Unit 5 · Electrochemistry

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

i. ✓ **True**
ii. ✗ **False**: Oxidation takes place at the anode; reduction takes place at the cathode.
iii. ✓ **True**
iv. ✗ **False**: The lower its standard reduction potential, the stronger it is as a reducing agent.
v. ✓ **True**
vi. ✗ **False**: A positive cell potential means a negative ΔG ($\Delta G = -nFE$), a spontaneous reaction.
vii. ✓ **True**
viii. ✗ **False**: Galvanizing protects iron with a coat of zinc.

Each carries 0.5 mark.

2 Label the diagram

K · 2

1. H_2 gas at 1 atm
2. glass tube
3. platinum foil coated with platinum black
4. 1 mol/L H^+ (HCl), 25 °C

Each carries 0.5 mark.

3 Multiple choice

i. **b.** the calomel electrode — K · 1

The **calomel electrode** (mercury, mercury(I) chloride and KCl solution) keeps a steady known potential, +0.241 V with saturated KCl, and needs no hydrogen gas or platinum black.

ii. **d.** copper — U · 1

A metal gives hydrogen with a dilute acid only if its reduction potential is below that of hydrogen (0 V). Zinc (−0.76 V), iron (−0.45 V) and nickel (−0.26 V) are; copper (+0.34 V) is above it, so it can't reduce H^+.

iii. **c.** 0.60 V — A · 1

$E°cell = E°cathode - E°anode = 0.34 - (-0.26) =$ **0.60 V**. Adding the two values as they are gives 0.08 V.

iv. **b.** is oxidized in place of the iron — U · 1

Zinc (−0.76 V) is lower in the series than iron (−0.45 V), so it becomes the anode of the cell on the hull and corrodes instead of the iron: a **sacrificial anode**.

v. **c.** water — K · 1

The cell runs $2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$, giving about 1.23 V and only water.

4 Short answers

a. MARKING SCHEME — U · 2

✓ The potential difference between a metal and the solution of its ions, from the double layer.
✓ Only a difference between two electrodes can be measured, so it is measured against a reference electrode.

b. MARKING SCHEME — U · 2

✓ One use.
✓ A second use.

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c. MARKING SCHEME A · 3

- ✓ The cell notation, zinc the anode on the left.
- ✓ Both half-reactions.
- ✓ The balanced cell reaction (two Ag^+ for each Zn).

5 Long answer

ANSWER U · 4

Corrosion is the slow eating away of a metal by the substances around it (air, water, acids), turning it into its oxides or other compounds.

A drop of water on iron makes a tiny galvanic cell. Where the iron is the **anode**, it is oxidized: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$. The electrons travel through the metal to the edge of the drop, where oxygen dissolved in the water is reduced at the **cathode**: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH–(aq)$.

Fe^{2+} and OH^- meet and give iron(II) hydroxide, which air oxidizes further to rust, hydrated iron(III) oxide, $Fe_2O_3 \cdot xH_2O$. Salt in the water carries the ions better and speeds it up.

Protection, any two: paint, oil or grease to keep out air and water; galvanizing (a coat of zinc); a sacrificial anode of zinc or magnesium joined to the iron.

MARKING SCHEME

- ✓ Corrosion: a metal slowly eaten away into its compounds by its surroundings.
- ✓ Anode: $Fe \rightarrow Fe^{2+} + 2e^-$.
- ✓ Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$, and rust is $Fe_2O_3 \cdot xH_2O$.
- ✓ Two ways of protection.

6 Numerical problems

a. ANSWER A · 4

i. Nickel has the lower reduction potential, so it is the anode:
$Ni(s) + 2Ag+(aq) \rightarrow Ni^{2+}(aq) + 2Ag(s)$. $E°cell = 0.80 - (-0.26) = \mathbf{1.06\ V}$.

ii. $n = 2$: $\Delta G° = -nFE° = -2 \times 96{,}485 \times 1.06 = -204{,}548$ J/mol $\approx \mathbf{-205\ kJ/mol}$.

iii. $Q = \dfrac{[Ni^{2+}]}{[Ag^+]^2} = \dfrac{0.10}{(0.010)^2} = 1000$. $E = 1.06 - (0.0592/2) \log 1000 = 1.06 - 0.0296 \times 3 = \mathbf{0.97\ V}$.

iv. **Yes**: the cell potential is still positive, so $\Delta G = -nFE$ is negative.

MARKING SCHEME

- ✓ The cell reaction and $E° = 1.06$ V.
- ✓ $\Delta G° = -205$ kJ/mol.
- ✓ $E = 0.97$ V.
- ✓ Spontaneous, since E is positive (ΔG negative).

b. ANSWER A · 4

i. Zinc (−0.76 V) is lower than nickel (−0.26 V), so **zinc is the anode**:
$Zn(s) + Ni^{2+}(aq) \rightarrow Zn^{2+}(aq) + Ni(s)$, $E°cell = -0.26 - (-0.76) = \mathbf{0.50\ V}$.

ii. $\log K = nE°/0.0592 = 2 \times 0.50/0.0592 = 16.9$, so $\mathbf{K \approx 8 \times 10^{16}}$: the reaction goes almost to completion.

iii. $Q = [Zn^{2+}]/[Ni^{2+}] = 1.0/0.010 = 100$. $E = 0.50 - 0.0296 \times \log 100 = 0.50 - 0.059 = \mathbf{0.44\ V}$.

iv. The **nickel electrode**: Ni^{2+} ions are reduced and nickel metal is deposited on it, while the zinc electrode dissolves.

MARKING SCHEME

- ✓ Zinc is the anode; $E° = 0.50$ V.
- ✓ $K \approx 8 \times 10^{16}$.
- ✓ $E = 0.44$ V.
- ✓ The nickel electrode gains mass, as nickel is deposited on it.

7 Think

ANSWER

Iron ($E°$ −0.45 V) lies below copper (+0.34 V) in reduction potential, so it is the stronger reducing agent: iron gives its electrons to Cu^{2+} ions, $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$. The iron of the bucket dissolves, leaving a hole, and the brown-red powder is copper metal. Blue Cu^{2+} ions are used

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up and pale green Fe^{2+} take their place, so the blue fades. Copper sulphate should be kept in a vessel that doesn't react with it: glass, plastic, or copper itself.

MARKING SCHEME

- ✓ Iron has the lower reduction potential, so it reduces Cu^{2+} (equation).
- ✓ The iron dissolves (the hole); copper metal is deposited and the blue Cu^{2+} is used up.
- ✓ Keep it in glass, plastic or copper.

8 Activity: Which nail rusts first?

(not marked)

WHAT STUDENTS SHOULD FIND

The nail in salt water rusts first and most: the dissolved ions carry the current of the corrosion cell better. The nail in tap water rusts more slowly. The nail under oil in boiled water hardly rusts, since boiling drove out the dissolved oxygen and the oil keeps air out: with no oxygen there is no cathode reaction. The galvanized nail stays bright: its zinc coat keeps water and air off, and where it is thin the zinc (−0.76 V) is oxidized in place of the iron (−0.45 V).

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	10	12	3	**33**

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