P A1 (pg 1 of 3) Oxidation Numbers

Name____________________Per______

In first year chemistry you learned a quick method of determining whether a reaction is an oxidation reduction reaction. That quick method was to look for any “lone” elements in the reaction, such as in single replacement reactions. You may recall the equation below from lab work.

$$2\,AgNO_3 + Cu \rightarrow 2\,Ag + Cu(NO_3)_2$$

In fact, all single replacement reactions are redox reactions. You may also recall that combustion reactions are also always redox reactions. Recall the combustion of methane (from the Bunsen burner) shown below.

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

You learned that double replacement reactions, precipitation-type or acid base-type are **never** redox reactions.

In this AP chemistry course, we will push further in to other types of reactions that do not necessarily involve “lone” elements, yet **will** be a redox reaction. We need a method to identify these reactions and we need a method to track the electrons lost and gained during the reaction. Tracking electrons will help identify the oxidizing agent − the species which causes oxidation *and* which element gets reduced itself. Likewise, tracking the electrons will also identify the reducing agent − the species which causes reduction *and* which element gets oxidized itself.

Chemists have devised a scheme for tracking electrons, which is like bookkeeping for electrons − each shared electron is assigned to the atom which attracts the electrons most strongly. Then a number, called the *oxidation state* or *oxidation number*, is given to each atom based on the electron assignments. In other words, the oxidation number is the charge that an atom would have *if* electrons were transferred completely, not shared. Tracking electrons will provide a tool to help balance challenging equations as well as providing the total number of electrons transferred − the same amount of electrons is always lost as is gained. This quantity of electrons transferred is useful in thermochemical and electrochemical calculations.

So be able to use oxidation numbers, you need to follow some rules to assign them. The following rules are *hierarchical.* That is to say, if any two rules conflict, follow the rule that is higher on the list.

1. The oxidation state of an atom in its standard elemental form is = 0. such as Cu, He, O_2, or P_4, etc.
2. The oxidation state of a monoatomic ion is equal to its charge. such as Ca^{2+}, Cl^- (as in $CaCl_2$).
3. The sum of the oxidation states of all atoms in: *This rule must always be followed.*
   - A neutral molecule or formula unit is = 0 H_2O (2 × ox state of H) + (ox state of O) = 0
   - An ion is equal to the charge of the ion. NO_3^- (ox state of N) + (3 × ox state of O) = −1
4. In ionic compounds, metals *always* have positive oxidation states.
   - Group 1A metals are *always* = +1 *K*Cl K = +1
   - Group 2A metals are *always* = +2 *Mg*Br_2 Mg = +2
5. In ionic or molecular compounds, nonmetals are assigned oxidation states as listed below (This too is a *hierarchical* list):
   - **Fluorine = −1** MgF_2 F = −1
   - **Hydrogen = +1** H_2O each H = +1 (unless 0, or −1 when with metals)
   - **Oxygen = −2** CO_2 each O = −2 (unless 0, or −1 in peroxides)
   - Group 7A = −1 CCl_4 each Cl = −1
   - Group 6A = −2 H_2S S = −2
   - Group 5A = −3 NH_3 N = −3

Answers *(you can get a worked out version online)*

1) +4, +3, +4, -3, 0
2) -1, +3, +5, -1
3) +5, +2, -3, +3, 0
4) +4, -2, +4, +6, 0

Practice

1. Give the oxidation number of the carbon in each of the following compounds:
   a. CF_2Cl_2
   b. $Na_2C_2O_4$
   c. HCO_3^-
   d. C_2H_6
   e. CH_2O

2. Give the oxidation number of the bromine in each of the following compounds:
   a. KBr
   b. BrF_3
   c. $HBrO_3$
   d. CBr_4

3. Give the oxidation number of the nitrogen in each of the following compounds:
   a. NO_3^-
   b. N_2F_4
   c. NH_4^+
   d. HNO_2
   e. N_2

4. Give the oxidation number of the sulfur in each of the following compounds:
   a. $SOCl_2$
   b. H_2S
   c. H_2SO_3
   d. SO_4^{2-}
   e. S_8

1. Give the oxidation number of the carbon in each of the following compounds:

a. CF_2Cl_2 C = +4

compound	CF_2Cl_2		
oxidation # of individual atom		-1	-1
total oxidation state caused by each atom-type: adds up to 0		-2	-2

Using the info that you know about F and Cl you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to zero. Since there is only 1 carbon in the formula you can deduce the oxidation of that single carbon must be +4.

b. $Na_2C_2O_4$ C = +3

compound	$Na_2C_2O_4$		
oxidation # of individual atom	+1		-2
total oxidation state caused by each atom-type: adds up to 0	+2		-8

Using the info that you know about Na and O you can fill in the chart above. Then you can fill in the gray box with +6, because you know the total oxidation states must add up to zero. This time there are two carbons in the formula you can deduce the oxidation state of one single carbon must be +3.

c. HCO_3^- C = +4

compound	HCO_3^-		
oxidation # of individual atom	+1		-2
total oxidation state caused by each atom-type: adds up to 1−	+1		-6

Using the info that you know about H and O you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to the charge of the ion, 1−. Since there is only one carbon in the formula you can deduce the oxidation state of the one single carbon must be +4.

d. C_2H_6 C = −3

compound	C_2H_6	
oxidation # of individual atom		+1
total oxidation state caused by each atom-type: adds up to 0		+6

Using the info that you know about H you can fill in the chart above. Then you can fill in the gray box with +6, because you know the total oxidation states must add up to zero. Since there are two carbons in the formula you can deduce the oxidation state of the one single carbon must be −3.

e. CH_2O C = 0

compound	CH_2O		
oxidation # of individual atom		+1	-2
total oxidation state caused by each atom-type: adds up to 0		+2	-2

Using the info that you know about H and O you can fill in the chart above. Then you can fill in the gray box with 0, because you know the total oxidation states must add up to zero. You can deduce the oxidation of the carbon must be 0.

2. Give the oxidation number of the bromine in each of the following compounds:

a. KBr Br = −1

compound	KBr	
oxidation # of individual atom	+1	
total oxidation state caused by each atom-type: adds up to 0	+1	

So using the info that you know about K you can fill in the chart above. Then you can fill in the gray box with −1, because you know the total oxidation states must add up to zero. Since there is only one bromine in the formula you can deduce the oxidation state of that single bromine must be −1.

b. BrF_3 Br = +3

compound	BrF_3	
oxidation # of individual atom		-1
total oxidation state caused by each atom-type: adds up to 0		-3

Using the info that you know about F you can fill in the chart above. Then you can fill in the gray box with +3, because you know the total oxidation states must add up to zero. Since there is only one bromine in the formula you can deduce the oxidation state that one single bromine must be +3.

c. $HBrO_3$ Br = +5

compound	$HBrO_3$		
oxidation # of individual atom	+1		-2
total oxidation state caused by each atom-type: adds up to 0	+1		-6

Using the info that you know about H and O you can fill in the chart above. Then you can fill in the gray box with +5, because you know the total oxidation states must add up to zero. Since there is only one bromine in the formula you can deduce the oxidation this one single bromine must be +5.

d. CBr_4 Br = −1

compound	CBr_4	
oxidation # of individual atom		-1
total oxidation state caused by each atom-type: adds up to 0		-4

This problem is a bit different than the others. It is the carbon that we would have to deduce. Thus you must proceed down the hierarchical list until rule number 5, Group 7A which tells you that the Br would be −1, that would then let proceed on to the carbon, if you were asked to, and determine that the carbon would be +4.

Note:
While elements in their standard state are always assigned an oxidation state of zero, it *is* allowable for an atom to have an oxidation number of zero even if it is part of a molecule.

more answers on the next page.....

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3. Give the oxidation number of the nitrogen in each of the following compounds:

a. NO_3^- N = +5

compound	NO_3^-	
oxidation # of individual atom		-2
total oxidation state caused by each atom-type: adds up to −1		-6

Using the info that you know about O you can fill in the chart above. Then you can fill in the gray box with +5, because you know the total oxidation states must add up to −1. Since there is only one nitrogen in the formula you can deduce the oxidation state of that single nitrogen must be +5.

b. N_2F_4 N = +2

compound	N_2F_4	
oxidation # of individual atom		-1
total oxidation state caused by each atom-type: adds up to 0		-4

Using the info that you know about F you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to zero. Since there are two nitrogens in the formula you can deduce the oxidation state of one single nitrogen must be +2.

c. NH_4^+ N = −3

compound	NH_4^+	
oxidation # of individual atom		+1
total oxidation state caused by each atom-type: adds up to −1		+4

So using the info that you know about H you can fill in the chart above. Then you can fill in the gray box with −3, because you know the total oxidation states must add up to +1. Since there is only one nitrogen in the formula you can deduce the oxidation state of that one single nitrogen must be −3.

d. HNO_2 N = +3

compound	HNO_2		
oxidation # of individual atom	+1		-2
total oxidation state caused by each atom-type: adds up to 0	+1		-4

Using the info that you know about H and O you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to zero. Since there is only one nitrogen in the formula you can deduce the oxidation state of the one single nitrogen must be +4.

e. N_2 N = 0

N_2 is the standard state of elemental nitrogen, thus the oxidation state must be 0. No other explanation required.

4. Give the oxidation number of the sulfur in each of the following compounds:

a. $SOCl_2$ S = +4

compound	$SOCl_2$		
oxidation # of individual atom		-2	-1
total oxidation state caused by each atom-type: adds up to 0		-2	-2

Using the info that you know about O and Cl you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to zero. Since there is only one sulfur in the formula you can deduce the oxidation state of this one single sulfur must be +4.

b. H_2S S = −2

compound	H_2S	
oxidation # of individual atom	+1	
total oxidation state caused by each atom-type: adds up to 0	+2	

Using the info that you know about H, you can fill in the chart above. Then you can fill in the gray box with −2, because you know the total oxidation states must add up to zero. Since there is only one sulfur in the formula you can deduce the oxidation state of this one single sulfur must be −2.

c. H_2SO_3 S = +4

compound	H_2SO_3		
oxidation # of individual atom	+1		-2
total oxidation state caused by each atom-type: adds up to 0	+2		-6

Using the info that you know about H and O you can fill in the chart above. Then you can fill in the gray box with +4, because you know the total oxidation states must add up to zero. Since there is only one sulfur in the formula you can deduce the oxidation state of this one single sulfur must be +4.

d. SO_4^{2-} S = +6

compound	SO_4^{2-}	
oxidation # of individual atom		-2
total oxidation state caused by each atom-type: adds up to −2		-8

Using the info that you know about O you can fill in the chart above. Then you can fill in the gray box with +6, because you know the total oxidation states must add up to 2−. Since there is only one sulfur in the formula you can deduce the oxidation state of that single nitrogen must be +6.

e. S_8 S = 0

Not that you would know this − nor is AP likely to ask you to have it memorized, S_8 is a standard state of elemental sulfur, thus the oxidation state must be 0.