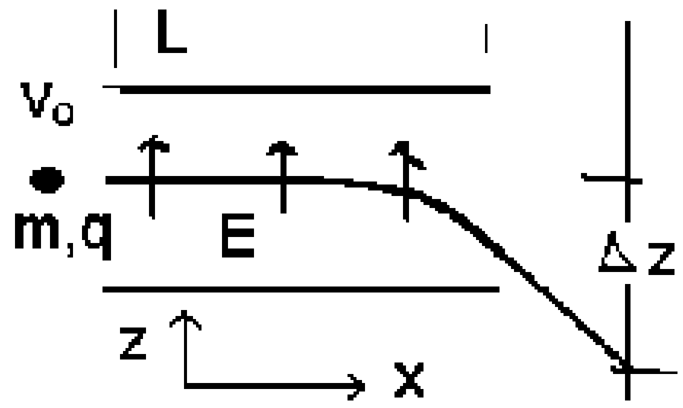
6.9. Deflection of electrons and ions in electric fields



$$\vec{F} = q \cdot \vec{E}$$

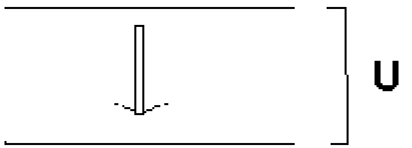
Comparison with m*g due to gravitation!

$$\Delta z(x) = \frac{1}{2} a \cdot t^2 = \frac{q \cdot E}{2 \cdot m} \cdot \frac{x^2}{v_x^2}$$

or at x=L

$$\boxed{\Delta z(L) = \frac{E \cdot L^2}{4 \cdot U}}$$

Why that?



particle in a potential U $\frac{m}{2} v^2 = e \cdot U;$

U „ fall throuh U" voltage

as a result: Electron volt as energy!

$$\frac{m}{2} v^2 = e \cdot U \Rightarrow v = \sqrt{\frac{2qU}{m}}$$

7. Electric current

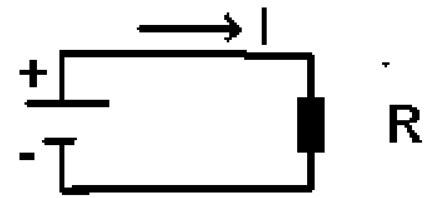
7.1. Intensity of current

Ex: Different effects

$$I = \frac{dQ}{dt}; [I] = Ampere; [Q] = A \cdot s$$

circuit:

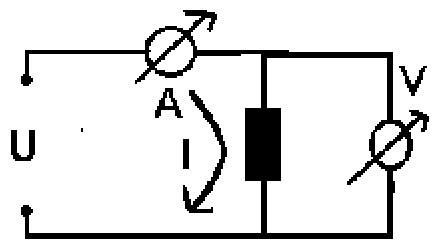
DC-current: I constant in time: $I = \frac{Q}{t}$



7.2. Ohms law

connection current ←→ voltage

R: Widerstand



Ampere meter uses most of time magnetic effects of currents!

at many conductors $I \sim U$ or $I = \frac{U}{R}$

$$[R] = \Omega(Ohm) = \frac{V}{A}$$

microscopic model
in analogy to fluid dynamics

$$\vec{j} = n \cdot q \cdot \vec{v} = \rho \cdot \vec{v}$$

$$\vec{j} = n \cdot q \cdot \vec{v} = \rho \cdot \vec{v}$$

number of charges/s durch die Eintrittsfläche

charges pro Vol.*velocity.

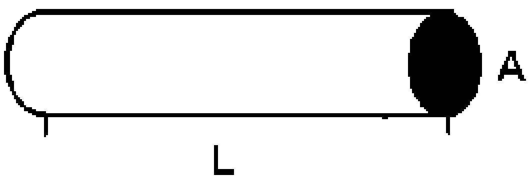
charge* density velocity.

average velocity $\langle \vec{v} \rangle = \frac{1}{n} \sum_k n_k \cdot v_k$ with n= $\sum_k n_k$

$$\Rightarrow \vec{j} = \rho \cdot \langle \vec{v} \rangle$$

charge conservation: $\int_A \vec{j} \cdot d\vec{A} = -\frac{dQ}{dt}$

charge out of a closed area = decline of charge in inside

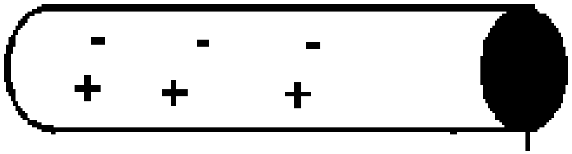


$U = I \cdot R$ L $\cdot \vec{E} = \vec{j} \cdot A \cdot \rho_0 \cdot \frac{L}{A}; \rho_0 =$ specific resistance

$\Rightarrow \vec{E} = \vec{j} \cdot \rho_0;$ with $\frac{1}{\rho_0} = \sigma_0$ (conductivity)

$\Rightarrow \vec{j} = \sigma_0 \cdot \vec{E} = n \cdot q \cdot \langle \vec{v} \rangle; \langle \vec{v} \rangle = \vec{v}_D($ drift velocity)

with Ohms law → drift velocity



metal grid

electrons + ions

force on e$^-$: $q = -e$: $q \cdot \vec{E}$

$$\frac{d\vec{v}}{dt} = \frac{q \cdot \vec{E}}{m} \Rightarrow \vec{v} = \frac{q \cdot \vec{E}}{m} \cdot t + \vec{v}_0 (= 0)$$

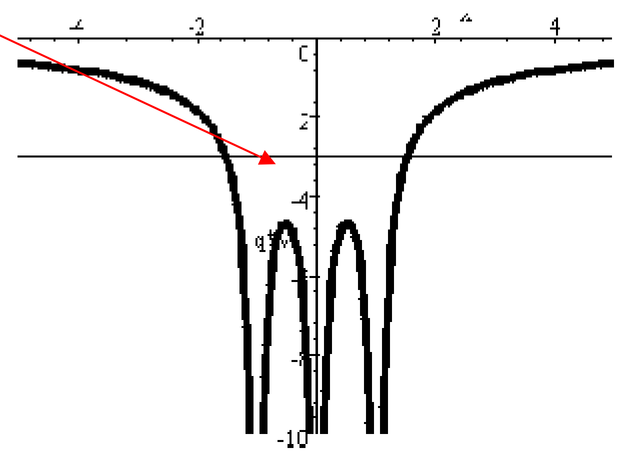
$$\Rightarrow \vec{v}_D = \frac{q \cdot \vec{E}}{m} \tau ; \tau =$$

average time between collisions

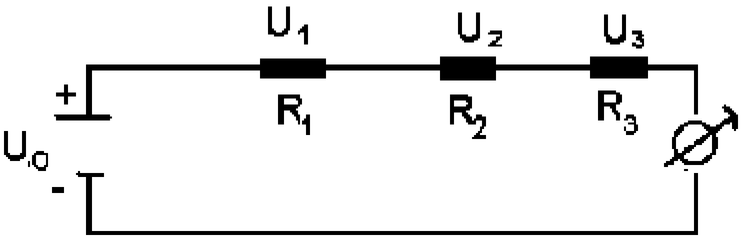
range of validity $\sqrt{\langle v_e^2 \rangle} \ggg v_D$

e.g:Na:2.5 $\cdot 10^{22}$ "free" electrons/cm^3

$$\sqrt{\langle v_e^2 \rangle} \approx 10^6 m/s ; \tau \approx 3 \cdot 10^{-14} s$$

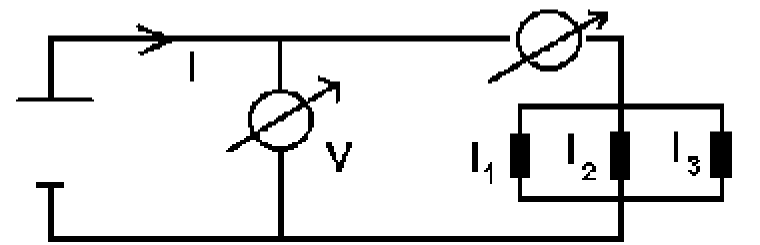


connections in series of resistors



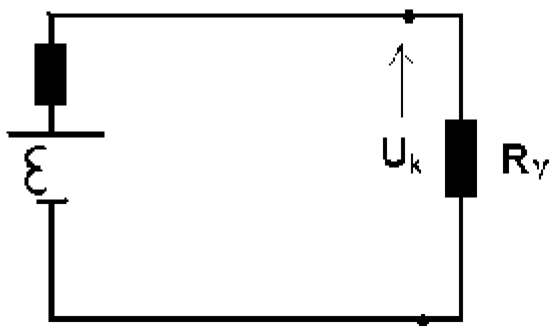
$$U_0 = \sum_i U_i \Rightarrow R = \sum_i R_i$$

Parallel connection



$$I = \sum I_i \Rightarrow \frac{1}{R} = \sum_i \frac{1}{R_i}$$

voltage sources:



transformation from chemical or mechanical energy into elektrical energy

ε : electro motoric force,

R_i : inner resistor R_V : consumer

U_k : disc tension,

normal case: $I \succ 0; U_k \prec \varepsilon$ $\varepsilon = R_i \cdot I + R_V \cdot I; *; R_V \cdot I = U_k$

$\Rightarrow$ $I = \frac{\varepsilon}{R_i + R_k}$ or with

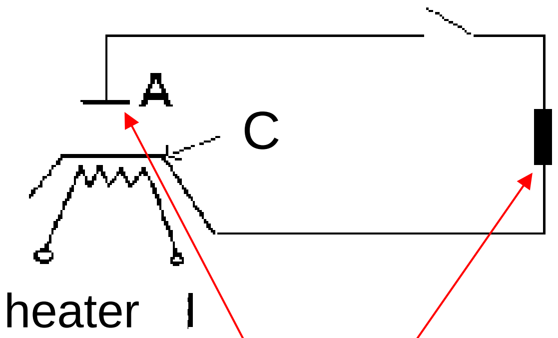
$U_k = \varepsilon * R_V / R_i + R_k$

limit cases: a) $R_V \to \infty$ „idle state" $U_k = \varepsilon$

b) $R_V \to 0$ „short circuit"

example for EMF: vacuum tube:(pressure) $\leq 10^{-5} mb$ or $10^{-3} P$)

EMF=electromotive force



electrons from cathode C

$E_{kin}^{e^-} \approx kT$ anode(A) voltage U_A

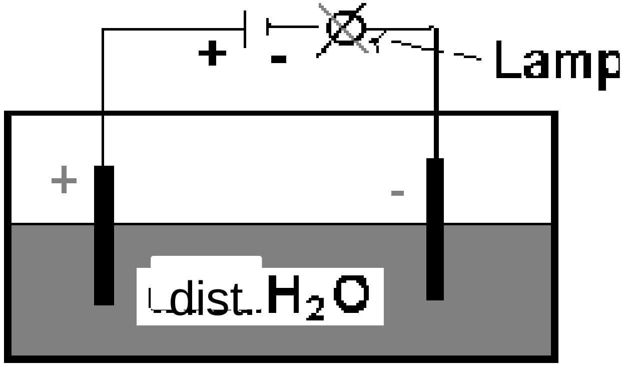
increases up to $E_{kin} \approx e \cdot U_A \Rightarrow$

$$I = \frac{U_A}{R}$$

current driven by "electromotive" force

$\approx 20\%$ efficient!

7.3. Electrolytically current conduction



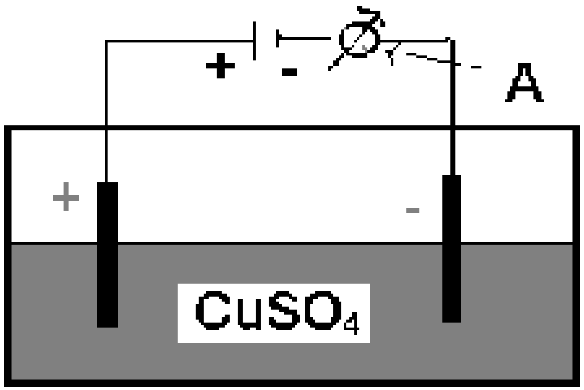
conductibility of liquids

Elekctrodes:+= Anode, - =Cathode

a) Distilled water →" no " current

b) NaCl- addition →Lamp lights up

Galvanise:



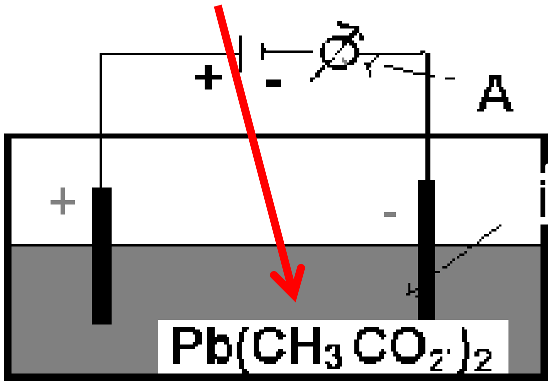
a) Obesrvation: a) current is flowing

b) At Anode arises gas (here O_2)

c) On cathode deposit copper

$CuSO_4$ - solution

Exp.: „lead tree"



lead acetat solution,
electrodes consisting out of lead

conclusion from experiments:

a) Dilution of materials ("Electrolytes") can conduct currents

b) Transport of charge is connected with transport of matter

Faraday's law

1. The mass of material M ~ of charges going through charge $Q = I \cdot t$, i.e.:M=k $\cdot I \cdot t$

   with k as electrochemical equivalent, for silver e.g:

   1.118 $\cdot 10^{-3} g/C$

   i.e.: at current of 1 A 1.118 mg silver gets deposited in a solution of silver nitrate pro second

2. Equal amounts of material (Q) deposit in different electrolytes chemical equivalent amounts.

1 Gram-equivalent ≙ 1 Gram-atom/weight

example:

	Ag	Cu
1 Gram-atom	107.9g	63.6g
weight	1	2
1 Gram-equivalent	107.9g	31.9g

In order to deposit one gram-equivalent one needs always the same charge:

F=96484 C/Gram-equivalent

Faraday-constant

Dilutions: Explanation: Example $CuSO_4$ (Crystal)

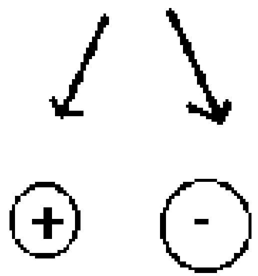
$$\underbrace{Cu^{++} \leftrightarrow SO_4^{--}}$$

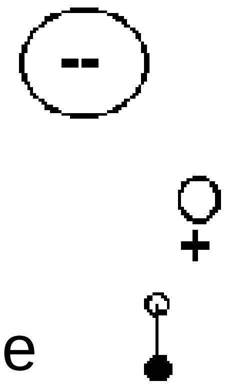
heteropolar bonds

or NaCl: $Na^+ \leftrightarrow Cl^-$

What happens?

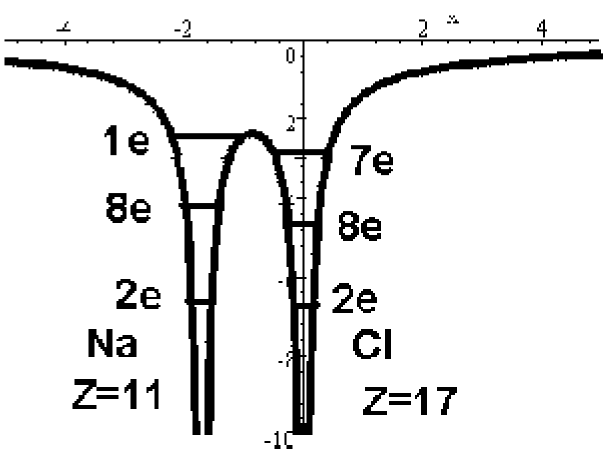
NaCl in H_2O

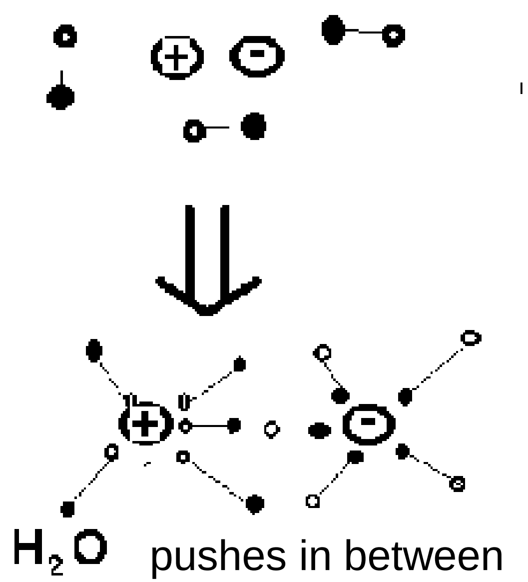




dipole

Potential:

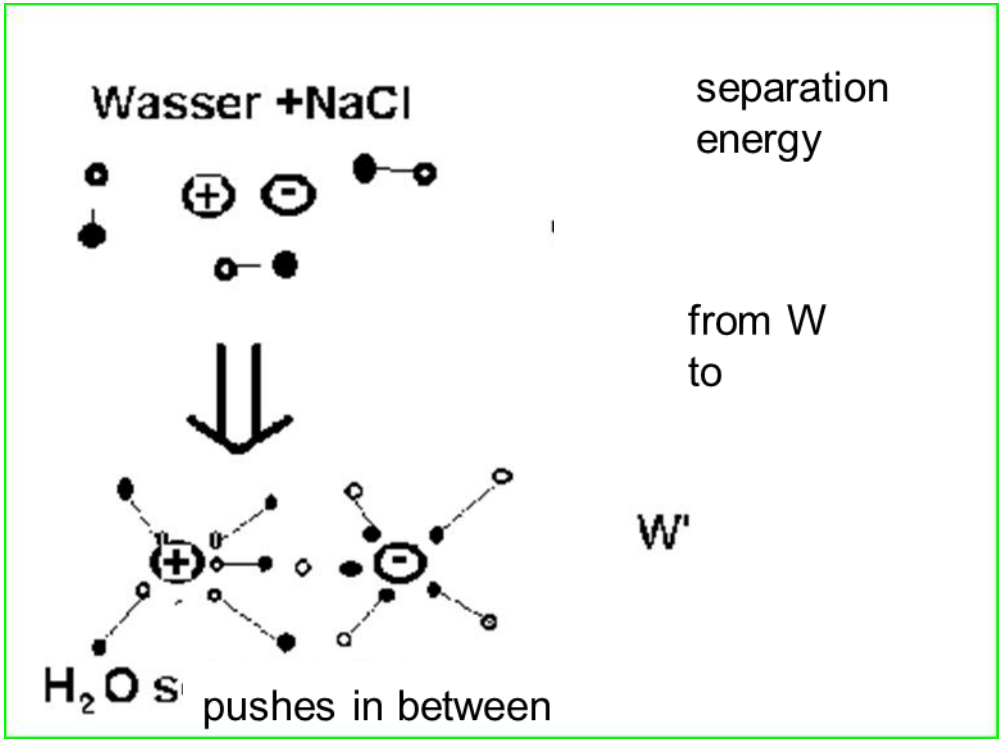




separation energy

from W to

W'



$$W = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r_0}$$

for $r_0 \simeq 2 \cdot 10^{-10} m$

to $$W' = \frac{1}{4\pi\varepsilon_0 \cdot \varepsilon} \cdot \frac{e^2}{r_0}$$

$$\varepsilon(H_2O) \approx 80$$

$$W' \simeq 10^{-20} J$$

Thermic energy of ions:

$\frac{3}{2}kT \approx 6 \cdot 10^{-21} J \Rightarrow$ „easy" dissociation!

For estimates:

1eV	$\simeq 1.6 \cdot 10^{-19} J$
	$\simeq 11600 K$

room temperature $\simeq \frac{1}{40} eV$

Also for C^{++}, SO_4^{--}

With electric field:

$Cu^{++} \rightarrow$ Cathode:',Cath-ions"

$SO_4^{--} \rightarrow$ Anode:"An-ions"

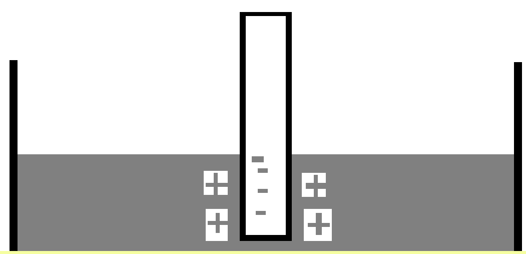
Reactions on electrods:

Cathode: $\Rightarrow Cu^{++} + 2e$

Deposits as a neutral copper-atom

Anode: →H_2O- molecule dissolves H_2SO_4 remains in solution!

Resolution of metals:

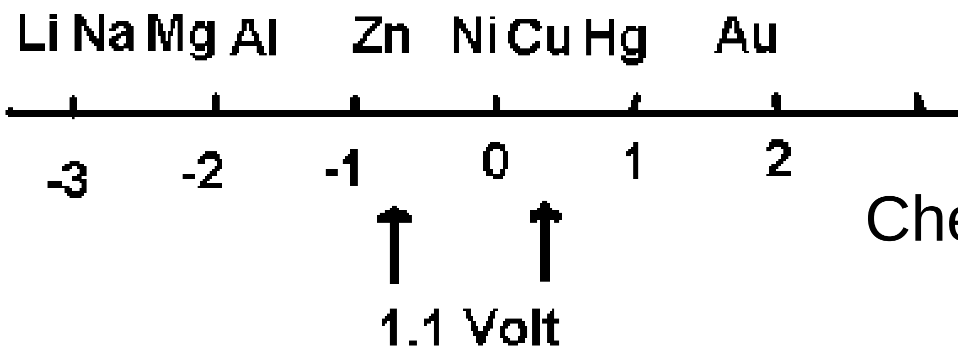


No free electrons!

on boundary surfaces: Strong potential, different depending on elements

different: Solution tension!

The degree is seen in the electrochemical tension chain !

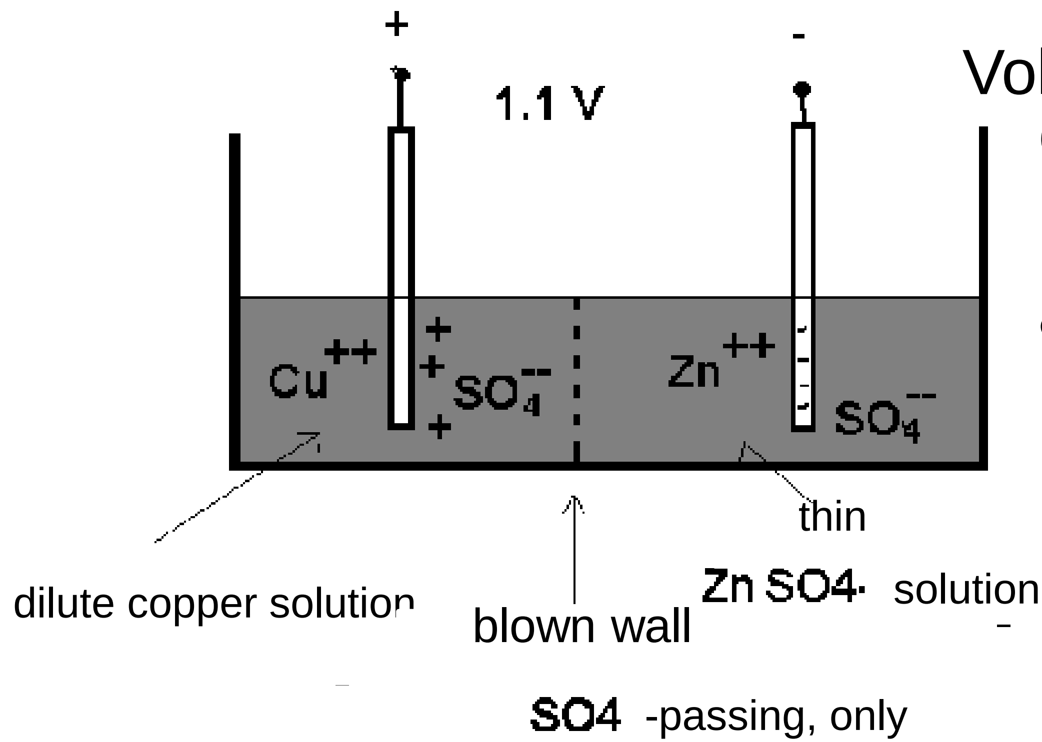


e.g.: Daniell-element

Chemical energy gets free!

$\Rightarrow$ Battery

Voltage on a Daniell-element



Galvanic element:
provides in l $\cdot s$

a charge I$\cdot t$: $I \cdot t = 96484C$

1 Gram-equivalent
of material of neg.
electrode dissolves into solution

Zn^{++}, 1 Gram-equivalent
dissolves

Energy= $\underbrace{\frac{1}{2}(Zn, SO_4, H_2O) - \frac{1}{2}(Cu, SO_4, H_2O)}$; $\frac{1}{2}$

chemical bindungs- separation heat,respectively

because of ++

$$= (53045 - 27980)cal = 25065 = 25065 \cdot 4.18 = 1.0477 \times 10^5 Ws$$

voltage $U = \frac{1.0477 \times 10^5}{96484} = 1.0859 V$

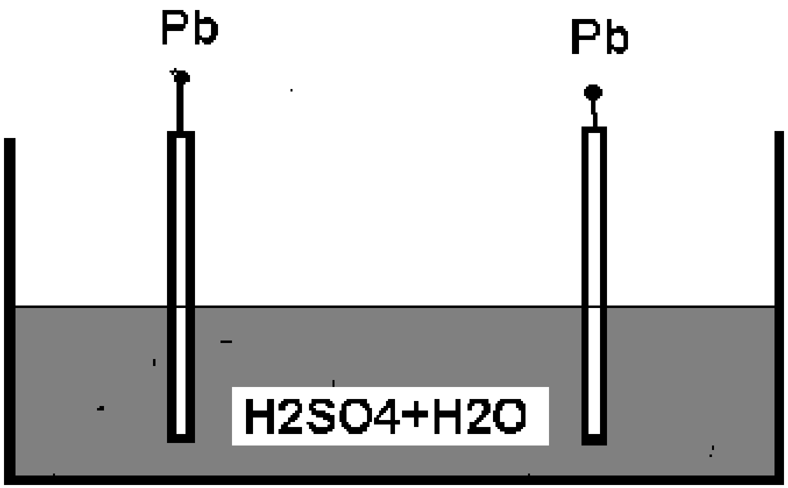
lead-battery:

surface: Pb $\rightarrow PbSO_4$; voltage =0

Anode:

$$PbSO_4 + SO_4^{--} + 2H_2O \rightarrow \boxed{PbO_2} + 2H_2SO_4$$

Charging:Voltage =2.4 V



Cathode:

$$PbSO_4 + 2H^+ \rightarrow \boxed{Pb} + H_2SO_4$$

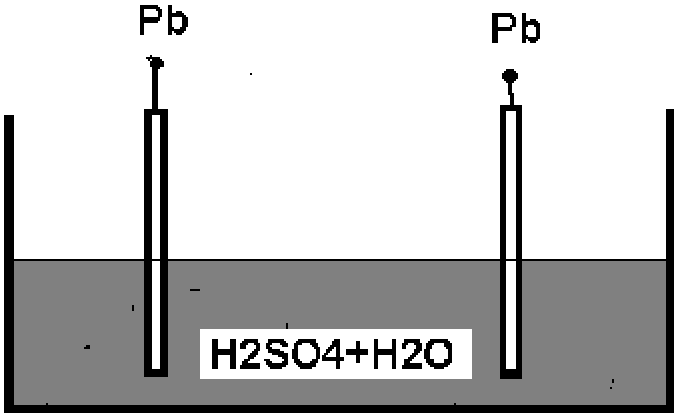
unequal electrodes $\Rightarrow$

voltage source: 2V

discharge:

Anode:

$$\boxed{PbO_2} + H_2SO_4 + 2H^+ \rightarrow PbSO_4 + 2H_2O$$



Cathode:

$$\boxed{Pb} + SO_4^{--} \rightarrow PbSO_4$$