Spontaneous Reactions

Outcomes:

- Develop an activity series experimentally
- Predict spontaneous reactions using an activity series

Redox Review:

NaH
+1 -1

Redox reactions involve the **TRANSFER** of **ELECTRONS** from one reactant to another.

"LEO is the lion, and GER is his roar"

- **LEO** means **LOSING ELECTRONS** *is* **OXIDATION**
- **GER** means **GAINING ELECTRONS** *is* **REDUCTION**

Example:

LEO

+1 -6=0

$$2HNO_3 + 3H_2S \rightarrow 2NO + 3S + 4H_2O$$

+1 +5 -2 +1 -2 +2 -2 0 +1 -2

GER

- The substance ***oxidized*** is: S^{-2}
- The substance ***reduced*** is: N^{+5}
- The ***oxidizing*** agent is: HNO_3
- The ***reducing*** agent is: H_2S

Spontaneous Reactions:

Are reactions that occur **WITHOUT** any **ADDED** **ENERGY**.

Example:

Zinc reacts with HCl spontaneously according to the reaction:

$Zn_{(s)} + 2H^+ \rightarrow Zn^{2+} + H_2$

$2H^+$ ~~$+2Cl^-$~~ Zn^{2+} ~~$2Cl^-$~~

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

0 +1 +2 0

- Is a **SINGLE** **REPLACEMENT** reaction
- Zn is **OXIDIZED**, H is **REDUCED**.
- H must be a strong enough **OXIDIZING** **AGENT** to remove **ELECTRONS** from Zn
- Zn must have a **LOW** **AFFINITY** for electrons so H can **TAKE** its electrons.

If we placed **COPPER** in HCl, **NO** **REACTION** occurs since H is **NOT** a strong enough **OXIDIZING** **AGENT** to take copper's electrons.

Spontaneous Reactions:

Competition for Electrons:

When two substances react:

- The **STRONGEST OXIDIZING AGENT** will **ACCEPT** electrons, becoming **REDUCED**.
- The **STRONGEST REDUCING AGENT** will lose **ELECTRONS**, becoming **OXIDIZED**.

Activity Series (reduction potential chart):

- Through experimentation, we can set up an activity series that lists substances in order of their ability as oxidizing or reducing agents.

- The substances at the **BOTTOM LEFT** (**LIKE F_2**) have a **HIGH AFFINITY** for electrons.
  - Are the **EASIEST** to **REDUCE** (best **GER**)
  - Are the **STRONGEST OXIDIZING AGENTS**

- The substances at the **TOP RIGHT** (**LIKE Li**) have a very **LOW AFFINITY** for electrons.
  - Are the **EASIEST** to **OXIDIZE** (best **LEO**)
  - Are the **STRONGEST REDUCING AGENTS**

→ See reduction potentials chart

The Spontaneity Rule:

In order for two species to react, one must want to gain electrons **MORE** than the other.

"Any species on the left side of the activity series will react spontaneously (oxidize) with any species on the right side above it ."

→ They are "**UP RIGHT SPONTANEOUS**"

Example:

Determine if the following will react spontaneously, if so, write the net reaction.

Compare Sn & H^+ → up right spont.

Tin strips in HCl$_{(aq)}$

$\boxed{Sn} + 2H\cancel{Cl} \rightarrow SnCl_2 + H_2$

$\boxed{H^+}\ \cancel{Cl^-}$ $\quad Sn^{2+}\ \cancel{Cl^-}$

Net: $Sn + 2H^+ \rightarrow Sn^{2+} + H_2$

The Spontaneity Rule:

Example:

Determine if the following will react spontaneously, if so, write the net reaction.

Na^+

$Fe + NaBr$

not Spont

Try this one…

$Pb(OH)_2 + Na$

Pb^{2+}

$Na(s)$

Spont:

$$Pb^{2+} + \cancel{2e^-} \rightarrow Pb(s)$$

$$(2Na(s) \rightarrow \cancel{2e^-} + 2Na^+) \times 2$$

$$Pb^{2+} + 2Na(s) \rightarrow Pb(s) + 2Na^+$$

Predicting an Activity Series:

We can construct an activity series (reduction potential chart) given experimental data

- Look at **ONE REACTION** at a time.
- Determine **LEO** and **GER HALF-REACTIONS** for each
- If **SPONTANEOUS**, the LEO should be **ABOVE** the GER
- **REVERSE** the **LEO** reaction (all reactions need to be **REDUCTION** reactions)

Example:

Given the following experimental data, construct an activity series.

$$Co^{2+} + In_{(s)} \rightarrow Co_{(s)} + In^{2+}$$

$$Cu^{2+} + Co_{(s)} \rightarrow Cu_{(s)} + Co^{2+}$$

$$Co^{2+} + Pd_{(s)} \rightarrow \text{no reaction}$$

$In^{2+} + 2e^- \rightarrow In(s)$

~~Pd~~

$Co^{2+} + 2e^- \rightarrow Co(s)$

~~Pd~~

$Cu^{2+} + 2e^- \rightarrow Cu(s)$

$Pd^{2+} + 2e^- \rightarrow Pd$

Predicting an Activity Series:

Try this one…

Construct an activity series given the following reactions.

$Zn^{2+} + Al_{(s)} \rightarrow Zn_{(s)} + Al^{3+}$ ✓

$Ag^{+} + Cd_{(s)} \rightarrow Ag_{(s)} + Cd^{2+}$

$Zn^{2+} + Cd_{(s)} \rightarrow$ ***no reaction*** ✓

$Al^{3+} + 3e^{-} \rightarrow Al(s)$

$Zn^{2+} + 2e^{-} \rightarrow Zn(s)$

$Cd^{2+} + 2e^{-} \rightarrow Cd(s)$

$Ag^{+} + 1e^{-} \rightarrow Ag(s)$