

## 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 2.2 in your textbook. Figure 2.14 on page 44 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. Surface tension means that water has more hydrogen bonds at the surface of the water than below the surface. As a consequence of the surface tension, objects that are denser than water can sometimes float on its surface.

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.

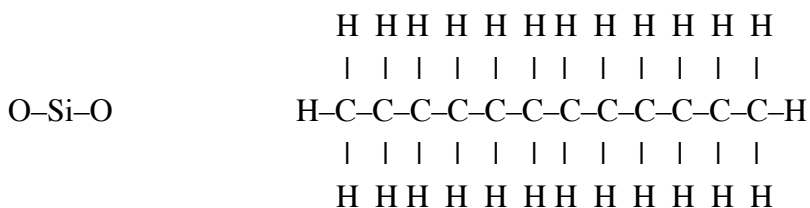
### c) Hydrophilic and hydrophobic substances

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 Vaseline on one finger. Smear a thin coat of it over half the slide.
- d) Put one drop of water on the Vaseline side of the slide and one drop of water on the non-Vaseline side. In the space below, describe the differences in the way the water drops behave when they contact the Vaseline and the glass.
- e) **Clean up:** When done, re-wash the slide with detergent until all the Vaseline 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 Vaseline 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 Vaseline is made of hydrocarbon molecules:



Silicon Dioxide

Hydrocarbon

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 Vaseline would repel water molecules:

**d) Demonstration of solubility (the ability to be dissolved) in water**

*Do this activity only if you are in one of the Right-side groups of the lab. If you are a Left-side lab group, do activity (e) instead. But both groups should give their data to the instructor when the activity is finished.*

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:

<u>Molecule</u>	<u>Do you predict it will dissolve in water (yes/no)?</u>
Copper sulfate	_____
Sugar	_____
Citric acid	_____
Moth flakes (Naphthalene)	_____

Now its time to test your predictions! Get a test tube rack containing four glass test tubes that contain water. At this point, a member of your group that will handle the chemicals must put on gloves and safety goggles.

- a) Using a 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) In your lab kit, locate small plastic test tubes containing four different chemical powders.
- 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.
- d) Put the caps on all test tubes.
- 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 left column of 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.

<u>Substance:</u>	<u>Solubility in Water</u>	<u>Solubility in Hexane</u>
Copper Sulfate	_____	_____
Sugar	_____	_____
Citric Acid	_____	_____
Moth flakes	_____	_____

*When you have entered your results in the water column in the above table, show your results to your instructor. Your instructor will then give you the results for the solubility in hexane column (based on other groups results). Copy those hexane results into the above results table.*

Next, answer study questions 8- 10 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) Your results probably showed that moth flakes dissolved poorly in water but well in hexane. This is because moth flakes and hexane are both \_\_\_\_\_ molecules.

h) **Clean up:** When done, put the copper sulfate tube into the copper sulfate rack in the fume hood. You can dump the solutions in the other three tubes down the sink. Then put those three empty tubes into a rack on the back of the room.

### **e) Demonstration of solubility (the ability to be dissolved) in hexane**

*Do this activity only if you are in one of the Left-side groups of the lab. If you are a Right-side lab group, do activity (d) instead. But both groups should give their data to the instructor when the activity is finished.*

In activity (d) it was demonstrated 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 will demonstrate this principle by trying to dissolve various substances using the hydrophobic solvent Hexane instead of the hydrophilic solvent water. Inspect the last page of this handout then predict whether each of the following molecules will dissolve in hexane:

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

Now its time to test your predictions! At this point, a member of your group that will handle the chemicals must put on gloves and safety goggles. Go to the fume hood and find the rack with test tubes containing hexane.

- a) Working in the fume hood, pick up four test tubes containing hexane. Using a 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) 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.
- c) Jiggle each test tube vigorously for one full minute without stopping to give each substance a chance to dissolve.

d) Inspect the test tubes to see which substances have dissolved. Record your results in the right column of the table below, in the “Solubility in Hexane” column (for now, don’t write anything in the “Solubility in Water” column). Write Dissolved in the blank if all or most of the substance dissolved in hexane. Write Did Not Dissolve if all or most of the substance did not dissolve in hexane.

<u>Substance:</u>	<u>Solubility in Water</u>	<u>Solubility in Hexane</u>
Copper Sulfate	_____	_____
Sugar	_____	_____
Citric Acid	_____	_____
Moth flakes	_____	_____

*When you have entered your results in the hexane column in the above table, show your results to your instructor. Your instructor will then give you the results for the solubility in water column (based on other groups' results). Copy those water results into the above results table.*

**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- 10 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) Your 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 (pages 46-48). 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.

<u>Substance:</u>	<u>pH:</u>	<u>More or less H<sup>+</sup> ions than water?</u>
<u>Milk</u>	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

### H) Buffer concepts

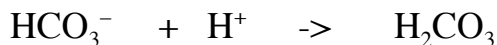
Adding a strong acid or a strong base to a solution can quickly change that solution's pH. For example, adding just a few drops of HCl (a strong acid) to pure water will change the water's pH from 7 to 2!

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.



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



Because the excess H<sup>+</sup> 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<sup>+</sup>. This would normally change the solution's pH. However, the carbonic acid in the buffer releases hydrogen ions to replace the H<sup>+</sup> destroyed by the base:



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.

### **I) Buffering against acids**

*Do this activity only if you are in one of the Right-side groups of the lab. If you are a Left-side lab group, do activity (J) instead. But both groups should give their data to the instructor when the activity is finished.*

- 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.

Fill in the first row of the results table below, based on the current colors of the solutions.

- e) Using the color of the solutions, determine the pH of both solutions.

Fill in the second row of the results table below, based on the current pHs of the solutions.

#### Buffering against acids results table:

	Unbuffered <u>water</u>	Buffered <u>water</u>
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 the solution’s pH with pH paper.

Fill in the drops of acid, color, and pH blanks in the Unbuffered column of the results table.

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 drops of acid, color, and pH blanks in the buffered column of the results table.

**Show your instructor your table before continuing.**

*When you have entered all your results in the table on the previous page, show your results to your instructor. Your instructor will then give you the results for the buffering against bases experiment (based on other groups' results). Copy those results for buffering against bases into the buffering against bases results table below.*

Buffering against bases results table:

	Unbuffered <u>water</u>	Buffered <u>water</u>
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:	_____	_____

i) **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.

## J) Buffering against bases

*Do this activity only if you are in one of the Left-side groups of the lab. If you are a Right-side lab group, do activity (I) instead. But both groups should give their data to the instructor when the activity is finished.*

- 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.

Fill in the first row of the results table below, based on the current colors of the solutions.

- e) Using the color of the solutions, determine the pH of both solutions.

Fill in the second row of the results table below, based on the current pHs of the solutions.

### Buffering against bases results table:

	Unbuffered <u>water</u>	Buffered <u>water</u>
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.**

- f) Obtain a dropper bottle containing sodium hydroxide (NaOH) Be careful. NaOH is a strong base.

g) Add three drops of the NaOH to your “Unbuffered Water” beaker. Stir it gently with a stirring stick. Determine its pH with pH paper.

Fill in the drops of base, color, and pH blanks in the Unbuffered column of the results table.

h) Now you will add NaOH, one drop at a time and stirring with a clean stirring stick, to the Buffered Water beaker. Count the number of drops of NaOH 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 drops of base, color, and pH blanks in the buffered column of the results table.

**Show your instructor your table before continuing.**

*When you have entered all your results in the table on the previous page, show your results to your instructor. Your instructor will then give you the results for the buffering against acids experiment (based on other groups' results). Copy those results for buffering against acids into the buffering against acids results table below.*

Buffering against acids results table:

	Unbuffered <u>water</u>	Buffered <u>water</u>
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:	_____	_____

i) **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.

### K) Buffer study questions

The answers to all of these questions are molecules and reactions found in the Buffer Concepts section (section H) of this handout.

16) Acids change the pH of a solution by adding  $H^+$  to the solution. What molecule in the buffer resisted pH change from the acid? In other words, what molecule in the buffer absorbed  $H^+$  to prevent the HCl acid from changing the pH by adding  $H^+$ ?

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

18) Bases change the pH of a solution by removing  $H^+$  from the solution. What molecule in the buffer resisted pH change from the base? In other words, what molecule in the buffer added  $H^+$  to prevent the NaOH base from changing the pH by removing  $H^+$ ?

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? \_\_\_\_\_

## Molecules of today's laboratory:

