Unit 14 · Hydrocarbons

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 True or false

i. ✓ **True** — U · 3

ii. ✗ **False**: Wurtz's reaction joins two alkyl groups; making propane needs two different halides, which gives a mixture of ethane, propane and butane.

iii. ✓ **True**

iv. ✗ **False**: Alcoholic KOH removes HBr and gives ethene; aqueous KOH gives ethanol.

v. ✗ **False**: Only HBr shows the peroxide effect; HCl still adds by Markovnikov's rule.

vi. ✓ **True**

Each carries 0.5 mark.

2 Label the diagram

1. σ bonds in one plane 2. π — K · 1

Each carries 0.5 mark.

3 Multiple choice

i. **c.** sp hybridized, with bond angles of 180° — K · 1

Each carbon of a triple bond is sp hybridized: its two sp orbitals point opposite ways, so the molecule is a straight line.

ii. **c.** propyne — U · 1

Only a terminal alkyne, with an H on a triple-bonded carbon, forms a copper(I) acetylide. Propyne, CH_3–C≡CH, has one; but-2-yne has none.

iii. **b.** propane — A · 1

Decarboxylation removes the –COONa group as Na_2CO_3, so the alkane has one carbon fewer than the salt: propane.

iv. **b.** 1-bromo-2-methylpropane — A · 1

With peroxide the addition goes by free radicals: Br• adds to the CH_2 end, leaving the more stable tertiary radical, so Br ends on the end carbon (anti-Markovnikov).

v. **b.** 3 — U · 1

Two C–H σ bonds and one C–C σ bond: 3 σ bonds (and 2 π bonds).

4 Short answers

a. MARKING SCHEME — U · 2

✓ When HX adds to an unsymmetrical alkene, the H goes to the carbon of the double bond that already has more hydrogens (X to the one with fewer).

✓ 2-chloropropane, CH_3–$CHCl$–CH_3.

b. MARKING SCHEME — A · 2

✓ $C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$

✓ $2\,HC{\equiv}CH + 2\,Na \xrightarrow{\text{liq. } NH_3} 2\,HC{\equiv}CNa + H_2$

c. MARKING SCHEME — U · 2

✓ A triple bond has two π bonds, each of which adds one Br_2 molecule (ethene has one π bond).

✓ 1,1,2,2-tetrabromoethane.

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d. MARKING SCHEME U · 3

- ✓ Conc. H_2SO_4 at 170 °C (or hot Al_2O_3).
- ✓ Dilute H_2SO_4 with $HgSO_4$.
- ✓ H_2 over Lindlar's catalyst.

5 Long answer

ANSWER U · 4

Initiation: light splits a chlorine molecule evenly: $Cl_2 \rightarrow 2Cl\bullet$.
Propagation: $Cl\bullet + CH_4 \rightarrow HCl + CH_3\bullet$; then $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$, and the new $Cl\bullet$ carries the chain on.
Termination: two radicals meet: $Cl\bullet + Cl\bullet \rightarrow Cl_2$, $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$, $CH_3\bullet + CH_3\bullet \rightarrow CH_3{-}CH_3$.
With methane in large excess, a chlorine atom nearly always meets a methane molecule rather than a chloromethane molecule, so further substitution is rare.

MARKING SCHEME

- ✓ Initiation: $Cl_2 \rightarrow 2Cl\bullet$ in UV light.
- ✓ The two propagation steps.
- ✓ A termination step.
- ✓ Excess methane: $Cl\bullet$ meets CH_4 rather than CH_3Cl.

6 Numerical problems

a. ANSWER A · 4

$2\,C_4H_{10} + 13\,O_2 \rightarrow 8\,CO_2 + 10\,H_2O$
Moles of butane = 12 000 g ÷ 58 g/mol = 206.9 mol.

i. $CO_2 = 4 \times 206.9 = 827.6$ mol × 44 g/mol = 36 414 g ≈ **36.4 kg**.
ii. $O_2 = 6.5 \times 206.9 = 1345$ mol × 22.4 L/mol ≈ 30 100 L ≈ **30.1 m³**.

MARKING SCHEME

- ✓ The balanced equation.
- ✓ 206.9 mol of butane.
- ✓ 36.4 kg of CO_2.
- ✓ 30.1 m^3 (3.01×10^4 L) of O_2.

b. ANSWER A · 4

i. Moles = 1.12 ÷ 22.4 = 0.0500 mol; M = 2.80 ÷ 0.0500 = **56 g/mol**. It decolorizes bromine water, so it is an alkene, C_nH_{2n}: 14n = 56, n = 4, $\mathbf{C_4H_8}$.
ii. Ethanal only means two identical halves, $CH_3CH{=}$ and ${=}CHCH_3$: **but-2-ene**, $CH_3{-}CH{=}CH{-}CH_3$.
iii. One Br_2 per molecule: 0.0500 mol × 160 g/mol = **8.0 g**.

MARKING SCHEME

- ✓ Molar mass 56 g/mol.
- ✓ C_4H_8 (an alkene, 14n = 56).
- ✓ But-2-ene, $CH_3{-}CH{=}CH{-}CH_3$.
- ✓ 8.0 g of bromine.

7 Think

ANSWER HA · 3

Its hydrogens can be removed by sodium or a very strong base, giving acetylide salts, and by silver and copper(I) reagents, giving acetylide precipitates; but it gives too few H^+ ions in water to change litmus. Its carbons are sp hybridized, with 50% s character (ethene 33%, ethane 25%), so they hold electrons closer to the nucleus and are more electronegative: the C–H bond's electrons are pulled towards carbon, the H leaves more easily, and the acetylide ion left is the most stable.

MARKING SCHEME

- ✓ Acidic in the sense that its H is replaced by metals and strong bases (acetylides), not in water.
- ✓ sp carbon, 50% s character, the most electronegative.
- ✓ So the C–H electrons are drawn to carbon and the anion is most stable.

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8 Activity: Testing for unsaturation (a teacher's demonstration)

(not marked)

WHAT STUDENTS SHOULD FIND

Hexane leaves the reddish-brown bromine water and the purple permanganate unchanged (in the dark): saturated. Hex-1-ene decolorizes both, and the permanganate gives a brown precipitate of MnO_2: unsaturated. Cyclohexane, C_6H_{12} like hex-1-ene but with only single bonds, leaves both colors: saturated. The C=C double bond reacted, by addition (bromine adds across it; permanganate adds two OH groups).

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	2	16	12	3	**33**

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