Reactivity of Metals and Redox - Notes

Unit 05, Chemistry Themed

What is “ore”?

- “a naturally occurring solid material from which a metal or valuable mineral can be profitably extracted.”

Clarifying Example:

- A soil sample with 2% gold is “ore”
- A soil sample with 0.000002% gold is “dirt”…it costs too much money to get that tiny amount of gold separated.

What conditions make it profitable?

- High value of the metal (gold, platinum, etc.)
- Ease of extraction: highly concentrated, geographically convenient, inexpensive to process

Getting a metal from metal ion - Redox

- Usually, metal-containing ores are metal ions in nature
- Cu^{2+} (low $ value) needs two electrons to become Cu (metal, high $ value)
- Redox reactions can supply these electrons
- “RedOx” stands for Reduction and Oxidation
- Reduction: reduces (lowers)the charge: Example, when Cu^{2+} is reduced to Cu, the charge lowers from +2 → 0
- Oxidation: increases the charge: Example, over time, Cu metal will “oxidize” from Cu to Cu^{2+} when exposed to oxygen. Charge went from 0 → +2
- Typically, exposure to oxygen will oxidize many metals, hence the name

Redox – happens in pairs

- Redox is a process where one substances loses electrons TO another substance
- You cannot just gain electrons from nowhere and you can't lose electrons to nowhere either
- Something is oxidized and something else is reduced, follow the change in charge

Example, rusting of iron:

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

- The charge on Fe goes from 0 to +3 (oxidizes)
- the charge on oxygen goes from 0 to -2 (reduces)
- NOTICE: Fe gains electrons and O loses the electrons that Fe gains!
- Nobody can magically get or lose electrons, except to someone else (no electron wizards)

Redox – definitions

- Remember rusting of iron: $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
  - The charge on Fe goes from 0 to +3 (oxidizes)
  - the charge on oxygen goes from 0 to -2 (reduces)
- You will need to be able to identify which substance is reduced and which is oxidized
- Reduced: the substance whose charge was reduced: Oxygen
- Oxidized: the substance whose charge increased: Iron

You also need to be able to identify the substance that "allowed" oxidation to happen and the substance that "allowed" reduction to happen: the oxidizing agent and the reducing agent

- Oxidizing agent = substance that was reduced, oxygen
  - Remember, nothing can be oxidized unless something else was reduced
- Reducing agent = substance that was oxidized, iron

Mnemonic for gain and loss of electrons

- Remember rusting of iron: $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
- There are several, I like “oil rig”:
  - Oxidation Is Loss of electrons, Reduction Is Gain
- Fe was oxidized, so it lost electrons (and became a cation)
- O was reduced, so it gained electrons (and became an anion)

Redox - half reactions

- Half reactions separate a redox reaction into an oxidizing half reaction and a reduction half reaction
  - Identify charges on reactant and product sides
  - Pick out what was oxidized and reduce and corresponding agents
  - Add electrons to get both half reactions balanced charge-wise
    - Often it helps to write out charges of zero above elements to help figure what is oxidized and what's reduced

Example:

- $ZnO + Ba \rightarrow BaO + Zn$
- Ba atoms were oxidized and were the reducing agent
- Half reaction: $Ba^{0} \rightarrow Ba^{2+} + 2e^{-}$
  - notice reactant and product sides have same total charge
- Half reaction: $Zn^{2+} + 2e^{-} \rightarrow Zn^{0}$

Activity Series - predicting redox

- Metals can be “sacrificial” - provide electrons for reduction of a valuable metal
- Activity series is a list of “electron preference →
- Lithium is highest on the list and oxidizes very easily (rarely found uncombined in nature)
  - Li is “most active”
- Gold is lowest on the list and does not oxidize easily (often found in pure state in nature)
  - Au is “least active”

Activity of Metals

Li
Rb
K
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Ni
Sn
Pb
H_2
Sb
Bi
Cu
Hg
Ag
Pt
Au

Activity Series - example

- Will a reaction take place between these two substances. If so, write a complete balanced equation for this reaction.
- Tin IV fluoride solution and Lead.
  - No reaction takes place. Fluoride is already with the more active metal
- Copper II chloride solution and zinc
  - Zinc is more active than copper, so a reaction will take place.
  - $CuCl_2$ (aq) + Zn (s) → Cu (s) + $ZnCl_2$ (aq)
- How do we know states of matter for products?
  - Cu is a solid, because it's color is black on the periodic table (and common knowledge about copper)
  - + $ZnCl_2$ is aqueous because the Zn ions take the place of the Cu ions

  (later on we learn about solubility tables where we can look this up)

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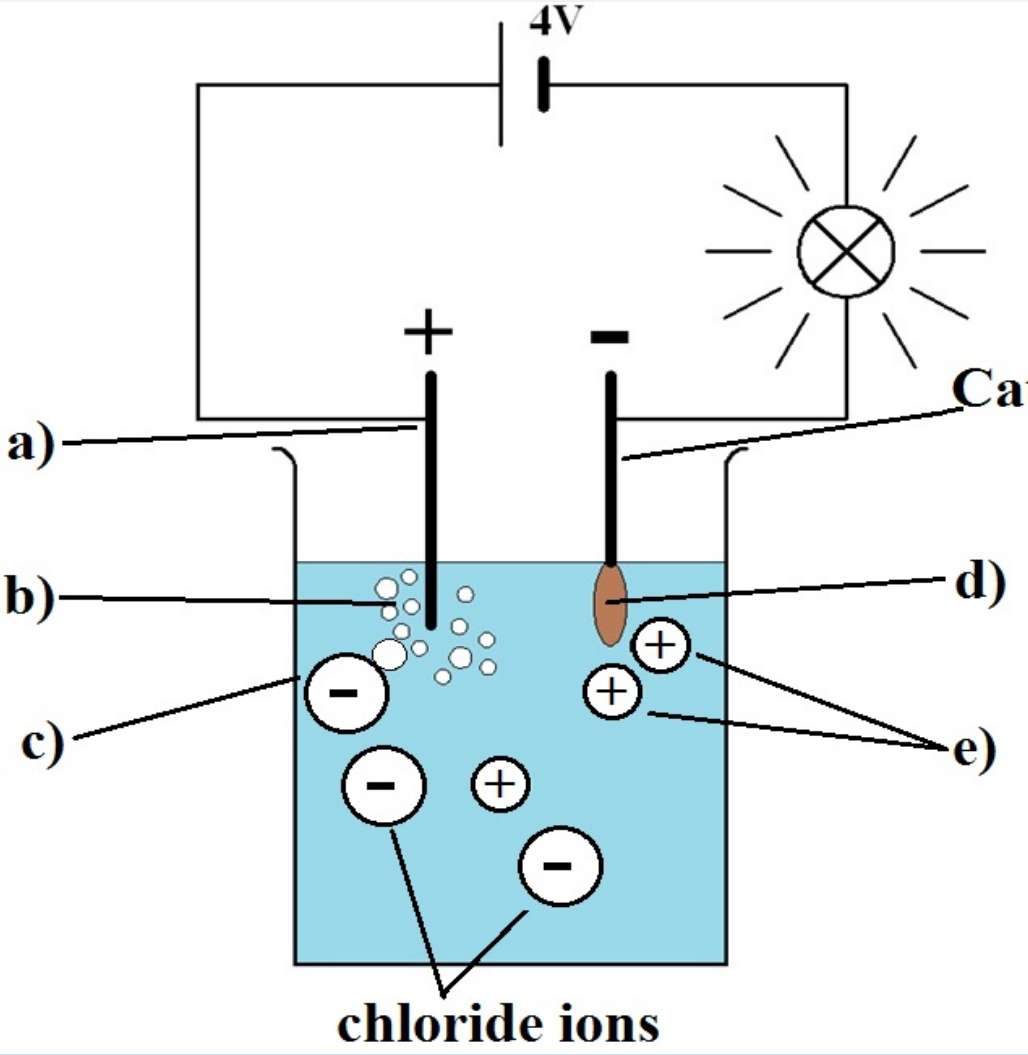
Electrolysis

- Practical definition: Using electricity to make a reaction happen, that wouldn't happen on its own
- Uses charged objects and a battery's ability move electrons in a circuit to force a redox reaction
- Electrolysis is used for plating – "gold plated", "chrome plated", etc. Applies a thin (cheap) outer layer of an expen$ive material
- Electrolysis is our only practical means of producing aluminum
- Electrolysis of water produces O_2 and H_2 gas

Hydrometallurgy vs. Electrometallurgy

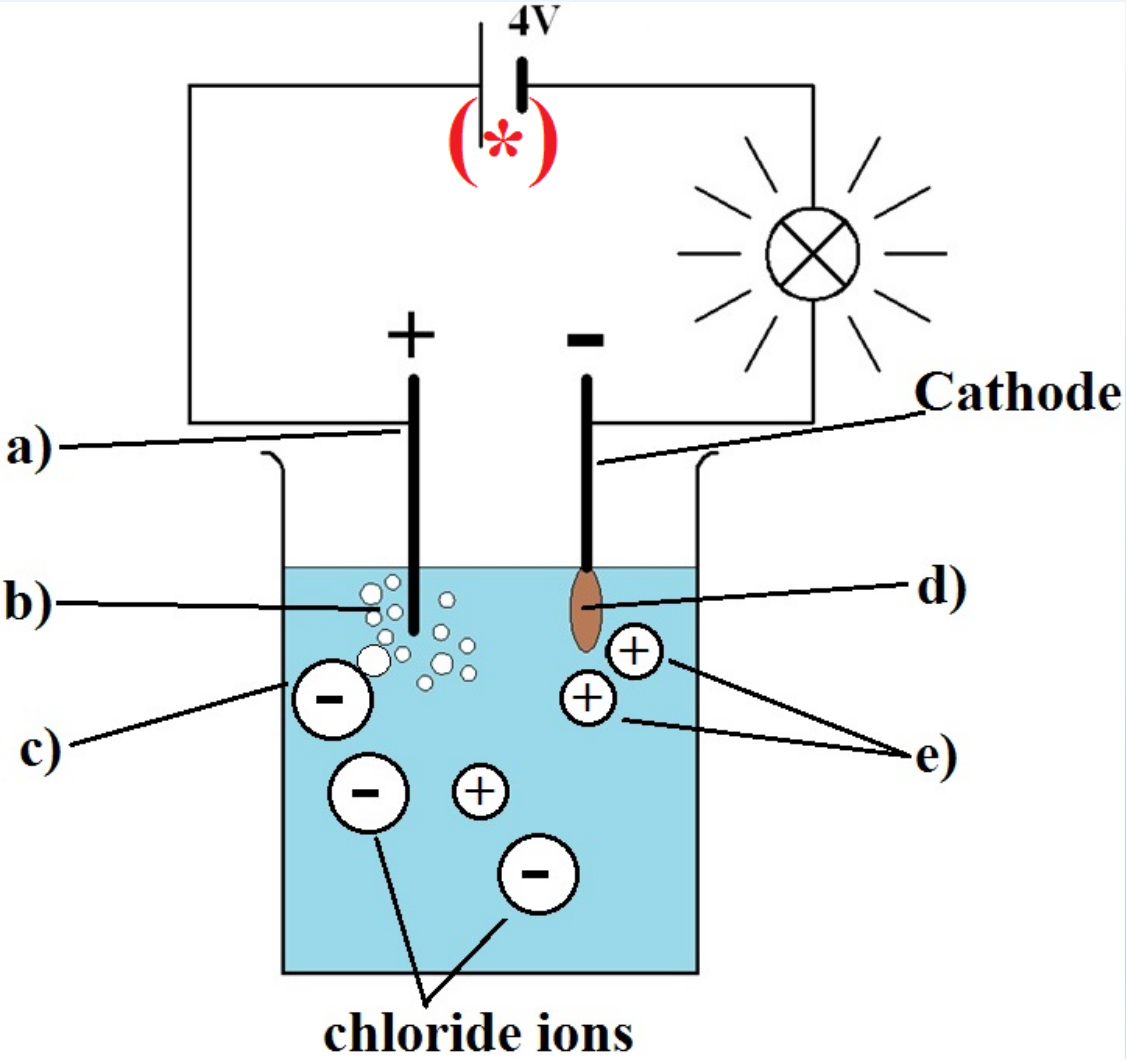
- Metallurgy: The study of extracting metals from their ore – reducing metal ions into valuable elemental metal
- Hydrometallurgy: Metallurgy involving aqueous reactions
  - Example: Many reactions happen much faster when the metal ion to be reduced is in water. Also, dissolving ore into water can concentrate the valuable metal ions from “worthless dirt”
- Electrometallurgy: Metallurgy using electricity
  - Example: electrolysis

Electrolysis: step-by-step example



1. Anode: where anions hang out (pos. terminal)
2. Cathode: where cations hang out (neg. terminal)
3. Switch on: Cl^- ions head to pos. terminal & Cu^{2+} ions head to neg. terminal
4. Electrons on Cl^- ion pulled off by strong positive charge, forms Cl_2 gas. Charge on Cl increases from Cl^- to Cl^0 in Cl_2 gas (oxidized)
5. Battery voltage "pushes" electrons to neg. terminal
6. Cu^{2+} ions attracted to neg. terminal pick up electrons. Copper is reduced to Cu^0 (metal).

Electrolysis: step-by-step example



Note: One thing flows contrary to what you might expect(*). Why do electrons move from positive to negative end of battery?

The battery produces energy (voltage) which "pushes" electrons to the negative end of a battery (which normally repels electrons).