Water, pH, and solubility

(Based on a Lab by Jim Adams, Las Positas College)

In this laboratory exercise you will demonstrate several of the unusual properties of water. In addition to this handout, you will need your textbook and your lecture outlines on water for this exercise.

Everyone in your group must wear safety goggles and gloves whenever this handout instructs you to.

A) Hydrogen bonds and the polarity of water molecules

To fully understand today's exercises, you will need to understand the polarity of water molecules and hydrogen bonding. Read the section 3.1 in your textbook. Figure 3.2 on page 48 is a great illustration of the way water molecules stick to each other through hydrogen bonding. When you are done, answer the study questions 1 and 2 below:

1) Draw a water molecule in the space to the right.
Include in your drawing any partial charges on the atoms.

2) Molecules such as water that have partially positive end and a partially negative end are called _________ molecules.

B) Surface tension demonstration

The hydrogen bonding between water molecules causes water to have many interesting properties. One such property is called surface tension. Try the following experiment to demonstrate surface tension:

a) Fill a small bowl about half full of water.

b) Obtain a razor blade and drop it into the bowl. Since the razor is made of steel, which is heavier than water, it shouldn't be too surprising that the razor sinks to the bottom of the bowl.

c) Remove the razor from the water and wait for the water's surface to become still. Then hold the razor flat over the water and lower it until it is very close to the surface of the water. Then carefully drop it onto the surface of the water. With a little luck, the razor will float on the surface of the water, although you may have to try a few times to make it float.

To understand why the razor floats, read about surface tension in chapter 2 of the textbook (page 52, and figure 2-16 on page 53), then answer study questions 3 – 4.

3) Describe the surface of water in terms of molecules and hydrogen bonds:

4) What property of water molecules allows them to have surface tension?

c) Hydrophilic and hydrophobic substances

In your printed lecture notes on water, read the sections on hydrophilic substances, hydrophobic substances, and how to predict if a substance is hydrophilic or hydrophobic from the structure of its molecules. Then test your understanding by turning to the last page of this handout. Next to each of the five molecules, write whether it is hydrophilic or hydrophobic. When you have done this, do the following experiment:

a) Obtain a glass microscope slide. At the sink, get some detergent and thoroughly clean and scrub it. After the slide has been cleaned, handle it only by the edges (to avoid getting oil from your hands on its surface).
b) Get a paper towel and dry the slide.
c) Get a tiny dab of Vasoline on one finger. Smear a thin coat of it over half the slide.
d) Put one drop of water on the Vasoline side of the slide and one drop of water on the non-Vasoline side. In the space below, describe the differences in the way the water drops behave when they contact the Vasoline and the glass.

e) Clean up: When done, re-wash the slide with detergent until all the Vasoline has been removed. Put the slide back where you obtained it.

Answer study questions 5–7 below:
5) Based on your description above, glass appears to be a Hydrophobic/Hydrophilic (circle one) substance, and Vasoline appears to be a Hydrophobic/Hydrophilic (circle one) substance.

6) To explain the differences you observed, you must consider the molecules involved. Glass is made from Silicon Dioxide molecules, while Vasoline is made of hydrocarbon molecules:

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                     H H H H H H H H H H H H
                     | | | | | | | | | | | |
   O–Si–O          H–C–C–C–C–C–C–C–C–C–C–C–C–H
                     | | | | | | | | | | | |
                     H H H H H H H H H H H H

Silicon Dioxide            Hydrocarbon
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Explain what it is about the structure of the glass molecule that would make you predict it would attract water molecules:

Explain what it is about the structure of the hydrocarbon molecule that would make you predict Vasoline would repel water molecules:

7) If you haven't cleaned your stove top for a while, you may notice that drops of spilled water "bead up" on the surface around the stove. Explain why this is so:

d) Demonstration of solubility (the ability to be dissolved)

In your water lecture outline, read about what "dissolve" means. Recall from your previous reading that any substance that dissolves in water is hydrophilic, but hydrophobic substances do not dissolve in water. Inspect the last page of this handout then predict whether each of the following molecules will dissolve in water:

Molecule	Do you predict it will dissolve in water (yes/no)?
Copper sulfate	____________
Sugar	____________
Citric acid	____________
Moth flakes (Napthalene)	____________

Now its time to test your predictions! Get a test tube rack, four clean dry test tubes, and a china marker (wax pencil) from the front counter. At this point, everyone in your group must put on gloves.

a) Using the china marker, write Copper Sulfate on one test tube, Sugar on the next test tube, Citric Acid on the next, and Moth Flakes on the last test tube.

b) Everyone in your group must now put on gloves and goggles.

c) Add only a **rice grain** sized piece of the appropriate chemical to each test tube. In other words, add a rice grain of copper sulfate to the first test tube, add a rice grain of sugar to the second test tube, etc., etc. Adding more than a rice grain size piece can give you incorrect results. <u>**Show your instructor your tubes before continuing.**</u>

d) Add de-ionized water (ultra-pure water) to each tube until it is about one-quarter full.

e) Jiggle each test tube vigorously for one full minute without stopping to give each substance a chance to dissolve.

f) Inspect the test tubes to see which substances have dissolved.

g) Record your results in the table below, in the "Solubility in Water column (for now, don't write anything in the "Solubility in Hexane" column). Write Dissolved in the blank if all or most of the substance dissolved in water. Write Did Not Dissolve if all or most of the substance did not dissolve in water.

Substance:	Solubility in Water	Solubility in Hexane
Copper Sulfate	__________	__________
Sugar	__________	__________
Citric Acid	__________	__________
Moth flakes	__________	__________

h) **Clean up:** When done, put the caps back on the test tubes and place them in the fume hood. Do not dump anything down the drain.

e) Demonstration of solubility in hexane

In the last experiment, you showed that water (a hydrophilic solvent) dissolves hydrophilic substances. This is sometimes called the *Like Dissolves Like* principle. The same principle applies to hydrophobic solvents. In other words, hydrophobic solvents dissolve hydrophobic substances.

You now will demonstrate this principle by repeating the previous experiment except you will use the hydrophobic solvent Hexane instead of the hydrophilic solvent water. First of all, re-inspect the molecules on the last page of this handout and (using the like dissolves like principle) predict which ones will dissolve in hexane.

Molecule	Do you predict it will dissolve in hexane (yes/no)?
Copper sulfate	____________
Sugar	____________
Citric acid	____________
Moth flakes/Napthalene	____________

Next, get four test tubes containing hexane from the counter and repeat steps a-g in the previous experiment, except that hexane is the solvent instead of water in step d. Record your results in the table above. **Show your instructor your results before continuing.**

Clean up: When done, put the caps back on the test tubes and place them in the fume hood. Do not dump anything down the drain.
Next, answer study questions 8 and 9 below:

8) When a liquid is able to surround the molecules of a solid and cause the solid's molecules to spread out in the liquid, the liquid is said to have the ability to_____ the solid. The ability of a solid to be dissolved by a liquid is called its _______.

9) The best solvents for polar molecules are polar/non-polar (circle one) liquids. The best solvents for non-polar molecules are polar/non-polar (circle one) liquids.

10) You results probably showed that moth flakes dissolved poorly in water but well in hexane. This is because moth flakes and hexane are both ______ molecules.

F) Acids, bases, and the pH scale

To understand the next exercises, you will need to understand acids, bases, and the pH scale. These concepts are explained in your water lecture outlines and your textbook. When you have read and understood these subjects, answer review questions 11–15 below.

11) Some people say acids are the opposite of bases. They say this because acids are defined as molecules that *release* _____ ion and bases are defined as molecules that *absorb* ______ ion.

12) Do you think acids and bases would undergo a chemical reaction when mixed together? Why or why not? If you are not sure, review the definition of chemical reaction in your lecture notes.

13) The scale for measuring the strength of acids or bases in a solution is the ________ scale.

14) A solution that is pH 10 is acidic/neutral/basic (circle one)
A solution that is pH 7.5 is acidic/neutral/basic (circle one)
A solution that is pH 7 is acidic/neutral/basic (circle one)
A solution that is pH 1 is acidic/neutral/basic (circle one)

15) A substance that, when added to solution, stabilizes the pH of that solution is called a _______________.

G) Measuring pH

In the following experiment, you will test the pH of some common household substances.

a) Obtain a pH test strip (a small piece of special paper that is used to determine the pH of liquids).

b) Dip the paper into the milk, then hold the pH paper against the color scale on the side of the pH paper container. By matching the color of the paper to the colors on the scale, determine the pH of the milk. Record the pH on the table below.

c) Repeat steps (a) and (b) on the other liquids on the countertop. Record the name of each substance and its pH in the table below. Also fill in the last column of the table.

Substance:	pH:	More or less H^+ ions than water?
Milk	_____	_____________
_____________	_____	_____________
_____________	_____	_____________
_____________	_____	_____________
_____________	_____	_____________
_____________	_____	_____________

H) Buffers

Adding a strong acid or a strong base to a solution can quickly change that solution's pH. For example, adding just a few drops of HCl (a strong acid) to pure water will change the water's pH from 7 to 2!

Living things cannot survive if their body fluids change in pH greatly. For example, your blood's pH is around 7.4, but if it changed to pH 7.0 you would probably not live. To keep our blood's pH steady, our body makes substances called buffers. A buffer is any substance that stabilizes the pH of a solution. In other words, buffers make solutions resistant to pH change.

Interestingly, the buffer in our blood is the same buffer found in Alka-Seltzer tablets. This buffer has two chemicals in it, carbonic acid and bicarbonate ion.

H_2CO_3	HCO_3^-
Carbonic acid	Bicarbonate ion

How does this buffer work? If a strong acid is added to a buffered solution, the bicarbonate ions absorb most of the H^+ ions released by the acid.

$$HCO_3^- + H^+ \rightarrow H_2CO_3$$

Because the excess H^+ is absorbed, the pH of the solution changes very little.

If a strong base is added to the solution, the base absorbs many of the solution's H^+. This would normally change the solution's pH. However, the carbonic acid in the buffer releases hydrogen ions to replace the H^+ destroyed by the base:

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

In summary, the buffer in our blood (and in Alka-Seltzer tablets) makes solutions resistant to both acids and bases. In this experiment, you will use Alka-Seltzer tablets to demonstrate buffering of solutions.

a) Obtain two 80 ml beakers and a china marker (wax pencil) from the front counter. On one beaker write "Unbuffered Water." On the other beaker write "Buffered Water."

b) Add 50 ml of deionized water to each beaker.

c) Add 10 drops of Universal Indicator to each beaker. An Indicator is a substance that changes to different colors at different pH's. In other words, if two solutions are the same color, they are roughly the same pH.

d) Add about 1/4 of an Alka-Seltzer tablet to the Buffered Water beaker. Wait until the tablet stops fizzing. The solution in this beaker is now buffered.

e) Using pH paper, determine the pH of both solutions. Fill in the first two rows of the table below:

	Unbuffered water	Buffered water
Color before addition of acid:	________	________
pH before addition of acid:	________	________
Number of drops of acid added:	________	________
Color after addition of acid:	________	________
pH after addition of acid:	________	________

f) Obtain a dropper bottle containing 3M hydrochloric acid (HCl). Be careful. HCl is a strong acid.

g) Add three drops of the HCl to your "Unbuffered Water" beaker. Stir it gently with a stirring stick. Determine its pH with pH paper. Fill in the rest of the first column of the table above.

h) Now you will add HCl, one drop at a time and stirring with a clean stirring stick, to the Buffered Water beaker. Count the number of drops of HCl it takes to make this solution the exact same color as the Unbuffered solution. (It should be much more than three drops, because this solution is buffered). When its color is the same as the Unbuffered solution, determine its pH using pH paper. Fill in the rest of the second column in the table above. **Show your instructor your table before continuing.**

i) **Clean up:** All solutions can go down the drain. Wash the beakers and stirring rods with water in the sink.

Your experiment should have shown that the buffered water was much more resistant to the acid than the unbuffered water. Will the buffer also protect the solution from strong bases?

Repeat steps a-i, except use 3 M Sodium Hydroxide (a strong base) instead of 3M HCl, starting in step f. Record all data on the table below:

	Unbuffered water	Buffered water
Color before addition of base:	________	________
pH before addition of base:	________	________
Number of drops of base added:	________	________
Color after addition of base:	________	________
pH after addition of base:	________	________

Show your instructor your tables before continuing.

Cleaning up: The solutions can go down the drain. Wash the beakers and the stirring rods with water in the sink then dry them and return them to where you obtained them.

Answer the following review questions about buffers. (You may need to review the buffers explanation at the beginning of this section).

16) What molecule in the buffer resisted pH change from the acid? In other words, what molecule in the buffer prevented the drops of HCl from changing the pH rapidly?________

17) Write the chemical equation showing how this molecule makes the solution resistant to acids:

18) What molecule in the buffer resisted pH change from the base?_______

19) Write the chemical equation showing how this molecule makes the solution resistant to bases:

20) Judging from the number of drops you added, is the buffer better at resisting acids or bases? ________________________

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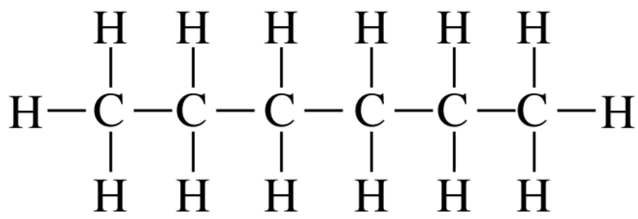
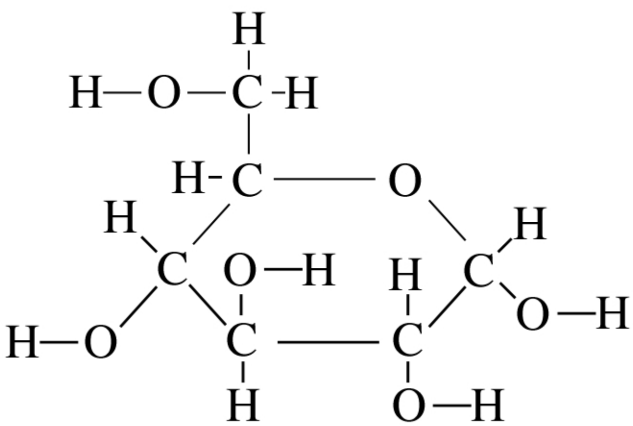
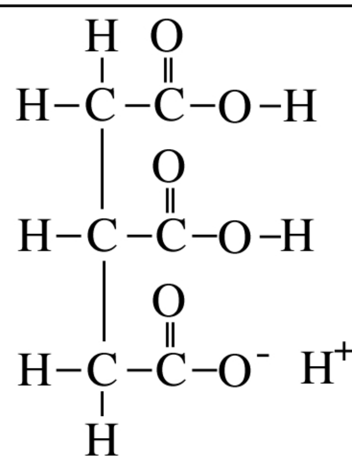
Molecules of today's laboratory:



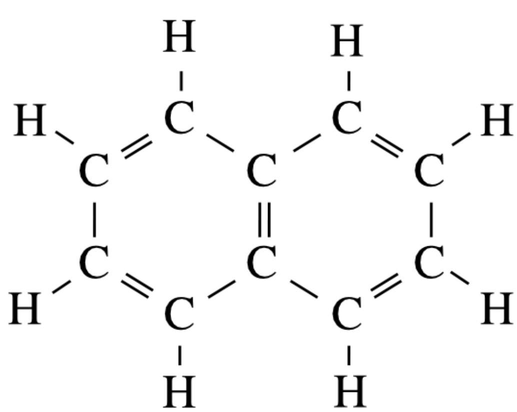
Hexane



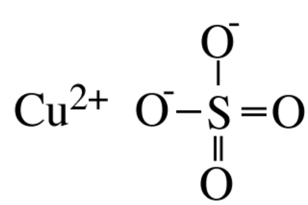
Glucose (Sugar)



Citric acid



Naphthalene (Moth flakes)



Copper sulfate