Unit 10 · Alcohols

ANSWER KEY · FOR TEACHERS

Full marks 33

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

1 Key words

K · 4

1. primary
2. absolute alcohol
3. power alcohol
4. denatured alcohol
5. fermentation
6. zymase
7. esterification
8. Lucas reagent

Each carries 0.5 mark.

2 Label the diagram

U · 2

1. ethanol (1°)
2. iodoethane
3. nitroethane
4. nitrolic acid: red in KOH

Each carries 0.5 mark.

3 Multiple choice

i. **b.** 2-methylbutan-2-ol — K · 1

The longest chain carrying the –OH has four carbons, numbered from the end that gives the –OH the lowest number: the –OH and a methyl group are both on carbon 2, **2-methylbutan-2-ol**, a tertiary alcohol.

ii. **c.** a tertiary alcohol — U · 1

The R of the Grignard reagent joins the carbonyl carbon, which already carries two groups: three carbons on the –OH carbon, a **tertiary** alcohol. Methanal gives a 1° alcohol, other aldehydes a 2° one.

iii. **d.** a tertiary alcohol — K · 1

A **tertiary** alcohol forms the most stable carbocation, so its chloride, insoluble, separates at once. A secondary one takes about five minutes; a primary one doesn't turn cloudy at room temperature.

iv. **b.** ethoxyethane — U · 1

At 140 °C two ethanol molecules lose one water molecule between them: $2\,C_2H_5OH \rightarrow C_2H_5OC_2H_5 + H_2O$, **ethoxyethane** (diethyl ether). At 170 °C ethanol gives ethene.

v. **a.** propan-1-ol — A · 1

Hydroboration–oxidation adds water **against Markovnikov's rule**: the –OH goes to the end carbon, giving **propan-1-ol**. Acid-catalyzed hydration would give propan-2-ol.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ Ethanol of 99.5% or more.
- ✓ 95.6% ethanol is an azeotrope, whose vapor has the same composition, so distillation stops there.

b. MARKING SCHEME — U · 2

- ✓ Propan-1-ol → propanal → propanoic acid; propan-2-ol → propanone.
- ✓ Orange to green.

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c. MARKING SCHEME A · 3

- ✓ With Na: sodium ethoxide and H_2.
- ✓ With PCl_5: chloroethane, $POCl_3$ and HCl.
- ✓ With ethanoic acid: ethyl ethanoate and water.

5 Long answer

ANSWER U · 4

A **primary** alcohol is dehydrogenated to an **aldehyde**: $CH_3CH_2OH \xrightarrow[300\,^\circ C]{Cu} CH_3CHO + H_2$.

A **secondary** alcohol gives a **ketone**: $CH_3CH(OH)CH_3 \xrightarrow[300\,^\circ C]{Cu} CH_3COCH_3 + H_2$.

A **tertiary** alcohol has no hydrogen on its –OH carbon, so it can't lose H_2; it loses water instead and gives an **alkene**: $(CH_3)_3C{-}OH \xrightarrow[300\,^\circ C]{Cu} (CH_3)_2C{=}CH_2 + H_2O$.

So the product tells the class: an aldehyde (1°), a ketone (2°) or an alkene (3°).

MARKING SCHEME

- ✓ 1° → aldehyde + H_2 (equation).
- ✓ 2° → ketone + H_2 (equation).
- ✓ 3° → alkene + H_2O, as it has no H on the –OH carbon (equation).
- ✓ The products tell the three classes apart.

6 Numerical problems

a. ANSWER A · 4

i. 90.0 kg/180 g/mol = 500 mol glucose → 1000 mol ethanol × 46 g = **46.0 kg**.

ii. 1000 mol CO_2 × 22.4 L = 22,400 L = **22.4 m³**.

iii. 46.0 × 0.85 = **39.1 kg**; 39,100 g / 0.79 g/mL = 49,500 mL ≈ **49.5 L**.

iv. 49.5 L is 10% of the blend: 49.5 × 10 = **495 L** of E10.

MARKING SCHEME

- ✓ 46.0 kg of ethanol.
- ✓ 22.4 m^3 of CO_2.
- ✓ 39.1 kg, 49.5 L.
- ✓ 495 L of E10.

b. ANSWER A · 4

i. 112 mL/22,400 mL = **0.00500 mol** H_2.

ii. $2\,ROH + 2\,Na \rightarrow 2\,RONa + H_2$: 2 × 0.00500 = 0.0100 mol alcohol; M = 0.60/0.0100 = **60 g/mol**.

iii. $C_nH_{2n+1}OH = 14n + 18 = 60$, so n = 3: **$C_3H_7OH$**. Isomers: **propan-1-ol**, $CH_3CH_2CH_2OH$, and **propan-2-ol**, $CH_3CH(OH)CH_3$.

iv. **Propan-2-ol**, the secondary alcohol, gives **propanone**, CH_3COCH_3.

MARKING SCHEME

- ✓ 0.00500 mol of H_2.
- ✓ 60 g/mol (two alcohol molecules per H_2).
- ✓ C_3H_7OH: propan-1-ol and propan-2-ol.
- ✓ Propan-2-ol gives propanone.

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7 Think

ANSWER HA · 3

With Lucas reagent the C–OH bond breaks: the protonated –OH leaves as water and a carbocation forms. A tertiary carbocation, with three alkyl groups pushing electrons towards it, is the most stable, so it forms fastest and the insoluble chloride separates at once.
Oxidation by dichromate needs a hydrogen on the carbon carrying the –OH, which leaves with the H of the –OH. In 2-methylpropan-2-ol that carbon carries three CH_3 groups and no hydrogen, so it can't be oxidized, and the dichromate stays orange.

MARKING SCHEME

- ✓ Lucas: the C–OH bond breaks, forming a carbocation.
- ✓ The tertiary carbocation is the most stable, so the reaction is fastest.
- ✓ Oxidation needs an H on the –OH carbon; the 3° alcohol has none.

8 Activity: Alcohol and water

(not marked)

WHAT STUDENTS SHOULD FIND

Methanol, ethanol and propan-1-ol mix completely; butan-1-ol and pentan-1-ol form two layers (only a little of each dissolves). The –OH group forms hydrogen bonds with water molecules, which lets the small alcohols mix. The longer hydrocarbon chain can't form hydrogen bonds and pushes the water away, so as the chain grows the alcohol becomes less soluble.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	6	12	12	3	**33**

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