Unit 13 · Aldehydes and Ketones

ANSWER KEY · FOR TEACHERS

Full marks 36

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. 2,4-DNP → **d.** an orange precipitate with any aldehyde or ketone
2. Tollens' reagent → **e.** a silver mirror with aldehydes
3. Fehling's solution → **f.** a brick-red precipitate with aliphatic aldehydes
4. iodine and NaOH → **b.** a pale yellow precipitate with a CH_3CO- group
5. Clemmensen reduction → **g.** the C=O turned into CH_2
6. Cannizzaro reaction → **a.** an alcohol and the salt of an acid, from an aldehyde with no α-hydrogen

K · 3

Each carries 0.5 mark.

2 Label the diagram

1. propanal C_2H_5CHO
2. propanone CH_3COCH_3
3. propan-1-ol C_3H_7OH
4. ethanoic acid CH_3COOH

A · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** propanone — U · 1

Water adds across the triple bond with the OH on the middle carbon (Markovnikov's rule); the enol rearranges to propanone. Only ethyne gives an aldehyde.

ii. **a.** aldehydes only — K · 1

H_2 over $Pd–BaSO_4$ replaces the chlorine of R–COCl with hydrogen, giving R–CHO.

iii. **b.** an aldehyde has only one carbon group, which pushes fewer electrons onto the carbonyl carbon and crowds it less — U · 1

Two alkyl groups make a ketone's carbonyl carbon less $\delta+$ and harder for a nucleophile to reach.

iv. **c.** butan-2-one — A · 1

Butan-2-one has a CH_3CO- group but no aldehyde group. Ethanal gives both tests; propanal and methanal give the mirror but have no CH_3CO-.

v. **b.** urotropine, $(CH_2)_6N_4$ — K · 1

$6\,HCHO + 4\,NH_3 \rightarrow (CH_2)_6N_4 + 6\,H_2O$: hexamethylenetetramine, a urinary antiseptic.

4 Short answers

a. MARKING SCHEME — A · 2

- ✓ Cutting the C=C and putting =O on each end gives ethanal, CH_3CHO.
- ✓ And propanal, CH_3CH_2CHO.

b. MARKING SCHEME — U · 2

- ✓ Oxygen is more electronegative than carbon, so the C=O electrons, especially the π electrons, are pulled towards oxygen: C $\delta+$, O $\delta-$.
- ✓ A nucleophile, rich in electrons, is drawn to the $\delta+$ carbon, and the π electrons move onto the oxygen.

c. MARKING SCHEME — U · 2

- ✓ The aldol needs an α-hydrogen to make a carbanion; ethanal has three, methanal none.
- ✓ Methanal gives the Cannizzaro reaction: methanol and sodium methanoate.

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d. MARKING SCHEME A · 2

✓ 2,2-Dichloropropane, $(CH_3)_2CCl_2$, and $POCl_3$.

✓ Propanone cyanohydrin, $(CH_3)_2C(OH)CN$ (2-hydroxy-2-methylpropanenitrile).

e. MARKING SCHEME U · 3

✓ Cold, dilute NaOH; an α-hydrogen is needed.

✓ Product: 3-hydroxybutanal (aldol).

✓ On heating, loss of water: but-2-enal.

5 Long answer

ANSWER A · 4

All three give an orange precipitate with 2,4-DNP: each has a C=O.
Tollens' reagent gives a silver mirror with ethanal and benzaldehyde (aldehydes), but not with propanone (a ketone).
Fehling's solution gives a brick-red precipitate of Cu_2O with ethanal only; benzaldehyde, an aromatic aldehyde, doesn't reduce it.
The iodoform test gives a pale yellow precipitate with ethanal and propanone ($CH_3CO–$), not with benzaldehyde. So: mirror and red precipitate, ethanal; no mirror, propanone; mirror but no red precipitate and no iodoform, benzaldehyde.

MARKING SCHEME

✓ 2,4-DNP orange with all three.

✓ Tollens' mirror with the two aldehydes, not propanone.

✓ Fehling's red with ethanal only.

✓ Iodoform with ethanal and propanone; the conclusion for each bottle.

6 Numerical problems

a. ANSWER A · 4

i. C_5H_{10} = 70 g/mol: 3.50 ÷ 70 = **0.0500 mol**.

ii. One mole each of ethanal and propanal: ethanal (44 g/mol) **2.20 g**; propanal (58 g/mol) **2.90 g**.

iii. **Ethanal** ($CH_3CO–$): $CH_3CHO + 3\,I_2 + 4\,NaOH \rightarrow CHI_3 + HCOONa + 3\,NaI + 3\,H_2O$. CHI_3 = 12 + 1 + 381 = 394 g/mol: 0.0500 × 394 = **19.7 g**.

MARKING SCHEME

✓ 0.0500 mol.

✓ 2.20 g of ethanal and 2.90 g of propanal.

✓ Ethanal, with the balanced equation.

✓ 19.7 g of iodoform.

b. ANSWER A · 4

i. C : H : O = 66.7/12 : 11.1/1 : 22.2/16 = 5.56 : 11.1 : 1.39 = 4 : 8 : 1, so C_4H_8O (72 g/mol): the molecular formula is **C_4H_8O**.

ii. A ketone with a $CH_3CO–$ group: **butan-2-one**, $CH_3COCH_2CH_3$.

iii. The C=O becomes CH_2: **butane**, $CH_3CH_2CH_2CH_3$.

iv. **Butanal**, $CH_3CH_2CH_2CHO$ (or 2-methylpropanal), a functional isomer.

MARKING SCHEME

✓ C_4H_8O.

✓ Butan-2-one, $CH_3COCH_2CH_3$.

✓ Butane.

✓ Butanal (or 2-methylpropanal).

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7 Think

ANSWER HA · 3

One product only means the alkene is symmetrical about its C=C: each half has three carbons and becomes a C_3 carbonyl compound. No silver mirror means it is a ketone, so each carbon of the C=C carries two carbon groups; a C_3 ketone is propanone, which has $CH_3CO–$ and gives the iodoform test. So each end of the double bond is $(CH_3)_2C=$: the alkene is 2,3-dimethylbut-2-ene, $(CH_3)_2C=C(CH_3)_2$.

MARKING SCHEME

- ✓ One product: a symmetrical alkene, each half C_3.
- ✓ No mirror: a ketone, so propanone (iodoform positive).
- ✓ 2,3-Dimethylbut-2-ene.

8 Activity: Smell and solubility

(not marked)

WHAT STUDENTS SHOULD FIND

Propanone mixes with water in all proportions; vanilla (vanillin, an aldehyde) and cinnamon (cinnamaldehyde) smell pleasant, as the higher aldehydes do. Propanone has no H on oxygen, so its molecules can't hydrogen-bond to each other, but water's H atoms hydrogen-bond to its carbonyl oxygen, so it dissolves.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	5	9	19	3	**36**

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