

Oxidation numbers and balancing redox equations

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Each answer shows the oxidation numbers or half-equations first, then the combined equation or calculation, with the final result in bold. Check the charge balance of your own equations against these worked solutions.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R3.2

Problem 1 Oxidation numbers of common species

1. $2(+1) + x + 4(-2) = 0$, so $x = +6$.
2. $(+1) + x + 4(-2) = 0$, so $x = +7$.
3. $x + 4(+1) = +1$, so $x = -3$.
4. $2(+1) + 2x = 0$, so $x = -1$ (peroxide).
5. $x + 3(-2) = -1$, so $x = +5$.

Problem 2 Sparkler chemistry

1. Mg: $0 \rightarrow +2$; O: $0 \rightarrow -2$.
2. **Magnesium is oxidised** ($0 \rightarrow +2$); **oxygen is reduced** ($0 \rightarrow -2$).
3. Oxidising agent: **O₂**. Reducing agent: **Mg**.

Problem 3 Zinc coating on a nail

1. **Zn $\rightarrow$ Zn²⁺ + 2e⁻**.
2. **Oxidation**: zinc loses electrons and its oxidation number rises from 0 to +2.
3. $3 \text{ mol} \times 2 = \mathbf{6 \text{ mol of electrons}}$.

Problem 4 Redox or not?

1. **Not redox**: no element changes its oxidation number (Ca +2, C +4, O -2, H +1, Cl -1 throughout).
2. **Redox**: I goes $-1 \rightarrow 0$ (oxidised) and Cl goes $0 \rightarrow -1$ (reduced).
3. **Not redox**: Ag stays +1, Cl stays -1, N stays +5. It is precipitation.

Problem 5 Roman numerals in names

1. Iron has +3 ($2x = +6$): **iron(III) oxide**.
2. Copper has +2 (sulfate is 2-): **copper(II) sulfate**.
3. Cr³⁺ and O²⁻ combine as 2 : 3: **Cr₂O₃**.

4. Tin has +2: **tin(II) chloride**.

Problem 6 Harder oxidation numbers

1. $2x + 7(-2) = -2$, so $x = +6$.
2. $2x + 3(-2) = -2$, so $x = +2$.
3. $2x + 6(+1) + (-2) = 0$, so $2x = -4$ and $x = -2$ (average).
4. $3x + 4(-2) = 0$, so $x = +8/3$ (a mixture of Fe^{2+} and Fe^{3+}).

Problem 7 Balancing two half-equations in acid

1. N: $+5 \rightarrow +2$, so 3 electrons gained. $\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$.
2. $\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^+ + 2\text{e}^-$.

Check 1: charge left $-1 + 4 - 3 = 0$, right 0. Check 2: charge left 0, right $+2 - 2 = 0$. Final answers: **$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{NO} + 2\text{H}_2\text{O}$** and **$\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}^+ + 2\text{e}^-$** .

Problem 8 Rhubarb leaves and permanganate

1. Lowest common multiple of 5 and 2 is 10: multiply the first by 2 and the second by 5.
2. **$2\text{MnO}_4^- + 16\text{H}^+ + 5\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$** .
3. Left: $-2 + 16 - 10 = +4$. Right: $+4$. The charges balance.

Problem 9 Thermite reaction

1. Al: $0 \rightarrow +3$. Fe: $+3 \rightarrow 0$.
2. Oxidising agent: **Fe_2O_3** (Fe is reduced). Reducing agent: **Al** (oxidised).
3. Two Fe^{3+} each gain 3 electrons: **6 electrons**.

Problem 10 Silver recovery from waste

1. Oxidation: $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$. Reduction: $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$.
2. $n(\text{Cu}) = 0.635 \div 63.5 = \mathbf{0.0100 \text{ mol}}$.
3. $n(\text{Ag}) = 2 \times 0.0100 = 0.0200 \text{ mol}$; $m = 0.0200 \times 107.9 = \mathbf{2.16 \text{ g}}$.

Problem 11 Making bleach

1. Cl_2 : **0**; NaCl : **-1**; NaClO : **+1**.
2. The same element, chlorine, is **both reduced ($0 \rightarrow -1$) and oxidised ($0 \rightarrow +1$)**.
3. One chlorine atom gains 1 electron and the other loses 1, so **1 electron is transferred per Cl_2** .

Problem 12 Balancing by oxidation numbers

1. Cu: $0 \rightarrow +2$ (+2). N: $+5 \rightarrow +2$ (-3).
2. 3 Cu atoms (+6) balance 2 N atoms (-6).

3. **$3\text{Cu} + 8\text{HNO}_3 \rightarrow 3\text{Cu}(\text{NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O}$** . Check N: $8 = 6 + 2$; H: $8 = 8$; O: $24 = 18 + 2 + 4$.

Problem 13 Permanganate in alkali

- $\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$.
- Add 4OH^- to both sides; $4\text{H}^+ + 4\text{OH}^-$ becomes $4\text{H}_2\text{O}$: $\text{MnO}_4^- + 4\text{H}_2\text{O} + 3\text{e}^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O} + 4\text{OH}^-$, which simplifies to **$\text{MnO}_4^- + 2\text{H}_2\text{O} + 3\text{e}^- \rightarrow \text{MnO}_2 + 4\text{OH}^-$** .
- Charge: $-1 - 3 = -4$ on the left, -4 on the right. O: $4 + 2 = 6$ and $2 + 4 = 6$. H: $4 = 4$.

Problem 14 Reading oxidation numbers from colours

- MnO_4^- **+7**, MnO_4^{2-} **+6**, MnO_2 **+4**, Mn^{2+} **+2**.
- $+7 \rightarrow +4$: **3 electrons**. $+7 \rightarrow +2$: **5 electrons**.
- Purple becomes (almost) colourless or very pale pink as Mn^{2+} forms.

Problem 15 Iron supplement tablet

- $\text{MnO}_4^- + 8\text{H}^+ + 5\text{Fe}^{2+} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} + 5\text{Fe}^{3+}$.
- $n(\text{MnO}_4^-) = 0.02240 \times 0.00200 = \mathbf{4.48 \times 10^{-5} \text{ mol}}$.
- $n(\text{Fe}^{2+})$ in $25.0 \text{ cm}^3 = 5 \times 4.48 \times 10^{-5} = \mathbf{2.24 \times 10^{-4} \text{ mol}}$; in $250 \text{ cm}^3 = 10 \times \text{that} = \mathbf{2.24 \times 10^{-3} \text{ mol}}$.
- $m = 2.24 \times 10^{-3} \times 55.8 = 0.1250 \text{ g} = \mathbf{125 \text{ mg}}$.

Problem 16 Breathalyser chemistry

- Cr: $+6 \rightarrow +3$, a gain of 3 per Cr, 6 per $\text{Cr}_2\text{O}_7^{2-}$. The carbon in CH_2OH goes from -1 to $+3$, a loss of 4.
- LCM of 6 and 4 is 12: dichromate half $\times 2$, ethanol half $\times 3$. **$2\text{Cr}_2\text{O}_7^{2-} + 16\text{H}^+ + 3\text{C}_2\text{H}_5\text{OH} \rightarrow 4\text{Cr}^{3+} + 11\text{H}_2\text{O} + 3\text{CH}_3\text{COOH}$** ($28\text{H}^+ - 12\text{H}^+ = 16\text{H}^+$ on the left; $14\text{H}_2\text{O} - 3\text{H}_2\text{O} = 11\text{H}_2\text{O}$ on the right).
- H: $16 + 18 = 34$ and $22 + 12 = 34$. O: $14 + 3 = 17$ and $11 + 6 = 17$. Charge: $-4 + 16 = +12$ and $+12$.

Problem 17 Analysing bleach with thiosulfate

- $n(\text{S}_2\text{O}_3^{2-}) = 0.02150 \times 0.100 = 2.150 \times 10^{-3} \text{ mol}$; $n(\text{I}_2) = \mathbf{1.075 \times 10^{-3} \text{ mol}}$.
- $\text{ClO}^- : \text{I}_2$ is $1 : 1$, so $1.075 \times 10^{-3} \text{ mol}$ in 25.0 cm^3 ; in the original $10.0 \text{ cm}^3 (\times 10) = \mathbf{1.075 \times 10^{-2} \text{ mol}}$.
- $c = 1.075 \times 10^{-2} \div 0.0100 = \mathbf{1.08 \text{ mol/dm}^3}$; mass = $1.075 \times 74.4 = \mathbf{80.0 \text{ g/dm}^3}$.

Problem 18 Spot the error in a redox equation

- Left: $-1 + 8 + 2 = +9$. Right: $+2 + 3 = +5$. The charges differ.
- Mn gains 5 electrons but each Fe^{2+} loses only 1, so five iron ions are needed: **5**.

3. $\text{MnO}_4^- + 8\text{H}^+ + 5\text{Fe}^{2+} \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} + 5\text{Fe}^{3+}$. Charge: $-1 + 8 + 10 = +17$ and $+2 + 15 = +17$.

Problem 19 Iodine in table salt

1. Atoms: I $1 + 5 = 6$ and $3 \times 2 = 6$; O 3 and 3 ; H 6 and 6 . Charge: $-1 - 5 + 6 = 0$ and 0 .

2. $n(\text{S}_2\text{O}_3^{2-}) = 0.01260 \times 0.00500 = 6.30 \times 10^{-5} \text{ mol}$; $n(\text{I}_2) = 3.15 \times 10^{-5} \text{ mol}$; $n(\text{IO}_3^-) = 1.05 \times 10^{-5} \text{ mol}$.

3. $m(\text{I}) = 1.05 \times 10^{-5} \times 126.9 = 1.33 \times 10^{-3} \text{ g} = 1.33 \text{ mg per } 50.0 \text{ g}$, so $\times 20 = 26.6 \text{ mg/kg}$.

Problem 20 Oxidation numbers in electron count

1. Left: $-2 + 14 - 6 = +6$. Right: $2 \times 3 = +6$. Balanced.

2. Cr: $2 \times (+6 \rightarrow +3) = -6$. I: $6 \times (-1 \rightarrow 0) = +6$. The totals are equal and opposite.

3. $n(\text{Cr}_2\text{O}_7^{2-}) = 0.0250 \times 0.0200 = 5.00 \times 10^{-4} \text{ mol}$; $n(\text{I}_2) = 3 \times 5.00 \times 10^{-4} = 1.50 \times 10^{-3} \text{ mol}$; $m = 1.50 \times 10^{-3} \times 253.8 = 0.381 \text{ g}$.