

Acids, bases and salts

Mark scheme and worked solutions for 30 questions: 15 multiple choice, 15 structured.

1 Core The characteristic properties of acids and bases [1]

Answer: A

Worked solution

Learn each indicator's colour in acid and in alkali. Litmus: red in acid, blue in alkali. Thymolphthalein: colourless in acid, blue in alkali. Methyl orange: red in acid, yellow in alkali. Dilute nitric acid is an acid, so the colours are red, colourless and red, which is row A.

2 Core The characteristic properties of acids and bases [4]

Mark scheme

(a) [1]

- H^+ (1)
- | **ALLOW** H_3O^+
- | **REJECT** H, H_2 , "hydrogen" without charge

(b) [1]

- OH^- (1)
- | **REJECT** OH without charge, O^{2-}

(c) [2]

- copper(II) oxide is an oxide of a metal, so it is a base (1)
 - it is insoluble in water / does not dissolve in water, and an alkali is a soluble base (1)
 - | **ALLOW** "alkalis must dissolve in water; copper(II) oxide does not"
-

Worked solution

All acids in water release hydrogen ions, H^+ , and all alkalis in water release hydroxide ions, OH^- . A base is any oxide or hydroxide of a metal. An alkali is a base that dissolves in water. Copper(II) oxide is a metal oxide, so it is a base, but it does not dissolve in water, so it cannot be an alkali. Every alkali is a base, but not every base is an alkali.

3 Core The characteristic properties of acids and bases

[1]

Answer: B

Worked solution

pH is a measure of hydrogen ion concentration: a low pH means many H^+ ions, a high pH means few. To put the solutions in order of increasing H^+ concentration, start with the highest pH and finish with the lowest: 12 (W), 8 (Z), 6 (X), 2 (Y). A common mistake is to list them in order of increasing pH, which gives the reverse order (A).

4 Supplement The characteristic properties of acids and bases

[1]

Answer: C

Worked solution

An acid is a proton donor and a base is a proton acceptor. Look at what happens to the hydrogen: NH_3 becomes NH_4^+ , so it has gained a proton (H^+). The HCl lost that proton, leaving Cl^- . So HCl is the proton donor (acid) and NH_3 is the proton acceptor (base). This definition works even though no water is present.

5 Core Oxides

[1]

Answer: A

Worked solution

Being shiny, malleable and a good electrical conductor are typical properties of a metal. The type of oxide an element forms is linked to its metallic character: oxides of metals (such as CaO and CuO) are basic, while oxides of non-metals (such as CO_2 and SO_2) are acidic. So element E is a metal that forms a basic oxide.

Mark scheme

(a) [2]

- hydrogen (1)
- magnesium chloride (1)

REJECT H (for hydrogen), "magnesium chlorine"

(b) [2]

- $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$: correct formulae of all species (1)
- correctly balanced, i.e. 2HCl and H_2 (1)

IGNORE state symbols, even if incorrect

(c) [2]

- zinc chloride, water, carbon dioxide in any order
- all three correct (2)
- any two correct (1)

(d) [1]

- fizzing / bubbles / effervescence (1)

ALLOW the solid disappears / dissolves**REJECT** "a gas is produced" (not an observation), "hydrogen produced"**Worked solution**

An acid reacts with a metal to give a salt and hydrogen: magnesium + hydrochloric acid $\rightarrow$ magnesium chloride + hydrogen. The salt from hydrochloric acid is a chloride. In symbols, magnesium chloride is MgCl_2 because Mg forms Mg^{2+} and chloride is Cl^- , so two HCl are needed: $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$. Check: 1 Mg, 2 H and 2 Cl on each side. An acid reacts with a carbonate to give a salt, water and carbon dioxide, so zinc carbonate gives zinc chloride, water and carbon dioxide. An observation is something you can see: the carbon dioxide makes bubbles (fizzing), and the powder disappears as it reacts.

Mark scheme

(a)

[2]

- strong acid: completely / fully dissociated (into ions) in aqueous solution (1)
- weak acid: partially dissociated (into ions) in aqueous solution (1)

ALLOW ionised for dissociated**REJECT** answers based on concentration, e.g. "a strong acid is concentrated"

(b)

[2]

- $\text{CH}_3\text{COOH} \rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$ with reversible arrow (1)
- state symbols all (aq): $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$ (1)

ALLOW $\text{CH}_3\text{CO}_2\text{H}$ and CH_3CO_2^- ; **ALLOW** H_3O^+ on the right if H_2O is included on the left

- a single arrow ($\rightarrow$) loses the first mark but can still score the state-symbol mark

(c)

[3]

- ethanoic acid (1)
- ethanoic acid is only partially dissociated / is a weak acid (1)
- so it has a lower concentration of hydrogen ions / H^+ than hydrochloric acid (of the same concentration) (1)

REJECT "ethanoic acid is more dilute" (the concentrations are the same)**Worked solution**

"Strong" and "weak" describe how much of an acid splits into ions in water, not how concentrated it is. A strong acid, like hydrochloric acid, is completely dissociated: $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$. A weak acid, like ethanoic acid, is only partially dissociated, so the equation uses the reversible sign: $\text{CH}_3\text{COOH}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$. Because only some ethanoic acid molecules release H^+ , a solution of ethanoic acid has fewer H^+ ions than hydrochloric acid of the same concentration. Fewer H^+ ions means a higher pH, so the pH 3 solution is ethanoic acid and the pH 1 solution is hydrochloric acid.

8**Core**

The characteristic properties of acids and bases

[6]

Mark scheme

(a)

[1]

- ammonia (1)

| ALLOW NH_3

(b)

[1]

- (turns from red to) blue (1)

(c)

[2]

- calcium sulfate (1)
- ammonia (1)
- in either order

(d)

[2]

- the calcium hydroxide (base) reacts with the ammonium sulfate / ammonium salt (1)
- ammonia (gas) is released into the air, so nitrogen is lost from the fertiliser / the fertiliser is wasted / less effective (1)

| ALLOW "the fertiliser is neutralised / destroyed" for the first mark

Worked solution

Bases react with ammonium salts when warmed to give off ammonia gas. The full word equation is: ammonium sulfate + calcium hydroxide → calcium sulfate + ammonia + water. Ammonia is an alkaline gas, so damp red litmus paper turns blue. A gardener adds ammonium sulfate to supply nitrogen to plants. If calcium hydroxide is added at the same time, the two react in the soil and the nitrogen escapes as ammonia gas, so the fertiliser is wasted.

9

Core

Preparation of salts

[7]

Mark scheme

(a)

[1]

- $\text{CuO} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{O}$ (1)

IGNORE state symbols

(b)

[2]

- to make sure all the (sulfuric) acid has reacted / is used up / neutralised (1)
- so the solution contains only copper(II) sulfate and water / the salt is not contaminated with acid (1)

ALLOW "the excess solid is easy to remove because it is insoluble" as the second mark

(c)

[1]

- filtration / filtering (1)

(d)

[3]

- heat / warm the filtrate to evaporate some of the water (until it is saturated / crystals start to form / crystallisation point) (1)
- leave the solution to cool so that crystals form (1)
- filter off / remove the crystals and dry them (between filter papers / in a warm place / low oven) (1)

ALLOW rinse with a little cold distilled water before drying**REJECT** "heat until all the water has evaporated / to dryness" for the first mark**Worked solution**

Copper(II) oxide is a base, so it neutralises sulfuric acid: $\text{CuO} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{O}$. Adding the oxide until some is left over (excess) guarantees that no acid remains, so the only dissolved substance is copper(II) sulfate. Copper(II) oxide is insoluble, so the leftover black solid is removed by filtration, leaving a blue filtrate. To get crystals, heat the filtrate to evaporate some water until it is saturated, then let it cool so crystals form. Filter off the crystals and dry them between filter papers. Do not boil it to dryness: the crystals would lose their water of crystallisation and any soluble impurities would stay in the solid.

10

Core

Preparation of salts

[1]

Answer: D**Worked solution**

Use the solubility rules. All sodium, potassium and ammonium salts and all nitrates are soluble. Chlorides are soluble except those of lead and silver. Sulfates are soluble except those of barium, calcium and lead. Carbonates are insoluble except those of sodium, potassium and ammonium. Barium sulfate and silver chloride are both exceptions to the "soluble" rules, so both are insoluble.

11 Core The characteristic properties of acids and bases

[1]

Answer: C

Worked solution

First decide whether the solution is acidic or alkaline. Thymolphthalein is colourless in acid and blue in alkali, so this solution is an alkali. Then recall the alkali colours of the other two indicators: litmus turns blue and methyl orange turns yellow.

12 Core The characteristic properties of acids and bases

[6]

Mark scheme

(a) [1]

- magnesium chloride (1)

(b) [2]

- $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$: correct formulae of all species (1)
- correctly balanced, i.e. 2HCl and 2H₂O (1)

IGNORE state symbols

(c) [2]

- carbon dioxide (1)
- the gas builds up in the stomach, causing bloating / discomfort / wind / burping (1)

ALLOW any sensible physical effect of producing gas in the stomach

(d) [1]

- neutralisation (1)
-

Worked solution

A base reacts with an acid to form a salt and water. This is called neutralisation. Hydrochloric acid makes chloride salts, so magnesium hydroxide gives magnesium chloride. Magnesium hydroxide is $\text{Mg}(\text{OH})_2$, with two hydroxide groups, so it needs two HCl and makes two water molecules: $\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$. Check: 1 Mg, 2 Cl, 4 H and 2 O on each side. A carbonate reacts with acid to give a salt, water and carbon dioxide, so calcium carbonate tablets also make carbon dioxide gas. Gas produced inside the stomach can make a person feel bloated or cause burping.

13 **Core** The characteristic properties of acids and bases

[1]

Answer: A

Worked solution

Nitric acid contains H^+ and NO_3^- ions. Potassium hydroxide solution contains K^+ and OH^- ions. When they are mixed, H^+ and OH^- combine to make water molecules. At exact neutrality, both H^+ and OH^- have been removed (apart from the tiny amounts present in pure water). The ions that did not take part, K^+ and NO_3^- , stay in the solution, which is potassium nitrate solution.

14 **Supplement** The characteristic properties of acids and bases

[1]

Answer: C

Worked solution

Compare two acids of equal concentration. A strong acid is completely dissociated, so it releases the most H^+ ions and has the lowest pH. A weak acid is only partially dissociated, so it releases fewer H^+ ions and has a higher pH. P (pH 1) behaves as a strong acid and Q (pH 4) as a weak acid, partially dissociated. Remember that any acid solution has a pH below 7, so pH below 7 on its own cannot tell you whether an acid is strong or weak.

15 **Supplement** Oxides

[1]

Answer: C

Worked solution

Basic oxides (metal oxides such as CaO and CuO) react only with acids. Acidic oxides (non-metal oxides such as CO_2 and SO_2) react only with bases. Amphoteric oxides react with both acids and bases, forming a salt and water each time. The two amphoteric oxides you need to know are aluminium oxide, Al_2O_3 , and zinc oxide, ZnO .

Mark scheme

(a) [2]

- acid: proton donor / donates H^+ (1)
- base: proton acceptor / accepts H^+ (1)

(b) [1]

- hydrochloric acid is completely / fully dissociated (in water) / is a strong acid (1)

ALLOW "the reaction goes to completion / is not reversible, so all HCl forms ions"

(c) [2]

- OH^- / hydroxide ion (1)
- it accepts a proton / H^+ (to form H_2O) (1)
- the second mark depends on OH^- being identified

(d) [1]

- CH_3COO^- / ethanoate ion (1)

ALLOW CH_3CO_2^- **REJECT** CH_3COOH **Worked solution**

An acid is a proton (H^+) donor and a base is a proton acceptor. A single arrow in a dissociation equation means that all of the HCl molecules split into ions: hydrochloric acid is completely dissociated, so it is a strong acid. In $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$, the OH^- ion picks up the H^+ to become H_2O , so OH^- is the proton acceptor, the base. For ethanoic acid, the forward reaction has CH_3COOH donating a proton. In the reverse reaction, the CH_3COO^- ion picks up an H^+ to form CH_3COOH again, so CH_3COO^- is acting as a base. Looking at who gains the H^+ always tells you which species is the base.

Mark scheme

(a)

[2]

- basic: calcium oxide and copper(II) oxide
- acidic: carbon dioxide and sulfur dioxide
- all four correct (2)
- two or three correct (1)

(b)

[2]

- metals form basic oxides (1)
- non-metals form acidic oxides (1)

(c)

[2]

- add copper(II) oxide to a (dilute) acid, e.g. hydrochloric / sulfuric acid, and warm (1)
- the copper(II) oxide reacts / dissolves / disappears and a (blue) solution of a salt forms / the acid is neutralised (so pH rises) (1)

ALLOW "add to acid containing universal indicator; the colour moves towards green"

Worked solution

Whether an oxide is acidic or basic depends on the element it comes from. Calcium and copper are metals, so CaO and CuO are basic oxides. Carbon and sulfur are non-metals, so CO₂ and SO₂ are acidic oxides. A basic oxide reacts with an acid to form a salt and water. Copper(II) oxide is insoluble, so you cannot test it with indicator in water. Instead, warm it with dilute acid: the black solid disappears and a blue solution of a copper(II) salt forms, showing it has neutralised the acid.

18

Supplement

Preparation of salts

[7]

Mark scheme

(a)

[2]

- a soluble barium salt, e.g. barium chloride / barium nitrate (solution) (1)
- a soluble sulfate, e.g. sodium sulfate / potassium sulfate / magnesium sulfate / dilute sulfuric acid (1)

REJECT barium carbonate, barium sulfate, calcium sulfate, lead(II) sulfate

(b)

[2]

- $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$ (1)
- state symbols: $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$ (1)
- the state-symbol mark requires the correct equation

(c)

[3]

- filter (the mixture) (1)
- wash the residue / precipitate with (distilled) water (1)
- dry it, e.g. in a warm oven / between filter papers / leave to dry (1)

REJECT crystallisation or evaporation of the filtrate

Worked solution

An insoluble salt is made by mixing two solutions: one containing its positive ion and one containing its negative ion. For barium sulfate you need soluble barium ions (barium chloride or barium nitrate solution) and soluble sulfate ions (sodium sulfate solution or dilute sulfuric acid). Barium sulfate forms as a solid precipitate: $\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{BaSO}_4(\text{s})$. The other ions stay in solution. Filter to collect the solid on the filter paper, wash it with distilled water to remove the soluble ions left on it, then dry it. The salt you want is the residue, not the filtrate.

19

Core

Preparation of salts

[1]

Answer: A**Worked solution**

"Hydrated" means chemically combined with water, as in blue copper(II) sulfate crystals, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. "Anhydrous" means containing no water, such as white CuSO_4 made by heating the hydrated crystals. The prefix "an-" means "without" and "hydr-" refers to water.

20 Core The characteristic properties of acids and bases [5]

Mark scheme

(a) [1]

- salt solution (1)

(b) [1]

- drain cleaner (1)

(c) [1]

- salt solution, rainwater, vinegar (1)

(d) [2]

- put a drop of the solution on the universal indicator paper / dip the paper into the solution (1)
 - compare the colour with a (pH) colour chart (1)
-

Worked solution

pH 7 is neutral, so the salt solution is neutral. Above 7 is alkaline and the highest pH (13, drain cleaner) is the most alkaline, meaning it has the highest concentration of OH^- ions. Below 7 is acidic and the lower the pH, the higher the H^+ concentration. Increasing H^+ means decreasing pH: salt solution (7), rainwater (5), vinegar (3). To measure pH, put a drop of the solution on universal indicator paper (using a clean glass rod) and match the colour to the pH colour chart.

21 Core The characteristic properties of acids and bases [1]

Answer: B

Worked solution

Learn the three general reactions of acids. Acid + metal $\rightarrow$ salt + hydrogen. Acid + base $\rightarrow$ salt + water. Acid + carbonate $\rightarrow$ salt + water + carbon dioxide. Only the carbonate reaction makes all three: a salt, water and a gas. Sodium carbonate + sulfuric acid $\rightarrow$ sodium sulfate + water + carbon dioxide.

22 Supplement The characteristic properties of acids and bases [1]

Answer: D

Worked solution

All acids release hydrogen ions, H^+ , in water. The rest of the ethanoic acid molecule becomes the ethanoate ion, CH_3COO^- . Because ethanoic acid is weak, only some of its molecules dissociate at any moment, and the ions can join back together, so we use $\rightleftharpoons$. For a strong acid such as hydrochloric acid, we use a single arrow instead: $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$.

23**Core**

Preparation of salts

[1]

Answer: D

Worked solution

Choosing a method for a soluble salt depends on the solubility of the other reactant. If the base, carbonate or metal is insoluble, you add it in excess and filter off the leftover solid. Sodium, potassium and ammonium compounds are all soluble, so any excess would stay dissolved in the product. For these salts you use titration: measure exactly how much acid neutralises a known volume of alkali (using an indicator), then mix those same volumes without the indicator and crystallise. Always check that the acid gives the right salt: nitric acid makes nitrates.

24**Supplement**

Preparation of salts

[1]

Answer: B

Worked solution

A hydrated substance is chemically combined with water. The water molecules that are part of the crystal are called water of crystallisation, and the formula shows how many there are: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ has five for every CuSO_4 . The crystals feel dry, but the water is still there, built into the crystal. Only heating drives it off, leaving white anhydrous copper(II) sulfate, CuSO_4 , which contains no water.

25**Core**

The characteristic properties of acids and bases

[1]

Answer: B

Worked solution

Bases are oxides or hydroxides of metals. Alkalis are the bases that are soluble in water. Of the hydroxides, only those of sodium, potassium, ammonium and (partially) calcium dissolve, so potassium hydroxide is an alkali. Copper(II) oxide and iron(III) hydroxide are bases but insoluble. Carbonates react with acids too, but they are not oxides or hydroxides, so they are not classed as bases here.

26**Core**

The characteristic properties of acids and bases

[6]

Mark scheme

(a) [1]

- blue (1)

(b) [1]

- colourless (1)

REJECT clear (as a colour), white

(c) [2]

- $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (1)
- state symbols: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$ (1)
- the state-symbol mark requires the correct equation

ALLOW $\text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l})$

(d) [2]

- sodium chloride (1)
- pH 7 (1)

Worked solution

Thymolphthalein is blue in alkali and colourless in acid (and in neutral solutions). At the start the flask contains sodium hydroxide, an alkali, so it is blue. Once all the alkali is neutralised and a little acid is in excess, the indicator becomes colourless. In every acid-alkali neutralisation, hydrogen ions from the acid combine with hydroxide ions from the alkali to form water: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$. The other ions, Na^+ and Cl^- , remain as sodium chloride solution. When exactly neutral the pH is 7.

Mark scheme

(a) [2]

- P (1)
- it reacts with both the acid and the (alkali / base) sodium hydroxide / it is amphoteric (1)
- the second mark depends on P being identified

(b) [2]

- an oxide that reacts with (both) acids and bases / alkalis (1)
- to produce a salt and water (1)

(c) [1]

- zinc oxide / ZnO (1)

REJECT aluminium oxide (this is P)

(d) [2]

- basic (1)
- it contains magnesium, which is a metal / it is a metal oxide, and metal oxides are basic (it reacts with acid but not with alkali) (1)

Worked solution

Magnesium oxide is a basic oxide: it reacts with acids but not with bases. Aluminium oxide is amphoteric: it reacts with both acids and bases, making a salt and water each time. P reacts with both reagents, so P is aluminium oxide; Q reacts only with the acid, so Q is magnesium oxide. The other amphoteric oxide you need to know is zinc oxide. Magnesium is a metal, and metal oxides are typically basic, which fits Q's results.

Mark scheme

(a) [3]

- J: (dilute) hydrochloric acid (1)
- K: (aqueous) sodium hydroxide (1)
- L: (aqueous) sodium chloride (1)

(b) [2]

- hydrogen (1)
- ammonia (1)

(c) [2]

- no bubbles / no fizzing / no (visible) change (1)
- the acid / H^+ ions have been neutralised / used up (by OH^- ions), so there is no acid left to react with the magnesium (1)

ALLOW "only sodium chloride solution and water remain, which do not react with magnesium"

Worked solution

Use the typical reactions of acids and alkalis. Only an acid reacts with magnesium to give bubbles (of hydrogen), so J is hydrochloric acid. Thymolphthalein turns blue only in alkali, and an alkali (a base) warmed with an ammonium salt gives off ammonia, the gas that turns damp red litmus blue. So K is sodium hydroxide. L shows no acid or alkali reactions, so it is the neutral sodium chloride solution. When K exactly neutralises J, the H^+ ions and OH^- ions combine to form water, leaving only sodium chloride solution. With no H^+ ions left, magnesium has nothing to react with, so no bubbles are seen.

Mark scheme

(a) [1]

- a substance that is chemically combined with water (1)

REJECT "a substance that contains water" / "a substance dissolved in water"

(b) [1]

- water of crystallisation (1)

(c) [2]

- MgSO_4 (1)
- anhydrous (1)

(d) [2]

- water (of crystallisation) is driven off / lost / escapes as water vapour / steam (1)
- constant mass shows that all the water has been removed (1)

Worked solution

A hydrated substance has water chemically combined with it; the water molecules that are part of the crystal are called water of crystallisation. Heating drives this water off as steam: $\text{MgSO}_4 \cdot 7\text{H}_2\text{O} \rightarrow \text{MgSO}_4 + 7\text{H}_2\text{O}$. The mass falls because water leaves the basin. When the mass stops changing, no more water is being lost, which shows all of it has gone. The white powder left is MgSO_4 , which contains no water, so it is anhydrous.

Mark scheme

(a) [3]

- lead(II) sulfate: method 3 (1)
- potassium sulfate: method 1 (1)
- zinc sulfate: method 2 (1)

(b) [2]

- lead(II) nitrate (solution) (1)
- any soluble sulfate solution, e.g. sodium sulfate / potassium sulfate / dilute sulfuric acid (1)

REJECT lead(II) chloride, lead(II) carbonate, barium sulfate, calcium sulfate

(c) [1]

- zinc / zinc oxide / zinc carbonate / zinc hydroxide (1)

(d) [2]

- potassium compounds (e.g. potassium hydroxide / potassium carbonate) are soluble (1)
- so the excess would dissolve and could not be removed by filtration / would contaminate the salt, so exact amounts of reactants are needed (1)

Worked solution

Use the solubility rules to decide. Lead(II) sulfate is one of the insoluble sulfates, so it is made by precipitation (method 3). To precipitate it, mix a solution containing lead ions with a solution containing sulfate ions. Lead(II) nitrate is used because all nitrates are soluble, while lead(II) chloride and lead(II) carbonate are insoluble. Any soluble sulfate, such as sodium sulfate or sulfuric acid, provides the sulfate ions. Potassium sulfate and zinc sulfate are both soluble. Zinc, zinc oxide and zinc carbonate are insoluble, so they can be added in excess to sulfuric acid and the leftover solid filtered off (method 2). Potassium hydroxide and potassium carbonate are soluble, so any excess would stay dissolved and contaminate the product. Instead, titration (method 1) is used to find the exact amounts that react.