CC8a Acids, alkalis and indicators

1 any two acids, e.g. battery acid, vinegar, fruit juice

any two alkalis, e.g. bleach, drain cleaner, oven cleaner

2 **a** The hazards associated with the use of a substance will be understood in any country.

b Wear safety gloves and handle with care (as corrosive).
Dispose of carefully or do not pour down drain (as harmful to the environment).
Keep away from flames/sources of ignition (as flammable).

3 increasing acidity: 9 < 7 < 6 < 4 < 1.

4 **a** pH = 1

b litmus, red; methyl orange, pink/red; phenolphthalein, colourless

5 The pH scale runs from 0 to 14, and is used as a measure of acidity and alkalinity. On the pH scale neutral solutions have pH of 7, acids have a pH below 7 and alkalis have a pH above 7. The higher the pH the more alkaline the solution, and the lower the pH the more acidic the solution.

6 **a** The pH will be 1 (or any number less than 7). The pH is less than 7 as the hydrogen bromide produces H^+ ions when it dissolves in water and this makes it acidic.

b H^+ and Br^- ions are formed.

7 hydrochloric acid H^+ and Cl^-, sulfuric acid H^+ and SO_4^{2-}, nitric acid H^+ and NO_3^-, sodium hydroxide Na^+, and OH^- potassium hydroxide K^+ and OH^- and calcium hydroxide Ca^{2+} and OH^-

8 The acidity increases and pH decreases.

S1 Acidic solutions will have a pH less than 7, contain excess H^+ ions and turn universal indicator red or orange (or turn blue litmus red).

Alkaline solutions will have a pH greater than 7, contain excess OH^- ions and turn universal indicator blue or purple (or turn red litmus blue).

E1 **a** When the pH of a solution is increasing the concentration of the hydroxide ions is increasing (the concentration of the hydrogen ions is decreasing) and the solution is becoming more alkaline (less acidic).

b When the pH of a solution is decreasing the concentration of the hydrogen ions is increasing (the concentration of the hydroxide ions is decreasing) and the solution is becoming more acidic (less alkaline).

Exam-style question

a The pH increases as the water dilutes the acid. This is because hydrogen ions are less concentrated in the solution (1) and it is becoming less acidic with a pH closer to 7 (1).

b The pH stays the same as pure water has a pH of 7 (1) and so doesn't change the pH (or change the concentration of hydrogen or hydroxide ions) (1) in the salt solution.

CC8b Looking at acids H

1 **a** A concentrated solution is a solution that contains a lot of solute in a unit volume.

b 125 g dm^{-3}

2 hydrogen ion (H^+ ion) concentration

3 pH 4

4 1000 times more acidic

5 pH 3

6 Strong acids: nitric acid, sulfuric acid and hydrochloric acid.
Weak acids: carbonic acid, ethanoic acid and boric acid.

7 **a** Butanoic acid is a weak acid as only a few of its molecules break up into ions in solution.

b Butanoic acid will have the highest pH as it is least acidic with the lowest concentration of hydrogen ions.

S1 **a** Concentrated acid solutions contain a lot of solute dissolved in a small volume of solution.

b Dilute acid solutions contain very little solute dissolved in a large volume of solution.

c Strong acid solutions contain mainly ions, formed by the complete dissociation of the acid molecules when they dissolve in water.

d Weak acid solutions contain only a few ions and lots of acid molecules. This is because the acid molecules do not dissociate completely into ions when they dissolve in water.

E1 A concentrated solution of a weak acid contains just a few hydrogen ions as only a small number of weak acid molecules break up when they dissolve. A dilute solution of a strong acid will also contain only a small number of hydrogen ions as a dilute solution contains only a small amount of acid molecules, which will all dissociate into ions. They could therefore have the same pH if they have the same low concentrations of hydrogen ions.

Exam-style question

a solutions M and J (1)

b Solution. (1) N A concentrated solution contains lots of acid molecules. As it is a strong acid, it will break up to produce a high concentration of hydrogen ions. (1) The higher the concentration of hydrogen ions the lower the pH and so it must be solution N, which has the lowest pH. (1)

CC8c Bases and salts

1 A base is a substance that neutralises (reacts with) an acid to form a salt and water.

2 $ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O$

zinc oxide + sulfuric acid → zinc sulfate + water

3 sodium oxide + nitric acid → sodium nitrate + water

4 $Li_2O(s)$ + $\mathbf{H_2SO_4(aq)}$ → $Li_2SO_4(aq)$ + $\mathbf{H_2O(l)}$

5 **a** nitric acid

b to speed up the reaction

c to make sure all the acid is neutralised (used up)

d to remove the excess solid magnesium oxide from the salt solution (to make sure the salt is pure)

e to speed up evaporation of the water

6 Each of the oxide ions from the tin oxide combines with two hydrogen ions from the acid to form water.

S1 1: add excess insoluble base/metal oxide to some acid → 2: heat, to speed up the reaction → 3: filter out excess insoluble base/metal oxide → 4: heat to evaporate some of the solution → 5: leave to allow crystals of salt to form.

E1 Step 1. Add aluminium oxide to nitric acid. Make sure an excess is added so all the acid is used up.

Step 2. Leave the mixture until the reaction is complete (warm the acid to speed up the reaction).

The reaction equations are:

$Al_2O_3(s) + 6HNO_3(aq) \rightarrow 2Al(NO_3)_3(aq) + 3H_2O(l)$

aluminium oxide + nitric acid → aluminium nitrate + water

Step 3. Filter the mixture to separate the excess aluminium oxide from the aluminium nitrate solution.

Step 4. Allow the water to evaporate to leave a solid sample of aluminium nitrate (heat gently to speed up the evaporation).

Exam-style question

As the acidic gases pass over calcium oxide, the oxide ions combine with excess hydrogen ions in the acid, the hydrogen ion concentration decreases and the pH of the solution increases (as it is less acidic).

CC8c Core practical – Preparing copper sulfate

1 Because it is formed by the reaction between a base and an acid. (1)

2 To speed up the reaction. (1)

3 The copper oxide is a solid (made up of larger particles) that gets stuck in the filter paper. (1) The particles of the copper sulfate are in solution (smaller) so pass through the filter paper. (1)

4 The water bath heats the acid to a fixed lower temperature. (1) It is safer than a Bunsen burner which will heat the acid and could make it boil. (1)

5 A chemical reaction always forms a new substance (1) so the change of colour (to blue) indicates a new substance being formed. (1)

6 The copper oxide (black solid) remains (does not react). (1)

7 because otherwise acid will be left over (1)

8 Wear eye protection/safety glasses (1) to reduce the risk of splashes damaging eyes (1) or clean up all spills (1) to reduce the risk of accidental damage to skin or other materials. (1)

9 a nickel oxide + hydrochloric acid → nickel chloride + water (1)

b $NiO(s) + 2HCl(aq)$ (1) → $NiCl_2(aq) + H_2O(l)$ (1)

c Step 1: add excess nickel oxide to some (dilute) hydrochloric acid (1) Step 2: filter out excess nickel oxide (1) Step 3: evaporate water to leave nickel chloride (1)

10 Small crystals are produced by fast evaporation of the water in the solution. (1) Large crystals are produced by slow evaporation of the water in the solution. (1)

CC8d Alkalis and balancing equations

1 Alkalis are bases that dissolve in water. Only some bases dissolve in water and so are alkalis.

2 a LiOH

b $Mg(OH)_2$

3 $KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

4 The numbers of atoms of each element are equal on both sides.

5 $Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + \mathbf{2}H_2O(l)$

6 $\mathbf{3}KOH(aq) + H_3PO_4(aq) \rightarrow K_3PO_4(aq) + \mathbf{3}H_2O(l)$

S1 A neutralisation reaction happens; a salt and water are produced; there is no other product; the reaction mixture gets warmer; the pH changes.

S2 Numbers are added before formulae; if needed; to obtain equal numbers on both sides of the equation; of atoms of each element.

E1 Numbers are added before formulae; if needed; to obtain equal numbers on both sides of the equation; of atoms of each element; equations show that a salt and water only are produced; they cannot show that the reaction mixture gets warmer; or that the pH changes.

Exam-style question

$Mg(OH)_2(aq) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$

correct formulae (1); balanced (1); state symbols (1)

CC8d Core practical – Investigating neutralisation

1 a calcium chloride (1)

b $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$ 1 mark for formulae, 1 mark for balancing, 1 mark for state symbols

2 a To indicate the dangers associated with the substance inside (1) to inform people about precautions needed to work safely with the substance. (1)

b Calcium oxide is corrosive (1) but calcium hydroxide is irritant/harmful (1) so calcium oxide could cause more damage to skin and eyes. (1)

3 To avoid damage to eyes (1) because hydrochloric acid is irritant/corrosive. (1)

4 a volume of acid (1); concentration of acid (1)

b mass of calcium hydroxide (1)

c Use a thermometer instead of indicator paper or a pH meter. (1)

5 a answer in the range 1.1 g to 1.4 g (1)

b Add smaller portions of calcium oxide between 1.0 g and 1.5 g (1) because this is the range in which the pH changes quickly around pH 7 (1) and there will be smaller changes in pH. (1)

6 a To make sure that it gives an accurate pH value / pH value close to the true value. (1)

b The pH meter has the higher resolution because it gives readings to 1 or 2 decimal places (1) but universal indicator paper only gives readings to the nearest whole pH unit. (1)

CC8e Alkalis and neutralisation

1 H^+ ions from the acid; react with OH^- ions from the alkali; to form water; higher tier may give $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

2 Hydrogen ions from the acid; react with hydroxide ions from the alkali; to form water; potassium ions from the alkali; react with sulfate ions from the acid; to form potassium sulfate.

3 Acids and alkalis are corrosive/irritant; there is a risk of harm to eyes and skin if they leave the evaporating basin.

4 pipette for the alkali; burette for the acid

S1 Titration allows acid and alkali to be mixed in the correct proportions; to produce a neutral solution; of the desired salt and water only; repeat the titration without the indicator; followed by crystallisation; to obtain the dry salt from the salt solution.

E1 Answer should include advantages and disadvantages of each method (examples below), with a reasoned conclusion.

Metal and acid advantages: can add excess metal then filter; which is quick.

Metal and acid disadvantages: sodium and potassium are too reactive; dangerous reaction; metal will also react with the water in the salt solution; to produce hydroxides; which will contaminate the salt.

Titration advantages: sodium hydroxide and potassium hydroxide are soluble bases/alkalis; so titration can be used to mix them with acids in the correct proportions; to produce a neutral solution; of the desired salt with water only; safer than adding metals to acids.

Titration disadvantages: need to repeat the titration without the indicator; need to repeat to obtain accurate titre; more apparatus needed.

Reasoned conclusion such as: titration is the better method because it is safer.

Exam-style question

Universal indicator shows a gradual colour change/does not give a sharp end-point. (1)

phenolphthalein/methyl orange (1)

CC8f Reactions of acids with metals and carbonates

8th **1** Gold is unreactive and does not react with dilute acids.

7th **2** **a** zinc + hydrochloric acid → zinc chloride + hydrogen

9th **b** $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

10th **c** $Zn(s) \rightarrow Zn^{2+}(aq) + 2e$

8th **3** $CaCl_2$

6th **4** (aq) is an aqueous solution and contains a solute dissolved in water; (l) is a pure liquid

9th **5** $ZnCO_3 + 2HNO_3 \rightarrow Zn(NO_3)_2 + CO_2 + H_2O$

8th **6** $2H^+(aq) + CO_3^{2-}(s) \rightarrow H_2O(l) + CO_2(g)$

S1

a Add dilute hydrochloric acid or sulfuric acid to magnesium/zinc/iron. There will be effervescence/fizzing as a gas is given off. Place a lighted splint in the tube. If there is a squeaky pop, this proves that hydrogen is present. An equation for the reaction between the chosen acid and metal, e.g. $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

b Add a dilute acid to a metal carbonate. There will be effervescence/fizzing as a gas is given off. Bubble the gas through limewater. If the limewater turns milky, this proves that carbon dioxide is present. An equation for the reaction between the chosen acid and metal carbonate, e.g. $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$

E1

zinc + hydrochloric acid → zinc chloride + hydrogen

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

Exam-style question

Place a lighted splint in the tube of gas. (1)
If there is a squeaky pop, this proves that hydrogen is present. (1)

CC8g Solubility

5th **1** Soluble: sodium chloride, lead nitrate, potassium hydroxide, ammonium carbonate

Insoluble: calcium sulfate, silver chloride, calcium carbonate

4th **2** All lead compounds are insoluble except lead nitrate.

6th **3** **a** barium sulfate

9th **b** $MgSO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + MgCl_2(aq)$

9th **c** $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

6th **4** **a** No precipitate is formed.

7th **b** Sodium nitrate and copper chloride are both soluble in water.

5th **5** **a** to rinse out any precipitate left inside the beaker

5th **b** to wash the precipitate and remove any of the soluble product left on it

6th **6** any two from: leave it on a warm radiator; leave it on a (sunny) windowsill; dry on tissue/filter paper; leave it to dry in air.

S1 Answer to include: use of lead nitrate solution; use of any soluble sulfate, e.g. sodium sulfate solution; mix the two solutions in a beaker; filter the mixture; rinse the beaker with a little distilled water; pour the washings through the funnel; pour a little distilled water over the precipitate; dry the precipitate in a warm oven or other suitable method of drying. Example of equation: $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) + 2NaNO_3(aq)$

E1 Answer to include:
a precipitate of copper carbonate forms from sodium carbonate solution and copper sulfate solution
$Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$;
a precipitate of barium sulfate forms from copper sulfate solution and barium chloride solution
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$;
a precipitate of barium carbonate forms from sodium carbonate solution and barium chloride solution
$Ba^{2+}(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s)$

Exam-style question

A description including: mix the solutions to form a precipitate (1); filter the mixture (1); wash the precipitate with a little distilled water (1); suitable method of drying (1).