Unit 6 · Oxidation and Reduction

ANSWER KEY · FOR TEACHERS

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

K · 4

1. oxidation → **b.** the loss of electrons
2. reduction → **a.** the gain of electrons
3. oxidizing agent → **g.** a substance that takes electrons from another and is itself reduced
4. reducing agent → **c.** a substance that gives electrons to another and is itself oxidized
5. oxidation number → **j.** the charge an atom would have if every bonding pair went to the more electronegative atom
6. disproportionation → **e.** one element both oxidized and reduced in the same reaction
7. electrolyte → **i.** a substance that conducts electricity, by its ions, when molten or dissolved
8. Faraday constant → **f.** the charge of one mole of electrons, 96,500 C

Each carries 0.5 mark.

2 Label the diagram

K · 2

1. copper plate, anode (+)
2. copper sulphate solution
3. iron spoon, cathode (−)
4. copper coat

Each carries 0.5 mark.

3 Multiple choice

i. **b.** +5 — K · 1

$3(+1) + x + 4(-2) = 0$, so $x = +5$, the highest phosphorus can reach (group 15).

ii. **d.** joined to the negative terminal, where reduction happens — K · 1

Electrons flow from the battery into the **cathode** (−), where cations take them: **reduction**. Oxidation happens at the anode (+).

iii. **b.** H_2 — U · 1

Hydrogen goes from 0 in H_2 to +1 in H_2O: it is oxidized, so H_2 is the **reducing agent**. Copper goes from +2 to 0: CuO is reduced, the oxidizing agent.

iv. **c.** oxygen — A · 1

At the anode, SO_4^{2-} is hard to oxidize, so water is oxidized instead: $2\,H_2O \rightarrow O_2 + 4\,H^+ + 4\,e^-$. Copper is deposited at the cathode.

v. **b.** 0.050 mol — A · 1

0.10 mol of Ag needs 0.10 mol of electrons ($Ag^+ + e^- \rightarrow Ag$). The same electrons go through the second cell, and each Cu^{2+} takes two: $0.10 \div 2 =$ **0.050 mol** of copper.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ Ions are fixed in the solid and free to move when molten.
- ✓ Electrons carry the current in the wires, ions in the electrolyte.

b. MARKING SCHEME — A · 2

- ✓ N in NH_4^+ is −3.
- ✓ N in NO_3^- is +5.

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c. MARKING SCHEME A · 3

- ✓ Cathode: $Pb^{2+} + 2e^- \rightarrow Pb$.
- ✓ Anode: $2Br^- \rightarrow Br_2 + 2e^-$.
- ✓ Oxidation at the anode.

5 Long answer

ANSWER U · 4

Oxygen and hydrogen: oxidation is the addition of oxygen to a substance (or the removal of hydrogen). Magnesium gains oxygen and becomes MgO.
Electrons: oxidation is the loss of electrons. Each Mg loses 2: $Mg \rightarrow Mg^{2+} + 2e^-$.
Oxidation number: oxidation is an increase in oxidation number. Mg goes from 0 to +2.
Electrons can't be created or destroyed: the electrons one substance loses must be taken by another, which is reduced. Here oxygen takes them, $O_2 + 4e^- \rightarrow 2O^{2-}$, and its oxidation number falls from 0 to −2.

MARKING SCHEME

- ✓ Oxidation as gain of oxygen (or loss of hydrogen), shown for Mg.
- ✓ Oxidation as loss of electrons, $Mg \rightarrow Mg^{2+} + 2e^-$.
- ✓ Oxidation as a rise in oxidation number, $0 \rightarrow +2$.
- ✓ The lost electrons are taken by oxygen, which is reduced ($0 \rightarrow -2$).

6 Numerical problems

a. ANSWER A · 4

i. Zn $0 \rightarrow +2$ (loses 2); the N that becomes NH_4^+ goes $+5 \rightarrow -3$ (gains 8). So 4 Zn for each N reduced: 4Zn and one NH_4NO_3. Then 4 $Zn(NO_3)_2$ need 8 more NO_3^-: $8 + 2 = 10$ HNO_3. Hydrogen: 10 on the left, 4 in NH_4^+, so 3 H_2O.

$$4\,Zn + 10\,HNO_3 \rightarrow 4\,Zn(NO_3)_2 + NH_4NO_3 + 3\,H_2O$$

ii. Reduction: $MnO_4^- + 8\,H^+ + 5\,e^- \rightarrow Mn^{2+} + 4\,H_2O$ (×2). Oxidation: $H_2O_2 \rightarrow O_2 + 2\,H^+ + 2\,e^-$ (×5). Adding (10 electrons each) and canceling 10 H^+:

$$2\,MnO_4^- + 5\,H_2O_2 + 6\,H^+ \rightarrow 2\,Mn^{2+} + 5\,O_2 + 8\,H_2O$$

MARKING SCHEME

- ✓ i: the changes, Zn up 2 and N down 8, and the ratio 4 : 1.
- ✓ i: the balanced equation.
- ✓ ii: the two half-equations, balanced.
- ✓ ii: the balanced equation (2, 5, 6 → 2, 5, 8).

b. ANSWER A · 4

i. $Q = It = 1.5 \times 40 \times 60 =$ **3600 C**.
ii. $3600 \div 96{,}500 =$ **0.0373 mol** of electrons.
iii. Each Ni^{2+} takes 2 electrons: $0.0373 \div 2 = 0.01865$ mol $\times$ 58.7 = **1.09 g**.
iv. 2.00 g ÷ 58.7 = 0.0341 mol of Ni, needing 0.0681 mol of electrons = $0.0681 \times 96{,}500 = 6575$ C. t = 6575 ÷ 1.5 = 4380 s, about **73 minutes**.

MARKING SCHEME

- ✓ Q = 3600 C.
- ✓ 0.0373 mol of electrons.
- ✓ 1.09 g of nickel.
- ✓ About 73 minutes (4380 s).

7 Think

ANSWER

Cl in Cl^- is −1, the **lowest** chlorine can go (group 17). It can only lose electrons, so Cl^- can only be a **reducing agent**.
Mn in MnO_4^- is +7, its **highest** (7 outer electrons). It can only gain electrons, so MnO_4^- can only be an **oxidizing agent**.

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S in SO_2 is +4, **between** −2 and +6, so SO_2 can go either way: it is an oxidizing agent towards a stronger reducer and a reducing agent towards a stronger oxidizer. Asmita is right only for such in-between oxidation numbers.

MARKING SCHEME

- ✓ Cl^- at its lowest, −1: only a reducing agent.
- ✓ MnO_4^- at Mn's highest, +7: only an oxidizing agent.
- ✓ SO_2 in between (+4): either, so she is right only for in-between states.

8 Activity: A nail in blue solution

(not marked)

WHAT STUDENTS SHOULD FIND

The nail is soon coated with a red-brown layer of **copper**, and over a day the blue fades, as the blue Cu^{2+} ions are used up and iron ions take their place. Iron is **oxidized** ($Fe \rightarrow Fe^{2+} + 2e^-$) and copper ions are **reduced** ($Cu^{2+} + 2e^- \rightarrow Cu$): $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	7	15	3	**33**

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