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World of CHEMISTRY

Chapter 18

Oxidation-Reduction Reactions and Electrochemistry

- Metal/Nonmetal oxidation reduction reactions
- Assign oxidation states
- What are oxidation and reduction
- Identify oxidizing and reducing agents

- Forest fire
- Rusting steel
- Internal combustion engine
- Food metabolism
- Most reactions that provide energy & batteries

$2\ Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

- Reactants: no charge (elemental)
- Sodium Chloride: Na^+ and Cl^-
- Electrons transferred from sodium atoms to chlorine atoms

- ***Oxidation-reduction reaction***: reaction in which one or more electrons are transferred
  - Also called ***redox reactions***
- ***Oxidation:*** loss of electrons
- ***Reduction:*** gain of electrons

- Sodium atom loses electron = sodium is ***oxidized***
- Chlorine atom gains electron = chlorine is ***reduced***
- Whenever a metal and nonmetal react to form an ionic compound, oxidation-reduction reaction occurs
  - ***Metal is oxidized*** (loses electrons)
  - ***Nonmetal is reduced*** (gains electrons)

- Uncombined element = no charge (neutral)
- Na metal = neutral
- Cl_2 gas = neutral
- Oxidation state = 0

- Sometimes called oxidation numbers
- In binary ionic compounds, charges are easily identified (Group # on Periodic Table)

Ion	Oxidation State
Na^+	+1
Cl^-	-1
Mg^{2+}	+2
O^{2-}	-2

- No ions present in covalent compounds (electrons are shared)
- Useful to assign imaginary charges to elements in covalent compounds which = the oxidation states
- Assume shared electrons are transferred to more electronegative atom

- Oxygen is more electronegative than Hydrogen
- Each hydrogen loses electron to oxygen
  - Hydrogen = oxidation state of +1
  - Oxygen = oxidation state of -2 (1 electron from each hydrogen)
- Most electronegative: F>O>N>Cl
  - NO_2
    - Oxygen = -2Nitrogen = +4

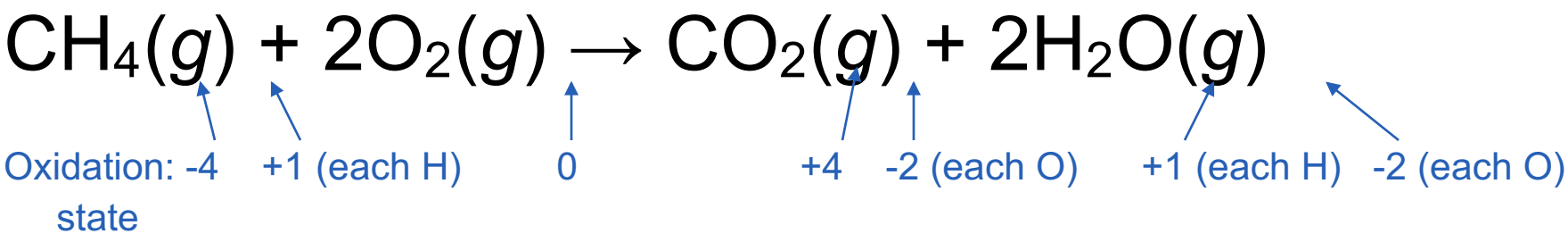
- Combustion of Methane:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Oxidation state: -4 | +1 (each H) | 0 | +4 | -2 (each O) | +1 (each H) | -2 (each O)

- Each change in oxidation state indicates a transfer of electrons
  - Carbon: -4 to +4 = lost 8 electrons

- ***Oxidation:*** an increase in oxidation state (loss of electrons)
- ***Reduction:*** a decrease in oxidation state (gain of electrons)
- ***Oxidizing agent*** = electron acceptor, reactant containing element that is reduced
- ***Reducing agent*** = electron donor, reactant containing element that is oxidized



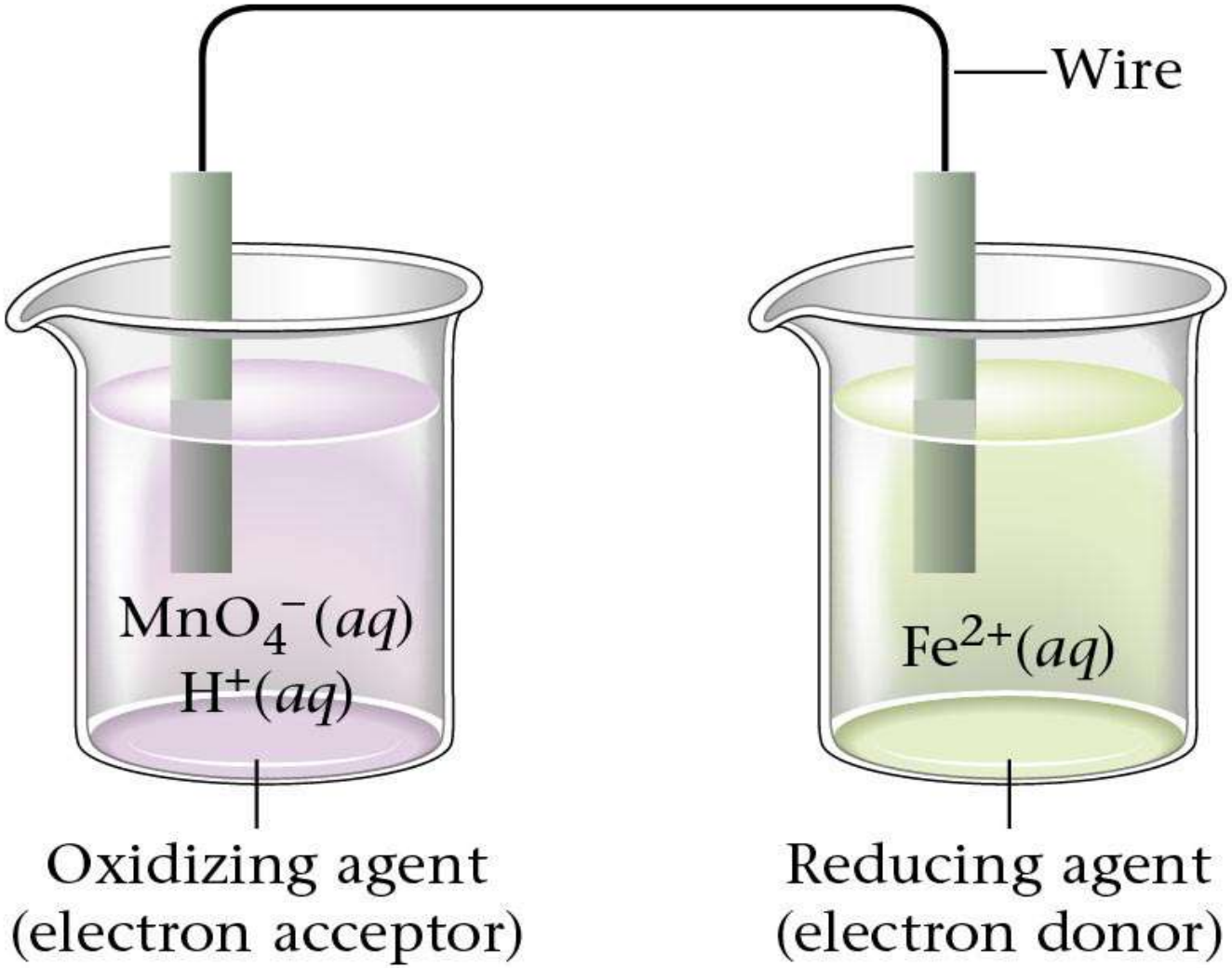
- Carbon = oxidized (increase in oxidation state)
- CH_4 = reducing agent (contains oxidized carbon & furnishes electrons)
- Oxygen = reduced (decrease in oxidation state)
- Oxygen = oxidizing agent

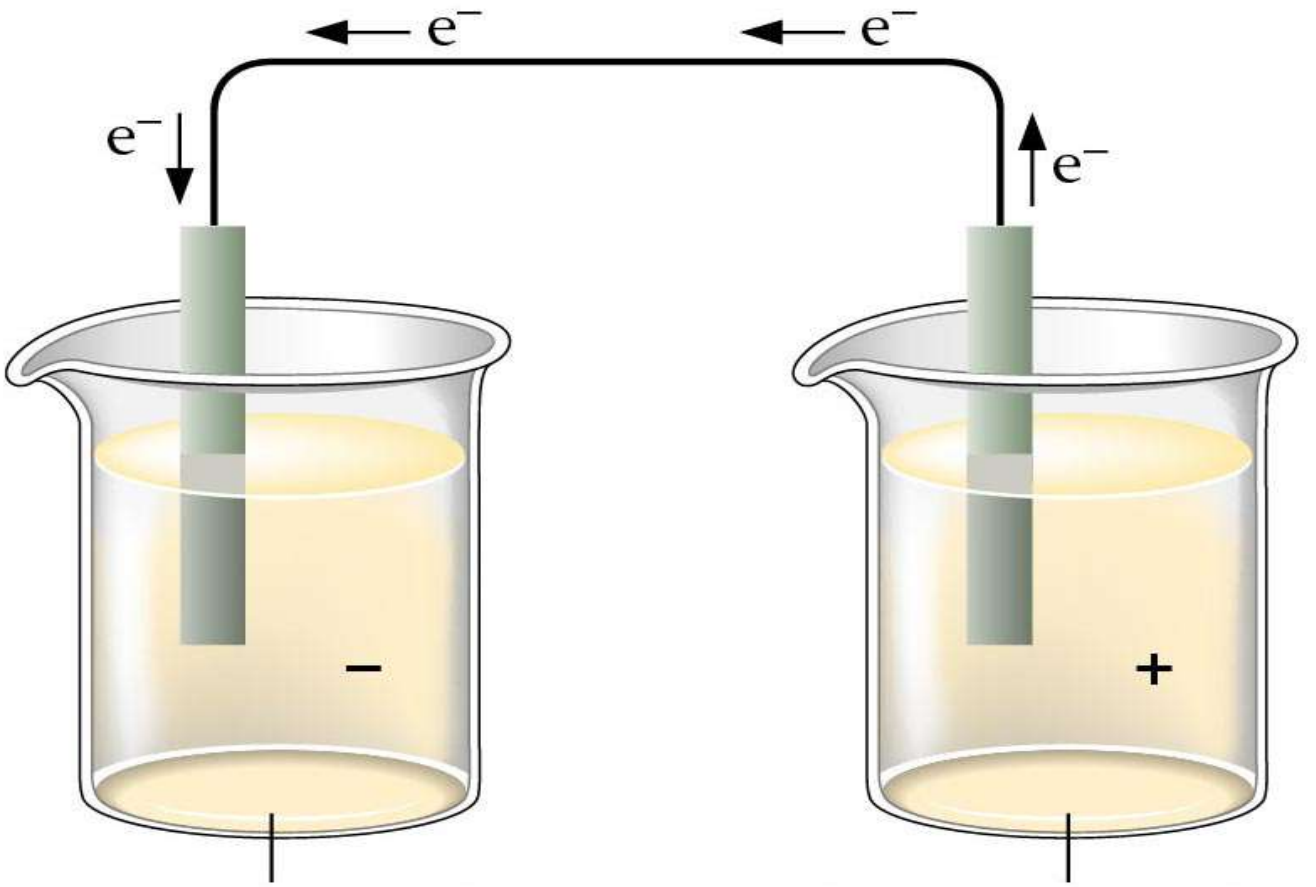
Rules for Assigning Oxidation States

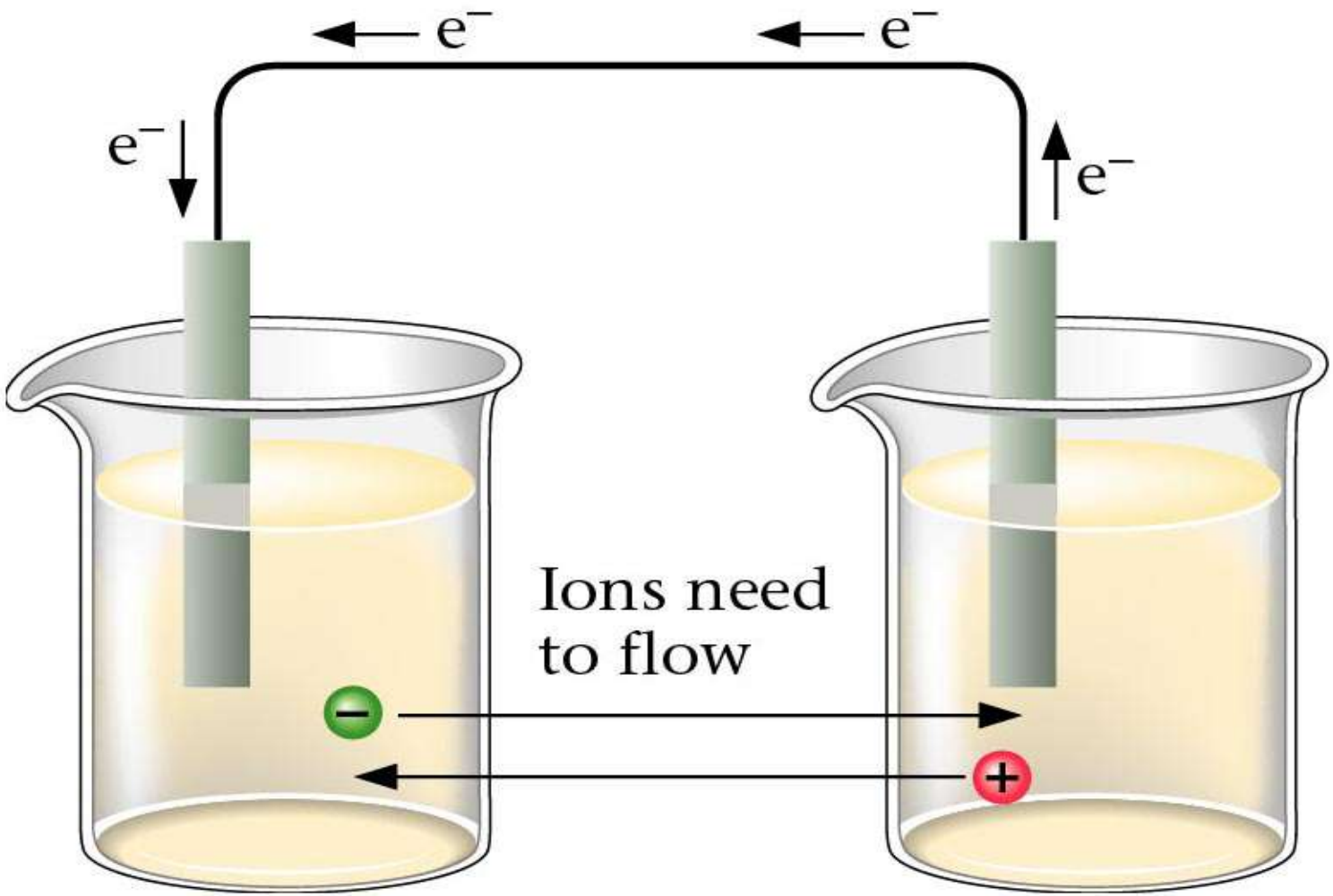
1. The oxidation state of an atom in an uncombined element is 0.
2. The oxidation state of a monatomic ion is the same as its charge.
3. Oxygen is assigned an oxidation state of -2 in most of its covalent compounds. Important exception: peroxides (compounds containing the O_2^{2-} group), in which each oxygen is assigned an oxidation state of -1.
4. In its covalent compounds with nonmetals, hydrogen is assigned an oxidation state of $+1$.
5. In binary compounds, the element with the greater electronegativity is assigned a negative oxidation state equal to its charge as an anion in its ionic compounds.
6. For an electrically neutral compound, the sum of the oxidation states must be zero.
7. For an ionic species, the sum of the oxidation states must equal the overall charge.

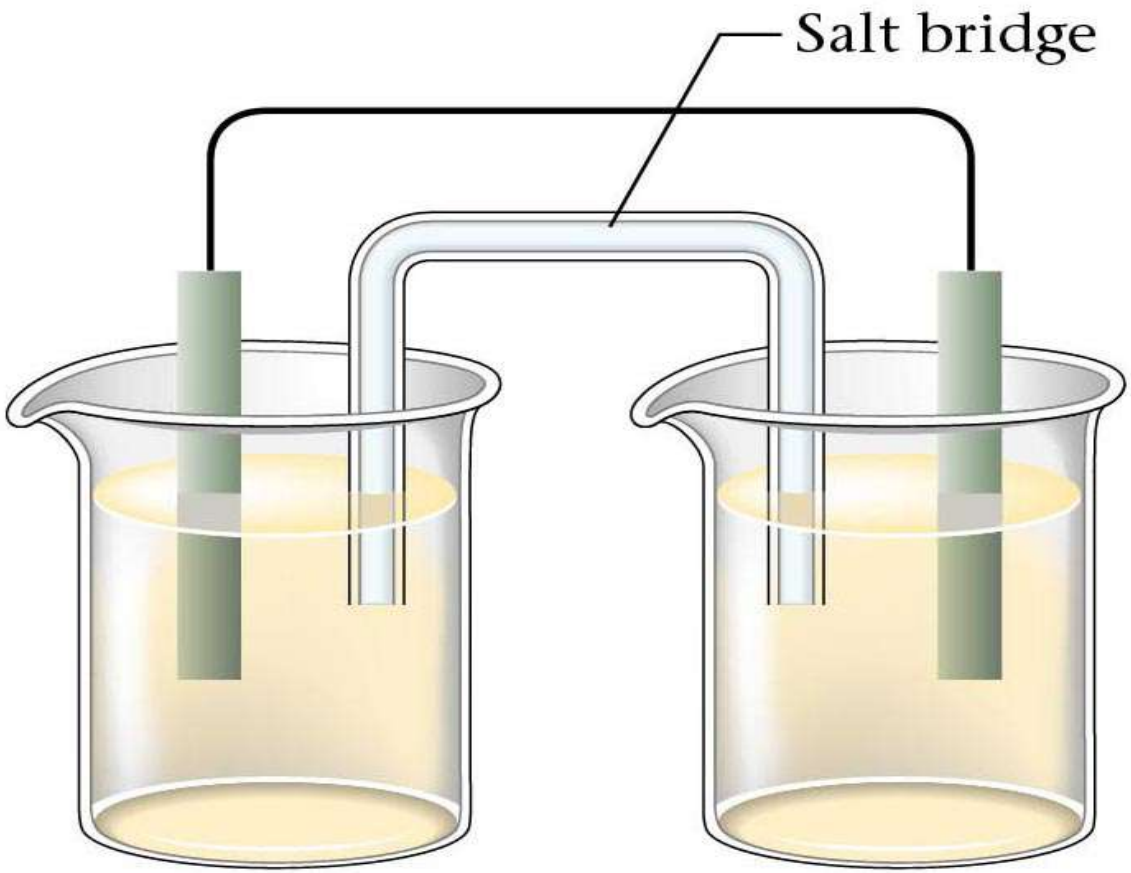
- *The study of the interchange of chemical and electrical energy*
- Battery uses energy from oxidation-reduction reaction to produce energy
- Involves two types of processes
  - Production of an electric current from a chemical reaction
  - Use of electric current to produce a chemical change

- Separate oxidizing agent (electron acceptor) from reducing agent (electron donor)
- Electron transfer must occur through a wire
- Current produced in wire by electron flow can be directed through a device to produce useful work
- Anode = electrode where oxidation occurs
- Cathode = electrode where reduction occurs

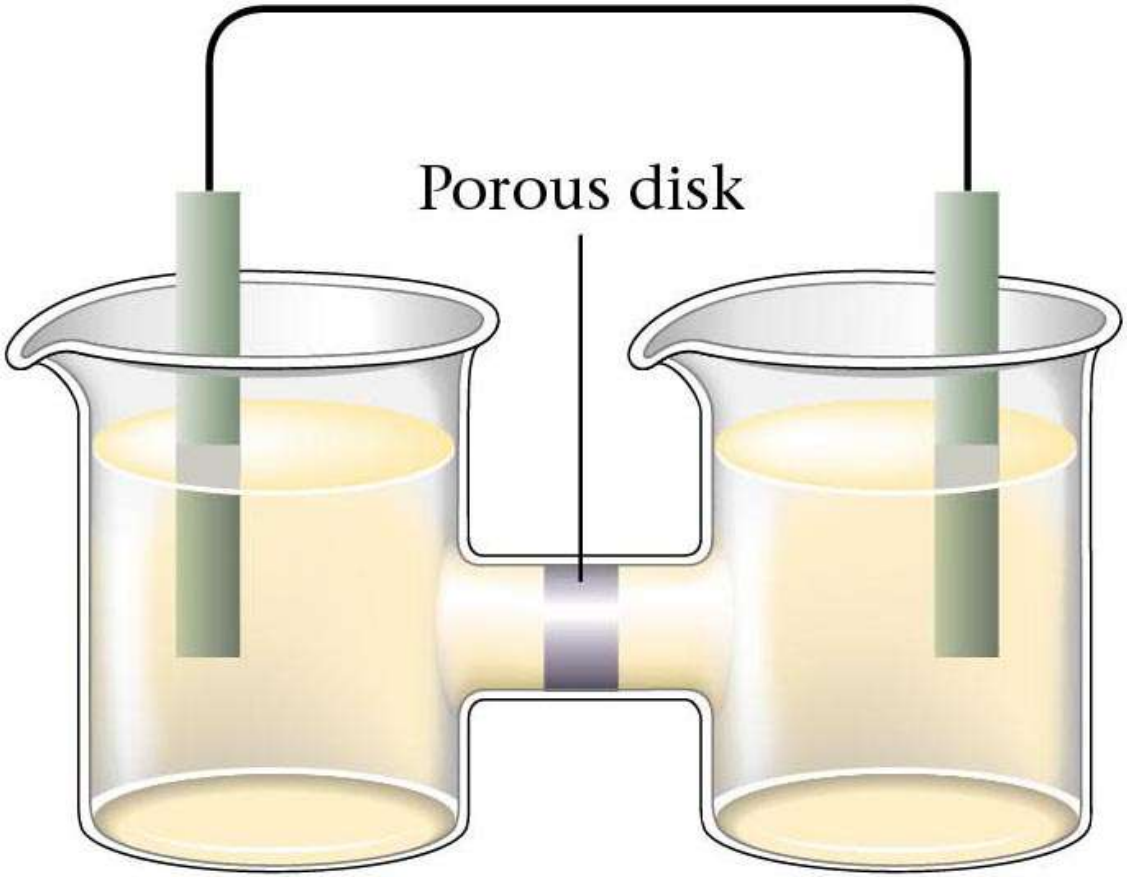

Wire
$MnO_4^-(aq)$
$H^+(aq)$
$Fe^{2+}(aq)$
Oxidizing agent
(electron acceptor)
Reducing agent
(electron donor)


e⁻
e⁻
e⁻
e⁻
−
+
Becomes negative as electrons arrive
Becomes positive as electrons leave


e⁻
e⁻
e⁻
e⁻
Ions need
to flow



(a)



(b)

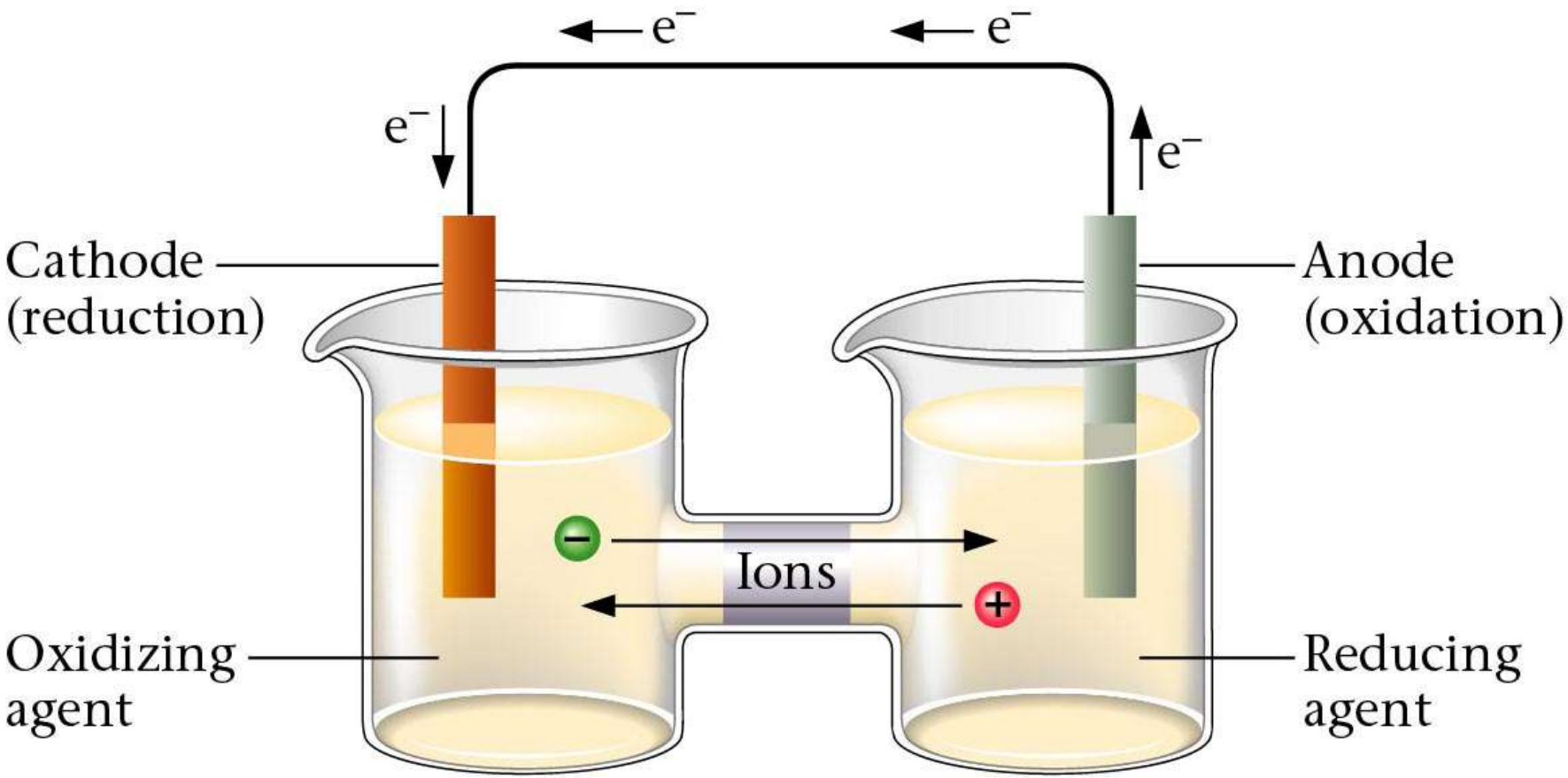

e⁻
e⁻
e⁻
e⁻
Cathode
(reduction)
Anode
(oxidation)
Ions
Oxidizing
agent
Reducing
agent

Figure 18.6: Schematic of one cell of the lead battery.

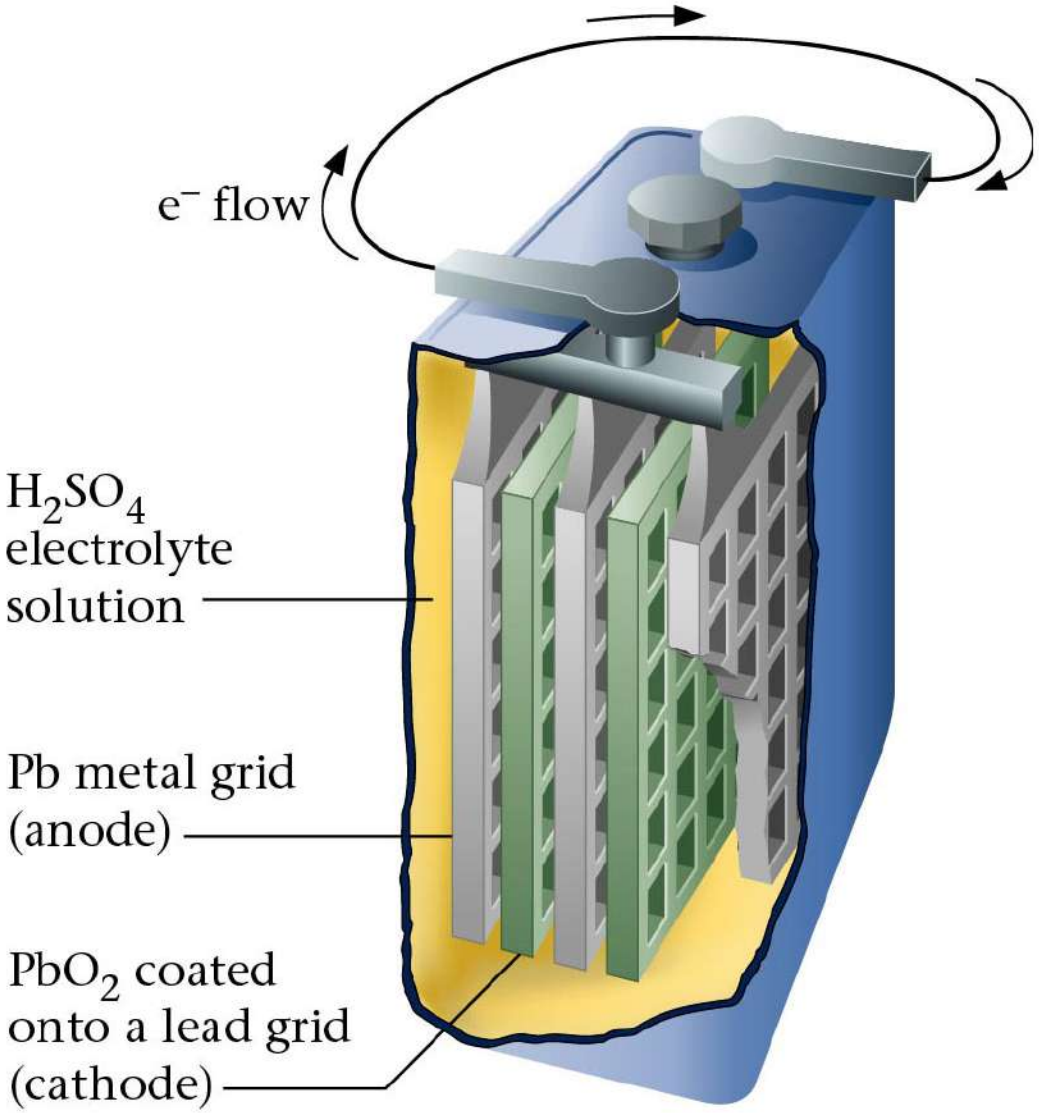
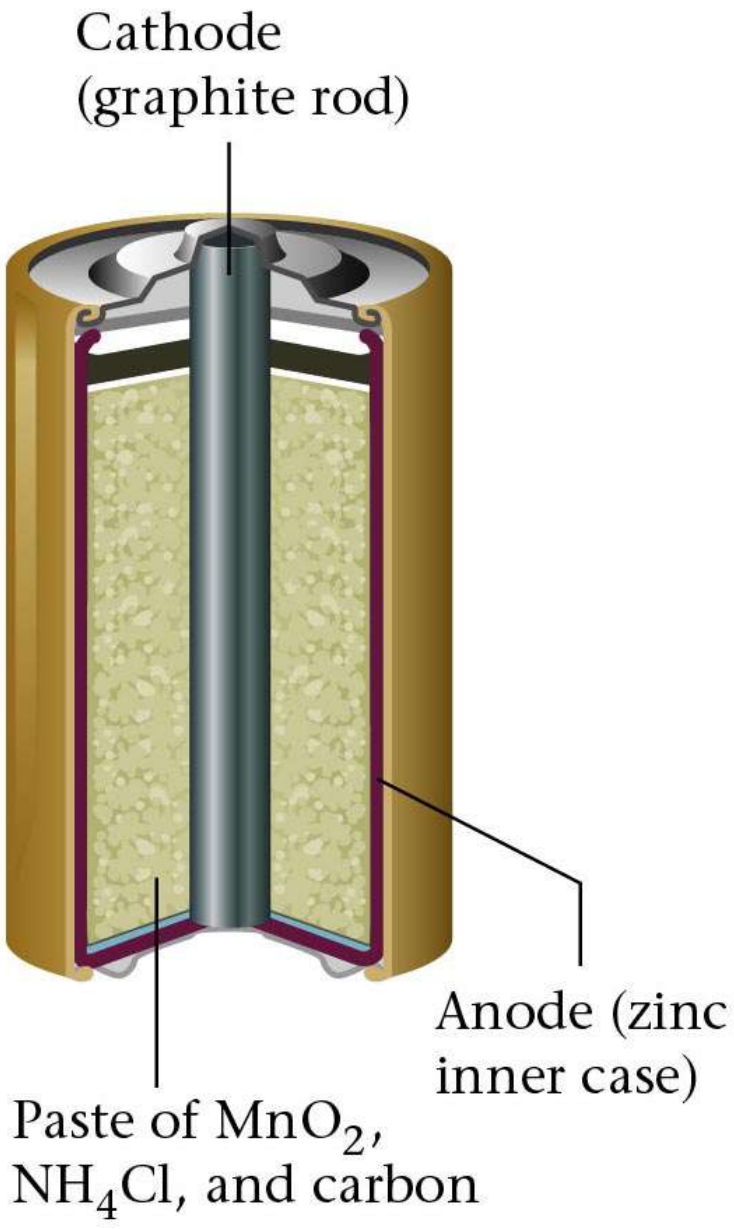
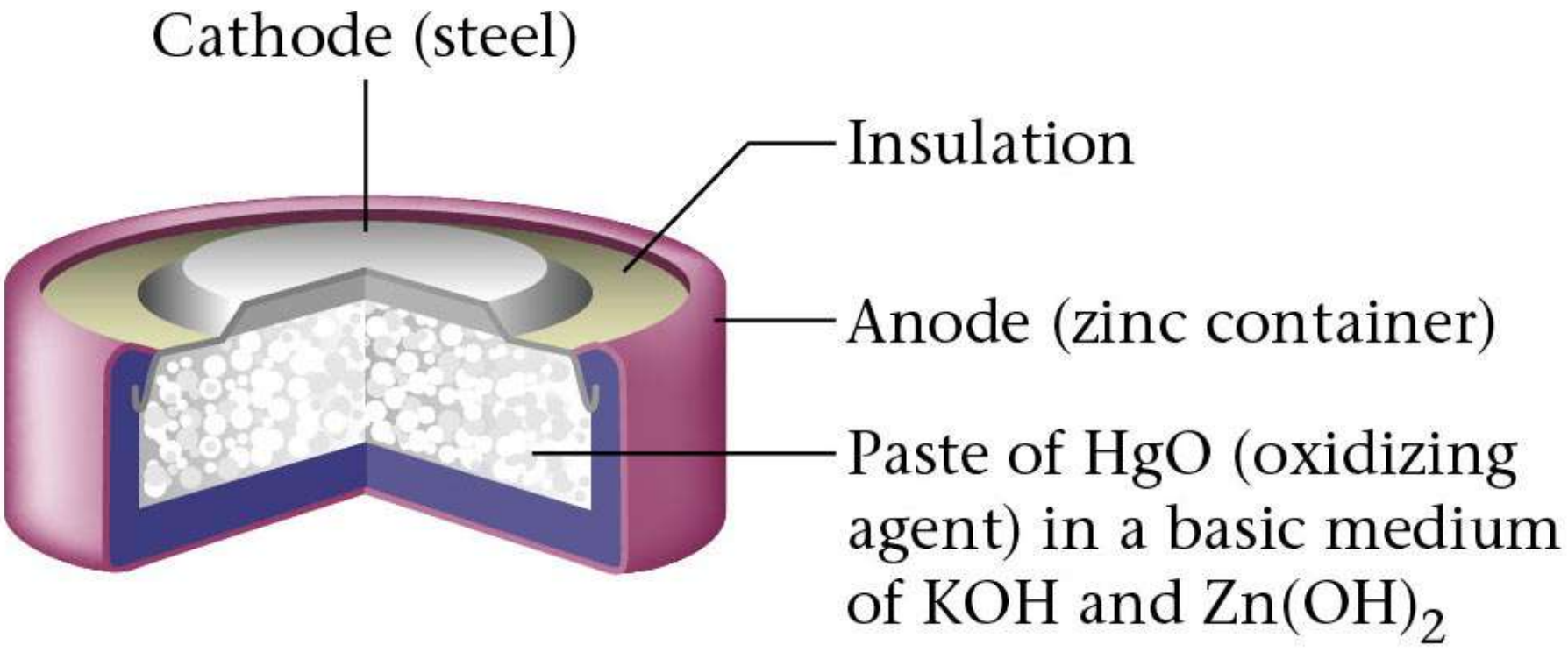


Figure 18.7: A common dry cell battery.




Cathode (steel)
Insulation
Anode (zinc container)
Paste of HgO (oxidizing agent) in a basic medium of KOH and $Zn(OH)_2$

- Electrical energy is used to produce a chemical change
- Force current through a cell to produce a chemical change that would not otherwise occur