pH of the Planet

In this activity students will collect a water sample from a local natural source. They will measure the pH of the sample using coloured indicator solutions.

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Instructions for the Activity (Teacher)

Experiment Outline

Students should work in small groups (usually pairs) to measure the pH of a local natural source of water. The activity involves two sections:

- Measure the pH of the sample from the local water source (and other samples if appropriate).
- Analyse the data.

Materials

- 6 (six) sample **containers** (*white or transparent containers to hold 1 cm depth of liquid*).
- a **dropper** or pipette
- a bottle of **rinsing water**
- bromothymol blue **indicator**
- *m*-cresol purple **indicator**
- **colour charts** for indicators
- **local water sample** from local natural water body

Optional

- other water samples
- universal indicator

Method

Part A - Testing the local water source

1. Label the sample containers 1 – 6 and mark 0.5 cm depth on each container.
2. Take a portion from the local water sample and fill three of the containers up to the mark.
3. Add three drops of **bromothymol blue** indicator to each container and swirl it to mix the solution thoroughly.
4. Use the colour chart to estimate the pH of each solution and record the result for each container to one decimal place.
5. If the pH of the sample is 7.6 or greater, repeat the test three times using ***m*-cresol purple** as the indicator and record the results to one decimal place.

Part B – Analysing and Submitting the Results

6. Decide which indicator gave the best measure of the pH of the sample. Usually this will be for the indicator that is well within its colour range.
7. Calculate the average result for your water sample using the results from the best indicator.
8. Add your result to the Class Table of Results.
9. When the class results are complete, calculate the class average result for the local water sample.
10. (optional) Repeat the method, Part A and B, for other water samples that are available.

Class Results Sheet

Record students' average pH values for the local water source (and other water sources if available - see teacher notes).

	Water Samples					
Group	**Local water source**	A	B	C	D	E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
Average						

Local water source: _____

Nature of water: _____

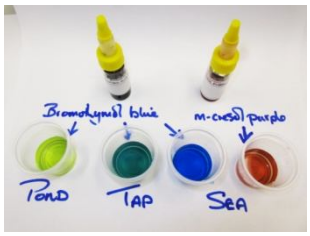
Date sampled: _____

Temperature: _____

Number of students involved: _____

Activity Worksheet (Student)

In this activity you will measure the pH (the acidity) of a local water sample. The pH is a number that allows you to compare different water samples.



Part A - Testing the local water source

- Label the sample containers 1 – 6 and mark 0.5 cm depth on each container.
- Take a portion from the local water sample and fill three of the containers up to the mark.
- Add three drops of **bromothymol blue** indicator to each container and swirl it to mix the solution thoroughly.
- Use the colour chart to estimate the pH of each solution and record the result for each container to one decimal place.
- If the pH of the sample is 7.6 or greater, repeat the test three times using ***m*-cresol purple** as the indicator and record the results to one decimal place.

Part B – Analysing and Submitting the Results

- With the help of your teacher, decide which indicator is likely to have given the best result.
- Average the results from the best indicator for each type of water tested.
- Add your results to the Class Table of Results.

	Types of Water Sampled						
Test	Indicator	Local water source	A	B	C	D	E
1	bromothymol blue						
2							
3							
4	*m*-cresol purple						
5							
6							
Average							

Teacher's Notes

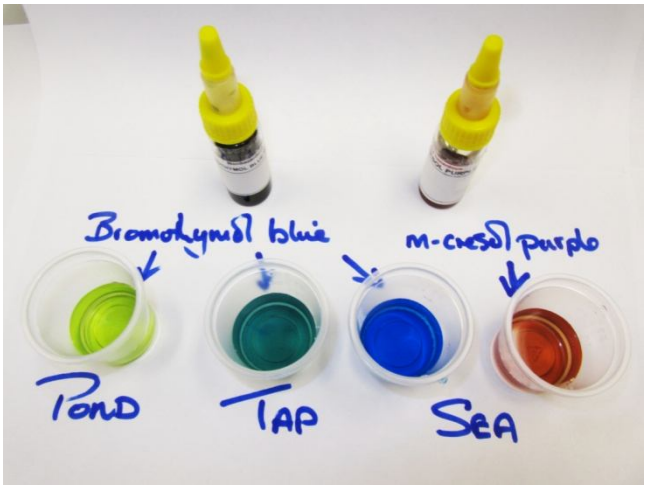
Chemistry is about us and everything about us. Exploring chemistry gives us deep insights into our world that are often surprising and useful. Acids are one of the first groups of substances that we recognize for their chemical properties, in the kitchen and the laundry as well as in the factory and the laboratory.

The activity will allow your class to explore the idea of acidity as it applies to our water supplies using the most common measure of acidity, pH. Students will learn a method of measuring pH and how to check its reliability. They will submit data to the Global Experiment database and be able to compare their results with others from around the world

Conducting the pH of the Planet Activity

The following notes are written to assist teachers use the pH of the Planet activity with their classes. The notes cover the following topics:

- Setting and Purpose for the Activity
- Learning outcomes
- Primary classes
- Junior high school classes
- Senior high school classes
- Materials and Equipment required
- Safety
- Pre-activity preparation
- Background about pH and acidity
- Ancillary activities



Setting and Purpose

This activity has been written to be included as part of an existing water related unit of work.
Some elaborations for the activity and ancillary activities are provided so that teachers can choose options to suit the time their class has available and the depth of understanding about the topic of water acidity appropriate for their class.

Learning Outcomes

Scientific processes:

- Measuring acidity and assessing the quality of the data.
- Interpreting data in terms of the environment and nature of the water involved.
- Asking scientific questions.
- Carrying out scientific investigations.

Chemistry background.

- Acids and bases.
- Chemical reactions that involve acids and bases.
- pH as a measure of acidity.

Primary Classes

- In the primary schools the activity provides an excellent opportunity for students to collect data using simple equipment and developing a useful skill of colour matching.
- Students should have some understanding of decimals and the process of averaging to understand the analytical part of the activity.
- The topic of acidity is one of the important chemical ideas that is firmly embedded in students' experiences of food and household chemicals.

- It provides a good example when distinguishing between physical and chemical processes and is one of the early experiences students have with chemical reactivity.
- The pH scale is best treated as a measure of acidity without reference to its chemical basis. However, the counter intuitive nature of the scale – lower pH implies more acidic – is unavoidable.
- Emphasis can be usefully placed on exploring the scale, relating the terms *neutral* to a pH of 7 and *acidic* to the region of the scale below pH 7 and *basic* to the region above 7.
- Students can usefully learn that substances with pH values well above or below 7 are both dangerous and the danger increases with the distance from neutrality.

Junior High School

- The explanations include hydrogen ions (H^+) or (H_3O^+) and simple chemical equations where appropriate.

Senior High School

- The explanations include strong and weak acids and chemical equilibrium where appropriate. Alternative methods of measuring pH such as pH meters can be used if available.

Materials and Equipment

Water samples:
The water samples can be collected in plastic drink bottles (1.5 L will be plenty). If samples need to be kept they should be stored in a refrigerator, allowed to come to room temperature before use, and used promptly after opening.
The local natural water source sample might come from the sea, a river, lake or large pond. Try to find a source that is a recognizable landmark that will be identifiable by students Collect the water sample as close to the time the class will be carrying out the measurements as possible.
If your students will be testing a range of other local samples you can ask them to collect samples and bring them to school. You should make sure you have some universal indicator in case students bring in samples that have pH values outside the range for most natural waters.

Indicators: Bromothymol blue is widely available from aquarium stores for use testing fresh water aquariums. *m*-Cresol purple is used for testing marine samples.

Bromothymol blue recipe:

Dissolve 0.1 g of bromothymol blue in 16 mL of 0.01 M NaOH.
When dissolved, slowly add 234 mL of water (distilled if possible).
Store at room temperature.

m-Cresol purple recipe:

Dissolve 0.1 g of *m*-Cresol purple in 26 mL of 0.01 M NaOH.
When dissolved, slowly add 224 mL of water (distilled if possible).
Store at room temperature.

Safety

The materials used in this activity are not hazardous in the form of the dilute solutions suggested in the procedures. However the solid indicators may cause irritation particularly if ingested. They should be handled with care when making up the indicators and hands should be washed afterwards.

Background Information - Acidity and pH

The first group of substances that people learn about based on chemical reactivity are often acids. Many acids are household products such as vinegar, hydrochloric acid or citric acid. Others, such as sulfuric and phosphoric acid, are used industrially, and millions of tonnes are manufactured each year.

Acids react with bases, a slightly less well known but equally important group of substances that includes ammonia, sodium bicarbonate and caustic soda (sodium hydroxide). Thousands of acids and thousands of bases have been identified, many of them naturally occurring and important in the processes of life.

Most of the common acid-base reactions occur in water. One of the special but not unique properties of water is that it can react as both an acid and a base. Because of this property, and because water is such a common and important substance, it is usually convenient to use it as the substance that divides acids from bases. Thus water acts as a base with acids and as an acid with bases. Samples of pure water and solutions that have the same acidity as pure water are said to be neutral. Acid-base reactions are often called neutralisation reactions.

acetic acid + sodium bicarbonate → water + sodium acetate + carbon dioxide

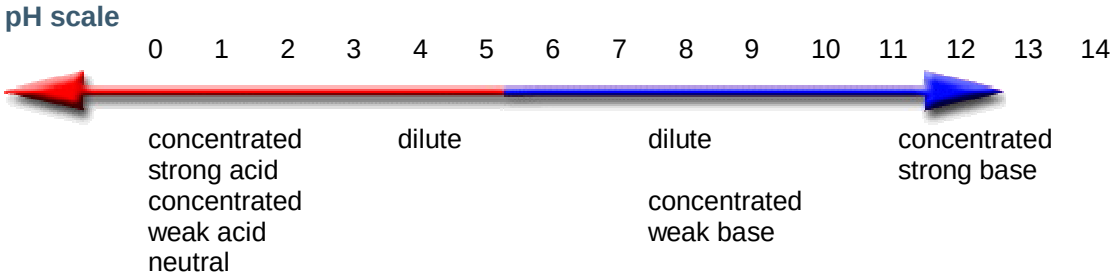
Variations in these acid-base reactions occur in cooking, in all the cells in our bodies and in many of the natural processes in the countryside.

Acid strength - The extent to which acids and bases react with water is a measure of how strong the acid or base is. Hydrochloric acid, a common strong acid, is found in the stomach and sold in hardware stores. It reacts almost completely with water. Other acids such as acetic acid, the acid found in vinegar, react only partially with water and are weak acids. Bases can be similarly classified as weak or strong.

The strength of an acidic solution, its acidity, is a useful property to know because it is an important indicator of how it might react chemically. For example concentrated hydrochloric acid is a useful substance for cleaning cement of brickwork, but concentrated acetic acid is much less effective. Diluting the acid reduces the acidity of an acidic solution and so adding water is usually a useful way of reducing the hazard of acid or base, spills.

pH scale - The pH scale is used to measure the acidity of solutions. The pH of most common solutions lie between 0 and 14. Lower values of pH imply greater acidity.

pH scale



Strong acids have the lowest pH and can have negative values for concentrated strong acids such as sulfuric acid. Strong bases have the highest values and can be greater than 14. Pure water on the other hand is neutral and has a pH of around 7 depending on the temperature.

H_3O^+ or H^+

It is common to refer to acids in terms of the concentration of hydrogen ions, H^+, rather than H_3O^+ ions. This is based on convenience and tradition and while hydrogen ions do not exist in water solutions, the terms are used interchangeably.

The utility of the pH scale comes from what it is that is actually measured. The measure is the extent of the reaction of the acid with water. For example with hydrochloric acid:

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Hydronium ions - The products are ions (they are charged particles) and the H_3O^+ ion (hydronium ion) is responsible for the acidic properties.

One of the reasons why acids form such a useful category of substances is because H_3O^+ ions are formed by all the common acids and hence acids have a range of common properties.

In the case of hydrochloric acid, the ionisation is essentially complete in water and HCl is called a strong acid. For acetic acid, much less H_3O^+ is formed and most of the acetic acid molecules are usually in the unionized form.

Measuring pH involves determining the concentration of H_3O^+. The range of values is great so a logarithmic scale is used:

$pH = -\log_{10}[H_3O^+]$

This means that the concentration of H_3O^+ at pH 8.5 is one thousandth of the concentration at pH 5.5 (a common range for natural water samples)

Measuring pH - The two most common measurements of pH involve using indicators or pH meters.

Indicators are weak acids that are coloured and that change colour when they undergo an acid-base reaction and (formally) lose the H^+ ion. The reactions are usually reversible so that the indicator has two molecular forms: the acid and the base:

$$\text{bromothymol blue} \underset{+H^+}{\overset{-H^+}{\rightleftharpoons}} \text{bromothymol blue}^-$$

acid form base form

The colour change in indicators usually occurs across a 10-fold change in H_3O^+ concentration and so covers a change in pH of one.

Indicator solutions that cover more extensive pH ranges such as universal indicator are mixtures of a number of indicators.

pH meters - work by measuring the potential of a pH sensitive glass electrode. The glass membranes are sensitive to damage and need to be stored and handled carefully to achieve a lifetime of 2 years, or perhaps, more.

The electrodes change with age and so the pH meter needs to be calibrated regularly. This is done using buffers of known pH. Buffer solutions are usually mixtures of the acid and base forms of a weak acid. Buffer solutions are usually made up from recipes, or bought as a tablet or in liquid form.

Interpreting pH values

pH values obtained in the activity need to be interpreted cautiously because there is a natural variability due to differing light levels and temperatures and artifacts of the different measuring techniques. In the case of freshwater sources the natural variability is quite large, commonly between 6.5 and 8.0. Marine waters usually are buffered and have a smaller range in pH variation, between 8.1 and 8.4.

Temperature changes cause changes in the pH of sample solutions and of pH sensors. Although these changes remain small if the temperature remains close to 20-25°C, bigger variation is to be expected with more extreme temperatures.

For natural waters, the pH also changes during the day due to the living material in the water. Respiration of organisms produces carbon dioxide which lowers the pH of the sample. In daylight the pH increases because the photosynthesizing organisms reduce the levels of carbon dioxide.

The geology of the area can also affect the pH of the local water. The presence of limestone can raise the pH considerably. In the case of the oceans, the limestone and other sources of calcium carbonate contribute to the normal ocean pH of 8.3, but the additional carbon dioxide in the atmosphere due to climate change is partially dissolving in the ocean decreasing the pH (by very small amounts).

Additional activities

The following activities would provide students with opportunities to gain a deeper understanding of the concept of acidity and pH.

- Changing pH – experiments that establish the variable stability of pH in different setting e.g. blowing into water samples.
- pH in everyday life – measuring pH in everyday liquids from around the house and materials such as soils.
- Natural indicators – exploring homemade indicators such as red cabbage juice.
- Variation in pH – Measurement of natural variation in pH in water during regular events (24 hours) and after rain etc.

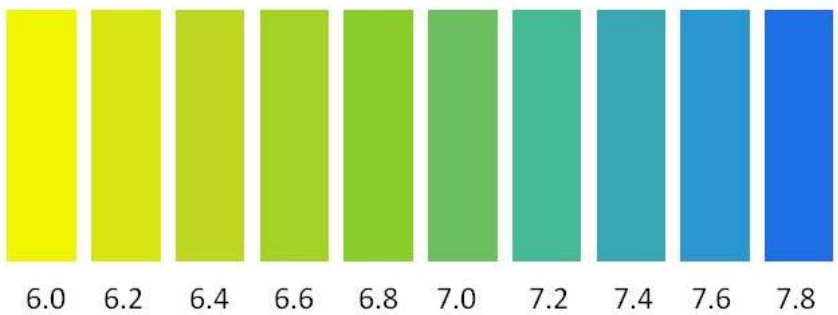
Class Results Sheet (Trial Data)

- Record students' average pH value for the local water source here and other water sources if available
- *(This data set was obtained using the above method by a class of 25 eleven-year-old students working in pairs.)*

	Types of Water Sampled					
Group	Local source **Lake**	A **Tap**	B **Fish tank**	C **Sea**	D	E
1	**6.7**	**8.0**	**6.6**	**8.1**		
2	**6.9**	**7.9**	**6.5**	**8.0**		
3	**6.5**	**8.0**	**6.6**	**8.1**		
4	**6.7**	**8.0**	**6.7**	**8.2**		
5	**6.7**	**8.4**	**6.4**	**8.0**		
6	**6.9**	**8.1**	**6.3**	**8.0**		
7	**6.8**	**7.7**	**6.3**	**8.4**		
8	**6.8**	**8.0**	**6.5**	**8.1**		
9	**6.8**	**8.1**	**6.7**	**8.4**		
10	**6.7**	**8.1**	**6.7**	**8.3**		
11	**6.8**	**8.2**	**6.5**	**8.3**		
12	**6.6**	**7.8**	**6.6**	**8.1**		
13	**6.6**	**7.8**	**6.4**	**8.1**		
14						
15						
Average	**6.7**	**8.0**	**6.5**	**8.2**		

- Local water source: **Brisbane River opposite Oxley School**
- Nature of water: **Fresh**
- Date sampled: **14/02/2011**
- Temperature: **22 ^{o}C**
- Number of students involved **25**

Indicator Colour Chart



Bromothymol Blue

m-Cresol Purple

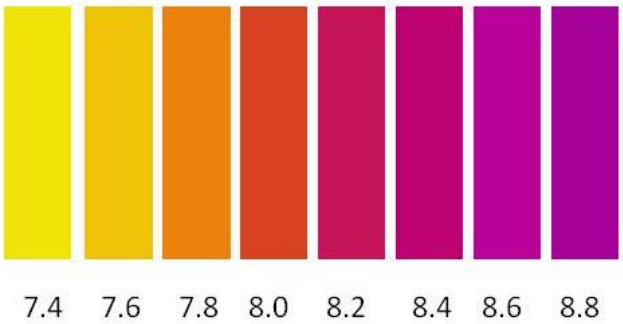


Table of RGB Indicator Colours

pH	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8
Bromothymol blue	241 231 19	216 231 19	189 215 35	165 210 38	137 206 44	108 192 95	70 185 149	57 166 180	44 150 210	30 110 230					
m-Cresol purple								240 227 7	239 195 7	237 130 13	215 66 35	198 20 88	189 1 113	186 2 154	166 2 154