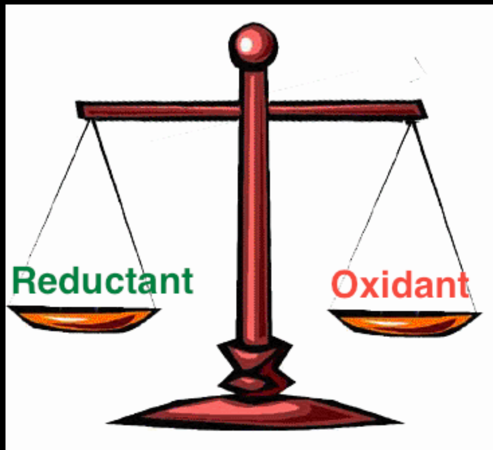
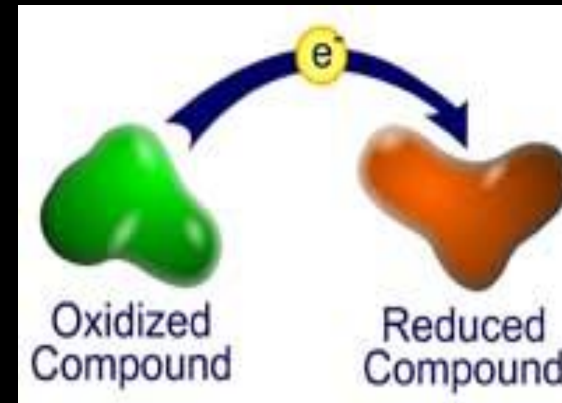




Redox Reactions

oxidation

$$Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$$

reduction

LPT

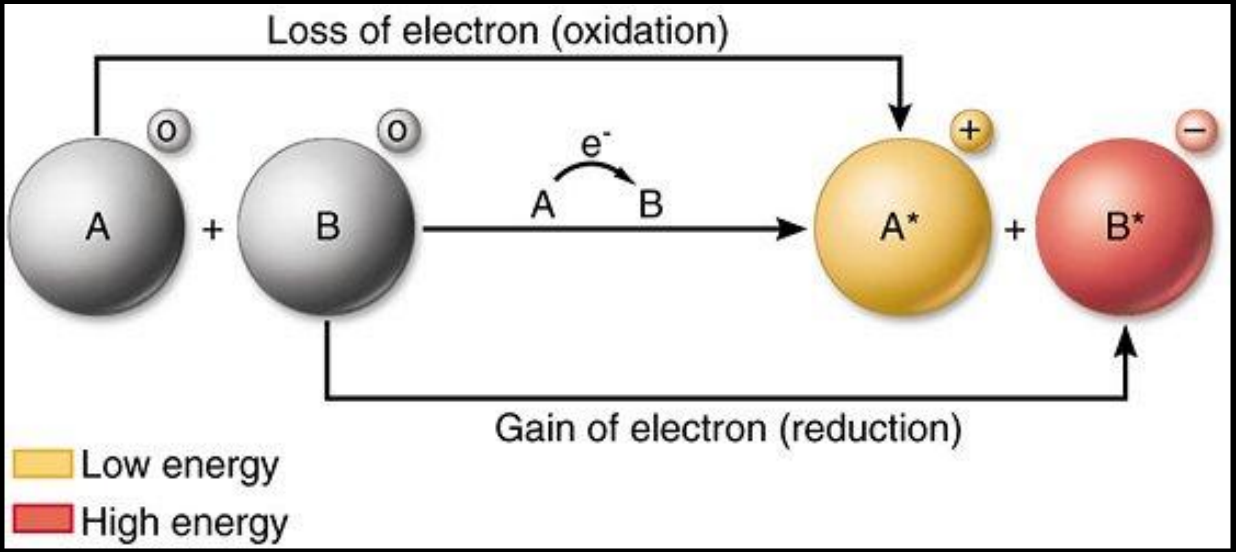
Redox Reactions

Electron transfer between atoms:

loss of electron = oxidation

gain of electron = reduction

simultaneous electron transfer = redox

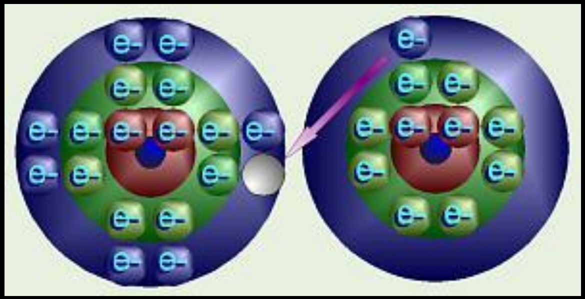


Historically, from studies of reactions of metals with oxygen

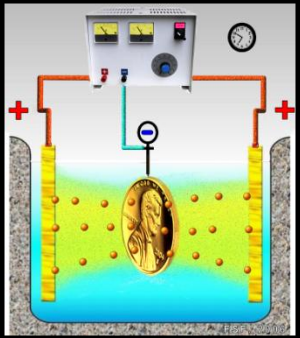
LPT

Redox Reaction Examples:

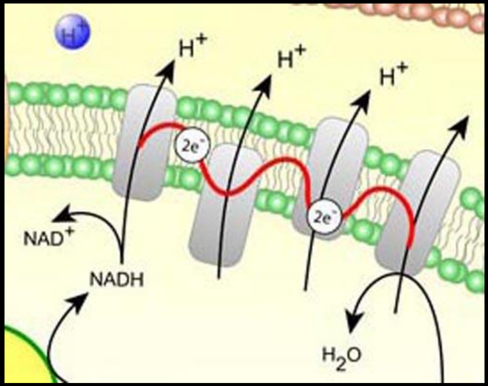
Batteries



Ionic Compounds



Electroplating



Electron Transport

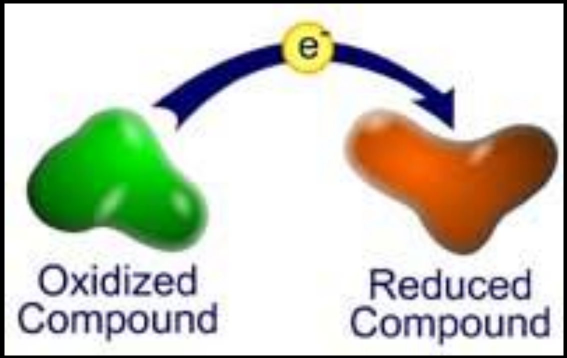
Corrosion

LPT

Leo, the Lion, Roars

Loses Electrons Oxidation

Leo Says GER (Gains Electrons Reduction)

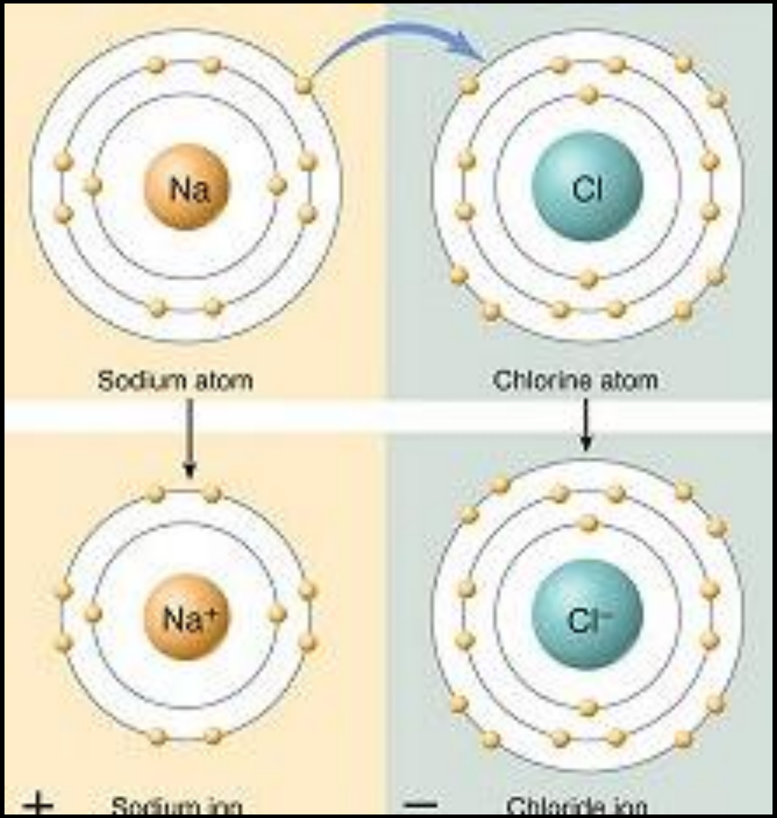


Redox Teminology

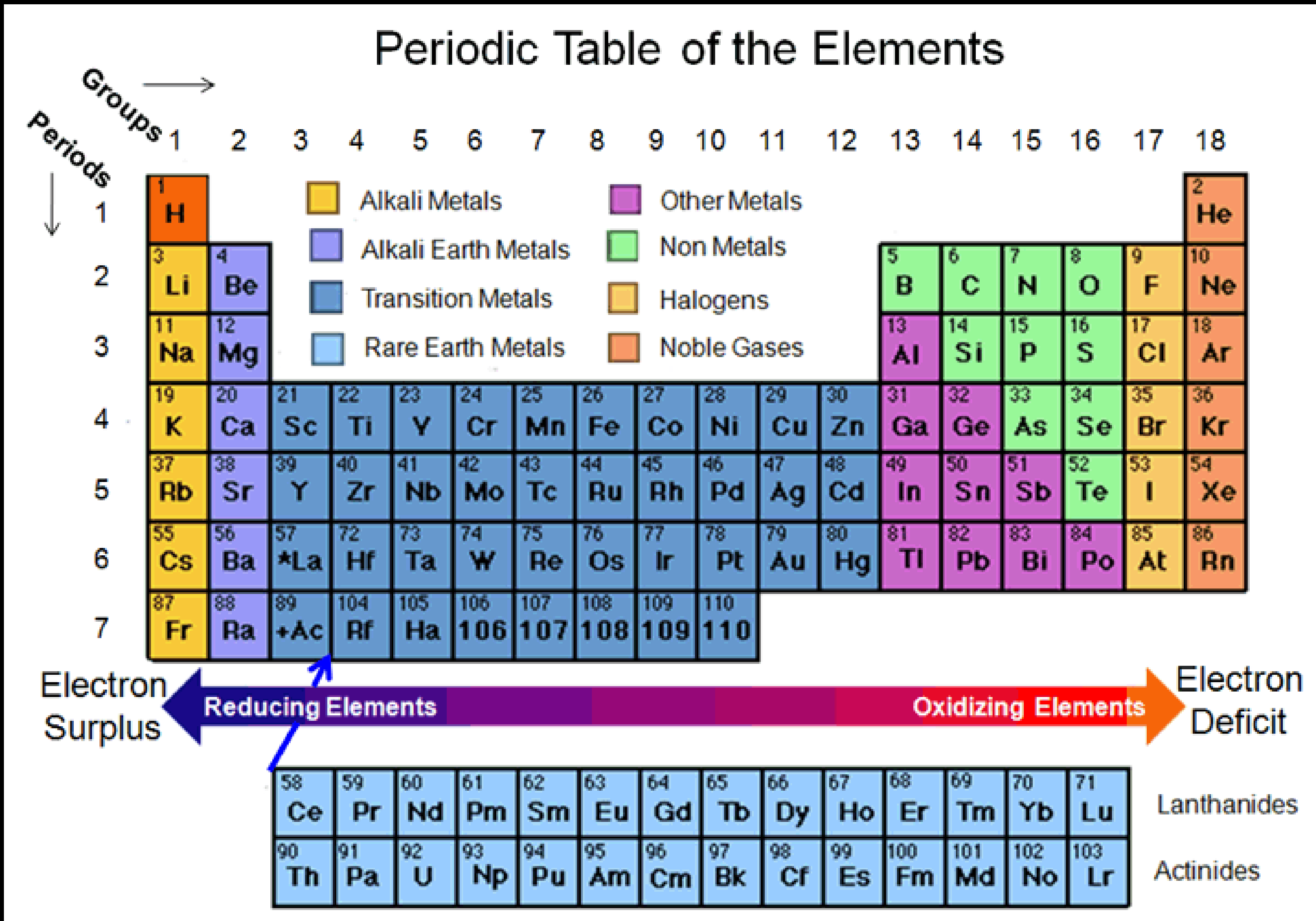
Object Losing Electrons:
is oxidized
is reducing agent

Object Gaining Electrons:
is reduced
is oxidizing agent

Reducing Agent
Oxidized



Oxidizing Agent
Reduced



Periodic Table of the Elements
Groups
Periods
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Alkali Metals
Alkali Earth Metals
Transition Metals
Rare Earth Metals
Other Metals
Non Metals
Halogens
Noble Gases
1 H 2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 57 *La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 89 +Ac 104 Rf 105 Ha 106 106 107 107 108 108 109 109 110 110
Electron Surplus
Reducing Elements
Oxidizing Elements
Electron Deficit
58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
Lanthanides
90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr
Actinides

LPT

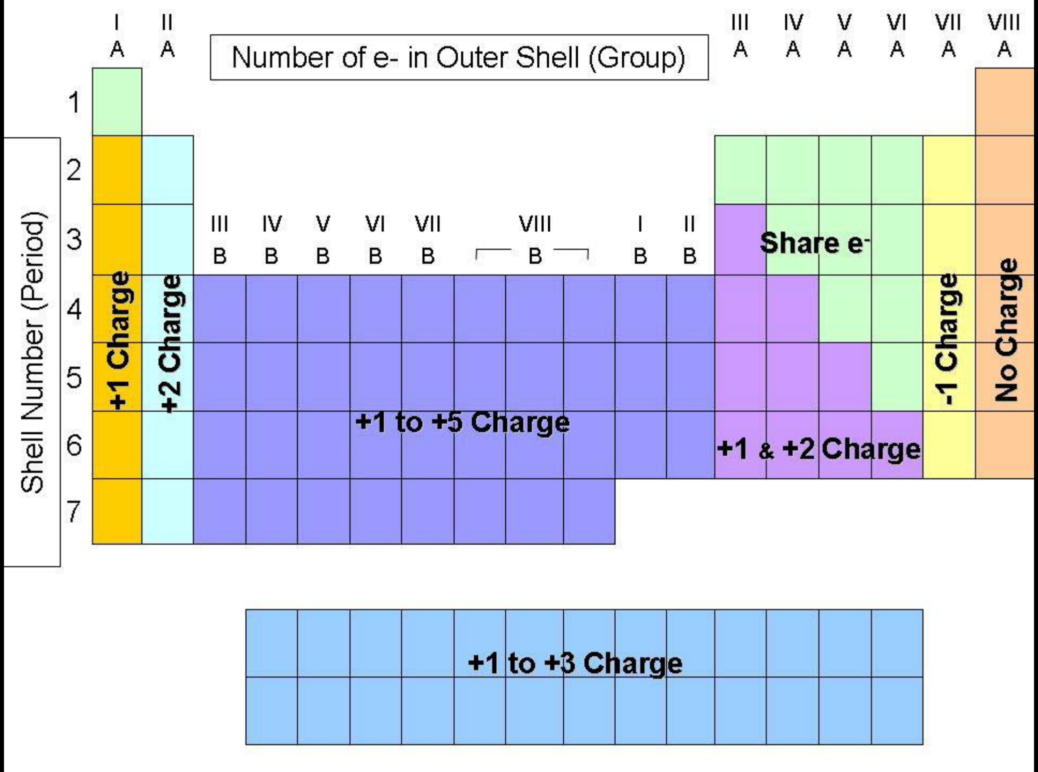
Oxidation Numbers

Real or hypothetical charge born by each atom

Pure Element: 0

Representative Elements: Family (Column) Charge

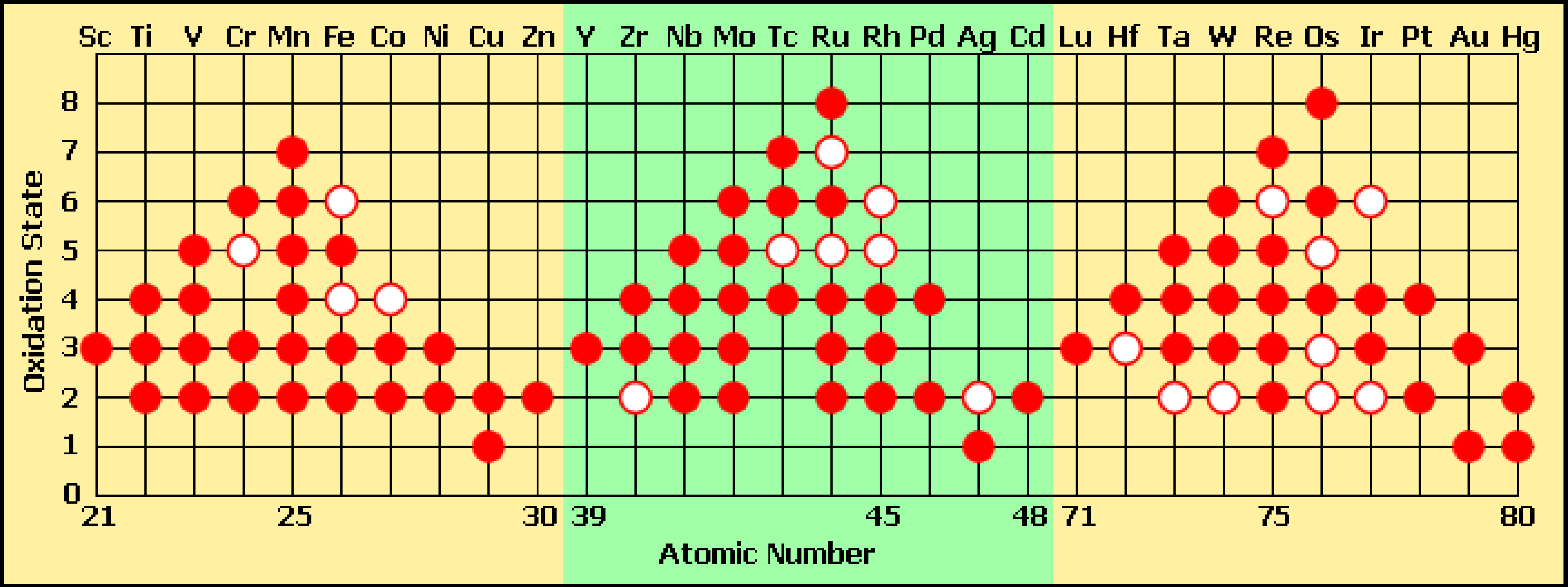
Transition Elements: Assigned to keep compound = 0



LPT

Oxidation Numbers

Transition Elements Have multiple Possible Charges



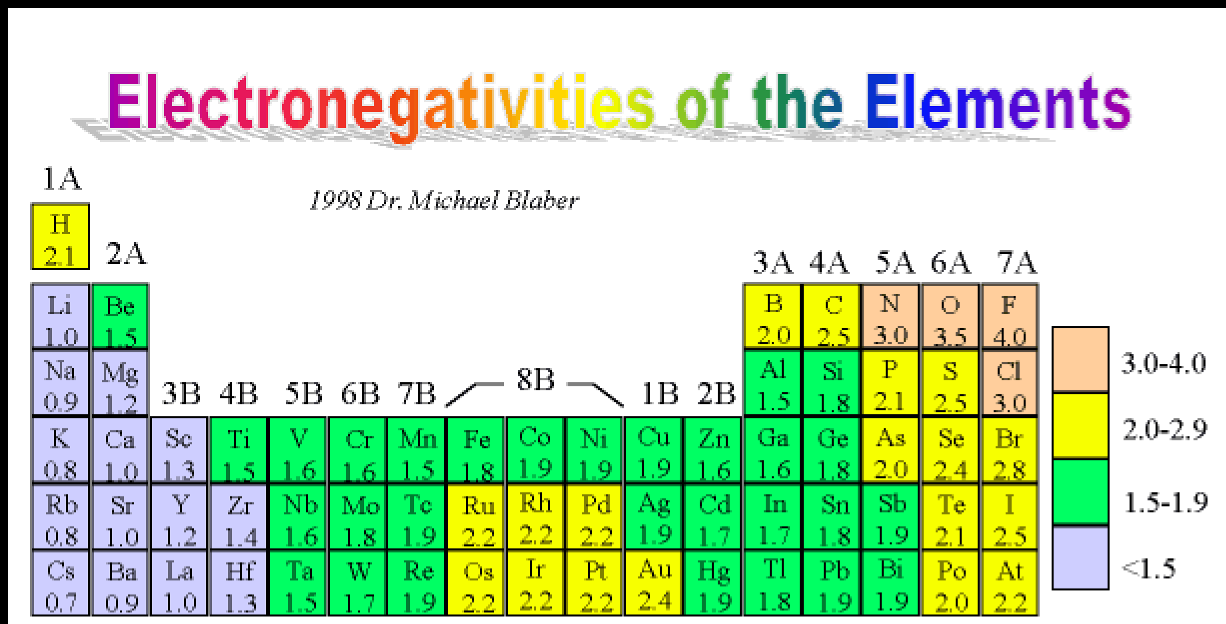
Solid Circle = commonly found   Open Circle = less common

LPT

Assigning Oxidation Numbers

Oxidation Numbers are means of tracking electron flow

Most Electronegative atom assumed to have both e⁻ of shared pair



Example: O-H bond ➔ Oxygen more electronegative

Oxygen has both e⁻ of the shared pair associated with the O-H bond

LPT

Assigning Oxidation Numbers (O.N.)

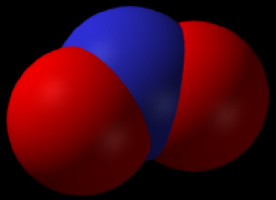
All shared electrons assigned to the most electronegative atom

No shared electrons assigned to the least electronegative atom

All unshared valence electrons assigned to both atoms

Oxidation Number:

(# valence e^-) – (# shared e^- + # unshared e^-)



Example: NO_2

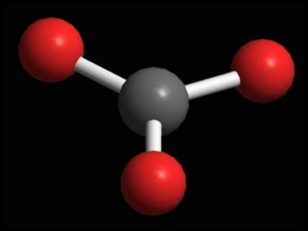
2 NO bonds

Oxygen more electronegative ➔ it gets unshared e^- for -2 O.N.

Nitrogen must balance 2 x -2 = -4 ➔ + 4

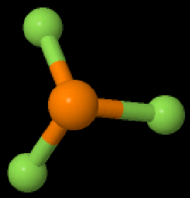
Assigning Oxidation Numbers (O.N.)

For Charged Species, O.N. assigned to add to total charge on the ion



Example: CO_3^{2-}

Oxygen = 3 x - 2 = - 6
Carbon = + 4
Check: - 6 = 4 = - 2



Example: PF_3

Fluorine = 3 x - 1 = - 3
Phosphorus = + 3
Check: 0 = 3 - 3

LPT

Redox Reaction

$CH_{4\,(g)} + 2\ O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\ H_2O_{\,(g)}$

C: oxidation state changes from - 4 to + 4

O: oxidation state changes from 0 to - 2

H: oxidation state does not change

Terms:

C: oxidized (Oxidation state increases)

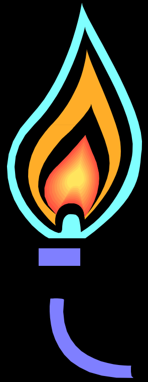
Oxidation: $CH_4 \rightarrow CO_2$

Reducing Agent (CH_4)

O: reduced (Oxidation state decreases)

Reduction: $O_2 \rightarrow H_2O$

Oxidizing Agent (O_2)



Redox Reaction

$$2\,Al_{(s)} + 3\,I_{2\,(s)} \rightarrow 2\,AlI_{3\,(s)}$$

Al: oxidation state changes from 0 to +3

I: oxidation state changes from 0 to - 1

Terms:

Al: oxidized (Oxidation state increases)

Oxidation: $Al \rightarrow Al^{3+}$

Reducing Agent (Al)

I: reduced (Oxidation state decreases)

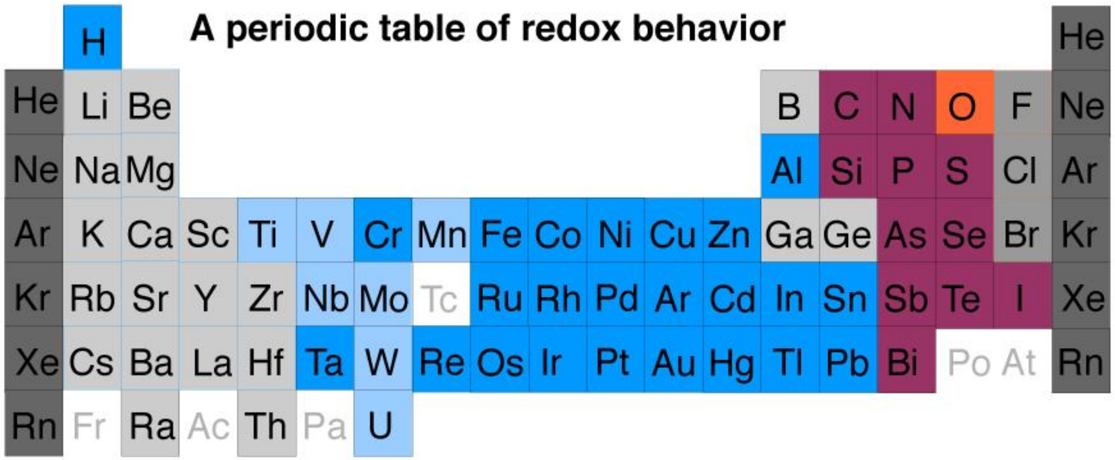
Reduction: $I_2 \rightarrow I^-$

Oxidizing Agent (I_2)

LPT

Railsback's *Some Fundamentals of Mineralogy and Geochemistry*

A periodic table of redox behavior



Atoms with positive charge (i.e. those with more electrons than protons) are chemically oxidized relative to their elemental condition.

Atoms with negative charge (i.e. those with more electrons than protons) are chemically reduced relative to their elemental condition.

Elements that exist in nature in just one positively charged state

For example, K^+ and Ca^{2+}.

Elements that exist in nature in more than one positively charged state

For example, Mo^{6+}, Mo^{4+}, & Mo^{2+}.

Elements that exist in nature in elemental (uncharged) form and in at least one positively charged state

For example, Fe^{3+}, Fe^{2+}, & Fe.

Elements that exist in nature in states ranging from positively charged to negatively charged

For example, S^{6+} to S^{2-}.

Elements that exist in nature in elemental (uncharged) form and in at least one negatively charged state

For example, O_2 to O^{2-}.

Elements that exist in nature in just one negatively charged state

For example, F^- and Cl^-.

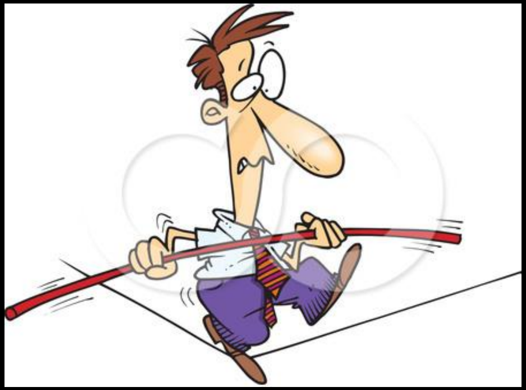
Elements that exist in nature in no charged state at all (the noble gases)

Elements with no redox chemistry in nature

Elements with at least some redox chemistry in nature

(and thus with multiple forms that can't be shown on a one-cell-per-element table like this one, but shown in their multiple forms on the Earth Scientist's Periodic Table of the Elements and Their Ions)

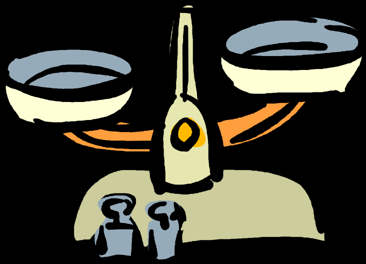
Elements with no redox chemistry in nature



Balancing RedOx Reactions

Half-Reactions

Account for electron transfers



Ion-Electron Method

Balancing Acidic / Neutral Half-Reactions

Separate reaction into two half-reactions: Oxidation & Reduction

For each half-reaction:

- Balance all elements except hydrogen and oxygen
- Balance oxygen with water
  - add one water for each excess oxygen to the other side
- Balance hydrogen with H^+
- Balance the charge with electrons

If needed, multiply one or both half-reactions to balance electrons

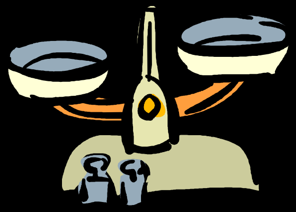
Add the two half-reactions together

Cancel chemical identities occurring on both sides

Check elemental balance

LPT

Balancing Example:



$$HNO_3 + H_2S \rightarrow NO + S + H_2O$$

Reduction: $NO_3^- \rightarrow NO$ (N changes from +5 to +2)

Oxidation: $H_2S \rightarrow S$ (S changes from -2 to 0)

Balancing Elements Reduction: $4\,H^+ + NO_3^= \rightarrow NO + 2\,H_2O$

Balancing Elements Oxidation: $H_2S \rightarrow S + 2\,H^+$

Balancing Charge Reduction: $3\,e^- + 4\,H^+ + NO_3^= \rightarrow NO + 2\,H_2O$

Balancing Charge Oxidation: $H_2S \rightarrow S + 2\,H^+ + 2\,e^-$

Equating Electrons Reduction: $6\,e^- + 8\,H^+ + 2\,NO_3^= \rightarrow 2\,NO + 4\,H_2O$

Equating Electrons Oxidation: $3\,H_2S \rightarrow 3\,S + 6\,H^+ + 6\,e^-$

Summing (canceling electrons):

$$8\,H^+ + 2\,NO_3^= + 3\,H_2S \rightarrow 2\,NO + 4\,H_2O + 3\,S + 6\,H^+$$

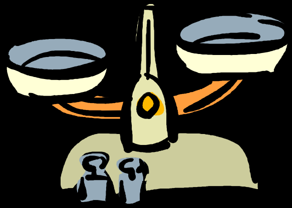
Canceling identical chemical entities:

$$2\,H^+ + 2\,NO_3^= + 3\,H_2S \rightarrow 2\,NO + 4\,H_2O + 3\,S$$

Adding Counter Ions: $2\,HNO_3 + 3\,H_2S \rightarrow 2\,NO + 4\,H_2O + 3\,S$

LPT

Balancing Example:



$$Pb + PbO_2 + H_2SO_4 \rightarrow PbSO_4 + H_2O$$

Reduction: $PbO_2 \rightarrow Pb^{2+}$ (Pb changes from +4 to +2)

Oxidation: $Pb \rightarrow Pb^{2+}$ (Pb changes from 0 to +2)

Balancing Elements Reduction: $4\ H^+ + PbO_2 \rightarrow Pb + 2\ H_2O$

Balancing Elements Oxidation: $Pb \rightarrow Pb^{2+}$

Balancing Charge Reduction: $4\ e^- + 4\ H^+ + PbO_2 \rightarrow Pb + 2\ H_2O$

Balancing Charge Oxidation: $Pb \rightarrow Pb^{2+} + 2\ e^-$

Equating Electrons Reduction: $4\ e^- + 4\ H^+ + PbO_2 \rightarrow Pb + 2\ H_2O$

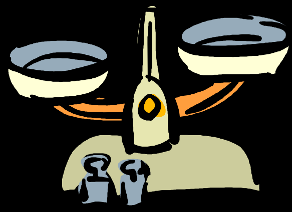
Equating Electrons Oxidation: $2\ Pb \rightarrow 2\ Pb^{2+} + 4\ e^-$

Summing (canceling electrons): $4\ H^+ + 2\ Pb + PbO_2 \rightarrow Pb + 2\ Pb^{2+} + 2\ H_2O$

Canceling identical chemical entities: $4\ H^+ + Pb + PbO_2 \rightarrow 2\ Pb^{2+} + 2\ H_2O$

Adding Counter Ions: $Pb + PbO_2 + 2\ H_2SO_4 \rightarrow 2\ PbSO_4 + 2\ H_2O$

Balancing Example:



$$CH_3OH_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} \longrightarrow CH_2O_{(l)} + Cr^{3+}{}_{(aq)}$$

Reduction: $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ (Cr changes from +6 to +3)

Oxidation: $CH_3OH \rightarrow CH_2O$ (C changes from -2 to 0)

Balancing Elements Reduction: $14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

Balancing Elements Oxidation: $CH_3OH \rightarrow CH_2O + 2\ H^+$

Balancing Charge Reduction: $6\ e^- + 14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

Balancing Charge Oxidation: $CH_3OH \rightarrow CH_2O + 2\ H^+ + 2e^-$

Equating Electrons Reduction: $6\ e^- + 14\ H^+ + Cr_2O_7^{2-} \rightarrow 2\ Cr^{3+} + 7\ H_2O$

Equating Electrons Oxidation: $3\ CH_3OH \rightarrow 3\ CH_2O + 6\ H^+ + 6\ e^-$

Summing (canceling electrons):

$$14\ H^+ + Cr_2O_7^{2-} + 3\ CH_3OH \rightarrow 2\ Cr^{3+} + 7\ H_2O + 3\ CH_2O + 6\ H^+$$

Canceling identical chemical entities:

$$Cr_2O_7^{2-} + 3\ CH_3OH + 8\ H^+ \rightarrow 2\ Cr^{3+} + 7\ H_2O + 3\ CH_2O$$

Adding Counter Ions:

$$K_2Cr_2O_7 + 3\ CH_3OH + 4\ H_2SO_4 \rightarrow Cr_2(SO_4)_3 + K_2SO_4\ 7\ H_2O + 3\ CH_2O$$

LPT

Balancing Basic Half-Reactions

Separate reaction into two half-reactions: Oxidation & Reduction

For each half-reaction:

- Balance all elements except hydrogen and oxygen
- Balance oxygen with water
    - add one water for each excess to same side
    - add 2 OH^- to the other side
- Balance hydrogen
    - add one OH^- on side with excess hydrogen
    - add one water to the other side (If needed)
- Balance the charge with electrons

If needed, multiply one or both half-reactions to balance electrons

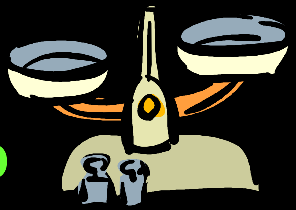
Add the two half-reactions together

Cancel chemical identities occurring on both sides

Check elemental balance

LPT

Balancing Example:



$Zn + NaNO_3 + NaOH \rightarrow Na_2ZnO_2 + NH_3 + H_2O$

Reduction: $NO_3^- \rightarrow NH_3$ (N changes from +5 to-3)

Oxidation: $Zn \rightarrow ZnO_2^{2-}$ (Zn changes from 0 to +2)

Balancing Elements Reduction: $NO_3^- \rightarrow NH_3$

Balancing Elements Oxidation: $Zn \rightarrow ZnO_2^{2-}$

Balancing Charge Reduction: $8\ e^- + NO_3^- + 6\ H_2O \rightarrow NH_3 + 9\ OH^-$

Balancing Charge Oxidation: $4\ OH^- + Zn \rightarrow ZnO_2^{2-} + 2\ H_2O + 2\ e^-$

Equating Electrons Reduction: $8\ e^- + NO_3^- + 6\ H_2O \rightarrow NH_3 + 9\ OH^-$

Equating Electrons Oxidation: $16\ OH^- + 4\ Zn \rightarrow 4\ ZnO_2^{2-} + 8\ H_2O + 8\ e^-$

Summing (canceling electrons):

$NO_3^- + 6\ H_2O + 16\ OH^- + 4\ Zn \rightarrow NH_3 + 9\ OH^- + 4\ ZnO_2^{2-} + 8\ H_2O$

Canceling identical chemical entities:

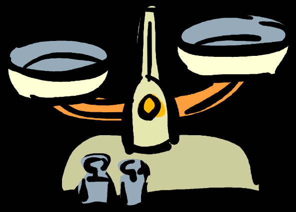
$NO_3^- + 7\ OH^- + 4\ Zn \rightarrow NH_3 + 4\ ZnO_2^{2-} + 2\ H_2O$

Adding Counter Ions:

$4\ Zn + NaNO_3 + 7\ NaOH \rightarrow NH_3 + 4\ Na_2ZnO_2 + 2\ H_2O$

LPT

Balancing Example:



$CoCl_2 + Na_2O_2 + NaOH + H_2O \rightarrow Co(OH)_3 + NaCl$

Reduction: $OO^{2-} \rightarrow OH^-$ (O changes from -1 to -2)
Oxidation: $Co^{2+} \rightarrow Co^{3+}$ (Co changes from +2 to +3)

Balancing Elements Reduction $OO^{2-} + OH^- + 2\ H_2O \rightarrow 5\ OH^-$
Balancing Elements Oxidation: $Co^{2+} \rightarrow Co^{3+}$

Balancing Charge Reduction: $OO^{2-} + 2\ OH^- + 2\ H_2O \rightarrow 6\ OH^-$
Balancing Charge Oxidation: $Co^{2+} \rightarrow Co^{3+} + 1\ e^-$

Equating Electrons Reduction: $2\ e^- + OO^{2-} + 2\ OH^- + 2\ H_2O \rightarrow 6\ OH^-$
Equating Electrons Oxidation: $2\ Co^{2+} \rightarrow 2\ Co^{3+} + 2\ e^-$

Summing (canceling electrons):

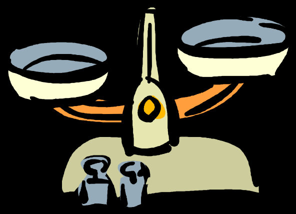
$2\ H_2O + OO^{2-} + 2\ OH^- + 2\ Co^{2+} \rightarrow 2\ Co^{3+} + 6\ OH^-$

Adding Counter Ions:

$2\ CoCl_2 + Na_2O_2 + 2\ NaOH + 2\ H_2O \rightarrow 2\ Co(OH)_3 + 4\ NaCl$

LPT

Balancing Example:



$$Bi_2O_3 + NaOH + NaOCl \rightarrow NaBiO_3 + NaCl + H_2O$$

Reduction: $OCl^- \rightarrow Cl^-$ (O changes from 0 to -2)

Oxidation: $Bi^{3+} \rightarrow BiO_3^-$ (Bi changes from +3 to + 5)

Balancing Elements Reduction $H_2O + ClO^- \rightarrow Cl^- + 2\ OH^-$

Balancing Elements Oxidation: $6\ OH^- + Bi_2O_3 \rightarrow 2\ BiO_3^- + 3\ H_2O$

Balancing Charge Reduction: $2e^- + H_2O + ClO^- \rightarrow Cl^- + 2\ OH^-$

Balancing Charge Oxidation: $6\ OH^- + Bi_2O_3 \rightarrow 2\ BiO_3^- + 3\ H_2O + 4\ e^-$

Equating Electrons Reduction: $4e^- + 2\ H_2O + 2\ ClO^- \rightarrow 2\ Cl^- + 4\ OH^-$

Equating Electrons Oxidation: $6\ OH^- + Bi_2O_3 \rightarrow 2\ BiO_3^- + 3\ H_2O + 4\ e^-$

Summing (canceling electrons):

$$2\ H_2O + 2\ ClO^- + 6\ OH^- + Bi_2O_3 \rightarrow 2\ Cl^- + 4\ OH^- + 2\ BiO_3^- + 3\ H_2O$$

Canceling identical chemical entities:

$$2\ ClO^- + 2\ OH^- + Bi_2O_3 \rightarrow 2\ Cl^- + 2\ BiO_3^- + H_2O$$

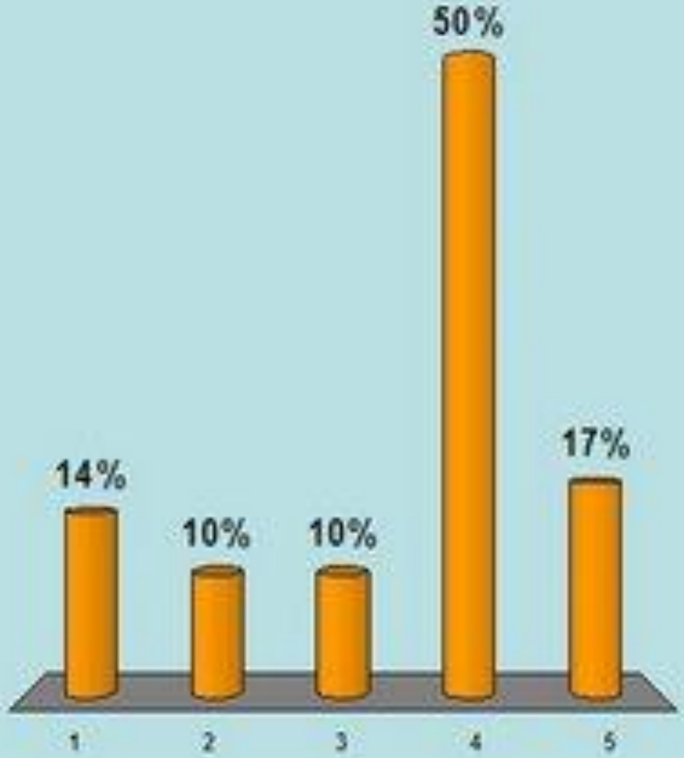
Adding Counter Ions:

$$Bi_2O_3 + 2\ NaOH + 2\ NaOCl \rightarrow 2\ NaBiO_3 + 2\ NaCl + H_2O$$

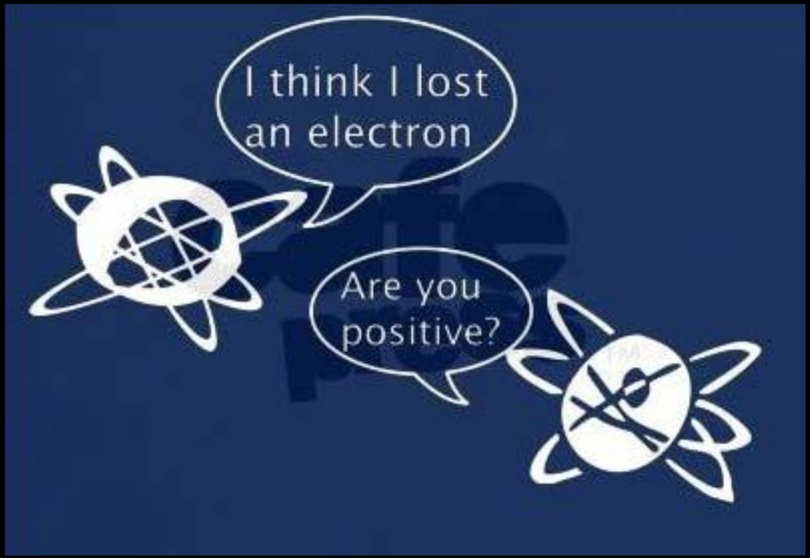
Balancing Redox Equations is:

UNE
The University of
NEW ENGLAND

1. The most fun I've ever had
2. Plenty of fun
3. Kind of fun
4. More fun than eating broken glass
5. Other



LPT



LPT