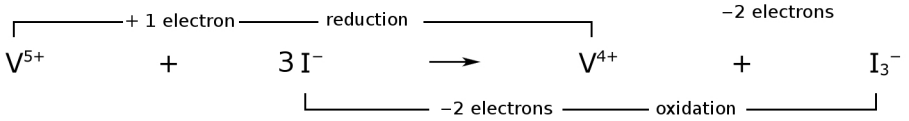
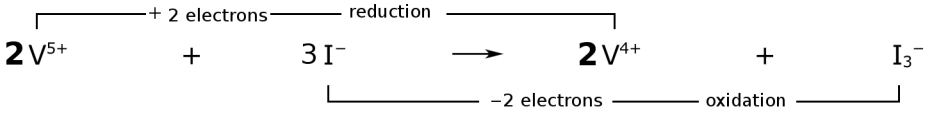
1. Assign the oxidation number to each species and identify the reduction and oxidation reaction. Any chemical that keeps the same oxidation state is not involved in the redox process (spectator ion).

2. Use "tie lines" to connect the corresponding species together and balance the masses of each chemical. Count the number of electrons exchanged.



3. Multiply each reaction by a coefficient so that the number of electrons in both reactions is the same.



Free electrons are not allowed in balanced redox reactions. However, it is possible to obtain "free charges" (positive or negative ions) on both sides provided they balance each other.

This equation is called a "net ionic equation" since it is written without the presence of spectator ions. It makes the reaction easier to understand. Spectator ions are present to neutralize the charges (electroneutrality), however, they are not directly involved in the chemical reaction and they can be replaced by another non reactive and stable ion.

Balanced redox reaction:

- Masses are balanced
- Charges are balanced (same on both sides, can be ≠ 0)
- No free electron.

Balance the following oxidation-reduction reactions

a. $H^+ + Zn(s) \longrightarrow Zn^{2+} + H_2(g)$ (Volta 1799 using metallic Cu or Ag cathode)

b. $Cu(s) + Ag^+ \longrightarrow Ag(s) + Cu^{2+}$

c. $Ce^{4+} + Sn^{2+} \longrightarrow Ce^{3+} + Sn^{4+}$

d. $Sn^{4+} + Al(s) \longrightarrow Sn^{2+} + Al^{3+}$

e. $Fe^{2+} + Br_2(\ell) \longrightarrow Fe^{3+} + Br^-$

f. $Al + FeO \longrightarrow Al_2O_3 + Fe$

g. $Ga^{3+} + I^- \longrightarrow Ga + I_3^-$

h. $Cu^{2+} + Cl^- \longrightarrow CuCl(s) + Cl_2(g)$

Answers:

a. $2H^+ + Zn(s) \longrightarrow Zn^{2+} + H_2(g)$

b. $Cu(s) + 2Ag^+ \longrightarrow 2Ag(s) + Cu^{2+}$

c. $2Ce^{4+} + Sn^{2+} \longrightarrow 2Ce^{3+} + Sn^{4+}$

d. $3Sn^{4+} + 2Al(s) \longrightarrow 3Sn^{2+} + 2Al^{3+}$

e. $2Fe^{2+} + Br_2(\ell) \longrightarrow 2Fe^{3+} + 2Br^-$

f. $2Al + 3FeO \longrightarrow Al_2O_3 + 3Fe$

g. $2Ga^{3+} + 9I^- \longrightarrow 2Ga + 3I_3^-$

h. $2Cu^{2+} + 4Cl^- \longrightarrow 2CuCl(s) + Cl_2(g)$