The position of hydrogen in the reactivity series

Hydrogen, although not a metal, is included in the reactivity series because it, like metals, can be displaced from aqueous solution, only this time the solution is an acid.

Hydrogen is placed between lead and copper. All metals above hydrogen in the reactivity series can displace hydrogen gas from dilute hydrochloric acid and dilute sulfuric acid. Those metals below hydrogen in the reactivity series cannot displace hydrogen from solutions of acids.

Chapter 16: Tests for ions and gases

Identification of cations (positive ions)

Identifying metal cations by using flame tests

The principle here is that the salts of some metals will impart a colour to a non-luminous Bunsen flame.

Test

1. The technique is first of all to clean the end of a piece of platinum or nichrome wire by dipping it into clean hydrochloric acid and then placing it in a roaring Bunsen flame. This procedure should be repeated until the wire no longer produces a colour in the flame.
2. The end of the wire should then be dipped into fresh hydrochloric acid and then into the solid sample under test.
3. The end of the wire should then be placed into a non-roaring, non-luminous Bunsen flame.

Result: In the table below are some of the common metal cations that can be tested in this way:

Metal cation	Colour of flame
Lithium, Li^+	Red
Potassium, K^+	Lilac
Calcium, Ca^{2+}	Brick red
Sodium, Na^+	Yellow / orange

Identifying the ammonium ion, NH_4^+

Test: Add aqueous sodium hydroxide to the solid, or solution, under test and warm the mixture.

Result: If ammonium ions are present then a pungent-smelling gas is produced. The gas produced turns damp red litmus paper blue. It is ammonia, NH_3.

Equation:

$$\underset{\text{ammonium ions (from the solution being tested)}}{NH_4^+(aq)} + \underset{\text{hydroxide ions (from the sodium hydroxide added)}}{OH^-} \rightarrow NH_3 + H_2O$$

Identifying metal cations by using precipitation reactions

Most metal hydroxides are insoluble and hence can be precipitated from aqueous solutions of metal salts by adding an aqueous solution of sodium hydroxide.

The technique is to add the reagent (i.e. the aqueous sodium hydroxide) a drop at a time to form the precipitate.

EXAMINER'S TIP

The ionic equations given here apply to any combinations of metal salt and sodium hydroxide. Although there is no requirement in the specification to learn ionic equations for these reactions, it is far easier to do so than to try to remember or work out individual equations for each separate combination of metal salt and sodium hydroxide.

Some common metal cations that can be identified using these reagents are shown in the table below:

Metal cation	Observation(s) with aq. sodium hydroxide	Equation for reaction
copper(II), Cu^{2+}	blue precipitate	$Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$
iron(II), Fe^{2+}	green precipitate	$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$
iron(III), Fe^{3+}	brown precipitate	$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

Identification of anions (negative ions)

Halide ions by precipitation with silver nitrate solution

Test: To an aqueous solution of the solid under test, add some dilute nitric acid followed by a few drops of silver nitrate solution.

Results:

Halide ion present	Observation	Equation for reaction
chloride ion, Cl^-	white precipitate (of silver chloride, AgCl)	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
bromide ion, Br^-	cream precipitate (of silver bromide, AgBr)	$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$
iodide ion, I^-	yellow precipitate (of silver iodide, AgI)	$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$

Sulfate ions, SO_4^{2-}, by precipitation with barium chloride solution

Test: To an aqueous solution of the solid under test, add dilute hydrochloric acid followed by a few drops of barium chloride solution.

Result: White precipitate (of barium sulfate)

Equation: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

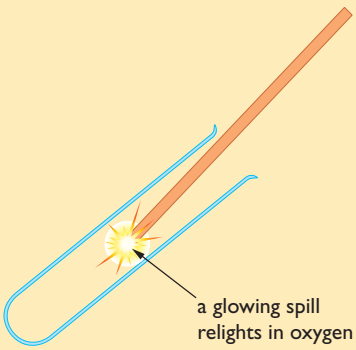
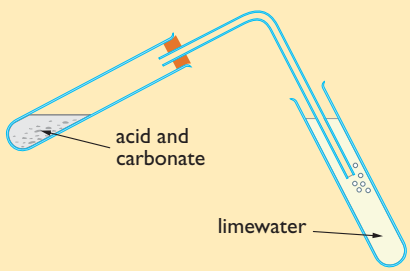
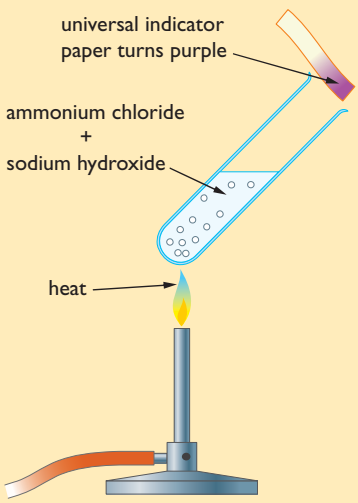
Carbonate ions using dilute acid

Test: To either the solid, or an aqueous solution of the solid, under test add dilute hydrochloric (or nitric) acid.

Result: Bubbles of gas. The gas produced turns limewater milky.

Equation: $CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$

Tests for gases

Name of gas	Test	Result if positive	Equation
hydrogen	mix with air and ignite	burns with a 'squeaky pop'	$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
oxygen	insert glowing spill 	spill relights	
carbon dioxide	bubble through limewater 	limewater turns milky	$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$ (the white solid, $CaCO_3$, turns the limewater milky)
chlorine	damp litmus paper OR moist starch-iodide paper	litmus paper turns white turns blue	$Cl_2(g) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$ (the iodine formed turns the starch blue)
ammonia	damp red litmus paper OR damp universal indicator (pH) paper 	turns blue turns purple	$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ (the hydroxide ions, OH^-, turn the litmus blue)

Examination Questions

1 Use the Periodic Table on p. 119 to help answer this question.

a) Which number increases from 3 to 10 in Period 2? *(1)*

b) Which number increases from 11 to 204 in Group 3? *(1)*

c) Which group contains elements whose ions all have a 1+ charge? *(1)*

d) Which group contains elements whose ions have a 2– charge? *(1)*

e) Give the number of a period that contains transition metals. *(1)*

(Total 5 marks)

2 A mixture contains an insoluble compound and a soluble compound.

The mixture is separated by adding hot water and then filtering.

This produces a **white** solid, **A**, and a **green** solution, **B**.

The white solid and the green solution were tested to find out what they were. The tables show the tests used and the results.

Tests on white solid A	
Test	**Result**
Carry out flame test	The flame was coloured brick red
Add dilute hydrochloric acid Test the gas produced	Bubbles seen Found to be carbon dioxide

a) (i) **Identify** the cation in solid **A**. *(1)*

(ii) The gas produced is carbon dioxide. State the test for carbon dioxide and the result of this test. *(2)*

(iii) **Identify** the anion in solid **A**. *(1)*

Tests on green solution B	
Test	**Result**
Add sodium hydroxide solution	Green precipitate
Add dilute nitric acid Then add silver nitrate solution	No change No change
Add barium chloride solution Then add dilute hydrochloric acid	White precipitate No change

b) (i) State the **formula** of the cation in solution **B**. *(1)*

(ii) State the **name** of the green precipitate. *(1)*

(iii) **Identify** the anion in solution **B**. *(1)*

(iv) State the **formula** of the white precipitate. *(1)*

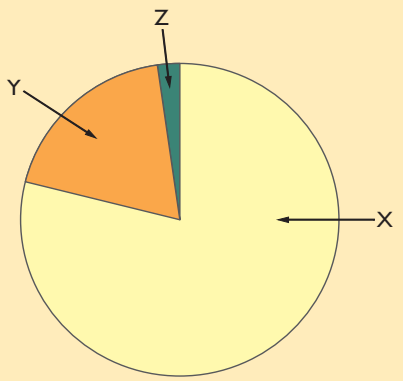
c) There are three anions that give a precipitate when dilute nitric acid and silver nitrate solution are added. Name **two** of these anions. *(2)*

d) (i) State the **formula** of solid **A**. *(1)*

(ii) State the **formula** of the compound in solution **B**. *(1)*

(Total 12 marks)

3 The pie chart shows the approximate percentages by volume of gases in dry air.



a) Which part of the pie chart (**X**, **Y** or **Z**) represents nitrogen? *(1)*

b) What is the approximate percentage of oxygen in dry air? *(1)*

c) What is the test for oxygen gas? *(2)*

d) Name the gas in dry air that is formed by the complete combustion of methane, CH_4 *(1)*

(Total 5 marks)

4 The table gives the colours of some indicators at different pH values.

Indicator	pH 1	3	5	7	9	11	13
litmus	red			purple	blue		
phenolphthalein	colourless					pink	
methyl orange	red		yellow				

a) (i) Use the table to find the pH of a solution in which litmus is red **and** methyl orange is yellow. *(1)*

(ii) Litmus is purple in sodium chloride solution. What colour is phenolphthalein in sodium chloride solution? *(1)*

b) A student was investigating the neutralisation of aqueous ammonia using hydrochloric acid.

She placed 25 cm^3 of aqueous ammonia in a conical flask and added a few drops of litmus.

She then slowly added hydrochloric acid to the mixture in the flask.

The indicator turned purple after she had added 15 cm^3 of hydrochloric acid.

The word equation for the reaction is: ammonia + hydrochloric acid → ammonium chloride

(i) Write a chemical equation for the reaction of ammonia with hydrochloric acid. *(2)*

(ii) Describe a chemical test to show that the solution obtained contains ammonium ions. Give the result of the test. *(3)*

(iii) The student used the same original solutions of aqueous ammonia and hydrochloric acid to make a pure sample of ammonium chloride crystals. Describe how she could do this. *(3)*

c) **(i)** Lead(II) chloride is insoluble. Name two solutions that react together to make lead(II) chloride. *(2)*

(ii) Write a **word** equation for this reaction. *(1)*

(Total 13 marks)

5 This question is about the reactions of the metals calcium, iron and zinc.

a) Samples of each of the powdered metals were placed in separate beakers of water. Only calcium reacted immediately.

Describe **two** observations that could be made during the reaction of calcium with water. Write a chemical equation for the reaction. *(3)*

b) A reaction occurred when powdered zinc was heated in steam.

Name the zinc compound formed. Write a chemical equation for the reaction. *(2)*

c) Some powdered zinc was added to a solution of iron(II) sulfate.

(i) Write an ionic equation to show the reaction that occurs. *(1)*

(ii) State the type of reaction occurring. *(1)*

d) Iron rusts slowly in the presence of water. Name one other substance that must be present for iron to rust. *(1)*

e) Galvanising is one method used to prevent iron from rusting.

(i) Describe how a sheet of iron is galvanised. *(1)*

(ii) A sheet of galvanised iron was scratched and left in the rain. The exposed iron did not rust. Explain why. *(2)*

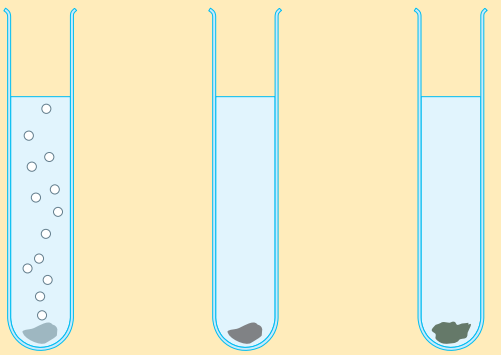
(Total 11 marks)

6 The reactivity of metals can be compared by their reactions with dilute hydrochloric acid.

Three different metals are added to separate test tubes containing this acid.

The diagram shows bubbles of hydrogen gas forming when a piece of zinc is added to dilute hydrochloric acid.

a) Complete the diagram to show the bubbles forming in the other two test tubes. *(2)*



b) Write a word equation for the reaction between zinc and dilute hydrochloric acid. *(1)*

c) Name **one** metal that does not form bubbles when it is added to dilute hydrochloric acid. *(1)*

d) Identify **two** substances, other than acids, that can be used in reactions to compare the reactivity of metals. *(2)*

(Total 6 marks)

7 A student tests a solution to see if it contains CO_3^{2-} ions. The first part of this test involves this reaction:

$2H^+(\_\_\_) + CO_3^{2-}(aq) \rightarrow H_2O(\_\_\_) + CO_2(\_\_\_)$

a) One state symbol is given in the equation. Write the other state symbols in the spaces provided. *(3)*

b) Name a reagent that can be used to provide the H^+ ions in the reaction. *(1)*

c) State the name for each of the following formulae: CO_3^{2-} and CO_2. *(2)*

d) The second part of the test involves using $Ca(OH)_2$ to detect the CO_2.

(i) What is the chemical name for $Ca(OH)_2$? *(1)*

(ii) The $Ca(OH)_2$ is dissolved in water to make a solution when doing the test for CO_2. What is the common name for this solution? ***(1)***

(iii) What is **seen** during this test for CO_2? ***(1)***

(iv) Complete the chemical equation for the reaction between these two substances.

$Ca(OH)_2 + CO_2 \rightarrow$ _____ + _____ ***(2)***

e) CO_2 is present in air. What effect does it have on rain water? ***(1)***

(Total 12 marks)

8 Sodium is a very reactive metal. It floats on water and reacts rapidly with water.

A small piece of sodium is placed in a trough of water. A reaction takes place and hydrogen gas is given off.

a) **(i)** Give **two** observations, other than the sodium floating, that you could make during the reaction. ***(2)***

(ii) Write a word equation for the reaction. ***(1)***

(iii) Universal indicator is added to the water in the trough. State what colour it turns and explain why. ***(2)***

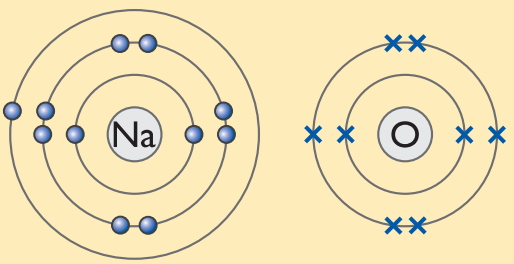
b) A piece of platinum wire is dipped into the solution in the trough and then held in a roaring Bunsen flame. The Bunsen flame becomes coloured.

(i) What colour does the flame become? ***(1)***

(ii) What name is given to this method of identification? ***(1)***

c) A piece of sodium is heated in a Bunsen flame. The sodium catches fire and reacts with the oxygen in the air. The product is sodium oxide.

(i) The diagrams show the electron arrangement in an atom of sodium and an atom of oxygen.



Sodium oxide contains ionic bonds. Describe what happens, in terms of electrons, when sodium reacts with oxygen. ***(3)***

(ii) Draw circles round the symbols that represent the two ions produced. ***(2)***

Na^+	Na^{2+}	Na^-	Na^{2-}
O^{2-}	O_2^-	O^-	O^{2+}

(Total 12 marks)

9 Three of the elements in Group 7 of the Periodic Table are chlorine, bromine and iodine.

a) Give the electronic configuration of chlorine. ***(1)***

b) How many electrons are there in the outer shell of an atom of iodine? ***(1)***

c) Bromine reacts with hydrogen to form hydrogen bromide. The chemical equation for the reaction is: $Br_2(g) + H_2(g) \rightarrow 2HBr(g)$

Describe the colour change occurring during the reaction. ***(2)***

d) Hydrogen bromide and hydrogen chloride have similar chemical properties.

(i) A sample of hydrogen bromide is dissolved in water. A piece of blue litmus paper is placed in the solution. State, with a reason, the final colour of the litmus paper. ***(2)***

(ii) A sample of hydrogen bromide is dissolved in methylbenzene. A piece of blue litmus paper is placed in the solution. State, with a reason, the final colour of the litmus paper. ***(2)***

(Total 8 marks)

10 Calcium and magnesium are metals in Group 2 of the Periodic Table.

a) **(i)** How many electrons are there in the outer shell of an atom of calcium? ***(1)***

(ii) Write the electronic configuration of an atom of magnesium. ***(1)***

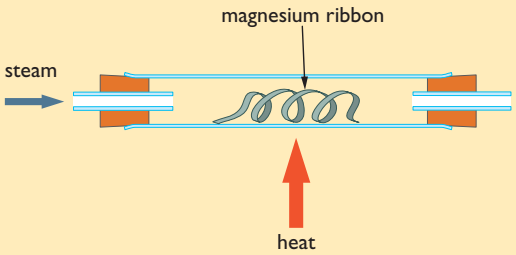
b) A student adds a piece of calcium to some cold water in a beaker. The products of the reaction are calcium hydroxide and hydrogen. Some of the calcium hydroxide dissolves in the water and some does not.

(i) Describe **two** observations that the student could make during the reaction. ***(2)***

(ii) Give the formula of calcium hydroxide. ***(1)***

(iii) When the reaction is complete, a piece of litmus paper is added to the solution in the beaker. State the final colour of the litmus paper and what this colour indicates about the solution. ***(2)***

c) The diagram shows apparatus for reacting magnesium with steam.



The products of this reaction are magnesium oxide and hydrogen.

(i) State the colour of magnesium and of magnesium oxide. *(2)*

(ii) State **two** ways in which the hydrogen could be collected. *(2)*

(iii) The hydrogen gas can be burned as it leaves the heated tube. Write a word equation for this reaction. *(1)*

(Total 12 marks)

11 Use information from the table below to answer this question.

increasing reactivity ↑	Name of metal	Colour of solid metal	Colour of a solution of the metal(II) sulfate
	magnesium	grey	colourless
	zinc	grey	colourless
	iron	dark grey	green
	copper	pink-brown	blue

a) When zinc is added to magnesium sulfate solution, no reaction occurs. State why. *(1)*

b) When iron filings are added to copper(II) sulfate solution, a reaction takes place.

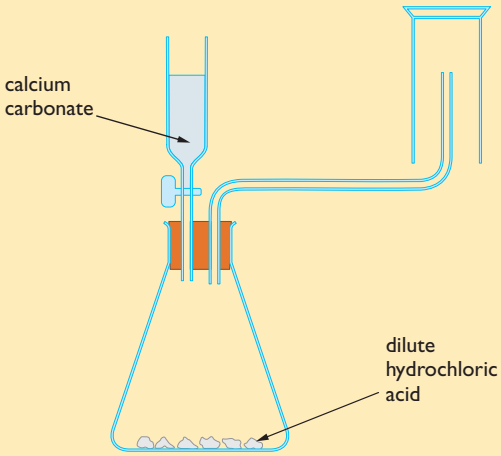
(i) Write a chemical equation for this reaction. *(2)*

(ii) Describe the colour changes to both the solid and the solution during this reaction. *(4)*

c) When copper is added to dilute sulfuric acid, no reaction occurs. When iron is added to dilute sulfuric acid, hydrogen gas and iron(II) sulfate solution are formed. What does this show about the reactivity of hydrogen compared to the reactivity of copper and the reactivity of iron? *(2)*

(Total 9 marks)

12 *a)* A student was asked to draw a diagram to show apparatus he would use to prepare carbon dioxide gas in the laboratory. This is the diagram he drew.



(i) State how the diagram is labelled incorrectly. *(1)*

(ii) Why is the method of collection of carbon dioxide unsuitable? How could the carbon dioxide be collected? *(2)*

(iii) Write a chemical equation, including state symbols, for the reaction that occurs in the conical flask. *(3)*

b) A teacher prepares a gas jar of oxygen. She then lights a piece of magnesium ribbon and places it in the gas jar. A vigorous reaction occurs. Give two observations she could make during the reaction between magnesium and oxygen. *(2)*

(Total 8 marks)

Notes