B14 · Investigation: plan and predict

Completed notes | Notes 1/2

Write a testable question, draw a labelled cell design, predict the anode and voltage from the table, plan safe handling and plan a battery.

1. Question, variables and design

A testable question

We have used the table to predict voltages. Now we test the predictions. A testable question links one thing we change to one thing we measure.

The variable you change is the **independent** variable. The variable you measure is the **dependent** variable. Here we change the metal and measure the voltage.

A fair test keeps everything else the same. These are the controlled variables: the **concentration**, temperature, electrode size and salt bridge.

The table values assume **1.0 mol/L** solutions at standard conditions. If a control changed, we could not tell what caused a change in voltage.

On the diploma: the independent variable is what you change, and the dependent variable is what you measure.

A labelled design

A half-cell is a metal strip, called an electrode, in a solution of its **ions**. The second half-cell is always copper in copper(II) sulfate.

A **salt bridge** lets ions move between the half-cells. This keeps the charge balanced and completes the circuit. A voltmeter joins the strips through wires.

Label the **anode**, the cathode, the direction of electron flow and the concentrations. Electrons flow in the wire from the anode to the cathode.

On the diploma: a labelled diagram needs the salt bridge, the solutions with concentrations, the wires and the meter.

Zn/Cu cell, 0.500 A for 30.0 min. q = 900 C

$n(e^-) = 900 \div (9.65 \times 10^4) = 0.00933$ mol

$Zn \rightarrow Zn^{2+} + 2e^-$, so zinc lost = 0.305 g

$Cu^{2+} + 2e^- \rightarrow Cu$, so copper gained = 0.296 g

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Completed notes | Notes 2/2

2. Predict, stay safe and plan a battery

Predict before measuring

The metal with the **lower** reduction value is the anode, because that metal is oxidized. The higher value is the cathode.

Zn/Cu: zinc (−0.76 V) is lower, so zinc is the anode. E°cell = cathode − anode = 0.34 − (−0.76) = **+1.10 V**. Dropping the minus sign gives a classic wrong answer.

Ag/Cu: silver (+0.80 V) has the higher value, so copper is the **anode**. E°cell = 0.80 − 0.34 = **+0.46 V**. Copper is not always the cathode.

When you double a half-reaction to balance electrons, you do not **double** its table value. The voltage does not depend on the number of copies.

A prediction is not an **observation**. Only a measurement shows what the cell does. Ask where a number came from: the table or a meter.

Safety and disposal

Read the **label** and the safety data sheet first. They are part of **WHMIS**, the system for labelling hazardous materials in workplaces.

Wear goggles, gloves and an apron. Silver nitrate stains skin. Copper(II) compounds harm life in water.

Collect solutions that contain metal **ions**. Do not pour them down the drain, because they can harm water life.

On the diploma: name the hazard from the label, then a matching precaution, and give a reason for each step.

Plan a battery

Cells in a row **add** their voltages. A device needs at least 3.0 V, and one Zn/Cu cell gives 1.10 V.

So 3.0 ÷ 1.10 = 2.7. We cannot use part of a cell, so round up and use **3** cells. They give 3 × 1.10 = 3.30 V. Two cells give only 2.20 V.

The voltage **falls** as the cell works, because the reactants get used up. So the plan must include a test over time.

A bigger table voltage does not always make a better battery. Magnesium gives 2.71 V with copper but reacts with water. On the diploma: name a practical fact such as safety, cost or lifetime.

B14 · Worked practice

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State symbols: (s) solid, (aq) dissolved in water, (l) liquid, (g) gas. Use the supplied reaction and conditions. B4 values name the Alberta Chemistry 30 Data Booklet table where used.

B14-P01 · Easy · Given the question "How does the metal in one half-cell change the cell voltage?" Name the independent variable and the dependent variable.

1. The independent variable is what you change, which is the metal.

2. The dependent variable is what you measure, which is the voltage.

B14-P02 · Easy · Name two variables that must be controlled when you compare metals joined to copper, and explain why.

1. Control the concentration (1.0 mol/L) and the temperature. Electrode size and the salt bridge also qualify.

2. If one of these changed, you could not tell whether the metal or the changed condition caused the change in voltage.

B14 · Worked practice

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B14-P03 · Easy · List the parts that a labelled diagram of a zinc and copper cell must show.

1. Two half-cells with the strips and solutions, the concentrations, the salt bridge, the wires and the voltmeter.

2. Label the anode, the cathode and the direction of electron flow in the wire.

B14-P04 · Easy · Explain what the salt bridge does in your design.

1. The salt bridge lets ions move between the two half-cells.

2. This keeps the charge balanced in each solution and completes the circuit, so the cell can keep running.

B14 · Worked practice

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B14-P05 · Medium · Given Fe^{2+}/Fe −0.45 V and Cu^{2+}/Cu +0.34 V. Predict the anode, the cell reaction and the voltage.

1. Iron has the lower value, so iron is the anode.

2. $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$. $E°cell = 0.34 - (-0.45) = +0.79$ V.

B14-P06 · Medium · Given Ag^{+}/Ag +0.80 V and Cu^{2+}/Cu +0.34 V. Which metal is the anode and what is the voltage?

1. Silver has the higher value, so silver is the cathode and copper is the anode.

2. $E°cell = 0.80 - 0.34 = +0.46$ V.

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B14-P07 · Medium · Given Ni^{2+}/Ni −0.26 V and Ag^{+}/Ag +0.80 V. Write the cell reaction and find the voltage. Explain why the silver table value is not doubled.

1. Nickel is the anode. Two silver ions take the two electrons: $Ni + 2Ag^{+} \rightarrow Ni^{2+} + 2Ag$.

2. $E°cell = 0.80 - (-0.26) = +1.06$ V. A table value does not depend on how many copies of the half-reaction are used.

B14-P08 · Medium · A student predicts +0.79 V and says this proves the measured voltage will be 0.79 V. Explain what is wrong.

1. A prediction is not an observation.

2. The table assumes standard conditions, so a real measurement can differ a little. Only a measurement shows what happens.

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B14-P09 · Challenging · Name two hazards or precautions for a plan that uses silver nitrate solution, and one disposal step.

1. Silver nitrate stains skin, so wear gloves, goggles and an apron. Read the label and the safety data sheet.

2. Collect the waste in a container. Do not pour it down the drain, because metal ions can harm water life.

B14-P10 · Challenging · A device needs at least 3.0 V. Using 1.10 V cells in a row, find how many cells are needed and the voltage of the battery.

1. The voltages add. 3.0 ÷ 1.10 = 2.7, and part of a cell cannot be used, so use 3 cells.

2. The battery voltage is 3 × 1.10 = 3.30 V. Two cells give only 2.20 V.

B14 · Worked practice

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B14-P11 · Challenging · Explain why a metal with a large cell voltage can still be a poor choice for a battery. Use magnesium as an example.

1. Magnesium with copper predicts +2.71 V.

2. Magnesium reacts with water, so it would be used up, and cost, mass and lifetime matter as well as voltage.

B14-P12 · Challenging · Given a plan and a prediction only. State what they can show and what they cannot show, and why a real measurement may differ.

1. A plan and a prediction show what you expect. They are not data.

2. Real strips, salt bridges and meters have small errors, and the table applies only at standard conditions.