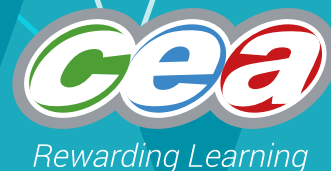


FACTFILE: GCSE DAS CHEMISTRY: UNIT 2.1



Metals and the Reactivity Series

Learning outcomes:

Students should be able to:

- 2.1.1 recall the reactivity series of metals, including K, Na, Ca, Mg, Al, Zn, Fe, and Cu;
- 2.1.2 describe the reactions, if any, of the above metals with the following and describe how to collect the gas produced where appropriate:
 - with air
 - with water
 - with steam.
- 2.1.3 explain how the reactivity of metals is related to the tendency of a metal to form its positive ion.
- 2.1.4 explain and describe the displacement reactions of metals with other metal ions in solution.
- 2.1.5 collect and/or analyse experimental data to predict where an unfamiliar element should be placed in the reactivity series or to make predictions about how it will react.
- 2.1.6 examine the relationship between the extraction of a metal from its ore and its position in the reactivity series, for example:
 - aluminium, a reactive metal, is extracted by electrolysis; and
 - iron, a less reactive metal, by chemical reduction.

Some metals are very unreactive, this means they do not easily take part in chemical reactions. Precious metals such as gold, silver and platinum are unreactive. However, some metals are very reactive. They easily take part in chemical reactions to make new substances. If we put the metals in order of their reactivity, from most reactive down to least reactive, we get a list called the reactivity series.

The Reactivity Series

Potassium	K	MOST REACTIVE
Sodium	Na	↓
Calcium	Ca	
Magnesium	Mg	
Aluminium	Al	
Zinc	Zn	
Iron	Fe	
Copper	Cu	

To make this series easier to learn a mnemonic may be constructed using the first letter of each metal in the series. For example:

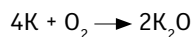
'Penny Savage Caught Mammoths And Zebras In Capetown'

Reactions of Metals

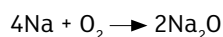
1. With air

The metals react when heated in air.

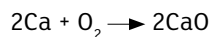
- Potassium burns with a lilac flame producing a white solid (potassium oxide)



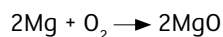
- Sodium burns with a yellow/orange flame producing a white solid (sodium oxide)



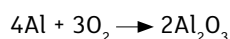
- Calcium burns with a brick red flame producing a white solid (calcium oxide)



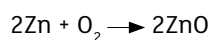
- Magnesium burns with a bright white light forming a white solid (magnesium oxide)



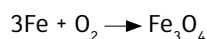
- Aluminium powder burns with a bright white light forming a white solid (aluminium oxide)



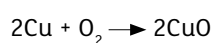
- Zinc glows orange and produces a yellow solid which changes to white on cooling (zinc oxide)



- Iron filings burn with orange sparks producing a black solid (Fe_3O_4)



- Copper glows orange and produces a black solid (copper(II) oxide)



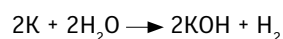
2. with cold water

Potassium, sodium and calcium all react with cold water.

Potassium	Sodium	Calcium
Floats	Floats	Granules sink and rise continuously
Moves very rapidly across the surface	Moves rapidly across the surface	Bubbles of gas released
Bubbles of gas released	Bubbles of gas released	Heat is released
Heat is released	Heat is released	Grey powdered solid forms in the water
Ignites with a lilac flame	Melts to form a sphere of molten metal	
Crackles at the end/explosion	Colourless solution forms	
Colourless solution forms		

When these metals react with cold water they produce a METAL HYDROXIDE and HYDROGEN GAS.

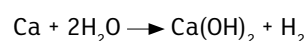
potassium + water \rightarrow potassium hydroxide + hydrogen



sodium + water \rightarrow sodium hydroxide + hydrogen



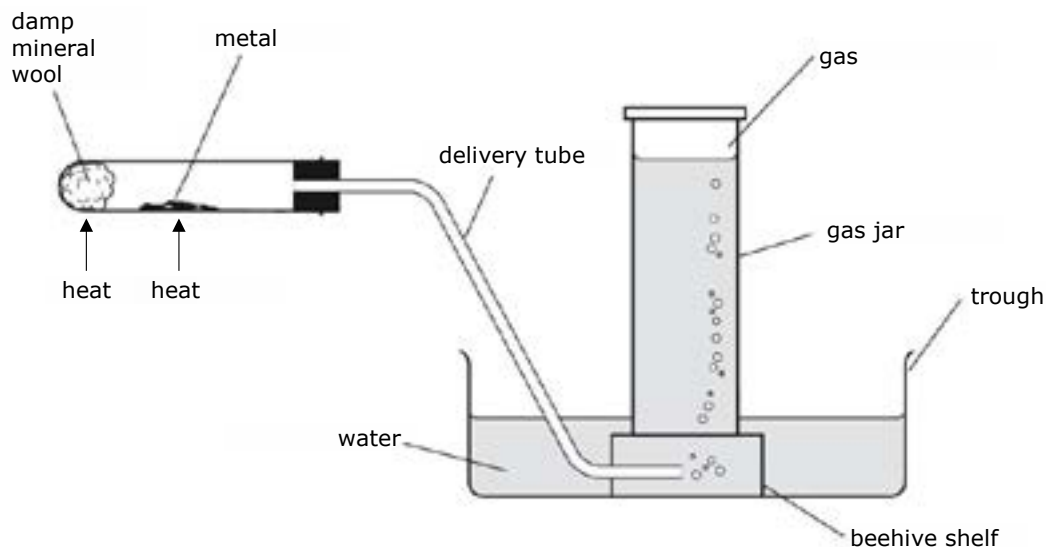
calcium + water \rightarrow calcium hydroxide + hydrogen



The metal hydroxides produced will turn universal indicator solution/pH paper **blue** indicating they are alkaline solutions. Hydrogen gas can be confirmed by placing a burning splint in contact with the gas and a squeaky pop will be produced. Magnesium only produces a few bubbles of gas even when left for several days with cold water. Zinc, iron and copper show no reaction with cold water.

3. with steam.

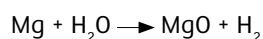
Magnesium, zinc, aluminium and iron all react with steam using the following apparatus:



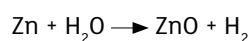
Magnesium	Zinc	Aluminium	Iron
Bright white light produced	Glows and produces a yellow powder	Glows and produces a white powder	Iron is heated until it glows red
White powder remains	Yellow powder turns white when cooled	White powder remains	Black solid forms

In these reactions a metal oxide and hydrogen gas are produced.

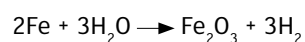
magnesium + steam \rightarrow magnesium oxide + hydrogen



zinc + steam \rightarrow zinc oxide + hydrogen



iron + steam \rightarrow iron(III) oxide + hydrogen



Copper is too unreactive to show any reaction with steam.

The reactivity of a metal can be linked to the ability of the metal to form its positive ion. The more reactive the metal, the greater tendency it has to form a positive ion (cation) in the context of a chemical reaction. For example:

- $\text{K} \rightarrow \text{K}^+ + \text{e}^-$
- $\text{Na} \rightarrow \text{Na}^+ + \text{e}^-$
- $\text{Ca} \rightarrow \text{Ca}^{2+} + 2\text{e}^-$

3. Displacement Reactions

A metal will displace (take the place of) a **less reactive** metal in a metal salt solution.

A sample set of results is shown below:

	Cu	Fe	Mg	Zn
CuSO ₄	no reaction	red-brown layer of copper on the iron filings, blue colour fades	red-brown layer of copper on the magnesium strip, blue colour fades	red-brown layer of copper on the zinc granules, blue colour fades
FeSO ₄	no reaction	no reaction	grey solid on the magnesium ribbon	grey solid on the zinc granules
MgSO ₄	no reaction	no reaction	no reaction	no reaction
ZnSO ₄	no reaction	no reaction	grey solid on the magnesium ribbon	no reaction

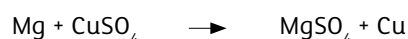
Using the information in the table it is possible to make the following conclusions:

- Magnesium is the most reactive metal. It **DISPLACES ALL** other metals from their metal salt solutions. The magnesium is never displaced from the magnesium sulfate solution.
- Copper is the least reactive metal. It does **NOT DISPLACE** any metals from their metal salt solutions. Copper is **ALWAYS** displaced from the solution of copper(II) sulfate.
- The order of reactivity of the metals can be confirmed (most reactive first):

Mg, Zn, Fe and then Cu.

It is possible to write equations for all of the reactions that took place. For example:

magnesium + copper(II) sulfate → magnesium sulfate + copper



By using experimental data it is possible to place metals in a reactivity series. A tick ✓ represents a

reaction and an *X* represents no reaction.

	Metal X	Metal Y	Metal Z
X sulfate		X	X
Y sulfate	✓		✓
Z sulfate	✓	X	

Metal X displaces both Y and Z – so it must be the **most reactive** and be at the top of this reactivity series.

Metal Y cannot displace either X or Z – so it must be the **least reactive** and be at the bottom of this reactivity series.

Metal Z displaces Y but cannot displace X – so it must be more reactive than Y but less reactive than X, and be in between them in this reactivity series.

Therefore, the order of decreasing reactivity is:

METAL X
METAL Z
METAL Y

Extraction of metals

The method used to extract metals from the ore in which they are found depends on their reactivity. For example, reactive metals such as aluminium are extracted by *electrolysis* while a less-reactive metal such as iron may be extracted by *reduction* with carbon or carbon monoxide.

Metals – in decreasing order of reactivity	Reactivity
potassium sodium calcium magnesium aluminium	extract by <i>electrolysis</i>
zinc iron	extract by <i>reduction</i> reaction using <i>carbon</i> or <i>carbon monoxide</i>

REVISION QUESTIONS

- 1 The reactivity of metals can be studied using displacement reactions. If a displacement reaction occurs there is a temperature rise.

In an experiment the following method was used:

- Pour some copper(II) sulfate solution into a polystyrene cup and record the temperature of the solution.
- Add a known mass of metal and stir.
- Record the maximum temperature of the mixture.
- Repeat the experiment.

The results of this experiment are shown in the table below.

Metal	Temperature increase (°C)		Average temperature rise (°C)
	Experiment 1	Experiment 2	
magnesium	11.5	16.5	14.0
silver	0.0	0.0	0.0
iron	3.0	4.0	3.5
gold	0.0	0.0	0.0
zinc	7.0	8.0	7.5

- (a) State two factors which should be kept the same in this experiment to make it a fair test.

[2]

- (b) State and explain which of the metals gave the least reliable temperature rise.

[1]

- (c) State and explain which of the metals used in the experiment is the most reactive.

[2]

- (d) Explain why there is no temperature rise when silver is added to copper(II) sulfate solution.

[1]

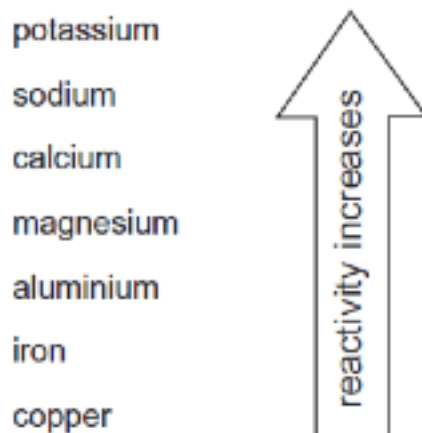
(e) Why do the results make it impossible to decide which of the metals is the least reactive?

_____ [1]

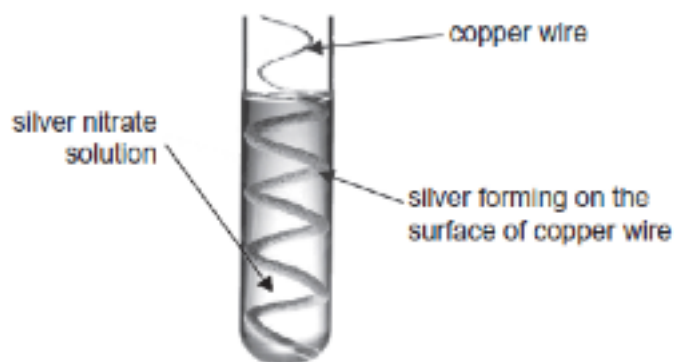
(f) Write a balanced symbol equation for the displacement reaction between zinc and copper(II) sulfate solution.

_____ [2]

2. A reactivity series of some metals is shown below:



- (a) Silver metal does not appear on the above reactivity series. Copper metal will react with silver nitrate solution to form silver as shown below.



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- (i) Write a balanced symbol equation for the reaction of copper with silver nitrate forming silver and copper(II) nitrate.

_____ [3]

- (ii) Indicate the position of silver on the reactivity series shown above. [1]

(iii) Silver nitrate solution is colourless. What is the colour of the solution at the end of this reaction?

_____ [1]

(iv) Explain why copper displaces silver from a solution of silver nitrate.

_____ [2]

