METALLURGY

1. Mg metal is extracted from
(A) Cryolite   (B) Carnallite   (C) Malachite   (D) Cassiterite

2. When haematite ore is burnt in air with coke along with lime at 200°C, the process not only produces steel but also produces an important compound (A), which is useful in making building materials. The compound (A) is
(A) SiO_2 (B) $CaSiO_3$ (C) FeO   (D) Fe_2O_3

3. Match **List-I** with **List-II** and select the correct answer using the codes given below the lists.

	List-I (Metals)					List-II (Process/methods involved in extraction process)
(a)	Au				1.	Self reduction
(b)	Al				2.	Liquation
(c)	Pb				3.	Electrolysis
(d)	Sn				4.	Bayer's process

	(a)	(b)	(c)	(d)			(a)	(b)	(c)	(d)
(A)	3	1	2	4		(B)	3	4	1	2
(C)	1	2	4	3		(D)	3	2	4	1

4.
(i) The slag obtained during the extraction is lighter and has lower melting point than the metal (Fe or Cu)
(ii) Froth floatation process may be used to increase the concentration of mineral chalcopyrites.

(A) T, T   (B) T, F   (C) F, T   (D) F, F

5. Main function of frothers is:
(A) Stick to the ore and then take it to rise upto the top
(B) Convert the insoluble ore into soluble part
(C) Make the ore hydrophobic
(D) None

6. Main function of the collectors in metallurgy is:
(A) Stick to the ore and then take it to rise upto the top
(B) Convert the insoluble ore into soluble part
(C) Make the ore hydrophobic
(D) None

7. Consider the following metallurgical processes
(i) Heating impure metal with CO and distilling the resulting volatile carbonyl (boiling point 43ºC) and finally decomposing at 150ºC to 200ºC to get the pure metal.
(ii) Heating the sulphide ore in air until a part is converted to oxide and then further heating in the absence of air to let the oxide react with unchanged sulphide.
(iii) Electrolysing the molten electrolyte containing approximately equal amounts of the metal chloride and $CaCl_2$ to obtain the metal.
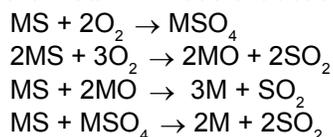The process used for obtaining sodium, nickel and copper are, respectively,
(A) (i), (ii) and (iii)   (B) (ii), (iii) and (i)   (C) (iii), (i) and (ii)   (D) (ii), (i) and (iii)

8. In purification of bauxite ore, it is mixed with coke and heated at 1800 °C in presence of nitrogen. this is :
(A) Hall's process   (B) Serpeck's process
(C) Baeyer's process   (D) Electrolytic reduction.

9. Reducing agent of haematite in blast-furnace is
    (A) Coke in furnace   (B) Coke in upper part and CO in lower part of furnace.
    (C) CO in most parts of the furnace   (D) CO in the furnace.

10. $PbS \xrightarrow[\Delta]{air} X$, $X + PbS \longrightarrow Pb + SO_2$

    'X' is
    (A) PbO (B) PbO_2 (C) PbO and $PbSO_4$ (D) PbO_2 and PbO
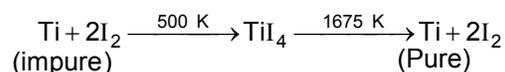
11. A metal obtained by a hydrometallurgical operation is :
    (A) Silver   (B) Iron   (C) Tin   (D) Aluminium

12. Identify the metal M whose extraction is based on the following reactions :
    $$MS + 2O_2 \rightarrow MSO_4$$
    $$2MS + 3O_2 \rightarrow 2MO + 2SO_2$$
    $$MS + 2MO \rightarrow 3M + SO_2$$
    $$MS + MSO_4 \rightarrow 2M + 2SO_2$$
    (A) Magnesium   (B) Aluminium   (C) lead   (D) tin

13. Which method of purification is represented by the equations ?

    $Ti + 2I_2 \xrightarrow{500\ K} TiI_4 \xrightarrow{1675\ K} Ti + 2I_2$
    (impure)   (Pure)

    (A) Cupellation   (B) Polling   (C) Van Arkel   (D) Zone refining

14. Which one of the following statements is **incorrect** ?
    (A) Tin is extracted by carbon reduction (smelting)
    (B) Aluminium is extracted by Hall's process which involves carbon reduction.
    (C) Extraction of lead does not involve bessemerisation
    (D) Silver is extracted by cyanide process

15. Extraction of zinc from zinc blende is achieved by :
    (A) electrolytic reduction
    (B) roasting followed by reduction with carbon
    (C) roasting followed by reduction with another metal
    (D) roasting followed by self-reduction

16. Which of the following statements is correct regarding the slag obtained during the extraction of a metal like copper or iron ?
    (A) The slag is lighter and has lower melting point than the metal
    (B) The slag is heavier and has lower melting point than the metal
    (C) The slag is lighter and has higher melting point than the metal
    (D) The slag is heavier and has higher melting point than the metal

17. Match correctly
    I   Bauxite   (a)   Lead
    II   Carnallite   (b)   Copper
    III   Malachite   (c)   Magnesium
    IV   Galena   (d)   Hall Process
    (A) I – a, II – b, III – c, IV – d   (B) I – d, II – c, III – b, IV – a
    (C) I – b, II – a, III – d, IV – c   (D) I – d, II – b, III – c, IV – a

18. Impure + I_2 $\longrightarrow$ Metal iodide $\xrightarrow[\Delta]{Heat}$ Pure Metal + I_2
    Vapour   Reused

    The above method of purification is :
    (A) Van – arkel process for Zr, Hg etc   (B) Distillation for Zn, Cd, Hg etc
    (C) Electro refining for W, Ag, Au, etc   (D) Zone refining of germanium gallium, silicon etc.

19.

Column – I	Column – II
(a) Chalcopyrites	(P) Self – reduction
(b) Galena	(Q) Sulphur containing ore
(c) Argentite	(R) Carbon reduction
(d) Malachite	(S) Leaching followed by displacement method.

20. **Select the incorrect statement**
(A) Carbon is a better reducing agent below 983K than carbon monoxide.
(B) Sulphide ores generally roasted to oxide for the extraction of metals instead of being directly reduced.
(C) Zinc not extracted from zinc oxide through reduction using CO but instead coke is used.
(D) Leaching of native ores of silver/gold or of their sulphide ores and the extraction of metals (silver/gold), is an example of hydrometallurgy.

Paragraph for Question Nos. 21 to 23

The mineral Coleminite is fused with sodium carbonate, compound (Z) is obtained along with white ppt. when (Z) reacts with conc. H_2SO_4 gives compound (B) which on strong heating gives (C), (C) on reduction with Mg produces (D) & nonmetal (X). Treatment of chlorine on a mixture of (C) & carbonate high temp. gives fuming liq. (E) which on reduction by $LiAlH_4$ gives gas (F) which causes headache. This gas (F) reacts with excess of Ammonia at low temperature giving an addition compound which on heating at 200°C gives a compound (G).

21. Compound (G)
(A) is isoelectronic with bezene
(B) is isostructural with benzene
(C) contains both coordinate and covalent bonds
(D) All the above

22. Compound (B) is weak acidic in ————— & strong acidic in ——————— .
(A) (i) H_2O & (ii) Glycol
(B) (i) H_2O & (ii) Sugar
(C) both A & B are correct
(D) None

23. In compound 'Z' how many atoms are sp^2 hybridised.
(A) Only 2
(B) Only 3
(C) Only 4
(D) Only 6

Paragraph for Question Nos. 24 to 26

Electrolytic purification of copper is required since the product of the Bessemer converter is impure. Sheets of pure copper are made the cathodes and blister copper is used as the anodes. The bath contains $CuSO_4$, H_2SO_4 and NaCl. Metallic copper goes into solution as Cu^{+2} ions at the anode and deposited at the cathode. Zinc and iron go into solution and do not deposit at the cathode alongwith copper. Silver goes into solution as Ag^+ ions, but forms a sludge in the electrolysis cell. The noble metals such as gold and platinum do not dissolve; they fall to the bottom when released from the copper anode. They help to pay for the copper refining process.

24. The different chemical behaviour of various metal ions (for example only Cu is deposited on the cathode) involved are explainable best using
(A) their amounts in impure copper
(B) the electrochemical series
(C) their ionization potentials
(D) their hydration energies

25. The voltage is kept low enough during the operation. This is to ensure that
(A) Fe^{+2} and Zn^{+2} ions are kept in solution only
(B) there is no risk of electric shock to the plant operators
(C) gold and platinum do not dissolve in solution and are recovered as solids
(D) temperature control is maintained to effect reaction rate control

26. The most important role of various electrolytes added to the electrorefining bath in this case is
(A) to reduce the temperature of bath
(B) to result in good electrical connectivity so as to have high production rates
(C) so that the anode acts as an attackable electrode
(D) to enhance the viscosity of electrolyte thus preventing leakage from bath.
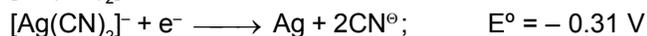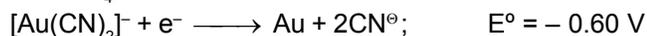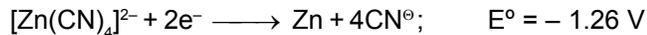
Paragraph for Question Nos. 27 to 29

Metallic gold is frequently found in aluminosilicate rocks and it is finely dispersed among other minerals. It may be extracted by treating the crushed rock with aerated sodium cyanide solution. During this process metallic gold is solowly converted to $[Au(CN)_2]^-$ which is soluble in water.

$$Au + CN^{\oplus} \longrightarrow [Au(CN)_2]^-$$

After equilibrium has been reached, the aqueous phase is pumped off and metallic gold is recovered from it by reacting the gold complex with zinc, which is converted to $Zn(CN)_4]^{2-}$

$$Zn + [Au(CN_2)]^- \longrightarrow [Zn(CN)_4]^{2-} + Au$$

Gold in nature is frequently alloyed with silver which is also oxidised by aerated sodium cyanide solution.

$$[Zn(CN)_4]^{2-} + 2e^- \longrightarrow Zn + 4CN^{\ominus}; \qquad E^\circ = -1.26 \text{ V}$$
$$[Au(CN)_2]^- + e^- \longrightarrow Au + 2CN^{\ominus}; \qquad E^\circ = -0.60 \text{ V}$$
$$[Ag(CN)_2]^- + e^- \longrightarrow Ag + 2CN^{\ominus}; \qquad E^\circ = -0.31 \text{ V}$$

27. Five hundred litres (500 L) of a solution 0.0100 M in $[Au(CN)_2]^-$ was evaporated to one third of the original volume and was treated with zinc (40 g). Assuming that deviation from standard conditions is unimportant in this case and all the concerned redox reaction go essentially to completion. Hence, the concentrations of $[Au(CN)_2]^-$ and of $[Ag(CN)_2]^-$ after reaction are :
(A) $Au(CN)_2]^- = 0.030$ M ; $[Ag(CN)_2]^- = 0.0030$ M
(B) $Au(CN)_2]^- = 0.0100$ M ; $[Ag(CN)_2]^- = 0.0090$ M
(C) $Au(CN)_2]^- = 0.030$ M ; $[Ag(CN)_2]^- = 0.0020$ M
(D) $Au(CN)_2]^- = [Ag(CN)_2]^- = 0.030$ M

28. $[Au(CN)_2]^-$ is a very stable complex under certain certain conditions. The concentration of cyanide ion which is required to keep 99 mol % of the gold in the form of the cyanide complex is :
(A) 2×10^{-28} M   (B) 3×10^{-14} M   (C) 5×10^{-28} M   (D) 5×10^{-14} M

29. There have been several efforts to develop alternative gold extraction which could replace this one because :
(A) sodium cyanide solutions corrode mining machinery
(B) sodium cyanide escapes into ground water and produces hydrogen cyanide cyanide which is toxic to many animals
(C) gold obtained by this process is not pure
(D) none of the above

Paragraph for Question Nos. 30 to 34

In metallurgy the first step after selecting a ore is to concentrate it. A very common method of concentration of ore is froth floatation process which is employed for sulphide ores such as copper pyrites ($CuFeS_2$). Next step is usually roasting in which sulphide ore is heated strongly in excess of air in a reverberatory furnace. The concentrated ore is then subjected to smelting in a blast furnace where slag is removed. The molten mass obtained in case of copper is subjected to self reduction where blister copper is obtained. The blister copper is finally subjected to electrolytic refining where anode is made of impure copper and cathode is made of pure copper. The electrolyte taken is $CuSO_4$, H_2SO_4 and NaCl. On passing the current copper is deposited on the cathode. Impurities like zinc, iron and silver go into the solution. The noble metals such as gold and platinum are also found in the form of impurities which do not get dissolved and settle down as anode mud.

30. Which of the following ore can be concentrated by froth floatation process :
(A) Epsom   (B) Silver glance (C) Haematite   (D) All

31. In case of copper, during smelting the flux used is :
(A) FeO   (B) SiO_2 (C) MgO   (D) Cu_2S

32. Which of the following is not an example of self reduction :

(A) $2PbO + PbS \longrightarrow 3Pb + SO_2$ (B) $2Cu_2O + Cu_2S \longrightarrow 6\,Cu + SO_2$

(C) $2Ag_2O + Ag_2S \longrightarrow 6Ag + SO_2$ (D) All are examples of self reduction

33. During electrolytic refining of copper only pure copper gets deposited on the cathode and not the other metals (impurities). This is best explained on the basis of :
(A) Ionisation potentials of the metals   (B) Electronegativities of the metals
(C) Density of metals   (D) Electrode potentials of metals

34. Which of the following is incorrect :
(A) Electrolytic refining of Al cannot be carried out in aqueous medium
(B) Silver (impurity) is extracted out as AgCl during electrolytic refining of copper
(C) An important side product in the metallurgy of copper is used in the manufacture of H_2SO_4
(D) None of the above is correct

Paragraph for Question Nos. 35 to 36

(Read the following passage and answer the questions numbered 5 to 6 . They have only one correct option)

Electrolytic purification of copper is required since the product of the Bessemer converter is impure. Sheets of pure copper are made the cathodes and blister copper is used as the anodes. The bath contains $CuSO_4$, H_2SO_4 and NaCl. Metallic copper goes into solution as Cu^{+2} ions at the anode and deposited at the cathode. Zinc and iron go into solution and do not deposit at the cathode alongwith copper. Silver goes into solution as Ag^+ ions, but forms a sludge in the electrolysis cell. The noble metals such as gold and platinum do not dissolve; they fall to the bottom when released from the copper anode. They help to pay for the copper refining process.

35. The voltage is kept low enough during the operation. This is to ensure that
(A) Fe^{+2} and Zn^{+2} ions are kept in solution only
(B) there is no risk of electric shock to the plant operators
(C) gold and platinum do not dissolve in solution and are recovered as solids
(D) temperature control is maintained to effect reaction rate control

36. The most important role of various electrolytes added to the electrorefining bath in this case is
(A) to reduce the temperature of bath
(B) to result is good electrical connectivity so as to have high production rates
(C) so that the anode acts as an attackable electrode
(D) to enhance the viscosity of electrolyte thus preventing leakage from bath.

Paragraph for Question Nos. 37 to 39

Metallic gold frequently is found in aluminosilicate rocks and it is finely dispersed among other minerals. it may be extracted by treating the crushed rock with aerated sodium cyanide solution. During this process metallic gold is slowly converted to $[Au(CN)_2]^-$, which is soluble in water. After equilibrium has been reached, the aqueous phase is pumped off and the metallic gold is recovered from it by reacting the gold complex with zinc, which is converted to $[Zn(CN)_4]^{2-}$. Gold in nature is frequently alloyed with silver which is also oxidised by aerated sodium cyanide solution.

37. The correct ionic reaction for the process are
(A) $4Au + 8CN^- + 2H_2O + O_2 \,(air) \rightarrow 4[Au(CN)_2]^- \,(soluble) \; + 4OH^-$

(B) $Au + 2CN^- \longrightarrow Au[(CN)_2]^-$

(C) $Zn + 2CN^- \longrightarrow Zn[(CN)_2]^-$

(D) $Zn + 4CN^- \longrightarrow Zn[(CN)_4]^{2-}$

38. There have been several efforts to develop alternative gold extraction processes which could replace this one. Why?
(A) Sodium cyanide solutions corrode mining machinery
(B) Sodium cyanide escapes into ground water and produces hydrogen cyanide which is toxic to many animals.
(C) Gold obtained by this process is not pure.
(D) The amount of gold in aluminosilicate rocks is very less.

39. The process described above in the passage is regarding
(A) ore dressing   (B) pyrometallurgical extraction
(C) hydrometallurgical extraction   (D) purification of metal

ANSWER AND SOLUTION

1. **(B)**
Sol. Carnallite is $MgCl_2.KCl.6H_2O$.

2. **(B)**

3. **(B)**
Sol. In the Bayer's process pure aluminium oxide is obtained from the bauxite ore. A low melting metal like tin can be refined by liquation method. Electrolysis is used in the refining of gold.

4. **(A)**

5. **(A)**

6. **(C)**

7. **(C)**

8. **(B)**

9. **(C)**

10. **(C)**
Sol. $PbS + O_2 \longrightarrow PbO + SO_2$

$PbS + 2O_2 \longrightarrow PbSO_4$

11. **(A)**
Sol. Extraction of silver is not a high temperature operation like most metals and is done by the cyanide process in water solution.

12. **(C)**

13. **(C)**

14. **(B)**

15. **(B)**

16. **(A)**

17. **(B)**
Sol. Bauxite $- Al_2O_3 . 2H_2O - Al$ is extracted by Hall's process
Carnallite - $MgCl_2. KCl. 6H_2O$
Malachite - $CuCO_3. Cu(OH)_2$
Galena - PbS

18. **(A)**
Sol. (a) $\rightarrow$ van – Arkel method for Zr – Hg
$\rightarrow$ Based on volatile nature of halides of methods.

19. **(a $\rightarrow$ P,Q,R) ; (b $\rightarrow$ P,Q ,R) ; (c $\rightarrow$Q,S) ; (d $\rightarrow$ R)**

Sol. (A) $CuFeS_2$; $Cu_2S + 2 Cu_2O \longrightarrow 6 Cu + SO_2$; $Cu_2O + C \longrightarrow 2 Cu + CO$

(B) PbS ; $PbS + 2PbO \longrightarrow 3Pb + SO_2$; $PbO + C \longrightarrow Pb + CO$; $PbO + CO \rightarrow Pb + CO_2$

(C) Ag_2S; Cyanide process, leaching with alkali metal cyanide followed by displacement with zinc dust.

(D) $CuCO_3. Cu(OH)_2$; Calcination $\longrightarrow CuO + C \longrightarrow Cu + CO$

20. (A)

21. (D)

22. (C)

23. (A)

Sol. 21 to 23

Z is borax

B is boric acid H_3BO_3

C is boric anhydride B_2O_3.

D - is MgO

X - is Boron

E is BCl_3

F is B_2H_6

G is borazole $B_3N_3H_6$. Hence the answers follow.

24. (B)

Sol. SRP zinc = – 0.76

SRP iron = – 0.44

SRP copper = + 0.34   (highest);   Hence only copper deposits, others do not.

25. (A)

Sol. Increasing voltage would cause deposition of Fe^{+2} and Zn^{+2} also to occur.

26. (B)

Sol. Water (pure) is a poor electrical conductor.

27. (C)

Sol. $\left. \begin{array}{c} [Au(CN)_2]^- \\ + \\ [Ag(CN)_2]^- \end{array} \right\}$ + Zn $\xrightarrow{\text{Re duction}}$ Certainly according to spontaneity and availability substance will be reduced.

$$E^o_{Ag|Zn} = -0.31 - (-1.26) = 0.95 \text{ V}$$
$$E^o_{Au|Zn} = -0.60 - (-1.26) = 0.66 \text{ V}$$

As $E^o_{Ag|Zn} > E^o_{Au|Zn}$

Hence, Ag complex will be reduced first :

   Mole of Ag in 500 L = 500 × 0.0030 = 1.5 mol

   Mole of Au in 500 L = 500 × 0.010 = 5.0 mol

   Mole of Zn in 40 g = $\dfrac{40}{65.38}$ = 0.61 mol

   $2[Ag(CN)_2]^- + Zn \longrightarrow [Zn(CN)_4]^{2-} + 2Ag$

1 mol of zinc reacts with 2 mol of Ag(I) or Au(I), 0.61 mol of zinc reacts with 1.2 mol $[Ag(CN)_2]^-$

   Remaining $[Ag(CN)_2]^-$ = 1.5 – 1.2 = 0.3 mol

$[Ag(CN)_2]^-$ will not be reduced as zinc gets over.

Hence, concentration of $[Ag(CN)_2]^-$, reaction get over = 0.010 × 3 = **0.030 M**

(due to evaporation to one-third)

Concentration of $[Ag(CN)_2]^-$ when reaction gets over = $\dfrac{0.3 \times 3}{500}$ = **0.002 M**

28. (D)

Sol. $Au^+ + 2CN^- \rightleftharpoons [Au(CN)_2]^-$

99 mol% $[Au(CN)_2]^-$

It means $\dfrac{[Au(CN_2)]^-}{[Au^+] + [Au(CN_2)]^-} = \dfrac{99}{100}$

$100[Au(CN)_2]^- = 99[Au^+] + 99[Au(CN)_2]^-$

$$[Au^+] = \frac{[Au(CN_2)]^-}{99} - (I)$$

$$K_f = \frac{[Au(CN_2)]^-}{[Au^+][CN^-]^2}$$

Putting the $[Au^+]$ from (I) in K_f

$$4 \times 10^{28} = \frac{99}{[CN^-]^2}$$

$\Rightarrow \qquad [CN^-] = 5 \times 10^{-14}$ M

29. **(B)**
Sol. This gold extraction process is hazardous due to toxic nature of hydrogen cyanide.

30. **(B)**
Sol. Froth floatation method is employed for sulphide ores. Silver glance (Ag_2S) is that.

31. **(B)**
Sol. $FeO + SiO_2 \longrightarrow FeSiO_3$

32. **(C)**

33. **(D)**

34. **(D)**
Sol. Because (A), (B) and (C) all are correct

35. **(A)**
Sol. (A) Increasing voltage would cause deposition of Fe^{+2} and Zn^{+2} also to occur.

36. **(B)**
Sol. (B) Water (pure) is a poor electrical conductor.

37. **(A)**

38. **(B)**

39. **(C)**