Exercise walk-through

4.1
Reactivity of metals and displacement (4.4.1.1–4.4.1.3)

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The reactivity of metals

- When metals react, their atoms lose electrons and form a **positive ion** .
- The more easily a metal does this, the more reactive it is.
- The **reactivity series** puts the metals in order: potassium, sodium, lithium, calcium, magnesium, zinc, iron, copper, from most to least reactive.
- Carbon and hydrogen are not metals, but they are included as reference points.

$$\mathrm{Zn(s)} + \mathrm{CuSO_4(aq)} \rightarrow \mathrm{ZnSO_4(aq)} + \mathrm{Cu(s)}$$

Electrolysis

- At the **cathode**, the metal forms if it is less reactive than hydrogen (such as copper). Otherwise hydrogen forms.
- At the **anode**, if the solution contains a **halide** ion (**chloride**, bromide or iodide), the **halogen** forms. Otherwise oxygen forms.
- hydrogen burns with a squeaky pop when a **lighted splint** is held near it;

$$\mathrm{Al}^{3+} + 3\mathrm{e}^- \rightarrow \mathrm{Al} \qquad 2\mathrm{O}^{2-} \rightarrow \mathrm{O}_2 + 4\mathrm{e}^-$$

Sources for this lesson

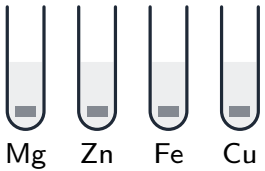
- AQA, *GCSE Chemistry (8462) specification*, section 4.4, and the required practicals handbook.
- Smithsonian Institution, "The Aluminum Apex of the Washington Monument" (1884 capstone, 100 troy ounces).
- C. M. Hall, US Patent 400,766, "Process of Reducing Aluminium from its Fluoride Salts by Electrolysis" (filed July 1886), and P. Héroult, French patent 175,711 (April 1886).
- Royal Society of Chemistry, *Practical Chemistry*: "Preparing a salt" and "Electrolysis of solutions".

Exercises 2.1·2.2

2.1 Place in reactivity order: calcium, copper, magnesium, sodium. [1]



2.2 Which of Mg, Zn, Fe and Cu does not react with dilute hydrochloric acid? [1]



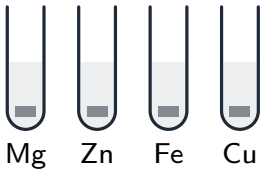
Exercises 2.1·2.2

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2.1 Sodium > calcium > magnesium > copper.

2.2 Which of Mg, Zn, Fe and Cu does not react with dilute hydrochloric acid? [1]



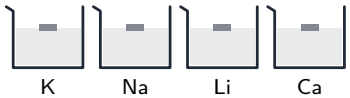
2.2 Copper.

Exercise 2.3

2.3 Why is aluminium extracted by electrolysis rather than carbon reduction? [1]



2.4 At room temperature, describe the water reactions of K, Na, Li and Ca, including the types of products. Contrast Mg with Zn, Fe and Cu in cold water. Give two conditions to keep the same when comparing suitable samples. [6]

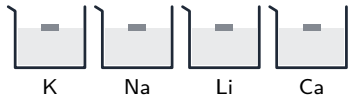


Exercise 2.3

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K	Na	Al	C	Zn	Fe

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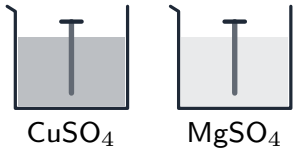


2.3 Aluminium is more reactive than carbon, so carbon cannot reduce its oxide.

2.4 K, Na, Li and Ca react with cold water to form the metal hydroxide and hydrogen. Magnesium reacts extremely slowly; Zn, Fe and Cu show no observable cold-water reaction under the stated comparison. Control any two appropriate conditions: water temperature/volume, exposed metal surface or sample condition, and observation time. Highly reactive metals use an approved teacher demonstration rather than an independent student acid comparison.

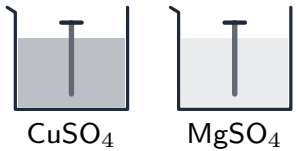
Exercise 3.1

3.1 Iron displaces copper from copper sulfate solution but cannot displace magnesium from magnesium sulfate. Deduce the reactivity order of the three metals and explain in terms of ions. [4]



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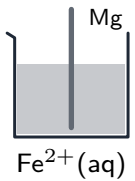
3.1 Iron > copper, because iron displaces copper – iron atoms form ions more readily; magnesium > iron, because iron cannot displace magnesium; order: Mg > Fe > Cu; reactivity is the tendency to lose electrons and form positive ions.

Setup for exercise 3.2

3.2 Explain, in terms of oxygen, which reactant is reduced and which is oxidised in: $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$. [3]

$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

3.3 *(HT)* For $Mg + Fe^{2+} \rightarrow Mg^{2+} + Fe$, write the two half-equations and state which species is reduced. [4]



Exercise 3.2

3.4 Clean, equally sized samples of metals X, Y and Z are placed separately in solutions of their salts. X displaces Y; Z displaces X. Order the three metals and explain the evidence. X also displaces copper but does not displace magnesium. What can you conclude about X? [5]



3.5 A metal M is found above carbon in the reactivity series. Its oxide cannot be reduced by heating with carbon. Another metal N is below carbon. A proposed process uses carbon to remove oxygen from N's oxide, but produces carbon dioxide. Explain the chemical choice for each metal and evaluate one environmental disadvantage of the proposed process. Do not describe a named industrial furnace. [4]



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3.2 Iron oxide loses oxygen to become iron – iron is reduced; carbon gains oxygen to become carbon dioxide – carbon is oxidised; overall, carbon reduces iron oxide to iron.

3.3 $Mg \rightarrow Mg^{2+} + 2e^{-}$; $Fe^{2+} + 2e^{-} \rightarrow Fe$; the iron(II) ion gains electrons, so Fe^{2+} is

Full solution on next slide

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Full solution 3.2

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3.3 $Mg \rightarrow Mg^{2+} + 2e^{-}$; $Fe^{2+} + 2e^{-} \rightarrow Fe$; the iron(II) ion gains electrons, so Fe^{2+} is reduced; magnesium is oxidised.

3.4 X > Y; Z > X; hence Z > X > Y. Magnesium > X > copper; the successful displacement means X forms positive ions more readily than copper, but less readily than magnesium. These results do not give X's exact identity.

3.5 Carbon cannot reduce M's oxide because M is more reactive than carbon; use another method such as electrolysis of a suitable molten compound. Carbon can remove oxygen from the oxide of the less reactive N. Producing carbon dioxide contributes to greenhouse-gas emissions; evaluate the supplied process, rather than claiming extraction has no environmental cost.