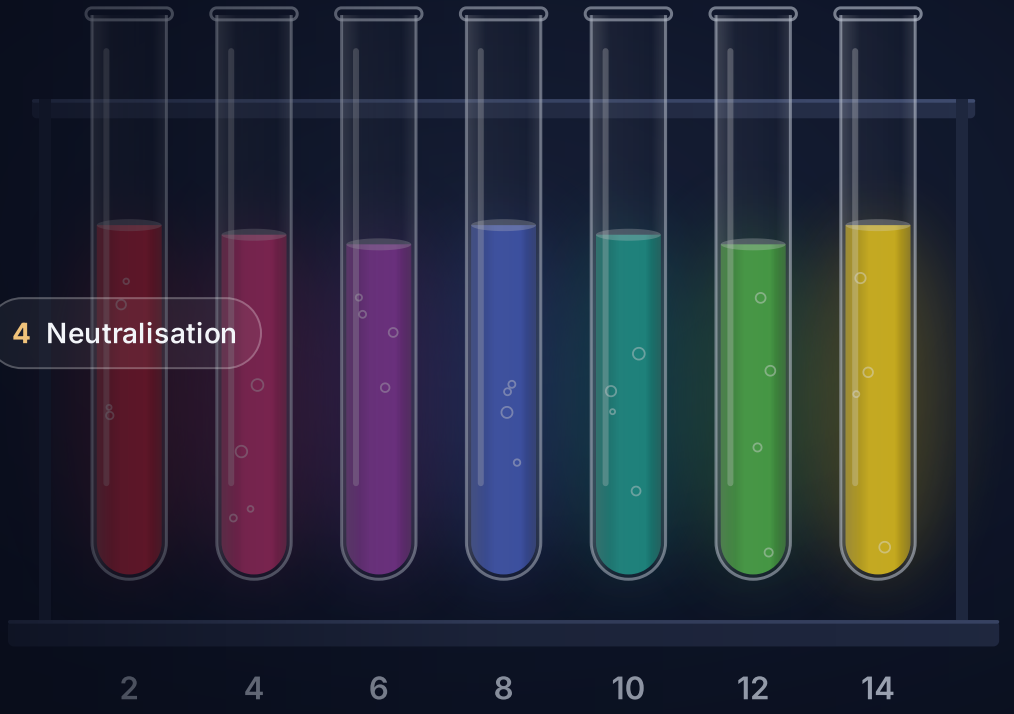
A CHEMISTRY LESSON

Acids and Bases

From lemons to soap

Lemon juice tastes sour, soap feels slippery. How can you tell an acid from a base without tasting or touching anything?

1 Acids and bases
2 The pH scale
3 Indicators
4 Neutralisation



Red cabbage juice in seven liquids, from the most acidic (pH 2) to the most basic (pH 14).

Acids and bases all around us

Many liquids in the kitchen and the bathroom are acids or bases. Chemists sort them into two families that behave in opposite ways.

Acids

- taste sour, like lemon or vinegar;
- turn litmus paper red;
- lemon juice (citric acid), vinegar (acetic acid), soft drinks, orange juice, the acid in your stomach.

Strong acids, like battery acid, burn the skin.

Bases

- taste bitter and feel slippery, like soap;
- turn litmus paper blue;
- baking soda, soap, ammonia, bleach, drain cleaner.

Strong bases, like drain cleaner, burn too. A base is also called an alkali: basic means alkaline.

NEVER TASTE TO FIND OUT

We know the sour taste of lemons and the bitter taste of baking soda from food. But in an experiment, never taste, touch or sniff an unknown liquid: test it with an indicator (part 3).

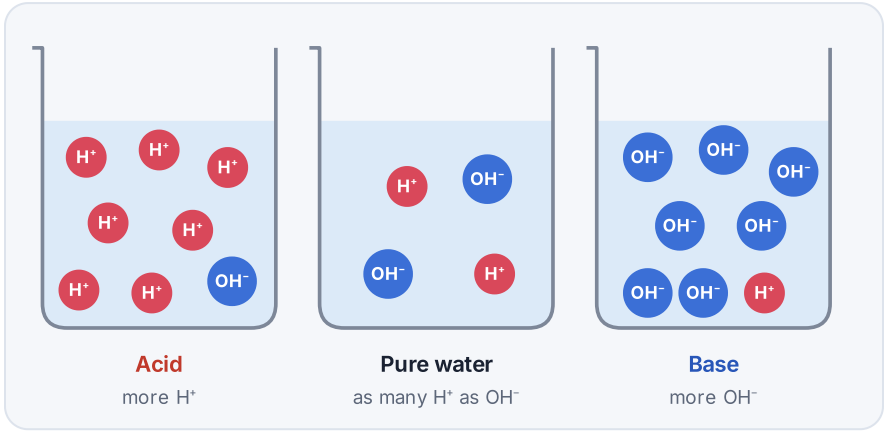
What makes a liquid acidic?

It all comes down to tiny particles called **ions**: atoms, or small groups of atoms, that carry an electric charge.

- An **acid**, dissolved in water, releases **hydrogen ions**, H^+.
- A **base** releases **hydroxide ions**, OH^-, which grab the H^+.
- In **pure water**, there are very few of each, and exactly as many H^+ as OH^-: water is **neutral**.

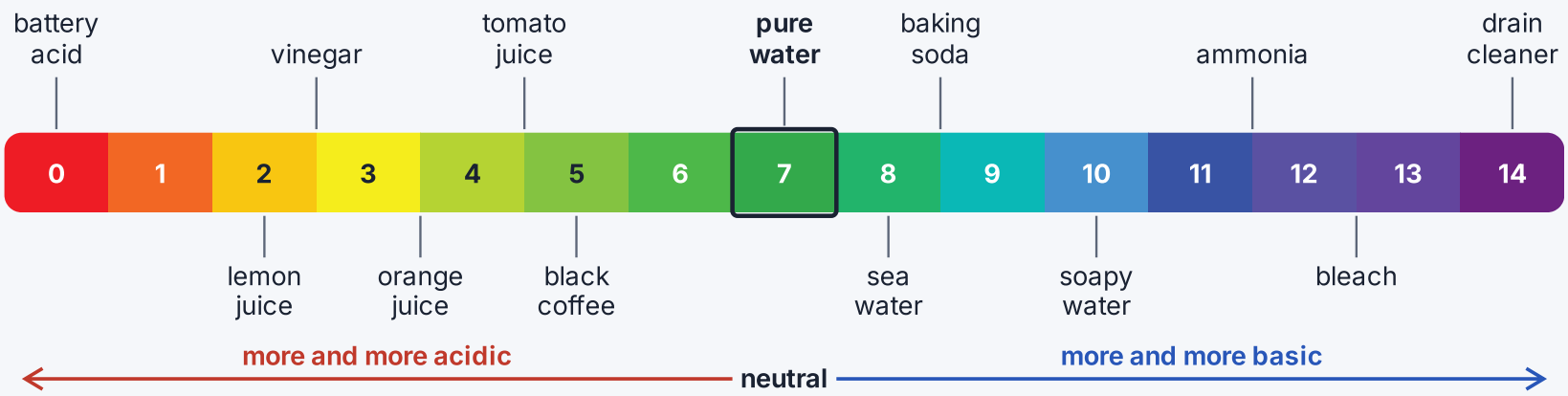
VERY FEW INDEED

In pure water, only about one molecule in 550 million splits into an H^+ and an OH^-.



The pH scale

To say how acidic or basic a liquid is, chemists give it a number from 0 to 14: its **pH**. The colours are those of universal indicator paper.



Below 7: acidic · 7: neutral · Above 7: basic

The values are approximate: they vary from one lemon, or one soap, to another.

Ten times more at each step

One pH unit lower means **10 times more** H^+ ions. Two units lower: 10 × 10 = 100 times more.



1 **Lemon juice (pH 2) or pure water (pH 7): how many times more H^+ in the lemon juice?**

5 units apart: 10 × 10 × 10 × 10 × 10 = 100,000 times more.

2 **One liquid is at pH 4, another at pH 6. Which is more acidic, and by how much?**

The one at pH 4: 2 units lower, so 10 × 10 = 100 times more H^+.

3 **You pour lots of pure water into vinegar. What happens to its pH?**

It rises towards 7, without going past it: the water dilutes the acid, but water alone can't make it basic.

The H in pH stands for hydrogen. The Danish chemist Søren Sørensen invented the pH scale in 1909, at the laboratory of the Carlsberg brewery in Copenhagen.

pH in your body and in nature

pH matters to living things: your body keeps each of its liquids at the right pH, and plants and sea creatures depend on the pH around them.

Where	pH	Good to know
Your stomach	**about 2**	Its hydrochloric acid helps digest food and kills germs.
Your skin	**about 5.5**	A thin, slightly acidic film helps protect it from microbes.
Your blood	**7.35 to 7.45**	Your body keeps it in this narrow range: outside it, you fall ill.
Rain	**about 5.6**	Carbon dioxide from the air makes it slightly acidic. Polluted acid rain falls below 5 and harms lakes and forests.
The ocean	**about 8.1**	It absorbs carbon dioxide from the air: since the start of the industrial era, its pH has dropped from 8.2 to 8.1, which makes life harder for shellfish and corals.
Garden soil	**4 to 8**	Hydrangeas flower blue in acidic soil and pink in basic soil.

Litmus paper

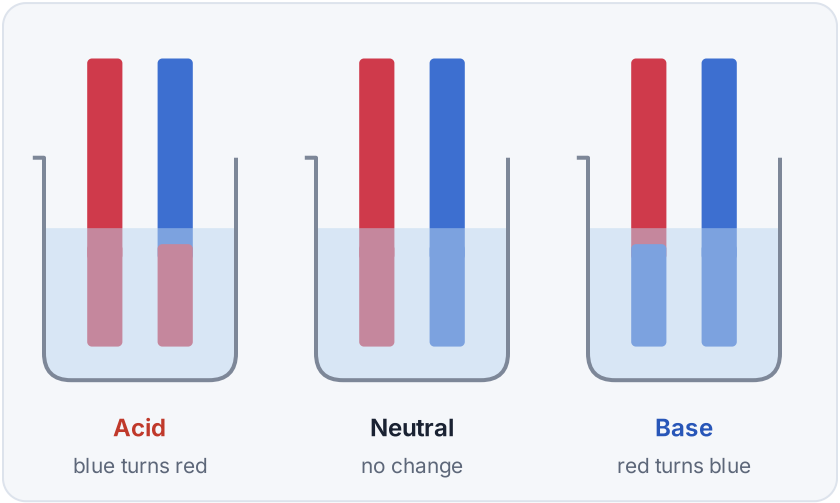
An **indicator** is a substance whose colour changes with pH. Litmus, made from lichens, is one of the oldest.

- In an **acid**, litmus turns red: blue paper turns red.
- In a **base**, it turns blue: red paper turns blue.
- In a **neutral** liquid, neither paper changes.

ACIDIC OR BASIC, NOTHING MORE

Litmus has only two colours: it tells whether a liquid is acidic or basic, not its exact pH. For that, you need universal indicator paper or a pH meter.

▶ Try it: the litmus test



An indicator from the kitchen

Red cabbage holds purple pigments, anthocyanins, whose colour changes with pH. With an adult, you can make your own indicator.

1 Chop a few red cabbage leaves, cover them with hot water and wait 10 minutes. The adult handles the hot water.

2 Strain the leaves out: the purple juice that is left is your indicator.

3 Pour a little into glasses of vinegar, water, water with baking soda, soapy water… and compare the colours.



pH 2	pH 4	pH 6	pH 8	pH 10	pH 12	pH 14
red	pink	purple	blue	blue-green	green	yellow

1 **The juice turns green in a liquid. Acidic or basic?**

Basic, and quite strongly so: green appears around pH 10 to 12.

2 **Can you test bleach or drain cleaner this way?**

No. They burn: test only kitchen liquids. Bleach would also wipe out the colour.

An acid and a base cancel each other out

Mix an acid and a base: the H^+ of the acid and the OH^- of the base join to form water. What is left over is a **salt**.

acid + base → salt + water

$HCl + NaOH \rightarrow NaCl + H_2O$

Hydrochloric acid and sodium hydroxide give sodium chloride, table salt, and water.

- **Antacids**, mild bases, soothe heartburn by neutralising some of the stomach's acid.
- Farmers spread **lime**, a base, on fields that are too acidic. In Sweden, lime is poured into thousands of lakes damaged by acid rain.



from the acid · from the base · **water, H_2O** · **the salt** stays dissolved

? **Is the salt always table salt?**

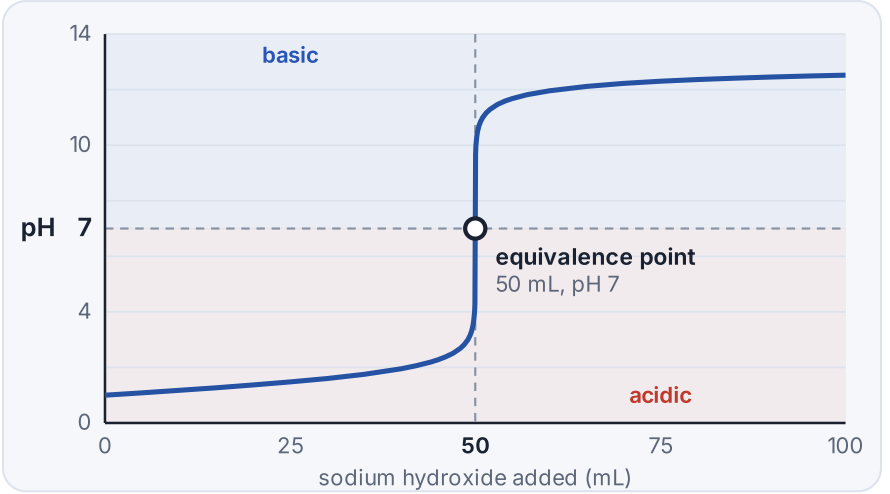
No. Chemists call "salt" anything made this way from an acid and a base. With hydrochloric acid and sodium hydroxide, it happens to be table salt.

Titration: finding the equivalence point

Chemists use titration to find out how much acid a liquid holds. In the titration lab, sodium hydroxide is added drop by drop to 50 mL of hydrochloric acid, both at 0.1 mol/L, while the pH is measured.

1. At first, the pH barely moves: there is still plenty of acid.
2. Near 50 mL, a few drops are enough: the pH **jumps** from about 3 to 11.
3. At exactly 50 mL, all the acid is neutralised: pH 7. That is the **equivalence point**.
4. After that, the base is in excess: the mixture is basic.

▶ Try it: the titration lab



AN INDICATOR TO STOP IN TIME

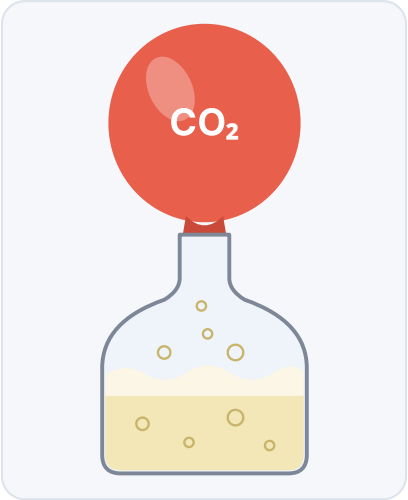
Phenolphthalein stays colourless in an acid and turns pink just past equivalence: you stop at the first pink that lasts.

Bubbles in the kitchen

Vinegar (an acid) and baking soda (a base) react together and give off a gas: **carbon dioxide**, CO_2, the gas in the bubbles of soft drinks.

Blow up a balloon without blowing

1. Pour 3 cm of vinegar into a small empty bottle.
2. With a funnel, put two teaspoons of baking soda into a balloon. Stretch the balloon over the neck of the bottle, letting it hang down the side.
3. Lift the balloon up: the baking soda falls into the vinegar, it fizzes, and the CO_2 blows up the balloon.



vinegar + baking soda → carbon dioxide + water + sodium acetate (a salt)

BAKING POWDER

Baking powder holds a base, baking soda, and a dry acid. In the wet batter and in the oven, they react: the CO_2 bubbles make cakes and muffins rise.

SAFETY

Staying safe

Strong acids and strong bases are **corrosive**: they burn the skin and the eyes. A few rules protect you.

✓ Good ideas

- Wear safety goggles during an experiment.
- Test an unknown liquid with an indicator.
- Keep each product in its own container, with its label.
- Store cleaning products out of reach of small children.
- If a product touches your skin or eyes, rinse with lots of water for a long time, then tell an adult.

× Bad ideas

- Tasting, touching or sniffing an unknown liquid.
- Mixing bleach and vinegar: they give off chlorine, a toxic gas.
- Mixing bleach and ammonia: toxic gases too.
- Pouring a product into an unlabelled bottle: someone might drink it.

THE RULE TO REMEMBER

Never mix bleach with another product.

REVIEW

Test yourself

1 **A liquid has a pH of 9. Acidic, neutral or basic?**

Basic: its pH is above 7.

2 **Which is more acidic: vinegar (pH 2.5) or black coffee (pH 5)?**

Vinegar: the lower the pH, the more acidic the liquid.

3 **Blue litmus paper turns red. What does that tell you?**

The liquid is acidic.

4 **pH 3 or pH 5: how many times more H^+ ions at pH 3?**

100 times: 2 units lower, 10 × 10.

5 **What do an acid and a base make when they neutralise each other?**

A salt and water. For example, HCl + NaOH → NaCl + H_2O.

6 **A friend wants to mix bleach and vinegar to clean better. What do you say?**

Don't! The mixture gives off chlorine, a toxic gas. Never mix bleach with another product.

TO SUM UP

The big ideas

1. In water, an **acid** releases H^+ ions and a **base** releases OH^- ions, which grab them. Pure water, with as many of each, is neutral.

2. The **pH** goes from 0 to 14: below 7, acidic; 7, neutral; above 7, basic. One unit lower means 10 times more H^+. An **indicator**, like litmus or red cabbage, shows it by its colour.

3. An acid and a base **neutralise** each other: acid + base → salt + water. The strongest ones burn: never taste, wear goggles, and never mix bleach.

Go further

▶ pH Scale Explorer | Virtual Litmus Test | Acid-Base Titration Lab | Practise in the Practice Room

Illustrations drawn for this lesson. The pH values are approximate: they vary from one product to another.