4.1 Reactivity of metals

Name: _____ Class: _____ Date: _____ **Total: 29 marks**

KEY WORDS reactivity series • displacement • reduction

Objective

Order metals by reactivity, predict displacement, choose extraction methods and (HT) use electron-transfer redox. Original questions for spec statements 4.4.1.1–4.4.1.4.

1 Key knowledge and worked examples

Reactivity series: K, Na, Li, Ca, Mg, (C), Zn, Fe, (H), Cu. Carbon and hydrogen are non-metal reference points; the comparison here is at room temperature. Reactivity = **tendency to form positive ions**.

- water: K/Na/Li/Ca react; Mg very slow; Zn, Fe, Cu none;
- dilute acid: Mg, Zn, Fe → salt + H_2; Cu none;
- **displacement**: a more reactive metal displaces a less reactive one – Zn + $CuSO_4$ → $ZnSO_4$ + Cu.

Extraction: gold occurs native; metals **below carbon** → **carbon reduction** (Zn, Fe, Cu oxides + C); metals **above carbon** (Al, Mg) → **electrolysis**. **Reduction = loss of oxygen; oxidation = gain of oxygen.**

(HT): **OIL RIG** – oxidation is loss (of electrons), reduction is gain. Ionic equation: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ (zinc oxidised, copper reduced).

potassium	cold water: hydroxide + hydrogen
sodium	cold water: hydroxide + hydrogen
lithium	cold water: hydroxide + hydrogen
calcium	cold water: hydroxide + hydrogen
magnesium	cold water: extremely slow
CARBON	reference for oxide reduction
zinc	dilute HCl / H_2SO_4: salt + hydrogen
iron	dilute HCl / H_2SO_4: salt + hydrogen
HYDROGEN	reference for acid / cathode products
copper	no reaction with cold water or dilute HCl

more reactive

Carbon and hydrogen are non-metals. Compare metals under matching conditions.

Worked example (3 marks, HT). Zinc is added to copper(II) sulfate solution. Write the ionic equation and identify what is oxidised.

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$; zinc loses two electrons – oxidised; copper ions gain them – reduced.

2 Practice

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]

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]

3 Exam-style questions

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]

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]

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

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]