Chem Rxs, Stoich__________ Z Ch 2.9, 4; H Ch 1-2, 1-3, 7-1, 7-2, 16-4–16-6

"The world of chemical events is like a stage on which scene after scene is enacted in a continuous succession. The players on this stage are the elements. To each of them is assigned a characteristic role, either that of supernumerary or that of an actor playing a part."

Clemens Alexander Winkler, 1897

Almost all the chemical processes which occur in nature ... take place between substances in solution." **Friedrich Wilhelm Ostwald**, 1890

(Nobel Prize for Chemistry in 1909 "in recognition of his work on catalysis and for his investigations into the fundamental principles governing chemical equilibria and rates of reaction".)

4.9 – Acid-Base Reactions
4.10 – Oxidation-Reduction Reactions

quiz on Friday

Exam I on Monday
covering Chapters 1 – 4

Acid Nomenclature

H-Nonmetal

Rule 1: (**without the presence of H_2O**)
like ionic compounds: cation + anion
hydrogen _ide

Examples:

HCl	hydrogen chloride
HF	hydrogen fluoride
H_2S	hydrogen sulfide
H_2Se	hydrogen selenide

Rule 2: (H acids, **when dissolved in H_2O**)
hydro_ic acid

ide -> ic

Examples:

HCl	hydrochloric acid
HF	hydrofluoric acid
H_2S	hydrosulfuric acid
H_2Se	hydroselenic acid

Comment:
(a) These H-containing compounds are named as if they were ionic. (b) Often the (*aq*) in the formulas of the acids is omitted when it is obvious from the context that they are acids.

H-Oxyanion

Rule 1: (**without the presence of H_2O**)
like ionic compounds: cation + anion
hydrogen hypo_ite
hydrogen _ite
hydrogen _ate
hydrogen per_ate

Rule 2: (HO acids, **when dissolved in H2O**)

hypo_ous acid
_ous acid
_ic acid
per_ic acid

ite -> ous
ate -> ic

Examples:

HClO	hypochlorous acid
$HClO_2$	chlorous acid
$HClO_3$	chloric acid
$HClO_4$	perchloric acid
HNO_2	nitrous acid
HNO_3	nitric acid
H_2SO_3	sulfurous acid
H_2SO_4	sulfuric acid
H_3PO_4	phosphoric acid

REVIEW FROM MONDAY

Properties of Arrhenius Acids and Bases

Arrhenius acids - produce $H^+(aq)$ ions upon dissolution in water

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

Arrhenius bases - produce $OH^-(aq)$ ions upon dissolution in water

$$Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2\,OH^-(aq)$$

Definition works since pure water ionizes to a very small extent in a process called **autoionization**

$$H_2O(aq) \rightarrow H^+(aq) + OH^-(aq)$$

Water is both an Arrhenius acid and an Arrhenius base. A substance having both acidic and basic properties is called **amphoteric.**

REVIEW FROM MONDAY

Modified Definition of Arrhenius Acids and Bases

Arrhenius acids - increase concentration of $H^+(aq)$ above that present in pure water by reacting with water

Arrhenius bases - increase concentration of $OH^-(aq)$ above that present in pure water by reacting with water – for ammonia

$$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$$

Broadens the applicable chemistry.

REVIEW FROM MONDAY

Acid and Base Anhydrides

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

$Na_2O(s) + H_2O(l) \rightarrow 2\,NaOH(aq)$

$P_4O_{10}(s) + 6\,H_2O(l) \rightarrow 4\,H_3PO_4(aq)$

$2\,HNO_3(aq) - \text{'}H_2O\text{'} \rightarrow N_2O_5(g)$

$Ba(OH)_2(s) - \text{'}H_2O\text{'} \rightarrow BaO(s)$

$2\,HBrO_4(aq) - \text{'}H_2O\text{'} \rightarrow Br_2O_7(g)$

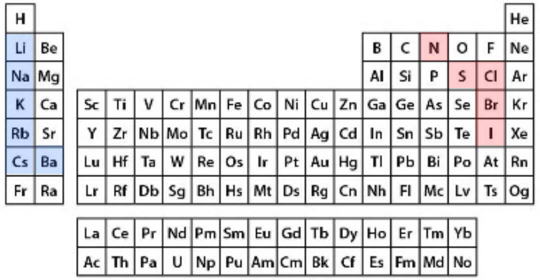
---

to find the **anhydride** "subtract" enough **units of H_2O** from the acid/base to remove all of the hydrogens

to find the acid/base add enough **units of H_2O** to the **anhydride**

REVIEW FROM MONDAY

Strong Acids and Strong Bases



seven strong acids to know		**soluble strong bases to know**	
hydrochloric acid	HCl	lithium hydroxide	$LiOH$
hydrobromic acid	HBr	sodium hydroxide	$NaOH$
hydroiodic acid	HI	potassium hydroxide	KOH
perchloric acid	$HClO_4$	rubidium hydroxide	$RbOH$
chloric acid	$HClO_3$	cesium hydroxide	$CsOH$
sulfuric acid	H_2SO_4	barium hydroxide	$Ba(OH)_2$
nitric acid	HNO_3		

REVIEW FROM MONDAY

Reactions of Acids and Bases: ACID + BASE → SALT + WATER

chemistry contained in net ionic equation (or **WHY YOU NEED TO KNOW YOUR IONS**)

ACIDS react with

1. **bases**

BASES react with

1. **acids**

-------------------- **salt and water** --------------------

$$2\ HBr(aq) + Ba(OH)_2(aq) \rightarrow BaBr_2(aq) + 2\ H_2O(l)$$

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

REVIEW FROM MONDAY

$$2\ \mathrm{HBr}(aq) + \mathrm{Ba(OH)_2}(aq) \rightarrow \mathrm{BaBr_2}(aq) + 2\ \mathrm{H_2O}(l)$$

$$\mathrm{HBr} \longrightarrow \mathrm{H}^+ + \mathrm{:\overset{..}{\underset{..}{Br}}:}^-$$

$$\mathrm{Ba(OH)_2} \longrightarrow \mathrm{Ba}^{2+} + 2\ \mathrm{H{-}\overset{..}{\underset{..}{O}}:}^-$$

REMEMBERING THE STRUCTURE FOR WATER

WE CAN UNDERSTAND ITS FORMATION BY THE ADDITION OF THE ACIDIC PROTON (H^+) TO THE BASIC HYDROXIDE (OH^-) TO FORM THE STABLE MOLECULAR COMPOUND (COVALENT BONDS) H_2O.

REVIEW FROM MONDAY

ACIDS react with

2. metal oxides

BASES react with

2. **nonmetal oxides**

-------------------- **salt and water** --------------------

$$2\,\mathrm{HCl}(aq) + \mathrm{MnO}(s) \rightarrow \mathrm{MnCl_2}(aq) + \mathrm{H_2O}(l)$$

$$2\,\mathrm{NaOH}(aq) + \mathrm{Cl_2O_5}(g) \rightarrow 2\,\mathrm{NaClO_3}(aq) + \mathrm{H_2O}(l)$$

$$2\,\mathrm{H^+}(aq) + \mathrm{MnO}(s) \rightarrow \mathrm{Mn^{2+}}(aq) + \mathrm{H_2O}(l)$$

$$2\,\mathrm{OH^-}(aq) + \mathrm{Cl_2O_5}(g) \rightarrow 2\,\mathrm{ClO_3^-}(aq) + \mathrm{H_2O}(l)$$

REVIEW FROM MONDAY

$$2\ HCl(aq) + MnO(s) \rightarrow MnCl_2(aq) + H_2O(l)$$

THIS REACTION CAN BE BEST SEEN BY RECOGNIZING MnO AS IONIC SO THAT OXYGEN IS PRESENT AS THE OXIDE ANION, O^{2-}, AND

$$:\ddot{\underset{\cdot\cdot}{O}}:^{2-} + 2H^{+} \longrightarrow H-\underset{\cdot\cdot}{\ddot{O}}-H$$

REVIEW FROM MONDAY

ACIDS react with

1. **carbonates**
   hydrogen carbonates

BASES react with

3. **ammonium salts**

-------------------- **salt and water** --------------------

+ $CO_2(g)$

+ $NH_3(g)$

$HNO_3(aq) + NaHCO_3(s) \rightarrow CO_2(g) + NaNO_3(aq) + H_2O(l)$

$KOH(aq) + (NH_4)_2SO_4(aq) \rightarrow 2\ NH_3(g) + K_2SO_4(aq) + 2\ H_2O(l)$

$H^+(aq) + NaHCO_3(s) \rightarrow CO_2(g) + Na^+(aq) + H_2O(l)$

$OH^-(aq) + NH_4^+(aq) \rightarrow NH_3(g) + H_2O(l)$

also **sulfites** and **hydrogen sulfites**

REVIEW FROM MONDAY

$$HNO_3(aq) + NaHCO_3(s) \rightarrow CO_2(g) + NaNO_3(aq) + H_2O(l)$$

Lewis Structure Of HCO_3^- And Of CO_2

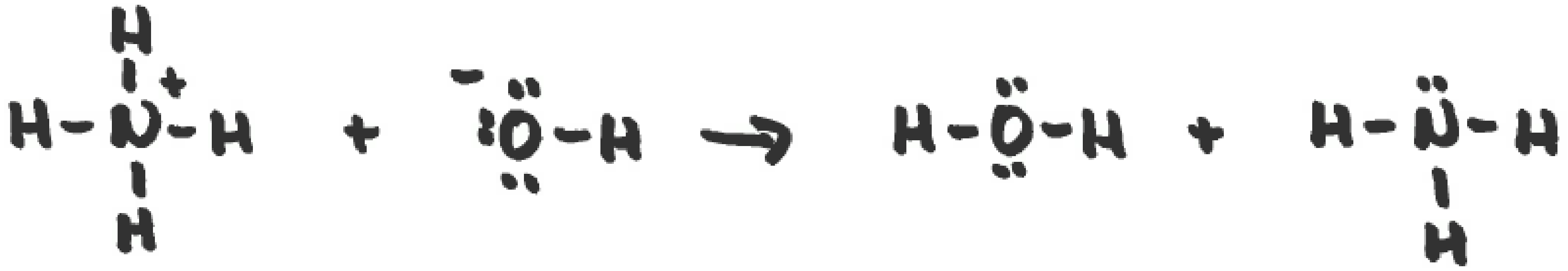
In The Presence Of H^+ You Might Expect The Proton To Add To HCO_3^- To Form Carbonic Aci H_2CO_3 - And You Would Be Perfectly Correct

H_2CO_3 Is Not Very Stable And It Decompose Into H_2O And CO_2. CO_2 Is Not Very Soluble In Water And Is Liberated From Solution As The Gas.

REVIEW FROM MONDAY

$KOH(\mathit{aq}) + (NH_4)_2SO_4(\mathit{aq}) \rightarrow 2\ NH_3(\mathit{g}) + K_2SO_4(\mathit{aq}) + 2\ H_2O(\mathit{l})$

AS BEFORE, LEWIS STRUCTURES ELUCIDATE THE REACTION WHERE THE STRONG BASE OH^- PLUCKS A PROTON OFF NH_4^+ TO MAKE WATER, LEAVING AMMONIA BEHIND:



GENERALLY IF A REACTION CAN MAKE WATER IT DOES.

REVIEW FROM MONDAY

Stoichiometry of Acid-Base Titrations

balanced equation
concentrations
end-point = equivalence point (end-point: indicator, potentiometric)

EX 10. A 25.0 mL sample of acetic acid (CH_3COOH) requires 28.33 mL of 0.953 M NaOH to reach the phenolphthalein end-point. What is the concentration of acetic acid?

$$\underset{25\text{ mL}}{CH_3COOH(aq)} + \underset{\substack{28.33\text{ mL}\\0.953\text{ M}}}{NaOH(aq)} \rightarrow NaCH_3COO(aq) + H2O(l)$$

$$\boldsymbol{n_A = (VM)_A = n_B = (VM)_B} \Rightarrow$$

$$V_A = (VM)_B / M_A = (28.33)(0.953) / 25.0 = 1.0799 \Rightarrow \mathbf{1.08\ M}$$

Oxidation Reduction Reactions

“classic” oxidation (combining with oxygen)

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

“classic” reduction (combining with hydrogen)

$$Ca(s) + H_2(g) \rightarrow CaH_2(s)$$

many other reactions also involve redox

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

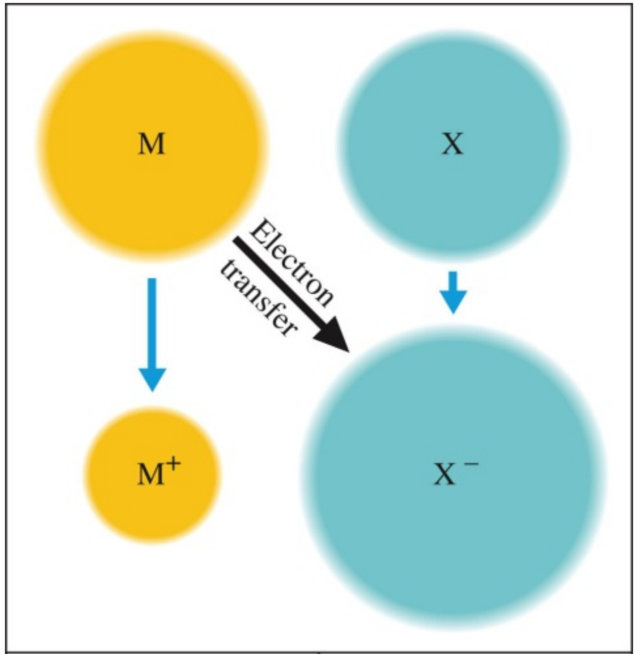
Identifying Redox (Reduction/Oxidation) Reactions

species that is oxidized (**reducing agent**)

species that is reduced (**oxidizing agent**)

OXIDATION
- oxidation number increases
- loses electrons
- reducing agent

REDUCTION
- oxidation number decreases
- gains electrons
- oxidizing agent



Oxidized	**Reduced**
Loses electrons	*Gains* electrons
Oxidation state *increases*	Oxidation state *decreases*
Reducing agent	*Oxidizing* agent

Oxidation Numbers (in Order of Priority)

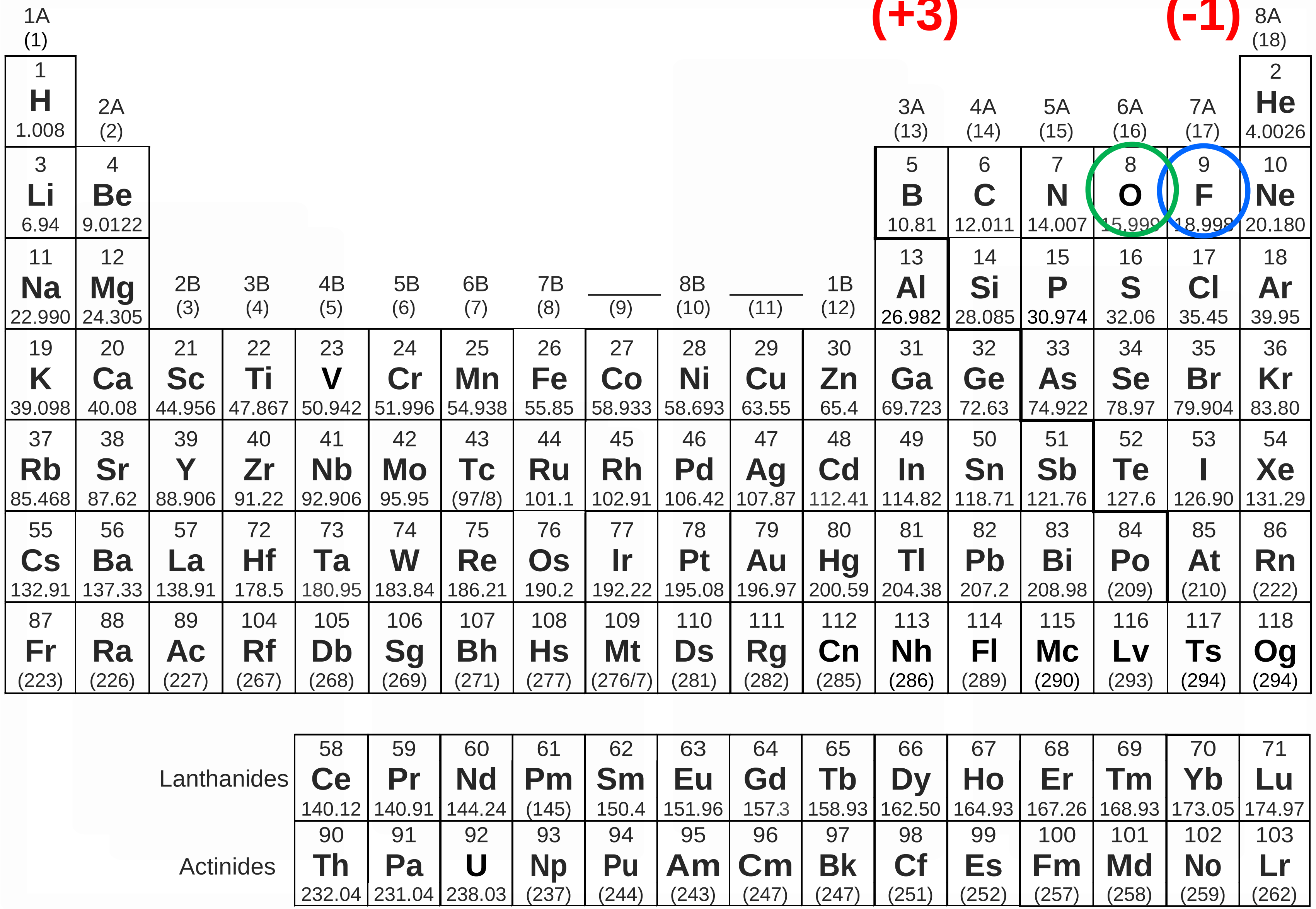
- Sum of the oxidation numbers (ON) of the atoms is zero for a neutral molecule and is the charge for an ion.
- Group I ON = 1, Group II ON = 2, Group III usually have ON = 3.
- Fluorine ON = -1 **always**. Other halogens usually have ON = -1 except in compounds with oxygen or other halogens when the oxidation number follows electronegativity and can be positive.
- Hydrogen has ON = 1 except in metal hydrides when the oxidation number is -1.
- Oxygen has ON = -2 except in compounds with fluorine when the oxidation number can be positive and in compounds containing the O-O bond. For peroxides (O_2^{2-}) ON = -1

+1 +2

(+3)

(-1)

(-2) -1



1A (1)																	8A (18)
1 **H** 1.008	2A (2)											3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305	2B (3)	3B (4)	4B (5)	5B (6)	6B (7)	7B (8)	—— (9)	8B (10)	—— (11)	1B (12)	13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.098	20 **Ca** 40.08	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.85	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.55	30 **Zn** 65.4	31 **Ga** 69.723	32 **Ge** 72.63	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.22	41 **Nb** 92.906	42 **Mo** 95.95	43 **Tc** (97/8)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.6	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.5	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (271)	108 **Hs** (277)	109 **Mt** (276/7)	110 **Ds** (281)	111 **Rg** (282)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (290)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

Lanthanides	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.96	64 **Gd** 157.3	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
Actinides	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Working with Oxidation Numbers

EX 12. Assign oxidation numbers (ON) to all of the elements in the following chemical compounds.

+1 -1
$NaCl$

+1 -2
ClO^-

+3 -2
$Fe_2(SO_4)_3$

+1 x -2 => 1 + x -4(-2) = 0
$KMnO_4$ => x = 7

+1 -1
H_2O_2

+4 -2
SO_2

0
I_2

+2 -1
CaH_2

-4 +1
CH_4

organic compounds always written CH other elements alphabetical

+1 -2
K_2O

KO_2 exists!

Working with Oxidation Numbers

EX 13. Assign oxidation numbers (ON) to the chlorine atom in the following acidic oxides.

oxide	**acid**	
Cl_2O	$HClO$	+1
Cl_2O_3	$HClO_2$	+3
Cl_2O_5	$HClO_3$	+5
Cl_2O_7	$HClO_4$	+7

Working with Oxidation Numbers

EX 14. The alkali metals react with water, evolving hydrogen gas.

$$2\ \mathrm{Na}(s) + 2\ \mathrm{H_2O}(l) \rightarrow 2\ \mathrm{NaOH}(aq) + \mathrm{H_2}(g)$$

What is being oxidized, what is being reduced, and how many moles of electrons are transferred?

OX: 2 Na (0) -> 2 Na (+); ΔON = +2 – 0 = 2 => lost 2 moles of e^-

RED: 2 H (+) -> H_2 (0); ΔON = 0 – 2 = -2 => gained 2 moles of e^-

two moles of electrons transferred in this reaction