Acids and Alkalis Notes

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An acid: a substance with a pH of less than 7. In solution acids are sources of hydrogen ions (H^+).

An alkali: a substance with a pH of more than 7. In solution alkalis are sources of hydroxide ions (OH^-). Alkalis are soluble bases.

Common laboratory acids are:	Common laboratory alkalis are:
1. HCl – Hydrochloric acid	1. LiOH – Lithium hydroxide
2. HNO_3 – Nitric acid	2. NaOH – Sodium hydroxide
3. H_2SO_4 – Sulfuric acid	3. KOH – Potassium hydroxide
4. CH_3COOH – Ethanoic acid	4. $Mg(OH)_2$ – Magnesium hydroxide

Please learn the formulae and the names of the substances above.

Exam note: popular short exam questions ask which ion makes a solution acidic or alkali.

Hydrogen ions make a solution acidic	Hydroxide ions make a solution alkali
H^+	OH^-

If you have more hydrogen ions in a certain volume, let's say per litre, then their concentration is higher. The higher the concentration of H^+ ions the **more acidic** the solution is and the **lower the pH**.

If you have more hydroxide ions in a certain volume, again let's say per litre, then their concentration is higher. The higher the concentration of OH^- ions the **more alkaline** the solution is and the **higher the pH**.

Exam hint: The pH scale is **logarithmic**. This means for every decrease of 1 on the pH scale, the concentration of H^+ ions increases by a factor of 10.

A solution at pH3 has 10x more H^+ ions than a solution at pH 4, and 100x more than pH 5!

What is the difference between a concentrated and dilute solution I hear you not asking 😊?

A concentrated solution: contains a lot of dissolved solute per unit volume.

A dilute solution: contains only a small amount of solute per unit volume.

We could also be asked to define a "strong" and "weak" acid.

Strong acids: completely **dissociate** into ions when they are dissolved in water. For example, HCl.

Weak acids: will only **partially dissociate** when they are dissolved in water. For example, CH_3COOH.

Dissociate means to split up and you **must** use this key word we can also accept **ionise** instead.

So, in HCl, all molecules will split into 1 H^+ ion and 1 Cl^- ion. Whereas, in CH_3COOH, only some molecules will split into 1 H^+ and 1 CH_3COO^- ion. Many molecules will not split at all.

Reaction rules

1. **Acid + metal → metal salt + hydrogen gas**
2. **Acid + metal oxide → metal salt + water**
3. **Acid + alkali → metal salt + water**
4. **Acid + metal carbonate → metal salt + carbon dioxide + water**

We MUST know these rules.

These rules don't usually come up as questions on their own like they are written in the box. It is usually an example where they will give you two reactants and ask you to write the products. Typically, in a balanced equation, for example, you could be given the following:

$$CaCO_3 + H_2SO_4 \rightarrow \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots$$

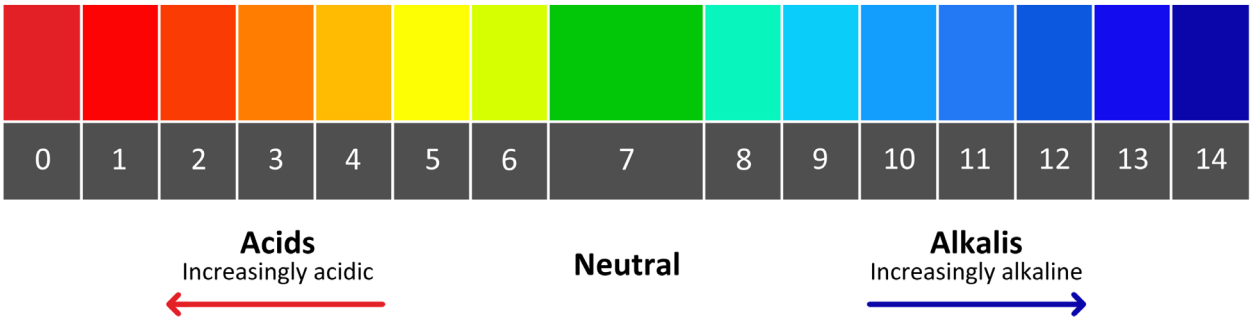
In this case we can use the rule for acids reacting with a metal carbonate to predict that our products will be a metal salt, in this case $CaSO_4$, as well as CO_2 and H_2O.

A neutralisation reaction: the reaction between an acid and alkali/base in which salt and water are produced.
In a neutralisation reaction the H^+ ions of the acid react with the OH^- ions of the alkali/base to form water. Ionic equation: $$\mathbf{H^+(aq) + OH^-(aq) \rightarrow H_2O(l)}$$ This is the ionic equation for any acid neutralising any alkali/base – a handy one to learn 😊

Indicators

A neutral solution has a pH of 7. A common indicator used to tell if a solution is acidic, neutral or alkali is universal indicator.

Universal indicator will turn red/orange in acidic solutions, green in neutral solutions and blue/purple in alkali solutions. The figure below shows a typical pH scale that we can use in the lab.



We could also use Litmus paper as an indicator.

Pink litmus paper will turn blue if it is placed into an alkali solution. Blue litmus paper will turn red in acidic solutions. Using Litmus paper does have a limitation. Litmus paper doesn't tell us how acidic or alkali a solution is just that it is acidic or alkali.

Alkalis turn red litmus paper blue

Acids turn blue litmus paper red

There are two other indicators that we need to know about:

1. **Methyl orange** – shows a red colour in acidic solutions and yellow/orange colour in alkali solutions. It is usually used in titration for acids.

2. **Phenolphthalein** – is pink in alkali solutions and colourless in acidic or neutral solutions. Phenolphthalein is the most commonly used indicator in acid-base titrations as it makes the end point very easy to see.

pH Graphs

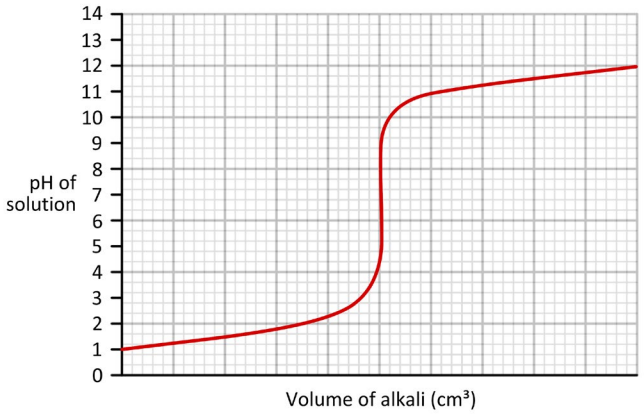
First of all, it's important to mention that pH graphs are not on the GCSE specification but questions involving them did appear in paper 1 in 2019 and 2021. So, it's not a bad idea at all to be familiar with them to avoid being caught off guard.

What are pH graphs? A pH graph is just a way of showing how the pH changes during a chemical reaction between an acid and an alkali.

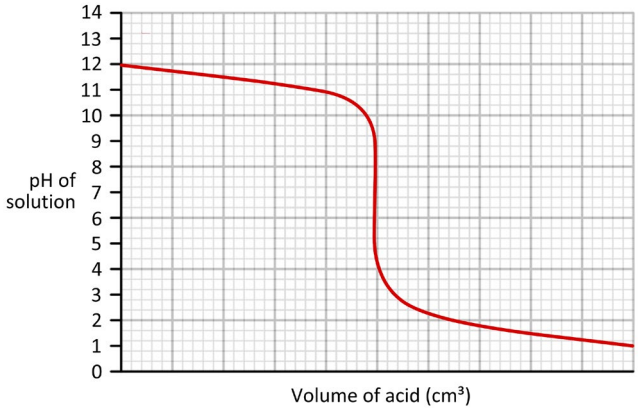
How do they work? pH graphs show how acidic or alkaline a solution is as you add another solution to it — usually an acid or an alkali/base. For example, if you slowly add a base like calcium hydroxide to an acid like hydrochloric acid, the pH will go up. A pH graph plots this change:

- The x axis shows the volume of base or acid that we're adding.
- The y axis shows the pH (from 0 to 14).

The figure below shows the two different versions of pH graphs that we could see in questions.

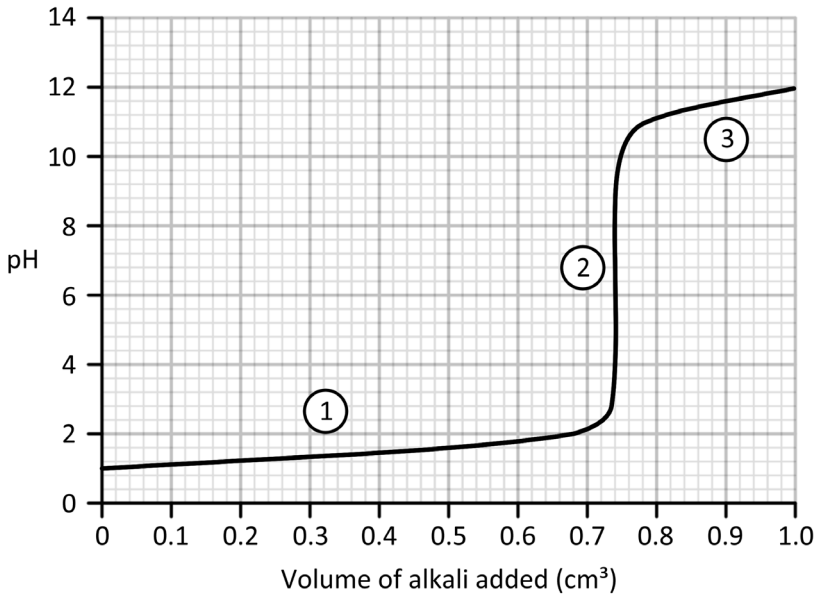


A pH graph showing an alkali added to an acid



A pH graph showing an acid added to an alkali

The figure below shows the meaning of the different sections of a pH graph.



Section 1: shows the pH increasing due to the alkali being added to the acid. This means that there is less H^+ ions in the solution.

Section 2: shows the solution is neutral.

Section 3: shows the pH continues to increase as there is now more OH^- ions in the solution.

Calculating pH Changes

The pH scale is actually a measure of the concentration of hydrogen ions (H^+) in a solution. The more H^+ ions there are, the more acidic the solution is, and the lower the pH. Does this mean that there is a pOH scale for OH^- ions? Yes indeed, but it's not on the GCSE specification and it's only rarely used by actual chemists.

When doing problems involving the pH scale the easiest way to do them is using the rule of 10's 😊

The rule of 10s: means that for every 1 unit change in pH, the hydrogen ion concentration changes by a factor of 10, so the number of zeros in your factor always equals the number of pH units changed.

So a change of 10, meaning 1 zero = 1 pH unit. A change of 100 meaning 2 zeros = 2 pH units and so on 😊

Let's look at some examples of these problems.

Example 1: An acid is altered so its pH changes from pH 4 to pH 3. How has the hydrogen ion concentration changed?

Step 1: Find the difference in pH

$$4 - 3 = 1.$$

Step 2: Figure out if the concentration is increasing or decreasing.
The pH number has gone down (from 4 to 3), this lower pH means the solution is more acidic. Therefore, the amount of H^+ ions must have increased.

Step 3: Apply the rule of 10's. A difference of 1 unit means 1 zero. (10^1)

Answer: The hydrogen ion concentration has increased by a factor of 10.

Example 2: A student has a beaker of hydrochloric acid with a pH of 2.
They add water to dilute the acid, which decreases the hydrogen ion concentration by a factor of 100.
What is the new pH of the acid?

Step 1: Turn the factor into pH units.

The factor is 100. The number 100 has 2 zeros. Therefore, the pH will change by 2 units.

Step 2: Figure out if the pH number is going up or down.
The hydrogen ion concentration has decreased (it has been diluted). Less H^+ means it is less acidic. Therefore, the pH number must go up (closer to 7).

Step 3: Calculate the new pH.

$$\text{Starting pH } 2 + 2 \text{ units} = 4.$$

Answer: The new pH is 4 😊

Example 3: A weak acid has a starting pH of 6. A chemist changes the solution, causing the hydrogen ion concentration to increase by a factor of 1,000. What is the new pH of the solution?

Step 1: Turn the factor into pH units.
The factor is 1,000. The number 1,000 has 3 zeros. Therefore, the pH will change by 3 units.

Step 2: **Figure out if the pH number is going up or down.**
The hydrogen ion concentration has increased. More H^+ ions means the solution is more acidic.
Therefore, the pH number must go down.

Step 3: Calculate the new pH.

$$\text{Starting pH } 6 \text{ take away } 3 \text{ units} = 3.$$

Answer: The new pH is 3.

Preparing Soluble Salts

The reaction between an acid and an insoluble metal oxide is used to produce different forms of soluble salt. This is quite a popular exam paper question, usually ranging between four to six marks.

Take the following example from AQA Higher Paper 1 2018 Q1 (iii) 6 Marks.

"***Describe a method to make pure, dry crystals of magnesium sulfate from a metal oxide and a dilute acid***."

The answer can be broken down into stages. Just like we would do in the practical.

Stage 1: Add excess magnesium oxide to the dilute acid – in this case we must use sulfuric acid as the salt must contain sulfate.
Reason: we always add excess to make sure that all of the acid is reacted.

Stage 2: Warm the reaction/gently heat
Reason: this is done to increase the rate of the reaction/speed up the reaction.

Stage 3: Filter to remove excess MgO
Reason: this removes the unreacted solid from the solution.

Stage 4: Evaporation
Reason: the filtrate is heated in an evaporation dish. This removes a lot of the water from the solution.

Stage 5: Crystallisation
Reason: transfer the remaining solution to a crystallisation dish and leave to dry slowly. The longer it takes to dry the larger the crystals will be.

Exam note: if you learn the five stages above and their explanation then you will be fully set for this type of question 😊. The key parts in the explanations have been underlined, please make sure to include these in your answer.

If the salt is produced from a **soluble reactant such as NaOH** you must **use a titration to ensure that the acid has been neutralised by the alkali** or vice versa.