Simple Step-by-Step Guides to Solving Chemistry Problems

Determining Oxidation Numbers

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Assigning Oxidation Numbers

Oxidation numbers which can be positive, negative or zero in value, are assigned to elements and simply represent the number of electrons lost or gained by an atom of that element in the compound. They are a 'bookkeeping tool' to allow chemists to keep track of electrons in reactions, identify species that are being oxidised/reduced and to balance redox reactions. Elements or ions that lose electrons undergo an increase in oxidation number and hence are said to be oxidised. Reduction on the other hand is accompanied by a decrease in oxidation number.

Rules for Assigning Oxidation Numbers

Although difficult to define, oxidation numbers are surprisingly easy to assign, using the following rules:

Rule 1: uncombined elements - for example, $Fe_{(s)}$, $O_{2\,(g)}$ have an oxidation number of zero.

Rule 2: the oxidation state of a monatomic ion is the same as the charge on the ion. Thus Ni^{2+} has an oxidation number of +2 and O^{2-} has a oxidation number of -2. Note the charge is given first then the number, whereas the number, then the charge is the used for ions.

Rule 3: the sum of the oxidation numbers of the elements in a neutral compound is zero, whilst equals the charge on a polyatomic ion equals the charge on the ion.

Rule 4: The oxidation number of group 1 and group 2 metals in compounds is +1 and +2, respectively. Fluorine in compounds always has an oxidation number of -1, whilst the remaining halogen elements have an oxidation number of -1 unless bonded to oxygen or fluorine.

Rule 5: Oxygen in compounds usually has an oxidation number of -2. However, in peroxides (O^{2-}) oxygen has an oxidation number of -1 and in combination with fluorine, oxygen has an oxidation number of +1.

Rule 6: The oxidation state of hydrogen is +1 in its compounds, except for metal hydrides, such as NaH, LiH, etc., in which the oxidation state for H is -1.

Determining Oxidation Numbers

Oxidation numbers (element underlined) can be readily determined by following the rules outlined above.

$\underline{F_2}$

oxidation number of F = **0** (Rule 1)

$\underline{V^{3+}}$

oxidation number of V = **+3** (Rule 2)

$\underline{NO}$

oxidation number of N + oxidation number of O = 0 (Rule 3)
oxidation number of N = 0 - oxidation number of O
oxidation number of N = 0 - -2 (Rule 5)
= **+2**

MnO_4^-

oxidation number of Mn + (4 x oxidation number of O) = -1 (Rule 2)
oxidation number of Mn = -1- (4 x oxidation number of O)
oxidation number of Mn = - 1 – {4 x -2 (Rule 2)}
= -1 + 8 = 7
= +12/2 = **+6**

$MgSF_6$

oxidation number of Mg + oxidation number of S + (6 x oxidation number of F) = 0 (Rule 3)
oxidation number of S = 0 – oxidation number of Mg – (6 x oxidation number of F)
oxidation number of S = 0 – +2 (Rule 4) – {6 x -1 (Rule 4)}
= 0 – 2 +6
= **+4**

Practice Problems

1. Give the oxidation number of the indicated atoms/ion.

a. S in H_2SO_4
b. C
c. C in CO
d. Na in NaCl
e. H in H_2O
f. Ba in $BaCl_2$
g. S in Al_2S_3
h. I in $Mg(IO_3)_2$
i. Mn in $KMnO_4$
j. Na in Na_2S

2. Give the oxidation numbers of all the elements in the following molecules and ions:

a. SO
b. SO_2
c. SO_3
d. SO_3^{2-}
e. SO_4^{2-}
f. ClO_2
g. ClO^-
h. ClO_2^-
i. ClO_3^-
j. ClO_4^-
k. N_2O
l. NO_2
m. N_2O_4
n. N_2O_5
o. NO_2^-
p. NO_3

3 . Indicate the oxidation number of phosphorus in each of the following compounds:

a. HPO_3
b. H_3PO_4
c. H_3PO_2
e. H_3PO_3
d. H_4P_2O

Answers are given in the next page.

Oxidation State Answers:

1. Give the oxidation number of the indicated atoms/ion.

a. S in H_2SO_4 H +1, S +6, O -2
b. C C 0
c. C in CO C +2, O -2
d. Na in NaCl Na +1, Cl -=1
e. H in H_2O H +1, O -2
f. Ba in $BaCl_2$ Ba +2, Cl -1
g. S in Al_2S_3 Al + 3, S -2
h. in $Mg(IO_3)_2$ Mg +2, I +5, O -2
i. Mn in $KMnO_4$ K +1, Mn +7, O -2
j. Na in Na_2S: Na +1, S -2

2. Give the oxidation numbers of all the elements in the following molecules and ions:

a. SO S +2: O -2
b. SO_2 S +4, O -2
c. SO_3 S +6, O -2
d. SO_3^{2-} S +4, O -2
e. SO_4^{2-} S +6, O -2
f. ClO_2 Cl +4, O -2
g. ClO^- Cl +1, O -2
h. ClO_2^- Cl +3, O -2
i. ClO_3^- Cl +5, O -2
j. ClO_4^- Cl +7, O-2
k. N_2O N +1, O -2
l. NO_2 N +4, O -2
m. N_2O_4 N +4, O -2
n. N_2O_5 N +2.5, O -2
o. NO_2^- N +3, O -2
p. NO_3^- N +5, O -2

3. Indicate the oxidation number of phosphorus in each of the following compounds:

a. HPO_3 ` +5
b. H_3PO_4 +5
c. H_3PO_2 +1