WATER AND ITS UNIQUE PROPERTIES

Exercise 1

Name

Date

Course Name

Abstract

There are several forces in nature that act on water molecules giving them unique properties. Some of them are cohesive and adhesive forces that make the molecules of water clump with each other and stick on any given surface. As a result of this, water demonstrates phenomena such as surface tension and capillary action. Surface tension enables water to develop resistance to any material that is placed on the surface of the water causing certain substances to float on water. It also causes water to withstand external disruptive forces for a longer duration before the surface tension breaks and the molecules of water fall apart causing it to flow off. Water also demonstrates capillary action through which it can move up very thin tubes like those in a plant carrying nutrients from the soil to all parts of the plant. This exercise demonstrates the various forces acting on water and properties of water through four different experiments.

Part 1: Surface Tension of Water

Experimental Procedure

1. A 100 mL beaker was taken and completely filled with tap water until it was full.
2. A needle was held vertically as close to the level of the water in the beaker without touching the surface of the water.
3. The needle was gently dropped in the water.
4. Next, the needle was retrieved, dried completely and was brought horizontally as close to the level of the water without touching the water in the beaker.
5. It was placed on the surface of the water gently.

Observation

When the needle was dropped into the water vertically, it pierced the surface of the water and fell to the bottom of the beaker owing to the higher density of the metal needle as compared to water. However, when the needle was placed on the surface of the water horizontally, it started floating on the water without any signs of falling in the water.

Discussion

When the needle is dropped in the water vertically, the surface area of the needle that is in contact with the water surface is very small and the higher density of the needle makes it sink to the bottom of the beaker. However, when the needle is placed on the water surface horizontally, it starts floating. This can be attributed to the surface tension of water due to the cohesive forces acting on water molecules.

The cohesive nature of molecules makes them cohere to the molecules of the substance with which they share contact. In the case of a beaker filled with water, the molecules of water on the sides and bottom cohere to the molecules of the beaker material. However, the water molecules on the surface are not in contact with any other substance and so, they associate with each other due to the cohesive forces acting on them. This clumping of water molecules on the surface creates a surface tension in the liquid making them resistant to being broken or stretched.

Objects can only float on the surface of water if they don’t disturb the surface tension. When a needle is dropped in the water vertically, the point of contact is minimal and the gravitational force acting on the needle is stronger than the cohesive forces acting on the water molecule causing the needle to sink to the bottom of the beaker. On the other hand, if the needle is placed on the surface of the water horizontally, the mass of the needle is distributed and the area of contact between the needle and water is higher ensuring that the surface tension of water is not disturbed and causing the needle to float on the water surface.

Part 2: Breaking Surface Tension

Experimental Procedure

1. A paper towel was placed on a flat surface and a drinking glass was placed on the paper towel.
2. The glass was filled with water up to just above the brim taking care that the water did not overflow from the glass.
3. The number of paper clips that could be added to the glass of water without breaking the surface tension and causing the water to overflow was predicted and recorded.
4. Paper clips were added to the water one at a time and they were found to sink to the bottom.
5. The addition of paper clips was continued until the water from the glass overflowed. The total number of paper clips added to the glass of water was counted and recorded.

Observation

As the water in the glass was filled to the brim, it was predicted that a maximum number of 10 paper clips could be added to the water before it overflowed from the glass. However, as the paper clips fell to the bottom of the glass, it was found that the water could hold much more than the predicted number of paper clips. As more paper clips were added, the water on the surface started forming a large dome before breaking and overflowing from the glass. The number of paper clips that caused the water to overflow from the glass was counted to be 27.

Analysis

This experiment demonstrates two types of cohesive forces – one acting between the water molecules on the surface and the other acting between the molecules of water and glass. As paper clips are dropped into the water, the water level rises in proportion to the amount of water displaced by each paper clip. However, instead of spilling from the glass, the water molecules cling to the surface of the glass on the brim and to each other due to the cohesive forces acting on the water molecules creating surface tension. As more and more paper clips are added, the dome of water on the surface gradually increases in size until the point when the surface tension is broken and water overflows from the glass.

The water in the glass was filled to the brim and so, it was predicted that not more than 10 paper clips could be added to the glass before the water overflowed. However, owing to the cohesive forces between the molecules and surface tension of water, it could withstand the addition of 27 paper clips before finally overflowing from the glass.

Part 3: Cohesive and Adhesive Properties of Water

Experimental Procedure

1. A paper towel was placed on a flat surface and a coin was placed on the paper towel.
2. A pipette was filled with tap water.
3. The number of water drops that could be added to the surface of the coin before the water flowed off from the coin was predicted and recorded.
4. With the help of the pipette, water drops were added to the surface of the coin one by one while counting the drops.
5. The addition of water drops was stopped once the water started flowing off from the surface of the coin and the total number of drops added was recorded.

Observation

The number of drops that could be added to the coin before the water overflowed was predicted to be 15. However, when the experiment was performed, it was noticed that the number of drops that could be added to the coin was 36 before the water started overflowing from the coin surface. As the water drops were added to the coin, it was observed that a dome of water started forming over the surface until the point that the forces acting on the dome were disrupted and the water started flowing off from the coin surface.

Analysis

There are several cohesive and adhesive forces acting on the molecules found in nature that make them clump with each other and attach to other surfaces. In this case, the cohesive forces acting on the water molecules make them associate with each other giving them solid-like properties and creating surface tension. In addition, there are adhesive forces acting on the water molecules that make them attach to the surface of the coin. Both these types of forces make the water molecules stay on the surface of the coin for as long as they can before the forces are overpowered and the water starts flowing from the surface.

As the surface of the coin was small, it was predicted that it could hold not more than 15 drops of water. However, owing to the cohesive forces that made the water molecules stick together and the adhesive forces that made them attach to the coin surface, as many as 36 drops could be added before the cohesive and adhesive forces were disrupted and the water flowed off from the surface.

Part 4: Capillary Action

Experimental Procedure

1. A drinking glass was filled with 0.5 cups of tap water.
2. To the water, 1 mL of red food colouring substance was added.
3. A celery stalk with leaves was taken and the stalk was cut diagonally.
4. The cut stalk was immediately placed in the coloured water and incubated for 4 hours.
5. At the end of the incubation period, the celery stalk and leaves were observed and the observations were recorded.

Observation

After an incubation period of 4 hours, the celery was examined and it was seen that it had taken up the colour of the red food colouring substance and the stalk and leaves appeared red in colour.

Analysis

The cohesive and adhesive properties of water make the water molecules stick to each other and also to the surface with which they make contact. These properties of water make it move up very thin tubes or capillaries such as those found in plants by means of capillary action. When water is mixed with a red food colouring substance, the molecules of water stick to the molecules of the dye carrying them up the celery stalk via capillary action. This makes the stalk and leaves of celery appear red in colour.

In nature, this capillary action of water is a very important phenomenon that helps plants survive and thrive. The roots of the plants draw water and nutrients from the soil and by means of capillary action, these nutrients are distributed to all the leaves of the plant. There are very narrow capillaries running throughout the plant that aid this process helping the plant get essential nutrients and water for photosynthesis from the soil.

PREPARATION OF pH INDICATORS FROM ANTHOCYANINS

Exercise 2

Name

Date

Course Name

Abstract

Several pigments found in nature have the capacity to change colour in different acidic and basic environments. One such pigment is Anthocyanin that is found in red cabbage. This pigment, when absorbed in filter paper, enables the strip to change colour in different acidic and basic environments so that the colour change can be visibly seen when tested with common household and other naturally occuring substances. In this exercise, homemade pH strips were made by staining filter paper pieces with the anthocyanin pigment present in red cabbage.

Experimental Procedure

1. A red cabbage was taken and its outer leaves were removed. Using a knife, the cabbage was chopped into roughly shaped small pieces about 1 inch in size.
2. In a vessel, 1 cup of water was taken and boiled on a stove. When the water started boiling, it was carefully transferred to a heat-safe container.
3. Around 1 cup of chopped cabbage was added to the container filled with boiling water.
4. A spoon was used to completely immerse the cabbage in the water and it was left for 20 minutes.
5. After 20 minutes, a spoon was used to mix the contents of the water so that the deep purple colour of the water was evenly distributed in the container.
6. A filter paper was taken and cut into 4 equally sized pieces.
7. One of the filter paper pieces was placed in the container ensuring that it was fully submerged in the coloured water. The filter paper was allowed to remain in the bowl and absorb the water for 5 minutes.
8. After 5 minutes, the filter paper was removed from the container and placed on a tray for drying.
9. The 5-minute submersion and drying steps were repeated for the remaining 3 pieces of filter paper.
10. The cabbage and coloured water were discarded and the drying of filter paper pieces was allowed to take place for 4 hours.
11. After the drying period, the filter paper pieces were cut into strips of size 0.5 cm x 5 cm.
12. These filter paper strips served as ‘homemade pH paper’ for the subsequent exercise.

Observation

When the cabbage pieces were submerged in boiling water, it was noticed that it started oozing out purple colour into the surrounding water. This colour stained the filter paper that was later immersed in the water making them coloured pH strips.

Analysis

Like a lot of plants, red cabbage contains the pigment Anthocyanin that has the ability to change colour depending on the acidity of the surrounding environment. It is purple in colour in a neutral environment, reddish-pink in an acidic environment, and bluish-green to yellow in a basic or alkaline environment. Hence, although not accurate, filter paper strips stained with this pigment can serve as pH strips for testing the acidic or basic nature of substances.

TESTING COMMON HOUSEHOLD MATERIALS

Exercise 3

Name

Date

Course Name

Abstract

pH is a measure of the concentration of hydrogen ions and hydroxide ions in a solution. It is a logarithmic scale with numbers in the range of 0 to 14, where 7 indicates neutral, lower pH values indicate acidity, and higher pH values indicate basicity of a solution. The pH of a substance is important in determining the properties of a solution such as the cleansing properties of soaps, washing detergents and cleaning solutions. It is also very important for industrial applications where the outcome of chemical processes depend on the starting hydrogen ion concentration of the reactants. In this exercise, homemade pH strips from the previous experiment and commercially available pH strips were used to test the pH of 12 different substances in order to classify them as acids or bases.

Experimental Procedure

1. Liquid household items were collected for pH testing which included shampoo, soap, lemon juice, soda, milk, and washing detergent.
2. A 24-well plate was taken for pH testing and labelled appropriately.
3. Safety goggles and gloves were worn and hydrochloric acid (HCl) and sodium hydroxide (NaOH) were added to Well-1 and Well-2 of the plate respectively using a pipette.
4. Distilled water was added to Well-3 of the plate using a pipette.
5. Each of the collected household items was added to the subsequent wells of the plate using a fresh pipette for each item.
6. The pH strips were collected and 12 commercial pH strips and 12 homemade pH strips were placed in two separate piles.
7. The commercial pH colour range guide was placed next to the plate for easy observation of change in colour. Each of the 12 commercial strips was placed one by one in each of the 12 samples in the wells and the colour change was observed and recorded.
8. The procedure was repeated using homemade pH strips and the standard colour range guide was used to observe and record the colour change.
9. Based on the observations, each substance was classified as acidic, basic, or neutral.

Observation

The commercial and homemade pH strips were used to test a total of 12 items for their acidic or basic nature. Apart from 9 common household items, standard HCl solution, standard NaOH solution, and distilled water were also used for pH testing. In each case, the colour change was noted and comparing to the colour range guide, the pH of the item was determined. The colour change observations using both types of strips are provided in Table 1.

It can be seen from Table 1 that the colour change that can be expected from commercial and homemade pH strips for the same acidity or basicity is different. Also, the colour changes in the commercial pH strips were found to be more accurate and distinctive as compared to the colour changes of homemade pH strips. Hence, commercial pH strips are more suited for industrial applications for which accurate pH of solutions needs to be deduced.

Well Plate	Item Tested	Commercial pH strip		Homemade pH strip	
		Color	pH	Color	pH
1	HCl (hydrochloric acid)	Orange	2	Light purple	2
2	NaOH (sodium hydroxide)	Purple	13	Dark yellow	13
3	Distilled water	Green	7	Blue	7
4	Shampoo	Green	5	Blue	5
5	Soap	Violet	12	Dark yellow	12

6	Lemon juice	Orange	2	Light purple	2
7	Soda	Light orange	3	Purple	3
8	Milk	Green	6	Blue	6
9	Washing detergent	Light blue	8	Blue	8
10	Apple juice	Yellow	4	Purple	4
11	Baking soda	Blue	9	Green	9
12	Toilet cleaning solution	Dark purple	14	Dark yellow	14

Table 1: Colour changes and the corresponding pH for 12 items including 3 standard solutions and 9 household items

Based on the pH deduced for each substance using the colour guide, each item was classified as acid, base, or neutral. This classification of the tested substances is provided in Table 2.

Well Plate	Item Tested	Acid/Base/ Neutral?	Explanation:
1	HCl(hydrochloric acid)	Acid	The colour change in the commercial and homemade strips was quite accurate.
2	NaOH(sodium hydroxide)	Base	The colour change matched the pH range in both commercial and homemade strips.
3	Distilled water	Neutral	The sample showed neutral colour range in both cases.
4	Shampoo	Acid	The sample showed colour changes in the acidic range.
5	Soap	Base	The soap sample was found to have a higher pH from the colour range guide.
6	Lemon juice	Acid	The colour change was, without doubt, in the acidic range.
7	Soda	Acid	The sample showed acidic colour change.
8	Milk	Neutral	The colour change was tending to neutral in both strips.
9	Washing detergent	Base	The colour change was in the range higher than neutral.
10	Apple juice	Acid	The colour change was clearly acidic.
11	Baking soda	Base	In both cases, the colour change was in the basic range.
12	Toilet cleaning solution	Base	The colour change was, without doubt, basic.

Table 2: Classification of tested substances as acid, base, or neutral based on the colour change

Analysis

A pH scale is a universal scale that is used to determine the acidity or basicity of a given solution. Solutions that are neutral have a pH of 7, while acidic solutions have a lower pH value and basic solutions have a higher pH value. The pH scale is logarithmic and is inversely proportional to the concentration of hydrogen ions in a solution; for example, a lower pH value indicates a higher concentration of hydrogen ions, which is the case with acidic substances and vice versa. For standard solutions, HCl has a pH of 1 and NaOH has a pH of 14. The pH values of most other substances lie within this range. Based on the pH values, substances may be classified as strong acids, strong bases, weak acids, and weak bases. This determination is especially important in industrial reactions where accurate classification of substances based on their hydrogen ion concentration is important for success of the reaction.

Several pigments found in plants such as hibiscus and red cabbage, and red wine can serve as suitable pH indicators. However, this method of pH testing is not very accurate and should only be used for approximation of pH values of substances. Based on the observations in this experiment, it was seen that the colour changes in commercially available strips was more distinct and the colour range guide was helpful in immediately identifying the pH of a solution. On the other hand, the homemade pH strips didn’t show distinct colour changes and was only useful in determining if the substance fell in the acidic, basic, or neutral range. Hence, for highly specific chemical reactions, commercially available pH strips are more reliable in determining the pH of a substance as compared to homemade pH strips.

BUFFERS IN A LIVING SYSTEM

Exercise 4

Name

Date

Course Name

Abstract

Buffers are solutions that retain their pH within a stable range even upon the addition of small volumes of strong acids or strong bases. They are conjugates of usually a weak acid and its salt or a weak base and its salt depending upon the pH range required. The addition of acids or bases to a buffer solution drive the dissociation of the weak acid or weak base one way or the other, thus maintaining equilibrium in the solution. Buffers are not only important for industrial applications where a stable pH needs to be maintained, but they are also an important part of living systems to ensure that the blood pH is maintained within a constant range so that all tissues and organs in the body function optimally. This experiment demonstrates the difference in pH when a strong acid is added to a buffered and an unbuffered solution.

Experimental Procedure

1. Using a graduated cylinder, 50 mL of distilled water was measured two times and taken in two plastic cups.
2. A digital scale was used to weigh 0.4 g of sodium bicarbonate powder and was added to one of the plastic cups. This was labeled as buffered solution and was stirred to mix well. The other cup was labeled as unbuffered solution.
3. One end of a drinking straw was immersed in the solution and a mouthful of air was blown through the straw for two minutes to introduce carbon dioxide in the solution.
4. The buffered solution was stirred well to mix the contents of the cup.
5. Using commercial pH strips, the pH of the buffered and unbuffered solutions was observed and recorded as Initial pH.
6. To both solutions, 3 drops of 1 M HCl was added and stirred to mix the contents well. The pH of both the solutions was observed and recorded.
7. The addition of HCl drops was continued in batches of three until a total of 18 drops was reached. After the addition of every subsequent batch of three drops, the pH of both the solutions was measured and recorded.
8. Using the results, a graph was created to track the changes in pH in the buffered and unbuffered solutions.

Observation

The pH of buffered and unbuffered solutions was measured after adding every three drops of HCl and the measured pH values were recorded. It was noticed that in case of the unbuffered solution, the pH value fell to 0 as soon as the first three drops of HCl were added and it remained at 0 for every subsequent addition of HCl. On the other hand, the buffered solution showed a marked resistance to changes in pH upon addition of HCl and it did not show a drastic fall in pH like the unbuffered solution. The pH values of both the buffered and unbuffered solutions are shown in Table 3.

	Un-buffered Solution	Buffered Solution
Initial pH	7	7.4
+ 3 drops HCl	0	7.1
+ 6 drops HCl	0	7
+ 9 drops HCl	0	6.8
+ 12 drops HCl	0	6.7
+15 drops HCl	0	6.5
+18 drops HCl	0	6.2

Table 3: Observation of pH values of buffered and unbuffered solutions after addition of every subsequent three drops of HCl

A graphic representation of the pH values of the buffered and unbuffered solutions is given in Figure 1.

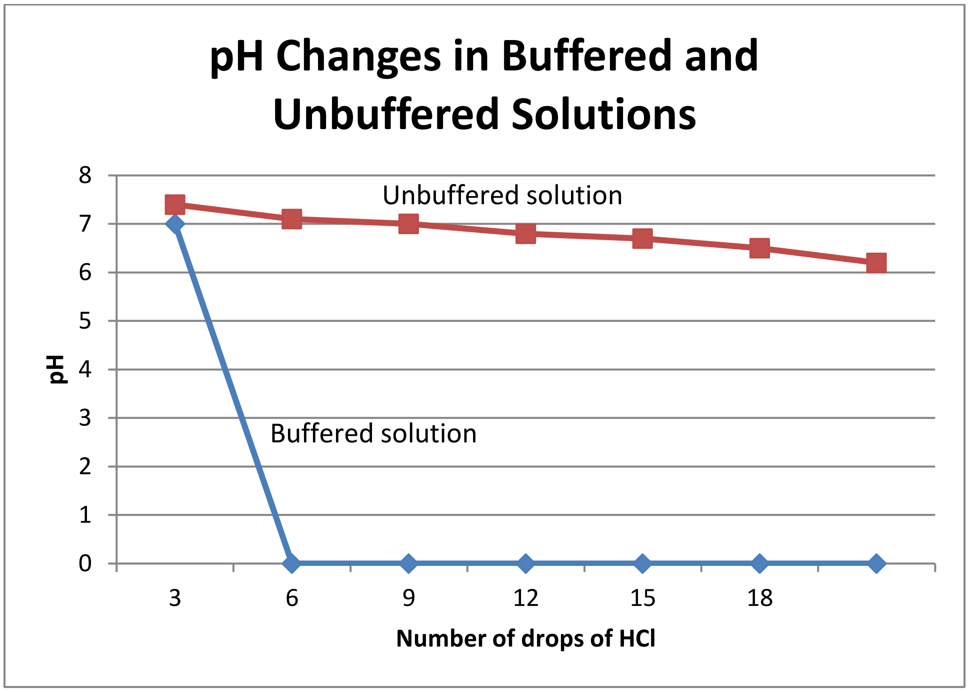

Figure 1: Graph showing the fall in pH for buffered and unbuffered solutions upon addition of HCl. The blue line indicates pH changes for the unbuffered solution and the red line indicates pH changes for the buffered solution.

Analysis

Buffers are solutions that can resist changes in pH upon the addition of acids or bases. These are widely used in industrial processes where it is imperative to maintain pH within a specific range for the successful outcome of the process. Buffers are usually made of a weak acid and its salt or a weak base and its salt. They can have any stable pH range, but what sets them apart from other solutions is that they resist changes in pH and retain their pH value even upon the addition of small volumes of strong acids and strong bases. In this experiment, the unbuffered solution shows a massive drop in pH from 7 to 0 upon the addition of HCl. However, the buffered solution shows very small changes in pH even after the addition of a slightly larger volume of HCl indicating that the buffer balances out the hydrogen ion concentration of the strong acid and retains its pH value.

The buffer system that was used in this experiment was the sodium bicarbonate – carbon dioxide system that is found in blood of living organisms. It is important that the pH of the blood is maintained between 7.35 and 7.45 otherwise body tissues may get damaged due to the imbalance in pH. In solution, sodium bicarbonate dissociates into sodium and bicarbonate ions, and the carbon dioxide produced as a result of cell metabolism drives this dissociation to ensure balance of pH.

In the absence of a functional blood buffer system, imbalance in the levels of carbon dioxide and oxygen in the blood can lead to acidosis or alkalosis. When breathing rate increases, more oxygen is taken into the body and the carbon dioxide levels drop. This causes the pH of the blood to increase and become alkaline, resulting in alkalosis. On the other hand, if the breathing rate is lowered, the levels of carbon dioxide in the blood increase causing the pH to drop. As a result, the blood becomes more acidic causing respiratory acidosis.