B14 · Investigation: plan and predict

Student notes - follow the slides, fill the blanks, work the questions

Goals: Write a testable question with the independent, dependent and controlled variables. Draw a labelled cell design and predict the anode, the equation and the voltage from the table. Plan safe handling and disposal and plan a battery with cells in a row.

Name: _____ Date: _____

Slide 1 of 8 · A testable question and its variables

A testable question links one thing we _____ to one thing we _____. Here we change the metal in one half-cell and measure the cell voltage.

The independent variable is the one we _____: the metal. The dependent variable is the one we measure: the _____.

Controlled variables stay the _____ for a fair test. The table values are for 1.0 mol/L solutions, so we control the _____.

We also control the temperature, the electrode _____ and the salt bridge. If two things changed, we could not tell which one caused the voltage change.

Example. We want to test the reduction table with real cells. Each metal is joined to a copper half-cell in copper(II) sulfate. Write a testable question. Name the independent variable, the dependent variable and two controlled variables.

Work:

Answer: _____

Try it. A student asks whether the concentration of the copper(II) sulfate solution changes the voltage of a zinc and copper cell. Name the independent variable, the dependent variable and two controlled variables.

Work:

Answer: _____

Slide 2 of 8 · A design with a labelled diagram

Half-cell 1 is a strip of metal X in a 1.0 mol/L solution of its _____. Half-cell 2 is a copper strip in 1.0 mol/L _____.

A salt bridge joins the solutions. It lets _____ move so that charge stays balanced and the circuit is complete. Wires join the strips through a _____.

Predict first, then label. The half-cell with the _____ reduction value is the anode, because that metal is oxidized. The _____ value is the cathode.

Electrons flow in the wire from the _____ to the _____. A good diagram also labels the solutions with their concentrations.

Example. We will join each metal half-cell to a copper half-cell. Draw the design for metal X in $X^{2+}(aq)$ joined to copper in $Cu^{2+}(aq)$. Label the parts. Assume X has the lower reduction value, and show the direction of electron flow.

Work:

Answer: _____

Try it. Draw a design to test a silver half-cell against a copper half-cell, both 1.0 mol/L. Given $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Ag^{+}/Ag) = +0.80$ V, label the anode, the cathode and the electron flow.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 8 · Predict before measuring

To predict, compare the two table values. The metal with the _____ value is the anode and is oxidized. The metal with the higher value is the _____.

For zinc and copper, $E°(Zn^{2+}/Zn) = -0.76$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. The cell reaction is $Zn + Cu^{2+} \rightarrow$ _____. Charge is +2 on each side.

The voltage is $E°cell = E°cathode - E°anode = 0.34 - (-0.76) =$ _____. A flipped sign would give a _____ cell voltage, which is wrong.

Copper is not always the cathode. Silver (+0.80 V) is higher than copper, so silver is the _____ and copper is the _____. Compare the two values _____.

Example. Predict the anode and E°cell when each metal is joined to a 1.0 mol/L copper half-cell. Given $E°(Zn^{2+}/Zn) = -0.76$ V, $E°(Fe^{2+}/Fe) = -0.45$ V, $E°(Ni^{2+}/Ni) = -0.26$ V, $E°(Ag^{+}/Ag) = +0.80$ V and $E°(Cu^{2+}/Cu) = +0.34$ V, do zinc, iron, nickel and silver.

Work:

Answer: _____

Try it. Given $E°(Fe^{2+}/Fe) = -0.45$ V and $E°(Ag^{+}/Ag) = +0.80$ V. An iron half-cell is joined to a silver half-cell, both 1.0 mol/L. Predict the anode, the cathode and E°cell.

Work:

Answer: _____

Slide 4 of 8 · Safe handling, labels and disposal

Read the label and the _____ first. They tell the hazards and the first aid. They come from _____, the Workplace Hazardous Materials Information System.

Plan protection: _____, gloves and an apron. Silver nitrate stains _____. Copper(II) compounds harm life in water.

Store solutions in _____ containers, so nobody mixes them up or spills them.

Collect solutions with metal ions in a _____. Do not pour them down the _____, because metal ions can harm water life. Follow the school disposal plan.

Example. A plan uses copper(II) sulfate and silver nitrate solutions. Name one hazard of each with a matching precaution. Then say how to handle the waste.

Work:

Answer: _____

Try it. A plan uses nickel(II) sulfate solution and nickel strips. Name one hazard and a matching precaution, one storage step and one disposal step. Which item can be reused?

Work:

Answer: _____

Slide 5 of 8 · Method: how to plan and predict an investigation

Step 1. Write a _____ question. It links one thing you change to one thing you measure.

Step 2. Name the variables. _____: what you change. _____: what you measure. Controlled: what stays the same.

Step 3. Draw a labelled _____. Show the solutions with concentrations, the salt bridge, the wires and the meter.

Step 4. _____ with the table. Find the anode, the cell reaction and E°cell before you measure.

Step 5. List _____ and disposal. Name a hazard, a precaution and how the waste is collected.

Example. Use the method on testing the reduction table by joining each metal to a copper half-cell. Plan the investigation and predict the result for zinc.

Work:

Answer: _____

Try it. Use the method on joining a nickel half-cell to a silver half-cell, both 1.0 mol/L. $E°(Ni^{2+}/Ni) = -0.26$ V and $E°(Ag^{+}/Ag) = +0.80$ V. Predict the anode and the voltage, and name one hazard.

Work:

Answer: _____

Slide 6 of 8 · Your turn: nickel and silver

Compare the two table values. The _____ value belongs to the metal that is oxidized, so that metal is the _____. Nickel (−0.26 V) is lower than silver (+0.80 V).

Balance the electrons first. Ni → Ni^{2+} + $2e^{-}$ gives 2 electrons, and each Ag^{+} takes _____, so double the silver half: $2Ag^{+}$ + $2e^{-}$ → _____.

Add the halves: Ni + $2Ag^{+}$ → Ni^{2+} + 2Ag. Check that the charge is _____ on each side. Do not _____ E° by the coefficient.

E°cell = 0.80 − (−0.26) = _____. Give the voltage with its sign and its _____. Silver nitrate stains skin, so wear _____.

Example. Given a plan to join a nickel half-cell, E°(Ni^{2+}/Ni) = −0.26 V, to a silver half-cell, E°(Ag^{+}/Ag) = +0.80 V, both 1.0 mol/L. Predict the anode, the cell reaction and the voltage. Name one hazard.

Work:

Answer: _____

Try it. Given a plan to join a zinc half-cell, E°(Zn^{2+}/Zn) = −0.76 V, to a silver half-cell, E°(Ag^{+}/Ag) = +0.80 V, both 1.0 mol/L. Predict the anode, the cell reaction and the voltage. Name one disposal step.

Work:

Answer: _____

Slide 7 of 8 · Plan a battery

Cells in a row _____ their voltages. One zinc and copper cell gives _____, and the device needs at least 3.0 V.

Divide: 3.0 ÷ 1.10 = 2.73. You cannot use part of a cell, so _____ to three cells. Two cells give only 2.20 V, which is not enough.

Three cells give 3 × 1.10 = _____, which is more than 3.0 V. The table gives the voltage at the start only. As reactants are used up, the voltage _____.

So the plan needs a _____: record the voltage over time while the device runs. A salt bridge adds _____, and magnesium gives more voltage but reacts with water.

Example. A small device needs at least 3.0 V. One zinc and copper cell gives E°cell = +1.10 V. How many cells in a row are needed? What must the plan check?

Work:

Answer: _____

Try it. A device needs at least 4.0 V. One nickel and copper cell gives E°cell = +0.60 V. How many cells in a row are needed? Why might the real battery give less voltage than the table predicts?

Work:

Answer: _____

Slide 8 of 8 · What a plan cannot show

A prediction uses the _____ and tells what we expect. An observation comes from a _____ and tells what really happens.

A plan only describes how we will get the measurement. A plan is _____ a prediction nor an observation, and it is not _____.

A prediction becomes a test of an idea only when we _____ it with an observation. A common wrong choice treats a predicted value as an _____.

Table values apply only at standard conditions: 1.0 mol/L solutions, _____ and 101.325 kPa for gases. Real cells differ a little, so measurements differ a _____ from predictions.

Example. A report lists 1.10 V for a zinc and copper cell under the heading Measured voltage. The value came from the reduction table. Is it an observation or a prediction? How can you tell? Why might a real measurement differ?

Work:

Answer: _____

Try it. A given sample data set lists an iron and copper cell with a table value of 0.79 V and a voltmeter reading of 0.76 V. These readings were not measured by us. Which number is the prediction and which is the observation? Is the plan itself either one?

Work:

Answer: _____

B14 · Practice

Investigation: plan and predict | Questions 1-2 of 7

1. Given the question "How does the metal in one half-cell change the cell voltage?" Name the independent variable, the dependent variable and two controlled variables.

Work:

Final answer (with unit): _____

2. Given a plan to join a zinc half-cell to a copper half-cell with a salt bridge and a voltmeter. List the parts that a labelled diagram must show.

Work:

Final answer (with unit): _____

B14 · Practice

Investigation: plan and predict | Questions 3-4 of 7

3. Given the table values $E°(Fe^{2+}/Fe) = -0.45$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. Predict the anode, the cell reaction and the voltage.

Work:

Final answer (with unit): _____

4. Given a plan that uses silver nitrate solution. Name two hazards or precautions and one disposal step.

Work:

Final answer (with unit): _____

B14 · Practice

Investigation: plan and predict | Questions 5-6 of 7

5. Given a nickel half-cell and a copper half-cell, both 1.0 mol/L. Predict the anode and the voltage (Data Booklet table values: $E°(Ni^{2+}/Ni) = -0.26$ V; $E°(Cu^{2+}/Cu) = +0.34$ V).

Work:

Final answer (with unit): _____

6. Given a device that needs at least 4.0 V and a cell of 1.10 V. Find the number of cells in a row, and give one thing that the plan should test.

Work:

Final answer (with unit): _____

B14 · Practice

Investigation: plan and predict | Questions 7-7 of 7

7. Challenge: Given a device that needs at least 6.0 V. Two cell designs are possible. Data Booklet table values: $E°(Zn^{2+}/Zn) = -0.76$ V, $E°(Mg^{2+}/Mg) = -2.37$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. Design 1 joins zinc and copper half-cells. Design 2 joins magnesium and copper half-cells. Predict the voltage of one cell of each design. Then find the number of cells in a row that each design needs.

Work:

Final answer (with unit): _____