

A PRIMER ON pH

A Presentation for ASTA Conference
September 30-October 1, 2008

Rebecca Richardson
Director
Regional In-Service Education Center
University of Montevallo
2790 Pelham Parkway
Pelham, AL 35124
205-503-5870
richardr@montevallo.edu

Martha Gothard
Science Specialist
AMSTI
University of Montevallo
2790 Pelham Parkway
Pelham, AL 35124
205-503-5870
gothardmc@montevallo.edu

Atomic Structure of Hydrogen:

1 proton in nucleus + 1 electron in first energy level (closest one to the nucleus)

What is left if a hydrogen atom loses its electron?

H⁺ ion
(hydrogen ion)

H₃O⁺ ion
(hydronium ion)

proton
(proton)

(three different names or representations for the same thing)

Molecular Structure of Water:

H₂O

H-OH

Autoionization of Water:



This is what water does ALWAYS naturally. The molecules are in constant motion and they are constantly ionizing, then recombining into molecules, then ionizing again. It's an ongoing occurrence. At any given time, at room temperature, the concentration of BOTH H₃O⁺ and OH⁻ are approximately 0.000 000 1 moles/liter (or 1 x 10⁻⁷ M). If water is all that is present, then the amount of H₃O⁺ and OH⁻ are always the same.

What if we add something that upsets the balance of these ions in aqueous (water) solution? Acids increase the concentration of H⁺ in the solution. Bases increase the concentration of OH⁻ in the solution. Since these 2 ions are in **equilibrium** in aqueous solution, adding one or the other upsets the equilibrium. Think of it as a see-saw effect – as one goes up, the other has to go down and vice versa.

So what is pH and what does it have to do with all of this?

The small letter “p” is actually a mathematical term. It literally means “negative logarithm of” (or “negative log of”) whatever comes after it. pH then literally means “negative log of H concentration”. In this case the H is literally the H⁺ ion that is present in aqueous solutions of all kinds (but is especially important to us in acidic or basic solutions).

Earlier we said that the concentration of H_3O^+ and OH^- are always 0.000 000 1 or 1×10^{-7} M in water at room temperature. **The logarithm of a number is the power to which you would raise the number 10 to get the value of the number.**

WHAT???? Don't throw your hands up in despair. This is actually really easy. Let's look at it step by step. Understanding this actually will help to clear up any misconceptions concerning pH.

If "p" H really means the "negative log of" the H^+ ion concentration, then

In water, the concentration of H^+ is 0.000 000 1 M, so

What power do you have to raise 10 to to get the value of 0.000 000 1???
(i.e. What is the logarithm (or log) of 0.000 000 1?)

$$0.000\ 000\ 1 = 10^{-7}$$

We would have to raise 10 to the -7 power to get a value of 0.000 000 1.
Therefore the log of 0.000 000 1 is -7.
If "p" means the negative log of – then we would have to take the negative of -7.

Everyone knows that a negative of a negative is a positive, therefore
 $-(-7) = 7$

This is how it is determined that the pH of water is equal to 7. Since water has EQUAL amounts of H^+ and OH^- , then it is considered to be **neutral**, therefore a pH of 7 is considered to be neutral.

What if we added a whole bunch of something to the water so that the H^+ ion concentration increased dramatically? What if the H^+ concentration went from

0.000 000 1 M to 0.01 M

Which amount is larger? 0.000 000 1
or 0.01

How would we find the pH of a solution with H^+ concentration of 0.01 M?

What power do you have to raise 10 to to get the value of 0.01???
(i.e. What is the logarithm (or log) of 0.01?)

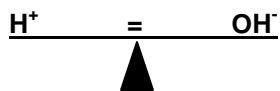
$$0.01 = 10^{-2}$$

We would have to raise 10 to the -2 power to get a value of 0.01.
Therefore the log of 0.01 is -2.
If "p" means the negative log of – then we would have to take the negative of -2.

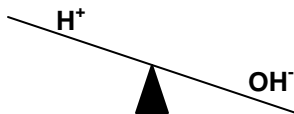
Everyone knows that a negative of a negative is a positive, therefore
 $-(-2) = 2$

As you can see, this presents a very interesting phenomenon (and a source of great dismay among students trying to understand pH). As the H^+ concentration **increases** the value of the pH actually **decreases**. (They did it that way JUST to confuse us, didn't they??? Well, let's don't allow them to confuse us. We are too smart for them.)

Remember that see-saw effect that I mentioned earlier? Since H^+ and OH^- are BOTH present in equilibrium in aqueous solutions as one GOES UP, the other GOES DOWN and vice versa.



in water they are equal
(the see-saw is balanced)

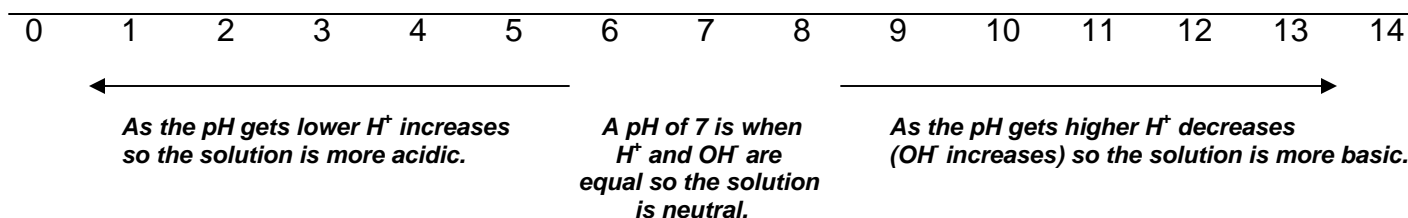


an acid solution has more H^+
so it HAS to have less OH^-



a base solution has more OH^-
So it HAS to have less H^+

Now the pH Scale should make a little more sense to us.



How do we measure pH?

The best way to measure pH is to use a piece of electronic equipment known as a **pH meter**. By inserting a probe into a solution, the electrical conductivity of the solution is measured and converted to a pH value. This method is not interfered with when the solution is not clear but has a color to it or is opaque.

The Alabama Science Assessment seems to want your students to know more about indicators than about pH meters (that will come in higher grades I suppose). **Indicators** are very interesting substances! They are very complex molecules (usually biochemical macromolecules) that change characteristic colors when in the presence of H^+ or OH^- ions. This color change “indicates” to us that an acid or a base is present and that is how they work. Many indicators are present naturally in flowers, fruits and vegetables and are responsible for their characteristic colors. (We are going to use some indicators extracted from some flowers and fruits in our workshop today.)

As you observe the demonstration, record your observations in the Data Table below.

DATA TABLE:

<i>Indicator Used</i>	<i>Acid</i>	<i>Neutral</i>	<i>Base</i>	<i>What type of indicator is this?</i>
Phenolphthalein				
Methyl Red				
Neutral Red				

Indicators can be categorized as being **acid indicators, base indicators, or universal indicators**. Based on your observations, predict the type of indicator that you just observed.

Acid Indicators – turn a characteristic color in the presence of H^+ ions to INDICATE an acid
Base Indicators – turn a characteristic color in the presence of OH^- ions to INDICATE a base
Universal Indicators – turn various colors depending on the concentration of H^+ or OH^- ions
(They can INDICATE not only the presence of an acid or base, they can also give an INDICATION of HOW acidic or HOW basic a solution is.)

In order to use indicators properly, we need to use some type of **standard** to measure against. To measure length we use a ruler to measure against. What makes the ruler a “standard”? It can be used as a standard because we KNOW the length of it. That makes it a standard.

We must have KNOWN acids, bases, and neutral substances to test our indicators with before using the indicators to test any type of “unknown” substance – just so that we are sure that we know exactly how the indicator is going to react in an acidic or basic environment. You need to be careful in selecting substances to use as standards (as well as selecting things to use as unknowns) in your classroom. Some things are too dangerous to bring in for use by students. A good substance to use as an acid standard is **vinegar**. Vinegar is a 5% solution of acetic acid. (This is a **dilute** solution of a **weak** acid.) A good solution to use as a base standard is a **saturated solution of baking soda**. To achieve a saturated solution, add as much soda to **distilled water** as you can get to dissolve. When you have reached the point where soda is staying on the bottom, let the solution stand and settle for a while and then carefully pour off the top part of the solution leaving the left over soda in the bottom of your original container. Of course the neutral substance must be water and ONLY **distilled or deionized water will work**.

(SPECIAL NOTE: Anytime you are making up solutions (standards or indicators) for acid/base testing, you MUST use distilled or deionized water – NOT TAP WATER. Tap water contains many ions that may interfere with acid/base testing.)

Litmus Paper – another type of Indicator

Litmus paper comes in two (actually three) varieties. Red litmus paper is just regular filter paper that has an indicator attached to the surface. Blue litmus paper is too, but it has a different indicator attached than the red litmus paper does. There is a third type of litmus paper called Neutral Litmus Paper that has some of both of the indicators (red and blue) attached to its surface. Supposedly it can test for either an acid or a base, BUT the results are not as clear cut as with the red and blue litmus so I don't recommend it's use.

When you are testing a substance with litmus paper, you should use STANDARDS (an acid, a base and a neutral) in order to show students what they are looking for and to provide a point of reference for them. You should also instruct them to test each substance with BOTH types of litmus paper.

Watch the demonstration and record your results in the Data Table below:

Substance	Red Litmus	Blue Litmus	Neutral Litmus
Acid			
Neutral			
Base			

Based on your results, what type of indicator is each type of litmus paper?

Universal Indicators and “Homemade” Indicators

Many indicators are present naturally in flowers, fruits and vegetables. Sometimes they are responsible for the characteristic color exhibited. Have you ever noticed that hydrangea blooms are sometimes blue and sometimes pink? (Of course, the wild ones are usually white.) This is a function of the acidity or basicity in the soil in which they are grown. The indicator in their leaves changes a different color based on the pH of the soil environment.

We can take advantage of these indicators and use them for testing substances BUT we have to get this substance out of the plant or fruit first. We can do this through a process called **extraction and filtration**. You can find many possibilities for this but here are a few I have used before that I know will work: deep red rose petals (lots of different flowers work well but DON'T use yellow flower petals of any kind), blueberries, and red cabbage. We will experiment with some others today and you can find many other possibilities in books or on the internet that you might want to try.

This general “recipe” for making indicators will work with pretty much anything you want to try. Cut up (or smush up) the flower petals, berries, cabbage, whatever and place it in a sturdy glass container. Pour some rubbing alcohol over the substance in the glass container.

(SPECIAL NOTE: Using the alcohol does 2 things to increase the usefulness of your “homemade” indicator. The polarity of the alcohol molecule is different from that of water so it will increase the different types of molecules that will go into your solution (your extract will be more robust) AND it will also serve as a preservative so that your indicator will last longer.)

Rinse a boiler, tea kettle or cup out with distilled water first to remove any ion remnants that may be clinging to the surface from previous use. Heat some DISTILLED WATER in the boiler, tea kettle, or whatever (that you just rinsed out with distilled water) so that it is almost boiling. Pour the hot water over the substance and alcohol in the sturdy glass container that you are using and then allow it to steep until it has cooled to room temperature.

(SPECIAL NOTE: Do NOT put this mixture in the microwave or on the stove top to heat. Alcohol is a flammable liquid and it may burst into flames!)

After your extract has cooled off, you must filter it into another container. A plastic dropper bottle works great (you can purchase these cheaply at a beauty supply store). To filter it you will need a funnel and some filter paper (coffee filters will work fine). This may take a while to complete but you have to filter out all solid particles in order to have a usable indicator solution.

Now you are ready to test your indicator solution. Remember that you MUST set up STANDARDS first for comparison purposes.

Follow the instructions given to test your indicator with the set of standards set up for your group and complete the Data Table below:

Data Table: Record here the indicator solution your group is testing: _____

<i>pH=2</i>	<i>pH=4</i>	<i>pH=6</i>	<i>pH=7</i>	<i>pH=8</i>	<i>pH=10</i>	<i>pH=12</i>

Based on your observations what type of indicator did you test? _____

Using Indicators to Test Unknown Substances

Once you have established what an indicator will do with a set of standards, you are ready to test unknown substances to see if the indicator will enable you to determine whether it is an acid, a base, or a neutral substance. **One drawback to using indicators is that substances with color cannot be tested very well because their color interferes with your ability to see what happens to the indicator.**

There are many household items that you can use to show your students how to use indicators to determine the approximate pH of a substance: lemon juice (without pulp works better), vinegar, ammonia, soap or detergent solution that are clear, Sprite or 7-Up, Club Soda, are some suggestions.

Use the litmus paper and indicator provided at your group's station to test your assigned "unknown" substance and record your results in the Data Table below:

Data Table:

<i>Substance being Tested</i>	<i>Reaction with Red Litmus</i>	<i>Reaction with Blue Litmus</i>	<i>Other Indicator Tested:</i>
			<i>Record Reaction Below</i>

Based on your test results is your substance an acid, a base, or a neutral substance?

Now Back to the ASA

If your students understand the basic concepts of pH and how indicators work, they will be able to answer whatever questions come up on the ASA. The **KEY CONCEPTS** that they need to have an understanding of are:

- Acids are acids because they have more H^+ in solution than water does.
- Bases are bases because they have less H^+ in solution (more OH^-) than water does.
- Neutral substances have equal amounts of H^+ and OH^- in solution.
- Indicators are substances that change color in the presence of H^+ or OH^- to let us know (or "indicate" to us) whether a substance is an acid, a base, or neutral.
- In order to use indicators properly, we must use some STANDARDS so that we have a point of reference for comparison purposes.

We have focused our attention on indicators and how they work. Students should also be familiar with the general characteristics of acids (they corrode metals, neutralize bases, taste sour, etc.) and bases (they feel slippery to the touch, neutralize acids, taste bitter, etc.) but that's a whole other workshop. Check back next year!