

Alkenes: double bonds and addition reactions

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

Name: _____ Date: _____ Class: _____

These 20 problems train you to describe the structure of alkenes, write and predict electrophilic addition reactions, apply Markovnikov's rule and handle addition polymers and yield calculations. They suit A Level, IB Chemistry and Class 11-12 students.

Work from the first problems towards the last: levels 1 and 2 build recall and one or two steps, level 3 asks for mechanisms, multi-step calculations and error spotting. Show every step and give units.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.3.4

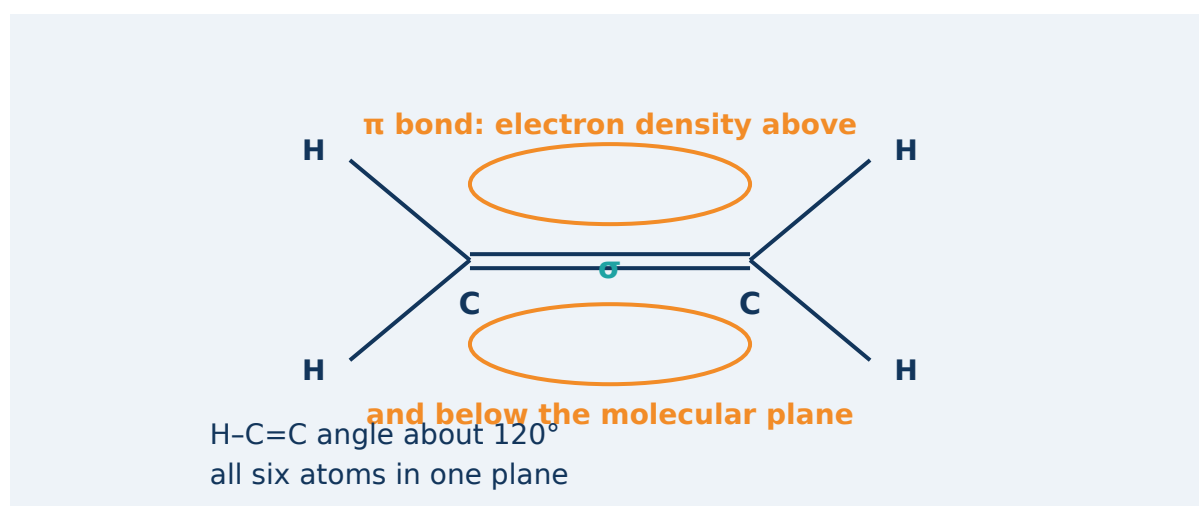
Problem 1 Alkene formulae (easy)

Aarav in Pune is revising alkene formulae.

1. State the general formula of the alkenes.
2. Write the molecular formulae of the alkenes with 5 and 8 carbon atoms.
3. Name $\text{CH}_3\text{CH}=\text{CHCH}_3$.

Problem 2 Shape of ethene (easy)

The molecule below is ethene.



In ethene the sigma bond lies between the nuclei; the pi bond is a cloud above and below the plane, where electrophiles attack.

1. State the shape around each carbon and the H-C-H bond angle.
2. Count the σ bonds and π bonds in one ethene molecule.
3. Explain why the six atoms stay in one plane.

Problem 3 Spotting unsaturation (easy)

Chiamaka in Lagos has two unlabelled liquids: hexane and hex-1-ene.

1. Describe a test that tells them apart.
2. State what she sees with each liquid.
3. Name the product formed with the unsaturated one if the reagent is Br₂.

Problem 4 Completing equations (easy)

Complete and balance the equations.

1. $\text{C}_3\text{H}_6 + \text{H}_2 \rightarrow$ (nickel, 150 °C)
2. C_4H_8 (but-1-ene) + Br₂ →
3. Name both products.

Problem 5 Electrophile or nucleophile (easy)

Mei in Singapore sorts species into electrophiles and nucleophiles.

1. Define an electrophile.
2. Classify H⁺, OH⁻, CN⁻ and the Br^{δ+} atom of a polarised Br₂ molecule.
3. Explain why an alkene attracts the first and not the second group.

Problem 6 Ethene to dibromoethane (easy)

Diego in Texas adds excess bromine to 1.40 g of ethene.

1. Write the equation.
2. Calculate the amount of ethene (M = 28.0 g/mol).
3. Calculate the maximum mass of 1,2-dibromoethane (C₂H₄Br₂, M = 187.8 g/mol).

Problem 7 Hydration of ethene (medium)

A plant in Mombasa hydrates 120 dm³ of ethene gas, measured at room temperature and pressure (24.0 dm³/mol), to make ethanol.

1. Write the equation.
2. Calculate the maximum mass of ethanol (M = 46.0 g/mol).
3. Give two reasons for recycling the unreacted gas.

Problem 8 Propene and hydrogen bromide (medium)

Propene reacts with HBr at room temperature.

1. Name the major and minor products.
2. Name the type of carbocation leading to each.
3. Explain why one product dominates.

Problem 9 Symmetrical or not (medium)

Wanjiru in Nairobi compares two alkenes with HBr.

1. Predict the product(s) from but-2-ene.
2. Predict the major product from pent-1-ene.
3. Explain why but-2-ene gives only one product.

Problem 10 Tertiary carbocation (medium)

Bilal in Lahore reacts 2-methylbut-2-ene, $(\text{CH}_3)_2\text{C}=\text{CHCH}_3$, with steam and H^+ .

1. Draw the carbocation formed in the first step (write its formula).
2. Name the alcohol formed.
3. Classify the alcohol as primary, secondary or tertiary.

Problem 11 Percentage yield (medium)

Emma in Leeds reacts 8.4 g of propene ($M = 42.0 \text{ g/mol}$) with excess HBr and isolates 18.5 g of 2-bromopropane ($M = 122.9 \text{ g/mol}$).

1. Calculate the amount of propene.
2. Calculate the theoretical mass of product.
3. Calculate the percentage yield.

Problem 12 Polymer repeat units (medium)

Kofi in Accra studies addition polymers.

1. Write the repeat unit of poly(propene).
2. Name the monomer of a polymer with repeat unit $-\text{CF}_2-\text{CF}_2-$.
3. Name the monomer of a polymer with repeat unit $-\text{CH}_2-\text{CH}(\text{CN})-$.

Problem 13 Length of a PVC chain (medium)

A PVC (poly(chloroethene)) chain has 1 800 repeat units.

1. Give the formula of the repeat unit and its molar mass.
2. Calculate the molar mass of the chain.
3. Calculate the amount of monomer needed for 25.0 kg of PVC.

Problem 14 Why addition occurs (medium)

Explain in terms of bonding.

1. Why do alkenes react with electrophiles?
2. Why does ethane not decolourise bromine water in the dark?
3. Why is the addition product more stable than the reactants?

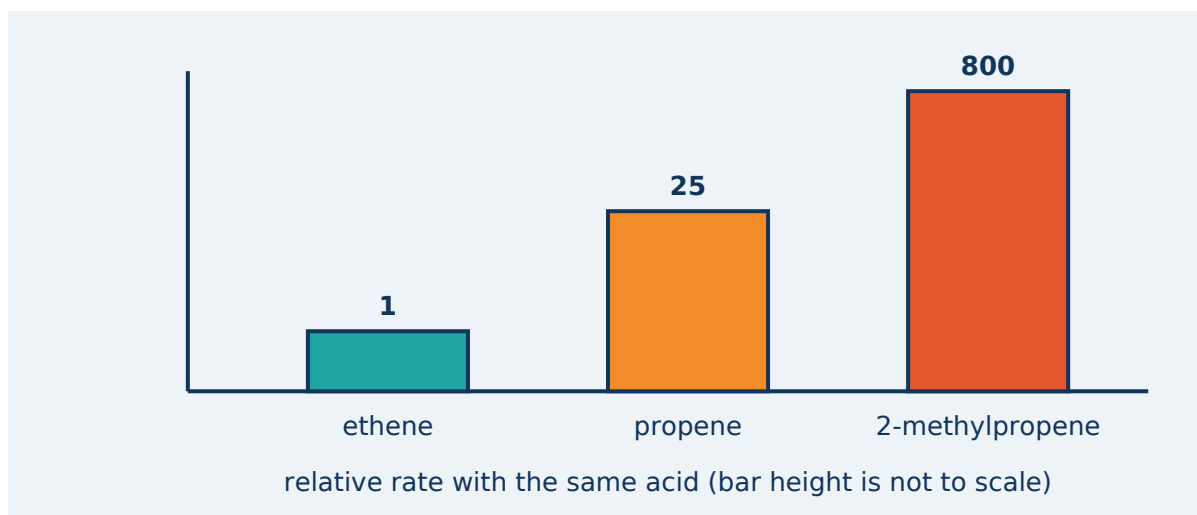
Problem 15 Disposal of addition polymers (medium)

Explain.

1. Why is poly(ethene) not biodegradable?
2. Give one advantage and one drawback of burning waste PVC.
3. Suggest why the sorting of plastics improves recycling.

Problem 16 Relative rates of addition (hard)

Mei in Singapore measured the relative rates of reaction of three alkenes with the same acid.

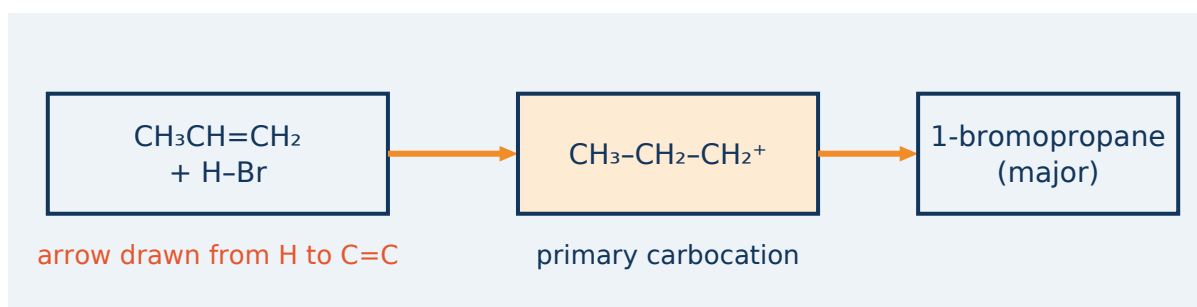


Relative rates of acid-catalysed addition for three alkenes (not to scale).

1. Rank the alkenes by rate.
2. Draw the carbocation formed from each (formula only).
3. Explain the trend.

Problem 17 Finding the errors (hard)

A student wrote the scheme below for propene and HBr.



A student scheme for propene and HBr. It contains errors to find.

1. Identify two errors in the mechanism.
2. Draw the correct intermediate and name the major product.
3. Explain what the student must do to the first curly arrow.

Problem 18 Unknown alkene by titration (hard)

A sample of an alkene (2.10 g) reacts exactly with 8.00 g of bromine ($M = 159.8 \text{ g/mol}$).

1. Calculate the amount of Br_2 .
2. Calculate the molar mass of the alkene.
3. Deduce its formula and name it.

Problem 19 Combustion analysis (hard)

A hydrocarbon (1.40 g) burns to give 4.40 g of CO_2 and 1.80 g of H_2O . Its molar mass is 56 g/mol.

1. Determine the empirical formula.
2. Deduce the molecular formula.
3. Draw the structures (names) of the alkene isomers and state which gives a single product with HBr .

Problem 20 Atom economy of ethanol (hard)

Ethanol can be made by (A) hydrating ethene or (B) heating bromoethane with sodium hydroxide: $\text{C}_2\text{H}_5\text{Br} + \text{NaOH} \rightarrow \text{C}_2\text{H}_5\text{OH} + \text{NaBr}$.

1. Calculate the atom economy of route A ($\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$).
2. Calculate the atom economy of route B (M : $\text{C}_2\text{H}_5\text{Br}$ 108.9, NaOH 40.0, $\text{C}_2\text{H}_5\text{OH}$ 46.0).
3. Compare the routes.