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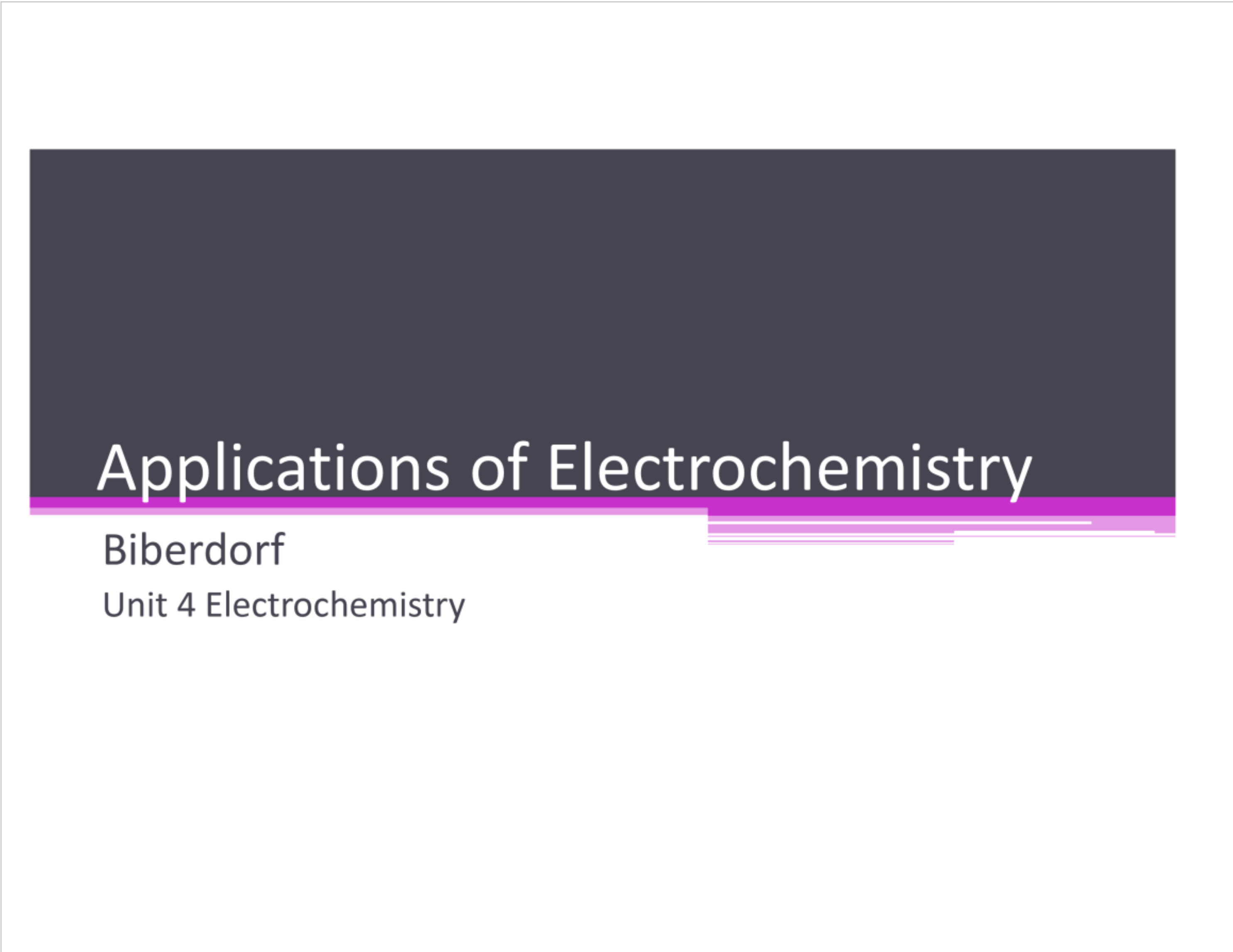
Tuesday, April 25, 2017 3:54 PM



Important Information

Due Today: HW10 and LE39

Due Tuesday: LE40 and HW11

Exam 4 is on Wednesday (5/3) at 7 PM!

Question

spontanuos $\Delta G = -$ $E_{cell} = +$

Given the below half-reactions, calculate the standard potential of the galvanic electrochemical cell.

$Cu^{2+} + 2e^{-} \rightarrow Cu$ $E° = +0.34\ V$

$Al^{3+} + 3e^{-} \rightarrow Al$ $E° = -1.66\ V$

$E_{cell} = +2V$

$Al \rightarrow Al^{3+} + 3e^{-}$ $E = +1.66V$

Question

Assuming $E_{cell}°$ = 2V, what is the maximum amount of electrical work that can be extracted from running this cell under standard conditions?

$Cu^{2+} + 2e^- \rightarrow Cu$ E° = +0.34 V
$Al^{3+} + 3e^- \rightarrow Al$ E° = –1.66 V

A. 2316 kJ/mol
B. 1158 kJ/mol
C. 579 kJ/mol
D. 239 kJ/mol

Question

$[Cu^{2+}] = 1M$

Given the below half-reactions, calculate the standard potential of the electrochemical cell.

* Equilibrium *

$G_{product} = G_{reactant}$

$Cu^{2+} + 2e^{-} \rightarrow Cu \quad E° = +0.34\ V$

~~$Cu^{2+} + 2e^{-} \rightarrow Cu \quad E° = +0.34\ V$~~

$Cu \rightarrow Cu^{2+} + 2e^{-} \quad E° = -0.34V$

0V

0.001M $Cu \rightarrow Cu^{2+}_{ox} + 2e^-$

1M $Cu^{2+}_{red} + 2e^- \rightarrow Cu$

$Cu^{2+}_{red} + Cu(s) \rightarrow Cu^{2+}_{ox} + Cu(s)$

Question

Calculate the emf of the following electrochemical cell.

anode/ox cathode/red

$Cu(s)|Cu^{2+}(0.001M)||Cu^{2+}(1M)|Cu(s)$

A. 0.176 V
B. – 0.176 V
C. 0.088 V
D. – 0.088 V
E. 0 V

$$E = E^{\circ} - \frac{0.0591}{n} \log Q$$

$$E = 0 - \frac{0.0591}{2} \log \frac{[Cu^{2+}_{ox}]}{[Cu^{2+}_{red}]}$$

$[Cu^{2+}_{ox}]$ = 0.001M, $[Cu^{2+}_{red}]$ = 1M

$$E = 0.08865V$$

Question

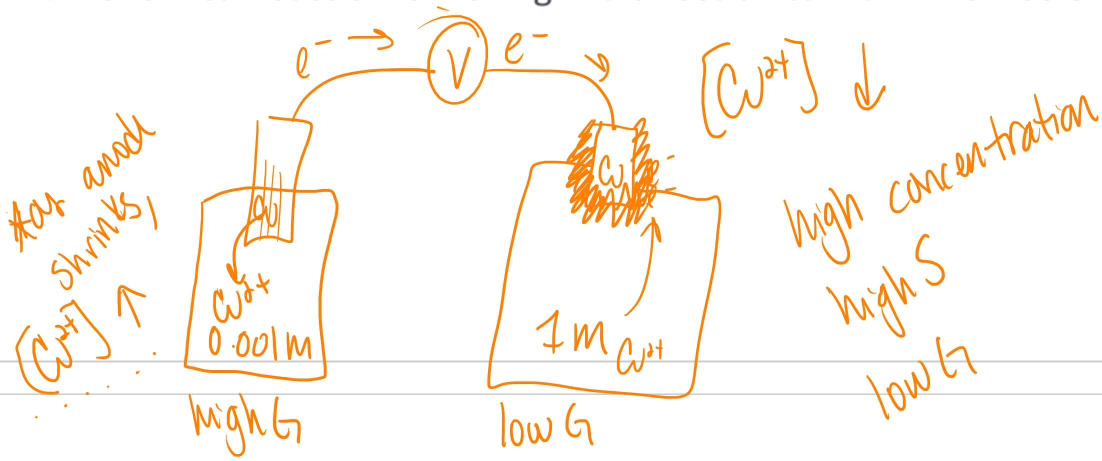
How does this cell produce a voltage?

$Cu(s)|Cu^{2+}(0.001M)||Cu^{2+}(1M)|Cu(s)$

A. More concentrated cell, lower free energy

B. Less concentrated cell, lower free energy

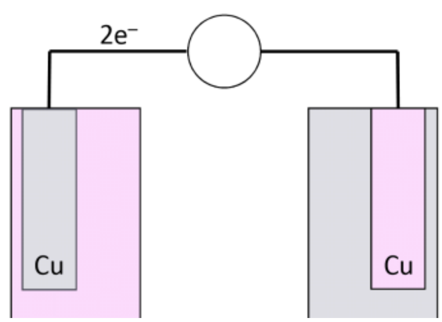
C. Chemical reaction is moving in a direction to maximize free energy



Explanation

A more concentrated cell has a lower free energy.

$Cu(s)|Cu^{2+}(0.001M)||Cu^{2+}(1M)|Cu(s)$



* stops when $[Cu^{2+}]_{ox} = [Cu^{2+}]_{red}$

or

run out of electrode

High G
As oxidation occurs, $[Cu^{2+}]$ increases

Low G
As reduction occurs, $[Cu^{2+}]$ decreases

Batteries

Biberdorf

Unit 4 Electrochemistry

Key Characteristics of Batteries: Potential (E)

* amount of work needed to move charge
* unit = V = $\frac{J}{C}$
* large E, good battery
* we can string batteries together to overcome a low E

$$E_{cell} = E_{cathode} - E_{anode}$$

Key Characteristics of Batteries: Capacity (Q)

↳ charge

* "total Energy"

* value of charge the system can generate at a specific voltage

* unit = C (coulomb)

$$Q = I \cdot t$$

Key Characteristics of Batteries: Current (I)

* how fast battery can generate charge
* unit = A = $\frac{C}{s}$ $\left(\frac{\text{charge}}{\text{time}}\right)$
* provides a time factor

$$I = \frac{Q}{t}$$

Key Characteristics of Batteries: Power (P)

* rate of doing work per unit time

* Unit = Watts (W) = $\frac{J}{s}$ $\frac{\text{Energy}}{\text{time}}$

$$P = \frac{VQ}{t} = V \cdot I$$

$$\left(\frac{J}{C}\right)\left(\frac{C}{s}\right) = \frac{J}{s}$$

Key Characteristics of Batteries: Cycle Life

* how well the battery recharges

Question

Which of the following terms is the most important thing to consider when creating a new battery application?

A. Power
B. Potential
C. Capacity
D. Current
E. Cycle Life

"efficiency"

how fast charge can be generated

Optimal Battery Characteristics

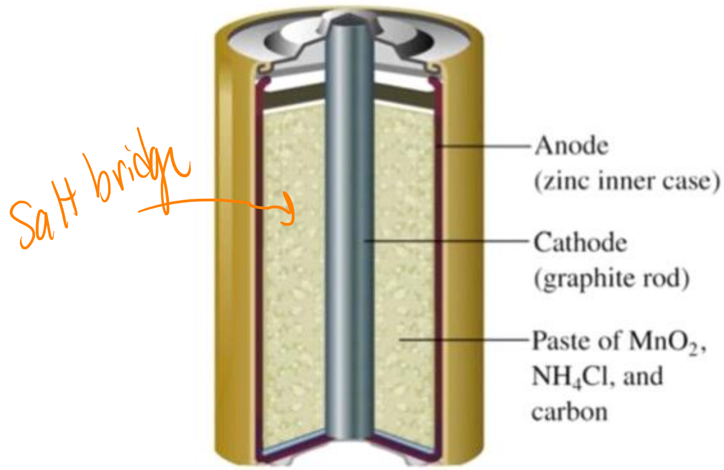
*perfect combination of energy density & power density

- light
- cheap
- (*) nontoxic
- solid
- efficient
- long-lasting
- small

Battery Type: Primary

* dry cells - paste inside the battery
  - ↳ not reversible
  - ↳ not rechargeable
  - ↳ alkaline batteries (1.5V)
    * different sizes for different max electric current

Dry Cells



anode: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$

cathode: $2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$

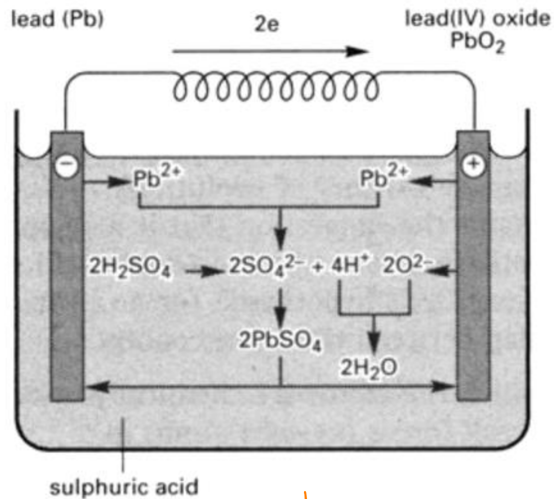
*slow reactions, constant V (1.5V), low I

Battery Type: Secondary

* rxn is reversible
  ↳ rechargeable

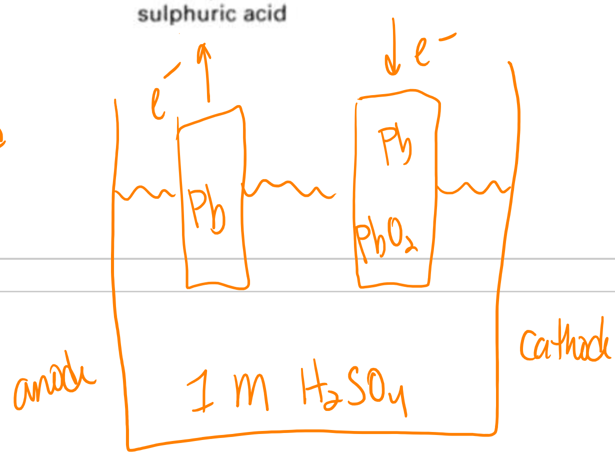
* NiCd (toxic)
* Li-ion
* Pb-storage (car battery)

Lead Storage Battery



$\overset{0}{Pb}$, $\overset{+2}{PbSO_4}$, $\overset{+4}{PbO_2}$

* all solids – no salt bridge needed



Lead Storage Battery (discharge)

anode: $\overset{0}{Pb}_{(s)} + SO_4^{2-}{}_{(aq)} \rightarrow \overset{+2}{PbSO_4}{}_{(s)} + 2e^-$

cathode: $\overset{+4}{PbO_2}{}_{(s)} + 4H^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2e^- \rightarrow \overset{+2}{PbSO_4}{}_{(s)} + 2H_2O_{(l)}$

overall: $Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)} \rightarrow 2PbSO_{4(s)} + 2H_2O_{(l)}$

overall: $Pb_{(s)} + PbO_{2(s)} + 2H_2SO_{4(aq)} \rightarrow 2PbSO_{4(s)} + 2H_2O_{(l)}$

$E_{cell} = 2V$

* 6 cells in a battery

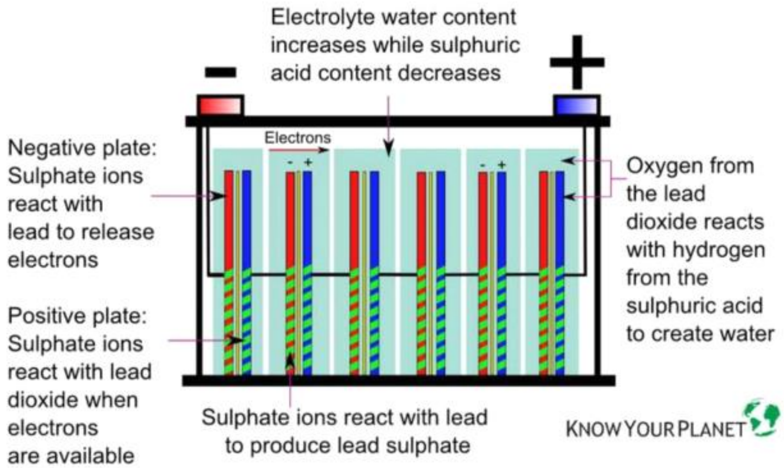
$6 \times 2V = 12V$

(*) discharge
- ↳ voltaic cell
- ↳ start car

(*) recharge
- ↳ electrolytic cell
- ↳ car is on
  - * alternator turns ME → EE
  - * recharge cell
- ↳ cathode becomes anode
- ↳ anode becomes cathode

} rxn flipped

12V Lead-Acid Battery (Discharge)



Question

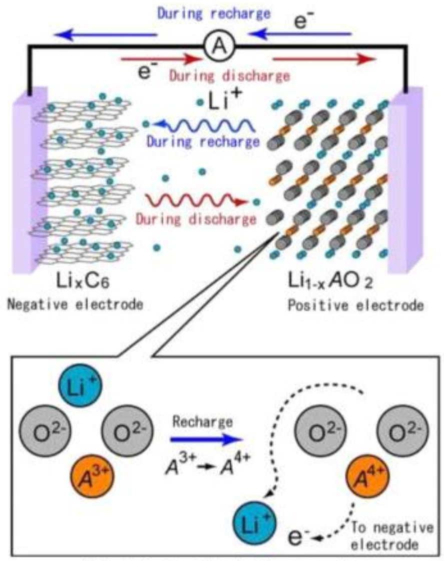
* discharge *

Which of the following species is the reducing agent in the Lead-Acid car battery?

A. Pb (s)
B. PbO_2 (s)
C. $PbSO_4$ (s)
D. H_2O (l)

oxidation/anode

Li-Ion Battery



Schematic view illustrating operating principle of Li-ion secondary battery

portable electronic devices

*anode: $LiC_6 \rightarrow C_6 + Li^+ + e^-$

*cathode: $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$

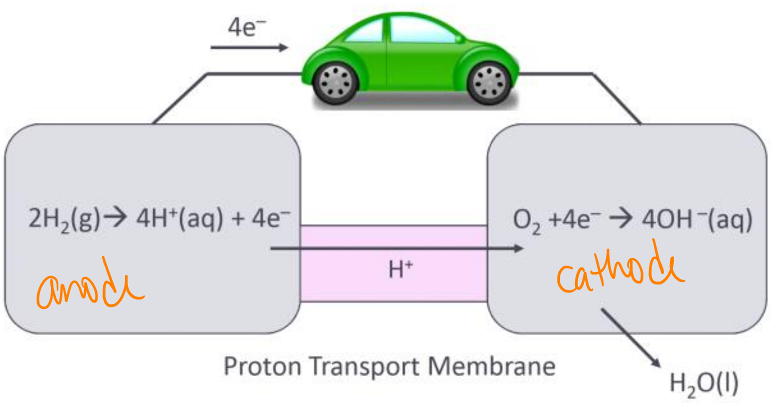
overall: $LiC_6 + CoO_2 \rightarrow C_6 + LiCoO_2$ $E_{cell} = 1.5V$

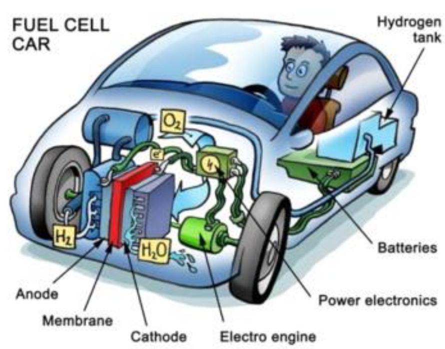
Battery Type: Fuel Cells

* voltaic cell where the fuel is continuously supplied
* not rechargeable

* refillable!

Fuel Cells





* H_2 + O_2 gas must be continuously supplied

Photovoltaic Cells