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".)

4.11 – Balancing Oxidation-Reduction Equations
4.12 – Simple Oxidation-Reduction Titrations

apology for M lecture

EXAM Monday at 12:00 Z Ch 1-4
NO statistics, historical atomic theory, Z Ch 4.7

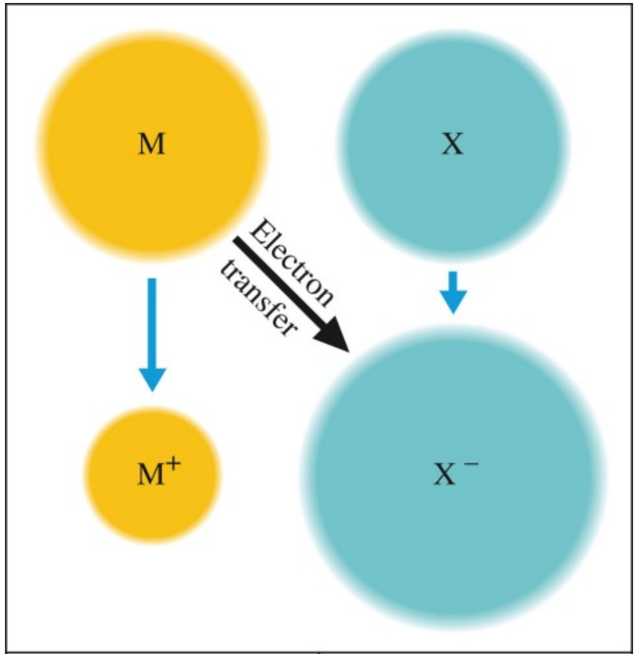
Identifying Redox (Reduction/Oxidation) Reactions

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

REVIEW FROM WEDNESDAY

+1	+2											(+3)				(-1)	
1A (1)	2A (2)	2B (3)	3B (4)	4B (5)	5B (6)	6B (7)	7B (8)	(9)	8B (10)	(11)	1B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1 H 1.008																	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											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)

(-2) -1

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

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

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

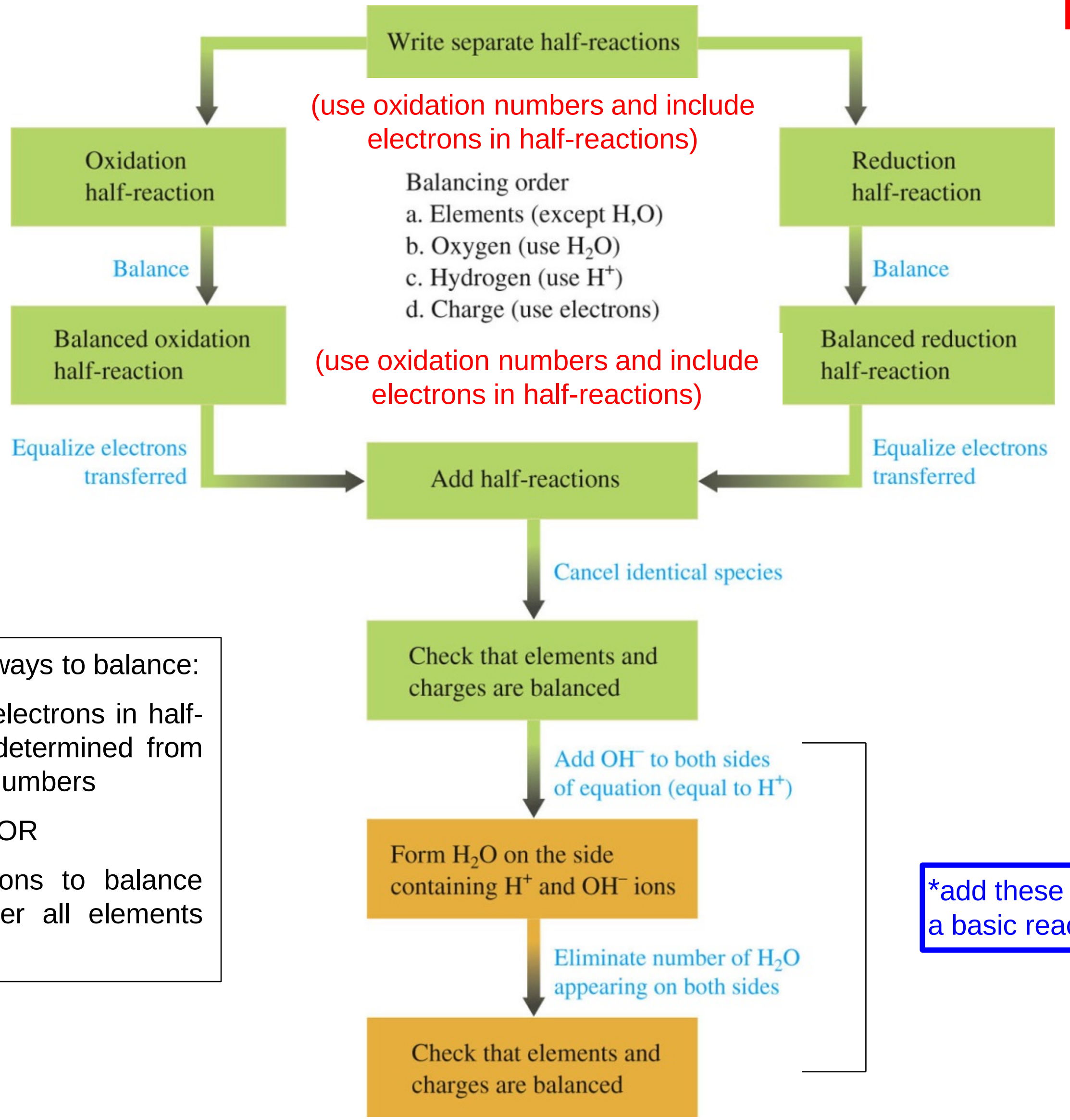
OX: 2 Na (0) -> 2 Na (+); ΔON = +2 – 0 = 2 => lost 2 moles of e^-

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

two moles of electrons transferred in this reaction

Balancing Redox Reactions

MUST OBTAIN HALF REACTIONS



* for basic reaction neutralize H^+ with OH^-

* for basic reaction neutralize H^+ with OH^-

*add these steps for a basic reaction

Basically two ways to balance:

1. start with electrons in half-reactions determined from oxidation numbers

OR

2. use electrons to balance charge after all elements balanced

Balancing Redox Reactions

EX 16. Balance in acidic solution

$$MnO_4^-(aq) + Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + Fe^{3+}(aq)$$

OX $(Fe^{2+} \rightarrow Fe^{3+} + e^-) \times 5$ (**balance electrons**)

$MnO_4^- + 5e^- \rightarrow Mn^{2+}$

$+ 4\ H_2O$ (balance O with water)

(balance H with H^+) $+ 8\ H^+$

RED $(MnO_4^- + 8\ H^+ + 5e^- \rightarrow Mn^{2+} + 4\ H_2O) \times 1$

BALANCED: $5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$

Balancing Redox Reactions

EX 16. Balance in acidic solution

$$SO_2(aq) + Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$$

OX

$$SO_2 \rightarrow SO_4^{2-} + 2e^-$$

$$+ 2\,H_2O \qquad + 4\,H^+$$

$$(\,SO_2 + 2\,H_2O \rightarrow SO_4^{2-} + 4\,H^+ + \mathbf{2e^-}\,) \times 3$$

RED

$$Cr_2O_7^{2-} + 6e^- \rightarrow 2\,Cr^{3+}$$

$$+ 14\,H^+ \qquad + 7\,H_2O$$

$$(Cr_2O_7^{2-} + 14\,H^+ + \mathbf{6e^-} \rightarrow 2\,Cr^{3+} + 7\,H_2O\,) \times 1$$

BALANCED: $3\,SO_2 + Cr_2O_7^{2-} + 2\,H^+ \rightarrow 3\,SO_4^{2-} + 2\,Cr^{3+} + H_2O$

Balancing Redox Reactions (without ON Numbers)

EX 16. Balance in acidic solution

$$SO_2(aq) + Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq) + SO_4^{2-}(aq)$$

OX

$$SO_2 \rightarrow SO_4^{2-}$$

$$+ 2\,H_2O \qquad + 4\,H^+$$

(charge on left = 0) $SO_2 + 2\,H_2O \rightarrow SO_4^{2-} + 4\,H^+$ (charge on right = +2 => + **$2e^-$**)

RED

$$Cr_2O_7^{2-} \rightarrow 2\,Cr^{3+}$$

$$+ 14\,H^+ \qquad + 7\,H_2O$$

(charge on left = +12 => + **$6e^-$**) $Cr_2O_7^{2-} + 14\,H^+ \rightarrow 2\,Cr^{3+} + 7\,H_2O$ (charge on right = +6)

BALANCED: $3\,SO_2 + Cr_2O_7^{2-} + 2\,H^+ \rightarrow 3\,SO_4^{2-} + 2\,Cr^{3+} + H_2O$

Balancing Redox Reactions

EX 17. Balance in basic solution

$$Ag(s) + CN^-(aq) + O_2(g) \rightarrow Ag(CN)_2(aq)$$

OX

$$Ag \rightarrow Ag(CN)_2 + 2e^-$$

$$+ 2\,CN^-$$

$$(Ag + 2\,CN^- \rightarrow Ag(CN)_2 + \mathbf{2e^-}) \times 2$$

$$O_2 + 4e^- \rightarrow 2\,H_2O$$ can only add H^+, OH^-, H_2O

$$4\,H_2O = 4\,OH^- + 4\,H^+ \qquad + 4\,OH^-$$ $(4\,H^+ + 4OH^- = 4\,H_2O)$

RED

$$(O_2 + 2\,H_2O + \mathbf{4e^-} \rightarrow 4\,OH^-) \times 1$$

BALANCED: $2\,Ag + 4\,CN^- + O_2 + 2\,H_2O \rightarrow 2\,Ag(CN)_2 + 4\,OH^-$

Oxidation Reduction Titrations

EX 18. How many moles of CH_2O form when 37 mL of 0.52 M $Cr_2O_7^{2-}$ reacts with excess CH_3OH according to

+6 -2   -2 +1 -2 +1   0 +1 -2

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

37 mL, 0.52 M   x moles

$$n_{CH_2O} = 3\,n_{Cr_2O_7^{2-}}$$
$$= 3\,(VM)_{Cr_2O_7^{2-}}$$
$$= 3(0.037)(0.52)$$
$$= 0.05772 \Rightarrow \mathbf{0.058\ mol}$$

Oxidation Reduction Titrations

EX 19. The iron in a 1.026 g sample of ore is quantitatively all converted to Fe(II) and then titrated with 0.0195 M $KMnO_4$. If 24.35 mL is required to reach the endpoint what is the mass percent iron in the ore? (M = 55.845)

$$MnO_4^-(aq) + 5\,Fe^{2+}(aq) + 8\,H^+(aq) \rightarrow Mn^{2+}(aq) + 5\,Fe^{3+}(aq) + 4\,H_2O(l)$$

24.35 mL
0.0195 M

1.026 g

$$n_{Fe^{2+}} = (m/M)_{Fe} = 5\,n_{MnO_4^-} = 5\,(VM)_{MnO_4^-}$$

$$m_{Fe} = 5\,M_{Fe}(VM)_{MnO_4^-}$$

$$= 5\,(55.845)(0.02435)(0.0195)$$

$$= 0.13258$$

=> wt% = 0.13258 (100) / 1.026 = **12.9 % iron**