6 Oxidation-Reduction

[A] Oxidation-reduction

(1) Oxidation is a process which liberates electrons, *i.e.*, de-electronation.

(2) Reduction is a process which gains electrons, *i.e.*, electronation.

Oxidation	Reduction
$M \longrightarrow M^{+n} + ne$	$M^{+n} + ne \longrightarrow M$
$A^{-n} \longrightarrow A + ne$	$A + ne \longrightarrow A^{-n}$
$n_2 > n_1$ $M^{+n_1} \longrightarrow M^{+n_2} + (n_2 - n_1)e$	$M^{+n_2} + (n_2 - n_1)e \longrightarrow M^{+n_1}$
$n_1 > n_2$ $A^{-n_1} \longrightarrow A^{-n_2} + (n_1 - n_2)e$	$A^{-n_2} + (n_1 - n_2)e \longrightarrow A^{-n_1}$

(3) Oxidants are substances which:

(a) oxidize other.

(b) reduced themselves.

(c) show electronation.

(d) show a decrease in oxidation no. during a redox change.

(e) has higher oxidation no. in a conjugate pair of redox.

(4) Reductants are substances which:

(a) reduce other.

(b) oxidized themselves.

(c) show de-electronation.

(d) show an increase in oxidation no. during a redox change.

(e) has lower oxidation no. in a conjugate pair of redox.

(5) A redox change is one in which a reductant is oxidized to liberate electrons, which are then used up by an oxidant to get itself reduced.

$$M_1 \longrightarrow M_1^{+n} + ne \quad \text{Oxidation}$$
$$M_2^{+n} + ne \longrightarrow M_2 \quad \text{Reduction}$$
$$M_1 + M_2^{+n} \longrightarrow M_1^{+n} + M_2 \quad \text{Redox reaction}$$

(6) A redox change occurs simultaneously.

[B] Types of Redox changes

(1) Intermolecular redox reactions : Two substances reacts; one of them is oxidant and other is reductant, *e.g.*,

$$10FeSO_4 + 2KMnO_4 + 8H_2SO_4 \longrightarrow 2MnSO_4 + 5Fe_2(SO_4)_3 + K_2SO_4 + 8H_2O$$
$$Fe^{2+} \longrightarrow Fe^{3+} + e$$
$$Mn^{7+} + 5e \longrightarrow Mn^{2+}$$

(2) Auto redox reactions or disproportionation : The same element is oxidized and reduced as well, *e.g.*,

$$2Cu^{2+} \longrightarrow Cu^{2+} + Cu^0$$

Cu^+ is oxidized to Cu^{2+} and Cu^+ is reduced to Cu.

(3) Intramolecular redox reactions : One element of a compound is oxidized and other element of the same compound is reduced, *e.g.*,

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

Cl is reduced ($Cl^{5+} + 6e \longrightarrow Cl^-$) and O is oxidized

$$[2(O^{2-})_3 \longrightarrow 3O_2^0 + 12e]$$
$$(NH_4)_2Cr_2O_7 \longrightarrow N_2 + Cr_2O_3 + 4H_2O$$

N is oxidized ($2N^{3-} \longrightarrow N_2^0 + 6e$) and Cr is reduced

$$[(Cr^{6+})_2 + 6e \longrightarrow (Cr^{3+})_2]$$

[C] Oxidation Number

(1) Oxidation no. of an element in a particular compound represents the no. of electrons lost or gained by an element during its change from free state into that compound.

or Oxidation no. of an element in a particular compound represents the extent of oxidation or reduction of an element during its change from free state into that compound.

(2) Oxidation no. is given positive sign if electrons are lost. Oxidation no. is given negative sign if electrons are gained.

(3) Oxidation no. represents real charge in case of ionic compounds. However, in covalent compounds it represents imaginary charge.

[D] Rules for Deriving Oxidation Number

Following rules have been arbitrarily adopted to decide oxidation no. of elements on the basis of their periodic properties.

(1) In uncombined state or free state, oxidation no. of an element is zero.

(2) In combined state oxidation no. of......

(a) ......F is always −1.

(b) ......O is −2. In peroxides it is −1. However in F_2O it is +2.

(c) ......H is +1. In ionic hydrides it is −1. (*i.e.*, IA, IIA and IIIA metals)

(d) ......halogens as halide is always −1.

(e) ......sulphur as sulphide is always −2.

(f) ......metals is always +ve.

(g) ......alkali metals (*i.e.*, IA group–Li, Na, K, Rb, Cs, Fr) is always +1.

(h) ......alkaline earth metals (*i.e.*, IIA group—Be, Mg, Ca, Sr, Ba, Ra) is always +2.

(3) The algebraic sum of all the oxidation no. of elements in a compound is equal to zero, *e.g.*, $KMnO_4$.

Ox. no. of K + Ox. no. of Mn + (Ox. no. of O) × 4 = 0

(4) The algebraic sum of all the oxidation no. of elements in a radical is equal to the net charge on the radical, *e.g.*, CO_3^{2-}.

Oxidation no. of C + 3 × (Oxidation no. of O) = −2

(5) Oxidation number can be zero, +ve, −ve (integer or fraction).

(6) Maximum oxidation no. of an element is = Group no. (Except O and F)

Minimum oxidation no. of an element is = Group no.−8 (Except metals)

[E] Oxidation State

It is defined as oxidation no. per atom, *e.g.*, in $KMnO_4$

Oxidation no. of Mn is = +7

Oxidation state of Mn is = Mn^{7+}

[F] Balancing a half reaction

Consider for example : $Fe_2O_3 \longrightarrow Fe_3O_4$

Step I : Write down the symbol of element with its oxidation number on two sides of reaction.

$$Fe^{3+} \longrightarrow Fe^{8/3+}$$

Step II : Write the elemental form of element in which it exist in that compound as shown below.

$$(Fe^{3+})_2 \longrightarrow (Fe^{8/3+})_3$$

Step III : Make the number of atoms same on two sides as reported below :

$$3(Fe^{3+})_2 \longrightarrow 2(Fe^{8/3+})_3$$

Step IV : Multiply the all digits on right hand side $\left[i.e., 2\times3\times\left(+\frac{8}{3}\right)=+16\right]$ and on left hand side [*i.e.*, 3 × 2 × (+3) = +18] than subtract the value of left hand side from right hand side [*i.e.*, +16 − (+18) = −2].

Put this number (−2) with electron on right hand side, with its sign.

$$3(Fe^{3+})_2 \longrightarrow 2(Fe^{8/3+})_3 - 2e$$

[G] Balancing of Redox Equations

Two methods are commonly used for this purpose.

1. Ion Electron Method

It involves three sets of rules depending upon the nature of medium (*i.e.*, neutral, acid or alkaline) in which reaction occurs.

(a) Neutral medium:

e.g., $H_2C_2O_4 + KMnO_4 \longrightarrow CO_2 + K_2O + MnO + H_2O$

Step 1. Select the oxidant, reductant atoms and write their half reactions, one representing oxidation and other reduction.

i.e., $(C^{3+})_2 \longrightarrow 2C^{4+} + 2e$

$$5e + Mn^{7+} \longrightarrow Mn^{2+}$$

Step 2. Balance the no. of electrons and add the two equations.

$$5(C^{3+})_2 \longrightarrow 10C^{4+} + 10e$$
$$10e + 2Mn^{7+} \longrightarrow 2Mn^{2+}$$
$$\overline{5(C^{3+})_2 + 2Mn^{7+} \longrightarrow 10C^{4+} + 2Mn^{2+}}$$

Step 3. Write complete molecule of the reductant and oxidant from which respective redox atoms were obtained.

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO$$

Step 4. Balance other atoms if any (except H and O).

In above example K is unbalanced, therefore,

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO + K_2O$$

(mentioned as product)

Step 5. Balance O-atom using H_2O on desired side.

$$5H_2C_2O_4 + 2KMnO_4 \longrightarrow 10CO_2 + 2MnO + K_2O + 5H_2O$$

(b) Acidic medium:

e.g., $NO_3^- + H_2S \xrightarrow{H^+} HSO_4^- + NH_4^+$

proceed like neutral medium for step 1 to step 4.

Step 1. $8e + N^{5+} \longrightarrow N^{3-}$

$$S^{2-} \longrightarrow S^{6+} + 8e$$

Step 2. $N^{5+} + S^{2-} \longrightarrow N^{3-} + S^{6+}$

Step 3. $NO_3^- + H_2S \longrightarrow NH_4^+ + HSO_4^-$

Step 4. No other atom (except H and O) is unbalanced and thus, no need for this step.

Step 5. Balance O-atom: Balancing of O-atom is made by using H_2O and H^+ ions.

Add desired molecules of H_2O on the side deficient with O-atom and double H^+ on opposite side. Therefore,

$$H_2O + NO_3^- + H_2S \longrightarrow NH_4^+ + HSO_4^- + 2H^+$$

Step 6. Balance charge by H^+:

$$3H^+ + H_2O + NO_3^- + H_2S \longrightarrow NH_4^+ + HSO_4^- + 2H^+$$

∴ Finally balanced equation is,

$$H^+ + H_2O + NO_3^- + H_2S \longrightarrow NH_4^+ + HSO_4^-$$

(c) Alkaline medium:

e.g., $Fe + N_2H_4 \xrightarrow{OH^-} Fe(OH)_2 + NH_3$

Proceed like neutral medium for step 1 to step 4.

Step 1. $Fe \longrightarrow Fe^{2+} + 2e$

$2e + (N^{2-})_2 \longrightarrow 2N^{3-}$

Step 2. $Fe + (N^{2-})_2 \longrightarrow Fe^{2+} + 2N^{3-}$

Step 3. $Fe + N_2H_4 \longrightarrow Fe(OH)_2 + 2NH_3$

Step 4. No other atom (except H and O) is unbalanced and thus, no need for this step.

Step 5. Balance O-atom: Balancing of O-atom is made by using H_2O and OH^- ions.

Add desired molecules of H_2O on the side rich with O-atoms and double OH^- on opposite side. Therefore,

$$4OH^- + Fe + N_2H_4 \longrightarrow Fe(OH)_2 + 2NH_3 + 2H_2O$$

Step 6. Balance charge by H^+:

$$4OH^- + 4H^+ + Fe + N_2H_4 \longrightarrow Fe(OH)_2 + 2NH_3 + 2H_2O$$

∴ Finally balanced equation is,

$$2H_2O + Fe + N_2H_4 \longrightarrow Fe(OH)_2 + 2NH_3$$

2. Oxidation State Method

e.g., $KMnO_4 + H_2C_2O_4 \longrightarrow CO_2 + K_2O + MnO + H_2O$

The initial step 1 should be written as

Step 1. $Mn^{7+} \longrightarrow Mn^{2+}$ *i.e.,* change in oxidation no. of Mn $(+7 \longrightarrow +2) = 5$ units

$(C^{3+})_2 \longrightarrow 2C^{4+}$ *i.e.,* change in oxidation no. of C $(+6 \longrightarrow +8) = 2$ units

Step 2. Proceed from step 2 to last step for neutral, acidic or alkaline medium as in ion electron method.

[H] Balancing of Half Reactions

Example 1. $I_2 \longrightarrow IO_3^-$ (Acid medium)

Step 1. Balance atoms other than O and H if needed, *i.e.,*

$$I_2 \longrightarrow 2IO_3^-$$

Step 2. Balance O-atoms using H^+ and H_2O as reported earlier.

$$I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+$$

Step 3. Balance charge by electrons.

$$I_2 + 6H_2O \longrightarrow 2IO_3^- + 12H^+ + 10e$$

This is balanced half reaction.

Example 2. $S_2O_3^{2-} \longrightarrow SO_2$ (Basic medium)

Step 1. As above $S_2O_3^{2-} \longrightarrow 2SO_2$

Step 2. Balance O-atom by H_2O and OH^- as reported earlier.

$$2OH^- + S_2O_3^{2-} \longrightarrow 2SO_2 + H_2O$$

Step 3. Balance charge by electrons.

$$2OH^- + S_2O_3^{2-} \longrightarrow 2SO_2 + H_2O + 4e$$

This is balanced half reaction.

• NUMERICAL PROBLEMS •

1. Determine the oxidation no. of following elements given in bold letters:
(a) $K\mathbf{Mn}O_4$, (b) $H_2\mathbf{S}O_5$, (c) $H_2\mathbf{S}_2O_8$, (d) $\mathbf{N}H_4\mathbf{N}O_3$, (e) $K_4\mathbf{Fe}(CN)_6$, (f) $\mathbf{Os}O_4$, (g) HCN, (h) HNC, (i) $\mathbf{HNO}_3$, (j) $K\mathbf{O}_2$, (k) $\mathbf{Fe}_3O_4$, (l) $K\mathbf{I}_3$, (m) $^-\mathbf{OCN}$, (n) $\mathbf{Fe}(CO)_5$, (o) $\mathbf{Fe}_{0.94}O$, (p) $NH_2 \cdot NH_2$, (q) $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ (r) NOCl, (s) $NOClO_4$, (t) $Na_2[\mathbf{Fe}(CN)_5NO]$, (u) $[\mathbf{Fe}(NO)(H_2O)_5]SO_4$, (v) $Na_2\mathbf{S}_4O_6$, (w) Dimethyl sulphoxide or $(CH_3)_2SO$, (x) $Na_2\mathbf{S}_2O_3$, (y) $\mathbf{Cr}O_5$ or $\mathbf{Cr}O(O_2)_2$, (z) $CaO\mathbf{Cl}_2$.
2. Determine the oxidation number of following elements given in bold letters :
(a) $\mathbf{Cu}H$, (b) $Na_2\mathbf{S}_3O_6$, (c) $\mathbf{N}_2O$, (d) $Ba_2\mathbf{Xe}O_6$, (e) C_3O_2, (f) $\mathbf{V}(BrO_2)_2$, (g) $Ca(\mathbf{Cl}O_2)_2$, (h) $Cs_4Na(H\mathbf{V}_{10}O_{28})$, (i) $LiAlH_4$, (j) $K[\mathbf{Co}(C_2O_4)_2 \cdot (NH_3)_2]$, (k) $[\mathbf{Ni}(CN)_4]^{2-}$, (l) $Na_2\mathbf{S}_2$, (m) $[\mathbf{Xe}O_6]^{4-}$, (n) HOCN, (o) $(CN)_2$
3. Find the oxidation number of Fe in Fe_3O_4 and in $Fe(III)_4[Fe(II)(CN)_6]_3$.
4. Find out the value of n in:
$$MnO_4^- + 8H^+ + ne \longrightarrow Mn^{2+} + 4H_2O$$
5. Calculate the oxidation number of Mn in the product formed on strongly heating Mn_2O_7.
6. Calculate the oxidation number of Mn in the product of alkaline oxidative fusion of MnO_2. **(IIT 2009)**
7. One mole of N_2H_4 loses 10 mole electrons to form a new compound Y. Assuming that all the N_2 appears in new compound, what is oxidation state of N in Y?
8. In the reaction, $Al + Fe_3O_4 \longrightarrow Al_2O_3 + Fe$
(a) Which element is oxidized and which is reduced?
(b) Total no. of electrons transferred during the change.
9. The composition of a sample of wustite is $Fe_{0.93}O_{1.00}$. What percentage of iron is present in the form of Fe (III)? **(IIT 1994)**
10. Select the species acting as reductant and oxidant in the reaction given below:
$$PCl_3 + Cl_2 \longrightarrow PCl_5$$
11. Identify the substance acting as oxidant or reductant reduced if any in the following :
(i) $AlCl_3 + 3K \longrightarrow Al + 3KCl$
(ii) $SO_2 + 2H_2S \longrightarrow 3S + H_2O$
(iii) $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$
(iv) $3I_2 + 6NaOH \longrightarrow NaIO_3 + 5NaI + 3H_2O$
12. Arrange the following in order of:
(a) Increasing oxidation no.of Mn: $MnCl_2$, MnO_2, $Mn(OH)_3$, $KMnO_4$
(b) Decreasing oxidation no. of X: HXO_4, HXO_3, HXO_2, HXO
(c) Increasing oxidation no. of I: I_2, HI, HIO_4, ICl **(IIT 1986)**
13. Which of the following are oxidants and which are reductants? Justify your answer with half equations?
$$Fe^{3+}, SO_3, NO_3^-, I^-, Na$$
14. HNO_3 acts only as oxidant whereas, HNO_2 acts as reductant and oxidant both.
15. Balance the following equations:
(a) $BaCrO_4 + KI + HCl \longrightarrow BaCl_2 + I_2 + KCl + CrCl_3 + H_2O$
(b) $SO_2 + Na_2CrO_4 + H_2SO_4 \longrightarrow Na_2SO_4 + Cr_2(SO_4)_3 + H_2O$
(c) $C_2H_5OH + I_2 + OH^- \longrightarrow CHI_3 + HCO_2^- + H_2O + I^-$ (Basic)
16. Write down the disproportionation of HNO_2 in cold water.
17. Eight mole of chlorine (Cl_2) undergoes a loss and gain of 14 mole of electrons to form two oxidation state of chlorine (Cl). Write down the two half reaction and equation for disproportionation of chlorine, Cl_2.

SOLUTIONS (Numerical Problems)

1. (a) $KMnO_4$: Ox. no. of K = +1 by rules

Ox. no. of Mn = a

Ox. no. of O = −2 by rules

$\therefore$ $1 + a + 4 \times (-2) = 0$

$\therefore$ $a = +7$

(b) H_2SO_5: Ox. no. of H = +1

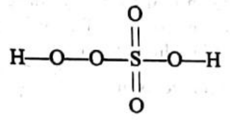
Ox. no. of O = −2

Ox. no. of S = a

$\therefore$ $2 \times 1 + a + 5 \times (-2) = 0$

$a = +8$ **(wrong)**

But this cannot be true as maximum ox. no. for S (VI gp) stands + 6. The exceptional value is due to the fact that two O-atoms in H_2SO_5 show peroxide linkage, *i.e.*,

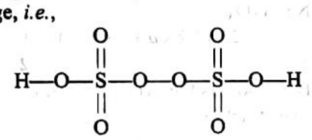


Thus, evaluation of ox. no. of S should be made as

$2 \times 1 + a + 3 \times (-2) + 2 \times (-1) = 0$

$\therefore$ $a = +6$

(c) $H_2S_2O_8$: Here too, two O-atoms form peroxide linkage, *i.e.*,



$\therefore$ $2 \times 1 + 2a + 6 \times (-2) + 2 \times (-1) = 0$

$\therefore$ $a = +6$

(d) NH_4NO_3: $2 \times a + 4 \times 1 + 3 \times (-2) = 0$ by rules

$a = +1$ **(wrong)**

No doubt there are two N-atoms in NH_4NO_3, but one N-atom has negative ox. no. (attached to H) and the other has positive ox. no. (attached to O). Therefore, evaluation should be made separately as

Ox. no. of N in NH_4^+	and Ox. no. of N in NO_3^-
$a + 4 \times (+1) = +1$	$a + 3 \times (-2) = -1$
$\therefore$ $a = -3$	$\therefore$ $a = +5$

(e) $K_4Fe(CN)_6$: By rules, Ox. no. of K = +1 **(MLNR 1986)**

Ox. no. of CN^{-1} = −1

Ox. no. of Fe = a

$\therefore$ $4 \times 1 + a + 6 \times (-1) = 0$

$\therefore$ $a = +2$

(f) OsO_4: $a + 4 \times (-2) = 0$

$\therefore$ $a = +8$

Note : 1. The element Os and Ru show highest oxidation state, *i.e.*, + 8.

2. Recently Ba_2XeO_6 has been reported in which ox. no. of Xe is + 8.

(g) HCN : The evaluation cannot be made directly in some cases, *e.g.*, HCN by using rules proposed earlier since we have no rule for ox. no. of both N and C.

In all such cases evaluation of ox. no. should be made using indirect concept or using fundamentals by which rules have been framed.

(1) Each covalent bond contributes one unit for ox. no.

(2) Covalently bonded atoms with less electronegativity acquires positive ox. no. whereas other with more electronegativity acquires negative ox. no.

(3) In case of co-ordinate bond, give + 2 value for ox. no. to atom from which co-ordinate bond is directed to a more electronegative atom and − 2 value to more electronegative atom.

If co-ordinate bond is directed from more electronegative to less electronegative atom, then neglect contribution of co-ordinate bond for both atoms in which co-ordinate bond exist.

Thus, H—C≡N	$\because$ Three bonds on N-atom and N is more electronegative
$1 + a + 3 \times (-1) = 0$	$\therefore$ Ox. no. of N
$a = +2$	$= 3 \times (-1) = -3$

(h) HNC : H—N⇄C

Ox. no. of H = +1

Ox. no. of N = [−2 (for covalent bond with C) + (−1) [for covalent bond with H] + 0 (No. contribution for co-ordinate bond)] = −3 (According to fundamental concept)

= −3

$\therefore$ $1 + (-3) + a = 0$

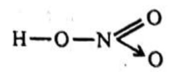
$\therefore$ $a = +2$

(i) HNO_3: By rules

$1 + a + 3 \times (-2) = 0$

$\therefore$ $a = +5$

By fundamental approach



Ox. no. of H = + 1

Ox. no. of N = + 1 (Covalent bond with O) + (+2) (Two covalent bond with O) + (+2) (Co-ordinate bond) = + 5

$\because$ N being less electronegative than O.

(j) **KO_2:** A super oxide of K; **(MLNR 1988)**

Ox. no. of K = +1

Ox. no. of O = a

$1+2\times a=0$

$\therefore \quad a=-\frac{1}{2}$

(k) **Fe_3O_4:** $3\times a+4\times(-2)=0$

$\therefore \quad a=+\frac{8}{3}$

or Fe_3O_4 is a mixed oxide of $FeO\cdot Fe_2O_3$

$\therefore$ Fe has two oxidation no. +2 and +3 separately. However, factually speaking ox. no. of Fe in Fe_3O_4 is an average of two values (*i.e.*, +2 and +3)

Average ox. no. $=\frac{+2+2\times(+3)}{3}=+\frac{8}{3}$

(l) **KI_3:** $1+3\times(a)=0$

$a=-\frac{1}{3}$

or KI_3 is $KI+I_2$

$\therefore$ I has two oxidation no. −1 and 0 respectively. However, factually speaking ox. no. of I in KI_3 is an average of two values −1 and 0.

Average Ox. no. $=\frac{-1+2\times(0)}{3}=-\frac{1}{3}$

(m) **^-OCN:** $^-O—C\equiv N$

$a+4-3=-1$ (Follow covalent rules)

$\therefore \quad a=-2$

(n) **$Fe(CO)_5$:** Sum of ox. no. of CO = 0

$\therefore \quad a+5\times(0)=0$

$\therefore \quad a=0$

(o) **$Fe_{0.94}O$:** $0.94\times a+(-2)=0$

$a=\frac{200}{94}$

(p) $NH_2\cdot NH_2$: Both N have same nature.

$a+2+a+2=0$

$\therefore \quad a=-2$

(q) **$FeSO_4\cdot(NH_4)_2SO_4\cdot 6H_2O$:** Ox. no. of Fe = a

Sum of ox. no. for $(NH_4)_2SO_4=0$

Sum of ox. no. for $H_2O=0$

Sum of ox. no. for $SO_4^{2-}=-2$

$\therefore \quad a+(-2)+0+6\times(0)=0$

$\therefore \quad a=+2$

(r) NOCl: $Cl—N=O$ or use NO^+Cl^-

Ox. no. of N = +1 (for covalent bond with Cl)

Ox. no. of N = +2 (for two covalent bonds with O)

$\therefore$ Total ox. no. of N in NOCl = +3

(s) **$NOClO_4$:** The compound may be written as $NO^+ClO_4^-$ for ClO_4^-.

For ClO_4^-, let Ox. no. of Cl = a

$a+4\times(-2)=-1$

$a=+7$

(t) **$Na_2[Fe(CN)_5NO]$:** NO in iron complex has NO^+ nature.

$\therefore \quad 2\times 1+[a+5\times(-1)+(+1)]=0$

$\therefore \quad a=+2$

(u) **$[Fe(NO)(H_2O)_5]SO_4$:**

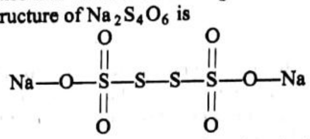
$a+1+5\times 0+(-2)=0$

$a=+1$

(v) **$Na_2S_4O_6$:** $2\times(+1)+4a+6\times(-2)=0$

$\therefore \quad a=+\frac{5}{2}$

Here also this value is the average oxidation no. of S. The structure of $Na_2S_4O_6$ is



Thus, ox. no. of each S-atom forming double bond is +5 whereas, ox. no. of each S-atom involved in pure covalent bonding is zero.

$\therefore$ Average ox. no. $=\frac{+5+5+0+0}{4}=+\frac{5}{2}$

(w) Dimethyl sulphoxide or $(CH_3)_2SO$:

Ox. no. of $CH_3=+1$; Ox. no. of O = −2

$\therefore \quad 2\times(+1)+a+(-2)=0$

$a=0$

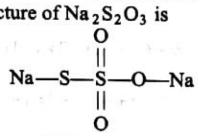
(x) **$Na_2S_2O_3$:**

$2\times 1+2\times a+3\times(-2)=0$

$\therefore \quad a=+2$

Here too it is the average ox. no.

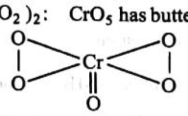
The structure of $Na_2S_2O_3$ is



The ox. no. of S involved in double bond is +5.

The ox. no. of other S-atom is −1.

(y) **CrO_5 or $CrO(O_2)_2$:** CrO_5 has butterfly structure as:



i.e., two peroxide bonds and thus four oxygen atoms have ox. no. = −1 and one oxygen atom has ox. no. −2

Thus, $a+4\times(-1)+1\times(-2)=0 \quad \therefore a=+6$

(z) **$CaOCl_2$:** In bleaching powder two Cl-atoms are as $Ca(OCl)\cdot Cl$, *i.e.*, one as Cl^- having ox. no. **−1** and other as OCl^- having ox. no. **+1.**

2. (a) **CuH:** $a+1=0$

$\therefore \quad a=-1$ ($\because$ H in CuH has +1 oxidation number)

(b) **$Na_2S_3O_6$:** $2\times 1+3\times a+6\times(-2)=0$

$\therefore \quad a=+\frac{10}{3}$

(c) N_2O: $2\times a+(-2)=0$

$a=+1$

Although it is average of two oxidation numbers as shown below :

$\underset{0}{N} \equiv \underset{+2}{N} \longrightarrow \underset{-2}{O}$

(d) Ba_2XeO_6: $2\times 2+a+6\times(-2)=0$

$a=+8$

(e) C_3O_2: $3\times a+2\times(-2)=0$

$\therefore \quad a=+\frac{4}{3}$

(f) $V(BrO_2)_2$: The BrO_2 ion is monovalent and thus oxidation number of $V=+2$

(g) $Ca(ClO_2)_2$: The ClO_2 ion is monovalent and thus for ClO_2^- ion

$a+2\times(-2)=-1 \quad \therefore \; a=+3$

(h) $Cs_4Na(HV_{10}O_{28})$:

$4\times1+1\times1+[1+10\times a+28\times(-2)]=0 \;\therefore\; a=+5$

(i) $LiAlH_4$: $1+a+4\times(-1)=0$

$\therefore \quad a=+3$

(j) $K[Co(C_2O_4)_2\cdot(NH_3)_2]$: $1+[a+2\times(-2)+2\times 0]=0$

$\therefore \quad a=+3$

(k) $[Ni(CN)_4]^{2-}$: $a+4\times(-1)=-2$

$a=+2$

(l) Na_2S_2: Like peroxide, ox. no. of S in S_2^{2-} is -1.

(m) $[XeO_6]^{4-}$: In per xenate Xe has $+8$ oxidation number

$a+6\times(-2)=-4$

$a=+8$

(**Note :** No per oxide bond).

(n) HOCN : Follow bonding rules to evaluate oxidation number.

$\overset{+1}{H}-\overset{-1}{O}-\overset{+1}{C}\equiv\overset{-3}{N}$

$\overset{-1\;\;+3}{}$

$+1\;\; -2\;\; +4\;\; -3$

(o) $(CN)_2$: $(\overset{+3}{C}\equiv\overset{-3}{N})_2$

Follow bonding rules to evaluate oxidation number.

3. Let the oxidation number of Fe be a

Fe_3O_4: $3\times a+4\times(-2)=0$

$a=+\frac{8}{3}$

Actually this is average oxidation number of Fe in Fe_3O_4. It exist in $FeO\cdot Fe_2O_3$ having oxidation number of Fe $+2$ in FeO and $+3$ in Fe_2O_3. Thus, average oxidation number

$$=\frac{2\times 1\text{atom of Fe (in FeO)}+3\times 2\text{atoms of Fe (in }Fe_2O_3)}{3\text{ (Total atoms of Fe)}}=+\frac{8}{3}$$

$Fe(III)_4[Fe(II)(CN)_6]_3$: Fe(III) has $+3$ oxidation number

Fe(II) has $+2$ oxidation number

Also, average oxidation number

$$=\frac{4\times(+3)+3\times(+2)}{7}=+\frac{18}{7}$$

4. Total charge on LHS = Total charge on RHS.

$(-1)+8+(-n)=+2$

$\therefore \quad n=5$

5. $2Mn_2O_7 \xrightarrow{\Delta} 4MnO_2+3O_2$, oxidation number of Mn in MnO_2 is $+4$.

6. $2MnO_2+4KOH+O_2 \longrightarrow 2K_2MnO_4+2H_2O$, oxidation number of Mn in K_2MnO_4 is $+6$.

7. $N_2H_4 \longrightarrow (Y)+10e$

$\because$ Y contains all N-atoms

$\therefore \quad (N^{2-})_2 \longrightarrow (2N)^a+10e$

Therefore, $2a-(-4)=10$

$a=+3$

8. $2Al^0 \longrightarrow (Al^{3+})_2+6e$ ...(1)

$8e+(Fe^{8/3+})_3 \longrightarrow 3Fe^0$ ...(2)

Multiplying Eq. (1) by 4 and Eq. (2) by 3, then adding

$8Al^0 \longrightarrow 4(Al^{3+})_2+24e$

$24e+3(Fe^{8/3+})_3 \longrightarrow 9Fe^0$

$8Al^0+3(Fe^{8/3+})_3 \longrightarrow 4(Al^{3+})_2+9Fe^0$

or $8Al+3Fe_3O_4 \longrightarrow 4Al_2O_3+9Fe$

Therefore, it is clear that

(a) **Al is oxidized and $Fe^{8/3+}$ is reduced.**

(b) Total no. of electrons transferred during change = **24.**

9. Oxidation no. of Fe in wustite is $=\frac{200}{93}=2.15$

It is an intermediate value in between two oxidation state of Fe as, Fe (II) and (III),

Let percentage of Fe (III) be a, then

$2\times(100-a)+3\times a=2.15\times100$

or $a=15.05$

$\therefore$ Percentage of Fe (III) = **15.05%**

10. $P^{3+} \longrightarrow P^{5+}+2e$

$2e+Cl_2^0 \longrightarrow 2Cl^{1-}$

$\therefore$ **PCl_3 is reductant and Cl_2 is oxidant.** | $\because$ In a conjugate pair of redox the one having higher ox. no. is oxidant.

11. In a conjugate pair, oxidant has higher ox. no.

(i) **For $AlCl_3$:** $Al^{3+}+3e \longrightarrow Al^0$;

$\therefore$ **Oxidant is $AlCl_3$**

For K : $K^0 \longrightarrow K^{1+}+e$

$\therefore$ **Reductant is K.**

(ii) **For SO_2 :** $S^{4+}+4e \longrightarrow S^0$;

$\therefore$ **SO_2 is oxidant.**

For H_2S : $S^{2-} \longrightarrow S^0+2e$

$\therefore$ **H_2S is reductant.**

(iii) No change in ox. no. of either of the conjugate pair.

$\therefore$ **None is oxidant or reductant.**

(iv) **For I_2 :** $I_2^0 \longrightarrow 2I^{5+}+10e$ and $I_2^0+2e \longrightarrow 2I^{1-}$

$\therefore$ **I_2 acts as oxidant and reductant both.**

12. (a) $MnCl_2 < Mn(OH)_3 < MnO_2 < KMnO_4$

Ox. no. +2 +3 +4 +7

(b) $HXO_4 > HXO_3 > HXO_2 > HXO$

Ox. no. +7 +5 +3 +1

(c) $HI < I_2 < ICl < HIO_4$

Ox. no. −1 0 +1 +7

13. Oxidants : Fe^{3+}, NO_3^-, SO_3

$Fe^{3+} + 3e \longrightarrow Fe$

$N^{5+} + 2e \longrightarrow N^{3+}$

$S^{6+} + 2e \longrightarrow S^{4+}$

Reductants : I^-, Na

$Na \longrightarrow Na^+ + e$

$2I^- \longrightarrow I_2 + 2e$

14. HNO_3 : Ox. no. of N is +5 in HNO_3

Maximum ox. no. of N is +5

Minimum ox. no. of N is −3

Thus, ox. no. of N in HNO_3 is maximum and it can decrease only. That is why HNO_3 acts as oxidant only.

HNO_2 : Ox. no. of N is +3 in HNO_2

Maximum ox. no. of N is +5

Minimum ox. no. of N is −3

Thus, ox. no. of N (in HNO_2) can show an increase or decrease as the case may be. That is why HNO_2 acts as oxidant and reductant both.

15. (a) $BaCrO_4 + KI + HCl \longrightarrow BaCl_2 + I_2 + KCl + CrCl_3 + H_2O$

Step I. $3e + Cr^{6+} \longrightarrow Cr^{3+}$

$2I^- \longrightarrow I_2 + 2e$

Step II. $6e + 2Cr^{6+} \longrightarrow 2Cr^{3+}$

$6I^- \longrightarrow 3I_2 + 6e$

$$2Cr^{6+} + 6I^- \longrightarrow 2Cr^{3+} + 3I_2$$

Step III. $2BaCrO_4 + 6KI \longrightarrow 2CrCl_3 + 3I_2$

Step IV. Balancing of other atoms except (H and O), *i.e.*, Ba, K and Cl.

$2BaCrO_4 + 6KI + 16HCl \longrightarrow 2CrCl_3 + 3I_2 + 6KCl + 2BaCl_2$

Step V. Balance H-atom

$2BaCrO_4 + 6KI + 16HCl \longrightarrow 2CrCl_3 + 3I_2 + 6KCl + 2BaCl_2 + 8H_2O$

(b) $SO_2 + Na_2CrO_4 + H_2SO_4 \longrightarrow Na_2SO_4 + Cr_2(SO_4)_3 + H_2O$

Step I. $S^{4+} \longrightarrow S^{6+} + 2e$

$6e + 2Cr^{6+} \longrightarrow (Cr^{3+})_2$

Step II. $3S^{4+} \longrightarrow 3S^{6+} + 6e$

$6e + 2Cr^{6+} \longrightarrow (Cr^{3+})_2$

$$3S^{4+} + 2Cr^{6+} \longrightarrow 3S^{6+} + (Cr^{3+})_2$$

Three S^{6+} atoms are distributed in $2Na_2SO_4$ and $1Cr_2(SO_4)_3$

Step III.

$3SO_2 + 2Na_2CrO_4 \longrightarrow 2Na_2SO_4 + Cr_2(SO_4)_3$

Balancing of other atoms, *i.e.*, S in SO_4.

Step IV. $3SO_2 + 2Na_2CrO_4 + 2H_2SO_4 \longrightarrow 2Na_2SO_4 + Cr_2(SO_4)_3$

Step V. Balance H-atom

$3SO_2 + 2Na_2CrO_4 + 2H_2SO_4 \longrightarrow 2Na_2SO_4 + Cr_2(SO_4)_3 + 2H_2O$

(c) $C_2H_5OH + I_2 + OH^- \longrightarrow CHI_3 + HCO_2^- + H_2O + I^-$

Step I. $(C^{2-})_2 \longrightarrow 2C^{2+} + 8e$

$2e + I_2^0 \longrightarrow 2I^{1-}$

Step II. $(C^{2-})_2 \longrightarrow 2C^{2+} + 8e$

$8e + 4I_2 \longrightarrow 8I^-$

$$(C^{2-})_2 + 4I_2 \longrightarrow 2C^{2+} + 8I^-$$

Step III. $2C^{2+}$ are distributed one each in CHI_3 and HCO_2^-, $8I^-$ are distributed three in CHI_3 and 5 in I^-

$\therefore$ $C_2H_5OH + 4I_2 \longrightarrow CHI_3 + HCO_2^- + 5I^-$

Step IV. Balancing other atoms...... no need since no other (except H and O) atoms are unbalanced.

Step V. Balance O-atom by OH^- and H_2O

$C_2H_5OH + 4I_2 + 2OH^- \longrightarrow CHI_3 + HCO_2^- + 5I^- + H_2O$

Step VI. Balance charge by H^+

$C_2H_5OH + 4I_2 + 2OH^- \longrightarrow CHI_3 + HCO_2^- + 5I^- + H_2O + 4H^+$

Do not leave OH^- and H^+ free in an equation and thus,

$C_2H_5OH + 4I_2 + 2OH^- + 4OH^- \longrightarrow CHI_3 + HCO_2^- + 5I^- + H_2O + 4H^+ + 4OH^-$

$C_2H_5OH + 4I_2 + 6OH^- \longrightarrow CHI_3 + HCO_2^- + 5I^- + 5H_2O$

16. $\overset{+3}{3HNO_2} \longrightarrow \overset{+2}{2NO} + \overset{+5}{HNO_3} + H_2O$

17. Cl_2 can undergo only in Cl^- state to show loss of electron. Since loss and gain of 14 electrons occurs between Cl_2 and thus 7 mole show oxidation.

$Cl_2 + 2e \longrightarrow 2Cl^-] \times 7$

$Cl_2^0 \longrightarrow 2Cl^{7+} + 14e$

$$8Cl_2 \longrightarrow 2Cl^{7+} + 14Cl^-$$

• SINGLE INTEGER ANSWER PROBLEMS •

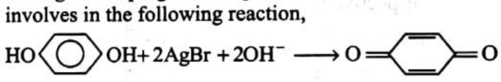
1. The positive oxidation no. of Xe in perxenate ion is:
2. The value of n in the reaction :
$$Cr_2O_7^{2-} + ne + 14H^+ \longrightarrow 2Cr^{3+} + 7H_2O$$
3. Total number of electrons involved in change:
$$2Al + Fe_2O_3 \longrightarrow Al_2O_3 + 2Fe.$$
4. If four mole of Br_2 undergo a loss and gain of six mole electrons to form two new oxidation state of Br. How much Br_2 mole acts as reductant?
5. The total number of electrons involved in redox change:
$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2.$$
6. The stoichiometric coefficient n in the reaction is:
$$nH_2CO_2 + 2KMnO_4 \longrightarrow nCO_2 + K_2O + MnO + H_2O$$
7. Intramolecular redox
$$(NH_4)_2Cr_2O_7 \longrightarrow N_2 + Cr_2O_3 + 4H_2O$$
shows a loss and gain of how much electron?
8. The stoichiometric coefficient of blue perchromate in its reaction with H_2SO_4 is ....
9. The tailing of mercury on exposure to air shows a change in oxidation number by ....
10. Total number of electrons involved per molecule oxidation of FeC_2O_4 to Fe^{3+} and CO_2.
11. No. of peroxide bonds in blue perchromate is ....
12. In the reaction $P_4 + NaOH \longrightarrow PH_3 + NaH_2PO_2$, mole ratio of NaH_2PO_2 and PH_3 is ....
13. In the reaction : $Mn^{2+} + S_2O_8^{2-} \longrightarrow SO_4^{2-} + MnO_4^-$ (acid mid.) the number of mole of $S_2O_8^{2-}$ required to oxidise 2 mole Mn^{2+}.
14. The ratio of oxygen atom having −2 and −1 oxidation numbers in $S_2O_8^{2-}$ is ....
15. Five mole of Ferric oxalate are oxidised by how much mole of $KMnO_4$ in acid medium?
16. 1 mole of Cu_2S reduces how many mole of $KMnO_4$? If the redox reaction is
$$Cu_2S + KMnO_4 + H_2SO_4 \longrightarrow CuSO_4 + MnSO_4 + K_2SO_4 + H_2O$$
17. Number of electrons lost per molecule of Fe_3O_4 during its oxidation to Fe_2O_3 is ....
18. Number of H_2O_2 mole needed to convert two mole of $Cr(OH)_3$ in alkaline medium into sodium chromate are ....
19. Number of mole of KO_2 required to absorb one mole of CO are ....
20. Six mole of I_2 undergoes disproportionation involving 10 electrons, what is the oxidation number of oxidised iodine atom?
21. The ratio of oxidation numbers of carbon in hydrocyanic acid and isocyanic acid is :
22. Oxidation number of Xe in Barium perxenate is :
23. The number of electrons involved in the change :
$$Cu_2S \longrightarrow Cu^{2+} + SO_2 \text{ is :}$$
24. On heating $FeCr_2O_4$ with Na_2CO_3 in presence of $KClO_3$, the total number of electrons lost by one Cr atom are :
25. The oxidation number of Cr in the product formed on heating $K_2Cr_2O_7$ with KOH is :
26. On combustion of CH_4 to CO_2 and H_2O, the oxidation number of carbon changes by :
27. Oxidation no. of carbon in NaCNS is :
28. On passing NO to $FeSO_{4(aq)}$ brown ring formation takes place, the oxidation number of Fe changes by :
29. The most common oxidation state of an element is −2. The number of electrons present in its outer most shell is:
30. The difference in oxidation number of two nitrogen atoms in NH_4NO_3 is ....
31. The difference in oxidation number of Cl atoms in $CaOCl_2$ is ....
32. How much of the following have per oxide bonds ? Blue per chromate, Barium per xenate, Barium per oxide, H_2SO_5, PbO_2, $H_2S_2O_8$, Permanganic acid, Perchloric acid.
33. The sum of the oxidation numbers of two different oxidation states of Fe atoms in Fe_3O_4 is ....
34. Number of electrons involved in the redox change : $2Fe + O_2 + 4H^+ \longrightarrow 2Fe^{2+} + 2H_2O$, are ....
35. Oxidation number of Na in Na-Hg amalgam is ....
36. In the reaction, $VO + Fe_2O_3 \longrightarrow FeO + V_2O_5$, the number of electrons used in redox reaction are ....
37. Number of O—O bonds in K_3CrO_8 is ....
38. 4 mole of Cl_2 undergoes disproportionation involving six electrons in change. How much Cl_2 molecules are oxidised?
39. Number of pi bonds in Br_3O_8 are ....
40. Among the following, the number of elements showing only one non zero oxidation state is .... **(IIT 2010)**
O, Cl, F, N, P, Sn, Tl, Na, Ti
41. The value of n in the molecular formula $Be_nAl_2Si_6O_{18}$ is .... **(IIT 2010)**
42. The difference in the oxidation number of the two types of sulphur atoms in $Na_2S_4O_6$ is .... **(IIT 2011)**

ANSWERS

1. Eight	2. Six	3. Six	4. One	5. Eight	6. Five	7. Six	8. Four	9. One	10. Three	11. Two	12. Three
13. Five	14. Three	15. Six	16. Two	17. One	18. Three	19. Two	20. Five	21. One	22. Eight	23. Eight	24. Zero
25. Six	26. Eight	27. Four	28. One	29. Six	30. Eight	31. Two	32. Four	33. Five	34. Four	35. Zero	36. Six
37. Four	38. One	39. Eight	40. Two	41. Three	42. Five						

OBJECTIVE PROBLEMS (One Answer Correct)

1. In which of the following highest oxidation state is not possible:
   (a) $[XeO_6]^{4-}$ (b) XeF_8
   (c) OsO_4 (d) RuO_4
2. Number of per oxide bonds in per xenate ion $[XeO_6]^{4-}$ is:
   (a) 0 (b) 2
   (c) 3 (d) 1
3. Oxidation number of Pr in Pr_6O_{11} is:
   (a) $\frac{22}{6}$ (b) $\frac{20}{6}$
   (c) 3 (d) 4
4. Oxidation number of S in H_2SO_5 is:
   (a) +8 (b) +6
   (c) +4 (d) +2
5. Which one is not correct about the change given below?
   $$K_4Fe(CN)_6 \xrightarrow{oxi} Fe^{3+} + CO_2 + NO_3^-$$
   (a) Fe is oxidised Fe^{2+} to Fe^{3+}
   (b) Carbon is oxidised from C^{2+} to C^{4+}
   (c) N is oxidised from N^{3-} to N^{5+}
   (d) Carbon is not oxidised
6. Which of the following is not a intramolecular redox?
   (a) $NH_4NO_2 \longrightarrow N_2 + 2H_2O$
   (b) $2Mn_2O_7 \longrightarrow 4MnO_2 + 3O_2$
   (c) $2KClO_3 \longrightarrow 2KCl + 3O_2$
   (d) $2H_2O_2 \longrightarrow 2H_2O + O_2$
7. Which of the following is not disproportionation?
   (a) $P_4 + 5OH^- \longrightarrow H_2PO_4^- + PH_3$
   (b) $Cl_2 + OH^- \longrightarrow ClO + ClO^-$
   (c) $2H_2O_2 \longrightarrow 2H_2O + O_2$
   (d) $PbO_2 + H_2O \longrightarrow PbO + H_2O_2$
8. Which of the following is intermolecular redox reaction?
   (a) $2\begin{array}{c}CHO\\|\\CHO\end{array} \xrightarrow{OH^-} \begin{array}{c}CH_2OH\\|\\COOH\end{array}$
   (b) $2C_6H_5CHO \xrightarrow{Al(OC_2H_5)_3} C_6H_5COOH + C_6H_5CH_2OH$
   (c) $4CrO_5 + 6H_2SO_4 \longrightarrow 2Cr_2(SO_4)_3 + 6H_2O + 7O_2$
   (d) $As_2S_3 + HNO_3 \longrightarrow H_3AsO_4 + H_2SO_4 + NO$
9. The number of electrons lost in the change are:
   $$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$$
   (a) 2 (b) 4
   (c) 6 (d) 8
10. The oxidation state of *A*, *B* and *C* in a compound are +2, +5 and −2 respectively. The compound is:
    (a) $A_2(BC)_2$ (b) $A_2(BC)_3$
    (c) $A_3(BC_4)_2$ (d) $A_2(BC_4)_3$
11. In the equation : $NO_2^- + H_2O \longrightarrow NO_3^- + 2H^+ + ne$; *n* stands for:
    (a) 1 (b) 2
    (c) 3 (d) 4
12. The oxidation number of sulphur in S_8, S_2F_2 and H_2S are:
    (a) 0, +1 and −2 (b) +2, +1 and −2
    (c) 0, +1 and +2 (d) −2, +1 and −2
13. In a reaction, 4 mole of electrons are transferred to 1 mole of HNO_3, the possible product obtained due to reduction is :
    (a) 0.5 mole of N_2 (b) 0.5 mole of N_2O
    (c) 1 mole of NO_2 (d) 1 mole of NH_3
14. The colour of $K_2Cr_2O_7$ changes from red-orange to lemon-yellow on treatment with KOH (*aq.*) because of:
    (a) Reduction of Cr (VI) to Cr (III)
    (b) Formation of chromium hydroxide
    (c) Conversion of dichromate into chromate ion
    (d) Oxidation of potassium hydroxide to potassium peroxide
15. During developing of an exposed camera film, one step involves in the following reaction,



(Hydroquinol)

$+2Ag + 2H_2O + 2Br^-$

which of the following best describes the role of hydroquinol :
    (a) It acts as an acid (b) It act as reducing agent
    (c) It acts as oxidant (d) It act as a base
16. Which of the following is not correct for the reaction,
    $$(CN)_2 + 2OH^- \longrightarrow CNO^- + CN^- + H_2O$$
    (a) It is a disproportionation reaction
    (b) N atom disproportionates and oxidation number of N are −3 in $(CN)_2$, −2 in CN^- and −5 in CNO^-
    (c) C atom disproportionate and oxidation number carbon are +3 in $(CN)_2$, +4 in CNO^- and +2 in CN^-
    (d) $(CN)_2$ undergoes auto redox
17. One mole of N_2H_4 loses 10 mole of electrons to form a new compound *y*. Assuming that all the nitrogen appears in the new compound, what is the oxidation state of N in *y*. (There is no change in the oxidation state of H.)
    (a) −1 (b) −3
    (c) +3 (d) +5
18. The oxidation number of carbon in CH_2O is :
    (a) −2 (b) +2
    (c) 0 (d) +4

19. The brown ring complex is formulated as $[Fe(H_2O)_5NO]SO_4$. The oxidation number of Fe is :
(a) +1 (b) +2
(c) +3 (d) 0

20. The oxidation number of phosphorus in $Ba(H_2PO_2)_2$ is :
(a) +3 (b) +2
(c) +1 (d) −1

21. The oxidation state of the most electronegative element in the products of the reaction, BaO_2 with dil H_2SO_4 are :
(a) 0 and −1 (b) −1 and −2
(c) −2 and 0 (d) −2 and +1

22. For the redox reaction,

$$MnO_4^- + C_2O_4^{2-} + H^+ \longrightarrow Mn^{2+} + CO_2 + H_2O$$

The correct coefficients of the reactants for the balanced reaction are :

	MnO_4^-	$C_2O_4^{2-}$	H^+
(a)	2	5	16
(b)	16	5	2
(c)	5	16	2
(d)	2	16	5

23. Oxidation number of carbon in C_3O_2 and Mg_2C_3 are respectively:
(a) $+\frac{2}{3}, -\frac{2}{3}$ (b) $+\frac{4}{3}, -\frac{4}{3}$
(c) $-\frac{4}{3}, +\frac{4}{3}$ (d) $-\frac{2}{3}, +\frac{2}{3}$

24. In the reaction : $NaH + H_2O \longrightarrow NaOH + H_2$, which one is not correct :
(a) H-atom undergoes oxidation
(b) H-atom undergoes reduction
(c) It is a redox change
(d) It is disproportionation reaction

25. Ozone tails mercury due to :
(a) oxidation of Hg
(b) reduction of Hg
(c) adsorption of O_3 on Hg
(d) none of these

26. The tailing of mercury is removed by :
(a) O_2 (b) H_2O_2
(c) SO_2 (d) O_3

27. Iodine has +7 oxidation state in :
(a) HIO_4 (b) H_3IO_5
(c) H_5IO_6 (d) all of these

28. Which of the following compound is not possible for +7 oxidation state of iodine ?
(a) IF_7 (b) I_2O_7
(c) ICl_7 (d) None of these

29. Amongst the following identify the species with an atom in +6 oxidation state: **(IIT 2000)**
(a) MnO_4^- (b) $Cr(CN)_6^{3-}$
(c) NiF_6^{2-} (d) CrO_2Cl_2

30. In the standardisation of $Na_2S_2O_3$ using $K_2Cr_2O_7$ by iodometry, the equivalent mass of $K_2Cr_2O_7$ is: **(IIT 2001)**
(a) $M/2$ (b) $M/6$
(c) $M/3$ (d) M

31. The reaction;

$$3ClO^-(aq.) \longrightarrow ClO_3^-(aq.) + 2Cl^-(aq.)$$

is an example of: **(IIT 2001)**
(a) oxidation reaction (b) reduction reaction
(c) disproportion (d) decomposition

32. Maximum oxidation state is present in: **(IIT 2004)**
(a) CrO_2Cl_2 and MnO_4^-
(b) MnO_2
(c) $[Fe(CN)_6]^{3-}$ and $[Co(CN)_6]^3$
(d) MnO

33. The reaction of white phosphorus with aqueous NaOH gives phosphine along with another phosphorus containing compound. The reaction type; the oxidation states of phosphorus in phosphine and the other product are respectively : **(IIT 2012)**
(a) redox reaction; −3 and − 5
(b) redox reaction; +3 and + 5
(c) disproportionation reaction; −3 and + 1
(d) disproportionation reaction; −3 and + 3

34. Which ordering of compounds is according to the decreasing order of the oxidation state of nitrogen? **(IIT 2012)**
(a) HNO_3, NO, NH_4Cl, N_2
(b) HNO_3, NO, N_2, NH_4Cl
(c) HNO_3, NH_4Cl, NO, N_2
(d) NO, HNO_3, NH_4Cl, N_2

35. Consider the following reaction :

$$xMnO_4^- + y\,C_2O_4^{2-} + zH^+ \longrightarrow xMn^{2+} + 2y\,CO_2 + \frac{z}{2}H_2O$$

The values of x, y and z in the reaction are, respectively : **[JEE (Main) 2013]**
(a) 2, 5 and 16 (b) 5, 2 and 8
(c) 5, 2 and 16 (d) 2, 5 and 8

36. Experimentally it was found that a metal oxide has formula $M_{0.98}O$. Metal M, is present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be : **[JEE (Main) 2013]**
(a) 6.05% (b) 5.08%
(c) 7.01% (d) 4.08%

SOLUTIONS (One Answer Correct)

1. (b) No doubt Xe shows + 8 oxidation state XeF_8 does not exist because of crowding of 8 F-atoms.
2. (a) Oxidation no. of Xe in $[XeO_6]^{4-}$ is + 8.
3. (a) Pr_6O_{11}, $6\times a+(11\times -2)=0$ (No O—O bond), $a=+\frac{22}{6}$
4. (b) H_2SO_5 is

```
        O
        ||
  HO—S—O—O—H
        ||
        O
```

i.e., one peroxide bond.
5. (d) Carbon is also oxidised.
6. (d) Intramolecular redox change involve oxidation of one atom and reduction of other atom within a molecule.
7. (d) Disproportionation involves oxidation reduction of same atom in a molecule.
8. (d) Intermolecular redox change involves oxidation of one molecule and reduction of other molecule.
9. (d)
$$3Fe^{\circ}+8e\longrightarrow(Fe^{+8/3})_3$$
$$[(H^{+})_2\longrightarrow(H^{\circ})_2+2e]\times 4$$
$$\overline{3Fe+4H_2O\longrightarrow Fe_3O_4+4H_2}$$
10. (c) $A_3(BC_4)_2$, $3\times 2+[5+4\times(-2)]\times 2=0$
11. (b) Balance charge on two sides.
12. (a) $S_8: a\times 8=0$ $\quad\therefore a=0$
$S_2F_2: a\times 2+2\times(-1)=0$ $\quad\therefore a=+1$
$H_2S: 2\times 1+a=0$ $\quad\therefore a=-2$
13. (b) $2N^{5+}\longrightarrow(N^{+})_2+8e$
2 mole HNO_3 gives one mole of N_2O.
14. (c) $K_2Cr_2O_7+2KOH\longrightarrow 2K_2CrO_4+H_2O$
15. (b) $Ag^{+}+e\longrightarrow Ag$; hydroquinol reduces Ag^{+} to Ag
16. (b) Rest all are true
17. (c) $(N^{2-})_2\longrightarrow(2N^{+a})+10e$
$\therefore\ 2a-(-4)=10$
$a=+3$
18. (c) $a+2\times(+1)-2\times 1=0$
19. (a) NO in iron complex has +1 oxidation state.
20. (c) $2\times 1+2[2\times 1+a+2\times(-2)]=0$
$\therefore\ a=+1$
21. (b) Products are $BaSO_4$ and H_2C_2.
22. (a) $2MnO_4^{-}+5C_2O_4^{2-}+16H^{+}\longrightarrow 2Mn^{2+}+10CO_2+8H_2O$
23. (b) $C_3O_2: 3\times a+2(-2)=0$
$a=+\frac{4}{3}$
$Mg_2C_3: 2\times 2+3\times a=0$
$a=-\frac{4}{3}$
24. (d) $Na\overset{-1}{H}+\overset{+1}{H_2}O\longrightarrow NaOH+\overset{0}{H_2}$
25. (a) $Hg+O_3\longrightarrow HgO+O_2$
HgO formed is responsible for tailing
26. (b) $HgO+H_2O_2\longrightarrow Hg+H_2O+O_2$
27. (d) Each has +7 oxidation state of I.
28. (c) Highest oxidation state of an element is noticed with fluorine and oxygen.
29. (d) Cr in $CrO_2Cl_2: a+2\times(-2)+2\times(-1)=0$,
$\therefore\ a=+6$
30. (b) $(Cr^{6+})_2+6e\longrightarrow 2Cr^{3+}$
$\therefore\ E_{K_2Cr_2O_7}=\frac{M}{6}$
31. (c) Cl-atom is oxidised ($Cl^{+}\longrightarrow Cl^{5+}+4e$) as well as Cl is reduced. ($Cl^{+}+2e\longrightarrow Cl^{-}$) such reactions are called disproportionation or auto-redox changes.
32. (a) Cr has + 6 and Mn has + 7 oxidation state.
33. (c) The balanced disproportionation reaction involving white phosphorus with aq. NaOH is

Oxidation of P^0 to P^{+1} state
$$P_4^0+3NaOH+3H_2O\longrightarrow\overset{-3}{P}H_3+3NaH_2\overset{+1}{P}O_2$$
Reduction of P^0 to P^{-3} state

34. (b) The oxidation state of N are +5, +2, 0 and −3 in HNO_3, NO, N_2 and NH_4Cl respectively.
35. (a) $2MnO_4^{-}+5C_2O_4^{2-}+16H^{+}\longrightarrow 2Mn^{2+}+10CO_2+8H_2O$
36. (d) Average oxidation no. of $M=+\frac{200}{98}$
(lies between 2 and 3)
Let % of M^{2+} be a and of M^{3+} be b
or $\frac{2\times a+(100-a)\times 3}{100}=2.04(\because a+b=100)$
$\therefore\ 2a+300-3a=\frac{200}{98}$
$\therefore\ +a=300-2.04\times 100$
$=300-204$
$=96$
Thus $M^{2+}=96\%$
$M^{3+}=4\%$

OBJECTIVE PROBLEMS (More Than One Answer Correct)

1. Which of the following are disproportionation redox changes?
(a) $(NH_4)_2Cr_2O_7 \longrightarrow N_2 + Cr_2O_3 + 4H_2O$
(b) $5H_2O_2 + 2ClO_2 + 2OH^- \rightarrow 2Cl^- + 5O_2 + 6H_2O$
(c) $3ClO^- \longrightarrow ClO_3^- + Cl^-$
(d) $2HCuCl_2 \xrightarrow[\text{water}]{\text{Dilution with}} Cu + Cu^{2+} + 4Cl^- + 2H^+$

2. Which one are correct about the reaction?
$HgS + HCl + HNO_3 \longrightarrow H_2HgCl_4 + NO + S + H_2O$
(a) Hg is reduced
(b) Sulphide is oxidised
(c) N is reduced
(d) HNO_3 is oxidant

3. Which of the followings are disproportionation reactions?
(a) $2O_3 \longrightarrow 3O_2$
(b) $4KClO_3 \longrightarrow 3KClO_4 + KCl$
(c) $2H_2O_2 \longrightarrow 2H_2O + O_2$
(d) $2KO_2 + 2H_2O \longrightarrow 4KOH + 3O_2$

4. For the reaction,
$KO_2 + H_2O + CO_2 \longrightarrow KHCO_3 + O_2$; the mechanism of reaction suggests that:
(a) acid-base reaction
(b) disproportionation reaction
(c) hydrolysis
(d) redox change

5. Which of the following can be used as oxidant and reductant both?
(a) HNO_2
(b) SO_2
(c) O_2
(d) CO

6. Which molecules represented by the bold atoms show their highest oxidation state?
(a) $H_2\underline{S}_2O_8$
(b) $\underline{P}_4O_{10}$
(c) $\underline{F}_2O$
(d) $\underline{Mn}_2O_7$

7. Which molecules represented by the bold atoms show their lowest oxidation state?
(a) $F_2\underline{O}$
(b) $H_2\underline{S}$
(c) $\underline{P}H_3$
(d) $\underline{N}_2H_4$

8. Which one are not correct about $CH_2 = CCl_2$?
(a) Both carbon are in +2 oxidation state
(b) Both carbon are in −2 oxidation state
(c) One carbon has +2 and other has −2 oxidation state
(d) The average oxidation number of carbon is zero

9. Which is correct about tailing of Hg?
(a) it is due to Hg_2O
(b) it is due to HgO
(c) it is removed by H_2O_2
(d) it is removed by O_3

10. Thermal decomposition of $(NH_4)_2Cr_2O_7$ involves :
(a) Oxidation of N
(b) Reduction of Cr
(c) Intramolecular redox
(d) Disproportionation

11. $LiAlH_4$ is used as :
(a) an oxidant
(b) a reductant
(c) a mordant
(d) water softner

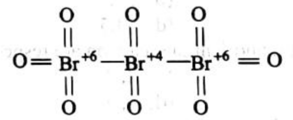
12. Which of the following are disproportionation reaction:
(a) $F_2 + H_2O \longrightarrow HOF + HF$
(b) $2HCHO + NaOH \longrightarrow HCOONa + CH_3OH$
(c) $P_{4(s)} + 3NaOH + 3H_2O \longrightarrow PH_3 + 3NaH_2PO_2$
(d) $2NO_2 + 2KOH \longrightarrow KNO_2 + KNO_3 + H_2O$

13. In which of the following oxidation no. of nitrogen atom is correctly matched :
(a) $HC\underline{N}$ −3
(b) $H\underline{N}C$ −3
(c) $HOC\underline{N}$ −3
(d) $(C\underline{N})_2$ −2

14. Select the correct statements :
(a) Oxidation number of oxygen in O_2^+ is $+\frac{1}{2}$
(b) Oxidation number of oxygen in O_2^- is $-\frac{1}{2}$
(c) Oxidation number of Cr in K_3CrO_8 is +5
(d) Average oxidation number of Br in tribromo-octaoxide (Br_3O_8) is $+\frac{18}{3}$

SOLUTIONS (More Than One Answer Correct)

1. (c,d) $e + Cl^{+} \longrightarrow Cl^{-}$ $\quad Cu^{+} \longrightarrow Cu^{2+} + e$
   $Cl^{+} \longrightarrow Cl^{5+} + 4e \quad Cu^{+} + e \longrightarrow Cu$
2. (b,c,d) $S^{2-} \longrightarrow S^{\circ} + 2e, \quad 3e + N^{5+} \longrightarrow N^{2+}$
3. (b,c,d) $Cl^{+5} \longrightarrow Cl^{+7} + Cl^{-}$
   $O^{-} \longrightarrow O^{-2} + O_2^0$
   $O_2^{-1/2} \longrightarrow O^{-2} + O_2^0$
4. (a,b,c,d) $4KO_2 + 2H_2O \longrightarrow 4KOH + 3O_2$
   (Hydrolysis and disproportionation)
   $4KOH + 4CO_2 \longrightarrow 4KHCO_3$ (Acid-base reaction)
5. (a,b,c,d) The element (in a molecule) having its oxidation state in the middle (*i.e.*, > minimum) and < maximum) can be used as reductant and oxidant both.
6. (a,b,d) The highest oxidation state is given by the gp. number (except O, F).
7. (b,c) The lowest oxidation state is given by (gp. number – 8) except metals.
8. (a,b) Average is zero.
9. (a,c) Hg gets oxidised by O_3 to give sticking nature on glass
   $$2Hg + O_3 \longrightarrow Hg_2O + O_2$$
   $$Hg_2O + H_2O_2 \longrightarrow Hg_2 + H_2O + O_2$$
10. (a,b,c) $(\overset{-3}{N}H_4)_2\overset{+6}{Cr_2}O_7 \longrightarrow \overset{0}{N_2} + \overset{+3}{Cr_2}O_3 + 4H_2O$
11. (b) It is a fact.
12. (b,c,d) $\overset{0}{F_2} + H_2\overset{-2}{O} \longrightarrow H\overset{0}{O}\overset{-1}{F} + H\overset{-1}{F}$
    $$2H\overset{0}{C}HO + NaOH \longrightarrow H\overset{+2}{C}OONa + \overset{-2}{C}H_3OH$$
    $$\overset{0}{P}_{4(s)} + 3NaOH + 3H_2O \longrightarrow \overset{-3}{P}H_3 + 3NaH_2\overset{+1}{P}O_2$$
    $$2\overset{+4}{N}O_2 + 2KOH \longrightarrow K\overset{+3}{N}O_2 + K\overset{+5}{N}O_3 + H_2O$$
13. (a,b,c) Oxidation no. of N in $(CN)_2$ is –3.
14. (a,b,c) In Br_3O_8 two Br atoms have +6 oxidation number and one has +4. The average oxidation no. is $+\frac{16}{3}$.



COMPREHENSION BASED PROBLEMS

Comprehension 1 : In the chemical change:
$aN_2H_4 + bBrO_3^{-} \longrightarrow aN_2 + bBr^{-} + 6H_2O$, answer the following questions:

[1] The element oxidised and reduced in the reaction are respectively:
(a) N_2H_4, BrO_3^{-} (b) N, Br
(c) H, Br (d) BrO_3^{-}, N_2H_4

[2] The number of electrons lost or gained during the redox change are:
(a) 8 (b) 10
(c) 12 (d) 6

[3] The equivalent mass of N_2H_4 in the above reaction is:
(a) 8 (b) 10.6
(c) 16 (d) 6.4

[4] The equivalent mass of $KBrO_3$ in the above reaction is:
(a) 167 (b) 27.83
(c) 55.67 (d) 83.5

[5] The values of *a* and *b* in the reaction are respectively:
(a) 3, 2 (b) 2, 3
(c) 4, 6 (d) 6, 4

[6] The species acting as oxidant and reductant respectively are:
(a) BrO_3^{-}, N_2H_4 (b) N_2H_4, BrO_3^{-}
(c) N_2, BrO_3^{-} (d) Br^{-}, N_2H_4

[7] The conjugate pair of oxidant-reductant is:
(a) BrO_3^{-}, Br^{-} (b) $N_2H_4^{-}, BrO_3^{-}$
(c) Br^{-}, N_2 (d) Br^{-}, BrO_3^{-}

[8] The reaction shows:
(a) intermolecular redox (b) auto redox
(c) intramolecular redox (d) either of these

Comprehension 2 : A redox reaction involves oxidation of reductant liberating electrons, which are then consumed by an oxidant. The sum of two half reactions give rise to net redox change. In half reaction charge and atoms are always conserved.

[1] Which of the following half reaction is correct for the redox change :
$$Fe_3O_4 \longrightarrow Fe_2O_3 + FeO$$
(a) $Fe^{+8/3} \longrightarrow Fe^{+3} + \frac{1}{3}e$
(b) $Fe^{+8/3} \longrightarrow Fe^{+2} - \frac{2}{3}e$
(c) $(Fe^{+8/3})_3 \longrightarrow 3Fe^{+2} + 2e$
(d) $2(Fe^{+8/3})_3 \longrightarrow 3(Fe^{+3})_2 + 2e$

[2] In the reaction :
$As_2S_3 + HNO_3 \longrightarrow H_3AsO_4 + H_2SO_4 + NO$ the element oxidised is :
(a) As only (b) S only
(c) N only (d) As and S both

[3] In the equation :
$NO_2^{-} + H_2O \longrightarrow NO_3^{-} + 2H^{+} + ne$, *n* stands for :
(a) 1 (b) 2
(c) 3 (d) 4

[4] In half reaction :
$S_2O_3^{2-} \longrightarrow S_4O_6^{2-}$, The number of electrons that must be added :
(a) 2, on right side (b) 2, on left side
(c) 3, on right side (d) 4, on left side

SOLUTIONS

Comprehension 1

[1] (b) $(N^{2-})_2 \longrightarrow N_2^0 + 4e$

$Br^{5+} + 6e \longrightarrow Br$

[2] (c) $(N^{2-})_2 \longrightarrow N_2^0 + 4e] \times 3$

$Br^{5+} + 6e \longrightarrow Br^-] \times 2$

[3] (a) $E_{N_2H_4} = \frac{\text{Molar mass of } N_2H_4}{\text{No. of } e \text{ lost by 1 molecule}} = \frac{32}{4} = 8$

[4] (b) $E_{KBrO_3} = \frac{\text{Molar mass of } KBrO_3}{6} = \frac{167}{6} = 27.83$

[5] (a) $(N^{2-})_2 \longrightarrow N_2^0 + 4e] \times 3$

$Br^{5+} + 6e \longrightarrow Br^-] \times 2$

$3N_2H_4 + 2BrO_3^- \longrightarrow 3N_2 + 2Br^-$

Balancing H atoms

$3N_2H_4 + 2BrO_3^- \longrightarrow 3N_2 + 2Br + 6H_2O$

[6] (a) BrO_3^- acts as an oxidant and N_2H_4 as reductant

[7] (a) BrO_3^- is oxidant and its conjugate reductant is Br^-

[8] (a) It is intermolecular redox where one species is oxidised and the other is reduced.

Comprehension 2

[1] (d) Electrons and atoms are conserved in half reaction.

[2] (d) $(As^{+3})_2 \longrightarrow 2As^{+5} + 4e$

$(S^{-2})_3 \longrightarrow 3S^{+6} + 24e$

[3] (b) Balance charge on two sides.

[4] (a) $2(S^{+2})_2 \longrightarrow (S^{+5/2})_4 + 2e$

STATEMENT EXPLANATION PROBLEMS

Read the statement **(S)** and explanation **(E)** given below. Choose the correct choices (a), (b), (c) from (d) the options:

(a) S is correct but **E** is wrong

(b) S is wrong but **E** is correct

(c) Both S and **E** are correct and **E** is correct explanation of S

(d) Both S and **E** are correct but **E** is not correct explanation for S

1. S : Reaction of white phosphorus with NaOH(*aq*) gives PH_3.

E : The reaction is disproportionation of P in alkaline medium.

2. S : Na_2SO_3 solution is oxidised by air but Na_3AsO_3 not. However Na_3AsO_3 is oxidised in presence of Na_2SO_3 by air.

E : The reaction is called induced oxidation.

3. S : Copper forms complexes $[CuCl_4]^{2-}$ but not $[CuI_4]^{2-}$.

E : $[CuI_4]^{2-}$ is not stable because Cu^{2+} is oxidant and I^- is reductant.

4. S : The passage of H_2S through aqueous solution of SO_2 gives yellow turbidity of S in solution.

E : The yellow turbidity of S is in colloidal state due to oxidation of H_2S by SO_2 *aq*.

5. S : Bleaching action of SO_2 is temporary whereas bleaching action of Cl_2 is permanent.

E : Bleaching by SO_2 and Cl_2 is due to oxidation.

6. S : Conversion of black lead painting is made to white by the action of H_2O_2.

E : Sulphur is oxidised to SO_4^{2-}.

7. S : CrO_5 on decomposition undergoes disproportionation.

E : CrO_5 undergoes intermolecular redox reaction.

8. S : NH_4NO_3 on heating gives N_2O.

E : NH_4NO_3 on heating shows disproportionation.

9. S : In azide ion average oxidation number of N is $-1/3$.

E : In azide ion two N atoms have zero oxidation number and one has oxidation number -1.

10. S : $K_2[CuCl_4]$ exists but $K_2[CuI_4]$ does not exist.

E : I^- is strong oxidant.

11. S : Oxidation number of Cu in CuH is -1.

E : Cu is placed below H in electrochemical series.

12. S : Oxidation state of H is +1 in CuH and -1 in CaH_2.

E : Ca is strong electropositive metal.

13. S : Oxygen atom in both O_2 and O_3 has oxidation number zero.

E : In F_2O, oxidation number of O is +2.

14. S : N atom has two different oxidation states in NH_4NO_2.

E : One N atom has –ve oxidation number as it is attached with less electronegative H atom and other has +ve oxidation number as it is attached with more electronegative atom.

15. S : $2H_2O_2 \longrightarrow 2H_2O + O_2$ is a auto redox change.

E : One oxygen atom is oxidised and one oxygen atom is reduced.

16. S : Oxidation number of metals in metal carbonyls is zero.

E : The oxidation number of CO has been taken to be zero.

17. S : SO_2 can be used as reductant as well as oxidant.

E : The oxidation number of S is +4 in SO_2 which lies in between its minimum (–2) and maximum (+6) values.

18. S : $KMnO_4$ is strong oxidant whereas Mn^{2+} is weaker reductant.

E : Stronger is the oxidant weaker is its conjugate reductant.

19. S : VO_2^+ and VO^{2+} both are called vanadyl ions.

E : VO_2^+ is dioxovanadium (V) ion and VO^{2+} is oxovanadium (IV) ion.

20. S : In the reaction,

$$3As_2S_3 + 28HNO_3 + 4H_2O \longrightarrow 6H_3AsO_4 + 9H_2SO_4 + 28NO$$

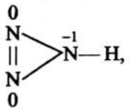
electrons transferred are 84.

E : As is oxidised from +3 to +5 and sulphur from –2 to +6.

21. S : If a strong acid is added to a solution of potassium chromate it changes its colour from yellow to orange.

E : The colour change is due to the oxidation of potassium chromate.

ANSWERS (Statement Explanation Problems)

1. (c) $4P + 3NaOH + 3H_2O \longrightarrow 3NaH_2PO_2 + PH_3$
2. (c) Explanation is correct reason for statement.
3. (c) Explanation is correct reason for statement.
4. (c) $2H_2S + SO_2 \longrightarrow 2H_2O + 3S$
5. (a) $Cl_2 + H_2O \longrightarrow 2HCl + O;$
   $SO_2 + 2H_2O \longrightarrow H_2SO_4 + 2H$
6. (c) $PbS + 4H_2O_2 \longrightarrow PbSO_4 + 4H_2O$
7. (a) $CrO_5 \xrightarrow{\Delta} CrO_3 + O_2$ (Disproportionation of O^-)
8. (a) $NH_4NO_3 \longrightarrow N_2O + 2H_2O$ (intermolecular redox)
9. (c) 

   Explanation is correct reason for statement.
10. (c) Explanation is correct reason for statement.
11. (c) The explanation is correct reason for statement.
12. (c) The explanation is correct reason for statement.
13. (d) The reason is that the sum of oxidation number of elements in a molecule is equal to zero.
14. (c) N in NH_4^+ is in −3 oxidation state and in NO_2^- it is in +3 oxidation state.
15. (c) The explanation is correct reason.
   $$2O^- \longrightarrow O_2^0 + 2e$$
   $$O^- + e \longrightarrow O^{2-}$$
16. (c) The explanation is correct reason for statement.
17. (c) The explanation is correct reason for statement.
18. (c) The explanation is correct reason for statement.
19. (d) Both statement and explanation are correct but explanation is not reason for statement.
20. (c) $(As^{3+})_2 \longrightarrow 2As^{5+} + 4e$
   $(S^{2-})_3 \longrightarrow 3S^{6+} + 24e$
   $[As_2S_3 \longrightarrow 2As^{5+} + 3S^{6+} + 28e] \times 3$
   $[3e + N^{5+} \longrightarrow N^{2+}] \times 28$
21. (a) $\underset{\text{yellow}}{2CrO_4^{2-}} \xrightarrow{H^+} \underset{\text{orange}}{Cr_2O_7^{2-}}$
   Cr in +6 state.

MATCHING TYPE PROBLEMS

Type I : Only One Match Is Possible

1. Match the following :

List A	List B
(a) Intermolecular redox change	(i) $CO_2 + C \longrightarrow 2CO$
(b) Intramolecular redox change	(ii) $As_2O_3 + 3H_2S \longrightarrow As_2S_3 + 3H_2O$
(c) Auto-redox change	(iii) $KClO_4 \longrightarrow KCl + 2O_2$
(d) Precipitation	(iv) $C_3O_2 \longrightarrow CO_2 + 2C$

Type II : More Than One Match Are Possible

2.

List A	List B
(a) HNO_2	(i) Oxidant
(b) HCN	(ii) Reductant
(c) CO	(iii) Complexing agent
(d) NaOCl	(iv) Acid
(e) $C_2O_4^{2-}$	(v) Base

3. Match the following with their minimum and maximum oxidation number if any as well as with respective variable oxidation number if any.

List A	List B
(a) N	(i) zero
(b) P	(ii) $-\frac{1}{3}$
(c) Mn	(iii) +3
	(iv) +5
(d) C	(v) +7
(e) Bi	(vi) +4
(f) Cl	(vii) –4

4.

Column-I	Column-II
(a) $O_2^- \rightarrow O_2 + O_2^{2-}$	(i) Redox reaction
(b) $CrO_4^{2-} + H^+ \rightarrow$	(ii) One of the products has trigonal planar structure
(c) $MnO_4^- + NO_2^- + H^+ \rightarrow$	(iii) Dimeric bridged tetra- hedral metal ion
(d) $NO_3^- + H_2SO_4 + Fe^{2+} \rightarrow$	(iv) Disproportionation

Type III : Only One Match From Each List

5.

List-A	List-B	List-C
(a) CH_4	(i) E. mass $= M/8$	(A) $C^{2+} \longrightarrow C^{4+}$
(b) CO	(ii) E. mass $= M/2$	(B) $C^{-4} \longrightarrow C^{4+}$
(c) $C_2O_4^{2-}$	(iii) E. mass $= M/12$	(C) $C^{3+} \longrightarrow C^{4+}$
(d) C_2H_4		(D) $C^{-2} \longrightarrow C^{4+}$

ANSWERS

1. a–i; b–iii; c–iv; d–ii
2. a–i, ii, iv; b–ii, iii, iv; c–i, iii; d –i, ii; e–ii, iii, v
3. a–i, ii, iii, iv; b–i, iii, iv; c–i, iii, iv, v, vi; d–i, vi, vii; e–i, iii, iv; f–i, iii, iv, v, vi
4. a–i, iv; b–iii; c–i, ii; d–i
5. a–i–B; b–ii–A; c–ii–C; d–iii–D