Intermediate General and Applied Science

Chemistry Module: Lab Manual

Developed by Christine Miller © 2018

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KEEP CALM
AND
WEAR YOUR
LAB COAT

Getting to Know Your Lab Manual

Each lab is designed to include a pre-lab reading and assignment, three activities, and a post-lab assignment. The pre-lab **reading** needs to be completed **before** you come to lab. The pre-lab **assignment** is due at the beginning of the lab and includes questions and activities based on the pre-lab reading. The three lab activities are designed to fit into a two-hour lab. The post-lab assignments are typically due within the week after the lab has been completed. However, due dates are ultimately set by your instructor.

Being familiar with the symbols in your lab manual will help you know what you are supposed to be doing during specific lab activities. There are symbols in this manual that indicate which type of activity is required. Below is a table summarizing these symbols.

Symbol	You should:
MARK: ____ **10**	This symbol is included on the pages that willbe handed in for marks. These pages will be either a pre- or post-lab assignment, and your instructor will let you know when it is due.
?	A simple question mark next to any of the text in your lab manual means that you are supposed to be thinking about the question being asked, but that you don't need to record an answer.
	This icon means that there is a question in your lab manual that you need to answer in writing in the space provided.
	This icon means that before proceeding, you need to check in with your instructor.

Lab 1: Safety and Measurement

Pre-Lab Reading 1

Safety (Student copy)

Safety in the lab is a serious issue. Some of the equipment and chemicals we use can be harmful if safety rules are not followed. Here are some guidelines to help you and others stay safe in the lab:

Plan Ahead	•Read your lab ahead of time. •Ask any questions before you start.
Stay Organized	•Keep your lab bench clear of unneccesary items. •Know ahead of time where safety equiment is in the lab.
Protect yourself	•Know where all safety equipment is in the lab. •Wear a lab coat at all times, and safety goggles as required. •If you get a chemical on your skin, rinse it immediately with plenty of water. •Do not eat or drink in the lab.
Report Accidents	•Let your teacher know right away if you spill something, break something, or get hurt.
Use Equipment Properly	• Be careful of cords, and unplug them properly. • Handle hot items with the approriate tools. • If you're not sure how to use/store something, ask your instructor.
Clean Up Afterwards	•Put everything away. •Clean your glassware and leave it to dry. •Wipe down your work area. •Wash your hands.

Hazard symbols are often found on the labels of chemicals we will be using in the chemistry lab. These symbols give us information about the possible dangers of using each type of chemical. You can find these symbols on certain household products as well. On the next page, you will find some examples of chemical hazard symbols. It is important to follow all safety precautions on the labels of substances we are using in the lab.

I understand the safety rules listed above and agree to follow them: (Student copy)

Name: ______________________   Signature: _____________________ Date: ___________________

Safety (Instructor copy)

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Name: ______________________ Signature: ___________________ Date: ___________________


CHEMICAL HAZARD SYMBOLS
Chemical hazard symbols are found on some home products, as well as bottles of chemical reagents in the lab. Here, we take a look at European hazard symbols and the various dangers that they warn of.
ENVIRONMENTAL HAZARD
Indicates substances that are toxic to aquatic organisms, or may cause long lasting environmental effects. They should be disposed of responsibly.
ACUTELY TOXIC
Indicates life-threatening effects, in some cases even after limited exposure. Any form of ingestion and skin contact should be avoided.
GAS UNDER PRESSURE
Container contains pressurised gas. This may be cold when released, and explosive when heated. Containers should not be heated.
CORROSIVE
May cause burns to skin and damage to eyes. May also corrode metals. Avoid skin & eye contact, and do not breathe vapours.
EXPLOSIVE
May explode as a consequence of fire, heat, shock or friction. Chemicals with this label should be kept away from potential ignition sources.
FLAMMABLE
Flammable when exposed to heat, fire or sparks, or give off flammable gases when reacting with water. Ignition sources should be avoided.
MODERATE HAZARD
May irritate the skin, or exhibit minor toxicity. The chemical should be kept away from the skin and the eyes as a precaution.
OXIDISING
Burns even in the absence of air, and can intensify fires in combustible materials. Should be kept away from ignition sources.
HEALTH HAZARD
Short or long term exposure could cause serious long term health effects. Skin contact and ingestion of this chemical should be avoided.
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BY NC ND

Measurement

We often go through the process of measurement in science to get information about "how much". Measurement results in both a number (giving information about quantity) and a unit (a standard accepted value attached to the amount).

Scientists use SI (Standard International) Units. In SI Units, the metre is the basic unit of length, the gram is the basic unit of mass, and the second is the basic unit of time. In addition to using basic units, we can add prefixes to show units in multiples of 10. For example, you would not measure the distance from your home to school in metres, but you may use *kilo*metres. The prefix *kilo* means 1000, and a kilometer contains 1000 metres. When measuring medications, pharmacists often need to use very small amounts of substances. A gram would be too large, so the unit of *milli*grams is used. The prefix *milli* means divided by 1000, meaning that 1 milligram is equal to one one-thousandth of a gram.

In addition, units are often abbreviated. Instead of writing out the entire unit, a symbol is used. For example, instead of writing gram, you might put simply the letter "g" which is the accepted symbol for grams. If your unit has a prefix in front of it, you would include that in the symbol also. This is why kilometres can be shortened to km.

See the table below for frequently used metric quantities, units and symbols. The standard or base unit is bolded.

Quantity	Unit	Symbol
Length	kilometer **metre** millimetre micrometre	km **m** mm µm
Mass	kilogram **gram** milligram	kg **g** mg
Volume	cubic metre **litre** millilitre	cm^3 **L** mL
Time	second minute hour	s min hr
Temperature	degree Celsius	°C
Amount of Substance	mole	mol
Electric Current	ampere	A

Pre-Lab Assignment 1

Name: ____________

MARK:

____

10

1. Why is it important to wear your lab coat in the lab? *(1 mark)*

2. What should you do if you accidentally break glassware in the lab? *(1 mark)*

3. Read the safety label below. What do you know about the substance? *(2 marks)*

Sodium Imaginate, C. Miller, 2018 [CC BY-SA]

4. What is the difference between flammable substances and oxidizing substances? *(2 marks)*

5. Use arrows to match the quantity on the left to its appropriate unit on the right: (4 marks)

Length	Grams
Mass	Metres
Amount of Substance	Litres
Volume	Moles

Activity 1: Measuring Volume

Measuring Volume of a Liquid

Volume is the amount of space a substance takes up. Today, we will be measuring the volume of both solids and liquids. The units we use for measurement of volume can vary based on what type of substance we are measuring. For example, I may measure the volume of a liquid in millilitres (mL), but the volume of a solid in cubic centimetres (cc). We also use different tools for measuring volume depending on the quantity, nature and shape of the substance we are measuring. For example, when cooking, you often measure salt using a tablespoon, but when renting storage space you measure the volume in cubic metres.

What are some liquids you measure in your daily life? What units do you use to measure these liquids?

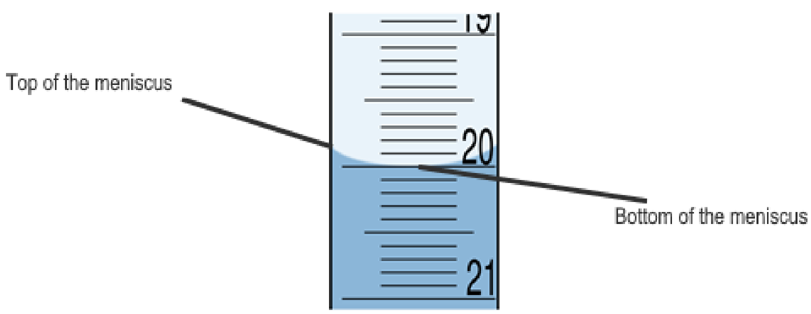
____

____

____

Take one of the plastic cups, fill it up to the line with water, and pour it into a 250 mL graduated cylinder.

Place the graduated cylinder on a flat surface and get into a position that lets you view the top of the liquid at eye level. When measuring liquids, there is a **meniscus.** The meniscus is a curve at the top of the liquid where it meets the sides of its container.



Measuring with a Meniscus.
Adapted from [Meniskus - verschiedene Varianten], by B. Lachner, Openclipart.org [[CC0 1.0]]

The bottom of the meniscus is where the measurement should be taken. So in the diagram above, the level reads as 20 mL.

What is the volume of water in your graduated cylinder?

What would have been the measurement if you had accidentally read from the top of the meniscus?

In what situation would this type of error cause serious problems?

Pour out approximately half of the water and re-measure the amount. Now what is the volume of water in your graduated cylinder?

Use water from the sink and the pipettes provided to make sure that you have exactly 100 mL of liquid in your graduated cylinder.

Show your instructor and set this aside to be used in Activity 1B.

Measuring Volume of a Solid

When measuring the volume of a regular solid (such as a rectangular prism or a cube), we can use the dimensions of length, width and height to calculate volume. The measurement of 1 cubic centimeter in a solid corresponds to 1 mL when measuring a liquid.

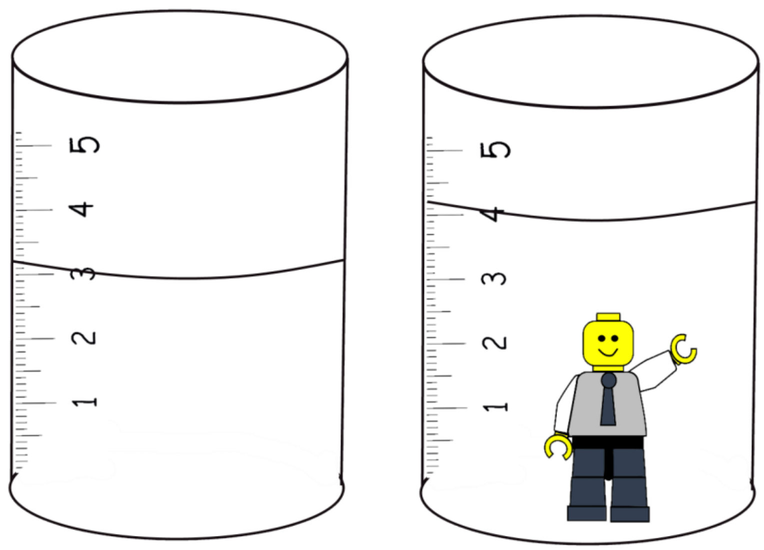
Measure the dimensions of your rectangular prism. (I measured prism ________.)

Length: ____cm Width: _____ cm Height: _____cm

The formula for volume of a rectangular prism is Length × Width × Height. Calculate the volume of your rectangular prism.

Your measurement is in cm^3. This corresponds to mL. What is your volume measurement in mL?

Measuring an irregularly shaped solid can be more difficult, since measurements of length, width and height will not help you calculate volume. In order to calculate the volume of an irregular shape, we can use a method called **displacement.** In this method, water is placed in a measuring tool (like a graduated cylinder or a measuring cup) and the level recorded. Then the object is placed into the water, and the increase in water level is equal to the volume of the object. Think about this in the context of getting into a hot tub: every time another person enters the hot tub, the water level rises the amount of space (volume) they take up. In the diagram below, the mini figure takes up approximately 1 mL of volume.



Measuring with displacement, Adapted images from mbnachhilfe_de (ruler)
and GDJ (Lego figures, via Pixabay [CC0]

Take one of the figurines from the lab supplies. Take a close look at the shape—is it irregular or regular? Could you measure it with a ruler? What makes this possible, or not possible? If you were to guess, how many cubic centimetres do you think it takes up?

Take your graduated cylinder you set aside after Activity 1B. The water level should be at exactly 100 mL. Gently drop the figurine into the water, and determine the new volume measurement.

What is the new volume in the graduated cylinder? What was the total increase from the 100 mL that were originally in the graduated cylinder? How many cubic centimetres is your figurine?

New Volume: _______   Total Increase: _______   Cm^3:_________

Activity 2: Measuring Mass

Mass is a measure of the quantity of matter and is related to weight. We typically use grams or kilograms to measure mass, since these are the SI units. Some people use ounces and pounds to measure mass, which is the Imperial unit of mass.

What are some things you might weigh in your daily life? What units do you usually use? What are some of the tools you use to make these measurements?

Item	**Unit**	**Measuring Tool**

Obtain a pocket scale. Examine the three buttons it has. What do you think these are for? Does the scale look easy to use? What types of things do you think people weigh with a pocket scale?

Take your scale and hit the “on” button. What is the reading that comes up initially? If it is not a zero, you can use the “tare” or “zero” button to reset the scale to zero.

Pour the water out of your graduated cylinder and remove your figurine and dry it off. Place the figurine on the scale.

How much does your figurine weigh? Include the units of this measurement.

Using your scale, weigh a few items you have around you, either from the lab or from your school supplies.

Record the items and their weights in the table below:

Item	Weight

What would be some items that would be difficult to weigh on the scale provided?

Take a look at the different types of scales on display. What types of things are they used to weigh? Does this change the units we use to measure weight?

Fill in the table below:

Type of Scale	Typical Use	Unit of Measurement	Other Possible Uses
Body Weight Scale			
Luggage Scale			
Kitchen Scale			

Activity 3: Measuring Temperature

Temperature is a measure of the heat energy present. The SI unit of measurement of temperature is degrees Celsius. The Celsius scale is based on the boiling and freezing points of water: 0 °C is the freezing point of water, and 100 °C is the boiling point of water. The tool we use to measure temperature is called a thermometer.

When do you use a thermometer in your daily life? Try to think of more than one example.

Take a general use thermometer from your instructor. What are the scale increments on your thermometer? What do you think it is made of? What do you think the purpose of this type of thermometer is?

Fill a beaker with approximately 200 mL of warm/hot tap water, and set it to the side. Also fill a small 25 mL graduated cylinder with warm/hot tap water and set it aside. Make sure you have a thermometer for each of these containers.

Read your thermometer to make sure you can accurately read the room temperature. You are going to graph the change in temperature of your water in increments of 1 min over a span of 10 minutes. Fill your results into the table below:

***Note:** once you put the thermometer into your warm water, allow the thermometer a few seconds to adjust to the temperature so that you get an accurate reading.

Complete the table below.

Time	**Temperature (200 mL)**	**Temperature (25 mL)**
Initial (time 0)*		
1 minute		
2 minutes		
3 minutes		
4 minutes		
5 minutes		
6 minutes		
7 minutes		
8 minutes		

9 minutes		
10 minutes		

Was the decline in temperature regular (did it go down by the same amount every minute)? Was the rate of decline the same for both containers? Did the temperature drop more or less quickly than you had expected? Do you think you would see the same trends if you started with ice water, and waited for the temperature to increase?

Obtain a body temperature thermometer from your instructor. What are some of the buttons on it? What units of temperature does it use? Hold the thermometer in your hand and read this temperature. Do you think this is an accurate measure of your body temperature?

Use a computer or your phone to look up what normal body temperature is in both degrees Celcius and degrees Farenheit and record them.

Which unit of temperature do you use when cooking? When reading the temperature outdoors? When taking a body temperature?

Challenge: Tricky Volumes

If you have time at the end of your lab, try finding the volume of the additional items provided by your instructor.

Item 1:

What is the challenge with finding the volume of this item?

How will you overcome this challenge?

Volume of item 1: ______________

Item 2:

What is the challenge with finding the volume of this item?

How will you overcome this challenge?

Volume of item 2: ______________

Item 3:

What is the challenge with finding the volume of this item?

How will you overcome this challenge?

Volume of item 3: ______________

Post-Lab Assignment 1

Name: _____________

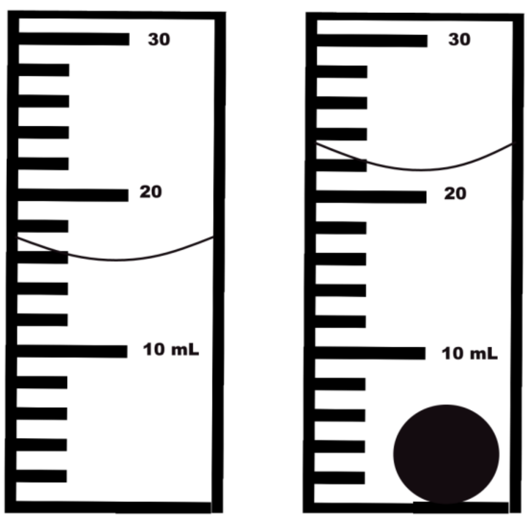
MARK:

______
20

1. List some of the types of safety equipment you saw in the lab: *(2 marks)*

2. How do you account for the meniscus when measuring the volume of a liquid? *(2 marks)*

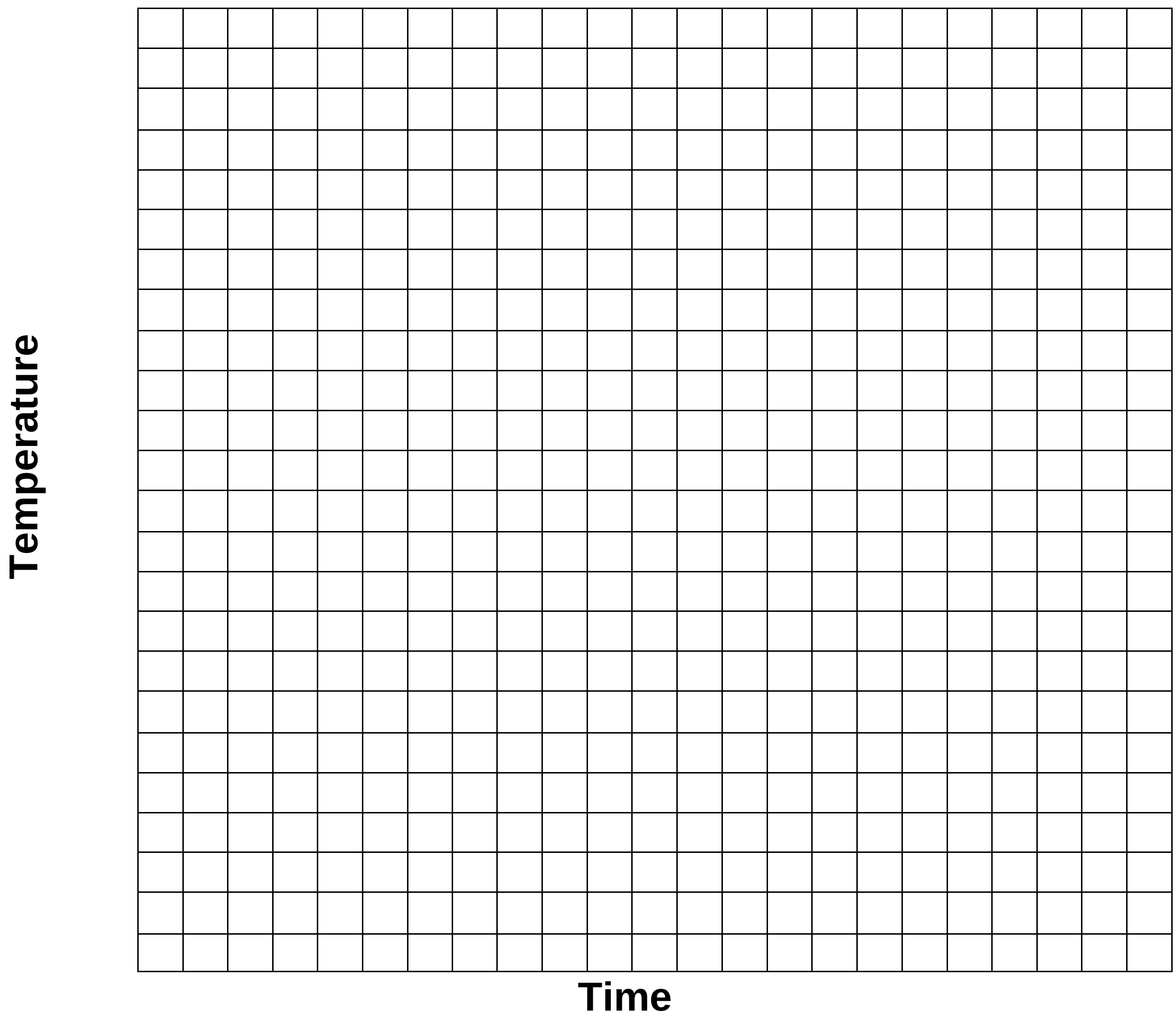
3. In the diagram below, what is the volume of the sphere? *(1 mark)*



4. What are some factors to consider when choosing which type of scale to use when measuring weight? *(2 marks)*

5. What is the Celsius scale based upon? *(1 mark)*

6. Create a graph of the changes in temperature over time based on your results from Activity 3 in the lab. Include appropriate units, and graph increments on your graph. *(9 marks)*



7. How would your graph have look differently if you had been recording the temperature of ice water over time? *(1 mark)*

8. What are some measurement tools you have used in the past week in your daily life? What did you use them for? *(2 marks)*

Lab 2: Rate of Reaction

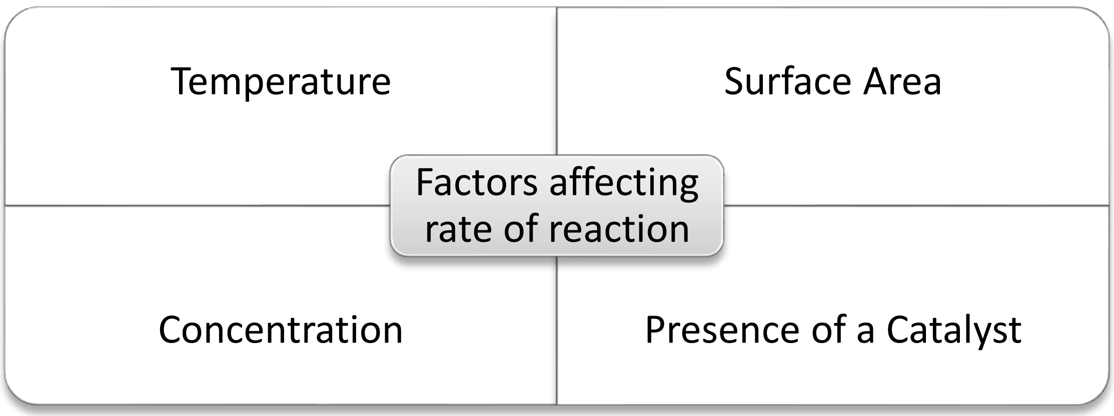
Pre-Lab Reading

Rate of Reaction:

What speed do you drive on a highway? What speed do you drive in a school zone? We measure our driving speed in kilometers per hour- this is a **rate**. It is a measure of how far you drive over a certain amount of time.

Similarly to rate of driving speed, we can also measure the speed at which a chemical reaction takes place. This is called the **rate of chemical reaction.** We do this by measuring how much **reactant** is converted to **product** over a certain amount of time.

Understanding the factors that affect reaction rates can help us speed up or slow down chemical reactions. The four main factors that affect reaction rate are: temperature, surface area, concentration, and presence of a **catalyst**.



There are certain chemical reactions we would like to slow down:

- Rust on your car
- Cut apples turning brown
- Food spoilage

Food spoilage is often a result of foods reacting with oxygen in the air. Many ways of preserving foods have to do with making sure oxygen does not come into contact with the food. Canning heats and then seals foods so that oxygen cannot enter. Vacuum packing foods seals out oxygen, and these foods are often packed with an unreactive gas like nitrogen or argon. B**utylated hydroxytoluene** (BHT), a common food preservative, binds with any oxygen, stopping the oxygen from oxidizing the food.

There are other chemical reactions we would like to make occur more quickly:

- Converting graphite to diamond (to create “lab” diamonds)
- Dissolving calcium buildup in your shower
- Ripening a banana

Many fruits are actually picked when they are not yet ripe. During the process of ripening, starch in the fruit is converted to sugar. This is why a green banana does not taste sweet- all of the sugar is still in the form of starch, which is not a sweet-tasting substance. A ripe banana has had time to convert the starch to sugar and tastes sweeter. Many bananas are picked while they are still unripe and green. The bananas are transported to their destination countries and, once there, ripened in chambers filled with ethylene gas, a gas which speeds up the ripening process, converting starch to sugar, and changing the skin colour from green to yellow.

Each of the six bulleted reactions listed above can be sped up or slowed down by manipulating one or more of the four factors that affect the rate of chemical reactions.

In biological systems, a **catalyst** can also be termed an **enzyme.** Enzymes are made by cells in your body and they have the purpose of increasing the rate of chemical reactions. Enzymes are used in all types of chemical reactions in your body. Here are just a few examples:

- Breaking down large molecules that you eat so that they can be absorbed into your bloodstream.
    - Starch is broken down into glucose with the help of the enzyme amylase.
    - Proteins are broken down into amino acids with the help of the enzyme protease.
    - Nucleic acids are broken down into nucleotides with the help of the enzyme nuclease.
- Breaking down hormones once your body does not need them anymore.
- Making new copies of DNA for the purpose of cell division.
- Breaking down glucose to extract the energy in its bonds.

You use the strategy of increasing surface area to change the rate of reaction when you chew your food. If you swallowed your food whole (like a snake) there would not be as many of the molecules in your food available to be in contact with your enzymes.

What effect on rate of reaction do you think this would have?

Concentration and temperature both have the same effect on rate of reaction. This is because reactions happen when particles collide—and temperature and concentration both affect the odds that two particles will have a collision and undergo a chemical reaction.

Pre-Lab Assignment

Name: _____________

MARK:
______
10

1. What are the 4 factors that affect the rate at which a reaction occurs? *(4 marks)*

2. What is an example of an everyday reaction we would like to have happen more quickly? *(1 mark)*

3. What is an example of an everyday reaction we would like to have happen more slowly? *(1 mark)*

4. Connect the terms to their definition: *(4 marks)*

Enzyme	A substance that speeds up the rate of reaction
Rate of reaction	The total area that the surface of a 3 dimensional object occupies
Surface Area	A biological catalyst
Catalyst	The speed at which reactants are converted to products

Activity 1: Temperature Affects Rate of Reaction

Alka-Seltzer is an antacid and pain reliever used to treat heartburn, stomach upset and indigestion. This product is sold as a tablet, which is placed in a glass of water that you then drink.

Alka-Seltzer tablets have three main ingredients: aspirin, citric acid and baking soda. The citric acid and baking soda do not react with one another while in tablet form, but once they are exposed to water, the two substances react to form water, carbon dioxide, and sodium citrate. Here is the chemical formula for this reaction:

$$3NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3CO_2 + 3H_2O$$

Baking soda + citric acid = sodium citrate + carbon dioxide + water

When this reaction occurs, you can see bubbles forming- this is the carbon dioxide being produced as the reaction occurs. You can roughly compare rates of reaction by how quickly the bubbles of carbon dioxide form; slow bubbling means a slow rate of reaction, fast bubbling means a fast rate of reaction.

Work with a partner. Take three 400 mL beakers from the front of the class. Fill one of the beakers with cold tap water, one with room temperature tap water, and one with hot tap water. Try to make sure that each of the beakers have the same amount of water- about 200 mL. Make sure you label your beakers so you know which is which.

One partner will drop an Alka-Seltzer tablet into each of the three beakers at the same time, the other partner will record the 3 reactions with their phone.

What happens, in general, when an Alka-Seltzer tablet is dropped in water?

What were some indications that a chemical reaction was taking place?

At which temperature did the reaction occur the fastest? How did you know it was occurring faster in these conditions?

Write a statement about the effect of temperature on the rate of chemical reactions:

What are some of the reactions in our daily lives whose rate we control by controlling temperature?

Activity 2: Concentration Affects Rate of Reaction

Baking soda is sodium bicarbonate ($NaHCO_3$). Just like Alka-Seltzer with its acid-base reaction, baking soda will react when placed in vinegar, which is acetic acid (CH_3COOH). This particular reaction is often used in elementary schools to make a “real” volcano. As the acidic vinegar reacts with the basic baking soda, carbon dioxide is produced and leaves the solution in the form of bubbles. Here is the chemical formula for this reaction:

$$\underset{\text{Baking Soda}}{NaHCO_3} + \underset{\text{Vinegar}}{CH_3COOH} \rightarrow \underset{\text{Carbon Dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} + \underset{\text{Sodium Acetate}}{NaC_2H_3O_2}$$

Baking Soda + Vinegar = Carbon Dioxide + Water + Sodium Acetate

Concentration is one of the factors that affects the rate at which a reaction takes place. Design an experiment using vinegar and baking soda that will show how concentration affects rate of reaction. You will need to have at least two variations of concentration. Make sure to record your experiment on your phone.

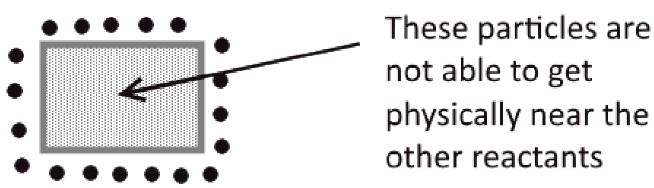
Before you carry out your experiment, what is your:

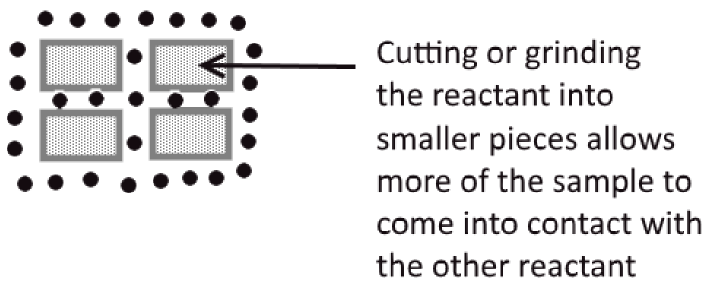
- Hypothesis: ____.
- Independent Variable: ________________________________.
- Dependent Variable: __________________________________.
- Experimental Design: ________________________________.

What were your results? (Which concentrations speed up or slow down reactions?)

Activity 3: Surface Area Affects Rate of Reaction

Rate of reaction is really about how quickly molecules or atoms collide- when a collision results in a change in chemical bonds, a chemical reaction has occurred. So far, in Activity 1, we observed an increase in rate of reaction due to increase in **temperature**. If you recall kinetic molecular theory, particles at higher temperatures are moving more quickly, and may be more likely to collide. We also saw in Activity 2 that **concentration** affects rate of reaction. This is because higher concentration means more particles in a smaller area, which increases the chances that a collision will occur. Another factor that will increase the chance that particles will collide is how much surface area a particular substance has. The larger the surface area, the more particles are available to have a collision and undergo a chemical reaction.





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Take two beakers and fill both with water that is the same temperature. Take two Alka-Seltzer tablets. Grind one of them into a powder, and leave the other as a whole tablet.

Which Alka-Seltzer sample has more surface area?

Which do you think will react more quickly in the water? How will you be able to tell which reacted more quickly?

One partner will drop the Alka-Seltzer into each beaker at the same time. The other partner will record the event on their phone.

Was your guess right? Was it easy to tell which reaction happened more quickly?

Challenge: Make a Mess

With the materials you have (beakers, water, vinegar, baking soda, Alka-Seltzer), what is the fastest (messiest!) reaction you can create? You have 3 tries to make the most explosive reaction you can. Make sure you list the factors you have taken into account on each try.

Attempt #1:

Factors:

Result:

Attempt #2:

Factors:

Result:

Attempt #3:

Factors:

Result:

Name: _______________

MARK:
______
10

Post-Lab Assignment

Watch the video, "[Catalytic decomposition of hydrogen peroxide (aka - elephant's toothpaste, Old Foamy)]", from [ISTscience] on YouTube at http://bit.ly/catalystsreaction.

1. If you want a reaction to happen **more quickly**, what should you do to the temperature? *(1 mark)*

2. If you want a reaction to happen **more slowly,** what should you do to the concentration? *(1 mark)*

3. If you want a reaction to happen **more quickly,** what should you do about the surface area? *(1 mark)*

4. What effect does the presence of a catalyst have on a chemical reaction? *(1 mark)*

5. In the video clip (catalysts reaction), what substance did the scientist add to the catalyst to trap the oxygen which formed? *(1 mark)*

6. What did the scientist say hydrogen peroxide **is not** very useful for? *(1 mark)*

Watch the video, "Effect of temperature on reaction rates" from Amanda Atkins, on YouTube at: https://www.youtube.com/watch?v=y8Tn3b-m_b4.

7. What was the effect of the cold and hot water on the glow sticks? (*2 marks)*

8. What could the creator of this video, Amanda Atkins, have done to improve this experiment? *(2 marks)*

Lab 3: pH Indicators

Pre-Lab Reading

Acids, Bases and the pH Scale

The pre-lab reading below comes from the website Compound interest, at www.compoundchem.com. It is a really neat blog written by Andy Brunning with all kinds of interesting stories related to chemistry. Take a look if you're interested!

The **pH scale** is something we are all familiar with. Most people will remember the pH scale from school chemistry lessons. It is the scale used to rank how strong an acid or an alkali a solution is. The colours associated with each number correspond to the colour that a universal indicator turns in solutions of that particular pH. A fair proportion of people probably do not know the chemistry behind the pH scale, though – where exactly do these numbers come from?

The clues are actually partly hidden in the scale's name. The 'H' in pH stands for the element, hydrogen. On a simple level, the pH scale can be thought of as a ranking of the amount of hydrogen ions in a solution: the more hydrogen ions, the lower the pH number. The 'p' in pH, to chemists at least, stands for the mathematical operation "$-\log_{10}$"(negative log10), or "power". pH, then, is simply equal to $-\log_{10}[H^+]$, where $[H^+]$ is the hydrogen ion concentration in a particular solution. (Note that, strictly speaking, we would usually use H_3O^+ to represent hydrogen ions, as this is the form they take in solutions. However, to keep things simple, we will continue to use H^+) (Brunning, 2017)

Water molecules have the chemical formula H_2O. However, these molecules are capable of splitting up slightly in solution, in H^+ and OH^- (hydroxide) ions. In a neutral solution, the concentrations of these two ions are equal. However, the addition of an acid or alkali can cause them to vary. Acids are a source of hydrogen ions, and adding them to water increases the concentration of hydrogen ions in solution, lowering the concentration of hydroxide ions. For alkalis, the opposite is true: they decrease the concentration of hydrogen ions, while increasing the concentration of hydroxide ions.

Substances are deemed acidic if they have a pH lower than 7, and alkaline if they have a pH higher than 7. **Indicators** are chemicals which change colour at different acidities or alkalinities, allowing us to determine whether a substance is acidic or basic.

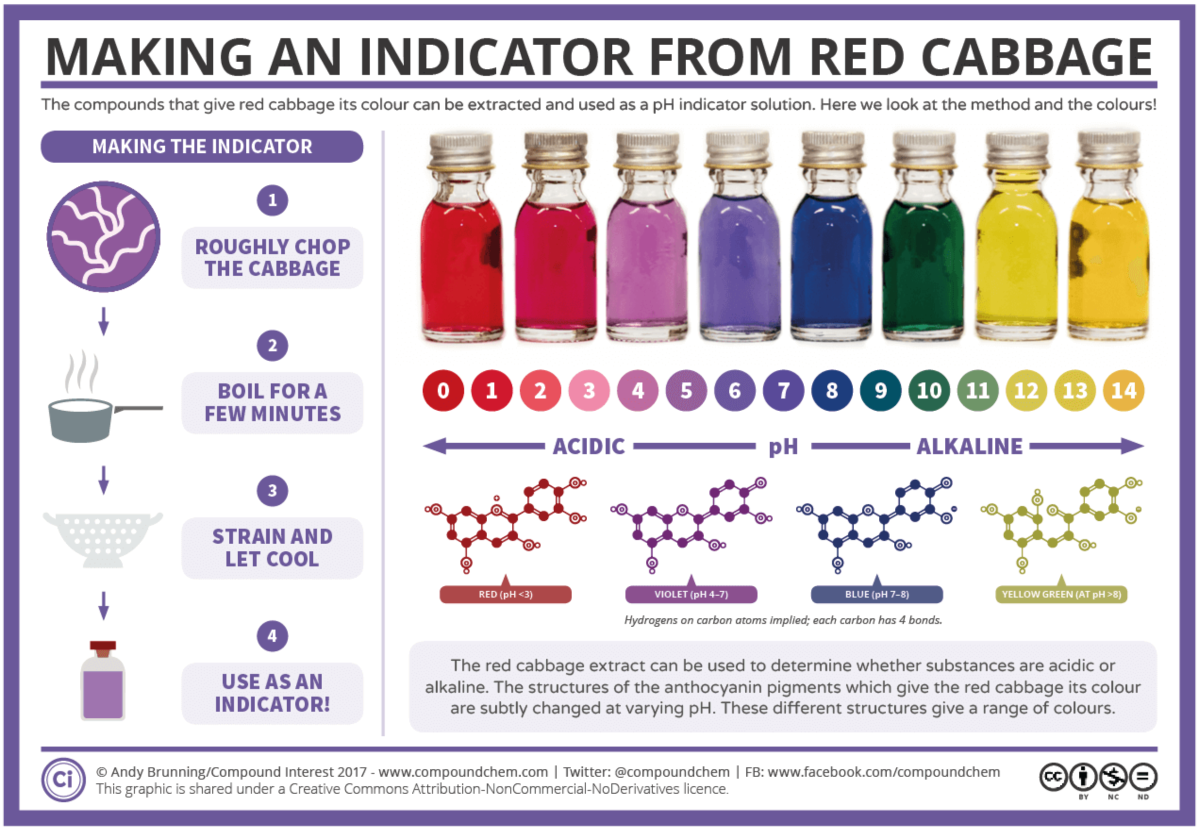
Red cabbage gets its colour from compounds called anthocyanins in its leaves. These anthocyanins are peculiar in that they're pH-sensitive, and this allows them to be used as pH indicators. If they are extracted from the red cabbage leaves by boiling the cabbage in water, the resulting solution can be added to different substances to test them. The pH of the solution they are added to can affect the structure of the anthocyanin molecules, subtly changing them in a way that causes them to appear a different colour, as shown in the graphic below.

Red cabbage is just one example of something you might find at home that can be used in this manner. The red leaves of poinsettia plants, common around Christmas time, can also be used! (Brunning, 2017)

ACIDS, ALKALIS, AND THE pH SCALE

The pH scale is a way of gauging the acidity or alkalinity of a solution. It is calculated using: $pH = -\log_{10}[H^+]$. Adding an acid to water increases the H^+ (H_3O^+) concentration, and decreases the OH^- concentration. An alkali does the opposite.

	pH	H^+ CONCENTRATION (in moles per litre)	OH^- CONCENTRATION (in moles per litre)	EVERYDAY EXAMPLE
ALKALINE (Turquoise → Blue → Purple)	14	1×10^{-14}	1	Drain Cleaner
	13	1×10^{-13}	0.1	Bleach
	12	1×10^{-12}	0.01	Ammonia
	11	1×10^{-11}	0.001	Soap
	10	1×10^{-10}	1×10^{-4}	Antacid Tablets
	9	1×10^{-9}	1×10^{-5}	Baking Soda
	8	1×10^{-8}	1×10^{-6}	Seawater
NEUTRAL (Green)	7	1×10^{-7}	1×10^{-7}	Pure Water
ACIDIC (Red → Orange → Yellow)	6	1×10^{-6}	1×10^{-8}	Urine (average)
	5	1×10^{-5}	1×10^{-9}	Black Coffee
	4	1×10^{-4}	1×10^{-10}	Tomato Juice
	3	0.001	1×10^{-11}	Soda
	2	0.01	1×10^{-12}	Lemon Juice
	1	0.1	1×10^{-13}	Stomach Acid
	0	1	1×10^{-14}	Battery Acid



In this lab, we will be testing the pH of various liquids. **You will need to bring three liquids with you to lab.** It is helpful if these liquids are clear, although it is not necessary. If you bring a hazardous substance (bleach, oven cleaner, paint thinner, etc.) please bring it in its original container so that we have all the safety information provided by the manufacturer. If you bring in food items, please put them in a smaller container since any food that enters the lab is no longer fit to eat.

Name: _______________

MARK:

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Pre-Lab Assignment

1. Do an internet search for natural substances that can be used as indicators. List three of these substances: *(3 marks)*

2. What are some examples of acidic foods we eat on a regular basis? *(2 marks)*

3. Explain why water has a neutral pH. *(2 marks)*

Do an Internet search to answer questions 4 and 5.

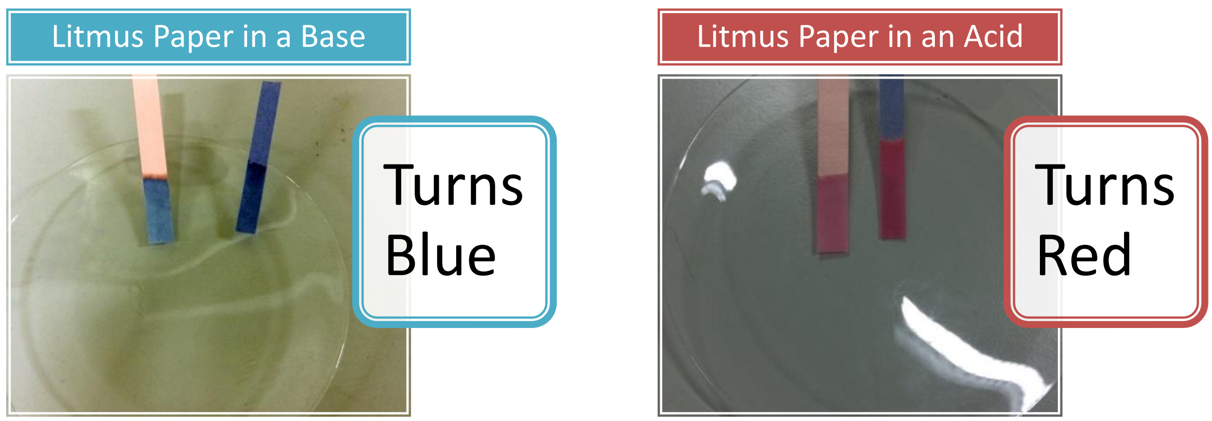
4. Normal body pH is 7.35. What would happen if your pH dropped below this? *(1 mark)*

5. What would happen if your body pH rose above this? *(1 mark)*

6. You need to bring 3 liquids to this lab to test their pH. What are your three liquids? *(1 mark)*

Activity 1: Litmus Paper

Litmus paper is a common indicator used to determine if a substance is acidic or basic. It is made from a combination of pigments extracted from a group of lichens of the *Roccella* genus. There are two types of litmus paper, blue and red. A basic substance causes litmus paper to turn blue. This means that red litmus paper dipped in a base will turn blue, and blue litmus paper dipped in a base will remain blue. Conversely, an acidic substance causes litmus paper to turn red. This means that blue litmus paper dipped in an acid will turn red, and red litmus paper dipped in an acid will remain red. See below for examples:



Litmus Paper Reactions in a Base or an Acid. Adapted from [Blue and Red litmus papers](), and [Blue and Red litmus papers in acid solution](), by Kanasskong, [CC BY-SA 4.0]

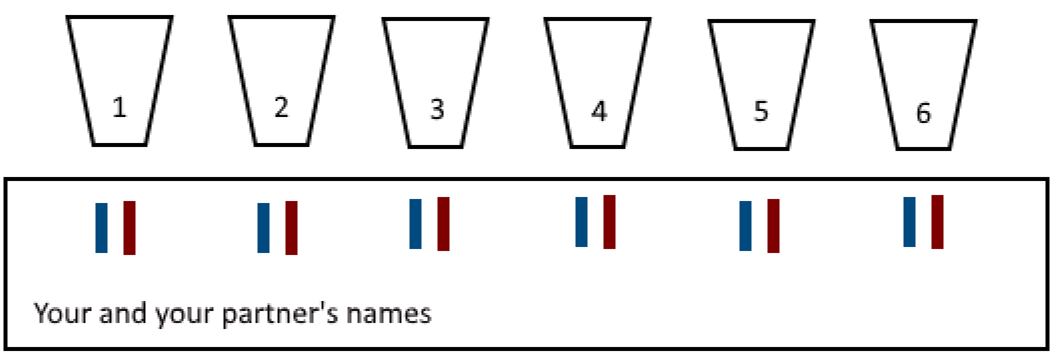
Working with a partner, you will test each of the samples you brought to lab to see if they are acidic or basic. Before we do that though, let's make a hypothesis! Fill out the first column in the table below with your substances, and then the second column with your best guess as to whether each substance is an acid or a base. You can indicate this with an "A" (for acidic) or "B" (for basic). Leave the rest of the table to record your results.

Substance	Hypothesis	Red Litmus	Blue Litmus	Result

Obtain 6 plastic cups, and six strips of both blue and red litmus paper. Handle the litmus paper with forceps (big tweezers) since sweat and oil from your skin can affect them.

As you proceed with the lab, please keep in mind that some of the samples you have brought in may be hazardous. Please follow all the safety instructions on the manufacturer's labels. Use gloves when necessary and rinse any skin that comes into contact with your samples with plenty of water. Inform your lab instructor if this happens.

Label your plastic cups with the name of the sample each will hold. Fill the cups about halfway with the sample. Lay a piece of paper towel in a strip in front of the cups and then place a blue litmus paper strip and a red litmus paper strip in front of each cup. Write your name and your partner's name on the bottom left corner of the paper towel. Your setup should look like this: (instead of numbers on your cups, you will have the name of your sample)



Carefully pick up one end of the red litmus paper, and dip it about halfway into sample 1 and then place it back on the paper towel in front of the sample to dry. Repeat for all of the samples. In the table above, record the colour of the litmus paper exposed to each substance. If the litmus paper remained red, write “red” in the appropriate cell, and if it turned blue, write “blue” in the appropriate cell.

Now repeat the process with the blue litmus paper. Record your results in the table. Take a picture of the cups, paper towel, and used litmus paper with your phone and email it to your instructor.

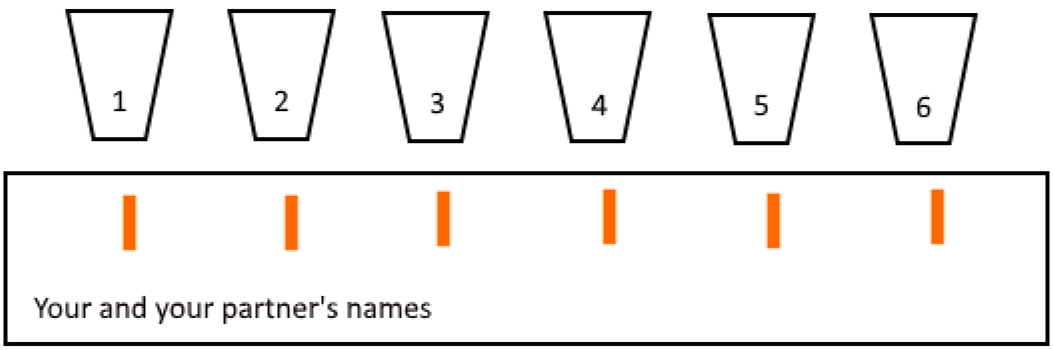
Leave your cups where they are, but roll up the paper towel, with the used litmus paper in it, and discard in the garbage bin.

Activity 2: pH Paper

pH paper is similar to litmus paper in that it gives us information about the pH of a given substance. However, pH paper gives us more detailed information than if the substance is simply acidic or basic. pH paper is made with several different indicator substances and the overall effect is that the paper turns a variety of different colours, based on the specific pH of a substance. You aren't just looking for red or blue, but for a range of colours indicating specific pH values. pH paper usually comes with a key showing which colours correspond to which pHs. See below for an example:

pH Indicator Paper Roll, by Kiyok (本人撮影),
via Wikimedia Commons [CC-BY-SA-3.0]

Using your samples from the last activity, create a similar setup, but instead of the litmus paper strips, lay out the pH paper strips. It should look like this:



C. Miller, 2018 [CC BY-SA]

Using your information from activity 1 about the acidity or basicity of each of your substances, write down your best guess of the exact pH for each of your samples. Record this in the table below.

Substance	Hypothesis	pH Paper	Result

Using the same procedure as you did the for the blue and red litmus paper, dip your pH papers into each of your samples. Record each of the colours and the corrosponding pH values in your table. Take a picture of your lab setup with your phone and email it to your instructor.

Leave your cups where they are, but roll up the paper towel, with the used pH paper in it, and discard in the garbage bin.

Activity 3: Red Cabbage

As you learned in the Pre-Lab Reading for this lab, red cabbage can be used as an indicator of pH. Your instructor has prepared a red cabbage indicator solution according to the instructions you read. Obtain a beaker of this solution and six plastic cups. Using the information you learned about your substances in Activity 2, predict what colour your red cabbage solution will turn when exposed to each of your samples. Record your predictions in the table below:

Substance	Hypothesis	Red Cabbage Solution	Result

Separate the red cabbage solution in your beaker into even amounts in each of the six plastic cups. Pour the remaining amount of your first sample into one of these plastic cups containing the red cabbage solution. Record the colour change, in any, in the third column of the table. Repeat for the rest of your samples.

Take a picture with your phone of the six cups containing the red cabbage solution and your samples and email it to your instructor.

Dispose of the contents of your cups according to your instructor's directions. Plastic cups and beakers should be rinsed and returned to the front lab bench.

Challenge: Make a Rainbow

Using either the pH paper or the red cabbage solution, use the vinegar and baking soda provided to create a colour gradient showing a range of pH from acidic to basic (alkaline). Try to get 5 different pH solutions. Take a picture of your final result with your phone and email it to your instructor.

Post-Lab Assignment

Name: ______________

MARK:

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1. What was the pH of each of your samples? *(2 marks)*

Sample	**pH**

2. What are some of the shared characteristics of your acidic samples? *(1 mark)*

3. What are some of the shared characteristics of your basic samples? *(1 mark)*

4. What are some parts of the lab that did not work or were unexpected? How did you solve these issues? *(2 marks)*

5. Do an internet search and record the definition of "Chemical Buffer". What are the purposes of chemical buffers in the human body? *(4 marks)*

Glossary

All definitions are paraphrased from Wikipedia.org.

Acid: a molecule or ion capable of donating a hydrogen ion.

Alkali: a molecule or ion capable of releasing a hydroxide ion.

Base: a molecule or ion capable of releasing a hydroxide ion.

Catalyst: a substance that increases the rate of a chemical reaction, but is not used up in the process.

Concentration: the amount of molecules of a substance within a defined space.

Displacement: occurs when an object is immersed in a fluid, pushing it out of the way and taking its place. The volume of the fluid displaced can then be measured, and from this, the volume of the immersed object can be deduced.

Enzyme: a macromolecular biological catalyst, which accelerates chemical reactions.

Indicator: a chemical detector for hydrogen or hydroxide ions that changes colour in response to changes in pH.

Mass: a property of a physical body and a measure of its resistance to acceleration. Determines the strength of its gravitational attraction to other bodies.

Meniscus: the curve in the upper surface of a liquid close to the surface of the container or another object caused by surface tension.

pH scale: a logarithmic scale used to specify the acidity or basicity of an aqueous solution. Solutions with a pH less than 7 are acidic, and solutions with a pH of greater than 7 are basic. Pure water is neutral, at pH 7.

Product: the substances formed in a chemical reaction.

Rate: a ratio in which two measurements related to one another, often with respect to time.

Rate of Chemical Reaction: the speed at which reactants are converted into products.

Reactant: a substance or compound consumed in the course of a chemical reaction.

Temperature: a physical quantity expressing hot or cold, measured with a thermometer.

Volume: the space that a substance or shape occupies or contains.

Weight: the force with which an object with mass is acted upon by gravity.

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Icons, throughout

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Litmus paper in base

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