acids of the same molarity are *much more* reactive than *weak* acids of the *identical* molarity and therefore have greater corrosive effects.

Today you will be working with various concentrations of three different strong acids, hydrochloric acid, nitric acid, and sulfuric acid. Nitric and sulfuric acids are examples of oxoacids because they contain oxygen and they have the ability to act as oxidizing agents when concentrated. For this reason they are described as ***oxidizing acids***, whereas hydrochloric acid is a non-oxidizing acid. In addition, concentrated sulfuric acid can also act as a ***dehydrating agent***. This means that it has a high affinity for water and will even "grab" it out of a molecule such as sugar ($C_{12}H_{22}O_{11}$).

How to Work Safely with Acids

Because acids are corrosive to skin and clothing, it is most important that they be handled with care and kept off of the skin! ***If an acid does get on your skin or clothing, immediately flush the area with plenty of water*** and report the incident to your instructor.

Note, however, that when an acid is added to a base or to water, *the reaction will generate heat -- take precautions*. If acid spills on your lab bench, neutralize it with the sodium bicarbonate ($NaHCO_3$(s)) provided. Household baking soda is sodium bicarbonate.

Properties of Strong Bases

In a sense, bases are the opposite of acids: they are proton *acceptors* or electron pair *donors*. Strong bases do this readily and are very corrosive, while weak bases are much less reactive. Many students

---

[1] Adapted from *Chemistry in Context Laboratory Manual*, ACS, Wm. C. Brown, Dubuque, IA, 1994 and a lab produced by CURI (1995), J. Conrad, C. Hendrickson, K. Waltz, M.A. Pearsall (authors), S. Piepho (editor)

think of a base only as something that contains an OH^- group. This is not necessarily the case, however, since lithium hydride (LiH) and ammonia (NH_3) are both bases. Common ***strong bases*** include sodium hydroxide (NaOH), potassium hydroxide (KOH), and barium hydroxide ($Ba(OH)_2$); most bases are however weak. Common examples of weak bases include ammonia (NH_3), which is the base present in dilute solution in household ammonia, and sodium bicarbonate ($NaHCO_3$, baking soda).

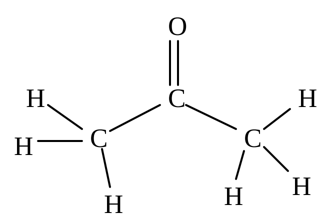
Like acids, the concentration of a base is measured in molarity (M) or, less often, in weight/weight percentage (% w/w). Once again a strong base of a given molarity is much more reactive than a weak base of the same molarity.

Precautions in Handling Bases

In this experiment you will investigate the effect of various concentrations of the strong base sodium hydroxide (NaOH) also known as lye (an active ingredient in Draino™). Because bases are corrosive to clothing and the skin, take the same precautions with them as you would with acids: ***Handle them with care and keep them off your skin!*** If you splatter a base on your skin or clothing, flush the area with lots of water and report the incident to your instructor. Furthermore, the addition of a base to an acid or to water generates heat - take precautions. If a base spills on your lab bench, neutralize it with dilute acetic acid solution.

Acetone: An Excellent Solvent

Acetone is a familiar sight in most organic chemistry laboratories. It has the structure shown below, and is *neither* an acid *nor* a base. It is highly flammable and must be kept away from heat and open flames. In addition, if it comes in contact with plastic or synthetic fabrics, it may damage or destroy them. Finally, when using acetone to clean glassware, do not breathe in more of the vapors than is necessary. This does not mean you should not breathe while cleaning your beakers - just don't gulp air like a fish out of water!



Acetone - $(CH_3)_2CO$

Oxidizing and Reducing Agents

Strong oxidizing agents and strong reducing agents are also chemicals that warrant respect. An ***oxidizing agent*** is a substance that oxidizes something else; it is itself reduced. Likewise a ***reducing agent*** reduces something else; it is itself oxidized in the reaction. Reactions involving oxidation and reduction are termed ***oxidation-reduction (redox)*** reactions. You will be learning more about what these terms mean in terms of electron transfer next week. In this laboratory we will experiment with household bleach (Clorox™), which is a potent oxidizing agent; household bleach is a dilute solution of sodium hypochlorite, NaOCl. As mentioned above, nitric acid and sulfuric acid are *oxidizing acids*; thus part of their reactivity is due to their ability to oxidize other substances.

Procedure:

Hair

Hair is made up of melanin, a pigment, and proteins that are linked by hydrogen bonds and sulfur bridges. This investigation will test the ability of a strong base, a strong acid, and a strong oxidizing agent (Clorox™) to react with the proteins in hair.

1. Obtain four small piles of hair of the same type and place them on separate large (4 inch) watch glasses. Describe the type of hair used here.
2. To each of the hair samples add a sufficient quantity of one of the reagents below so that some of the hair is immersed in the reagent. Allow the hair to react during the duration of your lab.
3. Record your observations towards the end of your laboratory period. Describe any color or structural changes in the hair.
   (a) tap water (the *control*)
   (b) 6 M NaOH (dilute)
   (c) 16 M HNO_3 (concentrated)
   (d) Clorox™ (5.25% NaOCl)

Reactions with Clothing

1. Obtain a piece of each kind of clothing (cotton, polyester, nylon) and place them on separate large (4 inch) watch glasses.
2. To each of the clothing samples add a couple drops of each of the reagents below onto different parts of the cloth.
   (a) 12 M HCl (concentrated)
   (b) 18 M H_2SO_4 (concentrated)
   (c) 12.5 M NaOH (concentrated)
   (d) Clorox™ (strong oxidizing agent)

If no change is evident after 5 minutes, try poking the area with a stirring rod. If there is still no change, rinse the fabric with tap water and dry with a hair dryer. Then poke the area again with a stirring rod: now are there any changes?

Polystyrene and Acetone

Polystyrene, also known as styrofoam, is used in molded and plastic items as an insulator (it keeps your coffee and fast food hot). In this portion of the lab, you will examine what happens when polystyrene *peanuts* and acetone come together; these *peanuts* are commonly used as packing material when shipping delicate items.

An environmental concern is that polystyrene is non-biodegradable. Recently "environmentally friendly" peanuts have been developed which are made of starch. In this experiment you will test both forms of packing material.

1. Fill a beaker with styrofoam shipping "peanuts" and dribble acetone over them. Remove the liquid "product" and place it on a watch glass to dry. Test the styrofoam peanuts in the same way with water.
2. Repeat the experiment with the starch peanuts (if available). Record your observations and summarize the differences in reactivity of the two types of packing material.

Biological Materials

1. *Sugar*. Table sugar (sucrose) is a simple carbohydrate with the molecular formula, $C_{12}H_{22}O_{11}$. Transfer a small amount of sugar (about a half-teaspoon) to the bottom of a 100 mL beaker. ***Carefully*** place **ONE drop** of concentrated (18 M) H_2SO_4 on the sugar.

2. *Egg White*. Egg white (egg albumin) is mostly protein and so can serve as a model for your skin. Place a small blob of egg white on a watch glass and investigate the effect of 6 M HNO_3 (nitric acid) on the egg white. Repeat the experiment using 6 M NaOH (sodium hydroxide) in place of the nitric acid. Repeat again using Clorox™ as the reagent to be tested on the egg white.
3. *Skin*. Dip your fingers into the very dilute (0.01 M) sodium hydroxide solution provided by the instructor. Rub your fingers together and report how it feels. Rinse your hands immediately with plenty of cold water.

Marble

1. To small marble chips add the following while noting differences in reactions and rates of reaction.
    (a) 6 M HCl (dilute)
    (b) 6 M H_2SO_4 (dilute)
    (c) 6 M HNO_3 (dilute)
    (d) 0.6 M H_2SO_4 (very dilute)

Metals

1. To small strips of zinc and copper, a paper clip (chromium plated iron or steel), and a piece of aluminum foil in the shape of a small cup to hold a small amount of liquid and add the following while noting differences in reactions and rates of reaction.
    (a) 6 M HCl (dilute)
    (b) 6 M H_2SO_4 (dilute)
    (c) 0.6 M H_2SO_4 (very dilute)
    (d) 6 M NaOH (dilute)

   Observe continually (wearing safety glasses!) until a definite reaction has occurred. ***Beware:*** you may not initially observe a reaction. *Do not lean over the container or remove your safety glasses! Be patient!!*
2. In the hood, place all of the above metals in 6 M HNO_3 (dilute). **Caution: Do not put your face close to the wellplate because a poisonous gas may be produced. Do not remove your wellplate from the hood until the evolution of gas has stopped.**

Disposal & Clean Up

When your work is complete empty the contents of your wellplate into the container provided. If there are any pieces of marble or metal remaining in your wellplate, try not to let them go down the drain as you rinse your wellplate several times with water. The resulting solution will be neutralized and discarded.

Write Up

Complete the write up sheet posted at the web page.

Questions:

1) Compare the results of the various compounds tested on hair with the control (tap water). Were any of the compounds *not* harmful to hair? If so, which one(s)?
2. Which material reacted the most with:
   (a) 12.5 M sodium hydroxide?
   (b) 18 M (concentrated) sulfuric acid?
3. Is the polyester or the cotton being disintegrated in the polyester/cotton material when the 18 M H_2SO_4 is added? What observations and evidence can you use to support your answer?
4. Is sodium hydroxide more reactive with natural (cotton) or synthetic (nylon, polyester) materials? Give evidence to back up your answer.

5. Which of the fabrics you tested would you recommend as a suitable material for a lab coat? Explain your reasoning?
6. Based on the behavior of nylons with acids and bases, would you say that nylon is an *acidic* or *basic* material? Explain your reasoning.
7. You undoubtedly noticed the volume loss when the styrofoam "peanuts" reacted with acetone. If the lost substance was air (and the remaining substance pure polystyrene), what purpose does the air have in the styrofoam "peanuts"?
8. If the concentrated sulfuric acid is extracting water molecules from the sucrose ($C_{12}H_{22}O_{11}$), what is the black product obtained?
9. The formula for marble is $CaCO_3$. What gas was most likely evolved? And how do you explain its' reaction with sulfuric acid?
10. Both bits of aluminum metal and NaOH(s) are constituents of solid Draino™, a common drain-cleaning product. Based on your observations in this lab, why do you think the aluminum is included as a component of Draino™?
11. What problems would you anticipate if your bathroom sink had aluminum plumbing?
12. On the basis of your observations, comment on the effectiveness of zinc coatings (galvanized metal) and chromium coatings (old automobile bumpers) as a protection against acid rain. What do these coatings protect iron against?