B13 · Batteries, fuel cells and chlorine for water

Student notes - complete the underlined spaces | Notes 1/3

Explain batteries as voltaic cells and write the reactions of lead-acid, alkaline and fuel cells. Explain chlorine production for water and judge a cell using evidence.

Name: _____ Date: _____

1. Batteries

A battery is one or more voltaic cells

A voltaic cell has an anode, a cathode and an electrolyte, which is a liquid with dissolved ions. A battery is one or more of them.

Cells joined in a row _____ their voltages, so more cells means more voltage.

A _____ cell is used once, because its reaction cannot easily be reversed. A _____ cell can be recharged.

During discharge a battery is a _____ cell. The reaction runs by itself and gives electricity.

During recharge a power supply forces the reverse reaction, so it is an _____ cell (B8). The electrode that was oxidized is now reduced, so the names anode and cathode swap.

On the diploma: to name the anode, ask where oxidation is happening in that direction. A battery can be one cell or several cells in a row.

The lead-acid cell

The booklet has two lead rows: $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$ (+1.69 V) and $PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$ (−0.36 V).

PbO_2 has the higher value, +1.69 V, so it is the _____. The lower row runs backward at the anode: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$. So lead is the _____.

$E°cell = 1.69 - (-0.36) =$ _____. One cell is not enough for a car, and voltages add. Six cells in a row give $6 \times 2.05 =$ _____.

Both halves move two electrons, so no multiplier is needed. The cell reaction is $PbO_2 + Pb + 2SO_4^{2-} + 4H^+ \rightarrow$ _____ $+ 2H_2O$. Atom check: Pb 2, S 2, O 10, H 4, charge 0.

H^+ and SO_4^{2-} are reactants, so they get used up and the acid gets _____. $PbSO_4$ is a solid that forms on both electrodes, so both electrodes _____ mass.

We cannot use part of a cell. If each cell gives 2.05 V and a battery needs 7.0 V, then $7.0 \div 2.05 = 3.41$, so round up to _____ cells.

On the diploma: reverse the lower half-reaction but keep its E° as printed, and never multiply E° by a coefficient. Common wrong choices forget the six cells or say the anode loses mass.

PbO_2 (+1.69 V) and $PbSO_4$/Pb (−0.36 V). Cathode: _____; anode: _____

$E°_{cell}$ = 1.69 − (−0.36) = _____

Six cells in a row: 6 × 2.05 = _____

Discharge: both electrodes _____ mass as $PbSO_4$ forms.

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2. Alkaline cells and fuel cells

The alkaline cell

An alkaline cell, like a flashlight cell, is a primary cell. Its half-reactions are given, so we do not need the table.

The anode is _____, which is oxidized because it loses electrons: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$. The cathode is _____, which is reduced: $2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$.

Add the halves and cancel the electrons, water and hydroxide ions. The overall reaction is $Zn + 2MnO_2 \rightarrow ZnO +$ _____. It is a _____ cell with a given voltage of about 1.5 V.

Used cells contain _____, like zinc and manganese compounds. In the garbage they can harm soil and water, so they should be recycled or disposed of properly.

On the diploma: when half-reactions are given, use them and do not search the booklet. An Evaluate item about batteries expects a benefit and a disposal concern.

The hydrogen fuel cell

Hydrogen is _____ at the anode: $2H_2 \rightarrow 4H^+ + 4e^-$. Oxygen is _____ at the cathode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$.

The electrons travel through the outside circuit, and that is the current we use. Hydrogen ions cross a _____ inside the cell to complete the circuit.

Both halves move four electrons, so they cancel. Overall: $2H_2 + O_2 \rightarrow$ _____. $E°_{cell} = 1.23 - 0.00 =$ _____, and we do not multiply E° by the 2.

A fuel cell is fed _____ all the time, so it keeps running. A battery stores a fixed amount of _____ and runs down.

On the diploma: the particle that is oxidized is the one that loses electrons. Do not multiply E° by the coefficient you used to balance electrons.

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3. Chlorine for water and judging cells

Chlorine for a pool

A pool system passes current through NaCl(aq). The cathode makes _____: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$. The anode makes _____: $2Cl^- \rightarrow Cl_2 + 2e^-$.

The table says water should be oxidized, but chlorine forms because of the chloride _____ from B9.

The Cl_2 then reacts with hydroxide: $Cl_2 + 2OH^- \rightarrow Cl^- + OCl^- + H_2O$. One chlorine goes from 0 to _____, so it is reduced. The other goes from 0 to _____, so it is oxidized.

The same element is both oxidized and reduced, which we call a _____.

The ion _____ cleans the water, because it is an oxidizing agent that oxidizes bacteria.

On the diploma: write the oxidation number of chlorine on each side before you name the change. Hydrogen is at the cathode and chlorine at the anode.

Judge a cell

Start with the _____. Then compare voltage, mass, lifetime, recharging, cost and _____ as separate pieces of evidence.

A higher voltage does not prove a _____ life or a lower _____. A primary cell is cheap and keeps its charge in storage, so it suits a flashlight that is used rarely.

A fuel cell runs as long as fuel arrives. But a claim of no emissions only covers the cell itself, so we need evidence about how the _____ is made and delivered.

On the diploma: a common wrong choice says the highest-voltage cell is best. Justify your choice with one advantage and one limit.

Extracting metals long ago

Early peoples heated copper ore with charcoal long before anyone knew about electrons: $2CuO + C \rightarrow 2Cu + CO_2$. Copper goes from +2 to 0, so it is _____. Carbon goes from 0 to +4, so it is _____.

Carbon gave electrons to copper(II), so carbon is the _____ agent. It is the one whose oxidation number goes up.

Trial and error came first, and the redox _____ explained it later. The model also showed that metals low on the table, like aluminium, have ions that accept electrons

so poorly that carbon cannot reduce them. Those need electrolysis (B12).

On the diploma: for a science and technology question, give one example in each direction.

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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.

B13-P01 · Easy · Explain the difference between a primary cell and a secondary cell, and give one example of each from this lesson.

B13-P02 · Easy · A lead-acid car battery is recharged. State what kind of cell it is during recharging, and what the power supply does.

B13-P03 · Easy · Given $PbO_2 + SO_4^{2-} + 4H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$ (+1.69 V) and $PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$ (−0.36 V). Name the cathode and the anode for a discharging lead-acid cell.

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B13-P04 · Easy · Write the cell reaction for the discharging lead-acid cell and find E°cell.

B13-P05 · Medium · A car battery has six lead-acid cells in a row. Find its voltage and explain why cells in a row are used.

B13-P06 · Medium · Describe what happens to the acid and to the mass of each electrode as a lead-acid battery discharges.

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B13-P07 · Medium · Given the alkaline cell half-reactions $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$ and $2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$. Add them and write the overall reaction.

B13-P08 · Medium · Why should used alkaline cells be recycled or disposed of properly instead of being thrown into the garbage?

B13-P09 · Challenging · Given $H_2 \rightarrow 2H^+ + 2e^-$ (0.00 V) and $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ (+1.23 V). Write the overall fuel cell reaction and find E°cell.

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B13-P10 · Challenging · A company says that its fuel cell makes only water, so its total emissions are zero. Evaluate the claim.

B13-P11 · Challenging · A flashlight is used only now and then. Compare an alkaline cell and a rechargeable cell for this job, and name the evidence that you would use.

B13-P12 · Challenging · Salt water is electrolyzed in a pool system. Name the product at each electrode, and show with oxidation numbers that $Cl_2 + 2OH^- \rightarrow Cl^- + OCl^- + H_2O$ is a disproportionation.