# Unit 8 · Electrolysis

**ANSWER KEY · FOR TEACHERS**

Full marks 41

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

## 1 Key words

1. electrolyte → **e.** conducts when molten or in solution, and is decomposed by the current
2. anode → **a.** the electrode joined to the positive terminal in electrolysis
3. cation → **f.** a positive ion
4. degree of ionization → **b.** the fraction of dissolved molecules split into ions
5. electroplating → **d.** coating a metal object with a thin layer of another metal
6. anode mud → **g.** less reactive metals that fall to the bottom in electrorefining

K · 3

Each carries 0.5 mark.

## 2 Label the diagram

1. oxygen, 10 $cm^3$
2. platinum anode (+)
3. reservoir
4. hydrogen, 20 $cm^3$
5. water with a little dilute sulphuric acid
6. platinum cathode (−)

K · 3

Each carries 0.5 mark.

## 3 Multiple choice

**i.** **c.** glucose — K · 1

Glucose dissolves as whole, uncharged molecules, so its solution has no ions and doesn't conduct. Potassium nitrate and sulphuric acid are strong electrolytes, ammonia solution a weak one.

**ii.** **b.** $NH_4Cl$ and NaOH — U · 1

Ammonium chloride is a salt and sodium hydroxide a strong base: both ionize almost completely. Ethanoic acid, carbonic acid and ammonia solution are weak electrolytes.

**iii.** **a.** joined to the positive terminal, where anions are discharged — K · 1

The anode is positive, so it attracts the negative ions, the anions, which give up electrons there (oxidation).

**iv.** **b.** hydrogen and chlorine — A · 1

$Na^+$ is too reactive to be discharged from water, so hydrogen comes off at the cathode. $Cl^-$ is concentrated, so it is discharged at the anode as chlorine. Sodium hydroxide is left in the solution.

**v.** **c.** in the anode mud at the bottom — U · 1

Gold and silver are less reactive than copper, so they don't dissolve from the anode. As the copper around them dissolves, they fall to the bottom as anode mud. (Iron, zinc and nickel dissolve but stay in the solution.)

## 4 Very short answers

**a.** MARKING SCHEME — K · 1

✓ Free electrons.

**b.** MARKING SCHEME — K · 1

✓ $NH_4Cl \rightarrow NH_4^+ + Cl^-$.

**c.** MARKING SCHEME — U · 1

✓ Reduction.

**d.** MARKING SCHEME — U · 1

✓ To thicken its oxide skin.



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## 5 Short answers

**a.** MARKING SCHEME — U · 2

- ✓ In the solid the ions are held in fixed places and can only vibrate.
- ✓ In solution the ions are free to move, so they can carry a current.

**b.** MARKING SCHEME — U · 2

- ✓ Strong or weak depends on how much splits into ions, not on how much dissolves.
- ✓ Only a small fraction of ethanoic acid ionizes (about 1.3% at 0.1 mol/L), so it conducts poorly.

**c.** MARKING SCHEME — A · 2

- ✓ With carbon electrodes $Cu^{2+}$ ions, which make the blue color, are deposited and not replaced.
- ✓ With copper electrodes the anode dissolves and replaces them as fast as they are deposited.

**d.** MARKING SCHEME — A · 2

- ✓ No, it is still a strong electrolyte: it is all split into ions.
- ✓ It has few ions because there is little of it: dilute is not the same as weak.

## 6 Long answers

**a.** ANSWER — K · 4

Any four:

1. On dissolving in water or melting, an electrolyte splits into cations and anions, without any current.
2. The total positive charge equals the total negative charge, so the solution is electrically neutral.
3. The ions move freely and at random through the solution.
4. Ionization is reversible: $AB \rightleftharpoons A^+ + B^-$.
5. The degree of ionization depends on the nature of the electrolyte, its concentration and the temperature.
6. When a current is passed, cations move to the cathode and anions to the anode.
7. At the electrodes the ions are discharged, forming the products of electrolysis.
8. The properties of the solution are the properties of its ions.

MARKING SCHEME

- ✓ A first postulate.
- ✓ A second postulate.
- ✓ A third postulate.
- ✓ A fourth postulate.

**b.** ANSWER — U · 4

In electrorefining, a thick slab of impure copper is the anode, a thin sheet of pure copper the cathode, and copper sulphate solution with some sulphuric acid the electrolyte. With the current, copper from the anode dissolves, $Cu \rightarrow Cu^{2+} + 2e^-$, and pure copper is deposited on the cathode, $Cu^{2+} + 2e^- \rightarrow Cu$. More reactive impurities (iron, zinc, nickel) dissolve but stay in the solution; less reactive ones (gold, silver) don't dissolve and fall below the anode as anode mud. The cathode copper is 99.99% pure.

MARKING SCHEME

- ✓ A thick slab of impure copper is the anode; a thin sheet of pure copper is the cathode; copper sulphate solution is the electrolyte.
- ✓ $Cu \rightarrow Cu^{2+} + 2e^-$ at the anode and $Cu^{2+} + 2e^- \rightarrow Cu$ at the cathode.
- ✓ More reactive impurities (iron, zinc, nickel) dissolve and stay in the solution.
- ✓ Less reactive ones (gold, silver) fall below the anode as anode mud.


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## 7 Numerical problems

**a.** ANSWER A · 2

$$10{,}000 \times \frac{1.3}{100} = 130$$

**130 molecules** are ionized, giving **260 ions** (130 $CH_3COO^-$ and 130 $H^+$). The other 9,870 stay whole.

MARKING SCHEME

✓ $10{,}000 \times 1.3 \div 100 = 130$ molecules.

✓ 260 ions.

**b.** ANSWER A · 2

One part is $45 \div 3 = 15$ cm$^3$. Hydrogen is 2 parts, **30 cm$^3$**; oxygen 1 part, **15 cm$^3$**.

MARKING SCHEME

✓ $45 \div 3 = 15$ cm$^3$ for one part.

✓ Hydrogen 30 cm$^3$, oxygen 15 cm$^3$.

**c.** ANSWER A · 3

i. $t = 25 \times 60 = 1{,}500$ s, so $Q = It = 0.2 \times 1{,}500 = \mathbf{300\ C}$.

ii.
$$n = \frac{300}{1.6 \times 10^{-19}} = 1.875 \times 10^{21} \text{ electrons}$$

iii. $Cu^{2+} + 2e^- \rightarrow Cu$, so the number of copper atoms is half the number of electrons: $1.875 \times 10^{21} \div 2 \approx \mathbf{9.4 \times 10^{20}}$ **atoms** (about 0.1 g of copper).

MARKING SCHEME

✓ $Q = It = 0.2 \times 1{,}500 = 300$ C.

✓ $300 \div (1.6 \times 10^{-19}) = 1.875 \times 10^{21}$ electrons.

✓ Half that number of copper atoms, about $9.4 \times 10^{20}$.

## 8 Think

ANSWER HA · 3

In salt water the anode gives off chlorine, not oxygen, so you wouldn't be splitting water any more, and chlorine is poisonous. Sulphate ions are not discharged, so with sulphuric acid only water is used up. Sodium sulphate or sodium hydroxide would also work, for the same reason.

MARKING SCHEME

✓ Salt gives chlorine at the anode, so water isn't what is split (and chlorine is poisonous).

✓ With sulphuric acid, sulphate ions aren't discharged, so only water is used up.

✓ Sodium sulphate or sodium hydroxide.

## 9 Activity: Which liquids conduct?

(not marked)

WHAT STUDENTS SHOULD FIND

Salt water lights the LED brightly; lemon juice and vinegar light it, though less brightly. Tap water may give a faint glow, from the few salts in it. Sugar water and oil leave it dark. In salt water, tiny bubbles form on both tips, more on the one joined to −. That is electrolysis.

| Marks by level | Knowledge | Understanding | Application | Higher ability | Total |
|---|---|---|---|---|---|
| **Marks** | 14 | 12 | 12 | 3 | **41** |



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