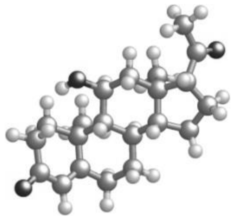

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The Reactivity Series of Metals
Displacement Reactions of Metals and the Extraction of Metals from their Compounds
Macroconcept: System

The Reactivity Series of Metals

The reactivity series of metals is given below:

• ***Most reactive***:	Potassium	K	valency = 1
	Sodium	Na	valency = 1
	Calcium	Ca	valency = 2
	Magnesium	Mg	valency = 2
	Aluminium	A*l*	valency = 3
	(***Carbon***)*	C	valency = 4
Reactivity Decreases	Zinc	Zn	valency = 2
	Iron	Fe	valency = 2, 3
	Tin	Sn	valency = 2, 4
	Lead	Pb	valency = 2, 4
	(***Hydrogen***)*	H	valency = 1
	Copper	Cu	valency = 1, 2
	Silver	Ag	valency = 1
• ***Least Reactive***:	Gold	Au	valency = 1, 3

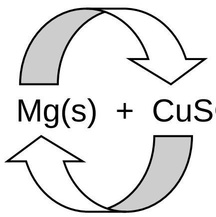
Note: carbon and hydrogen are non-metals, but have been included for reference.

<u>Displacement Reactions of Metals</u>

A ***more*** reactive metal (high in the reactivity series) can displace a ***less*** reactive metal (low in the reactivity series) from its compounds. For example, magnesium can displace copper from its compounds:

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

Reactive magnesium displaces the less reactive copper from its compounds.



$$Mg(s) + CuSO_4(aq) \rightarrow MgSO_4(aq) + Cu(s)$$

An ***ionic equation*** can also be written for this reaction. An ionic equation concentrates on the species that are reacting, and ignores the species that are not reacting – so-called ***spectator ions***.

If the above equation is re-written, breaking the copper(II) sulfate down into its component ions, we get:

$$Mg(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Mg^{2+}(aq) + SO_4^{2-}(aq) + Cu(s)$$

From this it can be seen that the magnesium is taking part in the reaction, starting as $Mg(s)$ and finishing as $Mg^{2+}(aq)$. The copper is also participating in the reaction, starting as $Cu^{2+}(aq)$ and finishing as $Cu(s)$. However, the sulfate ion is an un-reactive spectator ion. It is chemically unchanged by the reaction, starting and finishing as $SO_4^{2-}(aq)$.

If the equation is re-written once again, ignoring the sulfate ion, we get:

$$Mg(s) + Cu^{2+}(aq) + \cancel{SO_4}^{2-}(aq) \rightarrow Mg^{2+}(aq) + \cancel{SO_4}^{2-}(aq) + Cu(s)$$

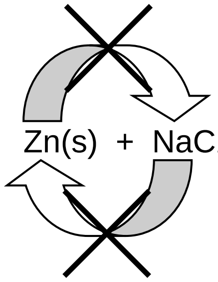
This finally gives us the ionic equation for the reaction:

$$Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$$

A ***less*** reactive metal (low in the reactivity series) cannot displace a ***more*** reactive metal (high in the reactivity series) from its compounds. For example, zinc cannot displace sodium from its compounds:

zinc + sodium chloride → No observed reaction

Zinc cannot displace the more reactive sodium from its compounds.

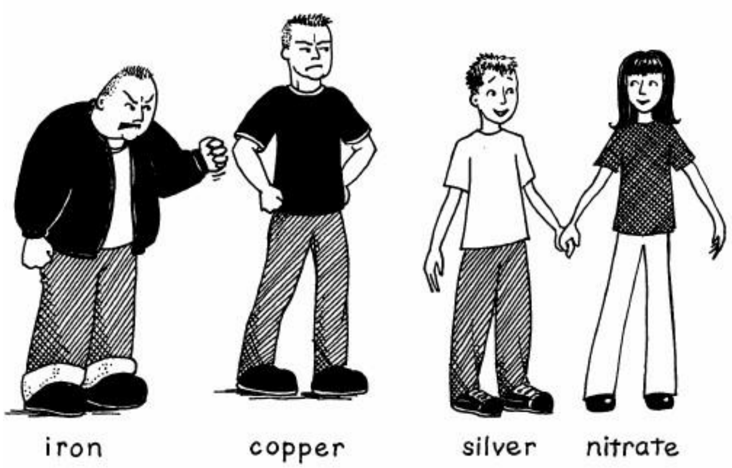


$Zn(s) + NaCl(aq) \rightarrow$ No observed reaction

Look at the following pairs of chemicals. Use the reactivity series of metals to decide whether or not a chemical reaction takes place when the two chemicals are mixed together. Write a word equation, a balanced chemical equation and an ionic equation for each reaction that you think will take place. Write "*no reaction*" if you think that no chemical reaction will take place.

1. Zinc Metal + Copper(II) Sulfate Solution	Word Equation:	
	Chemical Equation:	
	Ionic Equation:	
2. Lead Metal + Silver Nitrate Solution	Word Equation:	
	Chemical Equation:	
	Ionic Equation:	
3. Silver Metal + Magnesium Chloride Solution	Word Equation:	
	Chemical Equation:	
	Ionic Equation:	
4. Aluminium Metal + Iron(III) Chloride Solution	Word Equation:	
	Chemical Equation:	
	Ionic Equation:	

When copper metal is added to an aqueous solution of silver nitrate, a solid **Y** and a solution **Z** is formed. Identify the solid **Y** and the solution **Z**. Would you expect the reaction between iron metal and an aqueous solution of silver nitrate to be faster of slower than the reaction between copper metal and an aqueous solution of silver nitrate? Explain your answer:



Y = ………………………… **Z** = …………………………

Rate of reaction: ……………………………………………………………………..

Explanation: ……………………………………………………………………..

The Extraction of Metals from their Compounds

Very few metals are found as the pure element in nature. Most are found chemically combined with oxygen. Some examples are given in the table below:

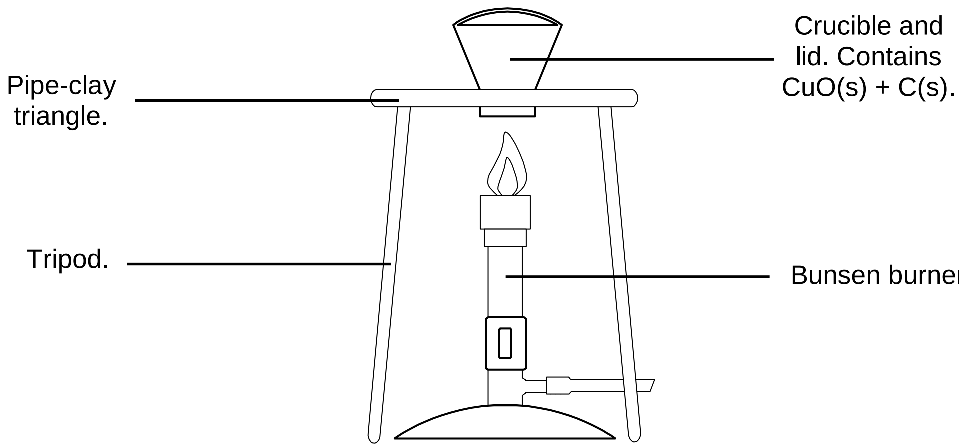
Metal:	Found in nature as:	Name of oxide:
Iron	Iron (III) oxide – Fe_2O_3	Haematite
Aluminium	Aluminium oxide – Al_2O_3	Bauxite
Tin	Tin (IV) oxide – SnO_2	Cassiterite

Before metals, such as copper, can be put to good use, they must first be extracted from their oxide. This can be achieved by reacting the metal oxide with charcoal (carbon). If the charcoal is ***more reactive*** than the metal, it will remove the oxygen from the metal oxide and leave a trace of the metal in the reaction vessel.

In the diagram below, copper(II) oxide is strongly heated with charcoal (carbon) in a crucible. Because carbon is higher than copper in the reactivity series, it is more reactive than copper, and so can displace copper from its oxide:

copper(II) oxide + carbon → copper + carbon dioxide

$$2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$$



Copper can also be extracted from copper(II) oxide by heating it in a stream of hydrogen gas. Why is this possible? Write a balanced chemical equation for the reaction:

Reason: ……………………………………………………………………………

Balanced chemical equation: …………………………………………………………

Which is the most suitable method for extracting iron from iron(III) oxide, heating the iron(III) oxide with carbon, or heating the iron(III) oxide in a stream of hydrogen gas? Give a reason for your answer. Write a balanced chemical equation to illustrate the method that you have chosen:

Most suitable method: ……………………………………………………………

Reason: ……………………………………………………………………………

Balanced chemical equation: …………………………………………………………

Activity 5

Metals such as sodium and aluminium are more reactive than carbon and therefore cannot be extracted form their oxides by heating with charcoal. Suggest an element that could be used to extract sodium and aluminium from their oxides. What problem is associated with using this method to extract sodium and aluminium?

Element that could be used: …………………………………………………………..

Problem: ………………………………………………………………………………

……………………………………………………………………………………………

Elements such as sodium and aluminium are actually extracted from their compounds by ***electrolysis***. This involves passing an electric current through the molten compound.

For example, in the extraction of aluminium from aluminium oxide, the positive aluminium ions* are attracted to the negative electrode (***cathode***) where they receive electrons to form atoms of aluminium:

aluminium ions + electrons → aluminium atoms

$$Al^{3+}(l) + 3e^{-} \rightarrow Al(l)$$

The negative oxide ions* are attracted to the positive electrode (***anode***) where they lose electrons to form molecules of oxygen:

oxide ions – electrons → oxygen

$$2O^{2-}(l) \rightarrow O_2(g) + 4e^{-}$$

Activity 6

Write balanced chemical equations, similar to the ones above, to show how sodium is extracted from molten sodium chloride by electrolysis:

At the negative electrode: ……………………………………………………………

At the positive electrode: ……………………………………………………………

Note:** a ***positive ion is called a ***cation***. A ***negative*** ion is called an ***anion***.

<u>The Discovery of Metals and their Position in the Reactivity Series</u>

Consider the reactivity series of the metals as you answer the following questions:

Which metallic elements were used by ancient civilisations thousands of years ago? Why have these metallic elements been available for so long?

Metals: …………………………………………………………………………………...

Reason: ……………………………………………………………………………….

……………………………………………………………………………………………….

Which metallic elements have only been extracted from their compounds recently (in the past 200 years)? Why were these metals not extracted form their compounds earlier?

Metals: …………………………………………………………………………………...

Reason: ……………………………………………………………………………….

……………………………………………………………………………………………….

Reflect on What You Have Learnt

1. Name a metal that can displace zinc from its compounds.

……………………………………………………………………………………

2. Name a metal that iron can displace from its compounds.

……………………………………………………………………………………

3. Define the term *displacement reaction*.

……………………………………………………………………………………

4. Give one example of a displacement reaction.

……………………………………………………………………………………

5. Name an element that can be extracted from its oxide by carbon.

……………………………………………………………………………………

6. Write a balanced chemical equation to illustrate your answer to Qu. 5.

……………………………………………………………………………………

7. Name an element that can be extracted from its oxide using hydrogen.

……………………………………………………………………………………

8. Write a balanced chemical equation to illustrate your answer to Qu. 7.

……………………………………………………………………………………

9. Name an element that is usually extracted from its oxide by electrolysis.

……………………………………………………………………………………

10. Write a balanced chemical equation, as well as ionic half-equations, to illustrate your answer to Qu. 9.

……………………………………………………………………………………

- Scan the QR code given below to view the answers to this assignment.

http://www.chemist.sg/metals/reactivity_series_worksheet_ans.pdf