

Oxidising alcohols and testing carbonyl compounds

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

Each answer gives the reasoning before the final result in bold. Atomic masses used: H 1.0, C 12.0, O 16.0, Ag 107.9. When an equation uses [O] or [H], the symbols stand for the oxidising or reducing agent, not free atoms.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.3.5

Problem 1 Classify the alcohols

1. Butan-1-ol: primary. Butan-2-ol: secondary. 2-methylpropan-1-ol: primary. 2-methylpropan-2-ol: tertiary.
2. **2-methylpropan-2-ol.**
3. Count the carbon atoms bonded to the C-OH carbon: one, two, one and three respectively.

Problem 2 Colour of dichromate

1. **Orange to green.**
2. Orange: $\text{Cr}_2\text{O}_7^{2-}$; green: Cr^{3+} .
3. A tertiary alcohol has no hydrogen on the C-OH carbon, so the mixture stays orange.

Problem 3 Oxidising propan-1-ol

1. **Propanal.**
2. **Propanoic acid.**
3. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + [\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{CHO} + \text{H}_2\text{O}$; $\text{CH}_3\text{CH}_2\text{CHO} + [\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{COOH}$. Both equations balance for atoms.

Problem 4 Oxidising propan-2-ol

1. **Propanone**, a ketone ($\text{C}=\text{O}$ inside the chain).
2. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_3 + \text{H}_2\text{O}$.
3. The carbonyl carbon has no hydrogen left, so a further oxidation would need a C-C bond to break.

Problem 5 Reading the carbonyl tests

1. Ethanal: silver mirror. Propanone: no change.
2. Both give an orange precipitate.

3. **Tollens' reagent** (or Fehling's solution) separates them; 2,4-DNPH does not.

Problem 6 Reducing carbonyls

1. **Propan-1-ol.**
2. **Butan-2-ol.**
3. Propan-1-ol is primary; butan-2-ol is secondary.

Problem 7 Yield of a ketone

1. $n = 8.80 / 88.0 = 0.100 \text{ mol.}$
2. Ratio 1 : 1, so mass = $0.100 \times 86.0 = 8.60 \text{ g.}$
3. Yield = $6.45 / 8.60 \times 100 = \mathbf{75.0 \%}.$

Problem 8 Distilling an aldehyde

1. **Distillation.**
2. Propanal boils at 49 °C, much lower than propan-1-ol at 97 °C, so it leaves the flask as it forms and cannot be oxidised to the acid.
3. They give small bubbles so that the liquid boils smoothly instead of bumping.

Problem 9 Boiling points and hydrogen bonds

1. Propan-1-ol: hydrogen bonds. Propanal: permanent dipole-dipole forces. Propanoic acid: hydrogen bonds (often in dimers).
2. Propanal has no O-H group, so its molecules cannot hydrogen-bond to each other.
3. The acid has both C=O and O-H, so molecules pair up through two hydrogen bonds, which **need more energy to separate.**

Problem 10 Two isomers of C₃H₆O

1. P is **propanal**; Q is **propanone**.
2. P: aldehyde; Q: ketone.
3. Q has no hydrogen on the carbonyl carbon, so it cannot be oxidised by the mild oxidant.

Problem 11 Naming hydroxynitriles

1. CH₃CH(OH)CN: **2-hydroxypropanenitrile.**
2. (CH₃)₂C(OH)CN: **2-hydroxy-2-methylpropanenitrile.**
3. The first product is chiral (four different groups: H, OH, CN, CH₃); the second has two CH₃ groups so it is not.

Problem 12 Why C=O is attacked by nucleophiles

1. Oxygen is more electronegative than carbon, so the shared electrons are pulled to

oxygen.

2. The carbon carries δ^+ and nucleophiles seek positive centres.

3. In an alkene the $C=C$ is electron-rich and non-polar; in $C=O$ the carbon is electron-poor, so **the type of attacking species reverses**.

Problem 13 Tertiary or secondary

1. Warm each with acidified potassium dichromate(VI).

2. Pentan-2-ol turns green; 2-methylbutan-2-ol stays orange.

3. **Pentan-2-one**.

Problem 14 Racemic mixtures

1. 2-hydroxypropanenitrile.

2. **Two enantiomers in equal amounts** (1 : 1).

3. The planar $C=O$ is attacked equally from both faces; the two enantiomers rotate light by equal and opposite amounts, so the net rotation is zero.

Problem 15 Identifying by melting point

1. **Propanal**.

2. Yes: propanal is an aldehyde, so it gives a silver mirror.

3. Impurities lower and widen the melting range, so a pure derivative is needed for a valid comparison.

Problem 16 Alcohol in wine

1. Left: 6 C, 18 H + 16 H = 34 H, 3 + 14 = 17 O, 4 Cr; charge $-4 + 16 = +12$. Right: 6 C, 12 + 22 = 34 H, 6 + 11 = 17 O, 4 Cr; charge +12. Both sides match.

2. $n(Cr_2O_7^{2-}) = 0.0200 \times 0.0184 = 3.68 \times 10^{-4} \text{ mol}$; $n(\text{ethanol}) = 3.68 \times 10^{-4} \times 3/2 = \mathbf{5.52 \times 10^{-4} \text{ mol}}$.

3. In 250 cm³: $5.52 \times 10^{-3} \text{ mol}$; mass = 0.2539 g; volume = $0.2539 / 0.789 = 0.322 \text{ cm}^3$ in 5.00 cm³ of wine: **6.4 %** by volume.

Problem 17 Four butanols

1. W: butan-1-ol; X: butan-2-ol; Y: 2-methylpropan-2-ol; Z: 2-methylpropan-1-ol.

2. W: butanal (then butanoic acid); X: butanone; Z: 2-methylpropanal.

3. A mirror means an aldehyde, so the alcohols are primary (W and Z); the chain shape separates them. A ketone means secondary (X only); no reaction means **tertiary (Y)**.

Problem 18 Find the error in the mechanism

1. The cyanide ion has attacked the oxygen, but oxygen carries δ^- .

2. The correct intermediate is **CH₃CH(O⁻)CN**, which gains H^+ to give CH₃CH(OH)CN.

3. CN^- is a nucleophile (it donates a lone pair from carbon) and it attacks the δ^+ carbon of $\text{C}=\text{O}$.

Problem 19 Identify a compound by data

1. m/z 72 confirms $\text{C}_4\text{H}_8\text{O}$ ($4(12) + 8 + 16 = 72$). The 1715 cm^{-1} peak shows $\text{C}=\text{O}$; the lack of a broad peak shows no $\text{O}-\text{H}$. The DNPH result confirms a carbonyl; no mirror means a ketone.

2. **Butanone**, $\text{CH}_3\text{COCH}_2\text{CH}_3$.

3. $\text{CH}_3\text{C}(\text{OH})(\text{CN})\text{CH}_2\text{CH}_3$, **2-hydroxy-2-methylbutanenitrile**; it is chiral (CH_3 , C_2H_5 , OH and CN are all different).

Problem 20 Silver from ethanal

1. $n = 2.20 / 44.0 = 0.0500\text{ mol}$.

2. $n(\text{Ag}) = 2 \times 0.0500 = 0.100\text{ mol}$; mass = $0.100 \times 107.9 = \mathbf{10.8\text{ g}}$.

3. Volume = $0.100 / 0.200 = 0.500\text{ dm}^3 = \mathbf{500\text{ cm}^3}$.