Acids, Bases, & the pH Scale

What does it mean for a solution to be acidic or basic (alkaline)?

It all has to do with hydrogen ions (abbreviated with the chemical symbol H^+). In water (H_2O), a small number of the molecules dissociate (split up). Some of the water molecules lose a hydrogen and become hydroxide ions (OH^-). The "lost" hydrogen ions join up with water molecules to form hydronium ions (H_3O^+). For simplicity, hydronium ions are referred to as hydrogen ions H^+. In pure water, there are an equal number of hydrogen ions and hydroxide ions. The solution is neither acidic or basic.

An **acid** is a substance that donates hydrogen ions. Because of this, when an acid is dissolved in water, the balance between hydrogen ions and hydroxide ions is shifted. Now there are more hydrogen ions than hydroxide ions in the solution. This kind of solution is acidic.

A **base** is a substance that accepts hydrogen ions. When a base is dissolved in water, the balance between hydrogen ions and hydroxide ions shifts the opposite way. Because the base "soaks up" hydrogen ions, the result is a solution with more hydroxide ions than hydrogen ions. This kind of solution is alkaline.

Acidity and alkalinity are measured with a logarithmic scale called **pH**. Here is why: a strongly acidic solution can have one hundred million million (100,000,000,000,000) times more hydrogen ions than a strongly basic solution! The flip side, of course, is that a strongly basic solution can have 100,000,000,000,000 times more hydroxide ions than a strongly acidic solution. Moreover, the hydrogen ion and hydroxide ion concentrations in everyday solutions can vary over that entire range.

In order to deal with these large numbers more easily, scientists use a *logarithmic* scale, the pH scale. Each one-unit change in the pH scale corresponds to a ten-fold change in hydrogen ion concentration. The pH scale ranges from 0 to 14. It's a lot easier to use a logarithmic scale instead of always having to write down all those zeros! By the way, notice how one hundred million million is a one with fourteen zeros after it? It is not coincidence, it is logarithms!

To be more precise, pH is the negative logarithm of the hydrogen ion concentration:

$$pH = -\log [H^+]$$

The square brackets around the H^+ automatically mean "concentration" to a chemist. What the equation means is just what we said before: for each 1-unit change in pH, the hydrogen ion concentration changes ten-fold. Pure water has a neutral pH of 7. pH values lower than 7 are acidic, and pH values higher than 7 are alkaline (basic). Table 1 has examples of substances with different pH values (Decelles, 2002; Environment Canada, 2002; EPA, date unknown).

pH Value	H^+ Concentration Relative to Pure Water	Example
0	10 000 000	battery acid
1	1 000 000	concentrated sulfuric acid
2	100 000	lemon juice, vinegar
3	10 000	orange juice, soda
4	1 000	tomato juice, acid rain
5	100	black coffee, bananas
6	10	urine, milk
7	1	pure water
8	0.1	sea water, eggs
9	0.01	baking soda
10	0.001	Great Salt Lake, milk of magnesia
11	0.000 1	ammonia solution
12	0.000 01	soapy water
13	0.000 001	bleach, oven cleaner
14	0.000 000 1	liquid drain cleaner

Table 1. The pH Scale: Some Examples

How Do You Measure the pH of a Solution?

The pH of a liquid or solution is often an important piece of information in science. Measuring pH can be done simply and quickly using **pH test paper**, **pH indicator sticks**, or a **pH meter**. pH test paper and indicator sticks are pieces

of paper or stiffer sticks that contain *pH indicators* (chemicals that change color depending on how acidic or basic a solution is). To measure pH, a piece of pH test paper or an indicator stick is dipped into the liquid. The color of the dipped paper/stick is then matched to a color key that comes with the container of pH test paper or indicator sticks. Each color on the key represents a different pH. An example of a used pH indicator stick and the corresponding color key is shown below in Figure 1. pH meters are electronic devices that used to measure pH. They consist of a probe that is dipped in a solution, and a digital readout. pH meters are even more precise than pH test paper or indicator sticks. Table 2 below discusses what types of pH measuring devices are best for different science project applications, and offers a quick link to purchasing different pH test papers and indicator sticks.

Figure 1. pH test paper (not shown) and pH indicator sticks (shown here) are dipped into a solution then matched against a color key to determine the solution's approximate pH (Michael Krahe, 2005).

Item	pH Detection Range	Detection Intervals	Try Purchasing	Sci Pro Comp
Wide range pH indicator stick	0-14	1	Hydrion (9800) Spectral 0-14 Plastic pH Strip (http://www.amazon.com/gp/product/B0045I6KIE/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6KIE)	Suitabl most b level p when t objecti find ou if some acidic basic.
Wide range pH test paper	1-14	1	Hydrion S/R Dispenser 1.0-14.0 (http://www.amazon.com/gp/product/B0045I6H4Q/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6H4Q)	
Short range pH test paper	0.0 - 6.0	0.5	Hydrion S/R Dispenser 0.0-6.0 (http://www.amazon.com/gp/product/B0045I6H78/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6H78)	Suitabl interm level p where objecti watch pH of a solutio change examp fermer foods.
Short range pH test paper	6.5 - 13.0	0.5	Hydrion S/R Dispenser 6.5-13.0 (http://www.amazon.com/gp/product/B0045I6H8C/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6H8C)	
Micro range pH test paper	2.9 - 5.2	0.2 / 0.3	Hydrion MicroFine Disp. 2.9-5.2 (http://www.amazon.com/gp/product/B0045I6JZI/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6JZI)	
Micro range pH test paper	5.5 -8.0	0.2 / 0.3	Hydrion MicroFine Disp. 5.5-8.0 (http://www.amazon.com/gp/product/B0045I6K0C/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6K0C)	

Item	pH Detection Range	Detection Intervals	Try Purchasing	Sci Pro Comp
Micro range pH test paper	7.9 - 9.7	0.3	Hydrion MicroFine Disp. 7.9-9.7 (http://www.amazon.com/gp/product/B0045I6K8E/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6K8E)	
pH test paper	9.2 - 10.6	0.2 / 0.3	Hydrion MicroFine Disp. 9.2-10.6 (http://www.amazon.com/gp/product/B0045I6K3Y/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0045I6K3Y)	
pH meters	0-14	0.1 or less depending on the meter	High quality pH meters can be expensive. We recommend checking if there is one available at your local high school chemistry laboratory before purchasing. Various models are available from Amazon.com (http://www.amazon.com/mn/search/?_encoding=UTF8&tag=sciencebuddie-20&linkCode=ur2&camp=1789&creative=390957&field-keywords=ph%20meters&url=search-alias%3Daps).	Suitabl more advanc resear where *exact* p solutio matter: examp when c buffers biotech project
pH calibration solution kit	3 solutions of pH: 4.0, 7.0, and 10.0		Atlas Scientific pH Calibration Kit (http://www.amazon.com/gp/product/B0063MWYMQ/ref=as_li_ss_tl?ie=UTF8&tag=sciencebuddie-20&linkCode=as2&camp=1789&creative=390957&creativeASIN=B0063MWYMQ)	Neces: calibra meters

Table 2. The items above can be used to measure pH for science projects and other hobby and home applications. Clicking the purchasing links will take you directly to the product at www.amazon.com (http://www.amazon.com/?_encoding=UTF8&tag=sciencebuddie-20&linkCode=ur2&camp=1789&creative=9325).

To get accurate pH readings always remember to:

- Wait a minute or two after you add an acid or a base to a solution. This will allow the reaction (ions being either donated [acid] or accepted [base]) to complete before you measure.
- Swirl or mix a solution well before measuring. This will help ensure that the solution is uniform.

When using pH test paper/indicator sticks you should also:

- Make sure to only use paper/sticks that have not been previously wetted.
- Wait for the color to stop changing (1-2 minutes maximum) before matching the paper/stick to the color key. Do not wait more than 5 minutes after the color has stabilized or it may start to fade and affect the accuracy of your reading.

When using a pH meter you should also:

- Carefully read the manual for the pH meter before using it.
- Rinse the pH meter probe with distilled water before every reading.
- Use solutions with known pH values, see Table 2, to make sure the pH meter is accurately calibrated.
- Make sure the pH meter probe is properly submerged in the solution before taking a reading.

Bibliography

For more information about the pH scale, try these references:

- Decelles, P. (2002). "The pH Scale," Virtually Biology Course, Basic Chemistry Concepts, Johnson County Community College. Retrieved July 24, 2006, from http://staff.jccc.net/pdecell/chemistry/phscale.html (http://staff.jccc.net/pdecell/chemistry/phscale.html).
- Khan Academy. (2009, September 7). *Acid Base Introduction: Arrhenius, Bronsted Lowry, and Lewis Acids and Bases*. Retrieved May 1, 2012, from http://www.khanacademy.org/science/chemistry/v/acid-base-introduction (http://www.khanacademy.org/science/chemistry/v/acid-base-introduction)

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