6. OXIDATION AND REDUCTION

The classical concept of oxidation and reduction

Addition of oxygen or electronegative element/ removal of hydrogen or electropositive element - OXIDATION

e.g., $2\ Mg + O_2 \longrightarrow 2\ MgO$

$2\ Na + Cl_2 \longrightarrow 2\ NaCl$

Removal of oxygen or electronegative element/ addition of hydrogen or electropositive element - REDUCTION

e.g., $C_2H_4 + H_2 \rightarrow C_2H_6$

1. **Define oxidation and reduction.** **2**

Electronic interpretation of oxidation and reduction

LOE- oxidation; GOE-reduction

$2\ Na + Cl_2 \longrightarrow 2\ NaCl$ or (Na^+Cl^-)

1. Define oxidation and reduction. (electronic interpretation) 2
2. **Write a short note on the electronic interpretation of oxidation and reduction. 3**
3. Write short note on oxidation and reduction in terms of electronic concept.
4. Define oxidation and reduction in terms of loss and gain of electrons. Illustrate your answer with a balanced chemical equation. 2
5. **Which one is oxidised and which one is reduced in the following reaction?**

   $\overset{0}{S} + \overset{+1+5\ -2}{HNO_3} \longrightarrow \overset{+4\ -2}{SO_2} + \overset{+4\ -2}{NO_2} + \overset{+1\ \ -2}{H_2O}$ 2
6. **You are given the equation**

   $Zn + HNO_3 \rightarrow Zn(NO_3)_2 + N_2O + H_2O$

   Explain with the electronic concept which one is oxidised and which is reduced. 2
7. **Prove that oxidation and reduction are simultaneous processes. 2**
8. Oxidation and reduction are simultaneous processes. Explain. 2
9. Give an example to show oxidation and reductions go simultaneously. 2
10. Justify by giving example that oxidation and reduction go side by side. 2

1. Oxidation is associated with

a. Change in atomic weight
b. Gain of electrons
c. Loss of electrons
d. Evolution of gases

2. Oxidation involves
   a. Increase in the valency of the negative part
   b. Decrease in the valency of the positive part
   c. Loss of electrons
   d. Gain of electrons
3. During oxidation
   a. Increases positive valency
   b. Decrease in positive valency
   c. Decrease positive valency
   d. Increase in atomic weight

Oxidation numbers and Rules for assigning oxidation numbers

11. Define oxidation number of an element in a compound. 1

Solution: the residual charge that an atom appears to bear when all other atoms are removed from the chemical species as their respective ions

12. Define oxidation number.
13. What is meant by the term oxidation number?

Rules to assign oxidation numbers:

1. *Free state - any element- 0*
2. *O - generally -2 (e.g., Na_2O), exceptions: peroxide -1, (e.g., Na_2O_2) and superoxide -1/2 (e.g., NaO_2) OF_2(+2, fluorine= -1)*
3. *H - generally +1, except metal hydrides -1*
4. *Alkali metals +1 (Li, Na, K, Rb, Cs, Fr)*
5. *Alkaline earth metals +2 (Be, Mg, Ca, Sr, Ba, Ra)*
6. *Cl - only in binary compounds with metals -1.*
7. *Total ON of neutral molecule 0, total ON of ion = its charge*
8. *More electronegative elements always assigned negative charge.*

14. Assign the oxidation number to the underlined element in each of the following:

a) $\underline{N}_2O_2$

x X 2 + -2 x 2 = 0

2x = 4

x = + 2

b) $\underline{N}H_3$ *c)* $NaH_2\underline{P}O_4$ *d)* $\underline{Mn}O_4$

e) $Na_2\underline{S}_2O_3$ *f)* $\underline{Pb}_3O_4$ *g)* $\underline{Ti}Cl_4$

h) $\underline{Mn}O_4^-$ *i)* $\underline{Cr}_2O_7^{-2}$ *j)* $Ca\underline{H}_2$

k) $\underline{N}H_4NO_3$

$NH_4NO_3 \longrightarrow NH_4^+ + NO_3^-$

In NH_4^+,

x + 4 (+1) = +1 or, x = -3

l) $NH_4\underline{N}O_3$

m) $\underline{Cr_2}(SO_4)_3$

$2\ Cr^{3+} + 3\ SO_4^{2-}$

15. Calculate the oxidation number of P in H_3PO_4, $H_2PO_4^{1-}$, NaH_2PO_2, $Ca_3(PO_4)_2$ & NaH_2PO_4. 1
16. Calculate the oxidation number of S in $Na_2S_2O_3$ and H_2SO_3. 2
17. Calculate the oxidation number of C in $H_2C_2O_4$ and CO_3^{2-}. 1
18. Calculate the oxidation number of Cl in $KClO_3$. 1
19. Calculate the oxidation number of chlorine in ClO_3^- and NaOCl. 2
20. What is the oxidation number of boron in $Na_2B_4O_7$? 1
21. Calculate the oxidation number of a) N in NH_4OH b) Cr in $K_2Cr_2O_7$ 2
22. Calculate the oxidation number of nitrogen in a. $NaNO_3$ b. NH_4^+ 2
23. **What is the oxidation state of sulfur and chromium in SO_4^{2-} and $Na_2Cr_2O_7$?**
24. **Calculate the oxidation number of a) N in NH_4Cl and b) S in $NaHSO_3$**
25. **Find the oxidation number of nitrogen in a. ammonia b. ammonium nitrate. 2**
26. Calculate the oxidation number of nitrogen in ammonium sulphate.
27. What is the oxidation number of Chromium in potassium chromate? 1
28. What is the oxidation of oxygen in H_2O_2 and phosphorus in PO_4^{3-}? 2

4. The oxidation number of N in HNO_3 is
   a) +1 b) +3 c)-3 d) +5
5. The oxidation number of iron in Fe_3O_4 is
   a. +2 b. +3 c. +8/3 d. +2/3
6. The oxidation number of C in HCHO is
   a. -2 b. +2 c. 0 d. +4
7. The oxidation number of the central atom of the oleum ($H_2S_2O_7$) is
   a) +2 b) +4 c) +6 d) +8
8. The oxidation number of C is +3 in
   a. CH_3-O-CH_3 c. CH_3-CH_2-OH d. Cl_3-CC-Cl_3 c. CH_3-CH_2-O-CH_3
9. In which of the following C has oxidation number -2?
   a. C_2H_2 b. C_2H_4 c. CH_4 d. Na_2CO_3
10. The oxidation number of the central atom of oleum is
    a. +7 b. +6 c. +5 d. +8
11. The oxidation number of iodine varies from
    a. -1 to +1 b. -1 to +7 c. +3 to+5 d. -1 to +5
12. A metal ion, M^{+3} loses 3 electrons, its ON will be
    a. +6 b. +3 c. 0 d. -3

13. Sulphur has the highest oxidation state in
    a. H_2SO_3 b. H_2SO_4 c. $Na_2S_2O_3$ d. $Na_2S_4O_6$
14. The oxidation number (ON) of iron in $K_4[Fe(CN)_6]$ is
    a. +1 b. +2 c. +4 d. +3
15. Select the compound in which chlorine is assigned the oxidation number +5.
    a. $HClO_3$ b. $HClO_4$ c. $HClO_2$ d. HClO
16. In which of the following compounds does N has oxidation number -1?
    a. NH_3 b. NH_2OH c. NO_2 d. NO
17. The oxidation number of oxygen is +2 in
    a. H_2O_2 b. H_2O c. OF_2 d. SO_2
18. Which particle contains nitrogen in the same oxidation state as in the ion $N_2O_2^{2-}$?
    A NH_2F **B** N_2O_4 **C** NO_3^- **D** HNF_2
19. Solutions containing chlorate (I) ions are used as household bleaches and disinfectants. These solutions decompose on heating as shown.
    $3\ ClO^- \rightarrow ClO_3^- + 2\ Cl^-$
    Which oxidation states are shown by chlorine in these three ions?

	ClO^-	ClO_3^-	Cl^-
A	+1	+3	-1
B	-1	+3	+1
C	+1	+5	-1
D	-1	+5	+1

20. In the treatment of domestic water supplies, chlorine is added to water to kill bacteria. Some ClO^- ions are formed.
    What is the change in oxidation number of chlorine when forming the ClO^- ion from aqueous chlorine?
    A –1 B 0 C +1 D +2
21. In conversion of Br_2 to BrO_3^-, the oxidation state of bromine changes from:
    a. 0 to +5
    b. 0 to -3
    c. -1 to -5
    d. +2 to +5
22. When hydrogen iodide is reacted with concentrated sulfuric acid, several reactions occur, including:
    $8HI + H_2SO_4 \rightarrow H_2S + 4H_2O + 4I_2$
    Which row gives the change in oxidation number of iodine and of sulfur in this reaction?

	change in oxidation number of iodine	change in oxidation number of sulfur

A	–1	+6
B	–1	+8
C	+1	–6
D	+1	–8

23. In a catalytic converter in the exhaust system of a car, carbon monoxide is oxidised to carbon dioxide, and nitrogen monoxide is reduced to nitrogen. What are the changes in oxidation number of carbon and nitrogen in these two processes?

	carbon	nitrogen
A	–2	+2
B	–1	+1
C	+1	–1
D	+2	–2

24. LiA*l*H$_4$ contains A*l*H$_4^-$ ions in which aluminium has an oxidation state of +3.
LiA*l*H$_4$ reacts with water, as shown.
LiA*l*H$_4$ + 4H$_2$O $\rightarrow$ 4H$_2$ + LiOH + A*l*(OH)$_3$
In this reaction, each of the four water molecules produces one hydroxide ion. It does this by losing one H^+ ion, which reacts with the LiA*l*H$_4$.
Which changes in oxidation number occur in this reaction?
A A*l* increases by 1 and H decreases by 1.
B H decreases by 2 and also increases by 1.
C H increases by 1 and also decreases by 1.
D O decreases by 1 and H increases by 1.

25. Ammonium ions are converted into nitrate ions by bacteria.
What is the change in the oxidation number of nitrogen?
A –6 **B** +6 **C** +8 **D** +9

26. In which reaction does the greatest change in the oxidation number of sulfur occur?
A S(s) + O$_2$(g) $\rightarrow$ SO$_2$(g)
B SO$_2$(g) + 1/2O$_2$(g) SO$_3$(g)
C SO$_3$(g) + H$_2$SO$_4$(l) $\rightarrow$ H$_2$S$_2$O$_7$(l)
D H$_2$S$_2$O$_7$(l) + H$_2$O(l) $\rightarrow$ 2H$_2$SO$_4$(l)

27. In the redox reaction shown, how do the oxidation states of vanadium and sulfur change?
$VO_2^+ + SO_2 \rightarrow V^{3+} + SO_4^{2-}$

	vanadium		sulfur	
	from	to	from	to
A	+1	+3	0	–2
B	+1	+3	+4	+6
C	+5	+3	0	–2
D	+5	+3	+4	+6

28. In which row do the oxidation numbers of vanadium increase?

	smallest		largest
A	VO_4^{3-}	VO_3^-	VO_2^+
B	VO^{2+}	V_2O_3	VO_4^{3-}
C	V_2O_3	VO^{2+}	VO_3^-
D	VO_4^{3-}	VO_2^+	VO_2^+

29. What is the average oxidation number of sulfur in each compound?

	$Ca(HSO_3)_2$	$Na_2S_2O_3$
A	4	2
B	4	4
C	6	2
D	6	4

30. The equation for the reaction between aqueous copper ions and aqueous iodide ions is as follows.

$2Cu^{2+}(aq) + 4\mathbf{I}^-(aq) \rightarrow 2Cu\mathbf{I}(s) + \mathbf{I}_2(aq)$

What is the change in oxidation state of copper?

A +2 to –1 *B* +2 to 0 *C* +2 to +1 *D* +4 to +2

31. Two moles of VO_2^+ ions react with one mole of zinc atoms in the presence of dilute acid. The products include Zn^{2+} ions and an ion, Y. Ion Y contains vanadium. Only zinc and vanadium change oxidation state in the reaction. What is ion Y?

A VO_3^- **B** VO^+ **C** VO^{2+} **D** VO_2^{2+}

29. Define oxidation and reduction. 2
30. Define oxidation with suitable examples. 1
31. Write short note on oxidation and reduction in terms of oxidation number.
32. **Which one is reduced and which one is oxidised in the following reaction?**

$$S + HNO_3 \longrightarrow SO_2 + NO_2 + H_2O$$

2

Solution:

$$\overset{0}{S} + \overset{+1+5-2}{HNO_3} \longrightarrow \overset{+4\ -2}{SO_2} + \overset{+4\ -2}{NO_2} + \overset{+1\ -2}{H_2O}$$

In this equation ON of S has increased, an increase in ON is called oxidation, hence S has been oxidized. The one that gets oxidised by reducing others is called a reducing agent. Hence S is the reducing agent.
Similarly, ON of N in HNO_3 has decreased, decrease in ON is called reduction, hence N or HNO_3 has been reduced. The one that gets reduced by oxidizing another is called an oxidising agent. Hence N or HNO_3 is the oxidising agent.

Or,

Sulphur (S) has been oxidized into SO_2 (or S^{+4}).
Nitrogen or N^{+5} (or HNO_3) has been reduced into N^{+4} or NO_2.
HNO_3 or N is an oxidising agent (oxidant), as it oxidises S into SO_2.
S is the reducing agent (reductant), as it reduces HNO_3 into NO_2.

32. The equation for a redox reaction is shown.
    $SnCl_2(aq) + 2HgCl_2(aq) \rightarrow SnCl_4(aq) + Hg_2Cl_2(s)$
    Which species is being oxidised in this reaction?
    A Sn^{2+} **B** Cl^- **C** Hg^+ **D** Hg^{2+}
33. The first stage in the chloride process for the manufacture of titanium consists of the following reaction.
    $2TiO_2 + 4Cl_2 + 3C \rightarrow 2TiCl_4 + 2CO + CO_2$
    What is reduced in this reaction?
    A carbon **B** chlorine **C** oxygen **D** titanium
34. Silicon reacts with a mixture of calcium oxide and magnesium oxide at 1200°C.
    $2MgO + 2CaO + Si \rightarrow 2Mg + Ca_2SiO_4$
    Which statement about this reaction is correct?
    A Calcium is reduced and silicon is neither oxidised nor reduced.
    B Magnesium is reduced and calcium is neither oxidised nor reduced.
    C Magnesium is reduced and silicon is neither oxidised nor reduced.
    D Silicon is reduced and calcium is neither oxidised nor reduced.
35. When concentrated sulfuric acid reacts with sodium iodide the products include sulfur, iodine, hydrogen sulfide and sulfur dioxide.
    Which statement is correct?
    A Hydrogen sulfide is the product of a reduction reaction.
    B Iodide ions are stronger oxidising agents than sulfate ions.
    C Sulfur atoms from the sulfuric acid are both oxidised and reduced.
    D Sulfur atoms from the sulfuric acid are oxidised to make sulfur dioxide.
36. NCl_3 reacts with H_2O.
    $NCl_3 + 3\ H_2O \rightarrow NH_3 + 3\ HClO$
    The oxidation state of nitrogen does not change in this reaction.
    Which statement is correct?
    A Chlorine is reduced.

B Chlorine is oxidised.
C Hydrogen is both oxidised and reduced.
D This is not a redox reaction.

37. A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only.
Each nitrogen atom increases its oxidation state by 5 in the reaction.
How many moles of oxygen gas react with 4 mol of ammonia in this reaction?
A 4 mol **B** 5 mol **C** 7 mol **D** 10 mol

38. Chlorine reacts with sodium bromide.
$Cl_2 + NaBr \rightarrow NaCl + Br_2$
Which words correctly describe this reaction?
1 redox
2 displacement
3 disproportionation
A 1, 2 and 3 B 1 and 2 only C 1 only D 2 only

Oxidising agents and reducing agents

33. Define oxidizing agents and reducing agents with suitable examples. 2

34. Distinguish between oxidant and reductant. 2

39. A reducing agent
    a. Oxidizes other substances
    b. Accepts electrons
    c. Has maximum oxidation number
    d. Itself gets oxidized

40. Better reducing agents have a good capacity of
    a. Losing electrons
    b. Gaining electrons
    c. Being reduced
    d. All of the above

41. $FeSO_4 + KMnO_4 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + K_2SO_4 + MnSO_4 + H_2O$; which element is reduced in the above reaction
    a. Fe b. S c. Mn d. K

42. In the reaction, $Cr_2O_7^{2-} + H^+ + I^- \rightarrow Cr^{3+} + H_2O + I_2$; which one is reduced?
    a. Cr b. H^+ c. O d. I^-

43. $NaH + H_2O \rightarrow NaOH + H_2$, in this reaction, NaH is
    a. Oxidized
    b. Reduced
    c. Both oxidized and reduced
    d. Neither oxidized nor reduced

44. In which of the following reactions, H_2 acts as a oxidizing agent?

a. $H_2 + Cl_2 \rightarrow 2\ HCl$
b. $2\ H_2 + O_2 \rightarrow 2\ H_2O$
c. $N_2 + H_2 \rightarrow 2\ NH_3$
d. $2\ Na + H_2 \rightarrow 2\ NaH$

45. In the reaction, $Na + NH_3 \rightarrow NaNH_2 + H_2$
a. Na is oxidized
b. Na is reduced
c. Na is both oxidized and reduced
d. Na remains unchanged

46. In the reaction
$Br_2 + CO_3^{2-} + H_2O \rightarrow Br^- + BrO_3^- + HCO_3^-$
a. Bromine is oxidized and carbonate is reduced
b. Bromine is reduced and water is oxidized
c. Bromine is neither reduced nor oxidized
d. Bromine is both reduced and oxidized

47. In the given reaction,
$$Cu + 2\ H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2\ H_2O$$
a. H_2SO_4 is oxidant
b. H_2SO_4 is reductant
c. H_2SO_4 is oxidant as well as acid
d. H_2SO_4 is acid

48. In which of the following reactions does hydrogen behave as an oxidizing agent?
a. $Cl_2 + H_2 \rightarrow 2\ HCl$
b. $C_2H_2 + 2\ H_2 \rightarrow C_2H_6$
c. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$
d. $2\ Na + H_2 \rightarrow 2\ NaH$

49. The reaction in which SO_2 is an oxidant is
a. $SO_2 + O_2 \rightarrow SO_3$
b. $SO_2 + Cl_2 \rightarrow SO_2Cl_2$
c. $SO_2 + H_2O + Br_2 \rightarrow HBr + H_2SO_4$
d. $SO_2 + H_2S \rightarrow H_2O + S$

Redox reaction

35. Define redox reaction. **1**

36. What is meant by redox reaction? 1

37. How would you show the following reaction is a redox reaction? 2
$Mg + Cl_2 \rightarrow MgCl_2$

38. How is the following ionic equation a redox reaction? 2
$Cl_2 + 2\ OH^- \rightarrow Cl^- + ClO^- + H_2O$

39. Distinguish between oxidation and reduction. **2**

Balancing redox reactions by Oxidation number method

 # Balance the following redox reaction with the oxidation number method,
$KMnO_4 + C_2H_2O_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + CO_2$

Step 1: writing oxidation number of each atom,

+1 +7 -2 +3 +1 -2 +1 +6 -2 +1 +6 -2 +2 +6 -2 +1 -2 +4 -2

$KMnO_4 + C_2H_2O_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + CO_2$

Step 2: showing the change in ON per atom,

Decrease in ON by 5 per atom

+1 +7 -2 +3 +1 -2 +1 +6 -2 +1 +6 -2 +2 +6 -2 +1 -2 +4 -2

$KMnO_4 + C_2H_2O_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + CO_2$

Increase in ON by 1 per atom

Step 3: Calculating the Changes in ON per molecule on the reactant side,

Decrease in ON of Mn per molecule = 5 x 1 = 5 → $KMnO_4$

Increase in ON of C per molecule = 1 x 2 = 2 → $C_2H_2O_4$

Step 4: Doing criss-cross multiplication in the reactant side,

2 $KMnO_4$ + **5** $C_2H_2O_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + CO_2$

Step 5: Balancing the oxidized and reduced atoms correspondingly on the product side,

2 $KMnO_4$ + 5 $C_2H_2O_4 + H_2SO_4 \rightarrow K_2SO_4$ + **2** $MnSO_4 + H_2O$ + **10** CO_2

Step 6: Balancing remaining atoms by hit and trial method (*first metals, then other non-metals and finally oxygen and hydrogen*)

2 $KMnO_4$ + 5 $C_2H_2O_4$ + ***3*** $H_2SO_4 \rightarrow K_2SO_4$ + 2 $MnSO_4 + H_2O$ + 10 CO_2

2 $KMnO_4$ + 5 $C_2H_2O_4$ + 3 $H_2SO_4 \rightarrow K_2SO_4$ + 2 $MnSO_4$ + ***8*** H_2O + 10 CO_2

Balancing redox reactions by Ion electron (half-reaction) method

Balance the following equation by ion electron (half-reaction) method.

$Zn + NaNO_3 + NaOH \rightarrow Na_2ZnO_2 + NH_3 + H_2O$

Solution:

Changing into ionic form;

0 +1 +5 -2 +1 -2 +1 +1 +2 -2 -3 +1 +1 -2

$Zn + Na^+ + NO_3^- + Na^+ + OH^- \rightarrow 2\ Na^+ + ZnO_2^{-2} + NH_3 + H_2O$

Balancing oxidation half reaction,

$Zn \rightarrow ZnO_2^{-2}$

Since the Zn (oxidized atom) is already balanced,

$Zn + 2\ OH^- \rightarrow ZnO_2^{-2}$ (balancing oxygen)

$Zn + 2\ OH^- \rightarrow ZnO_2^{-2} + 2\ H^+$ (balancing hydrogen)

$Zn + 2\ OH^- \rightarrow ZnO_2^{-2} + 2\ H^+ + 2e^-$ (balancing charge)

The reduction half equation is,

$NO_3^- \rightarrow NH_3$

$NO_3^- \rightarrow NH_3 + 3\ H_2O$ (balancing oxygen)

$NO_3^- + 9\ H^+ \rightarrow NH_3 + 3\ H_2O$ (balancing hydrogen)

$NO_3^- + 9\ H^+ + 8\ e^- \rightarrow NH_3 + 3\ H_2O$ (balancing charge)

Adding the balanced oxidation half and reduction half-reactions in such a way that electrons cancel out.

$\{Zn + 2\ OH^- \rightarrow ZnO_2^{-2} + 2\ H^+ + 2e^-\} \times 4$

$NO_3^- + 9\ H^+ + 8\ e^- \rightarrow NH_3 + 3\ H_2O$

$4\ Zn + 8\ OH^- + NO_3^- + H^+ \rightarrow 4\ ZnO_2^{-2} + NH_3 + 3\ H_2O$

$4\ Zn + 7\ OH^- + NO_3^- + H_2O \rightarrow 4\ ZnO_2^{-2} + NH_3 + 3\ H_2O$

$4\ Zn + 7\ OH^- + NO_3^- \rightarrow 4\ ZnO_2^{-2} + NH_3 + 2\ H_2O$

$4\ Zn + NaNO_3 + 7\ NaOH \rightarrow 4\ Na_2ZnO_2 + NH_3 + 2\ H_2O$

The above is the balanced chemical equation.

Note: In this method, oxygen is generally balanced by adding H_2O on the appropriate side, but for reactions in a basic medium OH^- is added on the appropriate side.

Long questions

40. Balance the following chemical equation by using the oxidation number or electron-ion number method.

a. $C + H_2O_2 \rightarrow CO + H_2O$ (H-O-O-H) $\rightarrow$ $(-O-O-)^{-2}$

b. $FeCl_3 + H_2S \rightarrow FeCl_2 + HCl + S$

c. $MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O$

d. $KMnO_4 + HCl \rightarrow KCl + MnCl_2 + H_2O + Cl_2$

e. $KMnO_4 + KCl + H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + H_2O + Cl_2$

f. $K_2Cr_2O_7 + SnCl_2 + HCl \rightarrow CrCl_3 + SnCl_4 + KCl + H_2O$

g. $S + HNO_3 \rightarrow SO_2 + NO_2 + H_2O$

h. $C + HNO_3 \rightarrow NO_2 + H_2O + CO_2$

i. $HNO_3 + H_2S \rightarrow NO + S + H_2O$

j. $HNO_3 + H_2S \rightarrow SO_2 + NO_2 + H_2O$

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

k. $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO + H_2O$

Hint only:

Cu - 2

N - 3

$Cu + H\mathbf{N}O_3 + HNO_3 \rightarrow Cu(\mathbf{N}O_3)_2 + NO + H_2O$

$\mathbf{3}\ Cu + H\mathbf{N}O_3 + \mathbf{2}\ HNO_3 \rightarrow Cu(\mathbf{N}O_3)_2 + NO + H_2O$

$3\ Cu + H\mathbf{N}O_3 + 2\ HNO_3 \rightarrow \mathbf{3}\ Cu(\mathbf{N}O_3)_2 + \mathbf{2}\ NO + H_2O$

$3\ Cu + \mathbf{6}\ H\mathbf{N}O_3 + 2\ HNO_3 \rightarrow 3\ Cu(\mathbf{N}O_3)_2 + 2\ NO + H_2O$

$3\ Cu + 6\ H\mathbf{N}O_3 + 2\ HNO_3 \rightarrow 3\ Cu(\mathbf{N}O_3)_2 + 2\ NO + \mathbf{4}\ H_2O$

$3\ Cu + \mathbf{8}\ HNO_3 \rightarrow 3\ Cu(\mathbf{N}O_3)_2 + 2\ NO + 4\ H_2O$

a. $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO_2 + H_2O$

b. $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + N_2O + H_2O$

c. $Zn + HNO_3 \rightarrow Zn(NO_3)_2 + NO_2 + H_2O$

d. $Zn + HNO_3 \rightarrow Zn(NO_3)_2 + N_2O + H_2O$

e. $CuSO_4 + HI \rightarrow \mathbf{Cu_2I_2} + H_2SO_4 + I_2$

f. $KI + H_2SO_4 \rightarrow K_2SO_4 + I_2 + H_2S + H_2O$

g. $NaOH + S \rightarrow Na_2S + Na_2S_2O_3 + H_2O$

h. $Cr_2O_7^{--} + Fe^{2+} + H^+ \rightarrow Cr^{+3} + Fe^{3+} + H_2O$

i. $MnO_4^- + C_2H_2O_4 + H^+ \rightarrow Mn^{++} + H_2O + CO_2$

j. $N_2H_4 + ClO_3^- \rightarrow NO + Cl^- + H_2O$

k. $C_{12}H_{22}O_{11} + HNO_3 \rightarrow NO_2 + C_2H_2O_4 + H_2O$

l. $Zn + NaNO_3 + NaOH \rightarrow Na_2ZnO_2 + NH_3 + H_2O$

41. Balance the following chemical equations, and identify oxidizing agent and reducing agent in each case.

a. $H_2S + H_2O_2 \rightarrow S + H_2S$

b. $C + HNO_3 \rightarrow NO_2 + H_2O + CO_2$

c. $MnO_4^- + S^{-2} + H_2O \rightarrow MnO_2 + S + OH^-$

42. Balance the following chemical equation by using the oxidation or ion electron method and indicate the number of HNO_3 molecules acting as an oxidizing agent and as an acidic agent.

$Zn + HNO_3 \rightarrow Zn(NO_3)_2 + N_2O + H_2O$

43. Point out the oxidant and reductant in the following redox reaction and balance the reaction by oxidation number method or ion-electron method.

$I_2 + HNO_3 \rightarrow HIO_3 + NO_2 + H_2O$

44. Identifying oxidation half, reduction half-reactions, oxidizing agent and reducing agent, balance the equation by ion electron or O.N. method.

$Fe^{+2} + H^+ + NO_3^- \rightarrow Fe^{+3} + NO + H_2O$

45. Consider the following reaction

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

a. Identify the reductant and oxidant in the reaction.

b. Write oxidation half and reduction half-reactions.

c. Balance both half-reactions in an acidic medium.

d. Write a balanced redox reaction. ***4***

46. Balance the following redox reaction by the method of your choice. Also point out oxidizing and reducing agent.

$KMnO_4 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O + KCl$ 3

47. H_2S is a reducing agent but SO_2 is both reducing and oxidizing agent. Why?

50. The ionic equation shows iodide ions reacting with manganate**(VII)** ions in acidic solution.

$uMnO_4^- + vH^+ + wI^- \rightarrow xMn^{2+} + yH_2O + zI_2$

The letters u, v, w, x, y and z all represent whole numbers. Two or more of u, v, w, x, y and z are the same as each other.

What is the lowest possible value of v?

A 2 **B** 8 **C** 10 **D** 16

51. Sodium dichromate (VI), $Na_2Cr_2O_7$, reacts with hydrogen peroxide, H_2O_2, producing Cr^{3+} ions, water and oxygen.

What is the correctly balanced ionic equation for this reaction?

A $Cr_2O_7^{2-} + 2H^+ + H_2O_2 \rightarrow 2Cr^{3+} + 2H_2O + 4O_2$

B $Cr_2O_7^{2-} + 8H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

C $Cr_2O_7^{2-} + 8H^+ + 6H_2O_2 \rightarrow 2Cr^{3+} + 10H_2O + 6O_2$

D $Cr_2O_7^{2-} + 14H^+ + 3H_2O_2 \rightarrow 2Cr^{3+} + 7H_2O + 3O_2$

52. When K_2MnO_4 is dissolved in water, the following reaction occurs.

$\mathbf{a}MnO_4^{2-}(aq) + \mathbf{b}H_2O(l) \rightarrow \mathbf{c}MnO_4^-(aq) + \mathbf{d}MnO_2(s) + \mathbf{e}OH^-(aq)$

What could be the values of a and c in the balanced chemical equation?

	a	*C*
A	2	1
B	3	1
C	3	2
D	4	3

53. Zinc atoms can be oxidised to Zn^{2+} ions by dichromate(VI) ions in acid solution. Chromium is reduced to Cr^{3+} in this reaction.

Which equation is correct?

A $Cr_2O_7^{2-} + Zn + 14H^+ \rightarrow 2Cr^{3+} + Zn^{2+} + 7H_2O$

B $Cr_2O_7^{2-} + Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

C $Cr_2O_7^{2-} + 3Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

D $2\ Cr_2O_7^{2-} + 3Zn + 14H^+ \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

54. When the equation is correctly balanced, what is the value of *c*?

$aC_2H_4 + bH_2O + cH^+ + 2MnO_4^- \rightarrow dC_2H_6O_2 + eMn^{2+}$

A 3 **B** 4 **C** 5 **D** 6

55. Z is a compound of sodium, chlorine and oxygen.

It contains 45.1% by mass of oxygen.

Z is prepared by reacting sodium hydroxide with chlorine.

Which row shows the conditions used for the reaction and the oxidation state of chlorine in Z?

	reaction conditions	oxidation state of Cl in Z
A	cold dilute NaOH	+1
B	cold dilute NaOH	+5
C	hot concentrated NaOH	+1
D	hot concentrated NaOH	+5

56. Two half-equations are shown.

$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$

$2OH^- + SO_3^{2-} \rightarrow SO_4^{2-} + H_2O + 2e^-$

The equation for the reaction between manganate(VII) ions and sulfite ions is shown.

$uMnO_4^- + vH_2O + wSO_3^{2-} \rightarrow xMnO_2 + ySO_4^{2-} + zOH^-$

Which statements are correct?

1. u = x = z
2. Manganese is reduced to oxidation state + 4.

3. Sulfur is oxidised from oxidation state + 4 to + 6.

A 1, 2 and 3 B 1 and 2 only C 1 and 3 only D 2 and 3 only

Disproportionation reactions

Disproportionation can be thought of as a 'self-reduction /oxidation' reaction.

Cl_2 (aq) + NaOH(aq) → NaCl (aq) + $NaClO_3$ (aq) + H_2O

When chlorine gas is passed into cold, dilute aqueous sodium hydroxide, the following reaction takes place and two salts are formed:

$Cl_2(g)$ + 2NaOH(aq) ⟶ NaCl(aq) + $H_2O(l)$ + NaClO(aq)

48. Balance the following chemical equation by using the oxidation number or electron-ion number method.

$P + NaOH + H_2O \rightarrow PH_3 + NaH_2PO_2$

49. Point out the oxidant and reductant in the following redox reaction and balance the reaction by oxidation number method or ion-electron method.

$NaOH + Br_2 \rightarrow NaBrO_3 + NaBr + H_2O$

57. Four equations representing reactions of nitrogen or one of its compounds are given.

Which equation represents a disproportionation reaction?

A $2HNO_3 + CaCO_3 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$

B $N_2 + 3H_2 \longrightarrow 2NH_3$

C $NH_4Cl + NaOH \longrightarrow NH_3 + NaCl + H_2O$

D $2NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$

58. Bromine reacts with aqueous sodium hydroxide at 25°C.

reaction 1: $Br_2(aq) + 2NaOH(aq) \longrightarrow NaBr(aq) + NaOBr(aq) + H_2O(l)$

The NaOBr formed is unstable at 25°C and reacts further.

reaction 2: $3NaOBr(aq) \longrightarrow 2NaBr(aq) + NaBrO_3(aq)$

Which reactions are disproportionations?

A both reaction 1 and reaction 2

B neither reaction 1 nor reaction 2

C reaction 1 only

D reaction 2 only

59. Chlorine dioxide, ClO_2, reacts with sodium hydroxide in the reaction shown.

$2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$

Which statement correctly describes this redox reaction?

A Chlorine atoms are oxidised and oxygen atoms are reduced.
B Chlorine atoms are reduced and oxygen atoms are oxidised.
C Some chlorine atoms are oxidised and some chlorine atoms are reduced.
D Some oxygen atoms are oxidised and some oxygen atoms are reduced.

60. HOCl (aq) is the molecule that kills bacteria when chlorine is added to water.
The following reaction produces this molecule.
$Cl_2(g) + H_2O(I) \rightarrow HOCl\ (aq) + H^+(aq) + Cl^-(aq)$
Which statement about this reaction is correct?
A Chlorine is both oxidised and reduced.
B Chlorine is oxidised but **not** reduced.
C Hydrogen is both oxidised and reduced.
D Hydrogen is oxidised but **not** reduced.

61. Electronegativity differences can be used to help determine the oxidation number of an atom in different species. A number of rules are used which include:
• The more electronegative atom is given a negative oxidation number.
• Hydrogen is more electronegative than Group1 metals.
• Oxygen is more electronegative than hydrogen.
Which row is correct?

	equation of reaction	redox reaction	disproportionation reaction
A	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$	✓	✗
B	$NaH + H_2O \rightarrow NaOH + H_2$	✓	✓
C	$3MnO_4^{2-} + 4H^+ \rightarrow MnO_2 + 2MnO_4^-$	✓	✓
D	$VO_3^- + 2H^+ \rightarrow VO_2^+ + H_2O$	✓	✗

62. Hot aqueous sodium hydroxide reacts with chlorine.
$6NaOH(aq) + 3Cl_2(g) \rightarrow 5NaCl\ (aq) + NaClO_3(aq) + 3H_2O(l)$
Which statement is correct?
A The oxidation numbers of chlorine and hydrogen both change in the reaction.
B The oxidation numbers of chlorine in the products are –1 and +1.
C If the aqueous sodium hydroxide is cold the reaction produces NaClO instead of $NaClO_3$.
D Sodium undergoes disproportionation in this reaction.

63. NH_4NO_3 decomposes into N_2O and H_2O on heating.
Which statements are correct?
1 The ammonium ion is behaving as a reducing agent.
2 The nitrate(V) ion is behaving as an oxidising agent.
3 It is a redox reaction.
4 It is a disproportionation reaction.
A 1, 2, 3 and 4

B 1, 2 and 3 only
C 3 and 4 only
D 3 only

64. Chlorine reacts with sodium bromide.
$Cl_2 + NaBr \rightarrow NaCl + Br_2$
Which words correctly describe this reaction?
1 redox
2 displacement
3 disproportionation
A 1, 2 and 3
B 1 and 2 only
C 1 only
D 2 only

65. In the equation: $Cr_2O_7^{2-} + 3\ Fe^{2+} + H^+ \rightarrow Cr^{3+} + Fe^{3+} + H_2O$;
The coefficients of Fe^{2+} and H^+ are respectively
a. 6,7 b. 6,14 c. 5,7 d. 5,14

Electrolysis

Conductors and non-conductors:

The substances which conduct electricity are called conductors. e.g:
Metals – Cu, Ag, Fe, Au
Salts – NaCl, CdS, PbS etc.
Acids – HCl, H_2SO_4, HNO_3
Alkali – NaOH, KOH, $Ca(OH)_2$

The substances which cannot conduct electricity are called non-conductors. e.g.: sugar, glucose, P, S etc.

Classification of conductors:

Metallic conductors: The conductors through which conduction of electricity takes place by the migration of electrons under the influence of an applied potential are called metallic conductors. For e.g.: metals, alloys, graphite etc.

Electrolytic conductors: The conductors through which the conduction of electricity takes place by the migration of ions towards oppositely chargedelectrodes due to the occurrence of chemical changes at the

surface of electrodes are called electrolytic conductors. For e.g.: a solution of weak and strong electrolyte, molten salt etc.

Electrolysis

The process of decomposition of an electrolyte by passing electric current through its aqueous solution or fused (molten) state is called electrolysis.

- The electrochemical cell in which the electrical energy is used to bring chemical reaction is called electrolytic cell.
- In this cell, two metallic electrodes are dipped into the solution of suitable electrolyte.
- Then, the electrodes are connected to the external source of electricity such as battery. (DC current is required)
- The electrode which is connected to the positive terminal of the battery is called anode and the electrode which is connected to the negative terminal of the battery is called cathode.
- When electricity is passed, chemical reactions take place inside the cell. i,e. cations move towards the cathode and anions move towards the anode.
- For example; Let us consider the electrolysis of molten NaCl.

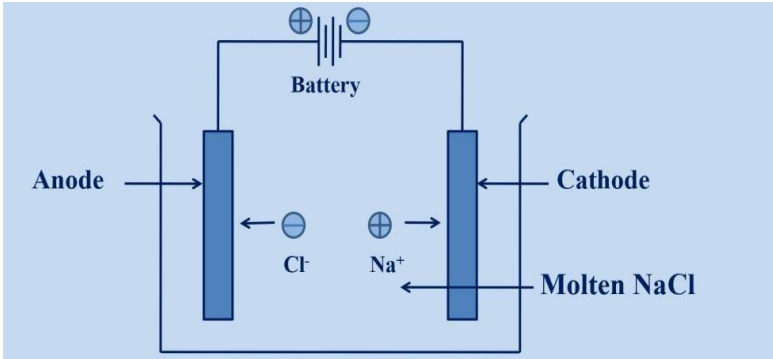

Fig.- Electrolysis of molten NaCl (Schematic)

Reactions involved:

$NaCl \rightarrow Na^+ + Cl^-$ (Molten)

At anode: $Cl^- - 1e^- \rightarrow Cl$ (oxidation) $Cl + Cl \rightarrow Cl_2$
At cathode: $Na^+ + 1e^- \rightarrow Na$ (reduction)

Electrolysis finds many applications in,

- purification of precious metals like: Cu, Ag
- manufacture of Ca, Na, Al
- manufacture of NaOH, Cl_2, F_2

50. What do you mean by electrolytic conduction? 2

Faraday's Laws of Electrolysis

First law

The amount of any substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed through it.

Let, W gram of substance be deposited or liberated at the electrode by passing Q amount of electricity (charge), then according to the first law.

$w \propto Q$

or, $w = zQ$

or, $\boxed{w = zIt}$ (since I = Q/t; or Q = It)

where z is a proportionality constant called electrochemical equivalent (ECE). I is current electricity, t is time

when, I = 1 ampere and t = 1 seconds, W = z

Hence, ECE (z) is defined as the mass of substance deposited or liberated when a current of 1 A is passed through the electrolytic cell for one second.

In other words, it is the mass of substance deposited or liberated on passing 1 coulomb charge.

Faraday(F)

It has been found that the same amount of electrons (charge) is required to deposit 1 gram equivalent of different substances, which is nearly equal to 96500 coulomb.

i.e., $\boxed{1\ F = 96500\ Coulomb}$

One faraday can also be defined as the amount of charge carried by 1 mole of electrons.

Relation between ECE and CE(Chemical equivalent)

According to Faraday's first law of electrolysis,

$$w = zQ$$

or, $$z = \frac{w}{Q}$$

We know, 1 F (96500 Coulomb) of electricity deposits one equivalent of a substance. Therefore, when w = E; Q= 1 F or 96500 coulomb

Hence, $$Z = \frac{E}{1\ F} = \frac{E}{96500}$$

where E is equivalent weight or chemical equivalent.

Equivalent weight of an element is defined as the parts by weight of that element that combines with or displaces 1.008 parts by weight of hydrogen, 8 parts by weight of oxygen or 35.5 parts by weight of chlorine.

The equivalent weight of elements can be calculated by dividing its atomic weight by valency. i.e., $E = A/V$

51. State Faraday's first law of electrolysis. 1
52. State and explain Faraday's first law of electrolysis. 2
53. What is E.C.E. (Electrochemical equivalent)? 1
54. Distinguish between ECE and Chemical equivalent. 2
55. Derive the mathematical relation between electrochemical equivalent and chemical equivalent. 2
56. Define one Faraday of electricity. 1
57. Show that the electric current carried by the transfer of a mole of electrons is 1 Faraday. 3
58. How would you justify that the value of one Faraday is 96500 coulombs? 2

59. Convert the following:
a. Charge of 4.0 x 10^{12} electrons into coulomb.
b. Chemical equivalent of Mg into ECE 2
60. How many coulombs of charge is required to deposit 81 g of Aluminum when the electrode reaction is:
$Al^{+++} + 3e^- \rightarrow Al$ 2

61. **How many coulombs are required to produce 80 g of Aluminium from molten Al_2O_3? 2**
62. **How many coulombs of electricity are required to deposit 33g of Ca from molten $CaCl_2$? 2**
63. **How much electric charge is required to deposit: i) 4.6 g of Sodium ii) 3 moles of Aluminium? 2**
64. **How many coulombs are required to produce 27 g of silver from $AgNO_3$?**
    (atomic weight of Ag = 108) 1
65. **How many coulombs of electricity are required to discharge 0.1 mole of Na+? (1Faraday = 96500) 2**
66. **How many coulombs are required to deposit 126 g of Cu from CuSO4 solution? (At. mass of Cu = 63.5) 2**
67. **0.197 g of copper is deposited by a current of 0.2 A in 50 min. Calculate its electrochemical equivalent. 2**
68. **An electrolytic cell contains a solution of CuSO4 and anode of impose copper. How many kg of copper will be deposited at cathode by 150 ampere passing for 12 hours? (ans= 2.13)**
69. **A current of 2.5 ampere passes through the solution of a metal sulphate for 30 minutes and deposits 1.52 g of metal at cathode. Find the equivalent weight of the metal. (ans = 32.58) 3**
70. **1.52 gm of a <u>trivalent</u> metal was deposited at cathode by passing a current of 2.5 Ampere through its salt solution (metallic sulphate) for 30 minutes. What is the atomic weight of the metal? (ans=97.78 amu) 3**
71. **Chromium metal can be plated put from acidic solution containing CrO_3 according to the following equation.**
    $CrO_3 + 6\ H+ + 6\ e- \rightarrow Cr(s) + 3\ H_2O$
    (i) How many grams of Cr can be plated out from 2400 Coulomb? (ans = 0.215)
    (ii) How long would it take to plate out 1.5 g of Chromium using 1.5 A current? (ans = 11135.85 s) 3
72. **Silver is electrodeposited on a metal plate of surface area 800cm^2 by passing 0.2 ampere current for 3 hours. Calculate the thickness of Ag deposited. (Given, specific gravity of Ag = 10.47 and atomic mass = 108)** (ans = 2.88 x 10^{-4} cm) **3**
73. **How long a current of 3A has to be passed through a solution of $AgNO_3$ has to be passed through a solution of $AgNO_3$ to coat a metal surface of 80cm^2 with 0.05mm thick layer (density of Ag = 10.5g/cc) 5**
74. **How many grams of Ag could be plated out on a serving tray by passing electricity through a solution of Ag(I) salt for 8 hours at a current of 9A. What is the area of tray if the thickness of the Ag-**

plating is 0.002cm? Density of Ag is 10g/cm^3. (Atomic mass of Ag = 107.8) (ans = 289 g: 1.45 x 10^4 cm^2) **4**

75. A metallic spoon is coated with Ag by passing a current of 5A through $AgNO_3$ solution for 5 hrs. What is the thickness of Ag-plating if the area of the spoon is 12 cm^2? (density of Ag-10.5gm/cc) 3

2. A coulomb charge corresponds to
   a. 6.0 x 10^{15} electrons
   b. 6.0 x 10^{17} electrons
   c. 6.0 x 10^{16} electrons
   d. 6.0 x 10^{18} electrons
3. The amount of silver deposited on passing 2.0 Faraday of charge through an aqueous solution of $AgNO_3$ is (at. wt. of Ag = 108 D)
   a. 54 g b. 108 g c. 216 g d. 324 g
4. One Faraday of electricity is equivalent to:
   a. 1602 × 10^{-12} coulombs
   b. 96500 coulombs
   c. 95.5 coulombs
   d. 22400 coulombs

Second Law

When the same quantity of charge (electricity) is passed through different electrolytic solutions the amount of different substances deposited or liberated at respective electrodes are directly proportional to their equivalent weights (or chemical equivalents).

Let W gram of substance is deposited or liberated by certain quantity of electricity and E is the equivalent weight of the substance. Then,

$W \propto E$

or W = constant x E

or, W/E = constant ……(i)

If same quantity of electricity deposits W_1, W_2, ….. grams of different substances which have equivalent weights E_1, E_2, ….. respectively. From equation (i),

$$\frac{W1}{E1} = \frac{W2}{E2} = \text{.....= constant} \quad \text{.....(ii)}$$

76. State and explain Faraday's second law of electrolysis. 2

77. An equal amount of current is passed through an aq. solution of trivalent metallic salt and dil. H_2SO_4. The volume of H_2 liberated was 96.5 ml at 27°C & 765 mmHg pressure and the wt. of metal deposited was 0.74 gm calculate the atomic weight of the metal.* 4

***(to be solved after studying gas laws)**

78. Michael Faraday (1971-1867) investigated quantitative aspects of electrolysis by measuring the amount of chemical change brought about by a known quantity of electricity.

a. State Faraday's law of electrolysis.

b. Define the terms ECE and CE and derive relationship between them

c. Write an application of electrolysis. 2+2+1

66. The process of electrolysis needs
    a. anode a. cathode c. electrolyte d. all of the above
67. Electrochemical equivalent (ECE) is
    a. electricity required to deposit 1 g of a substance
    b. amount of substance deposited or liberated by 1 C charge
    c. time taken to deposit 1 gram of substance
    d. amount of substance deposited by 1 ampere current for 1 hr.
68. The number of coulomb of electricity required to deposit 0.3 mole of Cu^{2+} is
    a. 9650 b. 2x9650 c. 4x9650 d. 6x 9650
69. How many Faradays are required to reduce 1 mol of BrO_3^- to Br^-?
    b. 3 b. 5 c. 6 d. 4
70. Which of the following statements is false?
    c. Michael Faraday introduced the laws of electrolysis.
    d. 1 Faraday equals to 96500 Coulombs
    e. Electrolysis is a redox phenomenon.
    f. Oxidation always occurs at cathode.
71. 3F of electricity are passed through molten Al_2O_3, aqueous solution of $CuSO_4$ and molten NaCl taken in three electrolytic cells. The amount of Al, Cu & Na deposited at the cathode will be in the ratio of
    g. 1mole: 2 mole: 3mole
    h. 3mole: 2 mole: 3mole
    i. 1mole: 1.5 mole: 3mole
    j. 1.5mole: 2 mole: 3mole

***** This is not a complete note. It is just to guide you. It is recommended to study prescribed textbooks (*especially missing topics*) along with this material. *****