Announcements

1.) The X-mas exam date has been finalized for December 17th 9 am – 12:00 pm. Room to be announced.

2.) This is the week of November 12th to 16th: Group 1 is doing the Gases tutorial while Group 2 is doing the Molar Volume lab

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Again, the cell potential does not tell you the rate of the chemical reaction. Battery makers for automobiles aim for the largest number of Cold Cranking Amps, a measure of how many Coulombs per second can be produced

➢To recharge the battery, the products of the discharge needs to be converted back to starting materials (electrolytic cell)

Cathode E^o_{red} = -0.36 V $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}$

Anode E^o_{ox} = -1.69 V $PbSO_4(s) + 2H_2O \rightarrow PbO_2(s) + 4H^+ 2e^- + SO_4^{2-}$

Cell notation: $PbSO_4$ | PbO_2 || $PbSO_4$ | Pb

➢Note that in recharge mode (electrolytic cell) the anode and cathode have switched places!
Nonetheless, the anode is always the electrode where oxidation occurs

➢E^o_{cell} -2V, which indicates the reaction is not spontaneous (expected).
Therefore to recharge we must apply an external voltage of at least 2 V to force this undesirable reaction to occur.
When a redox reaction is driven by electricity, it is called **electrolysis**

➢Recharging batteries is just one example of electrolysis but the principle is the same

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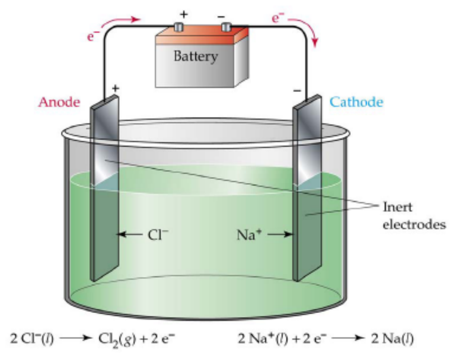
Example:
Industrial electrolysis of molten (not aqueous) NaCl to generate Na(s) + Cl_2(g)

A battery or power source drives the reaction. A small amount of $CaCl_2$ is also added to lower the melting point



Anode: $2Cl^-(\ell) \rightarrow Cl_2(g) + 2e^-$

Cathode: $2Na^+(\ell) + 2e^- \rightarrow 2Na(\ell)$

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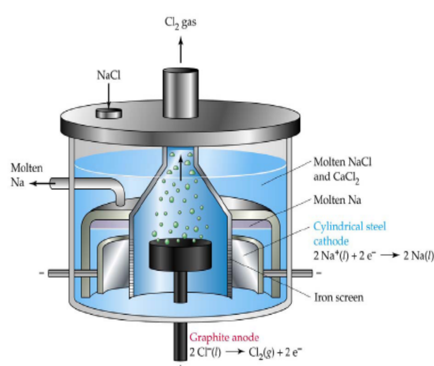
Challenge for you:
Calculate the minimum external voltage needed for this electrolysis

Industrial problem:
How do you keep Cl_2(g) from reacting with the Na(s) product?

The solution is a cell design that incorporates an inverted funnel to isolate the chlorine gas product (≡ Downs electrolysis cell)



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Another question:
Why use molten NaCl? Why not simply use NaCl dissolved in water?

Electrolysis of NaCl in water results in the same oxidation of Cl^- to Cl_2, but H_2O is reduced much more readily than Na^+

Anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

Possible cathode reactions:

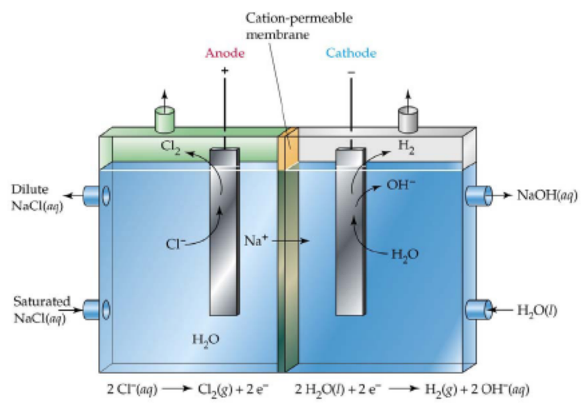
$2Na^+(aq) + 2e^- \rightarrow 2Na(s)$ $\quad E^o_{red} = -2.71$ V

$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$ $\quad E^o_{red} = -0.83$ V

∴ reduction of water is much more favourable

∴ No Na(s) is formed but that is not so bad because Cl_2, H_2, and NaOH are industrially important. Therefore, the electrolysis of salt water is important

Electrolysis cell for this purpose:



4. Quantitative Analysis

In redox reactions, electrons are formed or consumed in stoichiometric ratios. The amount of electrons can be measured by moles or by charge (Coulombs)

1 mole e^- = 96480 Coulombs (≡ Faraday's constant)

However, physicists, electricians, and engineers usually measure electric current instead of electrons

1 ampere (A) = 1 Coulomb per second

Thus, it is possible to express A in terms of electrons:

1 mole e^- = 96480 V

1.036×10^{-5} mol e^- = 1 C

6.240×10^{18} e^- = 1 C (using Avogadro number)
that is; 1 A = 6.240×10^{18} e^- per second

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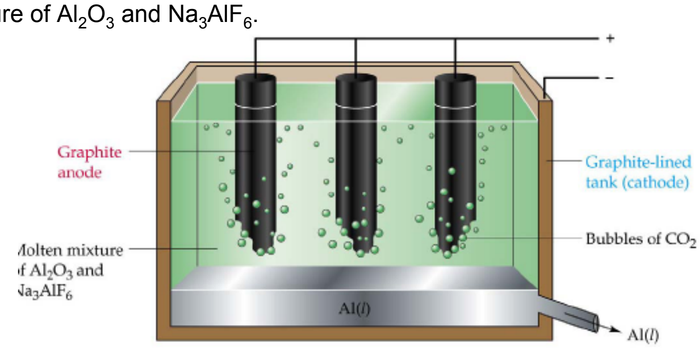
Take home exercise:
Calculate how many electrons go through your toaster if it draws 10 A of electricity for 4 minutes.

Since redox reactions are stoichiometric it should be possible to calculate how much electric current and what length of time is necessary for a particular reaction

Example:
Aluminium smelters in Canada electrolytically produce Al metal using a molten mixture of Al_2O_3 and Na_3AlF_6.



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Cathode: $Al^{3+} + 3e^- \rightarrow Al(\ell)$

Anode: $C(s) + 2O^{2-} \rightarrow CO_2(g) + 4e^-$

The production of 1 mole Al requires 3 mole e^-,
so it is possible to calculate the Coulombs needed and CO_2 emissions (knowing the voltage):

Current: $1\ A = 1\ C\ s^{-1}$ Voltage: $1\ V = 1\ J\ C^{-1}$

Power: $1\ W$ (Watt) $= 1\ J\ s^{-1}$ Energy: $1\ J$ = power x time = V x C

Process is energy intensive and environmentally unfriendly.

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Example based on #20 of the November 2006 exam.
In the silver button cell which generates 1.50 V,
the overall cell reaction is $Zn(s) + Ag_2O(s) + H_2O(\ell) \rightarrow Zn(OH)_2\ (s) + 2Ag(s)$

Suppose that a small cell of this type contains 0.200 g Ag_2O which is the (expensive) limiting reagent. Assuming the cell provides a current of 1.00×10^{-6} A, how many hours could the cell operate?

The number of moles of Ag_2O = 0.2/MM = 231.8 $gmol^{-1}$
=0.00086 mol.

Balanced reduction half reaction: $Ag_2O + 2H^+ + 2e^- \rightarrow 2Ag + H_2O$

∵ reducing one Ag_2O requires 2 e^-s, the reaction requires 2 x 0.00086 mol =0.00172 mol e^-

∴ The number moles of electrons consumed = 0.00172 mol x 96490 C mol^{-1} = 165.96 C

∴ $t = 165.96C/10^{-6}\ A = 1.66 \times 10^8\ s = 4.61 \times 10^4$ hr = answer E.

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Thermochemistry

C020

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ENERGY

When molecules react, there are energy changes, and energy can be released or consumed

Energy can appear and be measured as either:
Work: the ability to move a mass through a distance
or
Heat: increased molecular velocities, usually measured as temperature

The SI unit of energy is the joule, J

Note: 4.184 J = 1 calorie
Not to be confused with 1 Calorie = 1000 calories

Specific Heat

defined as the amount of heat required "to raise 1 gram of a substance 1 degree K; units: $Jg^{-1}K^{-1}$

Examples

Water	Specific Heat = 4.184 $Jg^{-1}K^{-1}$
Fe	Specific Heat = 0.451 $Jg^{-1}K^{-1}$
Glass	Specific Heat = 0.84 $Jg^{-1}K^{-1}$

$\therefore$ By knowing the specific heat of a substance one can calculate the amount of heat required to raise a substance from one temperature to a higher one

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Related to specific heats is a substance's heat capacity, C where the amount of material;
that is the mass is not factored in. Units = JK^{-1}

∴ The heat capacity is the amount of energy required to raise the system by 1 K.

For example, $C(H_2O) = 4.184\ JK^{-1}$

Heat capacity C = mass x specific heat

Heat changes due to Phase Changes

Heat energy may be used not only to change the temperature of a system but also to cause phase changes at constant temperature

These are called **latent heats**