# One Two academy | Metallurgy

**Maximum Mark: 25** **Chemistry** **Time: 50 minutes**

**Choose the correct answer:** **3 x 1 = 3**

1. Extraction of gold and silver involves leaching with cyanide ion. silver is later recovered by
   a) Distillation b) Zone refining c) Displacement with zinc d) liquation
2. The chemical composition of Kaolinite is
   a) $Al2O_3.H_2O$ b) $Al_2Si_2O_5(OH)_4$ c) $FeS_2$ d) $Fe_2O_3.3H_2O$
3. The incorrect statement among the following is
   a) Nickel is refined by Mond's process
   b) Titanium is refined by Van Arkel's process
   c) Zinc blende is concentrated by froth floatation
   d) In the metallurgy of gold, the metal is leached with diluted sodium chloride solution

**Answer Any four of the following:** **4 x 2 = 8**

4. What are the differences between minerals and ores?
5. Write the applications of copper.
6. Describe a method for refining nickel.
7. Explain the following terms with suitable examples.
   (i) Gangue (ii) slag
8. Write a note on Liquation process.

**Answer any three of the following:** **3 x 3 = 9**

9. Write a short note on electrochemical principles of metallurgy.
10. Describe the role of the following in the process mentioned.
    (i) Silica in the extraction of copper.
    (ii) Cryolite in the extraction of aluminium.
    (iv) Sodium cyanide in froth floatation.
11. Write a short note on alkali and acid leaching.
12. Explain the Van-Arkel method for refining zirconium/titanium

**Answer the following:** **1 x 5 = 5**

13. a) Explain zone refining process with an example.

**(Or)**

b) What are the observations found from Ellingham diagram and give its limitations.

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All the Best

# Answer Key attached in the next page !!!

This page is to prevent seeing answer key

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**Answer Key**

**Choose the Correct answer:**

1. – c) 2. -b) 3. -d)

**Answer any four of the following:**

4.

| Minerals | Ores |
|---|---|
| A naturally occurring substance obtained by mining which contains the metal in free state or in the form of compounds like oxides, sulphides etc... is called a mineral. | Minerals that contain a high percentage of metal, from which it can be extracted conveniently and economically are called ores. |
| All minerals are **not** ores | All ores **are** minerals. |
| Example: **Clay** is a mineral of Aluminium. | Example: **Bauxite** is the ore of Aluminium |

5. **Applications of Cu:**
   - Copper is the first metal used by humans and extended use of its alloy bronze resulted in a new era, 'Bronze age'
   - Copper is used for making coins and ornaments along with gold and other metals.
   - Copper and its alloys are used for making wires, water pipes and other electrical parts

6. **Mond's Process for refining Nickel:**

The impure nickel is heated in a stream of carbon monoxide at around 350 K. The nickel reacts with the CO to form a highly volatile nickel tetracarbonyl. The solid impurities are left behind.

$$Ni\ (s) + 4\ CO\ (g) \rightarrow [Ni\ (CO)_4]\ (g)$$

On heating the nickel tetracarbonyl around 460 K, the complex decomposes to give pure metal.

$$[Ni\ (CO)_4]\ (g) \rightarrow Ni\ (s) + 4\ CO\ (g)$$

7. **Gangue:**

The ores are associated with non-metallic impurities, rocky materials and siliceous matter which are collectively known as gangue.

**Slag:**

**slag** is defined as a fusible chemical species formed by the reaction between an added **flux** and **gangue** present in the ore during the smelting process

**Flux + gangue → Slag**

8. **Liquation Process:**

This method is employed to remove the impurities with high melting points from metals having relatively low melting points such as tin (Sn; mp= 904 K), lead (Pb; mp=600 K), mercury (Hg; mp=234 K), and bismuth (Bi; mp=545 K). In this process, the crude metal is heated to form fusible liquid and allowed to flow on a sloping surface. The impure metal is placed on sloping hearth of a reverberatory furnace, and it is heated just above the melting point of the metal in the absence of air, the molten pure metal flows down and the impurities are left behind. The molten metal is collected and solidified.

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**Answer any three of the following:**

9. **electrochemical principles of metallurgy:**

Similar to thermodynamic principles, electrochemical principles also find applications in metallurgical processes. The reduction of oxides of active metals such as sodium, potassium etc., by carbon is thermodynamically not feasible. Such metals are extracted from their ores by using electrochemical methods. In this technique, the metal salts are taken in a fused form or in solution form. The metal ion present can be reduced by treating it with some suitable reducing agent or by electrolysis.

Gibbs free energy change for the electrolysis process is given by the following expression

$$\Delta G^\circ = -nFE^\circ$$

Where,

n is number of electrons involved in the reduction process,

F is the Faraday = 96500 coulombs

$E^0$ is the electrode potential of the redox couple.

If $E^0$ is positive, then the $\Delta G$ is negative and the reduction is spontaneous and hence a redox reaction is planned in such a way that the e.m.f of the net redox reaction is positive. When a more reactive metal is added to the solution containing the relatively less reactive metal ions, the more reactive metal will go into the solution. For example,

$$Cu\ (s) + 2Ag^+\ (aq) \rightarrow Cu^{2+}\ (aq) + 2Ag\ (s)$$

$$Cu^{2+}\ (aq) + Zn\ (s) \rightarrow Cu\ (s) + Zn^{2+}\ (aq)$$

10. **(i) Role of Silica in the extraction of copper:**

Silica ($SiO_2$) acts as an acidic flux in the extraction of copper. It removes the gangue FeO by forming ferrous silicate slag.

$$SiO_2\ (flux) + FeO\ (gangue) \rightarrow FeSiO_3\ (slag)$$

**(ii) Cryolite in the extraction of aluminium**:

As $Al_2O_3$ is a poor conductor, cryolite improves electrical conductivity. In addition, cryolite lowers the melting point of the mixture.

**(iv) Sodium cyanide in froth floatation:**

In froth floatation process, sodium cyanide is used as a depressing agent. It selectively prevents other metal sulphides from coming to the froth.

11. **Alkali leaching**:

In this method, the ore is treated with aqueous alkali to form a soluble complex. For example, bauxite, an important ore of aluminium is heated with a solution of sodium hydroxide or sodium carbonate in the temperature range 470 - 520 K at 35 atm to form soluble sodium meta-aluminate leaving behind the impurities, iron oxide and titanium oxide.

$$Al_2O_3\ (s) + 2NaOH\ (aq) + 3H_2O\ (l) \rightarrow 2Na\ [Al(OH)_4]\ (aq)$$

The hot solution is decanted, cooled, and diluted. This solution is neutralized by passing $CO_2$ gas, to form hydrated $Al_2O_3$ precipitate.

$$2Na\ [Al(OH)_4]\ (aq) + 2CO_2\ (g) \rightarrow Al_2O_3.3H_2O\ (s) + 2NaHCO_3\ (aq)$$

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The precipitate is filtered off and heated around 1670 K to get pure alumina $Al_2O_3$.

**Acid leaching**:

Leaching of sulphide ores such as ZnS, PbS etc., can be done by treating them with hot aqueous sulphuric acid.

$$2ZnS\ (s) + 2H_2SO_4\ (aq) + O_2\ (g) \rightarrow 2ZnSO_4\ (aq) + 2S\ (s) + 2H_2O$$

In this process the insoluble sulphide is converted into soluble sulphate and elemental sulphur.

12. **Van-Arkel method for refining zirconium/titanium:**

This method is based on the thermal decomposition of metal compounds which lead to the formation of pure metals. Titanium and zirconium can be purified using this method. For example, the impure titanium metal is heated in an evacuated vessel with iodine at a temperature of 550 K to form the volatile titanium tetra-iodide. ($TiI_4$). The impurities are left behind, as they do not react with iodine.

$$Ti\ (s) + 2I_2\ (s) \xrightarrow{500\ K} TiI_4\ (vapour)$$

The volatile titanium tetraiodide vapour is passed over a tungsten filament at a temperature around 1800 K. The titanium tetraiodide is decomposed and pure titanium is deposited on the filament. The iodine is reused.

$$TiI_4\ (vapour) \xrightarrow{1800\ K} Ti\ (s) + 2I_2\ (s)$$

**Answer the following:**

13. a) **Zone refining process:**

- This method is based on the principles of fractional crystallisation.
- When an impure metal is melted and allowed to solidify, the impurities will prefer to be in the molten region. i.e. impurities are more soluble in the melt than in the solid-state metal.
- In this process the impure metal is taken in the form of a rod. One end of the rod is heated using a mobile induction heater which results in melting of the metal on that portion of the rod.
- When the heater is slowly moved to the other end the pure metal crystallises while the impurities will move on to the adjacent molten zone formed due to the movement of the heater.
- As the heater moves further away, the molten zone containing impurities also moves along with it.
- The process is repeated several times by moving the heater in the same direction again and again to achieve the desired purity level.
- This process is carried out in an inert gas atmosphere to prevent the oxidation of metals.
- Elements such as Germanium (Ge), silicon (Si) and gallium (Ga) that are used as semiconductors are refined using this process.

**(Or)**

b) **Observations from the Ellingham diagram:**

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- For most of the metal oxide formation, the slope is positive. It can be explained as follows. Oxygen gas is consumed during the formation of metal oxides which results in the decrease in randomness. Hence, $\Delta S$ becomes negative and it makes the term, $T\Delta S$ positive in the straight-line equation.
- The graph for the formation of carbon monoxide is a straight line with negative slope. In this case $\Delta S$ is positive as 2 moles of CO gas are formed by the consumption of one mole of oxygen gas. It indicates that CO is more stable at higher temperatures.
- As the temperature increases, generally $\Delta G$ value for the formation of the metal oxide becomes less negative and becomes zero at a particular temperature. Below this temperature, $\Delta G$ is negative and the oxide is stable and above this temperature $\Delta G$ is positive. This general trend suggests that metal oxides become less stable at higher temperature and their decomposition becomes easier.
- There is a sudden change in the slope at a particular temperature for some metal oxides like MgO, HgO. This is due to the phase transition (melting or evaporation).

**Limitations of Ellingham diagram:**

- Ellingham diagram is constructed based only on thermodynamic considerations. It gives information about the thermodynamic feasibility of a reaction. It does not tell anything about the rate of reaction. Moreover, it does not give any idea about the possibility of other reactions that might be taking place.
- The interpretation of $\Delta G$ is based on the assumption that the reactants are in equilibrium with the products which is not always true.

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