B4 · Predict reactions and investigate

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

Goals: Rank reducing agents and oxidizing agents from test results. Predict which way a reaction goes under standard conditions, using the Data Booklet table. Plan a virtual investigation and say what its results can and cannot show.

Name: _____ Date: _____

Slide 1 of 11 · Balanced does not mean spontaneous

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ and its reverse both balance for atoms and _____. Balancing cannot tell which direction happens.

A direction is _____ if it happens by itself, with no outside push of energy.

Spontaneous does not mean _____. A spontaneous reaction can still be slow.

To choose a direction we need evidence about which substance gives electrons more _____.

Example. Show that $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ and its reverse both balance. Can the balanced equation alone tell you which direction is spontaneous under standard conditions?

Work:

Answer: _____

Try it. A reaction is spontaneous under standard conditions, but a student sees no change after one minute. Is that a contradiction? Explain.

Work:

Answer: _____

Slide 2 of 11 · From observations to reducing-agent strength

Example test results: Zn in Cu^{2+} gives a copper deposit. Cu in Ag^{+} gives a silver deposit. Cu in Zn^{2+} shows _____.

A copper deposit means Cu^{2+} gained electrons. The electrons came from _____, so zinc is the stronger reducing agent.

Zn beats Cu and Cu beats Ag, so the order of reducing agents is _____. Read > as "is a stronger reducing agent than".

To keep the test fair, control the solution, temperature, strip area and _____.

Example. Given these example test results: Zn in Cu^{2+} gives a copper deposit; Cu in Ag^{+} gives a silver deposit; Cu in Zn^{2+} gives no change. Rank Zn, Cu and Ag as reducing agents.

Work:

Answer: _____

Try it. Given these example test results: Fe in Cu^{2+} gives a copper deposit; Zn in Fe^{2+} gives an iron deposit. Rank Zn, Fe and Cu as reducing agents.

Work:

Answer: _____

Slide 3 of 11 · Keep reducing agents and oxidizing agents in separate columns

The metals are reducing agents: Zn > Cu > Ag. Their ions are oxidizing agents, and they rank the _____ way: $Ag^{+} > Cu^{2+} > Zn^{2+}$.

Write the exact formula with its _____, such as Ag^{+}, not just silver.

Written as reductions, the strongest oxidizing agent goes at the _____. The strongest reducing agent is then at the bottom right.

List what is in the beaker: every ion, any metal, and _____. An acidic or “acidified” solution also has _____. A basic solution has OH^{-}.

Example. For the same pairs, the reducing agents rank Zn > Cu > Ag. Rank Ag^{+}, Cu^{2+} and Zn^{2+} as oxidizing agents and explain why the two lists run oppositely.

Work:

Answer: _____

Try it. Given: Fe gives electrons to Cu^{2+}, and Zn gives electrons to Fe^{2+}. Rank Zn^{2+}, Fe^{2+} and Cu^{2+} as oxidizing agents.

Work:

Answer: _____

Slide 4 of 11 · Read the Alberta reduction table

Every table row is a _____: something gains electrons. The number is E°, in _____.

The oxidizing agents are on the _____. The strongest is at the top. The reducing agents are on the _____. The strongest is at the bottom.

A higher E° means a stronger _____. So Ag^+ is stronger than Cu^{2+}. E° predicts direction, not _____.

Standard conditions are 1.0 mol/L solutions, _____ and 101.325 kPa for gases. The table is on Data Booklet page _____.

Example. Given from the Alberta Data Booklet: $E°(Ag^+/Ag) = +0.80$ V, $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Zn^{2+}/Zn) = -0.76$ V. Which ion pulls electrons most strongly, and which metal is the strongest reducing agent?

Work:

Answer: _____

Try it. Given: $E°(Mg^{2+}/Mg) = -2.37$ V, $E°(Fe^{2+}/Fe) = -0.45$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. Which metal is the strongest reducing agent, and which ion is the strongest oxidizing agent?

Work:

Answer: _____

Slide 5 of 11 · What the potential comparison means

One volt is one _____ per coulomb. A coulomb (C) is a unit of electric _____.

Voltage is energy per charge: 150 J ÷ 100 C = _____ V. Doubling both energy and charge gives the _____ voltage.

Every table value is compared with the standard hydrogen electrode, which is defined as _____ V.

E°reaction = E°(oxidizing agent) − E°(reducing agent). A positive value means the written direction is _____. A negative value means the _____ is spontaneous.

Example. The table lists E°(Ag^+/Ag) = +0.80 V and E°(Cu^{2+}/Cu) = +0.34 V. What baseline do these numbers compare to? If Ag^+ is the oxidizing agent and Cu is the reducing agent, what is E°reaction?

Work:

Answer: _____

Try it. A reaction transfers 240 J of energy for every 160 C of charge. What is the potential difference in volts? What is it if the energy and the charge both triple?

Work:

Answer: _____

Slide 6 of 11 · Complete prediction: copper with silver ions

Ag^+ is the oxidizing agent. Cu is the reducing agent, so read its row _____: Cu → Cu^{2+} + $2e^-$. In the table, Ag^+ on the left is _____ Cu on the right, so the reaction is spontaneous.

Multiply the silver half by _____, add and cancel the $2e^-$: Cu + $2Ag^+$ → Cu^{2+} + 2Ag.

E°reaction = E°(oxidizing agent) − E°(reducing agent) = +0.80 − (+0.34) = _____ V. Positive means the written direction is _____.

Do not multiply E° by a coefficient. Predict a silver _____, a shrinking copper strip and a _____ solution from Cu^{2+} (Data Booklet colours, printed p. 11).

Example. Given Cu(s) and Ag^+(aq) under standard conditions, with E°(Ag^+/Ag) = +0.80 V and E°(Cu^{2+}/Cu) = +0.34 V. Predict whether the reaction is spontaneous, write the net ionic equation and predict what you would see.

Work:

Answer: _____

Try it. Given Mg(s) and Cu^{2+}(aq) under standard conditions, with E°(Cu^{2+}/Cu) = +0.34 V and E°(Mg^{2+}/Mg) = −2.37 V. Predict whether the reaction is spontaneous and write the net ionic equation.

Work:

Answer: _____

Slide 7 of 11 · Method: how to predict a redox reaction with the table

Step 1. _____ what is in the beaker: every ion, any metal, and water. Add H^+ if it is acidic and OH^- if it is basic.

Step 2. Find the strongest _____ (highest on the left) and the strongest _____ (lowest on the right).

Step 3. Write the two halves. _____ the reducing agent's row so it is an oxidation.

Step 4. Calculate $E°_{reaction} = E°_{(oxidizing\ agent)} - E°_{(reducing\ agent)}$.

Step 5. A _____ $E°_{reaction}$ is spontaneous. A negative $E°_{reaction}$ is not spontaneous.

Check: never _____ $E°$ by a coefficient.

Example. Use the method on Cu(s) and $Ag^+(aq)$ with $E°(Ag^+/Ag) = +0.80$ V and $E°(Cu^{2+}/Cu) = +0.34$ V. Is the reaction spontaneous?

Work:

Answer: _____

Try it. Use the method on Zn(s) and $Cu^{2+}(aq)$ with $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Zn^{2+}/Zn) = -0.76$ V. Is the reaction spontaneous?

Work:

Answer: _____

Slide 8 of 11 · Select partners from a mixture before calculating

First list what is in the _____. Then pick the strongest oxidizing agent and the strongest reducing agent only from that list.

Ag^+ has the higher E° (+0.80 V against +0.34 V), so it is the stronger _____. Zn^{2+} has the lowest E°, so Zn is the stronger _____.

$Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$. E°reaction = +0.80 − (−0.76) = _____ V. Subtracting a negative is the same as _____.

Cu and Cu^{2+} are in the mixture but not in the net equation. We do not _____ every substance into the equation.

Example. Given a standard mixture of Zn(s), Cu(s), Ag^+(aq) and Cu^{2+}(aq), with E°(Ag^+/Ag) = +0.80 V, E°(Cu^{2+}/Cu) = +0.34 V and E°(Zn^{2+}/Zn) = −0.76 V. Select the strongest reducing agent and oxidizing agent, write the net ionic equation and find E°reaction.

Work:

Answer: _____

Try it. Given a standard mixture of Fe(s), Cu(s), Ag^+(aq) and Cu^{2+}(aq), with E°(Ag^+/Ag) = +0.80 V, E°(Cu^{2+}/Cu) = +0.34 V and E°(Fe^{2+}/Fe) = −0.45 V. Select the strongest reducing agent and oxidizing agent, write the net ionic equation and find E°reaction.

Work:

Answer: _____

Slide 9 of 11 · Your turn: copper with zinc ions

Write the roles for the direction as written. Cu is the _____ and Zn^{2+} is the _____.

$E°_{reaction} = E°(\text{oxidizing agent}) - E°(\text{reducing agent}) = -0.76 - (+0.34) =$ _____ V.

A negative value means the written direction is _____. The reverse, Zn with Cu^{2+}, gives +1.10 V and is spontaneous.

In the table, Zn^{2+} is below Cu, so nothing happens. A copper _____ can safely hold a Zn^{2+} solution.

Example. Given Cu(s) and Zn^{2+}(aq), with $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Zn^{2+}/Zn) = -0.76$ V. Is $Cu + Zn^{2+} \rightarrow Cu^{2+} + Zn$ spontaneous under standard conditions? Justify with the numbers.

Work:

Answer: _____

Try it. Given Cu(s) and Fe^{2+}(aq), with $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Fe^{2+}/Fe) = -0.45$ V. Is $Cu + Fe^{2+} \rightarrow Cu^{2+} + Fe$ spontaneous under standard conditions? Justify with the numbers.

Work:

Answer: _____

Slide 10 of 11 · Plan a virtual metal–ion investigation

A fair test changes _____ at a time. Compare different metals in the same ion solution.

Keep equal: clean strips of equal _____, concentration, time and temperature. Add a control, such as Cu in Cu^{2+}.

Record the deposit, metal loss and solution appearance. Also record _____, because it is a result.

Before each run make a _____ with a reason. The simulation is a fixed model, not real _____. Running it again adds no new _____.

Example. Question: which of Zn, Cu and Ag is the strongest reducing agent? Plan a fair investigation. State the factor you change, three factors you keep the same and what you record.

Work:

Answer: _____

Try it. A student puts Zn in Cu^{2+} for 5 s and Ag in Zn^{2+} for 60 s. Why is this not a fair comparison, and how can it be fixed?

Work:

Answer: _____

Slide 11 of 11 · Make an evidence-based claim

A good conclusion has a _____, then evidence, then an electron explanation.

As reducing agents, Zn > Cu > Ag. The ions rank _____ as oxidizing agents.

Zn reacts with Cu^{2+}, so Zn gives electrons to Cu^{2+}. Cu reacts with Ag^{+}, so Cu is a stronger reducing agent than _____.

No visible change does not _____ a reaction is impossible. A limitation can be an oxide coating or a reaction too _____ to see.

Example. Given these example results: Zn reacts with Cu^{2+} and Ag^{+}; Cu reacts with Ag^{+}; Ag reacts with neither Zn^{2+} nor Cu^{2+}. State a ranking, cite two comparisons and name one limitation.

Work:

Answer: _____

Try it. Given these example results: Zn reacts with Fe^{2+}; Fe reacts with Cu^{2+}; Cu reacts with neither Fe^{2+} nor Zn^{2+}. State a ranking, cite two comparisons and name one limitation.

Work:

Answer: _____

B4 · Practice

Predict reactions and investigate | Questions 1-2 of 8

1. Given Zn(s), $Ag^+(aq)$, $E°(Ag^+/Ag) = +0.80$ V and $E°(Zn^{2+}/Zn) = -0.76$ V from the Alberta table. Predict which way the reaction goes under standard conditions. Write the balanced equation.

Work:

Final answer (with unit): _____

2. Given Ag(s), $Cu^{2+}(aq)$, $E°(Ag^+/Ag) = +0.80$ V and $E°(Cu^{2+}/Cu) = +0.34$ V from the Alberta table, decide whether $2Ag + Cu^{2+} \rightarrow 2Ag^+ + Cu$ is spontaneous under standard conditions. Show the E° values.

Work:

Final answer (with unit): _____

B4 · Practice

Predict reactions and investigate | Questions 3-4 of 8

3. Given test results for three unknown metals: metal P reacts with Q^{2+} and gets a coating of Q. Metal Q reacts with R^{2+} and gets a coating of R. Each metal forms one ion: P^{2+}, Q^{2+} or R^{2+}. The conditions are the same in each test. Rank the reducing agents and the oxidizing agents.

Work:

Final answer (with unit): _____

4. A trial shows no visible deposit after ten seconds. Does this alone prove that the reaction cannot happen under standard conditions? Explain.

Work:

Final answer (with unit): _____

B4 · Practice

Predict reactions and investigate | Questions 5-6 of 8

5. Plan a fair test to compare Zn(s) and Ag(s) as reducing agents with Cu^{2+}. Name the one thing you change, two things you keep the same and one thing you record.

Work:

Final answer (with unit): _____

6. Given the table pair $Cu^{2+} + 2e^- \rightarrow Cu$ with $E° = +0.34$ V, a student triples it and reports +1.02 V. Explain the error.

Work:

Final answer (with unit): _____

B4 · Practice

Predict reactions and investigate | Questions 7-8 of 8

7. Given the Data Booklet table values $E°(Ag^+/Ag) = +0.80$ V, $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Zn^{2+}/Zn) = -0.76$ V. A solution that contains $Cu^{2+}(aq)$ must be stored. Can it be kept in a zinc container? Can it be kept in a silver container? Explain with the table.

Work:

Final answer (with unit): _____

8. Challenge: Given a solution that contains both $Ag^+(aq)$ and $Cu^{2+}(aq)$. A strip of nickel is placed in it. Data Booklet table values: $E°(Ag^+/Ag) = +0.80$ V, $E°(Cu^{2+}/Cu) = +0.34$ V and $E°(Ni^{2+}/Ni) = -0.26$ V. Which ion reacts first? Write the balanced equation and find $E°_{reaction}$ in volts.

Work:

Final answer (with unit): _____