

With 2019 NCEA  
Exam included

# Part Two

**2020**  
Version

## **NCEA Science 1.5** **Acids and Bases AS 90944**



## Achievement Criteria



AS 90944  
S1.5

*Aspects of acids and bases* will be selected from:

Atomic structure

- ☐ electron arrangement of atoms and monatomic ions of the first 20 elements (a periodic table will be provided)
- ☐ ionic bonding
- ☐ names and formulae of ionic compounds using a given table of ions.

Properties

- ☐ acids release hydrogen ions in water (HCl ; hydrochloric acid,  $\text{H}_2\text{SO}_4$  : sulphuric acid,  $\text{HNO}_3$  : nitric acid)
- ☐ reactions (of acids with bases) to form salts (Bases include metal oxides, hydroxides, carbonates and hydrogen carbonates)
- ☐ pH and effects on indicators.

Uses

- ☐ neutralisation
  - ☐ carbon dioxide formation
  - ☐ salt formation.
- 
- ☐ Rates of reaction and particle theory.

## Acids– their characteristics



Acids are a family of substances which all show **acidic characteristics** or properties. These properties relate to how the acids react with other chemicals.

They have a **sour taste** and react with metals. Acids can be found in nature and called **organic acids** or manufactured in the laboratory and called **mineral acids**.



# Physical and Chemical Properties of Acids

- ☐ pH < 7
- ☐ Turn blue litmus paper **red**
- ☐ Turn Universal indicator **red – yellow**
- ☐ Neutralised by bases
- ☐ React with carbonates to form a metal salt, water and carbon dioxide gas
- ☐ React with most metals to form a metal salt and hydrogen gas
- ☐ React with metal oxides to form a metal salt and water
- ☐ React with metal hydroxides to form a metal salt and water
- ☐ Have a sour taste

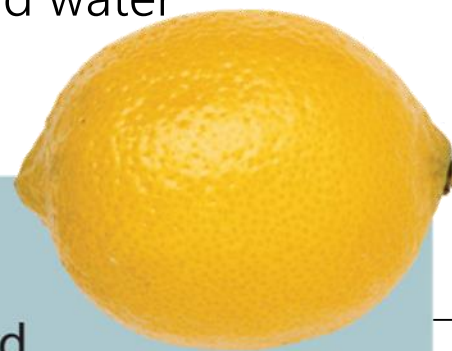
Acid

Sour taste

Turns blue litmus red

reacts with some metals to produce H<sub>2</sub>

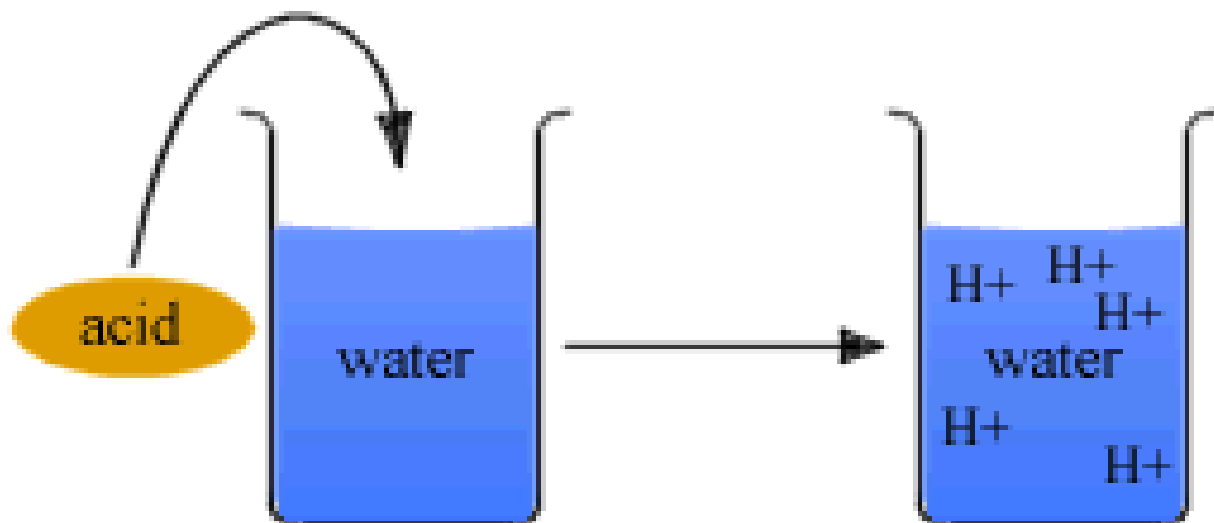
Dissolves carbonate salts, releasing CO<sub>2</sub>



## Acids – their characteristics

An **Acid** donates its **Hydrogen ion** ( $\text{H}^+$ ), which is really just a proton - the electron remains behind.

Common acids include the strong acids  $\text{HNO}_3$  - nitric acid,  $\text{HCl}$  - hydrochloric acid, and  $\text{H}_2\text{SO}_4$  - sulfuric acid.



## Common acids - names and formula

Name	Chemical formula	Salts formed
hydrochloric acid	HCl	-chlorides (Cl <sup>-</sup> )
sulfuric acid	H <sub>2</sub> SO <sub>4</sub>	-sulfates (SO <sub>4</sub> <sup>2-</sup> )
nitric acid	HNO <sub>3</sub>	-nitrates (NO <sub>3</sub> <sup>-</sup> )



## Bases – their characteristics



**Bases** are a family of chemicals that can remove acid particles ( $\text{H}^+$ ) from a solution. They have opposite properties from acids.

Bases have a slippery feel to them and common household bases include floor clearers and antacid tablets to fix indigestion. Bases that dissolve into water are called an alkali, and produce  $\text{OH}^-$  ions.



## Chemical and Physical Properties of Bases

- ☐ pH > 7
- ☐ Turn red litmus paper **blue**
- ☐ Turn Universal indicator **blue – purple**
- ☐ Neutralise acids
- ☐ Feel soapy
- ☐ Bases that dissolve in water are called alkalis, they form OH<sup>-</sup> ions.

Base  
Bitter taste  
Turns red litmus blue  
Slippery to the touch





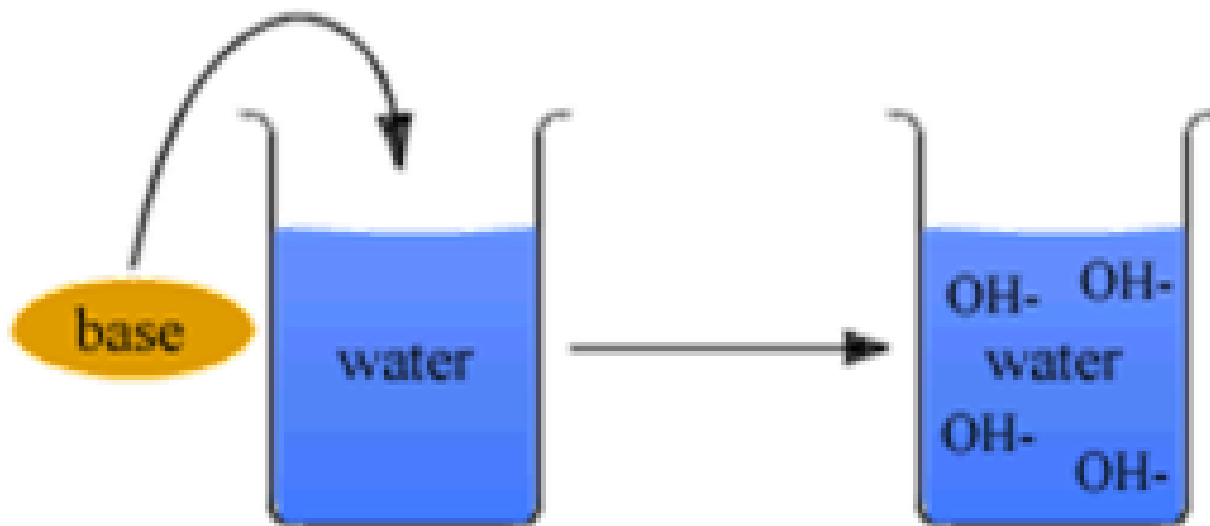
## Bases – their characteristics

A **Base** accepts a **Hydrogen ion** that have been donated from an Acid. They release hydroxide ions into solution.

Common bases include the strong bases NaOH – sodium hydroxide, and other metal oxides, hydroxides, carbonates and hydrogen carbonates

Some substances such as water are **amphiprotic** and can act as both an acid or a base depending on what other substance the water is with.

*i*  
extra  
info

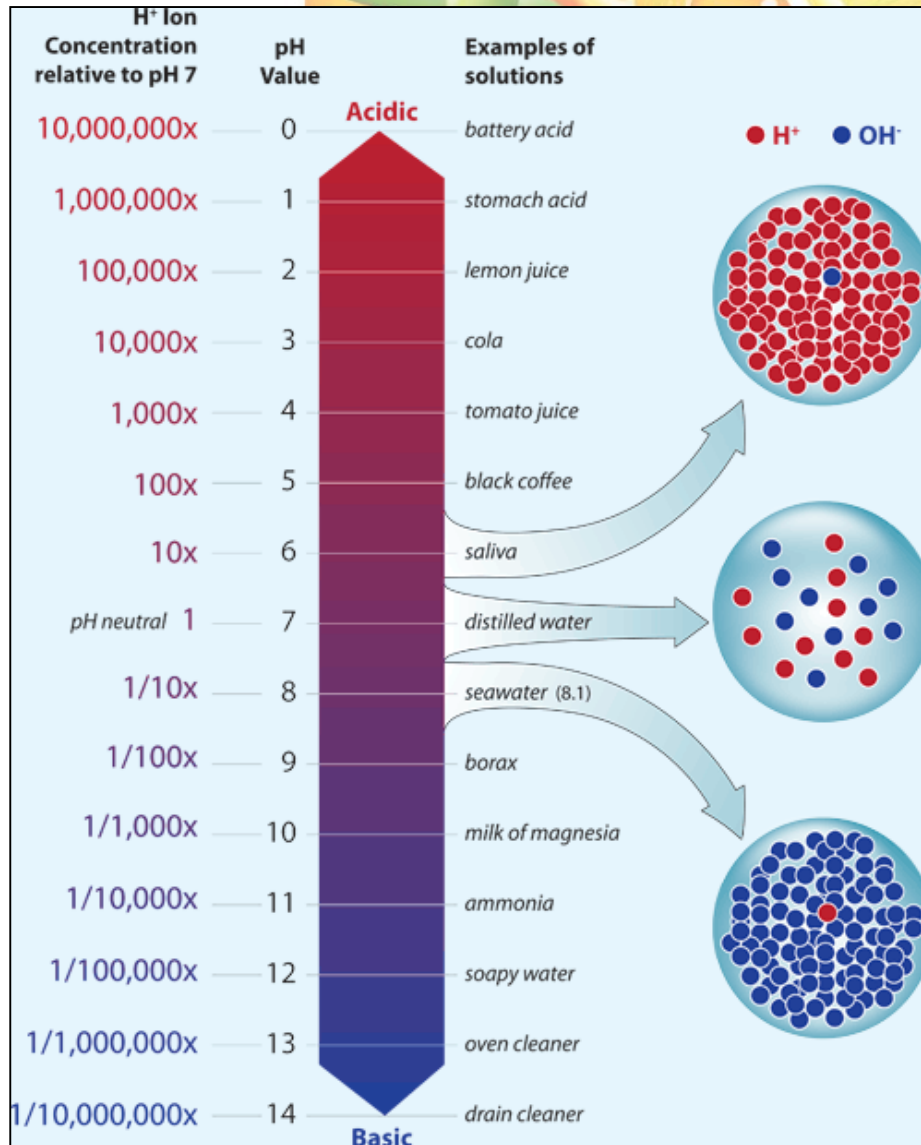


## Common bases - names and formula

Name	Chemical formula
sodium hydroxide	NaOH
calcium hydroxide	Ca(OH) <sub>2</sub>
sodium hydrogen carbonate	NaHCO <sub>3</sub>
calcium carbonate	CaCO <sub>3</sub>

Bases this year include **metal oxides** (- O<sup>2-</sup>), **metal hydroxides** (- OH<sup>-</sup>), **metal carbonates** (- CO<sub>3</sub><sup>2-</sup>) and **hydrogen carbonates** (- HCO<sub>3</sub><sup>-</sup>)

# The pH scale measures level of acidity and alkalinity



The **pH scale** measures how acidic or alkaline a substance is. Substances with a pH of 7 are **neutral**, substances with a pH greater than 7 are **alkaline** (or 'basic') and substances with a pH lower than 7 are **acidic**. Alkalis are 'bases' that are soluble in water. (All alkalis are bases but not all bases are alkalis.) The pH of a substance is determined by the concentration of hydrogen ions. The higher the concentration of hydrogen ions the lower the pH.

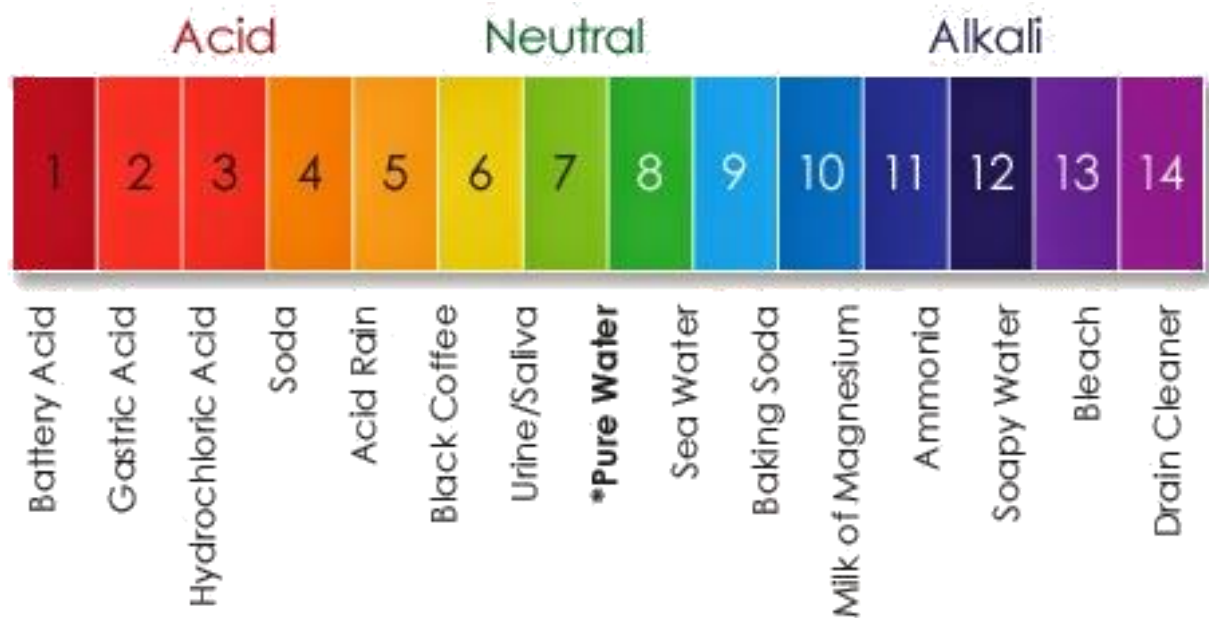


# Acidic, Alkaline or Neutral in terms of the pH scale

Acids have a pH less than 7

Neutral substances have a pH of 7

Alkalis have pH values greater than 7



The pH scale is **logarithmic** and as a result, each whole pH value below 7 is ten times more acidic than the next higher value. For example, pH 4 is ten times more acidic than pH 5 and 100 times more acidic than pH 6.

# Understand the difference between strong and weak acids and bases

<b>Strong Acids</b> Readily donate all their protons when dissolved	<b>Weak Acids</b> donate only a small proportion of protons	<b>Neutral solution</b>	<b>Weak Bases</b> Accept only a small proportion of protons	<b>Strong Bases</b> Readily accept protons
Concentration of $H^+$ ions is <b>greater</b> than that of $OH^-$ ions		Concentration of $H^+$ ions is the <b>same</b> as that of $OH^-$ ions	Concentration of $H^+$ ions is <b>less</b> than that of $OH^-$ ions	

Increasing acidity

Increasing alkalinity



# pH of Laboratory Acids and Bases



Strong Mineral Acids

Weak Organic Acids

Water, Chlorides

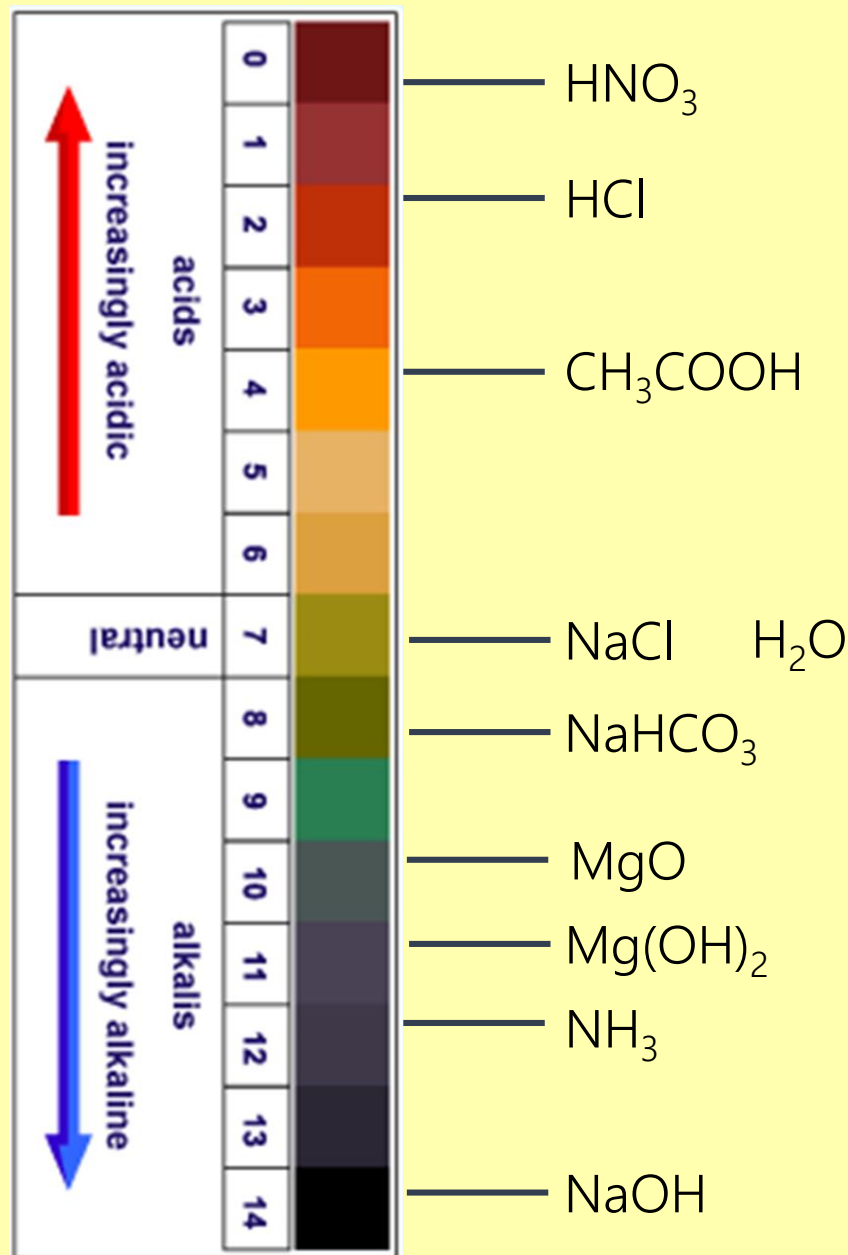
Carbonates

Oxides

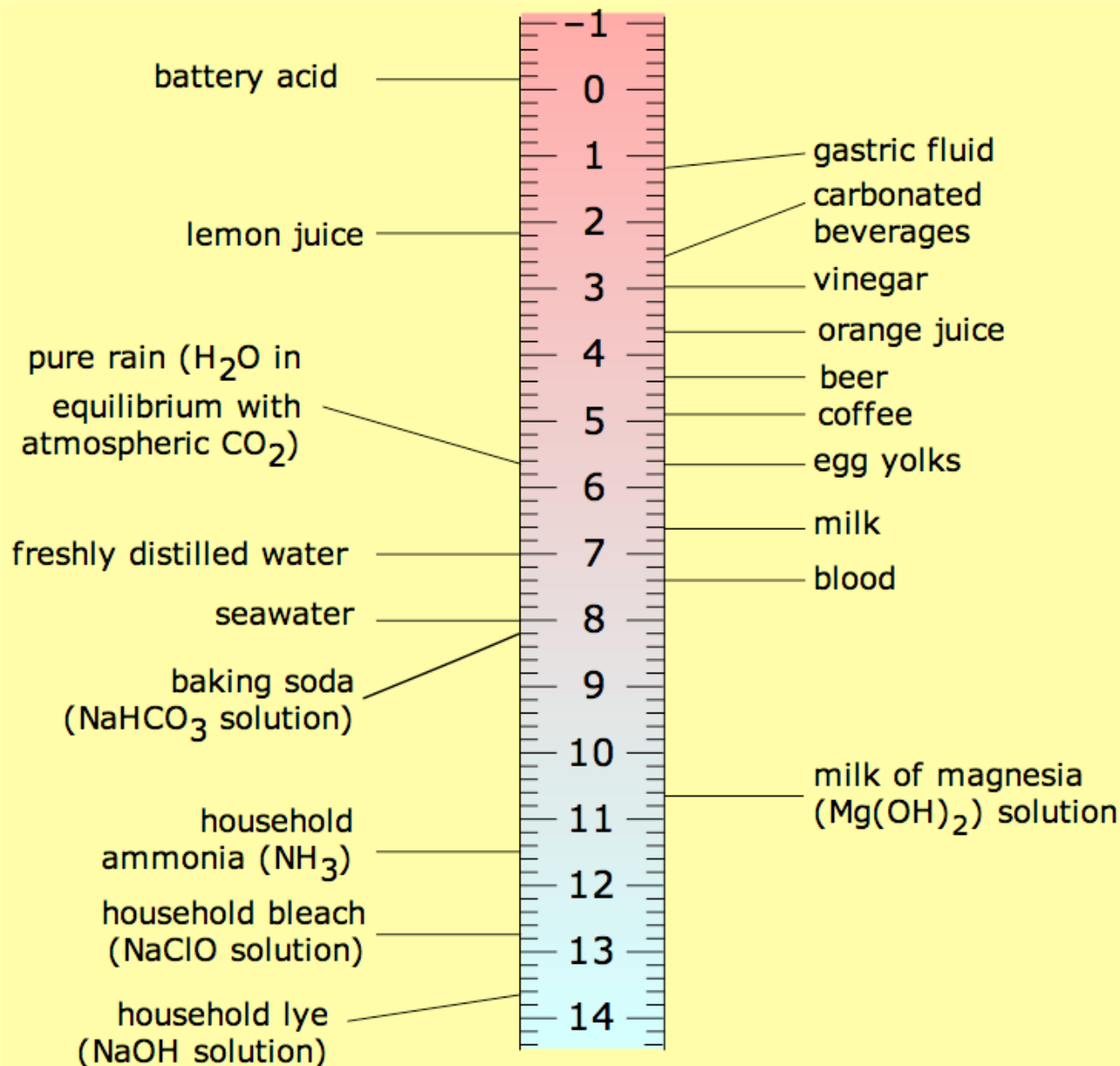
Most Hydroxides

Ammonia

Sodium Hydroxide



# pH of common substances



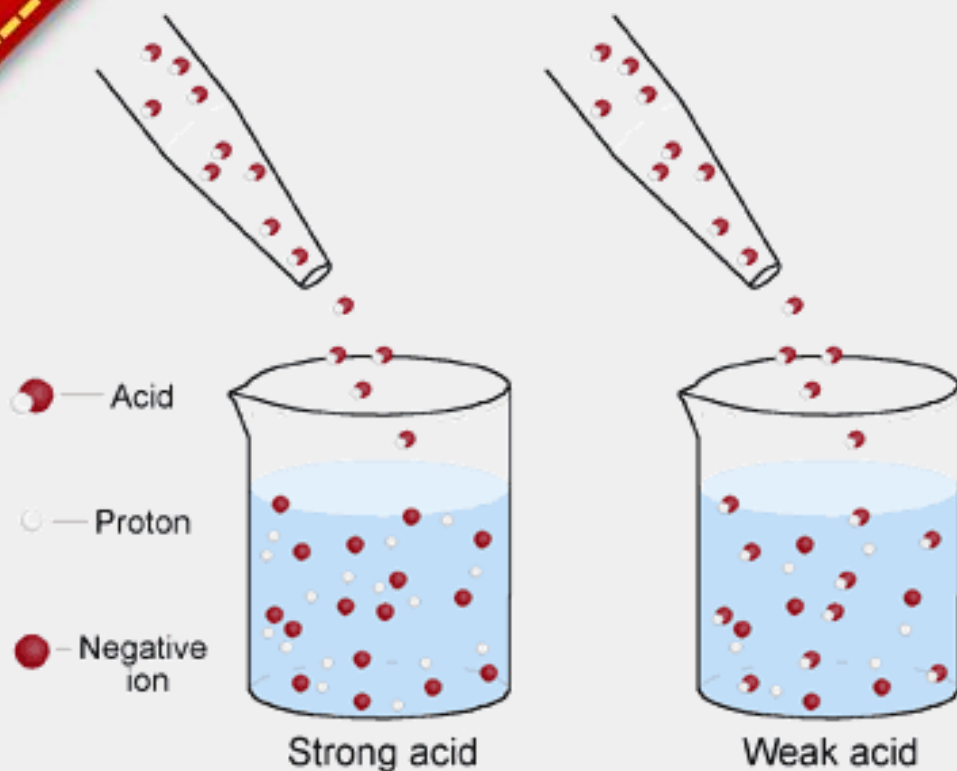
Pure water is **neutral**. But when chemicals are mixed with water, the mixture can become either acidic or basic. Examples of acidic substances are vinegar and lemon juice. Lye, milk of magnesia, and ammonia are examples of basic substances

# Background Knowledge



## Strong and weak acids

You can define acids as being "strong" or "weak". **Strong acids** are compounds that completely break up in water. All of the  $\text{H}^+$  ions (protons) break away from the original acid molecule in water. A **weak acid** only loses some of its  $\text{H}^+$  ions (protons) in water.

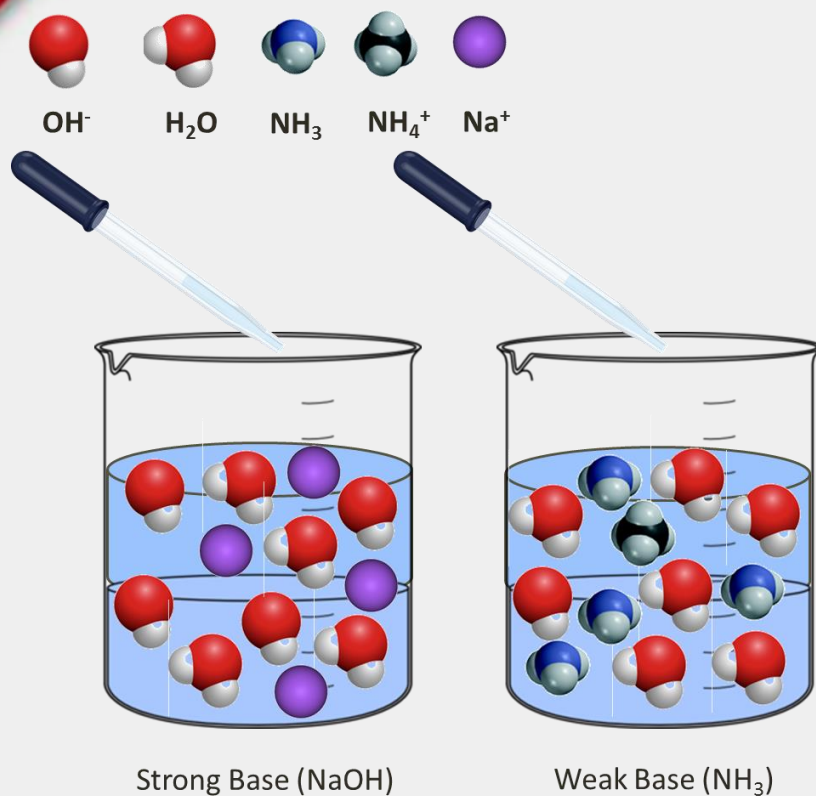


For strong acids, after reacting there will be no intact acid molecule left. In weak acids there will be mostly unreacted acid molecules left.

# Background Knowledge



## Strong and weak bases



You can define bases as being "strong" or "weak". **Strong bases** are compounds where each molecule will accept an H<sup>+</sup> ion. A **weak base** is a compound where only some of the molecules will accept a H<sup>+</sup> ion. Most weak base molecules remain unreacted.

**Note:** For strong alkalis, all of the OH<sup>-</sup> ions break away from the molecule in water.

## NCEA 2014 Acids and ions

Excellence  
Question

**Question 3c:** A student was given two beakers (Beaker 4 and Beaker 5) each containing different liquids. The liquid in Beaker 4 had a pH of 1. The liquid in Beaker 5 had a pH of 6.

Discuss which liquid is more acidic and how you know this.

In your answer you should:

- use the pH to determine which liquid is more acidic
- compare the amount of hydrogen ions AND hydroxide ions in Beaker 4 (pH 1) with the amount of hydrogen ions AND hydroxide ions in Beaker 5 (pH 6).

### Answer 3c:

Beaker with a pH of one is more acidic. In both solutions there are an excess of hydrogen ions compared to hydroxide ions, but in the solution with a lower pH the number of hydrogen ions is much more in excess compared to hydroxide ions; whereas when the pH is 6 the hydrogen ions are still in excess but not by as much.



## NCEA 2015 Acids and ions

Merit  
Question

**Question 3b:** Water is formed in the reaction below.  
Explain what ions form water in this reaction, and where they come from.  
 $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$

### Answer 3b:

When HCl reacts it donates an  $\text{H}^+$  and when NaOH reacts it provides  $\text{OH}^-$ , and these two ions combine to form (neutral)  $\text{H}_2\text{O}$ .



Indicators are used to determine whether substances are acid, base or neutral.



**Indicators** can be used to determine the pH of a solution by the colour change.

The most common indicator is found on **litmus paper**. It is red with acids and blue with bases.

**Universal Indicator**, which is a solution of a mixture of indicators and shows a full range of colours for the pH scale.

An indicator is a large organic molecule that works like a colour dye. They react and change colour depending on the hydrogen ion concentration. Most of the indicators are weak acids.

Did you  
know

# Red and Blue Litmus paper works as an indicator

Added to...	Blue Litmus	Red litmus
Acid solution	Turns red	Stays red
Neutral solution	Stays blue	Stays red
Base solution	Stays blue	Turns blue

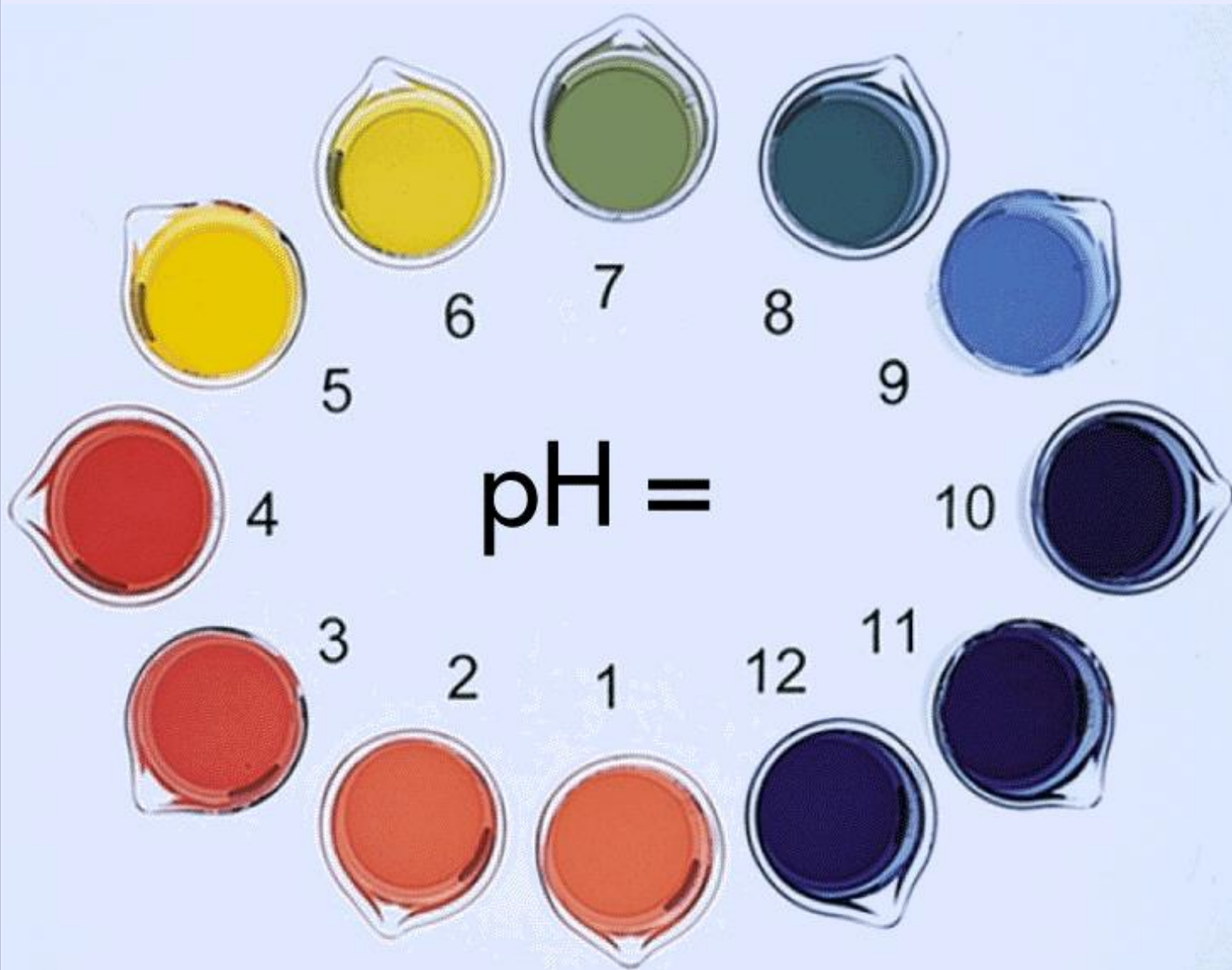


Blue litmus paper turning red in acid



Red litmus paper turning blue in base






# Universal Indicator is used to give the pH



The Universal Indicator is similar to the Litmus paper in that the acids turn the indicator mostly red and the bases turn the indicator mostly blue. It does have an **advantage over the litmus paper** as it **shows neutral** by having a **green** colour and also has different colours to **estimate the pH** of the solution not just whether it is acid or base.



# Putting it all together

Blue litmus													
Red litmus													
Universal indicator													
pH	1 - 2		3 - 6		7		8 - 12			13 - 14			
description	Strong Acids Readily donate all their protons when dissolved		Weak Acids donate only a small proportion of protons		Neutral solution		Weak Bases Accept only a small proportion of protons			Strong Bases Readily accept protons			
H <sub>3</sub> O <sup>+</sup> / OH <sup>-</sup> concentration	Concentration of H <sup>+</sup> ions is <b>greater</b> than that of OH <sup>-</sup> ions				Concentration of H <sup>+</sup> ions is the <b>same</b> as that of OH <sup>-</sup> ions			Concentration of H <sup>+</sup> ions is <b>less</b> than that of OH <sup>-</sup> ions					





## NCEA 2012 pH and Indicators - (Part ONE)

Excellence  
Question

**Question 3:** Beaker one contains sulfuric acid solution and 5 drops of universal indicator.

Beaker two contains pure water and 5 drops of universal indicator.

Sodium hydroxide solution was added to both beakers until no more changes were observed.

(b) What is the colour of universal indicator in each solution at the **start**?

(c) Describe the colour changes as sodium hydroxide solution is added to each beaker, AND explain what this tells you about the changing pH of each solution.

(d) Explain the relationship between the pH of the solutions and the **ions** in the solutions, as the sodium hydroxide is added to each of the beakers.

### Beaker one (acid)

The solution would be red to start with as the pH would be 1–2. The ions present in solution would be  $\text{H}^+$ . The pH would be low as there is a high number of  $\text{H}^+$  ions present.

As NaOH is added the solution would go orange, then yellow, then green. When the solution is orange and yellow the pH is still less than 7 as there are still more  $\text{H}^+$  than  $\text{OH}^-$  ions. When the solution becomes green the amount of  $\text{OH}^-$  ions added (from the NaOH) cancel out the  $\text{H}^+$  ions from the sulfuric acid and form water in a neutralisation reaction. At this stage the pH would be 7.

As more NaOH is added the solution then becomes blue and then purple. When the solution is blue the pH is 8–11 as there are now more  $\text{OH}^-$  ions present than  $\text{H}^+$  ions. When it becomes purple the pH is 13–14 as there are now many more  $\text{OH}^-$  ions present than  $\text{H}^+$  ions.

## NCEA 2012 pH and Indicators - (Part TWO)

Excellence  
Question

**Question 3:** Two beakers are shown below. Beaker one contains sulfuric acid solution and 5 drops of universal indicator.

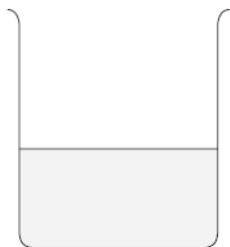
Beaker two contains pure water and 5 drops of universal indicator.

Sodium hydroxide solution was added to both beakers until no more changes were observed.

(b) What is the colour of universal indicator in each solution at the **start**?

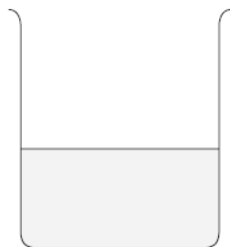
(c) Describe the colour changes as sodium hydroxide solution is added to each beaker, AND explain what this tells you about the changing pH of each solution.

**Beaker one**



Sulfuric acid + 5 drops  
universal indicator

**Beaker two**



Pure water + 5 drops  
universal indicator

### Beaker two (water)

The solution is green initially as water contains equal numbers of  $\text{H}^+$  and  $\text{OH}^-$  ions and is pH 7. As NaOH is added, the solution would become blue (pH 8 - 11) and then purple (pH 13 - 14). Because the water was neutral to start with, as more  $\text{OH}^-$  ions are added, the solution becomes more basic as the  $\text{OH}^-$  ions are immediately in excess.

## NCEA 2013 pH and Indicators - (Part ONE)

Achieved  
Question

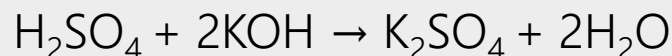
**Question 2a:** Potassium hydroxide (KOH) was added to a solution of sulfuric acid containing universal indicator until no further change was observed. The experiment was repeated, but a piece of red litmus paper and a piece of blue litmus paper were each dipped into the solution after each 5 mL of potassium hydroxide was added. The results of the experiments are shown in the table below.

Volume of KOH added (mL)	Colour of solution with universal indicator	Colour of red litmus paper	Colour of blue litmus paper
0	red	Stays red	Turns red
5	Orange-yellow	Stays red	Turns red
10	green	Stays red	Stays blue
15	blue	Turns blue	Stays blue
20	purple	Turns blue	Stays blue

Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and potassium hydroxide.

<http://www.nzqa.govt.nz>

Sulfuric acid + potassium hydroxide → potassium sulfate + water



## NCEA 2013 pH and Indicators - (Part ONE)

Achieved  
Question

**Question 2b:** Discuss what happened in this reaction as the potassium hydroxide was added to the sulfuric acid.

- relate the colours of the solution observed to the acidity and pH of the solution
- explain why the different colours of the solution were produced AND link these colours to the ions present during the reaction.
- explain the advantages of using universal indicator compared to litmus paper.

As the **KOH is added**, the **H<sub>2</sub>SO<sub>4</sub> is being neutralised until water is formed**, then after that the solution becomes more basic. When no KOH (0mL) has been added, the solution is red and has a pH of 1–2 and there is an excess of H<sup>+</sup> ions. As 5mL is added the solution becomes orange-yellow, the pH becomes 4–6. There is still an excess of H<sup>+</sup> ions but not as big an excess as when the pH was lower.

When 10 ml has been added and the solution is green, the pH is 7, which is neutral. At this point, the number of H<sup>+</sup> and OH<sup>-</sup> ions is equal and they cancel each other out to form water. After 15 mL has been added and the solution is blue, the pH is 9–12 and there is now an excess of OH<sup>-</sup> ions. When 20 mL have been added and the solution is purple, the pH is 13–14 and there is now a greater excess of OH<sup>-</sup> ions than when the solution was blue.

Litmus paper is useful to tell us if a solution is acidic, basic or neutral. (When blue litmus turns red and red litmus stays red, this tells us the solution is acidic. When both blue and red litmus papers stay the same, this tells us the solution is neutral. When red turns blue, this tells the solution is basic.) UI however tells us more information and tells us how acidic, basic a solution is or if it is neutral. Litmus is limited as it only tells us if it is acid, basic, or neutral whereas UI tells us how acidic or basic it is.

## NCEA 2014 pH and Indicators

Achieved  
Question

**Question 3a:** A student has three unlabelled beakers each containing a colourless liquid. One contains **water**, one contains a solution of baking soda (**sodium hydrogen carbonate**), and one contains white vinegar (a solution of **ethanoic acid**). To work out which liquid is which, the student put a drop from each beaker onto a piece of blue litmus paper and a piece of red litmus paper. She then added universal indicator to each beaker. The following results were obtained below. Complete the last column of the table above to identify the three liquids.

	<b>Colour of blue litmus paper</b>	<b>Colour of red litmus paper</b>	<b>Colour with universal indicator</b>	<b>Name of liquid</b>
<b>Beaker 1</b>	stays blue	stays red	turns green	Beaker 1 = water
<b>Beaker 2</b>	turns red	stays red	turns orange	Beaker 2 = vinegar
<b>Beaker 3</b>	stays blue	turns blue	turns blue	Beaker 3 = baking soda



## NCEA 2014 pH and Indicators

Excellence  
Question

**Question 3b:** Use the information in the table to show how each of the liquids can be identified.

	Colour of blue litmus paper	Colour of red litmus paper	Colour with universal indicator	Name of liquid
Beaker 1	stays blue	stays red	turns green	Beaker 1 = water
Beaker 2	turns red	stays red	turns orange	Beaker 2 = vinegar
Beaker 3	stays blue	turns blue	turns blue	Beaker 3 = baking soda

In your answer you should:

- use all of the observations for each beaker
- state the approximate pH from the colour of the universal indicator.

<http://www.nzqa.govt.nz>

**Beaker 1 = water.** The green colour of the universal indicator indicates that this solution has a pH of 7 and therefore is neutral. The fact that both litmus papers stay the same colour also indicates that the liquid is neutral and has a pH of seven, and therefore Beaker 1 must be water.

**Beaker 2 = vinegar.** The orange colour of the universal indicator indicates that the solution is acidic and has a pH of 4–5. Because the blue litmus turns red, this also indicates that the solution is acidic, and therefore Beaker 2 must be vinegar (ethanoic acid)

**Beaker 3 = baking soda.** The blue colour of the universal indicator indicates that the liquid is basic and has a pH of 9–10. Because the red litmus turns blue, this also indicates that the liquid is basic, and therefore Beaker 3 must be basic, as baking soda (sodium hydrogen carbonate) is basic.

## NCEA 2014 pH and Indicators

Excellence  
Question

**Question 4:** A beaker contains sodium hydroxide solution and 5 drops of universal indicator. Sulfuric acid was added to the beaker until no more changes were observed.

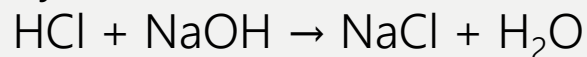
**(b)** Describe how the indicator colour changes as the sulfuric acid is added to the beaker, AND explain what this tells you about the changing pH of this solution.

**(c)** Explain the relationship between the changing **pH** of the solution and the **ions** in the solution as the sulfuric acid is added to the beaker.

- ☐ The solution would be purple to start with, as the pH would be 13–14. The pH would be high, as there is a high number of  $\text{OH}^-$  ions present. At this stage  $\text{OH}^-$  ions are in excess when compared to  $\text{H}^+$  ions.
- ☐ As  $\text{H}_2\text{SO}_4$  is added, the solution would go blue. At this stage the pH would be 8–12 and  $\text{OH}^-$  ions are still in excess of  $\text{H}^+$  ions, but not by as much as when the solution was purple.
- ☐ When the solution becomes green, the amount of  $\text{H}^+$  ions added (from the  $\text{H}_2\text{SO}_4$ ) cancel out the  $\text{OH}^-$  ions from the sodium hydroxide and form water in a neutralisation reaction. At this stage the pH would be 7.
- ☐ As more  $\text{H}_2\text{SO}_4$  is added, the solution then turns yellow, then orange, and then red. When the solution is yellow or orange, the pH is 3–6 as there are now more  $\text{H}^+$  ions present than  $\text{OH}^-$  ions.
- ☐ When it becomes red, the pH is 1–2, as there are now many more  $\text{H}^+$  ions present than  $\text{OH}^-$  ions.

## NCEA 2015 pH and Indicators

**Question 3a:** The chemical equation below represents the reaction between hydrochloric acid and sodium hydroxide:

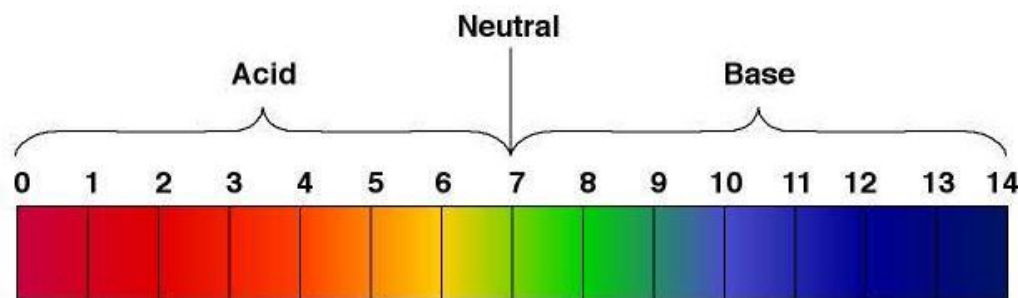


Complete the table below to show the approximate pH for each of the three solutions.

Answer 3a:

	Colour when UI is added	pH
<b>HCl</b>	red	1 - 3
<b>NaOH</b>	purple	12 - 14
<b>H<sub>2</sub>O</b>	green	7

Achieved  
Question



The pH Scale

**Question 3c:** NaOH is gradually added to a solution of HCl with universal indicator present, until no further colour change occurs.

Discuss what is occurring in the beaker at each of the pH's shown, as the NaOH is added.

In your answer you should refer to:

- the colours that would occur at each pH
- the relative amounts of hydrogen and hydroxide present at each of the pH's shown.

pH = 1 (before any NaOH is added): pH = 4, pH = 7, pH = 10, pH = 13

**Question 3c:** NaOH is gradually added to a solution of HCl with universal indicator present, until no further colour change occurs.

Discuss what is occurring in the beaker at each of the pH's shown, as the NaOH is added.

In your answer you should refer to:

- the colours that would occur at each pH
- the relative amounts of hydrogen and hydroxide present at each of the pH's shown.

pH = 1 (before any NaOH is added): pH = 4, pH = 7, pH = 10, pH = 13

**Answer 3c:**

As the NaOH is added, the HCl is **being neutralised** until water is formed, then after that the solution **becomes more basic**.

When no NaOH has been added, the solution is red and has a pH of 1–2 and there is an excess of  $\text{H}^+$  ions. The concentration of hydroxide ions is very low. At pH 4, the solution is orange–yellow and there is still an excess of  $\text{H}^+$  ions but not as big an excess as when the pH was lower. At pH 7 the solution is green, which is neutral. At this point, the number of  $\text{H}^+$  and  $\text{OH}^-$  ions is equal and they cancel each other out to form neutral water.

At pH 10 the solution is blue, and there is now an excess of  $\text{OH}^-$  ions. At pH 13 the solution is purple, and there is now a greater excess of  $\text{OH}^-$  ions than when the solution was blue.



## NCEA 2016 pH and Indicators

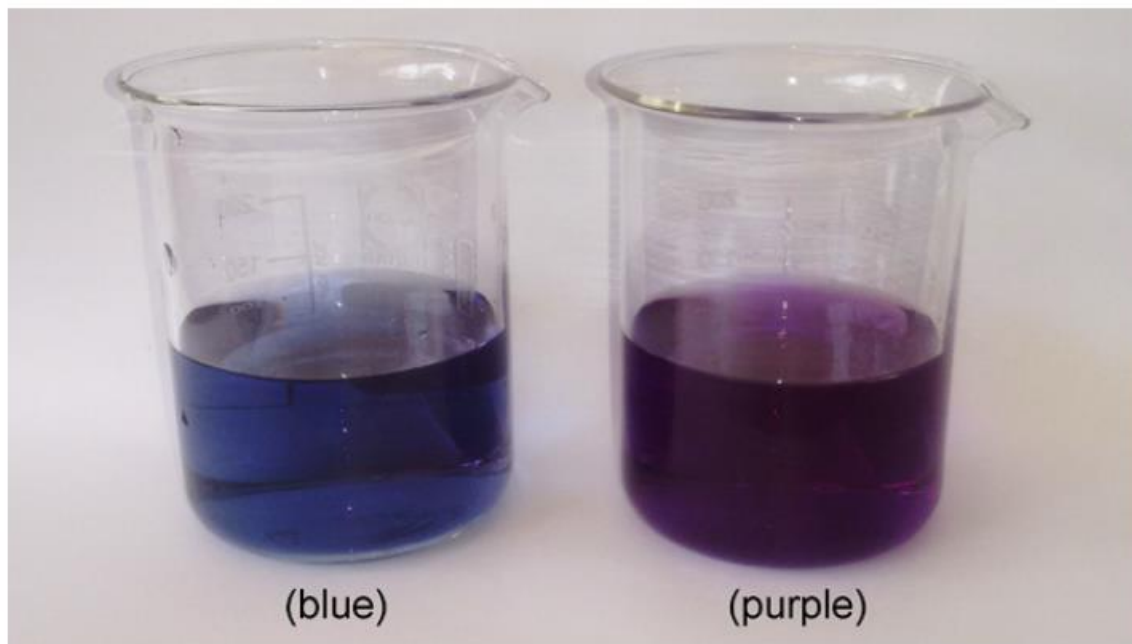
Merit  
Question

**Question 3a:** A student added universal indicator to the solutions in two beakers as shown below.

Explain why the solutions are different colours.

**Answer 3a:**

Potassium hydroxide (KOH) has a higher hydroxide ion concentration  $[\text{OH}^-]$  than potassium carbonate ( $\text{K}_2\text{CO}_3$ ) and therefore has a higher pH / is more basic than  $\text{K}_2\text{CO}_3$ . Universal Indicator is purple at a pH of 12–14, whereas Universal Indicator is blue for a base with a lower pH of 8–11.



(blue)

(purple)

Beaker 1

Beaker 2

Potassium carbonate

Potassium hydroxide

## NCEA 2016 pH and Indicators

Excellence  
Question

**Question 3c:** Explain what will happen to the indicator colour in **Beaker 2 (potassium hydroxide)** as the hydrochloric acid is added.

Relate this to the changing pH, the ions present in the beaker, and the type of reaction occurring.

### Answer 3c:

- ❑ Beaker 2 is initially purple since  $[\text{OH}^-]$  is much greater than  $[\text{H}^+]$ ; the pH is 12–14.
- ❑ As HCl is added, the  $\text{H}^+$  start to neutralise some of the  $\text{OH}^-$ .
- ❑ As the pH decreases to 8–11, the solution turns blue and  $[\text{OH}^-] > [\text{H}^+]$ .
- ❑ Once enough HCl has been added such that  $[\text{OH}^-] = [\text{H}^+]$ , the UI turns green since all the  $\text{OH}^-$  have been neutralised by  $\text{H}^+$  ions to form water, and the pH equals 7.
- ❑ As more HCl is added, the pH decreases to pH 3–6 since  $[\text{H}^+] > [\text{OH}^-]$ , so the UI turns yellow / orange.
- ❑ As more HCl is added, the pH decreases to 1–2 since  $[\text{H}^+]$  becomes much greater than  $[\text{OH}^-]$ , so UI turns red.



Beaker 2  
Potassium hydroxide

## NCEA 2017 pH and Indicators (Part ONE)

**Question 3b:** A solution of sodium hydroxide (NaOH) is slowly stirred into a beaker of hydrochloric acid (HCl) with universal indicator added. The HCl and universal indicator solution **starts out red**.

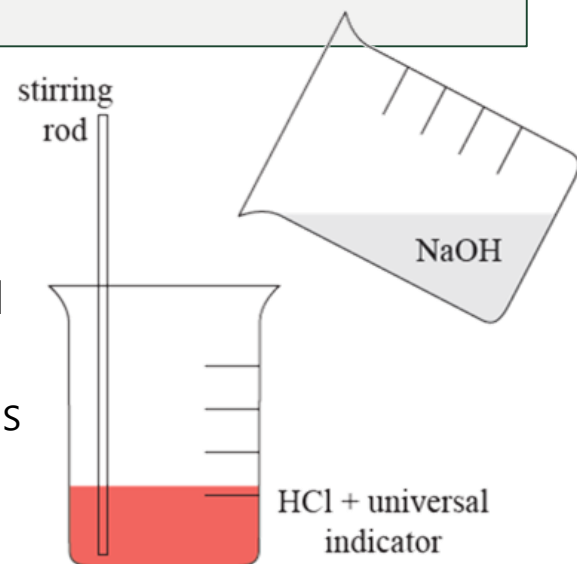
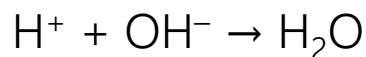
Explain the changes in the colour of the universal indicator as the sodium hydroxide solution is slowly added until no further colour changes occur.

In your answer, you should:

- relate the changes in the colour of the universal indicator to the approximate pH of the solution
- link the pH to the relative concentrations of hydrogen ions and hydroxide ions in solution
- explain the neutralisation reaction occurring.

<http://www.nzqa.govt.nz>

The HCl is initially red since  $[H^+]$  is much greater than  $[OH^-]$ ; the pH is 1–2. As NaOH is added, the  $OH^-$  start to neutralise some of the  $H^+$ . As the pH increases to 3–6, the solution turns orange / yellow and  $[H^+] > [OH^-]$ . Once enough NaOH has been added such that  $[OH^-] = [H^+]$ , the UI turns green since **all** the  $H^+$  have been **neutralised** by the added  $OH^-$  ions to form water, and the pH equals 7.



## NCEA 2017 pH and Indicators (Part TWO)

**Question 3b:** A solution of sodium hydroxide (NaOH) is slowly stirred into a beaker of hydrochloric acid (HCl) with universal indicator added. The HCl and universal indicator solution **starts out red**.

Explain the changes in the colour of the universal indicator as the sodium hydroxide solution is slowly added until no further colour changes occur.

In your answer, you should:

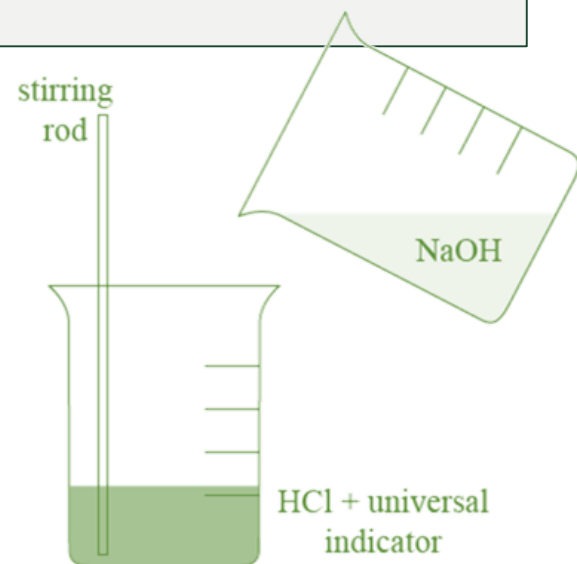
- relate the changes in the colour of the universal indicator to the approximate pH of the solution
- link the pH to the relative concentrations of hydrogen ions and hydroxide ions in solution
- explain the neutralisation reaction occurring.

<http://www.nzqa.govt.nz>

As more NaOH is added, the pH increases to pH 8–11 since

$[\text{OH}^-] > [\text{H}^+]$ , so the UI turns blue. As yet more NaOH is added, the pH increases to 12–14 since  $[\text{OH}^-]$  becomes much greater than  $[\text{H}^+]$ , so UI turns purple.

[Information may be given in a table.]



## NCEA 2018 pH and Indicators

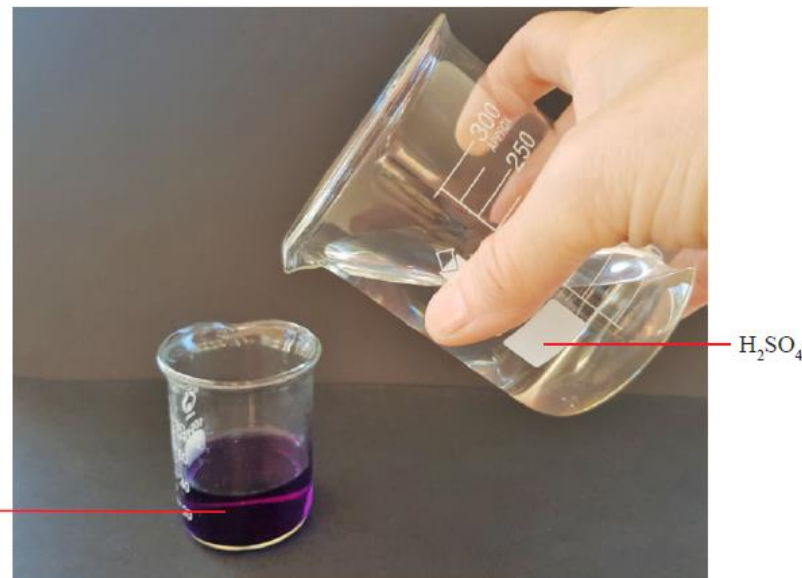
**Question 2c:** A solution of potassium hydroxide is placed in a beaker. Universal indicator is added to it. The solution is purple, as shown in the diagram below. Sulfuric acid is slowly added to the beaker until **no more colour changes are seen**. Explain in detail what happens to the **colour** of the solution while the sulfuric acid is being added to the potassium hydroxide. Link your answer to the concentration of **ions** and the changing **pH** of the solution.

*In discussion accept  $H^+$  or  $H_3O^+$ .* As the  $H_2SO_4$  is added, the KOH is being neutralised until water is formed. When no  $H_2SO_4$  is added, the solution is purple and has pH 13–14 because there is an excess of  $OH^-$  ions.

While the  $H_2SO_4$  is being added, the solution becomes blue with a pH of 8–10. There is still an excess of  $OH^-$  ions, but not as big. When the numbers of  $H^+$  and  $OH^-$  ions are equal, the solution is neutralised, green and the pH is 7. As more  $H_2SO_4$  is added, the solution becomes yellow pH of 4–5. There is a small excess of  $H^+$  ions but not as big. As more  $H_2SO_4$  is added, the solution becomes red with a pH of 1–2. There is a significant excess of  $H^+$  ions.

<http://www.nzqa.govt.nz>

KOH and  
universal indicator  
before adding  $H_2SO_4$





**Question 3a:** Three unlabelled bottles containing different colourless solutions are known to be:

- hydrochloric acid, HCl
- sodium chloride, NaCl
- sodium hydroxide, NaOH.

These unlabelled solutions can be identified using red litmus paper and baking soda,  $\text{NaHCO}_3$ .

(i) Complete the table

Unlabelled solution	Observation (if any)	
	with red litmus paper	with baking soda, $\text{NaHCO}_3$
hydrochloric acid, HCl	Stays red / no change	Fizzes / bubbles / heat / reacts
sodium chloride, NaCl	Stays red	No reaction
sodium hydroxide, NaOH	Turns blue	No reaction

**Question 3a:** (ii) Explain how the observations allow you to identify each solution, giving reasons for any changes or reactions occurring.

Unlabelled solution	Observation (if any)	
	with red litmus paper	with baking soda, $\text{NaHCO}_3$
hydrochloric acid, $\text{HCl}$	Stays red / no change	Fizzes / bubbles / heat / reacts
sodium chloride, $\text{NaCl}$	Stays red	No reaction
sodium hydroxide, $\text{NaOH}$	Turns blue	No reaction

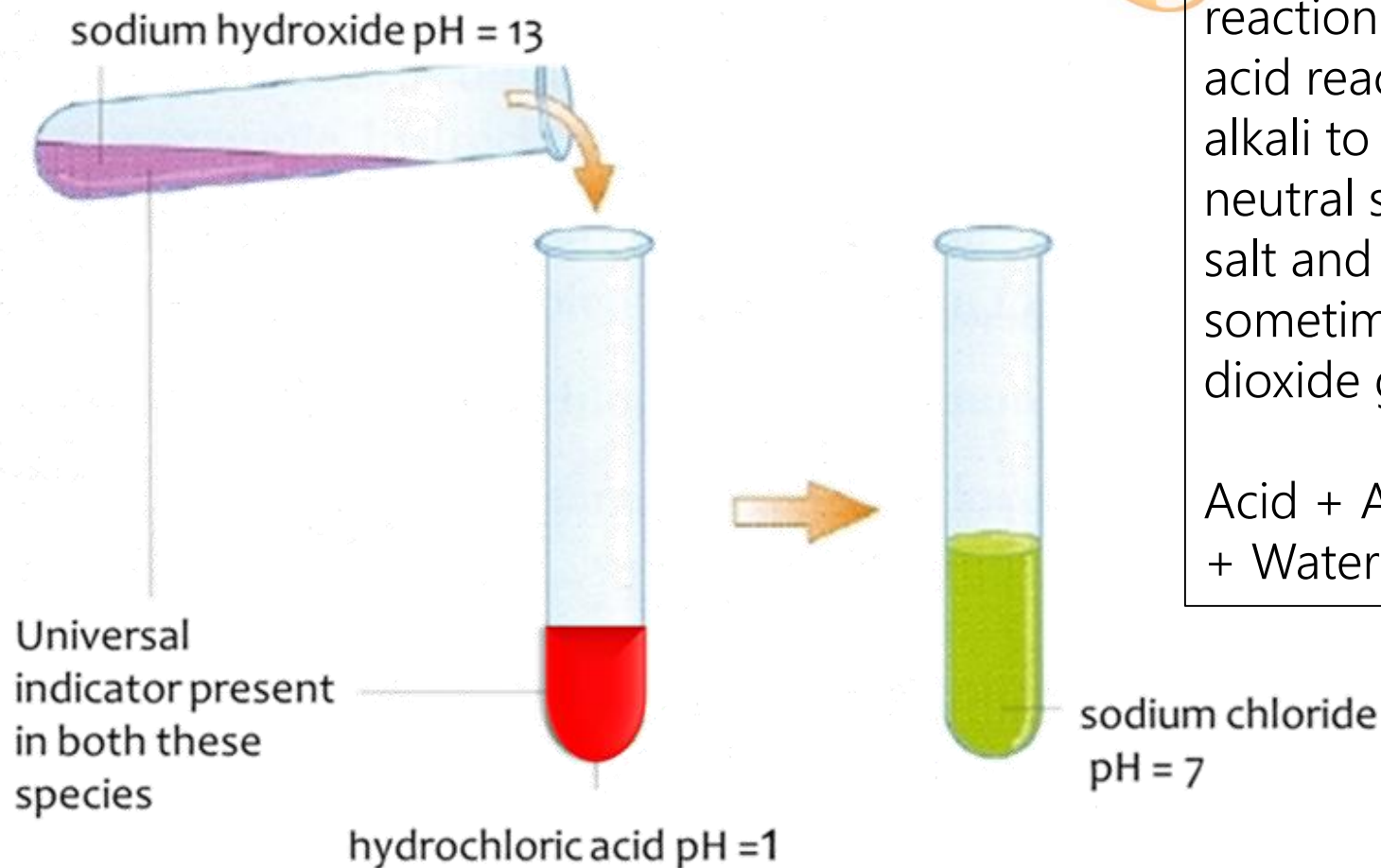
Only the sodium hydroxide will turn the litmus blue, since it is a base.

Add baking soda to the remaining two solutions. Since hydrochloric acid is an acid, it will undergo a (neutralisation) reaction with the baking soda to produce bubbles / fizzing / heat of carbon dioxide.

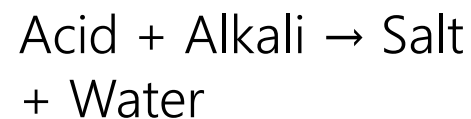
No changes will be observed with the sodium chloride since it is a neutral salt.



During neutralisation reactions, hydrogen ions combine with hydroxide ions to form water molecules.



**Neutralisation** is a reaction where an acid reacts with an alkali to form a neutral solution of a salt and water. (and sometimes carbon dioxide gas)



During neutralisation reactions hydrogen ions combine with hydroxide ions to form water molecules

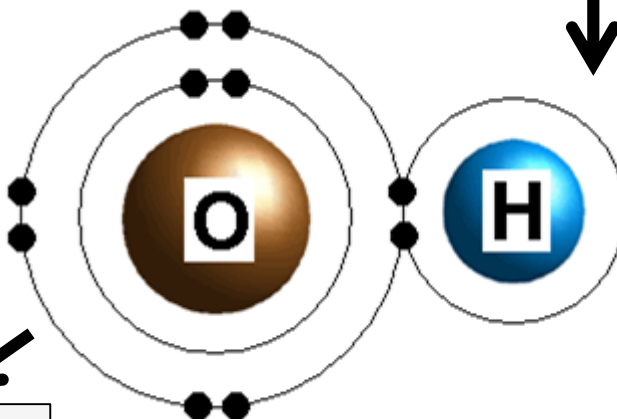
From an acid

From a base

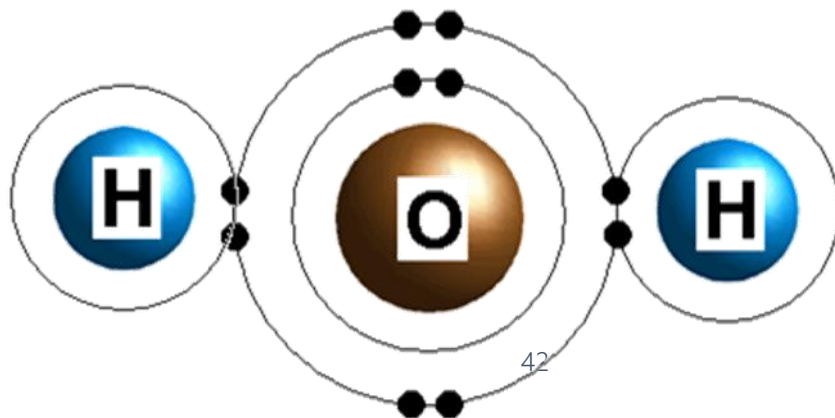
Hydrogen ion  
1 proton  
0 electrons  
= +1 charge



Hydroxide:  
9 protons  
10 electrons  
= -1 charge



Neutralisation



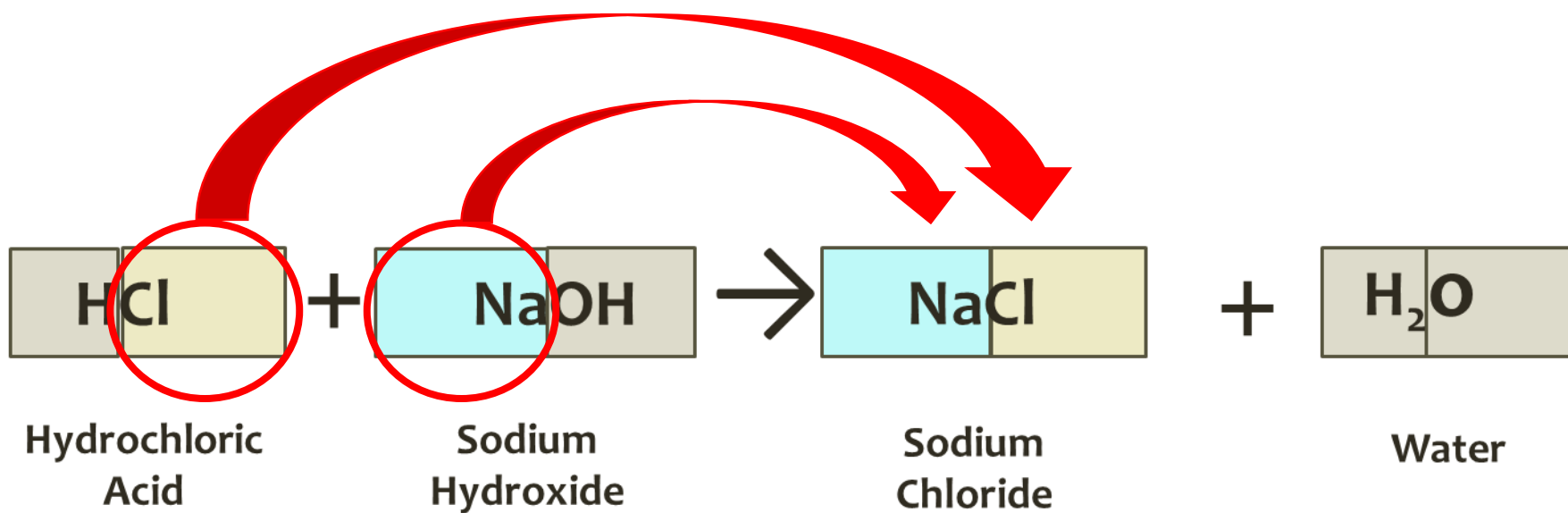
Water  
10 protons  
10 electrons  
= 0 charge



## Names of salts

When salts are formed the name depends upon the **acid reacted** and the **metal** that forms part of the base compound.

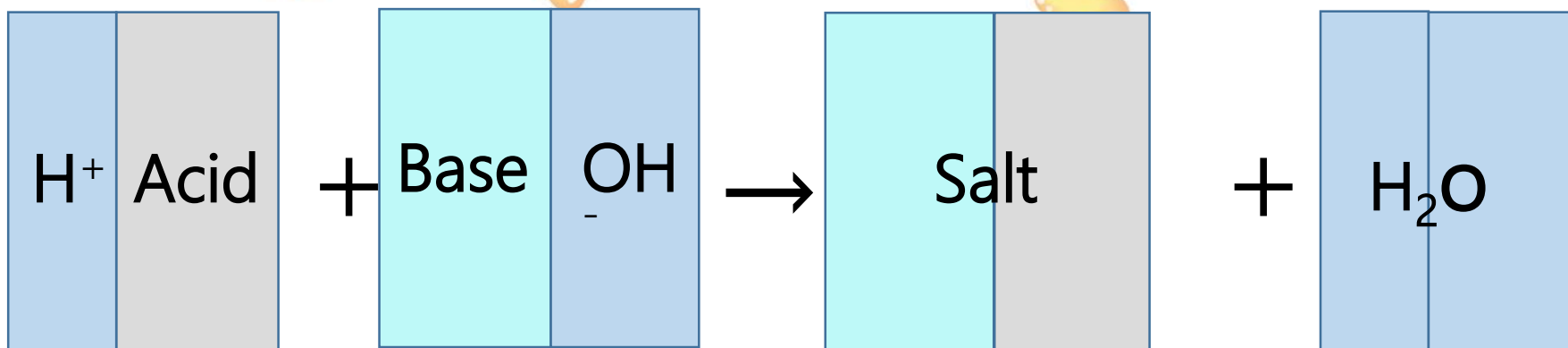
Name of acid	Name of salt formed	Formula of ion
hydrochloric acid	chloride	$\text{Cl}^-$
sulfuric acid	sulfate	$\text{SO}_4^{2-}$
nitric acid	nitrate	$\text{NO}_3^-$



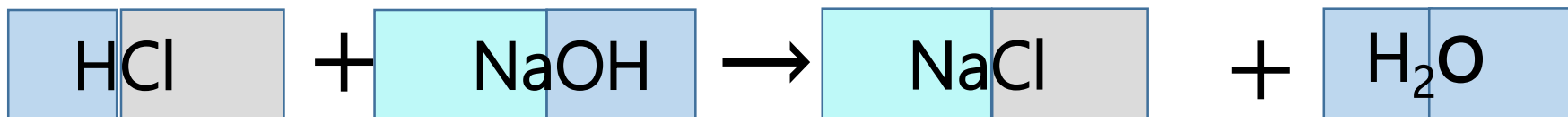


# Balanced equations for salt formation - Hydroxides

Hydroxides **neutralise** acids and a salt and water are formed



## Example



Hydrochloric  
Acid

+

Sodium  
Hydroxide

→

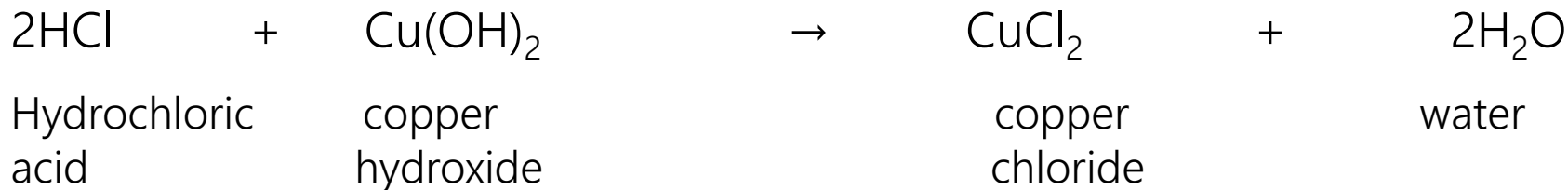
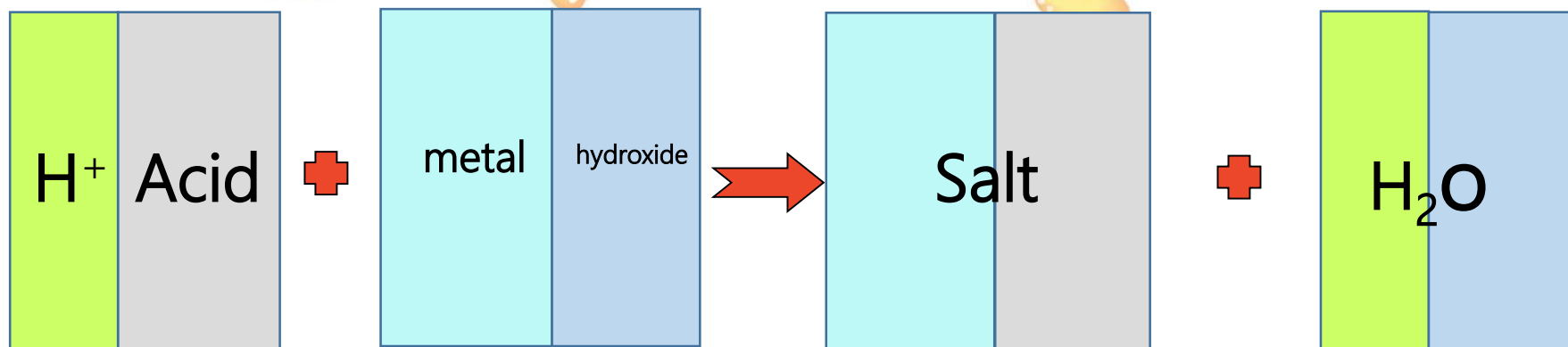
Sodium  
Chloride

+

Water

# Acid and Hydroxides reaction

Hydroxides **neutralise** acids and a salt and water are formed

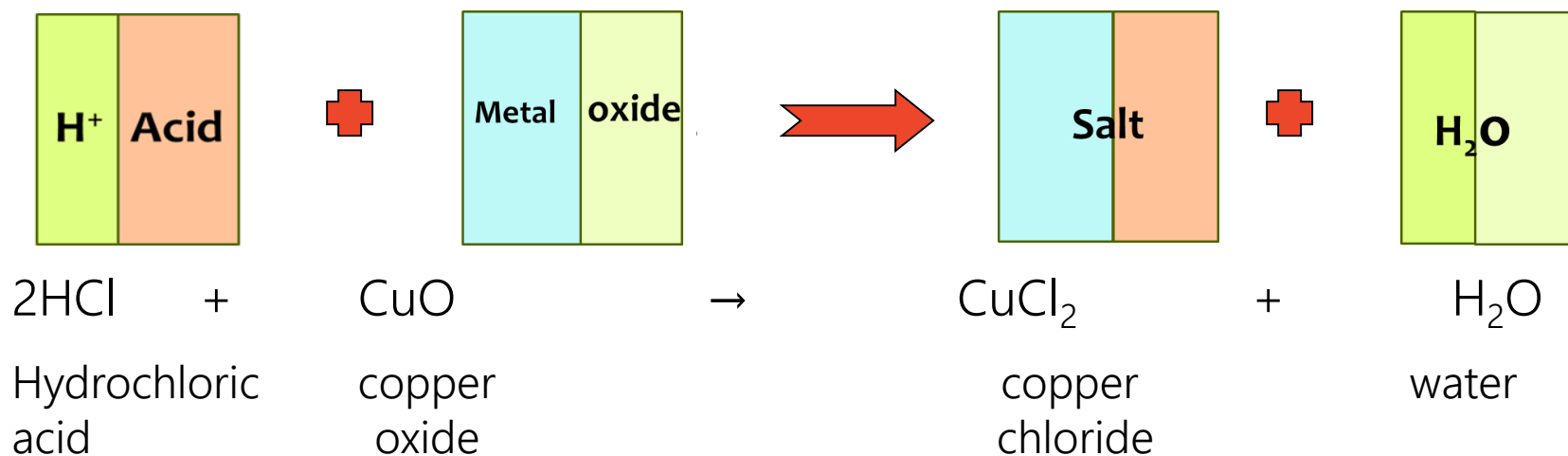


Bases used in S1.5 are limited to: metal hydroxides ( $\text{MOH}$ ), metal oxides ( $\text{MO}$ ), metal carbonates ( $\text{MCO}_3$ ) and metal hydrogen carbonates ( $\text{MHCO}_3$ ).

(M – metal)

# Acid and Oxide reactions

Acids react with metals oxides in a neutralisation reaction to give a metal salt and water.

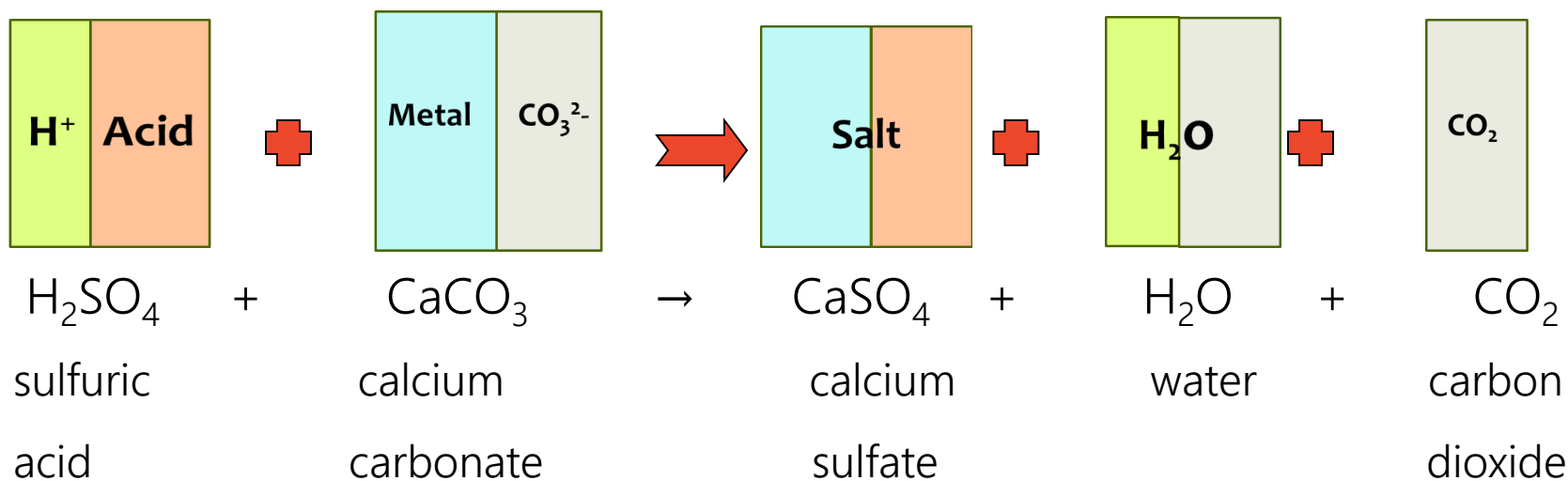


Note: When the above reaction takes place in a water solution the copper and the chloride ions are dissolved and exist separately in the water. Only when the water is removed by evaporation does the copper chloride salt form.

Did you  
know

# Acid and Carbonate reactions

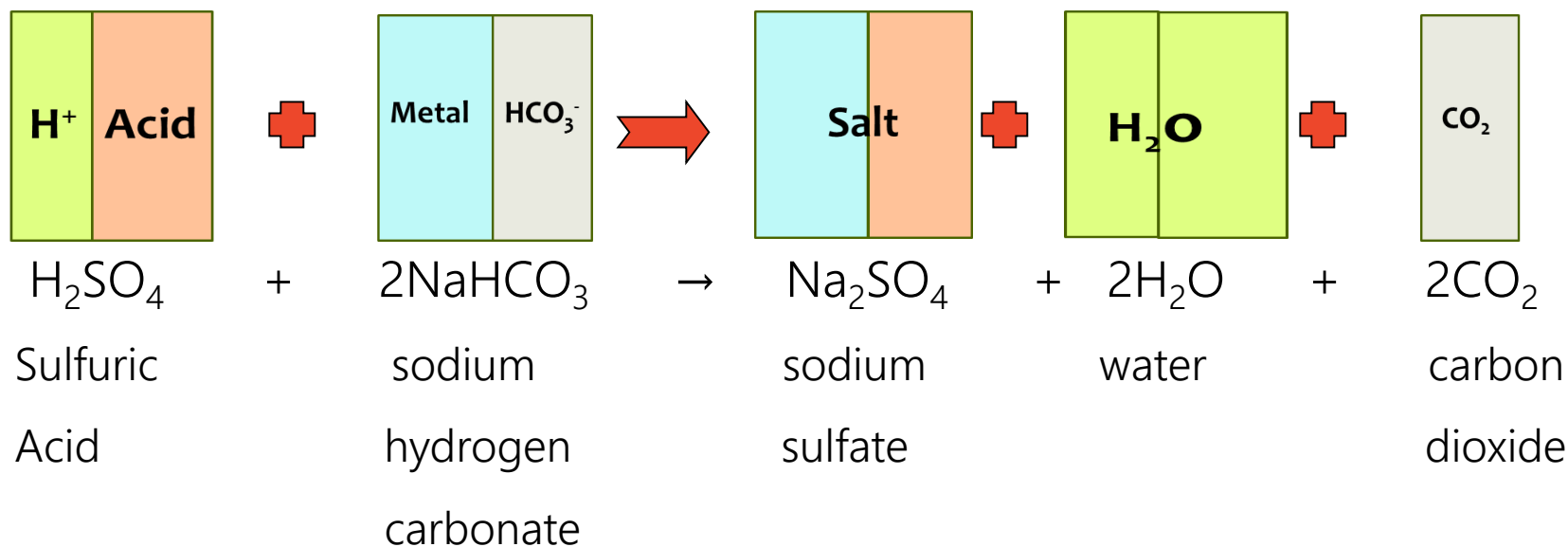
Acids react with Carbonates to give a salt and water and carbon dioxide.



We can test to see if carbon dioxide has formed by bubbling the gas into another test tube filled with limewater. The limewater will turn cloudy if the gas is carbon dioxide.

## Acid and Hydrogen Carbonate reactions

Acids react with Hydrogen Carbonates to give a salt and water and carbon dioxide.



Hydrogen carbonate and acid also produce carbon dioxide gas that can be tested with limewater.



# Acid reactions summary

## 1. Acid and Metal Oxide

**General equation** acid + metal oxide → salt + water

**Word equation** nitric acid + copper oxide → copper nitrate + water

**Formula equation**  $2\text{HNO}_3 + \text{CuO} \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$

## 2. Acid and Metal Hydroxide

**General equation** acid + metal hydroxide → salt + water

**Word equation** nitric acid + copper hydroxide → copper nitrate + water

**Formula equation**  $2\text{HNO}_3 + \text{Cu}(\text{OH})_2 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$

## 3. Acid and Metal Hydrogen Carbonates

**General equation** acid + metal hydrogen carbonate → salt + water + carbon dioxide

**Word equation** sulfuric acid + sodium hydrogen carbonate → sodium sulfate + water + carbon dioxide

**Formula equation**  $\text{H}_2\text{SO}_4 + 2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O} + 2\text{CO}_2$

## 4. Acid and Metal Carbonate

**General equation** acid + metal carbonate → salt + water + carbon dioxide

**Word equation** hydrochloric acid + magnesium carbonate → magnesium chloride + water + carbon dioxide

**Formula equation**  $2\text{HCl} + \text{MgCO}_3 \rightarrow \text{MgCl}_2 + \text{H}_2\text{O} + \text{CO}_2$

## NCEA 2012 Neutralisation

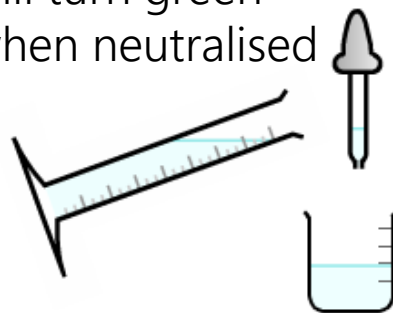
Excellence  
Question

**Question 2a:** A student wanted to make the neutral salt, sodium nitrate. Explain how to make sodium nitrate by mixing sodium carbonate and nitric acid solutions using school laboratory equipment. Explain how litmus paper could be used during the process described to show the salt being produced is **neutral**.

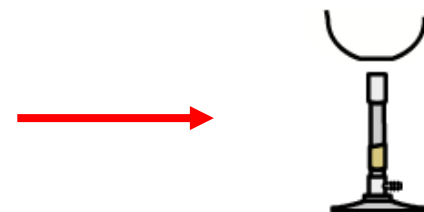
### How to make it

Mix the two solutions together, then take the resulting solution and put it in an evaporating dish. It could be heated using a Bunsen burner or left somewhere warm for a few days. The water would evaporate off leaving behind the neutral salt sodium nitrate.

Add universal indicator to acid and add base. UI will turn green when neutralised



Heat to remove water. The sodium nitrate will remain



**Litmus paper:** The solution will be neutral when red and blue litmus papers both stay the same colour. When blue paper changes to red the solution is acidic. When red paper changes to blue the solution is basic.

## NCEA 2012 Acid Reactions

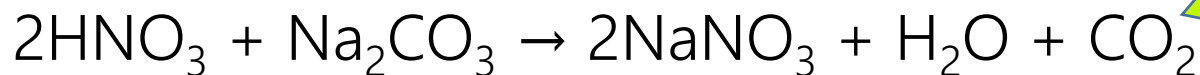
**Question 2c:** Write a word equation AND a balanced symbol equation for the reaction between sodium carbonate and nitric acid.

Word equation:

nitric acid + sodium carbonate → sodium nitrate + water + carbon dioxide.

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2012 Acid Reactions

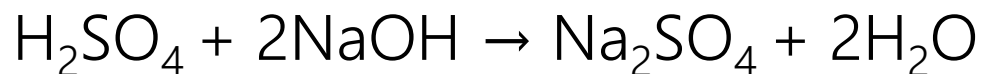
**Question 3a:** Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and sodium hydroxide.

Word equation:

Sulfuric acid + sodium hydroxide → sodium sulfate + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## Question 4b: Experiment One

A student carried out an experiment in the lab using the following method:

Step one: Universal indicator was added to a solution of hydrochloric acid in a beaker.

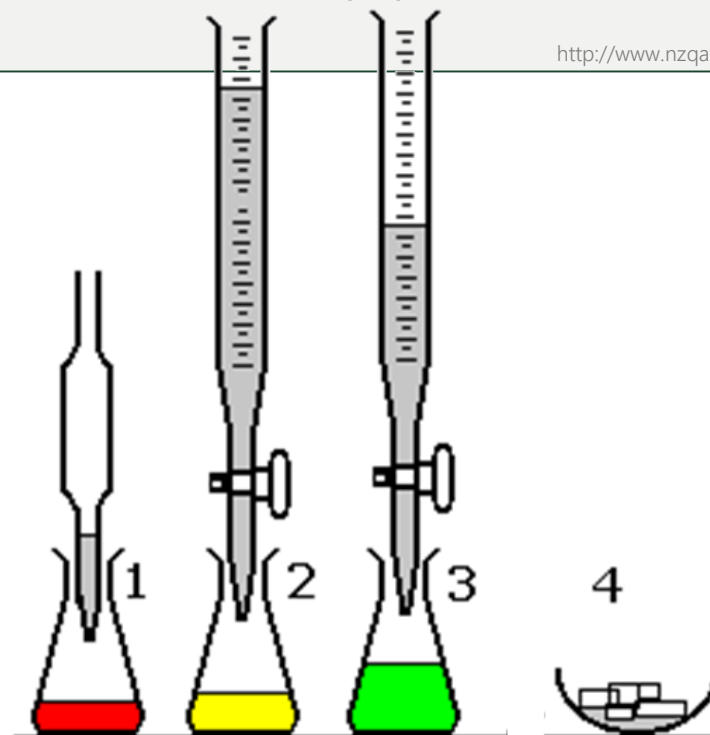
Step two/three: Calcium hydroxide was added slowly until the solution turned yellow then green.

Step four: The contents of the beaker were then poured into an evaporating dish and left in a sunny place for several days.

**Explain the purpose of each step in the method and how the equipment and chemicals used achieve that purpose.**

<http://www.nzqa.govt.nz>

UI is used to check the pH of the solution. Calcium hydroxide is added so that it reacts with HCl to form calcium chloride. It is added until the solution is green so that the solution formed is neutral. The contents are put into an evaporating dish so that the water can evaporate to leave the salt calcium chloride. It is left for a few days to ensure that all the water has evaporated as this process takes time.





### Experiment Two

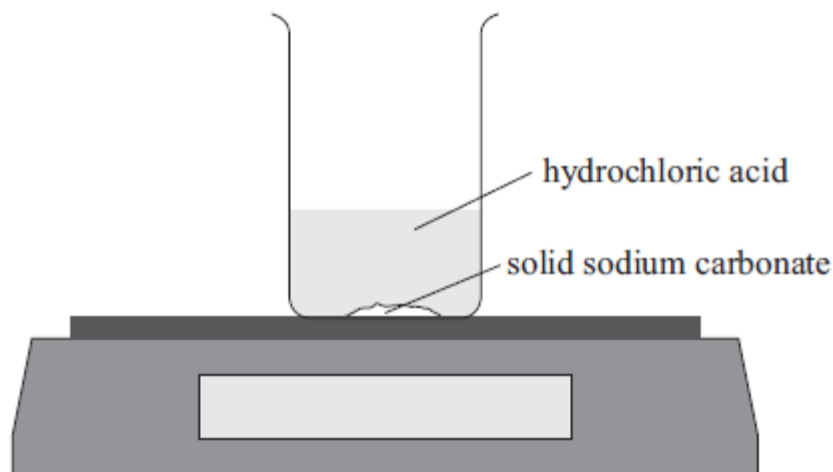
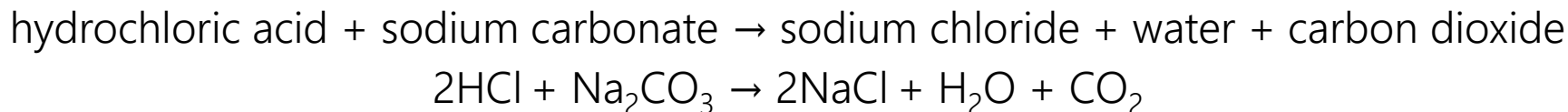
In another experiment the following method was used:

Step one: A beaker was placed on a balance as shown in the diagram below.

Step two: Hydrochloric acid was added to solid sodium carbonate in the beaker.

Step three: The mass was recorded over time.

Write a word equation AND a balanced symbol equation for the reaction between hydrochloric acid and sodium carbonate.



### Experiment Two

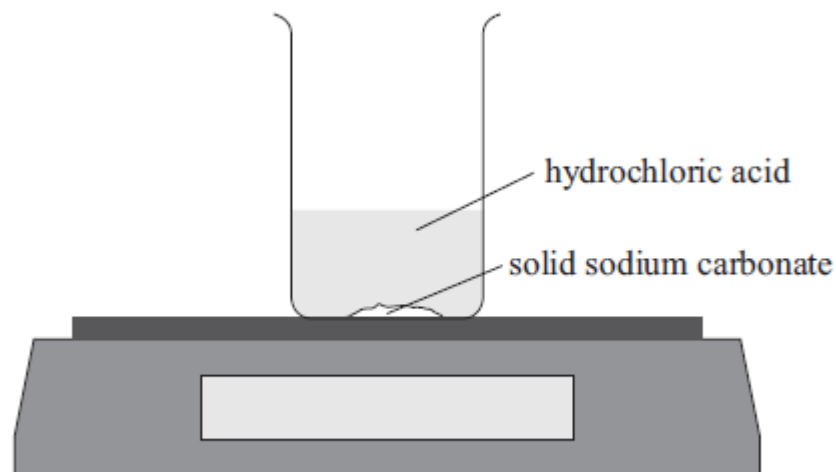
(d) Explain why the mass of the beaker and contents would decrease over time.

In your answer you should:

- state any other observations that would be made as hydrochloric acid reacts with the sodium carbonate
- explain how the products formed by the reaction lead to the decrease in mass of the beaker and contents.

**Observations:** Fizzing would be observed.

The fizzing observed is due to carbon dioxide gas being released, and therefore because the carbon dioxide gas is leaving the beaker, there is less mass remaining in the beaker and therefore the balance measures less weight.



## NCEA 2013 Acid Reactions

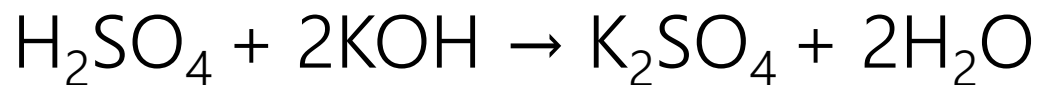
**Question 2a:** Write a word equation AND a balanced symbol equation for the reaction between sulfuric acid and potassium hydroxide.

Word equation:

Sulfuric acid + potassium hydroxide → potassium sulfate + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2014 Acid Reactions

**Question 2c:** Write a word equation AND a balanced symbol equation for the reaction between calcium carbonate and hydrochloric acid.

Word equation:

Hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water.

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2014 Acid Reactions

**Question 4a:** A beaker contains sodium hydroxide solution and 5 drops of universal indicator.

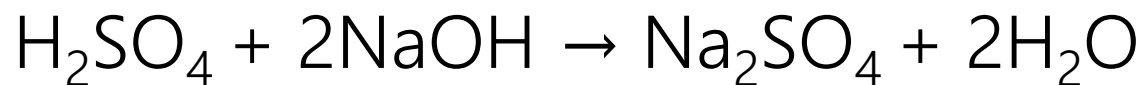
Sulfuric acid was added to the beaker until no more changes were observed.

(a) Write a word equation AND a balanced symbol equation for the reaction between sulphuric acid and sodium hydroxide.

Word equation:

Sulfuric acid + sodium hydroxide → sodium sulfate + water

Balanced symbol equation:



Excellence  
Question

## NCEA 2015 Acid Reactions

Question 1c: Write a word equation AND a balanced symbol equation for the reaction between nitric acid and calcium carbonate.

Word equation:

nitric acid + calcium carbonate → calcium nitrate + carbon dioxide + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question



## NCEA 2015 Acid Reactions

**Question 3d:** In a different chemical reaction, hydrochloric acid reacts with magnesium hydroxide.

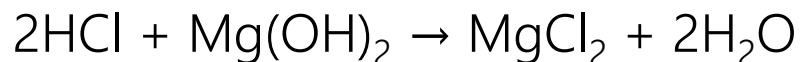
Write a word equation and a balanced chemical equation for this reaction in the boxes below.

Word equation:

Hydrochloric acid + magnesium hydroxide → magnesium chloride + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2016 Acid Reactions

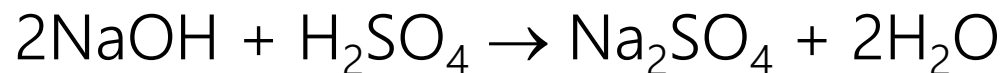
**Question 1d:** Write a word equation AND a balanced symbol equation for the reaction between **sodium hydroxide** and **sulfuric acid**.

Word equation:

sodium hydroxide + sulfuric acid → sodium sulfate + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2016 Acid Reactions

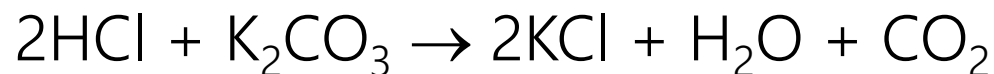
**Question 3b:** Write a word equation AND a balanced symbol equation for the reaction between **hydrochloric acid** and **potassium carbonate** in Beaker 1.

Word equation:

hydrochloric acid + potassium carbonate → potassium chloride + water + carbon dioxide

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2017 Acid Reactions

**Question 1d:** Write a word equation AND a balanced symbol equation for the reaction between sodium hydrogen carbonate ( $\text{NaHCO}_3$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ).

Word equation:

sodium hydrogen carbonate + sulfuric acid  $\rightarrow$  sodium sulfate + water + carbon dioxide

Achieved  
Question

Balanced symbol equation:



Excellence  
Question

## NCEA 2017 Acid Reaction – identify unknowns (Part ONE)

**Question 2b:** Three unlabelled colourless solutions are known to be:

- nitric acid ( $\text{HNO}_3$ )
- sodium chloride ( $\text{NaCl}$ )
- sodium hydrogen carbonate ( $\text{NaHCO}_3$ ).

How could each of these unlabelled solutions be identified using only **potassium carbonate** ( $\text{K}_2\text{CO}_3$ ) solution, and **red litmus paper**?

In your answer you should:

- complete the table
- explain how the observations allow you to identify each solution
- include balanced symbol equation(s) for any reactions.

<http://www.nzqa.govt.nz>

Unlabelled solution	Observation (if any) with red litmus paper	Observation (if any) with potassium carbonate ( $\text{K}_2\text{CO}_3$ )
Nitric acid ( $\text{HNO}_3$ )	Remain red	Bubbles of gas form/fizzes/heat
Sodium chloride ( $\text{NaCl}$ )	Remain red	No reaction
Sodium hydrogen carbonate ( $\text{NaHCO}_3$ )	Turn blue	No reaction

**Question 2b:** Three unlabelled colourless solutions are known to be:

- nitric acid ( $\text{HNO}_3$ )
- sodium chloride ( $\text{NaCl}$ )
- sodium hydrogen carbonate ( $\text{NaHCO}_3$ ).

How could each of these unlabelled solutions be identified using only **potassium carbonate** ( $\text{K}_2\text{CO}_3$ ) solution, and **red litmus paper**?

In your answer you should:

- complete the table
- explain how the observations allow you to identify each solution
- include balanced symbol equation(s) for any reactions.

<http://www.nzqa.govt.nz>

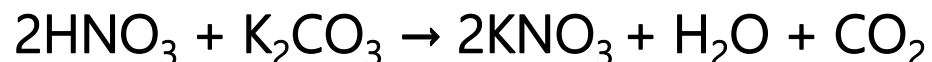
Prepare a test tube each filled with a sample (5mL) of the unknown substance.

Test each sample with dampened red litmus paper. Observations of 2 samples will be for the red litmus paper to remain red – place those 2 samples to one side. 1 of the samples will turn the red litmus paper blue. This solution can be identified as sodium hydrogen carbonate as it is a base.

With the remaining 2 samples add a small amount of potassium carbonate to both.

The sample that bubbles are observed to form will be nitric acid – as this is a neutralisation reaction between an acid and a base (the potassium carbonate) and the bubbles of gas will be carbon dioxide. (see equation below) The third test tube that does not react will be sodium chloride solution as this is neutral.

Balanced symbol equation(s):





## NCEA 2017 Acid Reactions

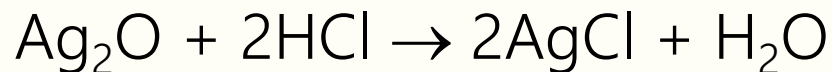
**Question 3a:** (ii) Silver oxide is a base and will react with hydrochloric acid. Write a word equation AND a balanced symbol equation for the reaction between silver oxide and hydrochloric acid.

Word equation:

Silver oxide + hydrochloric acid → silver chloride + water

Achieved  
Question

Balanced symbol equation:



Excellence  
Question



## NCEA 2018 Acid Reactions

**Question 2:** Solutions of potassium hydroxide, KOH, and sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, are added together in a beaker.

(a) Name the type of reaction occurring.

(b) Write the word equation and the balanced symbol equation for this reaction.

(a) Neutralisation reaction / acid-base.

(b) potassium hydroxide + sulfuric acid → potassium sulfate + water





**Question 3a:** Some magnesium carbonate powder is added to dilute nitric acid in an open conical flask. The flask is on an electronic balance, as shown in the illustration. Write the word equation AND the balanced symbol equation for the reaction between the nitric acid and magnesium carbonate.

Magnesium carbonate + nitric acid → magnesium nitrate + water + carbon dioxide



**Question 1a:** Write the word equation AND the balanced symbol equation for the reaction between the nitric acid and calcium carbonate.

Word equation

Nitric acid + calcium carbonate → calcium nitrate + water + carbon dioxide

Balanced symbol equation



**Question 3b:** In an investigation, copper sulfate can be made by reacting solid copper carbonate with sulfuric acid,  $\text{H}_2\text{SO}_4$ .

(i) Name the type of reaction occurring.

(ii) Write the word and the balanced symbol equation for this reaction.

Acid-base reaction or neutralisation.

Word equation

Sulfuric acid + copper carbonate  $\rightarrow$  copper sulfate + water + carbon dioxide

Balanced symbol equation



**Question 3b:** (iii) Describe how you could make **solid** copper sulfate crystals in a school laboratory.

In your answer, include how you would know the reaction had been completed.

Add the solid copper carbonate to the sulfuric acid. The reaction is completed when bubbles (of carbon dioxide) are no longer produced, as the reactant (sulfuric acid) has been used up and neutralised.

Alternatively, the reaction could be followed by measuring the pH using universal indicator or probe, and the reaction would be complete at pH 7.

Leave the resultant solution in a warm place / heat until water has evaporated to leave copper sulfate behind.





# Reaction Rate

The reaction rate is the speed at which a chemical reaction occurs. This is measured by how quickly the reactants change into products or how quickly one of the reactants disappears. Reactions can vary in their reaction rate



Iron oxidising



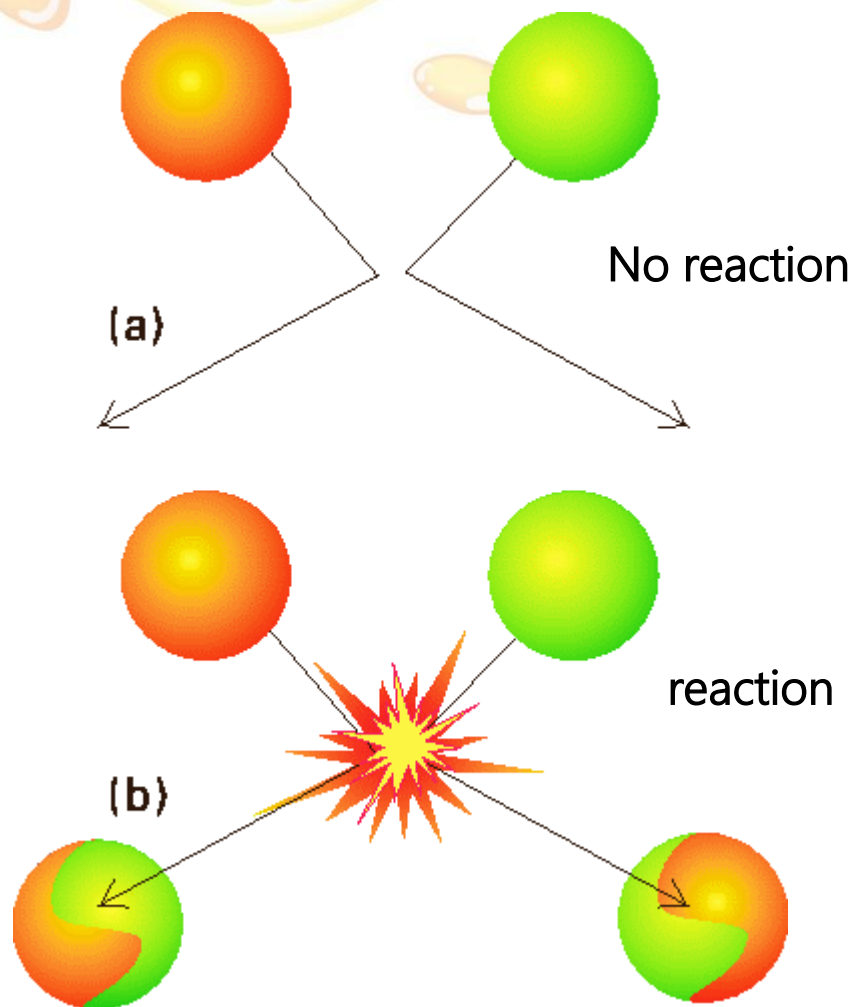
oxygen and hydrogen combusting

# Collision Theory

Chemical reactions between particles of substances only occur when the following conditions have been met:

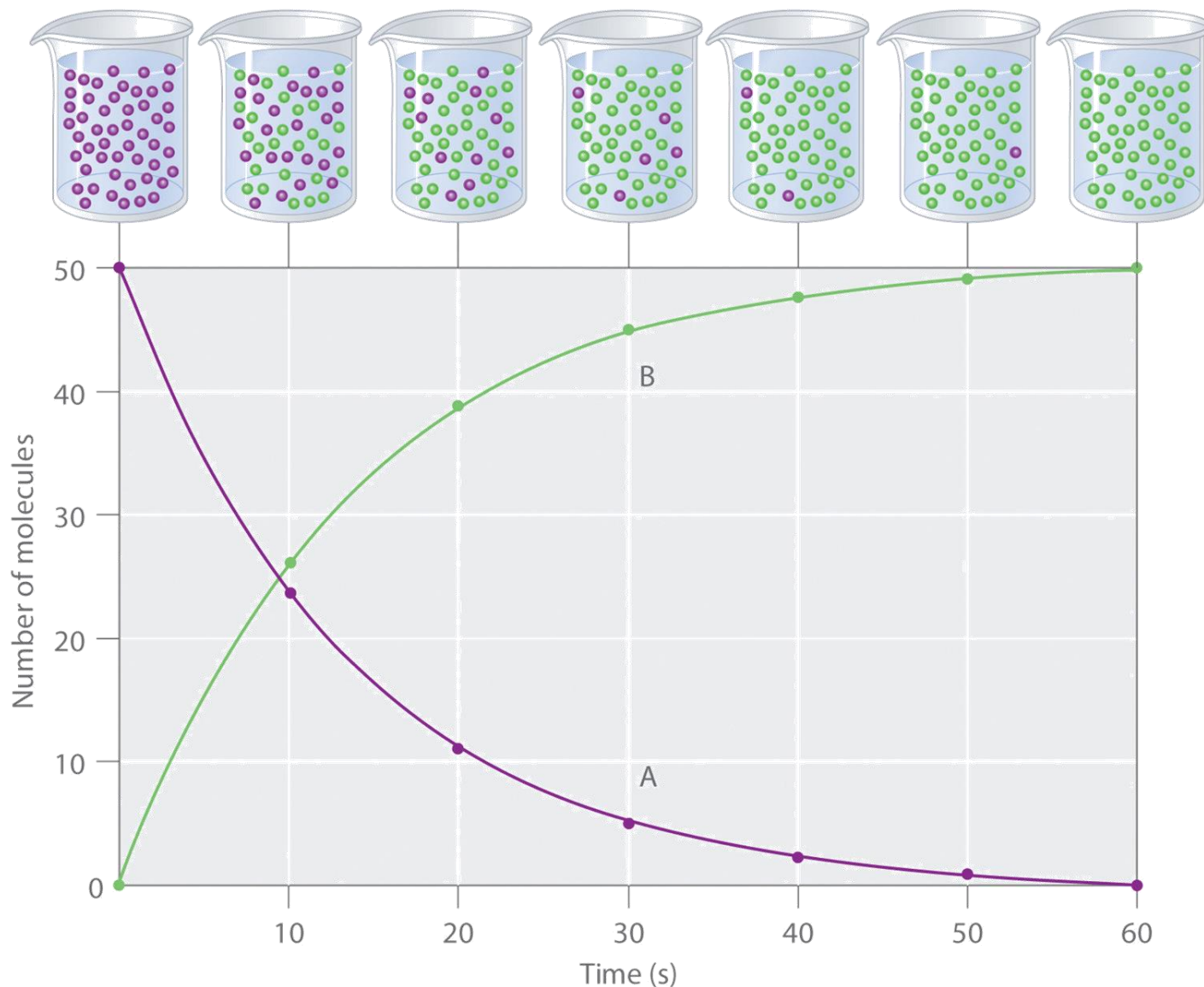
- **Particles must collide.**
- **With enough energy ( called activation energy EA)**
- **And with the correct orientation**

If these conditions are met the collision will be considered **successful**. (effective)

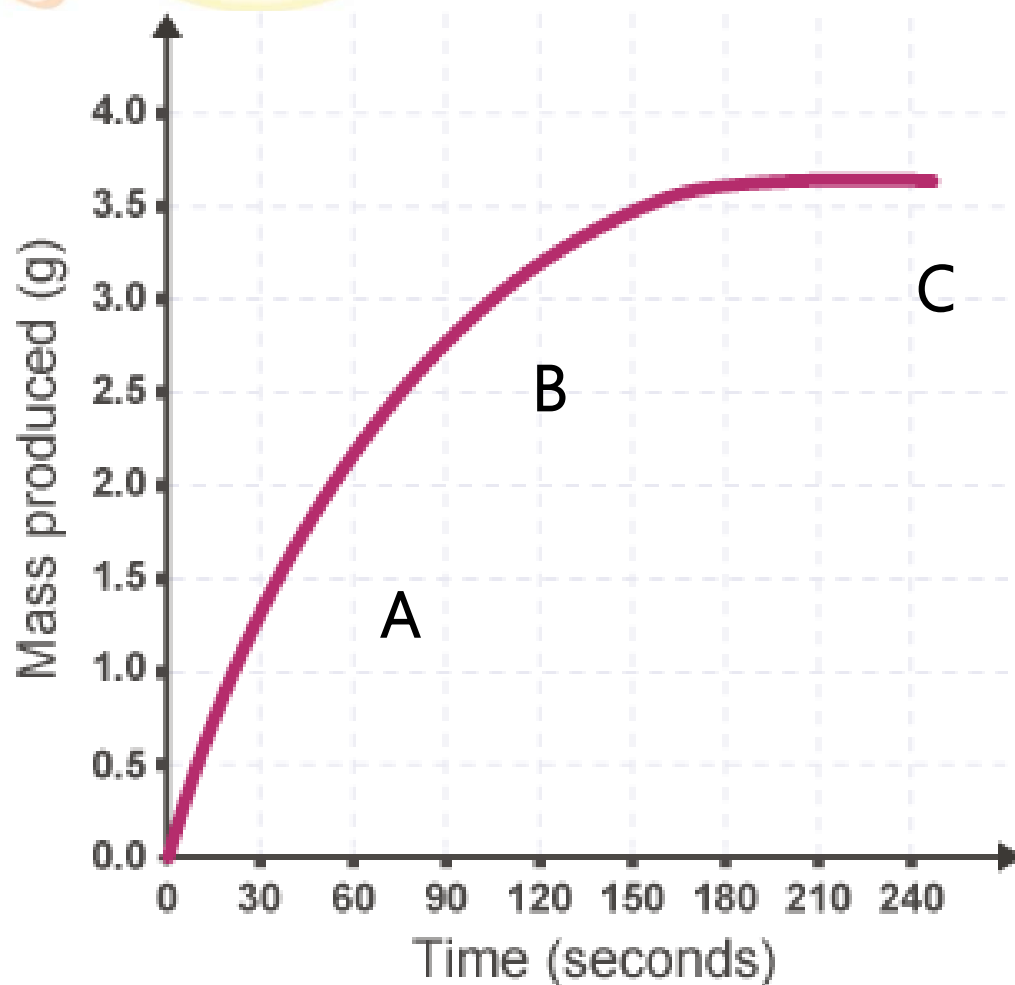


## Reactions over time

Reactions take place over time. As the amount of reactants decrease the amount of products increase. The reaction rate is shown as a curve because the amount of reactants at the start is greater and the reaction rate slows as they decrease

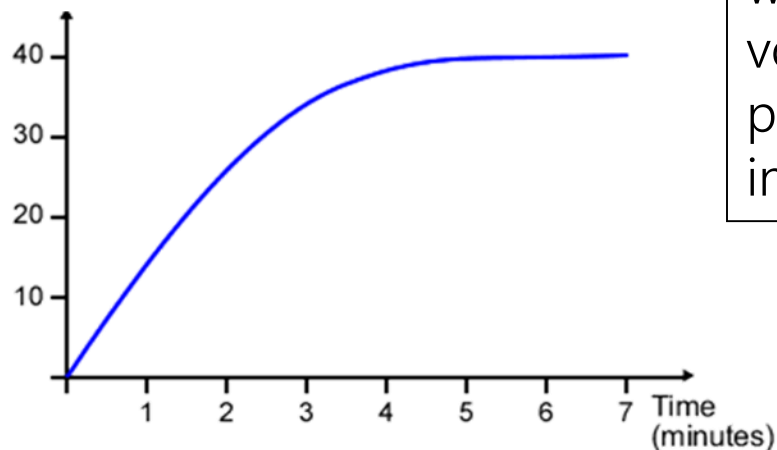


- A. Reactions start out **relatively fast** because there is a much higher concentration of reactant particles available to collide and therefore the frequency of collisions will be high. The **gradient of the line** on the graph for products formed will be **high**.
- B. As the reaction proceeds there will be less reactant particles available to collide as many have already reacted to form products. The **gradient of the line** will be **lower**.
- C. When the reaction has come to **completion**, when all of the reactants have reacted to form particles, then there will be **no further collisions** and the **gradient of the line** will be **zero**.

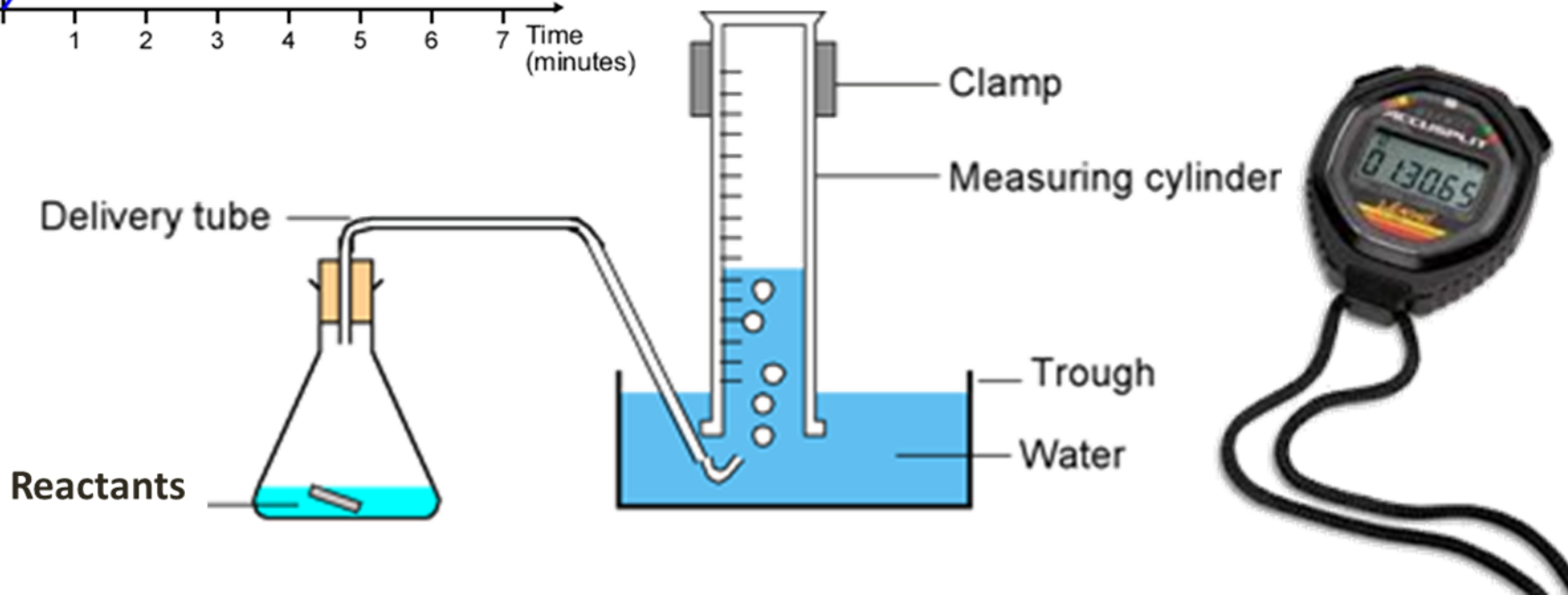


# Measuring the rate of reaction

Volume of gas  
produced  $\text{cm}^3$



When gas is one of the products it can be collected in an upside down cylinder. The water displacement is a measure of the volume of gas produced. The amount produced needs to be recorded at set time intervals and then graphed.

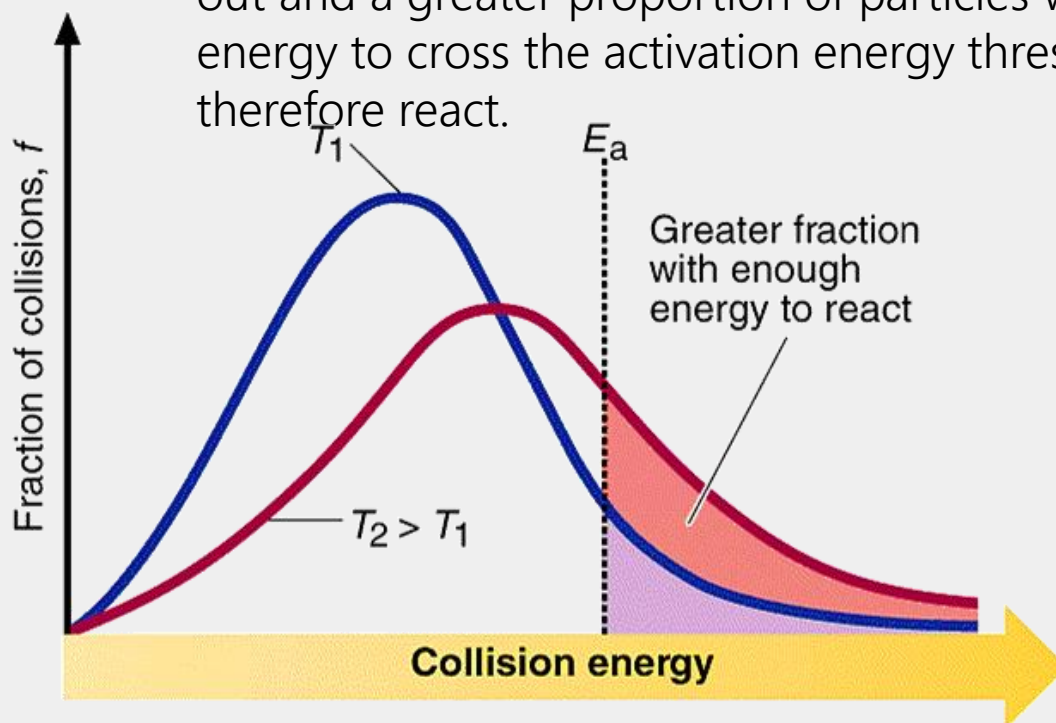




## Activation Energy ( $E_A$ )

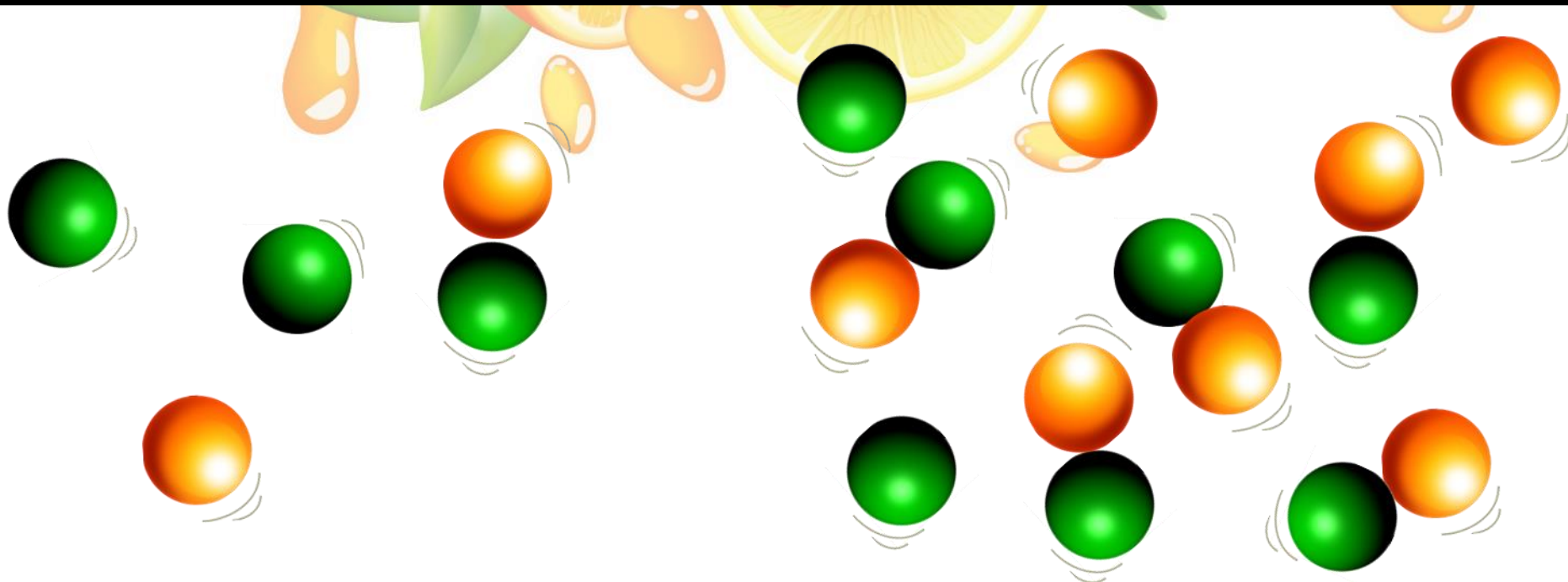
Activation energy is the initial energy required for a reaction to occur. It could be provided in the form of heat or kinetic energy.

At lower temperatures ( $T_1$ ) most particles will have the same collision energy when they collide. As the temperature is increased ( $T_2$ ) the range of collision energy is more spread out and a greater proportion of particles will have enough energy to cross the activation energy threshold and therefore react.





## Reaction rate can be increased by increasing the concentration



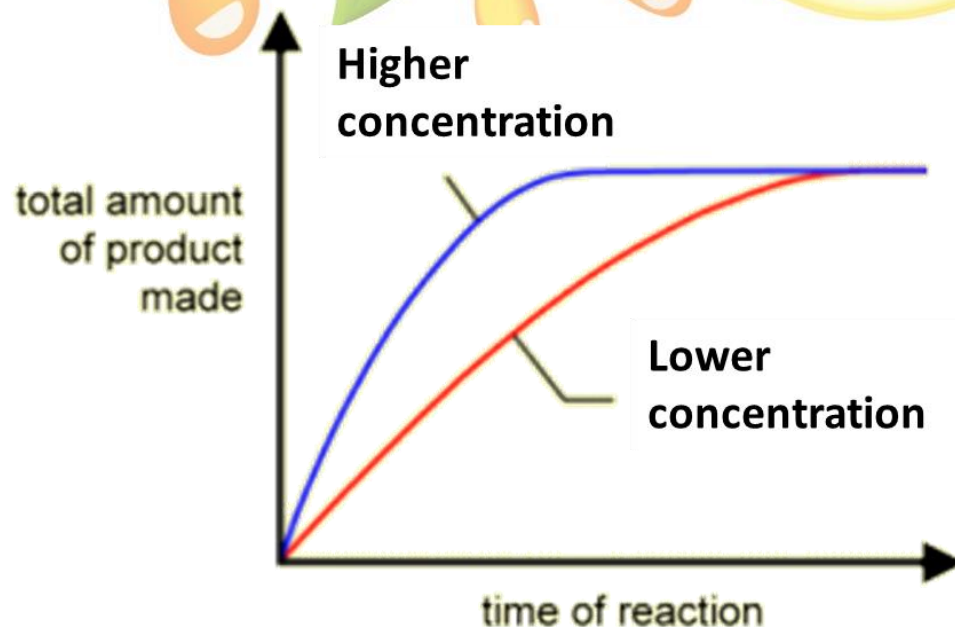
**Low concentration = few collisions**

**High concentration = more collisions**

If there is a **higher concentration of a reactant**, there is a greater chance that particles will collide because there is less space between particles. There are **more particles per unit volume**. The **higher frequency of collisions** means there are more **successful collisions** per unit of time and this will **increase the rate of the reaction**.

If there is a lower concentration, there will be fewer collisions and the reaction rate will decrease.

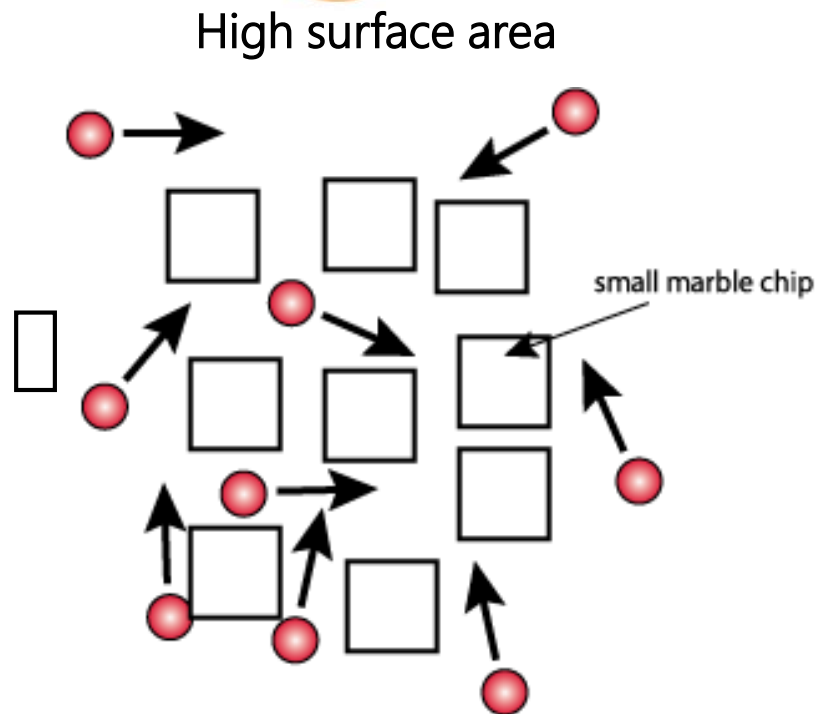
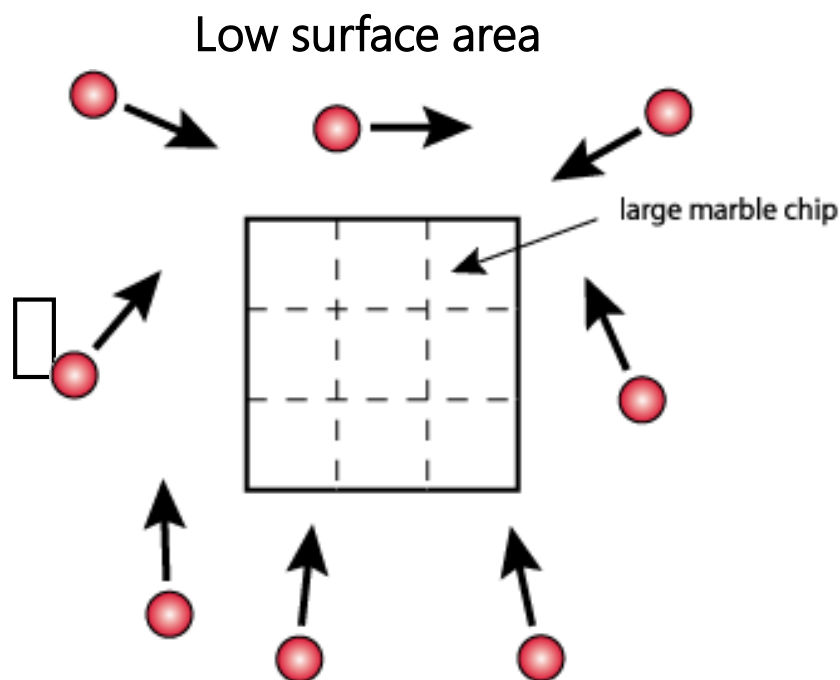
## Reaction rate can be increased by increasing the concentration



It is important to note that the total amount of product made depends upon the total amount of reactants at the start. A solution that contains only half the particles of another will require twice the volume to produce the same quantity of product.

Also, note that the **proportion of successful collisions does not change** by increasing the concentration only the frequency (amount of collisions per unit of time) of collisions is increased.

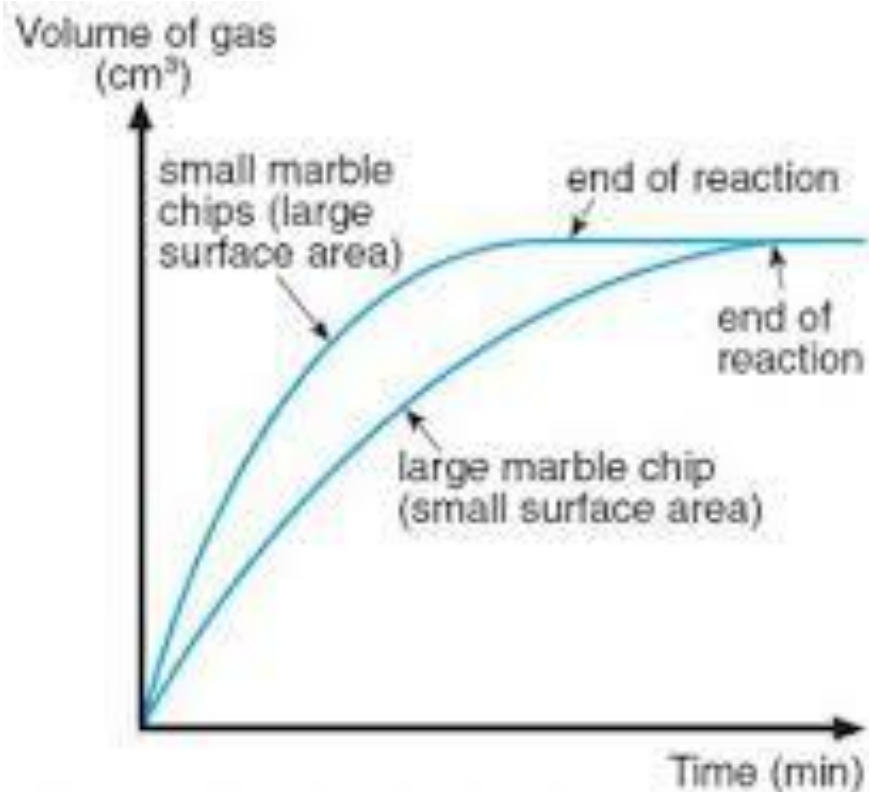
# Reaction rate can be increased by increasing the Surface Area



**Surface area** can be increased by grinding and crushing large lumps into a finer powder. The smaller the pieces the greater the surface area.

## Reaction rate can be increased by increasing the surface area

By increasing surface area, a greater number of reactant particles are exposed and therefore able to collide. The frequency of collisions (number of collisions per unit of time) will increase and therefore the number of successful collisions so the reaction rate will also increase.

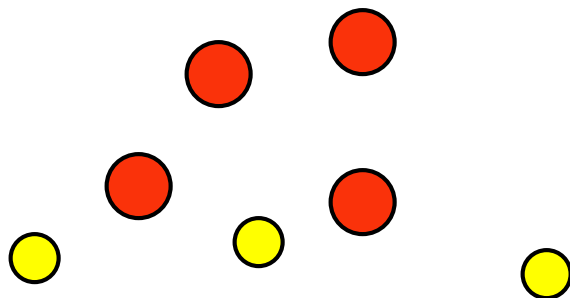


An example is comparing the reaction between marble (calcium carbonate) and hydrochloric acid to produce carbon dioxide gas.

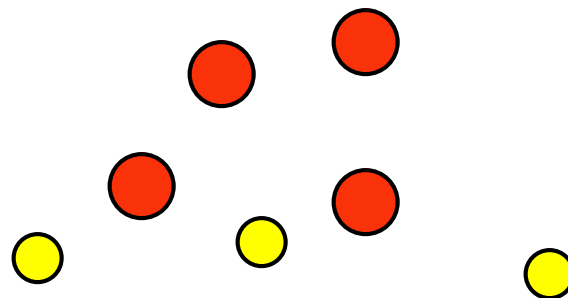
Note: although the reaction rate is higher for the smaller marble chips the total amount of gas (CO<sub>2</sub>) produced is the same for both reactions as they both started off with the same amount of reactants.

# Reaction rate can be increased by increasing the Temperature

Low temperature



High temperature



Increasing temperature effects the reaction rate in two ways.

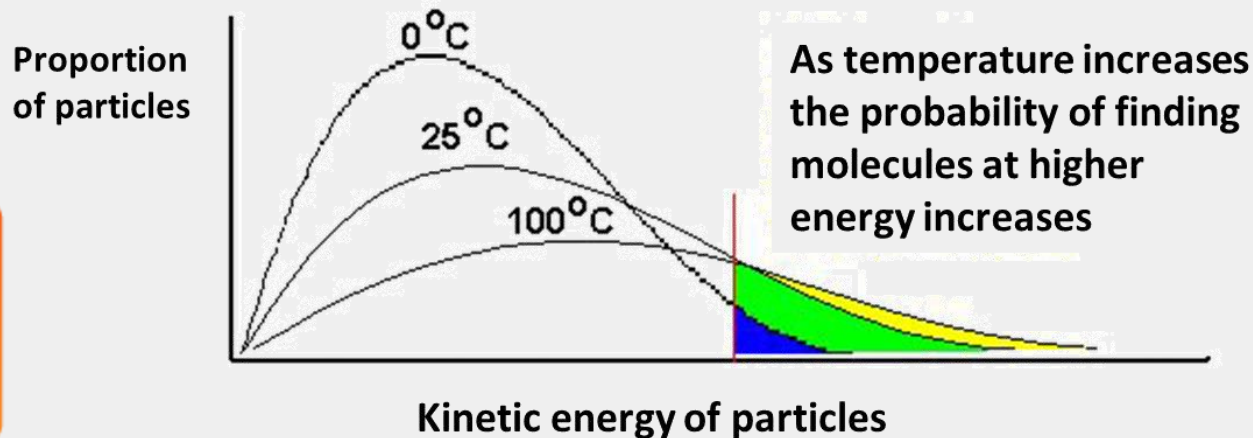
Firstly when you raise the temperature of a system, the particles move around a lot more (because they have more kinetic energy). When they move around more, they are **more likely to collide and the frequency of collisions increases**, therefore the number of successful collisions increase and so reaction rate increases as well. When you lower the temperature, the molecules are slower and collide less frequently therefore the reaction rate decreases.

Secondly at a higher temperature a **larger proportion of particles have sufficient (kinetic) energy to have the energy required during a collision for it to be successful** and therefore a reaction to occur. This increases the proportion of successful collisions and therefore the reaction rate.

## Background Knowledge

### Reaction rate can be increased by increasing the Temperature

GZ Science Resources



*i*  
extra  
info

At any given temperature there will be a range in the kinetic energy of particles. At a lower temperature a greater proportion of particles are likely to have insufficient kinetic energy during a collision in order for a successful collision, and therefore a reaction, to take place.

Increasing the temperature also increases the probability of a successful collision.



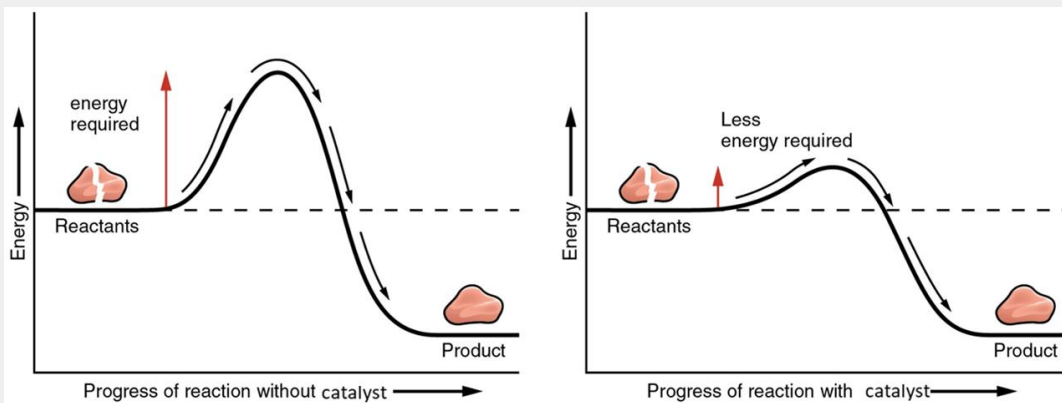
# Background Knowledge

## Reaction rate can be increased by using a catalyst.

GZ Science Resources

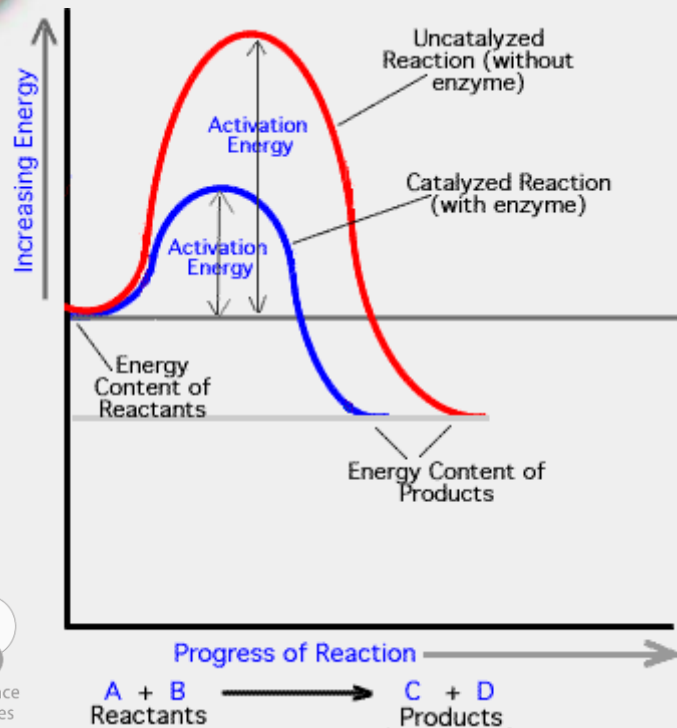
A catalyst is a substance that increases the reaction rate without being used up or forming part of the products. Only some reactions have catalysts that are effective, but for many reactions there is no catalyst that works.

A catalyst lowers the minimum amount of energy required for a reaction to take place. This means that the particles can successfully collide with less energy than they required before the catalyst was added. **A greater proportion of particles will successfully collide**, and therefore the reaction rate will be increased.



# Background Knowledge

Reaction rate can be increased by using a catalyst.



Cell metabolism consists of reactions between chemicals. Chemical reactions require an amount of energy in order for them to be successful. This energy is called activation energy.

**Catalysts** are substances that lower the amount of activation energy required – less energy is needed for a reaction to be successful. They are not used up in the reaction and do not form part of the product. They can be reused over and over.

**Enzymes** are biological catalysts.

# Factors affecting Reaction Rate



## Increase the frequency of collisions

➤ By **increasing surface area**: smaller pieces of reactant expose more reactant particles to collisions. Stirring will also increase the reaction rate

➤ By **increasing the concentrations**: more reactant particles exist in a given volume so more collisions occur (per unit volume)

## Increase the energy of collisions

> by **increasing temperature**: particles move faster so have more kinetic energy. More collisions will be effective (successful)

Note: increasing temp also increases frequency of collisions (collisions per unit time)

## Make it easier for reaction to occur

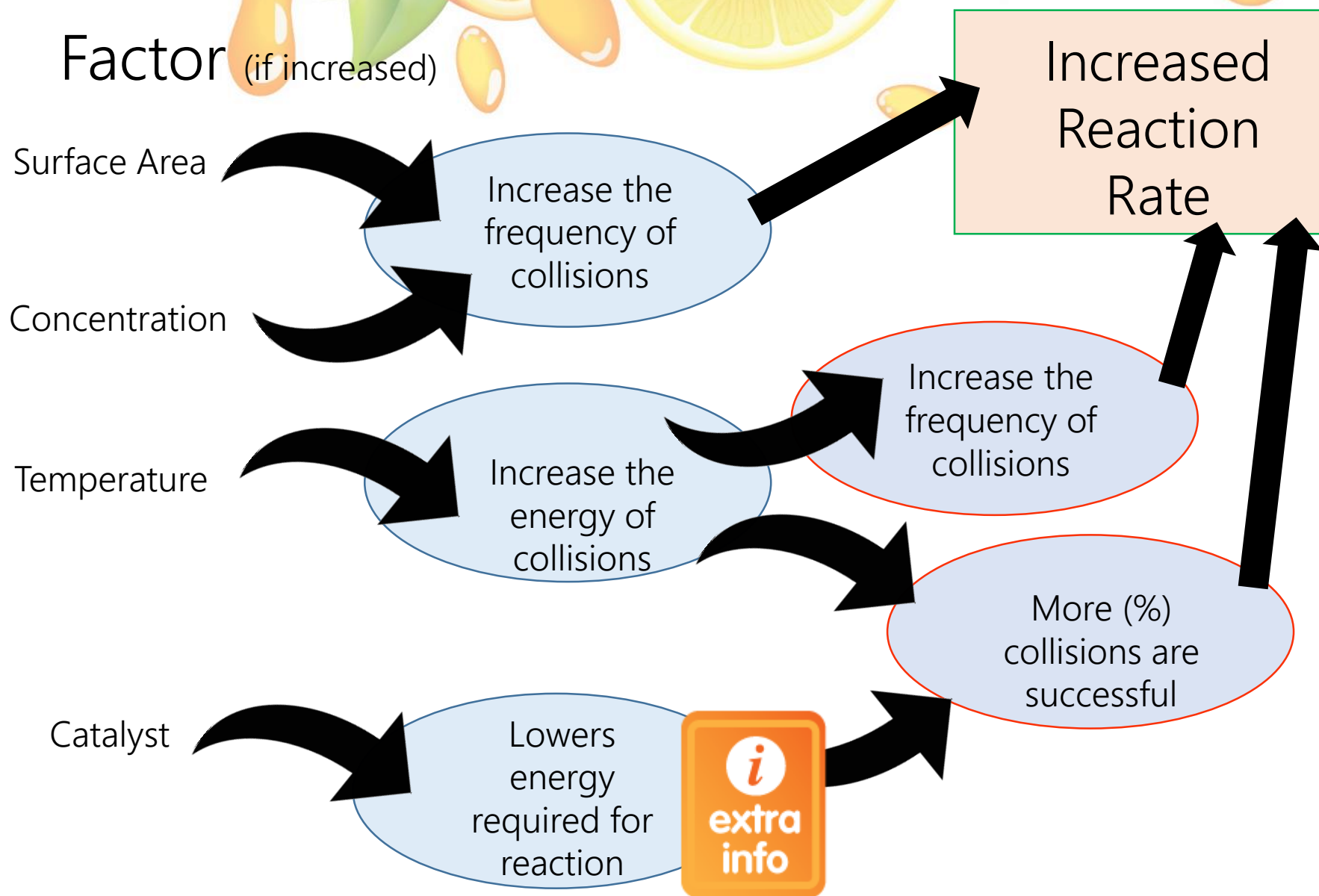
> by **using a catalyst**: allows reaction to occur with less energy so more collisions are effective (successful)

Reaction rate can also be slowed down by decreasing these

## Writing Reaction rate Answers

1. Always **identify the factor involved**, ideally at the beginning of the answer: surface area, temperature, concentration or catalyst. If you are unsure look at the remaining questions as the same factor is rarely used twice.
2. Particles need to **collide** with **sufficient kinetic energy** and in the **correct orientation** in order for an effective/successful collision to occur.
3. Increasing surface area and concentration of reactants increases the **number of collisions per unit of time** (frequency) and particles per unit volume available to react.
4. Increasing temperature increases **both** the number of collisions per unit of time **and** the average amount of kinetic energy the particles have, so more particles have sufficient energy to obtain the activation energy requirements. Discuss both effects.
5. Link the increase in **effective/successful collisions** to an increase in **reaction rate**.

# Summary of Reaction rates

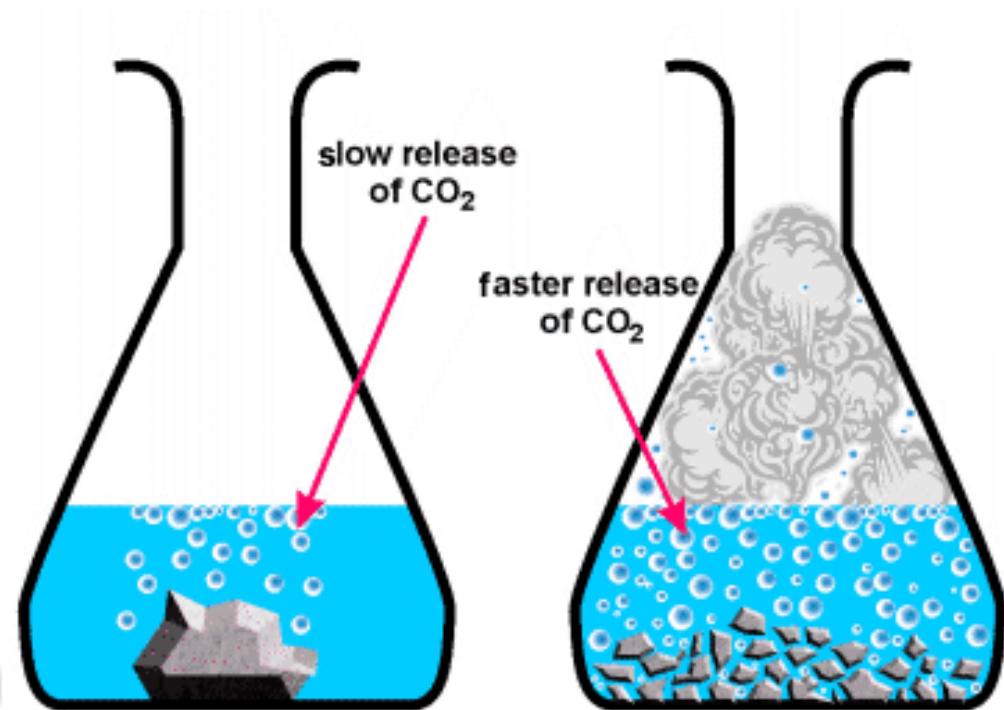


## NCEA Reaction rate

Hydrochloric acid was reacted with calcium carbonate in the form of marble chips (lumps) and powder (crushed marble chips) in an experiment to investigate factors affecting the rate of a chemical reaction..

**Explain why the hydrochloric acid would react faster with the powder.**

When the marble chips are crushed there is a **greater surface area**. This means there are now **more particles for collisions** to occur between the acid and the calcium carbonate. Because more collisions can now occur **more frequently** the **reaction rate is faster**.





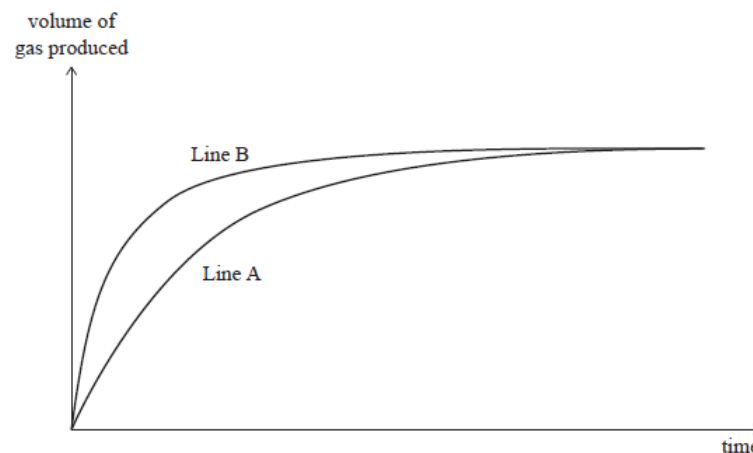
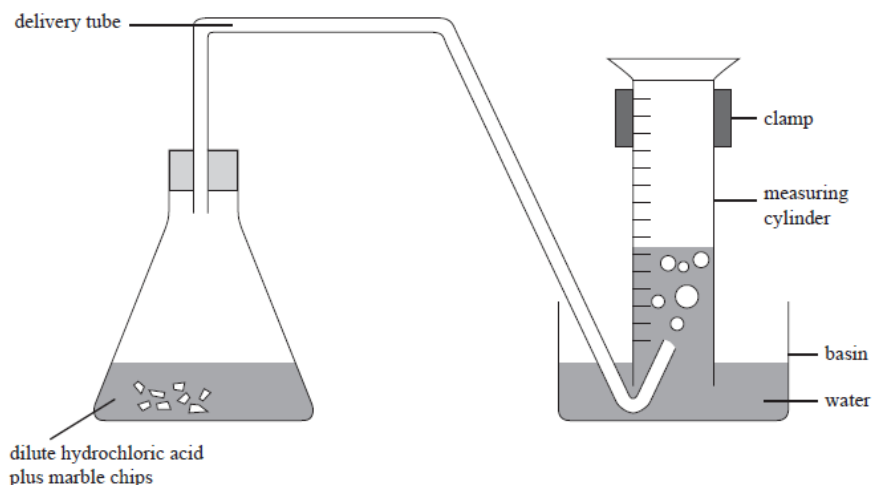
## NCEA 2012 Reaction Rates – (Part One)

Excellence  
Question

**Question 4a :** The following experiment was carried out at  $20^{\circ}\text{C}$  and then repeated at  $40^{\circ}\text{C}$ .

Marble chips (calcium carbonate) were added to hydrochloric acid in a conical flask. The mass and size of marble chips, and the concentration and volume of hydrochloric acid used, were the **same** for both experiments. The flask was connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.

The volume of gas produced at the two different temperatures was measured for a few minutes and the results were used to sketch the graph shown below.



## NCEA 2012 Reaction Rates – (Part One)

Excellence  
Question

**Question 4a :** State which line on the graph represents the reaction at  $40^{\circ}\text{C}$  and explain how you worked this out.

In your answer you should:

- identify which line represents the reaction at  $40^{\circ}\text{C}$
- explain why the line you have identified is the reaction at  $40^{\circ}\text{C}$
- give reasons for the different rates of reaction in terms of particles
- explain why both lines end up horizontal.

The reaction is faster at the higher temperature, because the  $\text{H}^+$  ions have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions per unit time (higher frequency), and more of these collisions will be effective, as the particles will collide with more energy.

Line B represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at  $40^{\circ}\text{C}$ .

Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, ie one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.

## NCEA 2013 Reaction Rates – (Part One)

Excellence  
Question

**Question 3a :** The table below shows the size of marble chips (calcium carbonate) used in a chemical investigation into factors affecting rate of reaction.

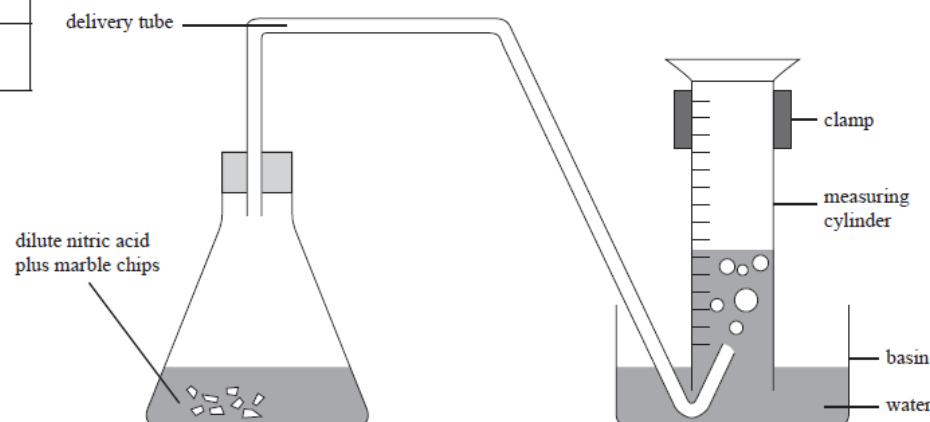
**Experiment 1:** 10 mL of hydrochloric acid was added to a boiling tube containing small marble chips.

**Experiment 2:** 10 mL of hydrochloric acid of the same concentration as in Experiment 1 was added to another boiling tube containing large marble chips.

In both experiments the total mass of the marble chips was the same.

The boiling tubes were connected to an inverted measuring cylinder in a basin of water, as shown in the diagram below.

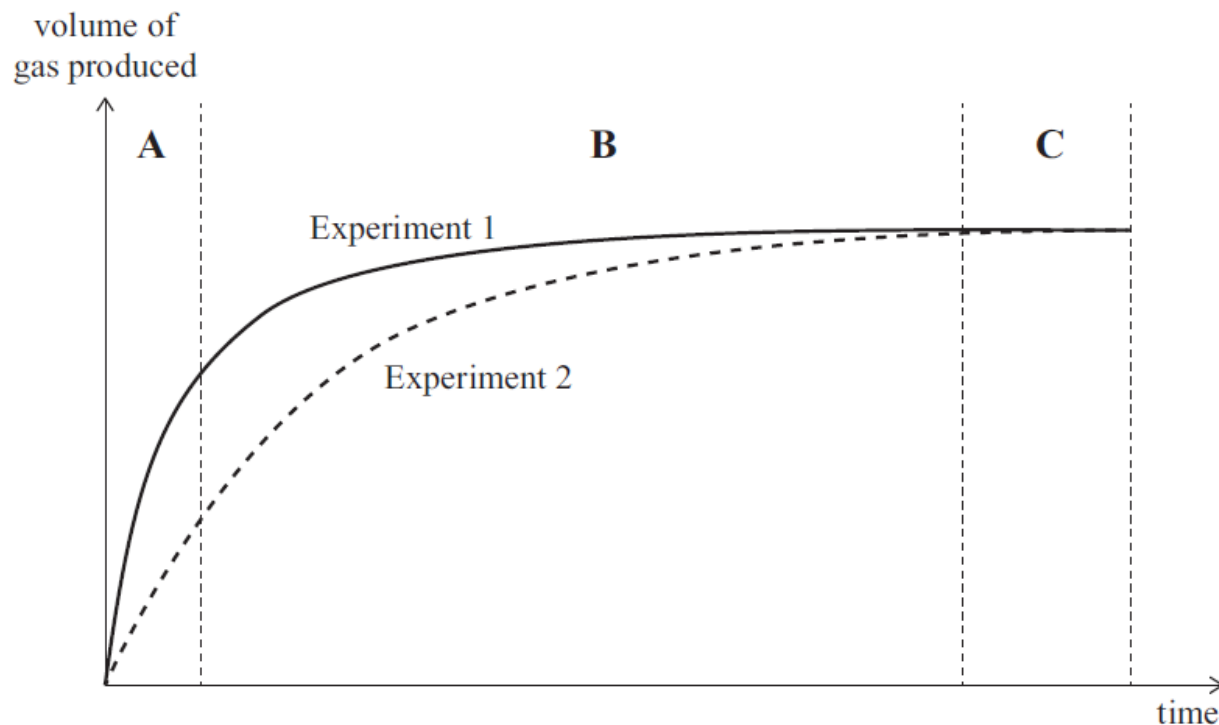
Experiment	Size of marble chips (calcium carbonate)
Experiment 1	small marble chips
Experiment 2	large marble chips



## NCEA 2013 Reaction Rates – (Part One)

Achieved  
Question

**Question 3a :** The graph below shows the results for the volume of gas produced over a period of time.  
State what factor affecting the rate of reaction is being investigated in this experiment.

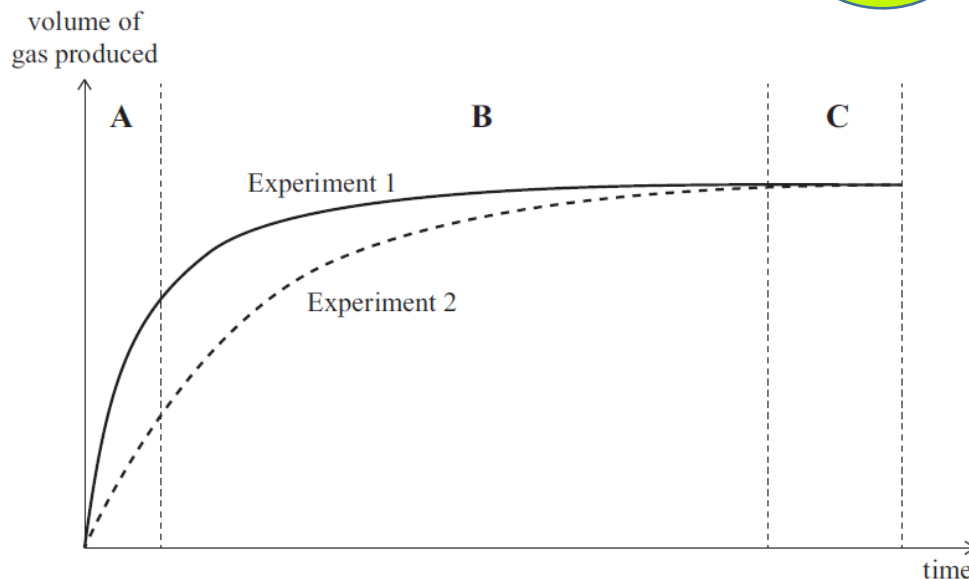


The factor being investigated is surface area of the calcium carbonate / marble chips.

## NCEA 2013 Reaction Rates – (Part Two)

Excellence  
Question

**Question 3b :** Explain what is happening in **Experiment 1** in sections A, B, and C of the graph in terms of reaction rate. In your answer you should refer to particle collisions.



**Answer 3b :** In section A of the graph the rate is fastest as there are more collisions between the  $\text{HCl}$  and  $\text{CaCO}_3$ . This is because at the start of the reaction there are more particles available for collision. In section B the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the  $\text{HCl}$  and  $\text{CaCO}_3$  have already collided and have been used up, therefore fewer particles and therefore fewer collisions. In part C the reaction has stopped, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react.

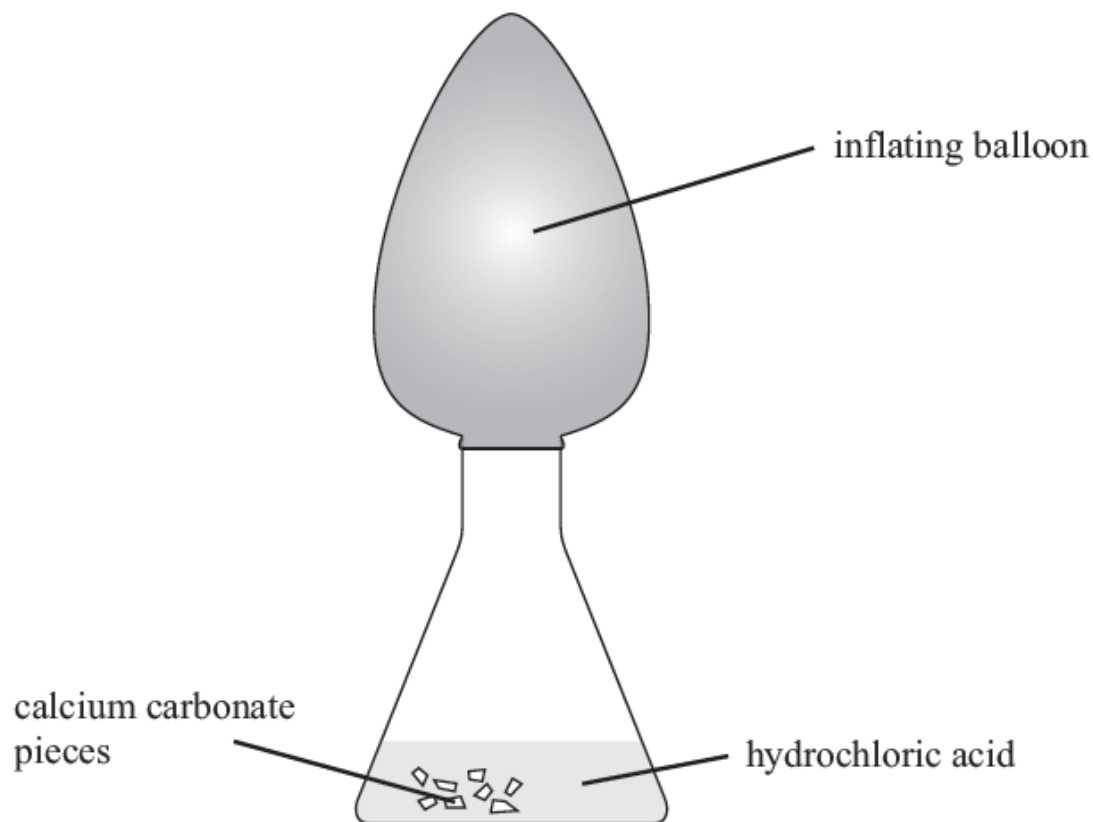


## NCEA 2014 Reaction Rates - (Part One)

Achieved  
Question

**Question 2a (i) :** Calcium carbonate pieces are placed in a flask and hydrochloric acid is added. Immediately a balloon is placed over the top of the flask. The balloon then starts to inflate. Explain why the balloon inflates.

**Answer 2a (i) :** When a metal carbonate reacts with an acid, carbon dioxide gas is released. This gas causes the balloon to inflate.

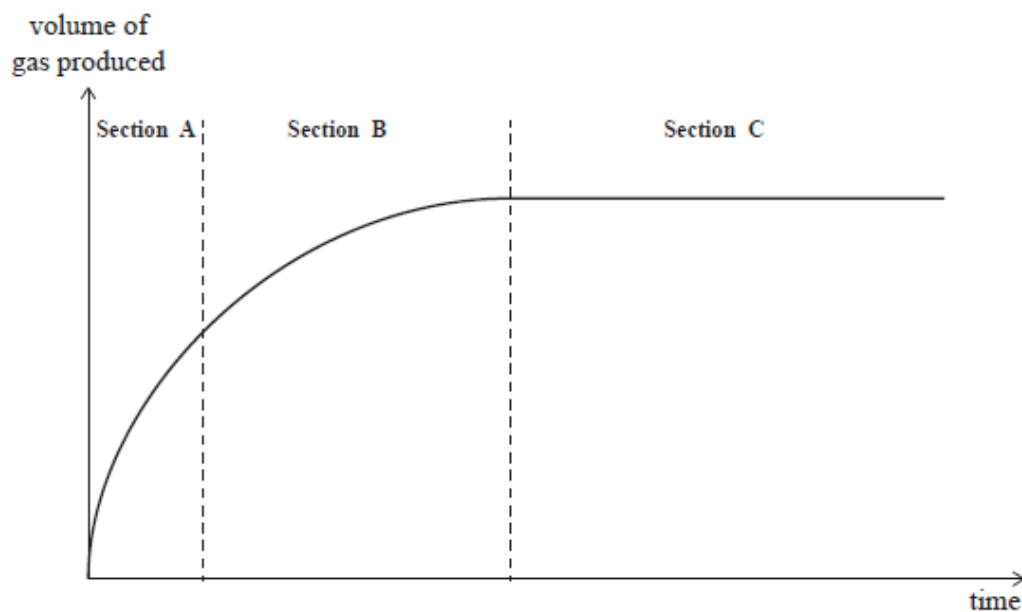
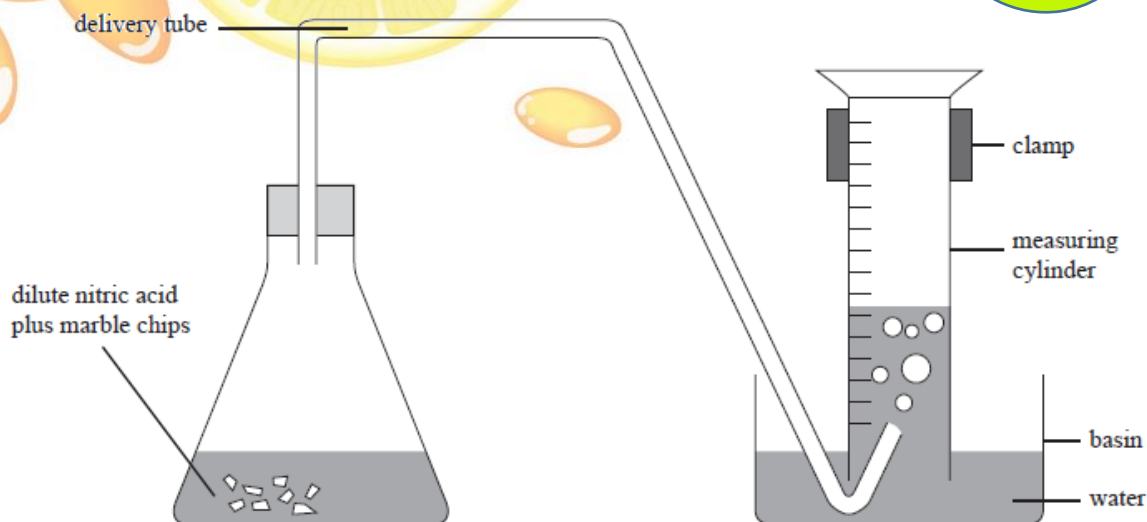


# NCEA 2015 Reaction Rates

Excellence  
Question

**Question 1a:** Marble chips (calcium carbonate) were added to nitric acid in a conical flask. The temperature of the acid was  $50^{\circ}\text{C}$ . The flask was connected to an inverted measuring cylinder in a basin of water to measure the volume of gas produced, as shown in the diagram beside. The graph beside shows the volume of gas produced against time.

Explain what is happening in terms of particle collisions and rate of reaction in **each section** of the graph.



# NCEA 2015 Reaction Rates

Excellence  
Question

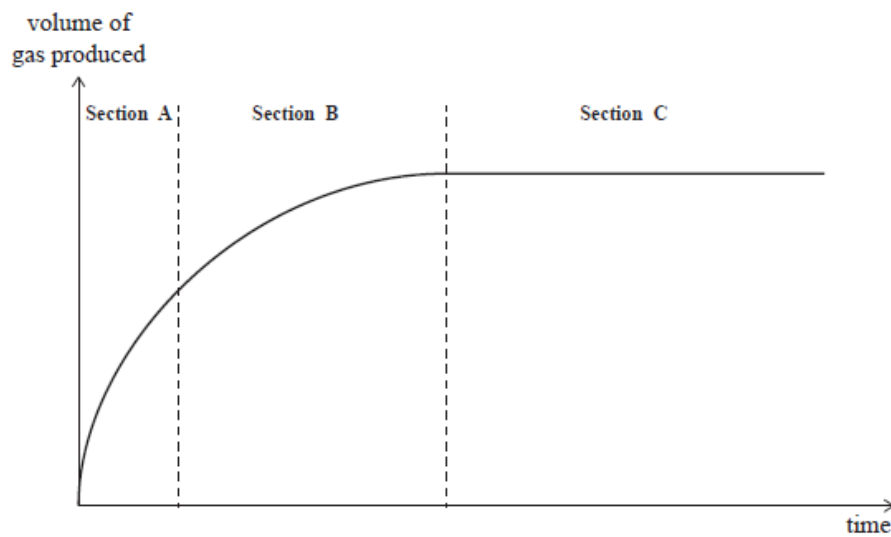
**Answer 1a:** As the reactant particles collide, they form product particles.

As the reaction proceeds, there are fewer and fewer reactant particles left to collide, and so the rate of reaction becomes slower.

At the start (section A) of the reaction, more product particles are being formed. This is because at the start of the reaction there are many particles present; therefore there will be many collisions, and the more collisions (per unit time), the faster the rate of reaction, and the more gas produced.

In section B, there are now fewer (less) reactants, and so there are fewer collisions per second (unit time); therefore a slower rate of reaction and so less product is formed.

In section C, the reaction has stopped, as one of the reactants (marble chips or nitric acid) has run out, so there are no particles left to react.



## Link in each section

Relative amount of reactants:products

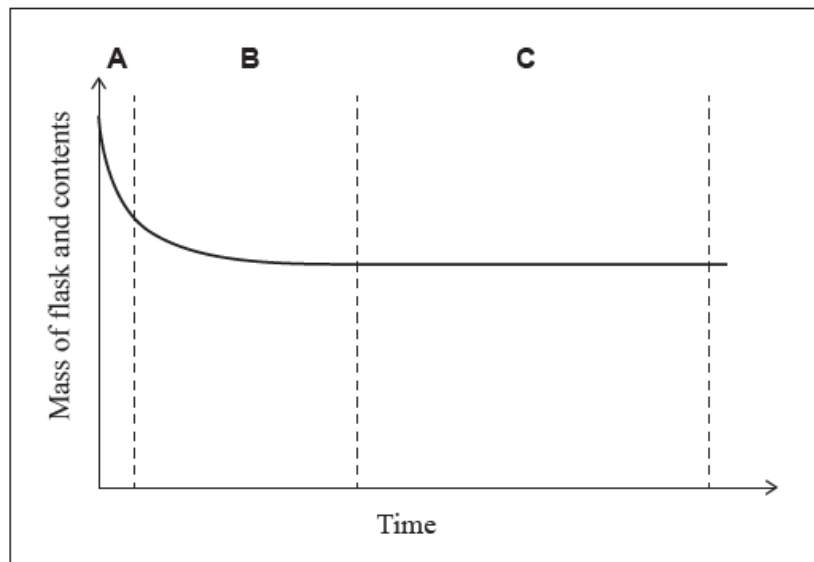
Collisions per unit of time

Rate of reaction

Amount of gas produced

**Question 3b:** Some magnesium carbonate powder is added to dilute nitric acid in an open conical flask. The flask is on an electronic balance, as shown in the illustration. The total mass of the flask and its contents is measured over time and recorded on the graph below. (i) Why does the mass of the flask and its contents decrease during the reaction?

Change in mass over time



One of the products is carbon dioxide gas. The gas escapes, and so the mass of the flask and its contents decreases.



**Question 3b:** Some magnesium carbonate powder is added to dilute nitric acid in an open conical flask. (ii) Explain what is happening in sections A, B, and C of the graph. Link your answer to rates of reaction and particle collisions.

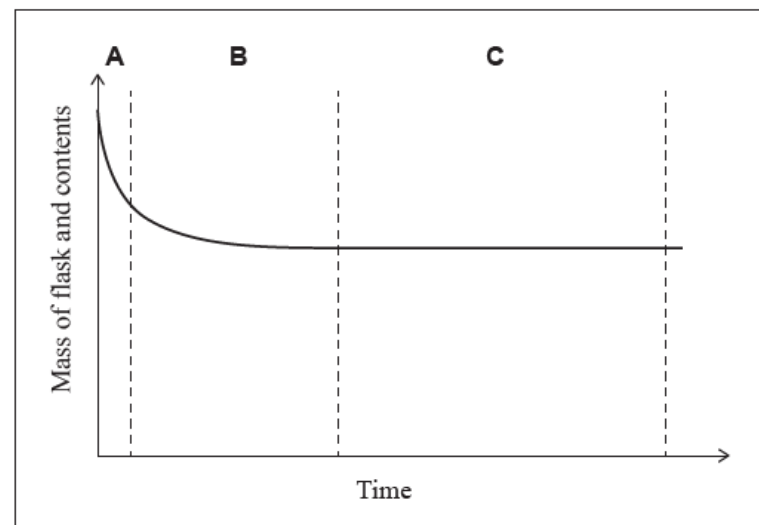
When reactant particles collide successfully, they form product particles. As the reaction progresses, the number of reactant particles decreases, the frequency of successful collisions decreases, leading to a slower rate of reaction.

**Section A:** There are more reactant particles, so more collisions per second. More product particles are being formed, including more gas, so more gas escapes and the mass decreases quickly.

**Section B:** There are fewer reactant particles, so fewer successful collisions per second and so less product is being made, so the mass decreases less quickly.

**Section C:** The reaction has stopped as one of the reactants has been used up, so there are no more collisions between reacting particles.

Change in mass over time



## NCEA 2013 Reaction Rate Factors – (Part Three)

Excellence  
Question

**Question 3c :** Explain why **Experiment 1** was faster than **Experiment 2**.

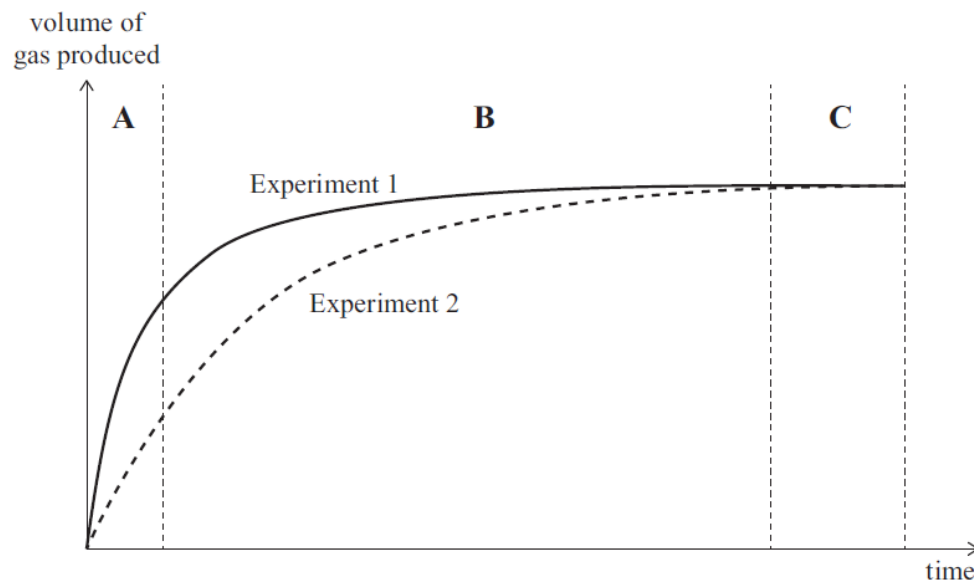
In your answer you should:

- explain how the graph shows that Experiment 1 is faster
- explain how the size of the marble chips affects the number of particle collisions.

**Experiment 1:** small marble chips.

**Experiment 2:** large marble chips.

The rate of Experiment 1 is faster as the slope in section A of the graph is steeper than in Experiment 2. It is faster because when smaller chips are used, the surface area of the chips is greater. Because there is more surface area, there is more surface for the HCl particles to collide. Because there are more collisions occurring more frequently, the rate is faster.

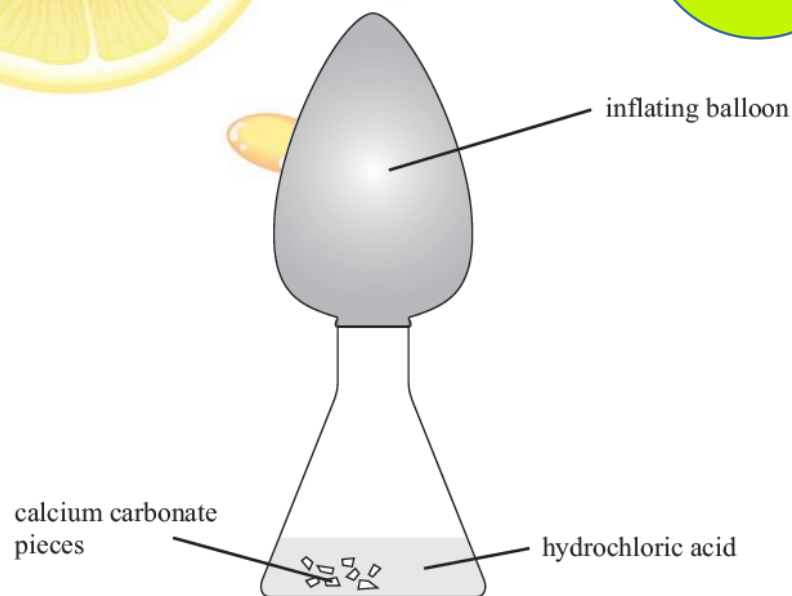




## NCEA 2014 Reaction Rate Factors - (Part Two)

Excellence  
Question

**Question 2a (ii):** In a second experiment, the same mass of calcium carbonate in a powdered form is used. Explain why the balloon inflates faster when powdered calcium carbonate is used.



**Answer 2a (ii):** It is faster when powder is used, because the surface area of the powder is greater. Because there is more surface area, there is more surface with which the HCl particles can collide. Because more collisions occur more frequently, the rate is faster, and  $\text{CO}_2$  will be generated more quickly.

Explains that when the concentration is increased, there are more particles present in the same volume and so therefore there is a greater chance of collisions occurring per unit time.

## NCEA 2014 Reaction Rate Factors - (Part Three)

Excellence  
Question

**Question 2b :** Using the same chemical substances (calcium carbonate and hydrochloric acid), discuss a different way to make the balloon inflate faster. In your answer you should refer to rates of reaction and particle collisions.

**Answer 2b :** One way of making the reaction occur faster is to increase the concentration of the acid used. When this happens there are more HCl particles in the same volume of acid, and therefore there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster,  $\text{CO}_2$  is produced more rapidly, and the balloon inflates faster.

**OR**

The other way is to increase the temperature of the acid. When this happens, the HCl particles move faster; because they are moving faster, there is a greater chance of collisions occurring more frequently, and so the rate of reaction is faster. Because the rate is faster,  $\text{CO}_2$  is produced more rapidly, and the balloon inflates faster.

## NCEA 2015 Reaction Rate Factors

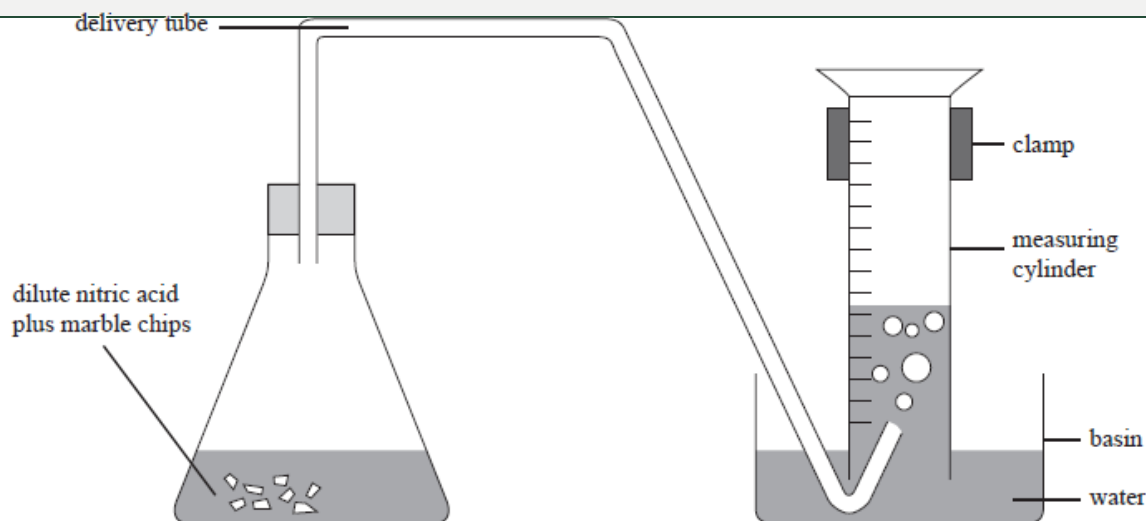
Excellence  
Question

**Question 1b:** The reaction was carried out again but this time at 20°C. The mass and size of the marble chips, and the concentration and volume of nitric acid used were kept the same.

- (i) Draw a line on the graph that represents the reaction at 20°C.
- (ii) Explain why you drew this line where you did, and explain if this means that the rate of reaction is slower, the same, or faster.

In your answer you should

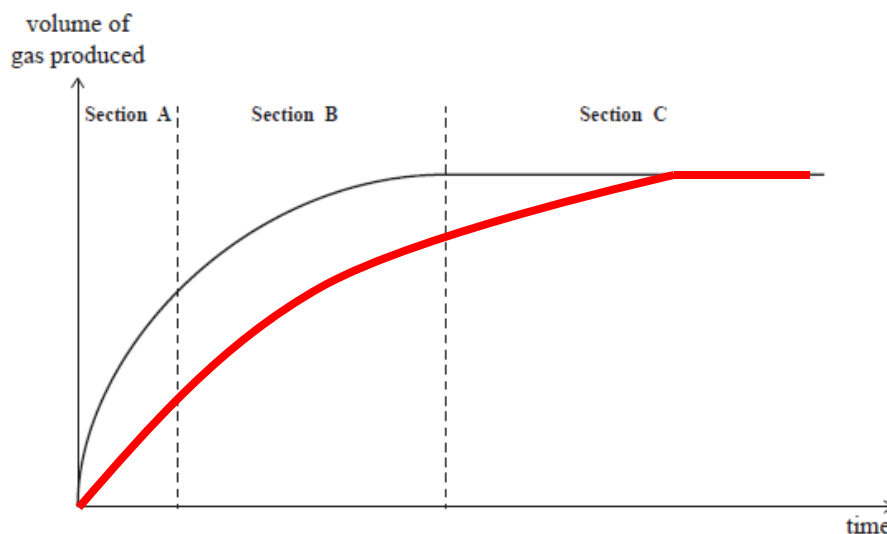
- discuss why you drew your line with the slope that you did, and why you stopped the line at the point that you did
- explain the effect of temperature on reaction rate, in terms of particle collisions.



## NCEA 2015 Reaction Rate Factors

Excellence  
Question

**Answer 1b:** The reaction is slower at the lower temperature, because the particles have less kinetic energy, and therefore are moving slower. When they are moving slower, there will be less frequent collisions, and less of these collisions will be effective, as the particles will collide with less energy. The line drawn represents this slower reaction, as it is less steep at the start. Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, i.e. one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with.



## NCEA 2016 Reaction Rates – (Part One)

Achieved  
Question

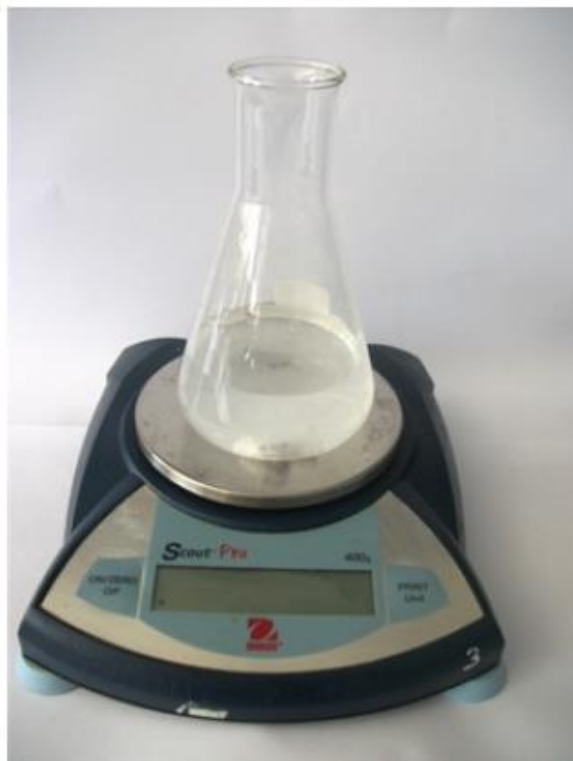
**Question 2a:** A sample of calcium carbonate is added to dilute hydrochloric acid in an open conical flask. The total mass of the flask and contents is measured over time.

Three experiments are carried out at 25°C using the same mass of calcium carbonate, and the same volume of acid:

For each of the experiments reacting calcium carbonate and dilute acid together, the mass of the flask and its contents decreases over time.

Describe why this happens.

	Calcium carbonate pieces	pH of acid
<b>Experiment 1</b>	Chips	1
<b>Experiment 2</b>	Powdered	1
<b>Experiment 3</b>	Powdered	5



The mass of the flask and its contents decreases over time because one of the products is carbon dioxide gas. Since the reaction takes place in an open conical flask, the mass of the  $\text{CO}_2$  gas is lost to the surroundings.



## NCEA 2016 Reaction Rate Factors – (Part Two)

**Question 2b (i) :** Identify the factor affecting the reaction rate being investigated in Experiments 1 and 2.

Achieved  
Question

Surface area.

	Calcium carbonate pieces	pH of acid
<b>Experiment 1</b>	Chips	1
<b>Experiment 2</b>	Powdered	1
<b>Experiment 3</b>	Powdered	5

**Question 2b (ii) :** Explain how this factor affects the rate of reaction in the two flasks, with reference to particle collisions. Explain any observations, including changes in mass, over the course of **Experiments 1 and 2** until the reactions are finished.

Excellence  
Question

The mass of the flask and its contents will decrease faster with the powder (experiment 2) compared to the chunks (experiment 1), and the gas production will be faster. This is because the powder has a larger surface area than the large chips, so more particles of calcium carbonate are exposed for the acid to react with / collide with, and therefore experiment 2 has a higher frequency of successful collisions, and subsequently a faster rate of reaction.

Both reactions will get to the same mass, as both have

the same amount of reactants and therefore release the same amount of  $\text{CO}_2$ , but at different rates.



## NCEA 2016 Reaction Rate Factors – (Part Three)

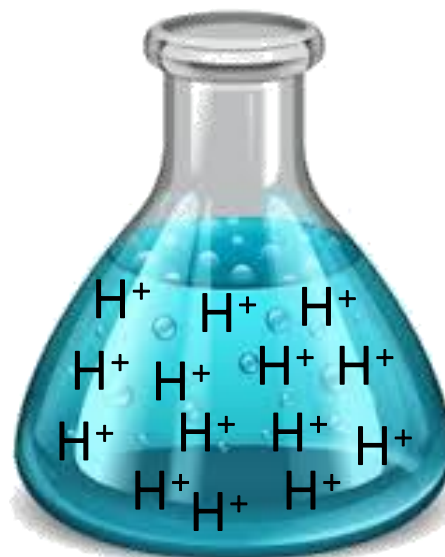
Excellence  
Question

**Question 2c:** Compare and contrast the rate of reaction of **Experiments 2 and 3**, with reference to particle collisions and the **concentration of hydrogen ions** in the solution.

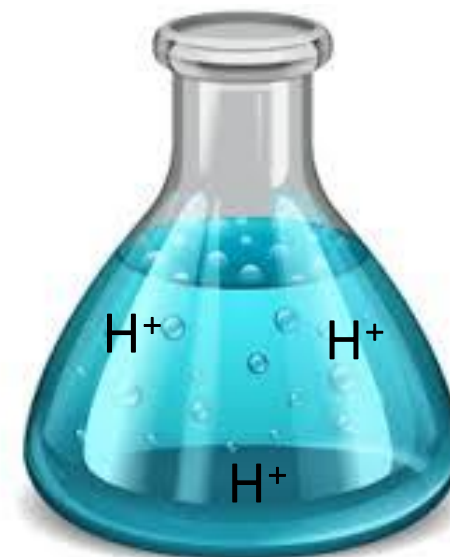
	Calcium carbonate pieces	pH of acid
<b>Experiment 1</b>	Chips	1
<b>Experiment 2</b>	Powdered	1
<b>Experiment 3</b>	Powdered	5

An acid with a pH of 1 has a higher  $[H^+]$  than an acid with a pH of 5. Since experiment 2 has more  $H^+$  ions per unit volume / a higher concentration of  $H^+$  ions, it will have a higher frequency of successful collisions (more successful collisions per second) and subsequently a higher / faster rate of reaction.

Strong Acid pH 1



Weak Acid pH 5



**Question 1a:** A sample of powdered sodium hydrogen carbonate ( $\text{NaHCO}_3$ ) was added to sulfuric acid ( $\text{H}_2\text{SO}_4$ ) in a flask, and fizzing was observed.

Two experiments were carried out with the acid at different temperatures, using the same amount of powdered sodium hydrogen carbonate and the same concentration and volume of sulfuric acid:

What caused the fizzing?

The carbon dioxide gas forming which is a product of the neutralisation reaction

Experiment	Temperature of acid, °C
1	30
2	55

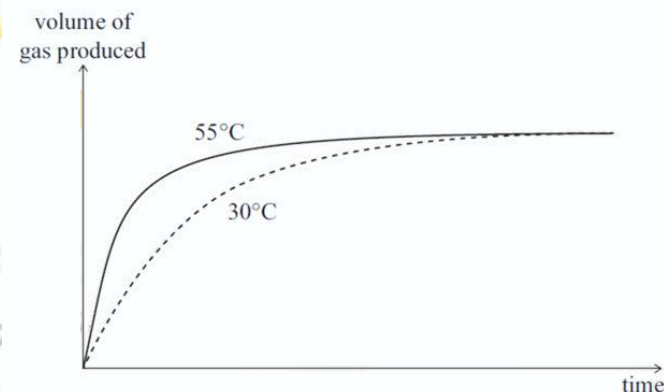
**Question 1b:** Why was the fizzing fastest immediately after the sodium hydrogen carbonate had been added? Your answer should refer to particle collisions.

At the beginning of the experiment the rate is fastest as there are more collisions between the  $\text{H}_2\text{SO}_4$  and  $\text{NaHCO}_3$ . This is because at the start of the reaction there are more particles available for collision, and therefore **more products are being produced per unit time** so more gas observed fizzing. After a while the rate of reaction is slowing down as the number of particles available for collision is becoming fewer as some of the  $\text{H}_2\text{SO}_4$  and  $\text{NaHCO}_3$  have already collided and have been used up, therefore fewer particles and therefore fewer collisions and less gas produced (less fizzing)

Eventually the reaction will stop, as all of the reactants (or one of them) have reacted, and therefore there are no particles present that can collide and react and no gas/fizzing seen.

**Question 1c:** The rate of reaction for each experiment was found by measuring the volume of gas produced over time, as shown in the graph below. What is the effect of increasing temperature on the rate of reaction?

Your answer should refer to particle collisions and explain why both lines finish at the same point.



The reaction is faster at the higher temperature (55°C), because the  $H^+$  ions in the acid have more kinetic energy, and therefore are moving faster. When they are moving faster, there will be more collisions per unit time (frequency), and more of these collisions will be effective (successful), as the particles will collide with more energy. Successful reactions produce carbon dioxide gas so the volume of gas will increase faster with the higher temperature.

The solid line represents the faster reaction, as it is steeper at the start. This represents the reaction carried out at 55°C.

Both lines become horizontal at the same point on the Y-axis, as this is when both reactions have finished, ie one of the reactants has been completely used up and therefore no more gas is produced. Both finished with same amount of gas produced, as both reactions had the same amount of reactants to start with. Both times finish at the same point.

## NCEA 2018 Reaction rate Factors

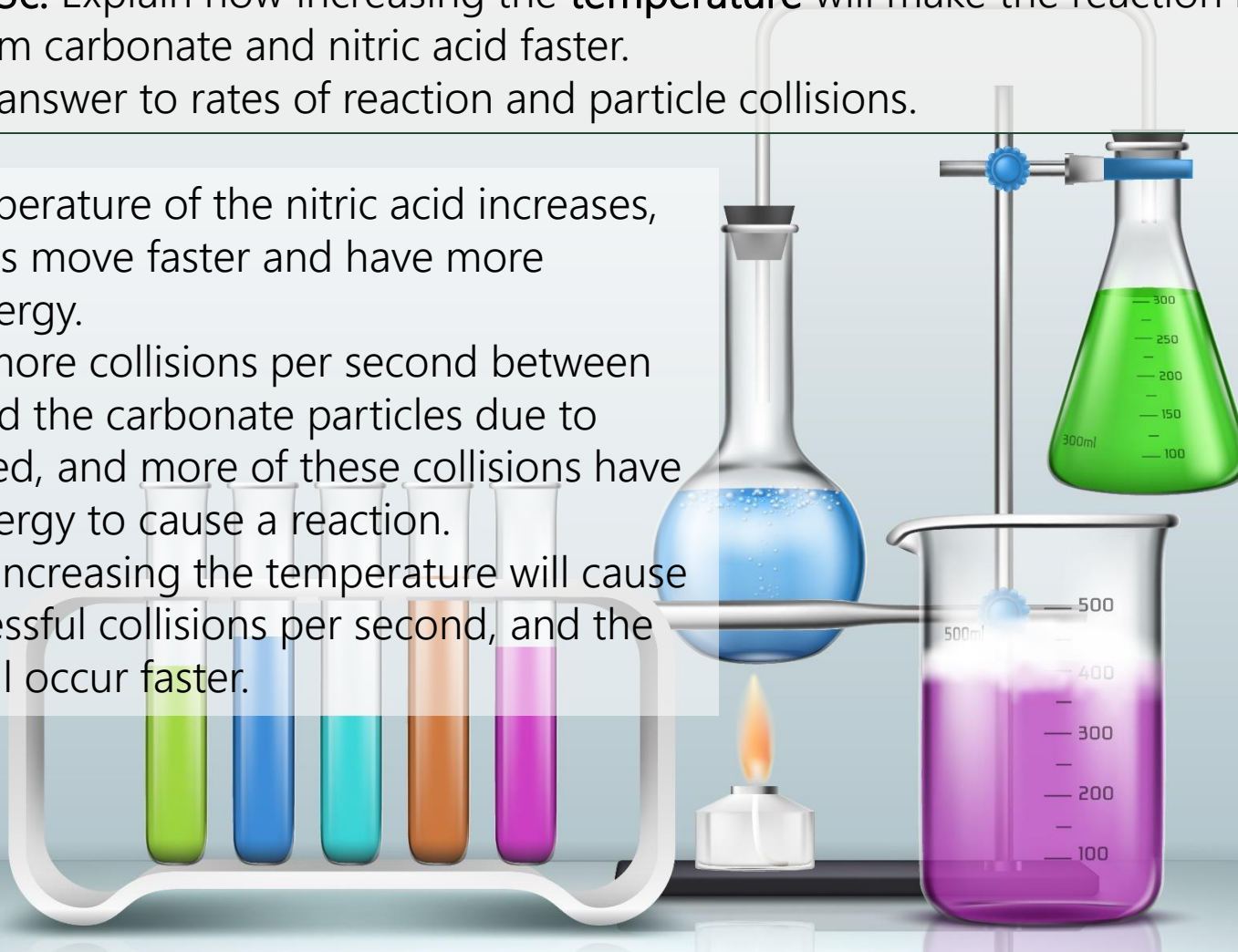
<http://www.nzqa.govt.nz>

**Question 3c:** Explain how increasing the **temperature** will make the reaction between magnesium carbonate and nitric acid faster. Link your answer to rates of reaction and particle collisions.

As the temperature of the nitric acid increases, the particles move faster and have more (kinetic) energy.

There are more collisions per second between the acid and the carbonate particles due to higher speed, and more of these collisions have enough energy to cause a reaction.

Therefore, increasing the temperature will cause more successful collisions per second, and the reaction will occur faster.



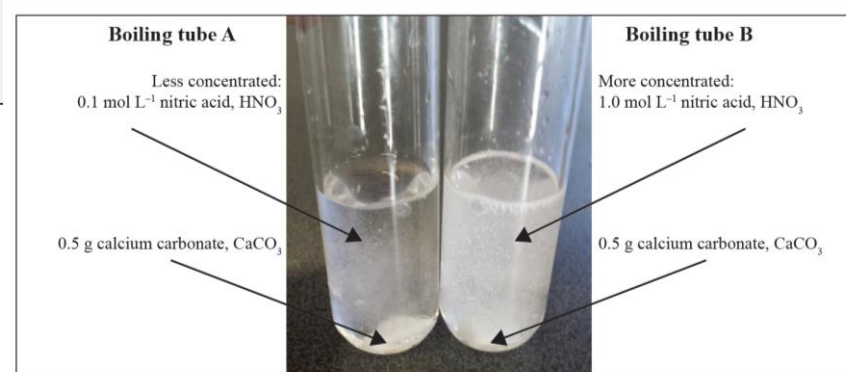


**Question 1b:** Two boiling tubes both contain 10 mL of nitric acid,  $\text{HNO}_3$ . Boiling tube A contains a  $0.1 \text{ mol L}^{-1}$  solution of nitric acid and boiling tube B contains a more concentrated  $1.0 \text{ mol L}^{-1}$  solution of nitric acid. A piece of marble chip (calcium carbonate,  $\text{CaCO}_3$ ) with a mass of 0.5 g is added to each boiling tube and the reaction is observed and photographed.

The temperature of the acid in both boiling tubes is  $20^\circ\text{C}$ . (b) Explain the effect of using a higher concentration of nitric acid on the **rate** of this reaction, compared to using a lower concentration of acid.

Your answer should refer to particle collisions.

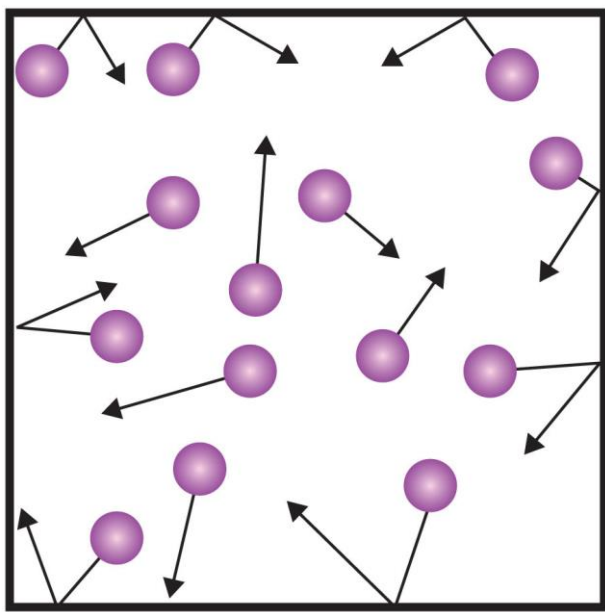
When more concentrated acid is used, there are more acid particles /  $\text{H}^+$  ions / nitric acid particles in (the same volume of) the acid. Because of this, there are more particles available to collide with the calcium carbonate particles. Because there are more to collide, more successful collisions occur per second or per unit time, and the rate of reaction is faster.



Needs to link ideas of increased conc. to more particles for more successful collision per second/frequency of collisions resulting in increased / faster the rate of reaction.

**Question 1c:** In a second investigation, two different boiling tubes each contain 10 mL of the same concentration 1 mol L<sup>-1</sup> nitric acid, HNO<sub>3</sub>. The nitric acid in **boiling tube A** is at 20°C and the nitric acid in **boiling tube B** is at 40°C. A piece of marble chip (calcium carbonate, CaCO<sub>3</sub>) with a mass of 0.5 g is added to each boiling tube, and the reaction is observed.

Explain the effect of increasing the temperature of the nitric acid from 20°C to 40°C on the **rate** of reaction. Your answer should refer to particle collisions.



As the temperature of the nitric acid increases, the particles move faster and have more (kinetic) energy. There are more collisions per second between the acid and the carbonate particles due to higher speed, and more of these collisions have enough energy to cause a reaction.

Therefore, increasing the temperature will cause more successful collisions per second, and the reaction will occur faster.

Need to fully explain both the effect of collisions with more energy AND increase in frequency of collisions