

Document: Complete Solution Key

Chapter: Chapter 3 (Metals & Non-Metals)

Format: CBSE Step-by-Step Rubrics

SECTION A: OBJECTIVE & CONCEPTUAL MCQS (10 MARKS)

1 Mark for each correct option with detailed chemical rationale

Ans 1. (a) Calcium

[1 Mark]

Rationale: Calcium reacts with oxygen to form calcium oxide (CaO), an ionic compound with a very high melting point ($\sim 2572^\circ\text{C}$). CaO dissolves in water to form calcium hydroxide [$\text{Ca}(\text{OH})_2$, slaked lime]. Non-metal oxides like CO_2 and SiO_2 do not fit this profile, and iron oxide is insoluble in water.

Ans 2. (b) Bromine

[1 Mark]

Rationale: Bromine (Br_2) is the only non-metal that exists as a reddish-brown liquid at standard room temperature. Mercury is also liquid, but it is a metal.

Ans 3. (c) Zinc is more reactive than tin

[1 Mark]

Rationale: Zinc lies above iron and tin in the reactivity series. If food cans were coated with zinc, acidic substances present in food would react with zinc to form toxic zinc salts. Tin is much less reactive and safe for food storage.

Ans 4. (c) Homogeneous mixture

[1 Mark]

Rationale: An alloy is a homogeneous mixture of two or more metals, or a metal and a non-metal, prepared in the molten state.

Ans 5. (b) Carbon, Diamond, Graphite

[1 Mark]

Rationale: Carbon is the parent non-metal. Diamond is an allotrope of carbon and the hardest known natural substance. Graphite has free mobile electrons in its hexagonal sheets, making it a good conductor of electricity.

Ans 6. (d) Iron

[1 Mark]

Rationale: Sodium and calcium react vigorously with cold water. Magnesium reacts with hot water. Iron reacts only with red-hot steam: $3\text{Fe(s)} + 4\text{H}_2\text{O(g)} \rightarrow \text{Fe}_3\text{O}_4\text{(s)} + 4\text{H}_2\text{(g)}$.

Ans 7. (c) Conc. HCl : Conc. HNO_3 in 3 : 1 ratio

[1 Mark]

Rationale: Aqua regia is a freshly prepared fuming mixture of 3 parts concentrated hydrochloric acid and 1 part concentrated nitric acid by volume, capable of dissolving noble metals like gold and platinum.

Ans 8. (b) Acidified copper sulphate solution

[1 Mark]

Rationale: The electrolyte in the electrorefining of copper is an aqueous solution of acidified copper(II) sulphate ($\text{CuSO}_4 + \text{dil. H}_2\text{SO}_4$).

Ans 9. (a) Al_2O_3 and ZnO

[1 Mark]

Rationale: Both aluminium oxide (Al_2O_3) and zinc oxide (ZnO) display both basic and acidic properties, reacting with acids as well as alkalis to yield salt and water.

Ans 10. (c) CO

[1 Mark]

Rationale: Carbon monoxide (CO), nitrous oxide (N_2O), and water (H_2O) are neutral non-metal oxides that do not change the color of litmus.

SECTION B: ASSERTION & REASONING (4 MARKS)

Ans 11. (a) Both A and R are true, and R is the correct explanation of A.

[1 Mark]

Justification: Sodium and potassium have very low ionization energies and react violently with atmospheric oxygen and moisture. Immersion in kerosene isolates them from air and moisture.

Ans 12. (a) Both A and R are true, and R is the correct explanation of A.

[1 Mark]

Justification: Conduction of electricity requires free mobile charge carriers. In solid ionic crystals, ions are fixed in lattice positions by strong Coulombic forces. Conduction only occurs when molten or dissolved in water.

Ans 13. (b) Both A and R are true, but R is NOT the correct explanation of A.

[1 Mark]

Justification: Both statements are correct facts. However, magnesium reacts with hot water because thermal energy overcomes the activation barrier for the reaction, whereas floating is a physical consequence of hydrogen gas bubbles adhering to its surface.

Ans 14. (a) Both A and R are true, and R is the correct explanation of A.

[1 Mark]

Justification: Highly electropositive metals have a far higher affinity for oxygen than carbon does. Therefore, carbon cannot reduce their stable oxides to free metals; they must be isolated by electrolytic reduction.

SECTION C: SHORT ANSWER QUESTIONS & ANOMALIES (12 MARKS)

2 Marks each with step-wise mark distribution

Ans 15.

[2 Marks]

- Aluminium forms a tenacious, impermeable protective oxide film (Al_2O_3) upon atmospheric exposure that prevents further corrosion. It is also light and an excellent conductor of heat. | [1 mark]
- Gold and platinum are situated at the bottom of the reactivity series, have extremely low chemical reactivity, and do not react with air, water, or ordinary acids. Hence, they occur uncombined. | [1 mark]

Ans 16.

[2 Marks]

- Liquid metal: **Mercury (Hg)**. | [0.5 mark]
- Liquid non-metal: **Bromine (Br_2)**. | [0.5 mark]
- Lustrous non-metal: **Iodine (I_2)** (or diamond). | [1 mark]

Ans 17. Amphoteric oxides: Metal oxides that react with both acids and bases to produce salt and water. | [0.5 mark]

[2 Marks]

(i) Reaction with acid: $\text{Al}_2\text{O}_3(\text{s}) + 6\text{HCl}(\text{aq}) \rightarrow 2\text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ | [0.75 mark](ii) Reaction with base: $\text{Al}_2\text{O}_3(\text{s}) + 2\text{NaOH}(\text{aq}) \rightarrow 2\text{NaAlO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ (Sodium aluminate). | [0.75 mark]**Ans 18. Mineral:** Naturally occurring inorganic substance with a definite chemical composition found in the Earth's crust. | [0.5 mark]

[2 Marks]

Ore: A mineral from which a metal can be extracted profitably and conveniently. | [0.5 mark]**Conclusion:** All ores are minerals, but all minerals are not ores, because not all minerals have sufficient metal concentrations for economic extraction (e.g., clay contains aluminium, but bauxite is its ore). | [1 mark]**Ans 19.**

[2 Marks]

- Observations: (i) The colorless solution turns **light blue** due to the formation of Cu^{2+} ions. (ii) A shining **silvery-white coating** of metallic silver deposits on the coin. | [1 mark]
- Balanced equation: $\text{Cu}(\text{s}) + 2\text{AgNO}_3(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)_2(\text{aq}) + 2\text{Ag}(\text{s})$. | [1 mark]

Ans 20. Galvanization: The process of protecting iron and steel articles from rusting by depositing a thin sacrificial layer of metallic zinc. | [1 mark] [2 Marks]

Protection Mechanism: Zinc is more electropositive than iron. Even if the coating is damaged, zinc preferentially oxidizes (sacrificial protection), forming a basic zinc carbonate film that preserves the exposed iron beneath. | [1 mark]

SECTION D: CHEMICAL DEDUCTIONS & METALLURGY ANALYSIS (18 MARKS)

3 Marks each with precise intermediate steps

Ans 21. Ionic Bonding & Dot Structures of Na_2O

[3 Marks]

1. Electronic configuration: **Na (Z = 11): 2, 8, 1; O (Z = 8): 2, 6.** | [0.5 mark]

2. Electron-Dot Representation:

Two sodium atoms lose 1 electron each: $2\text{Na} \rightarrow 2\text{Na}^+ + 2\text{e}^-$ [2, 8]

One oxygen atom gains 2 electrons: $\text{O} + 2\text{e}^- \rightarrow [\text{:}\ddot{\text{O}}\text{:}]^{2-}$ [2, 8]

Formula: $[\text{Na}^+]_2 [\text{:O:}]^{2-} \rightarrow \text{Na}_2\text{O}$ | [1.5 marks]

3. Physical properties: (i) High melting and boiling points due to strong inter-ionic electrostatic attractions. (ii) Soluble in water, insoluble in non-polar organic solvents like petrol/kerosene. | [1 mark]

Ans 22. Roasting vs. Calcination of Zinc Ores

[3 Marks]

1. **Roasting** heats sulfide ores in excess air, while **calcination** heats carbonate ores in limited or no air. | [1 mark]

2. Balanced equations:

• Roasting of ZnS : $2\text{ZnS(s)} + 3\text{O}_2\text{(g)} \rightarrow [\Delta] 2\text{ZnO(s)} + 2\text{SO}_2\text{(g)}$ | [0.5 mark]

• Calcination of ZnCO_3 : $\text{ZnCO}_3\text{(s)} \rightarrow [\Delta] \text{ZnO(s)} + \text{CO}_2\text{(g)}$ | [0.5 mark]

3. Reduction of ZnO : Heating with coke (carbon): $\text{ZnO(s)} + \text{C(s)} \rightarrow \text{Zn(s)} + \text{CO(g)}$. | [1 mark]

Ans 23. Metals and Nitric Acid Exception

[3 Marks]

1. Nitric acid (HNO_3) is a powerful oxidizing agent. It oxidizes liberated hydrogen to water (H_2O) and is itself reduced to nitrogen oxides (NO_2 , NO , N_2O). | [1 mark]

2. Metals evolving H_2 with ~1% HNO_3 : **Magnesium (Mg) and Manganese (Mn).** | [1 mark]

3. Iron with dilute HCl : $\text{Fe(s)} + 2\text{HCl(aq)} \rightarrow \text{FeCl}_2\text{(aq)} + \text{H}_2\text{(g)}$. | [1 mark]

Ans 24. Electrolytic Refining of Copper

[3 Marks]

1. Cell setup: (i) Cathode: Thin strip of pure copper. (ii) Anode: Slab of impure blister copper. (iii) Electrolyte: Acidified copper sulphate solution ($\text{CuSO}_4 + \text{H}_2\text{SO}_4$). | [1 mark]

2. Electrode half-reactions:

Anode (Oxidation): $\text{Cu(s)} \rightarrow \text{Cu}^{2+}\text{(aq)} + 2\text{e}^-$ | [0.5 mark]

Cathode (Reduction): $\text{Cu}^{2+}\text{(aq)} + 2\text{e}^- \rightarrow \text{Cu(s)}$ | [0.5 mark]

3. Behavior of impurities: Electropositive impurities (Fe, Zn) dissolve into the electrolyte as ions. Noble, less electropositive metals (Ag, Au, Pt) do not dissolve and settle below the anode as **anode mud**. | [1 mark]

Ans 25. Reactivity Series Deduction

[3 Marks]

1. **Metal B** is the most reactive metal because it is the only one capable of displacing iron from iron(II) sulphate solution. | [1 mark]

2. Decreasing order of reactivity: **B > A > C > D.** | [1 mark]

3. Observation: Metal B will displace copper from copper(II) sulphate solution; the blue color of the solution will fade, and reddish-brown copper will deposit on B. | [1 mark]

Ans 26. Corrosion of Common Metals**[3 Marks]**

1. Silver articles react with hydrogen sulfide (H_2S) present in the air to form a black coating of **silver sulfide** (Ag_2S). | [1 mark]
2. Copper reacts with moist CO_2 and oxygen to form green **basic copper carbonate** $[\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2]$. | [1 mark]
3. Rust ($\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$) is soft and porous; it flakes off, continuously exposing fresh iron. In contrast, the aluminium oxide (Al_2O_3) layer is dense, uniform, and non-porous, completely protecting the underlying metal. | [1 mark]

SECTION E: COMPETENCY & CASE-BASED QUESTIONS (8 MARKS)

4 Marks for each case study with direct evaluation criteria

Ans 27. Case Study 1: The Thermite Process**[4 Marks]**

1. Thermochemical equation: $\text{Fe}_2\text{O}_3(\text{s}) + 2\text{Al}(\text{s}) \rightarrow 2\text{Fe}(\text{l}) + \text{Al}_2\text{O}_3(\text{s}) + \text{Heat}$. | [1 mark]
2. Redox identification: **Aluminium (Al) is oxidized** (gains oxygen); **Iron(III) oxide (Fe_2O_3) is reduced** (loses oxygen). | [1 mark]
3. The enthalpy change of this displacement is so large that the liberated energy heats iron above its melting point (1538°C), resulting in molten metal that fuses the rail joint directly. | [1 mark]
4. Yes, manganese dioxide reacts analogously: $3\text{MnO}_2(\text{s}) + 4\text{Al}(\text{s}) \rightarrow 3\text{Mn}(\text{l}) + 2\text{Al}_2\text{O}_3(\text{s}) + \text{Heat}$. | [1 mark]

Ans 28. Case Study 2: Alloys & Amalgams**[4 Marks]**

1. 24-carat gold is 100% pure gold. 22-carat gold contains 22 parts by mass of pure gold alloyed with 2 parts of either **copper (Cu)** or **silver (Ag)** to provide hardness. | [1 mark]
2. Constituents: (i) Brass: **Cu + Zn**. (ii) Bronze: **Cu + Sn**. (iii) Solder: **Pb + Sn**. | [1 mark]
3. Solder has a **low melting point** (lower than pure lead or tin), enabling it to melt easily when heated with a soldering iron to join circuit components without damaging them. | [1 mark]
4. An alloy containing mercury is called an **amalgam**. Medical application: **Dental amalgam** (mercury-silver alloy) used for filling tooth cavities. | [1 mark]

SECTION F: LONG ANSWER SYNTHESIS & EXPERIMENTAL PROVING (10 MARKS)

5 Marks each with complete stepwise mechanisms

Ans 29. Complete Metallurgy Across Reactivity Strata**[5 Marks]****1. Mercury from Cinnabar (HgS):**Step 1: Roasting in air converts HgS to mercuric oxide: $2\text{HgS}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow [\Delta] 2\text{HgO}(\text{s}) + 2\text{SO}_2(\text{g})$ | [0.5 mark]Step 2: Thermal decomposition yields mercury: $2\text{HgO}(\text{s}) \rightarrow [\Delta] 2\text{Hg}(\text{l}) + \text{O}_2(\text{g})$ | [1 mark]**2. Sodium Isolation:**

Carbon cannot reduce sodium oxide because sodium has a much higher affinity for oxygen than carbon does. | [0.5 mark]

Extracted by **electrolysis of molten (fused) NaCl** (Downs Cell):At Cathode (Reduction): $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}(\text{l})$ | [0.5 mark]At Anode (Oxidation): $2\text{Cl}^- \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$ | [0.5 mark]**3. Copper from Copper Glance (Cu_2S):**Step 1: Partial roasting: $2\text{Cu}_2\text{S}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow [\Delta] 2\text{Cu}_2\text{O}(\text{s}) + 2\text{SO}_2(\text{g})$ | [0.5 mark]Step 2: Auto-reduction: $2\text{Cu}_2\text{O}(\text{s}) + \text{Cu}_2\text{S}(\text{s}) \rightarrow [\Delta] 6\text{Cu}(\text{s}) + \text{SO}_2(\text{g})$ | [1 mark]

Ans 30. Rusting Experiment & Deductive Analysis**[5 Marks]****1. Rusting Conditions Experiment:**

- *Tube 1 (Dry air)*: Anhydrous CaCl_2 absorbs all moisture. Nails do not rust (proves water is needed). | **[0.5 mark]**
- *Tube 2 (Air-free water)*: Boiled distilled water expels dissolved oxygen; oil layer prevents atmospheric air from dissolving. Nails do not rust (proves oxygen is needed). | **[0.5 mark]**
- *Tube 3 (Air and water)*: Ordinary water exposed to air. Nails rust prominently. Proves **both air and water** are mutually indispensable. | **[1 mark]**

2. Identification of 'M': Metal 'M' is **Iron (Fe)**; oxide 'N' is **Triferric tetroxide (Fe_3O_4)**. | **[0.5 mark]**

Reaction with steam: $3\text{Fe(s)} + 4\text{H}_2\text{O(g)} \rightarrow \text{Fe}_3\text{O}_4\text{(s)} + 4\text{H}_2\text{(g)}$. | **[1 mark]**

3. Identification of 'P': Metal 'P' is **Sodium (Na)**. | **[0.5 mark]**

Reaction with water: $2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)} + \text{Heat}$. | **[1 mark]**