
MICROSCALE GLOBAL WATER KIT INSTRUCTIONS

Global Experiment for the International Year of Chemistry

pH of the Planet

(Testing the pH of Different Water Sources)

Overview of the pH Activity

The title “**pH of the Planet**” refers to the testing of the pH of different water samples. Since the activity is part of the Global Experiment, students from all over the World will be submitting their data to the Global database and so the pH of the waters of our Planet will be in the spotlight. 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. An average value from the class results will be reported to the Global Experiment Database together with information about the sample and the school.

Background to the pH Activity

pH measurement is one of the most common tests performed on water. This is because the pH of a body of water is an indication of the quality of that water, both for aquatic systems living in the water as well as for human consumption. All organisms can only tolerate a certain amount of acidity and therefore function within a particular pH range. If the pH changes only slightly, these organisms may die. Similarly, humans can only drink water that is in a specific pH range otherwise we may suffer serious health problems. The pH of water is greatly affected by the addition of certain chemicals to water. For example: the dumping of chemicals into water by individuals, industries and communities can change the pH and other properties of the water. Pollutants such as sulfur dioxide from car and coal power station emissions escape into the atmosphere and produce acid rain that drastically reduces the pH of streams and rivers. When acidic water comes into contact with metals and other chemicals, the water can become even more poisonous. pH is therefore a critical factor of the health of a particular body of water, and as students perform this activity they need to be aware of the impact that human activities can have on water quality.

Submitting Results to the Global Database

The following information should be submitted to the database. If the details of the school and location have already been submitted in association with one of the other activities, these results should be linked to the previous submission.

Date the water was sampled:

Name of local water source: (e.g. Limpopo River)

pH of local water source:

Nature of water: (fresh, salt, sea etc.)

Water temperature: (temperature while measuring the pH)

Number of students involved

School/class Registration number

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Instructions for the Activity (Teacher)

Experiment Outline

Students should work in small groups (4 – 6 students, or pairs if numbers permit) to measure the pH of a water sample collected from a local source (fresh, salt, sea, etc.). One Microscale Global Water Kit should be used per group. The results should be analyzed and reported on the International Year of Chemistry Global Experiment Database.

Just prior to performing the pH activity, use the thermometer in the School Resource Kit to measure the temperature of the water sample. Record the value on the Results Sheet.

The pH of the Planet activity involves the following steps:

1. Collection of a natural water sample from an identifiable source.

Thereafter, to find the pH of the sample:

2. Measuring out 2 ml volumes of the water sample into the large wells of the comboplate.
3. Adding drops of a coloured indicator to the sample and matching these colours to pH values using a colour indicator chart specific for each indicator.

Lastly, to complete the activity:

4. Analyzing the data and reporting results to the Global Experiment Database.

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Students' Instructions

Materials needed for the pH Activity

Collect the following:

- 1 x sample of water from local source such as fresh (dam, pond or river) or sea water (100 – 250 ml)
- Tap water (for rinsing)
- Permanent marker or ink pen (used for labelling of propettes)
- A piece of white paper

Components from the Microscale Global Water Kit:

- 1 x comboplate
- 1 x 2 ml plastic syringe
- 2 x propettes (for indicators)
- 1 x plastic microspatula per water sample (for stirring)

Components and Chemicals from the School Resource Kit

- a thermometer - ASK YOUR TEACHER FOR THE THERMOMETER
- bromothymol blue indicator solution – ASK YOUR TEACHER FOR THIS INDICATOR
- *m*-cresol purple indicator solution - ASK YOUR TEACHER FOR THIS INDICATOR
- colour charts for the bromothymol blue and *m*-cresol purple indicators - ASK YOUR TEACHER FOR THE COLOUR CHARTS

Safety Precautions

The water in this activity is not safe to drink. Direct contact with water samples and indicator solutions should be avoided. Wash your hands with soap and water after doing the activity.

Testing the pH of your Water Sample with Bromothymol Blue Indicator

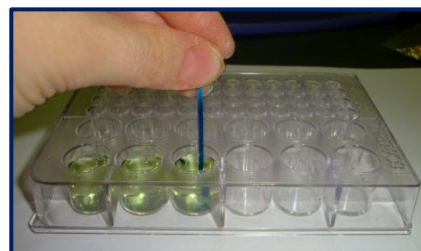
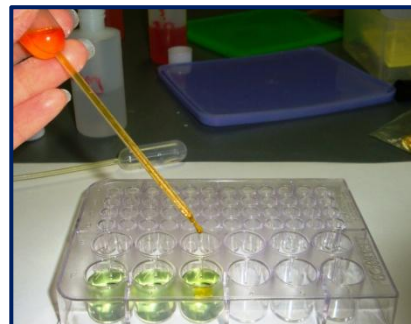
1. Before you start, make sure that all of your equipment is clean and dry. If there is any residue in the wells of the comboplate or in the syringe, the water sample may be contaminated and the pH results may be affected.
2. Using the thermometer from the School Resource Kit, measure and record the temperature of the water sample.
3. Place the comboplate on the piece of white paper to help you see the indicator colours better.

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4. Use the clean, dry 2 ml syringe to remove 2 ml of the test water sample from the container.
5. Add the 2 ml of water sample from the syringe to a large well of the comboplate, such as well F1.
6. Repeat steps 4 and 5 another two times, this time adding your water sample to wells F2 and F3.
7. Use a permanent marker or ink pen to label the bulb of a clean propette with the abbreviation "BTB" for **bromothymol blue**.
8. Fill the propette with the bromothymol blue indicator solution. Carefully add three drops of the indicator solution to each of wells F1, F2 and F3 containing your water sample. The drops must all be equal in size.

HINT: You can share the bromothymol blue indicator in your propette with another group or groups because you only need three drops at a time.

9. Stir the sample in each well with a clean microspatula to thoroughly mix the contents.
10. Use the colour indicator chart for bromothymol blue to estimate the pH of the water sample in each of wells F1 to F3. Record each result to one decimal place on the Students' Result Sheet. Determine the average pH of your sample.

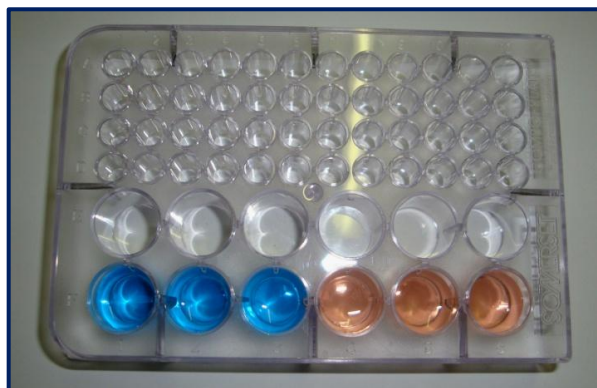


This fresh water sample from Tendele in the Drakensberg (South Africa) shows a pH of about 6.5 with bromothymol blue.

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Testing the pH of your Water Sample with *m*-Cresol Purple Indicator (only for samples with pH ≥ 7.6)

1. If the pH of your sample is 7.6 or greater using bromothymol blue indicator, you must repeat the procedure again but this time using the *m*-cresol purple indicator.
2. Use the syringe to add 2 mL of the same water sample to wells F4, F5 and F6.
3. Use the marker or ink pen to label another clean propette. This time use the abbreviation "**mCP**" for ***m*-cresol purple**.
4. Fill the propette with the *m*-cresol purple indicator solution. Add three equal-sized drops of the indicator solution to the sample in each well. (Remember to share the indicator with other groups.)
5. Stir the contents of the wells with a clean microspatula. (Do not use the microspatula you used before when adding bromothymol blue, unless you have properly cleaned and dried it.)
6. Use the colour indicator chart for *m*-cresol purple to estimate the pH of the sample in each of wells F4 to F6. Record each result on the Students' Result Sheet as before. Find the average pH of your sample to one decimal place.



This sea water sample from Durban (South Africa) shows a pH of about 7.8 with bromothymol blue (three wells on the left). It has been tested further with *m*-Cresol purple in the wells on the right, where it shows a pH value of between 7.8 and 8.0.

Analysing and Submitting your results

1. Decide which indicator solution gave the best measure of the pH of your sample.
2. Add the average result you have selected to the Class Table of Results.
3. If the entire class has used the same water sample, calculate the class average result for the local water sample. This is the pH value that will be submitted to the Global Experiment Database.
4. If different groups have tested other water samples, then the average pH values of the different water samples can also be submitted to the Global Experiment Database as long as each sample is appropriately identified.

**Rinse and dry all of the equipment you used and place it safely back in the kit.
Wash your hands with soap and water.**

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Students' Observations and Results Sheet for the pH Activity

Complete a separate Results Sheet for each water sample tested.

1. Complete the following table:

Date of water sample collection	
Date the pH measurement was performed	
Temperature of water at time of measuring pH°C
Type of water (sea, river, pond, swamp, etc.)	
Describe where you found the water	

2. Record the pH values of your water sample in the table below.

Well Number	pH value with Bromothymol Blue Indicator	pH value with m-cresol Purple Indicator	Average pH value using best indicator

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Teacher's Notes

Using the Activity with your Students

This activity has been written so that it can be included as part of an existing water-related unit of work. However teachers may wish to use it just to give their students an experience of contributing to an international scientific experiment.

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 pH and acidity appropriate for their class.

Learning outcomes range from using simple equipment and making and recording observations for younger students, to an introduction to pH and acidity for older students. The activity lends itself to discussions of the role of nature on the pH of water bodies, as well as the impact of human activities on the acid concentration - and therefore quality - of water supplies intended for human consumption.

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Teacher's Summary of School Results

pH of the Planet Observation Table
(summarizing results from a school)

NAME OF SCHOOL: _____

LOCATION OF SCHOOL: _____

NUMBER OF STUDENTS: _____

Type of water	Description of water source	Temperature of Water at time of Measuring pH/°C	Average pH value of Water Sample
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

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Teacher's Summary of School Results - Sample

pH of the Planet Observation Table (summarizing results from a school)

NAME OF SCHOOL: *St. Benedict's College*

LOCATION OF SCHOOL: *Bedfordview,
Johannesburg,
South Africa*

NUMBER OF STUDENTS: *160*

Type of water	Description of water source	Temperature of Water at time of Measuring pH/ °C	Average pH value of Water Sample
<i>1. Distilled Water</i>	<i>Bottled - purchased from a pharmacy</i>	<i>23</i>	<i>6.1</i>
<i>2. Fresh</i>	<i>Stream in Tendele, the Drakensberg, South Africa</i>	<i>23</i>	<i>6.5</i>
<i>3. Sea Water</i>	<i>Sea at Durban, Kwa Zulu Natal, South Africa</i>	<i>23</i>	<i>7.9</i>
<i>4. Tap water</i>	<i>From a tap in the classroom</i>	<i>22</i>	<i>7.7</i>

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Sample of Students' Observations and Results Sheet for the pH Activity

Complete a separate Results Sheet for each water sample tested.

1. Complete the following table:

Date of water sample collection	<i>20 October 2010</i>
Date the pH measurement was performed	<i>27 October 2010</i>
Temperature of water at time of measuring pH	<i>23.°C</i>
Type of water (sea, river, pond, swamp, etc.)	<i>Sea Water</i>
Describe where you found the water	<i>Collected from the sea at Durban whilst on holiday</i>

2. Record the pH values of your water sample in the table below.

Well Number	pH value with Bromothymol Blue Indicator	pH value with m-Cresol Purple Indicator	Average pH value using best indicator
<i>F1</i>	<i>7.8</i>		<i>7.9 (since the pH values with each indicator are so close, we have taken the average of 7.8 and 8.0 i.e. 7.9)</i>
<i>F2</i>	<i>7.8</i>		
<i>F3</i>	<i>7.8</i>		
<i>F4</i>		<i>8.0</i>	
<i>F5</i>		<i>8.0</i>	
<i>F6</i>		<i>8.0</i>	

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Additional Information about the Activity

Safety Precautions

It should be emphasized that the water samples will not be safe to taste or drink. The students should be made aware of this at the start of the activity.

The materials used in this activity are not hazardous in the form of the dilute solutions suggested in the procedures, but students should still wash their hands with soap and water after doing the activity.

Teachers should take care when preparing the indicator solutions, because the solid indicators may cause irritation particularly if ingested. The indicators have been specially packaged in bottles so that contact with the solids is kept to a minimum. However, they should still be handled with care when preparing the indicator solutions and hands should be washed afterwards.

Materials and Equipment Listing

Materials needed for the pH of the Planet Activity

Collect the following:

- 1 x sample of water from local source such as fresh (dam, river or pond), or sea water. (100 – 250 ml)
- Tap water (for rinsing)
- Permanent marker or ink pen (to label the propettes containing indicator solutions)
- A piece of white paper (to place under the comboplate as this helps to observe the colours better)
- Universal indicator solution (optional – only required if the pH of the water sample does not fall within the range of either the bromothymol blue or *m*-Cresol purple indicators)
- Other water samples (optional – a group can collect and test more than one water sample if desired)

Components from the Global Water Kit:

- 1 x comboplate
- 1 x 2 ml plastic syringe
- 2 x propettes (you may need a third one if Universal indicator solution is also used)
- 1 x plastic microspatula per water sample

Components from the School Resource Kit

- a thermometer - THE TEACHER MUST SUPPLY THE THERMOMETER
- bromothymol blue indicator solution –THE TEACHER MUST SUPPLY THIS INDICATOR
- *m*-Cresol purple indicator solution – THE TEACHER MUST SUPPLY THIS INDICATOR
- colour charts for the bromothymol blue and *m*-Cresol purple indicators - THE TEACHER MUST SUPPLY THE COLOUR CHARTS

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Notes on Materials Procurement:

1. The IYC Global Water Kit (GWK) will be made available to selected schools in countries where resources for carrying out the Global Experiment are lacking. However, any school can use the kits for the Global Experiment. The apparatus in these learner kits is small scale and mostly plastic making it robust and safe to use in any environment. A laboratory is not needed and the kits can be safely taken into the field. Students can work in groups of 4 to 6. If the school has received a School Pack, it should contain 10 GWKs which will cater for classes of 40 to 60 learners working in groups. For the pH of the Planet activity, students will need the comboplate, syringe, propettes and microspatulas found in the GWK. As with any kind of apparatus, students must take care of the kit components by ensuring that they always clean, rinse and dry the equipment after each activity. The equipment should always be placed back into the kit for the next group to use.
2. The School Resource Kit (SRK) has been specially designed as a supporting kit for the Global Water Kit. It is to be maintained and managed by the teacher, who must distribute the items as required per activity. For the pH activity, the teacher must make the thermometer, indicator solutions and indicator colour charts available to learners for determining the temperature of the water, as well as for measuring the pH of water samples. The thermometer should be handled with care and put back into the cardboard tube after use to protect it from breakage. Both the bromothymol blue and *m*-Cresol purple indicators are supplied as solids. Teachers are responsible for preparing the solutions in the bottles prior to the pH activity. The method for solution preparation is provided below. There is only one colour indicator chart for each indicator per SRK, which means that teachers need to ensure that the charts are returned to the kit after the pH activity has been completed.
3. The bromothymol blue indicator can be prepared as follows:
 - a) Remove the screw cap from the plastic bottle containing the solid bromothymol blue.
 - b) Carefully measure and pour 25 ml of ethanol into the bottle. Replace and tighten the cap and carefully swirl the bottle to dissolve the solid in the ethanol.
 - c) Once dissolved, remove the cap and add 25 ml of distilled water to the solution in the bottle. The bottle should now be full to the top.
 - d) Replace the lid once again and carefully invert the bottle to mix the contents of the bottle. The solution is now ready to use. Store at room temperature.

If ethanol is not available, surgical spirits or uncoloured methylated spirits can be used to dissolve the solid bromothymol blue. Distilled water is often available from petrol stations and pharmacies, but if it cannot be found then cooled, boiled water can be used as an alternative.

4. The *m*-Cresol purple indicator can be prepared as follows:
 - a) Remove the screw cap from the plastic bottle containing the solid *m*-Cresol purple.
 - b) Carefully measure and pour 25 ml of ethanol into the bottle. Replace and tighten the cap and carefully swirl the bottle to dissolve the solid in the ethanol.
 - c) Once dissolved, remove the cap and add 25 ml of distilled water to the solution in the bottle. The bottle should now be full to the top.
 - d) Replace the lid once again and carefully invert the bottle to mix the contents of the bottle. The solution is ready for use. Store at room temperature.

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- Both the bromothymol blue and *m*-Cresol purple solutions prepared in this way are orange in colour. For this reason, students should carefully follow the instruction about clearly labelling the propettes used for the indicator solutions. The labels can be removed after the activity once the propettes have been rinsed. Since only 3 drops of indicator solution are used at a time, the teacher can fill two or three propettes with each indicator solution before the activity begins i.e. 3 propettes of bromothymol blue solution and three propettes of *m*-Cresol purple solution. The teacher must clearly label the propettes so that students do not mix them up. If this system of propettes is used, then teachers can keep the bottles of indicator solutions aside as their stock solutions. Students can collect the propettes as required from a central location. They should then share the propettes containing each indicator with the other groups in the class, because each group will only need a few drops per solution. In this way, contamination of the stock indicator solutions is avoided and wastage of the indicators is also prevented. If students return the propettes at the end of the activity, the teacher can use these again with another class.
- Teachers may already have bromothymol blue indicator solutions in their cupboards that they use for the teaching of acidity and pH. These solutions can also be used provided they are very close to 0.05% — in concentration. Dilution of more concentrated solutions will be required to make them compatible for use with this activity.
- Universal indicator is only required if a water sample has a pH value that does not fall within the pH ranges of the bromothymol blue and *m*-Cresol purple. The same method of filling the wells with 2 ml of sample should be followed, with addition of three drops of Universal indicator solution. A Universal indicator chart is also needed from which to determine the pH value of the sample. (Note that the Universal indicator solution should have a similar concentration to the other 2 indicators i.e. 0.05% —)
- Water samples: The water samples can be collected in clean, plastic drink bottles (500 ml will be plenty), or in any other suitable container. It will be more appropriate if the container is made of a transparent material. If a 2 ml sample cannot be easily removed from a container (such as a half-filled bottle) using the syringe, then a small volume of the water sample can be poured into a cup or other container for easier access.

The local natural water source sample to be reported to the Global Experiment Database might come from the sea, river, lake, large pond or an estuary. Local tap water can also be tested. The water source should be a familiar landmark that will be identifiable by students from other schools for comparative purposes. Collect the water sample as close to the time the class will be carrying out the activity as possible.

A group of students may test more than one water sample. There are twelve large wells in the comboplate which means that 4 water samples can be tested (if their pH values all fall within the range of bromothymol blue indicator) or 2 samples can be tested (if the pH of each sample needs to be checked with both bromothymol blue and *m*-Cresol purple indicators). A separate results sheet should be completed for each water sample.
- All equipment must be thoroughly rinsed as soon as the pH tests have been completed, otherwise the indicator solutions may stain the plastic of the comboplate and propettes.

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Student Learning Outcomes

Science Process Skills

- Taking samples that are representative of a system.
- Measuring volume using graduated apparatus.
- Interpreting data in terms of environment and nature of the water involved.
- Recording of the scientific data and observations in an appropriate manner.
- Measuring acidity and assessing the quality of the data.
- Using the pH scale.
- Asking scientific questions about pH and acidity of water samples.
- Carrying out scientific investigations by selecting and controlling variables.

Chemistry background

- Acids and bases.
- Chemical reactions that involve acids and bases.
- The pH scale and pH as a measure of acidity.
- Determining acid (H_3O^+) concentration from pH and vice versa.

Learning outcomes for 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.

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Learning outcomes for Junior High School

The explanations include hydrogen ions (H^+) or (H_3O^+) and simple chemical equations where appropriate. (See background notes at the end of this document)

Learning outcomes for 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. (See background notes at the end of this activity)

Extension Activities

The following activities can be carried out to help students gain a deeper understanding of the concepts of acidity and pH. In some cases, the Global Water Kit can be used but for other activities additional equipment may be required.

- Changing pH – experiments that establish the variable stability of pH in different settings e.g. blowing into water samples.
- pH in everyday life – measuring pH in everyday liquids from around the house and materials such as soils. Students can be asked to collect things from their homes such as milk, cool drinks, etc. They can then test these using the small or large wells of the comboplate. Different indicators can be used according to availability, such as bromothymol blue, methyl orange, methyl red, phenolphthalein, Universal indicator, etc.
- 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.
- Older students can also explore how the nature of an acid and/or base affects its pH and conductivity. For example, using the Global Water Kit together with a simple conductivity meter (or indicator such as an LED), it can be shown that 0.1 M hydrochloric acid ($HCl(aq)$) has a greater conductivity than 1 M acetic acid ($CH_3COOH(aq)$). However, if one tests the pH of each acid using Universal Indicator, the two acids have the same pH values. It can be deduced that the strength of the acetic acid is much lower than that of the hydrochloric acid.

Background Information on Acidity and pH

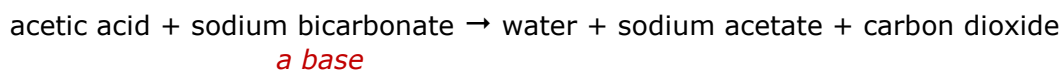
The first group of substances that people learn about based on chemical reactivity are often **acids**. Many acids are household products such as vinegar, hydrochloric acid or citric acid. Others, such as sulfuric and phosphoric acid, are used industrially, and millions of tonnes are manufactured each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

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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.



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.

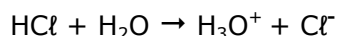
The strength of an acidic solution, its acidity, is a useful property to know because it is an important indicator of how it might react chemically. For example concentrated hydrochloric acid is a useful substance for cleaning cement or brickwork, but concentrated acetic acid is much less effective.

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.



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. 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:



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.

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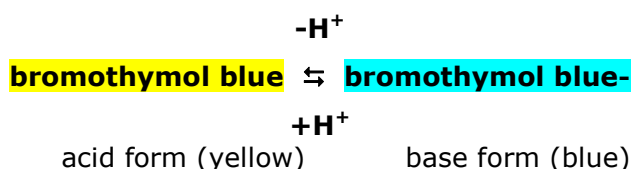
Measuring pH involves determining the concentration of H_3O^+ . The range of values is great so a logarithmic scale is used:

$$\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$$

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:



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 artefacts 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.