Chemistry 12

Electrochemistry I

Name: Notes
Date:
Block:

1. **Oxidation Numbers**
2. **Electron gain and loss**
3. **Agents**

Electrochemistry is the study of the interchange of chemical and electrical energy.

- Reactions with electron transfers are commonly called **oxidation-reduction reactions (redox reactions)**
- Not all reactions involve an electron transfer!

Oxidation Numbers

Oxidation number is the real or apparent **charge** of an atom or ion. Also called **"combining capacity"**.

Rules for Assigning Oxidation Numbers (simplified):

1. Atoms in elemental form have a charge of zero

   ex. Na, O_2

2. Oxygen always has a charge of = -2

3. Hydrogen always has a charge of = $+1$

4. Oxidation numbers in a neutral compound must add up to zero

   ex. $\overset{+1}{H}\overset{-1}{Cl}$ $\boxed{H = +1 \quad Cl = -1}$

5. Oxidation numbers in a polyatomic ion must add up to its given charge

   ex. $\underbrace{\overset{+5}{P}\overset{-2}{O}_4^{3-}}_{-3}$ ×4 $\quad +5 \; -8$ $\boxed{O = -2 \quad P = +5}$

6. Follow regular rules when assigning charges

   ex. $\underbrace{\overset{+2}{Mg}\overset{-1}{F}_2}_{0}$ ×2 $\quad +2 \; -2$ $\boxed{Mg = +2 \quad F = -1}$

7. The more electronegative element should have a negative charge

   re: Chem 11
   it is "hungry" for electrons

Hint!!

It might be helpful to break up a compound in a dissociation equation first!

Ex: $KMnO_4 \rightarrow \overset{+1}{K^+} + \overset{+7\ -2}{MnO_4^-}$

$+1 \quad +7\ -8 \quad -1$

$\boxed{K=+1 \quad Mn=+7 \quad O=-2}$

Ex: $Na_2Mo_2O_5 \rightarrow 2\overset{+1}{Na^+} + \overset{+4\ -2}{Mo_2O_5^{2-}}$

$+1 \quad +8\ -10 \quad -2$

$\boxed{Na=+1 \quad Mo=+4 \quad O=-2}$

Example: Assign the oxidation number of each atom in the following species

a) H_2O

$\overset{+1}{H_2}\overset{-2}{O}$

$\underbrace{+2\ -2}_{0}$

$\boxed{H=+1 \quad O=-2}$

b) $AsO_4{}^{3-}$

$\overset{+5}{As}\overset{-2}{O_4}{}^{3-}$

$\underbrace{+5\ -8}_{-3}$

$\boxed{As=+5 \quad O=-2}$

c) $Pb(NO_3)_2$

$\overset{+2}{Pb^{2+}} + \cancel{2}\overset{+5\ -2}{NO_3^-}$ (ignore)

$+5\ -6$

$\boxed{Pb=+2 \quad N=+5 \quad O=-2}$

d) C_4H_{10}

$\overset{-\frac{5}{2}}{C_4}\overset{+1}{H_{10}}$

$\div 4 \quad -10 \quad +10 \quad \times 10$

$\boxed{H=+1 \quad C=-\frac{5}{2}}$

e) $Al_2(SO_4)_3$

$\cancel{2}\overset{+3}{Al^{3+}} + \cancel{3}\overset{+6\ -2}{SO_4^{2-}}$

$+6\ -8$

$\boxed{Al=+3 \quad S=+6 \quad O=-2}$

f) $CO_3{}^{2-}$

$\overset{+4}{C}\overset{-2}{O_3}{}^{2-}$

$+4 \quad -6$

$\boxed{O=-2 \quad C=+4}$

g) $NH_4{}^+$

$\overset{-3}{N}\overset{+1}{H_4}{}^{+}$

$-3 \quad +4$

$\boxed{N=-3 \quad H=+1}$

h) $Na_2Cr_2O_7$

$\cancel{2}\overset{+1}{Na^+} + \overset{+6\ -2}{Cr_2O_7^{2-}}$

$+1 \quad +12 \quad -14$

$\boxed{Na=+1 \quad Cr=+6 \quad O=-2}$

MORE PRACTICE!

Determine the oxidation number for **each atom** in the following compounds:

F_2 0	Fe_2O_3 +3 -2	$CaCO_3$ +2 +4 -2 Ca^{2+} + CO_3^{2-}	BrO_2^- +3 -2
PbI_2 +2 -1	H_2 0	$S_2O_3^{2-}$ +2 -2	CN^- +2 -3
ZnO +2 -2	NH_4OH -3 +1 -2 +1 NH_4^+ + OH^- -3 +4 N=-3 H=+1 O=-2	P_4 0	Cs_2O_2 +2 -2
$S_2O_8^{2-}$ +7 -2	N_2H_4 -2 +1	MnO_4^- +7 -2	PO_3^{3-} +3 -2
N_2O_5 +5 -2	WBr_4 +4 -1	K_2S +1 -2	SeO_3^{2-} +4 -2
SF_6 +6 -1	NO_2 +4 -2	MnO_2^- +3 -2	$Na_2Mo_2O_5$ +1 +4 -2
$NaNO_3$ +1 +5 -2 Na^+ + NO_3^-	H_2CO +1 0 -2	OH^- -2 +1	Cl_2O +1 -2
O_3 0	Ba_2XeO_4 +2 +4 -2	PCl_3 +3 -1	P_2O_5 +5 -2
U_3O_8 $+\frac{16}{3}$ -2	Pb 0	$ZnBr_2$ +2 -1	$S_2O_3^{2-}$ +2 -2
$(NH_4)_2SeO_4$ $2NH_4^+$ + SeO_4^{2-} -3 +1 +6 -2	CH_3OH C=-2 H=+1 O=-2 CH_3^+ + OH^- -2 +1 -2 +1	$LiAlH_4$ -1 -3 +1	CH_3COO^- O = -2 H = +1 C = 0
$FeCl_3$ +3 -1	$(NH_4)_2C_2O_4$ $2NH_4^+$ + $C_2O_4^{2-}$ -3 +1 +3 -2	BF_3 +3 -1	SiO_4^{4-} +4 -2

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Electron gain and loss

Loss e^-	Gain e^-
• Oxidation number increases	• Oxidation number decreases
• Called "oxidation"	• Called "reduction"
L oss **E** lectrons **O** xidation more (+)	**G** ain **E** lectrons **R** eduction more (−)
O xidation **I** s **L** oss	**R** eduction **I** s **G** ain

LEO says GER

OIL RIG

Fe : 0 → +2
lost e^-
$\boxed{\text{Oxidation}}$

$$\overset{0}{Fe}_{(s)} + \overset{+2}{Cu}{}^{2+}_{(aq)} \rightarrow \overset{+2}{Fe}{}^{2+}_{(aq)} + \overset{0}{Cu}_{(s)}$$

Cu : +2 → 0
gain e^-
$\boxed{\text{reduction}}$

Practice:

Consider the following reaction:

$$2\ \overset{0}{Al} + \overset{+3}{Fe}_2\overset{-2}{O}_3 \rightarrow \overset{+3}{Al}_2\overset{-2}{O}_3 + 2\ \overset{0}{Fe}$$

Determine the oxidation numbers for each atom and write the value on top of the element in the reaction.

1. Are electrons gained or lost by each iron (III) ion? gain e^-
   a. How many? $3e^-$
2. Are electrons gained or lost by each Al atom? lost e^-
   a. How many? $3e^-$
3. How many electrons were transferred in total during the reaction? 3 (from Al to Fe)
4. What happened to the oxide ion, O^{2-} during the reaction?
   The oxidation number stayed the same – neither reduced/oxidized

☆ **The number of electrons** lost **by the species being oxidized must always equal the number of electrons** gained **by the species being reduced.** ☆

Practice:

1. Consider the following reactions. For each reaction:

   a) Determine the **oxidation number** for each of the atoms.

   b) Identify if the reaction is a **redox** reaction. (**red**uction/**ox**idation) → must have ox # change

0 0 +4 -2

(1) $C + O_2 \rightarrow CO_2$

lost gain Yes

-3 +1 +1 -1 -3 +1 -1

(6) $NH_3 + HCl \rightarrow NH_4Cl$

no ox # change NO

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

(2) $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

no ox # change NO

+2 +4 -2 +1 -1 +2 -1 +4 -2 +1 -2

(7) $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

no ox # change NO

+2 -1 +2 -1

(3) $ZnCl_2 \rightarrow Zn^{+2} + 2Cl$-

no ox # change NO

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

(8) $3\ I_2 + 3\ H_2O \rightarrow 6\ H^+ + 5\ I^- + IO_3^-$

gain lost Yes

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

(4) $2\ NaI + Pb(NO_3)_2 \rightarrow PbI_2 + 2\ NaNO_3$

no ox # change NO

0 0 +2 -1

(9) $Zn + Br_2 \rightarrow ZnBr_2$

lost gain Yes

0 +2 +2 0

(5) $Cu + Ni^{2+} \rightarrow Cu^{2+} + Ni$

lost gained Yes

+1 +4 -2 +1 -2 +4 -2

(10) $H_2CO_3 \rightarrow H_2O + CO_2$

no ox # change NO

loss e⁻ → ox # ↑

2. When $\underset{+6}{Mn}O_4^{2-}$ undergoes **oxidation**, it may form:

A. $\overset{+2}{MnO}$

B. $\overset{+6}{MnO_3}$

C. $\overset{+7}{MnO_4^-}$

D. $\overset{+3}{Mn_2O_3}$

3. During the reaction, electrons transfer from:

gain 5e⁻

+7 -2 +2 +1 +2 +3 +1 -2

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

lose 1e⁻

A. Fe^{3+} to Fe^{2+}

B. Fe^{2+} to MnO_4^-

C. MnO_4^- to Fe^{2+}

D. MnO_4^- to Mn^{2+}

Agents

Another way of looking at it is that one species ***causes*** the electron loss or gain. A species that is being oxidized causes the other species to gain electrons and be reduced.

e^-

$$MnO_4^- + 5\,Fe^{2+} + 8\,H^+ \rightarrow Mn^{2+} + \underbrace{5\,Fe^{2+} \rightarrow 5\,Fe^{3+}}_{\text{Oxidizing (acting as a reducing agent)}} + 4\,H_2O$$

A substance that is reduced acts as an Oxidizing (OA) **agent.**

A substance that is oxidized acts as a reducing (RA) **agent.**

Practice:

a) Assign oxidation numbers to all atoms in the equation.

b) Indicate the oxidizing and reducing agents in each of the following reactions.

1. 0 0 +4 −2 reduced (OA)

   $C + O_2 \rightarrow CO_2$

   oxidized (RA)

   Oxidizing agent (gets reduced): O_2 *Reducing Agent (gets oxidized):* C

2. oxidized (RA)

   −3 +1 0 +4 −2 +1 −2

   $4\,NH_3 + 7\,O_2 \rightarrow 4\,NO_2 + 6\,H_2O$

   reduced (OA)

   Oxidizing agent (gets reduced): O_2 *Reducing Agent (gets oxidized):* NH_3

3. reduced (OA)

   0 0 −4 +1

   $C + 2\,H_2 \rightarrow CH_4$

   oxidized (RA)

   Oxidizing agent (gets reduced): C *Reducing Agent (gets oxidized):* H_2

4. reduced (OA)

   0 +3 −1 0 +2 −1

   $3\,Sr + 2\,FeBr_3 \rightarrow 2\,Fe + 3\,SrBr_2$

   oxidized (RA)

   Oxidizing agent (gets reduced): $FeBr_3$ *Reducing Agent (gets oxidized):* Sr

5. oxidized (RA)

   +2 −2 +5 −2 +4 −2 0

   $5\,CO + Cl_2O_5 \rightarrow 5\,CO_2 + Cl_2$

   reduced (OA)

   Oxidizing agent (gets reduced): Cl_2O_5 *Reducing Agent (gets oxidized):* CO

6. oxidized (RA)

   −3 +1 0 0

   $4\,PH_{3\,(g)} \rightarrow P_{4\,(g)} + 6\,H_{2\,(g)}$

   reduced (OA)

   Oxidizing agent (gets reduced): PH_3 *Reducing Agent (gets oxidized):* PH_3

<u>Worksheet</u>

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