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

1 Spot the error

ANSWER U · 3

At the cathode a cation **gains** electrons, so they go on the left. At the anode an anion **gives up** electrons, so they go on the right; and two Cl^- make one Cl_2, so his anode equation doesn't balance either.

Cathode: $\mathbf{Mg^{2+} + 2e^- \rightarrow Mg}$ (reduction). Anode: $\mathbf{2Cl^- \rightarrow Cl_2 + 2e^-}$ (oxidation).

MARKING SCHEME

- ✓ The cathode equation is wrong: electrons are gained, so they go on the left: $Mg^{2+} + 2e^- \rightarrow Mg$.
- ✓ The anode equation is wrong: electrons are given up and the atoms don't balance: $2Cl^- \rightarrow Cl_2 + 2e^-$.
- ✓ Reduction at the cathode, oxidation at the anode.

2 Predict every cell

ANSWER A · 5

a. **potassium** at the cathode; **chlorine** at the anode (only K^+ and Cl^- are present).
b. **hydrogen**; **chlorine** (K^+ is too reactive to be discharged from water; Cl^- is concentrated).
c. **hydrogen**; **oxygen** (with so little Cl^-, OH^- is discharged).
d. **hydrogen**; **oxygen**, 2 : 1 (SO_4^{2-} isn't discharged, so the water is split).
e. **silver is deposited**; **the silver anode dissolves** ($Ag \rightarrow Ag^+ + e^-$), with no gas, and the solution stays the same.

MARKING SCHEME

- ✓ a. potassium; chlorine.
- ✓ b. hydrogen; chlorine.
- ✓ c. hydrogen; oxygen.
- ✓ d. hydrogen; oxygen.
- ✓ e. silver deposited; the anode dissolves.

3 Check the claim

ANSWER HA · 4

i. $0.1 \times 0.013 =$ **0.0013**; $0.01 \times 0.042 =$ **0.00042**; $0.001 \times 0.125 =$ **0.000125** mol.
ii. Right: a bigger **fraction** of the acid is ionized as it is diluted. Wrong: the number of ions **in each liter** falls, by about 3 times each time, because there is so much less acid. So the bulb is dimmer, not brighter, at 0.001 mol/L.
iii. For each molecule dissolved: more of the molecules there are ionized, so each molecule of acid does more to carry the current. The solution as a whole still has fewer ions.

MARKING SCHEME

- ✓ The three values 0.0013, 0.00042 and 0.000125 mol.
- ✓ Right: the fraction ionized rises.
- ✓ Wrong: the ions in each liter fall, so the bulb is dimmer.
- ✓ "Better" only for each molecule dissolved, since a larger fraction is ionized.

4 Two cells, one current

ANSWER

i. 0.1 g needs 300 C, so 0.50 g needs 1,500 C. $t = Q \div I = 1{,}500 \div 0.25 = 6{,}000$ s = **100 minutes**.
ii. The anode **loses about 0.50 g**; the solution **stays the same blue**, since Cu^{2+} ions go in as fast as they come out.

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iii. 300 C is $300 \div (1.6 \times 10^{-19}) = 1.875 \times 10^{21}$ electrons. Each Ag^+ takes one electron and each Cu^{2+} two, so there are **1.875×10^{21} silver atoms** and **about 9.4×10^{20} copper atoms**: twice as many silver atoms. A · 5

MARKING SCHEME

- ✓ 1,500 C for 0.50 g.
- ✓ 100 minutes.
- ✓ The anode loses about 0.50 g and the color stays the same.
- ✓ 1.875×10^{21} electrons, so that many silver atoms.
- ✓ Half as many copper atoms, about 9.4×10^{20}, as Cu^{2+} takes two electrons.

5 Hydrogen from Dhulikhel

ANSWER A · 4

i. 2×40 to 2×45 = **80 to 90 units** a day.

ii. 2 kg = 2,000 g = 1,000 mol. $1{,}000 \times 22.4$ L = 22,400 L = **22.4 m³**.

iii. $V_2 = \dfrac{101.3 \times 22.4 \times 293}{273 \times 86}$ = **about 28 m³**.

iv. Half the volume of the hydrogen: **about 14 m³**.

MARKING SCHEME

- ✓ 80 to 90 units a day.
- ✓ 22.4 m^3 at STP.
- ✓ About 28 m^3 at 86 kPa and 20 °C.
- ✓ About 14 m^3 of oxygen.

6 Which explanation fits the evidence?

ANSWER HA · 3

Arrhenius's. Three different copper salts share a color, and all acids a taste, with no current flowing. What they share is an ion: Cu^{2+}, H^+. So those ions must already be in the solution.
A dry crystal doesn't conduct because its ions are locked in place and can only vibrate, not because it has no ions: melted or dissolved, it conducts.

MARKING SCHEME

- ✓ Arrhenius's idea.
- ✓ The color and the taste come from a shared ion (Cu^{2+}, H^+), present with no current.
- ✓ A crystal's ions can't move; it doesn't conduct for that reason.

7 Fix the plan

ANSWER A · 4

- The spoon must be the **cathode**, joined to −, since the metal ions are deposited there.
- The anode must be a plate of **silver**, which dissolves to keep up the supply of ions.
- The electrolyte must be a solution of a **silver salt**, not copper sulphate.
- A **small, steady direct current** is needed: a large current gives a rough, loose coat that flakes off.

MARKING SCHEME

- ✓ The spoon is the cathode (−).
- ✓ The anode is a silver plate.
- ✓ The electrolyte is a silver salt solution.
- ✓ A small, steady current, because a large one gives a loose, rough coat.

8 Where does it all go?

ANSWER

i. **Cathode: 198 kg**; **solution: 1.2 kg** (iron and nickel); **anode mud: 0.8 kg** (silver and gold).

ii. **No.** The anode loses 200 kg and the cathode gains only 198 kg.

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iii. **It slowly falls.** Iron and nickel dissolve at the anode, using up some of the current, but they aren't discharged at the cathode. So a little more Cu^{2+} is deposited than goes in, and iron and nickel ions build up in its place. **A · 4**

MARKING SCHEME

- ✓ 198 kg, 1.2 kg and 0.8 kg.
- ✓ No: 200 kg lost, 198 kg gained.
- ✓ Cu^{2+} slowly falls.
- ✓ Iron and nickel use up current at the anode but aren't deposited, so less copper goes in than comes out.

9 Reading the tubes

ANSWER **A · 3**

i. Hydrogen: 16, 16, 16, 16 cm^3. Oxygen: 7, 8, 8, 8 cm^3.
ii. **No.** After the first stretch the gases form at exactly 16 : 8 = 2 : 1.
iii. Oxygen dissolves in water about twice as well as hydrogen, so at the start some oxygen dissolves instead of collecting. Once the water holds all it can, every bubble collects.

MARKING SCHEME

- ✓ The amounts in each stretch.
- ✓ No: it is 2 : 1 after the first stretch.
- ✓ Some oxygen dissolves in the water at first.

10 Design a fair test

ANSWER **A · 4**

i. She changes the temperature of the solution (for example 20, 40, 60 °C), and measures the current with the ammeter.
ii. Any three: the amount of salt in the water; the depth of the rods and the distance between them; the same rods and battery.
iii. The current rises with temperature: resistance falls when an electrolyte is heated, because the ions move faster.
iv. The current decomposes the solution and gases form on the rods, so the solution would slowly change and the results wouldn't be fair.

MARKING SCHEME

- ✓ Changes the temperature; measures the current.
- ✓ Any three things kept the same.
- ✓ The current rises, because the ions move faster.
- ✓ A long run changes the solution, by electrolysis.

11 Predict, then explain

ANSWER **HA · 3**

At first: the copper coat on A dissolves as Cu^{2+} ions ($Cu \rightarrow Cu^{2+} + 2e^-$), and no gas comes off, since a copper anode gives up electrons more easily than any anion can be discharged. Copper is deposited on B, now the cathode.
Once A's coat is gone: A is bare carbon, an inert anode, so OH^- is discharged and oxygen bubbles off. Copper goes on forming on B, and the blue fades.

MARKING SCHEME

- ✓ At first A's copper dissolves, with no gas.
- ✓ Copper is deposited on B.
- ✓ When the coat has gone, oxygen bubbles off A, since carbon is inert.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	3	29	10	**42**

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