MA99 EDUCATION

Organic Chemistry: Summary 07

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2027 AND 2028

1. Naming, in one page

PIECE OF THE NAME	WHAT IT ENCODES	EXAMPLE
Stem: meth, eth, prop, but, pent, hex	Carbons in the longest chain	hexane has six
Suffix ane, ene, yne	Single, double or triple carbon to carbon bond	but-2-ene
Locant before the suffix	Which carbon the bond or group starts on	pent-2-ene
Prefix with a locant	A branch or a halogen and where it is	2-methylbutane
Suffix ol, al, one, oic acid	Alcohol, aldehyde, ketone, carboxylic acid	propanoic acid
Two words ending yl and anoate	An ester, alcohol first then acid	ethyl ethanoate

Number so that the first point of difference gets the lowest locant. That rule settles every case, including the ones that look ambiguous.

1.1 The functional groups

GROUP	HOW YOU RECOGNISE IT AND WHAT IT DOES
Haloalkane	A halogen on a carbon. Made by addition to an alkene or substitution on an alcohol.
Alcohol	OH on a carbon. Combusts, dehydrates, substitutes and oxidises. The hinge of the module.
Aldehyde	C=O at the end of the chain. The halfway product of oxidising a primary alcohol.
Ketone	C=O inside the chain. The end product of oxidising a secondary alcohol.
Carboxylic acid	C=O and OH on one carbon. Weak acid, highest boiling point of its mass.
Amine	NH_2 on a carbon. Basic, and hydrogen bonds.
Amide	C=O joined to N. The link in nylon.
Ester	C=O joined to O joined to C. Made from an acid and an alcohol, losing water.

2. Every reaction in the module, on two pages

2.1 Alkanes

REACTION	REAGENT AND CONDITIONS	EQUATION
Complete combustion	Excess oxygen	$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
Incomplete combustion	Limited oxygen	Gives carbon monoxide and soot, and less energy
Substitution	A halogen with ultraviolet light	$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

2.2 Alkenes, and every one of these is an addition

REAGENT	CONDITIONS	EQUATION	PRODUCT
Hydrogen	Nickel catalyst, heat	$C_2H_4 + H_2 \rightarrow C_2H_6$	alkane

REAGENT	CONDITIONS	EQUATION	PRODUCT
Bromine	Room temperature	$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$	dihaloalkane, and the test for unsaturation
Hydrogen chloride	Room temperature	$C_2H_4 + HCl \rightarrow C_2H_5Cl$	haloalkane
Water as steam	Phosphoric acid, 300 degrees Celsius, 60 atmospheres	$C_2H_4 + H_2O \rightarrow C_2H_6O$	alcohol

Markovnikov. Where both the alkene and the reagent are unsymmetrical, the hydrogen adds to the carbon that already has more hydrogens. Propene with hydrogen bromide gives mainly 2-bromopropane.

2.3 Alcohols

REACTION	REAGENT AND CONDITIONS	EQUATION	PRODUCT
Combustion	Excess oxygen	$C_2H_6O + 3O_2 \rightarrow 2CO_2 + 3H_2O$	carbon dioxide and water
Dehydration	Concentrated sulfuric acid, 170 degrees Celsius	$C_2H_6O \rightarrow C_2H_4 + H_2O$	alkene
Substitution	Hydrogen bromide	$C_2H_6O + HBr \rightarrow C_2H_5Br + H_2O$	haloalkane
Oxidation, distilled	Acidified dichromate, distil off as formed	Primary alcohol gives the aldehyde	aldehyde
Oxidation, refluxed	Acidified dichromate, excess, reflux	Primary alcohol gives the carboxylic acid	carboxylic acid
Oxidation of a secondary	Acidified dichromate	Gives a ketone and stops there	ketone
Oxidation of a tertiary	Acidified dichromate	No reaction, the solution stays orange	nothing



Figure 1 · The oxidation ladder. The apparatus decides where a primary alcohol stops.

2.4 Acids, esters and fats

REACTION	REAGENT AND CONDITIONS	EQUATION
Esterification	Alcohol, concentrated sulfuric acid, reflux	$C_2H_6O + C_2H_4O_2 \rightarrow C_4H_8O_2 + H_2O$
Acid hydrolysis	Dilute acid and water, reflux	$C_4H_8O_2 + H_2O \rightarrow C_2H_6O + C_2H_4O_2$
Base hydrolysis	Sodium hydroxide, reflux, goes to completion	$C_4H_8O_2 + NaOH \rightarrow C_2H_3O_2Na + C_2H_6O$

REACTION	REAGENT AND CONDITIONS	EQUATION
Neutralisation	Sodium hydroxide	$C_2H_4O_2 + NaOH \rightarrow C_2H_3O_2Na + H_2O$
Test for an acid	Sodium hydrogen carbonate	$C_2H_4O_2 + NaHCO_3 \rightarrow C_2H_3O_2Na + H_2O + CO_2$
Saponification	Sodium hydroxide on a fat, boiled	$C_{57}H_{110}O_6 + 3NaOH \rightarrow 3C_{18}H_{35}O_2Na + C_3H_8O_3$

3. Physical properties, in one table

FAMILY	STRONGEST FORCE BETWEEN MOLECULES	BOILING POINT AT SIMILAR MASS	SOLUBILITY IN WATER
Alkane	Dispersion only	Lowest	Negligible at any length
Alkene	Dispersion only	Very close to the alkane	Negligible
Haloalkane	Dipole to dipole	Higher than the alkane	Low
Aldehyde and ketone	Dipole to dipole	Higher again	Short ones dissolve, then falls away
Ester	Dipole to dipole	Similar to a ketone	Short ones dissolve
Alcohol	Hydrogen bonding	High	Fully miscible to about three carbons
Carboxylic acid	Two hydrogen bonds per pair	Highest	Fully miscible to about four carbons
Amine	Hydrogen bonding	High	Short ones dissolve

Two sentences that carry every physical property question

Within a family, boiling point rises with chain length because a longer molecule has more electrons and more contact area, so more dispersion force acts.

Across families at the same mass, boiling point rises with the strength of the intermolecular force, and boiling never breaks a covalent bond.

4. Production and polymers

4.1 The two ethanol routes

	FERMENTATION	HYDRATION OF ETHENE
Feedstock	Sugar, renewable	Ethene, from crude oil or natural gas
Conditions	25 to 37 degrees Celsius, atmospheric pressure, anaerobic	300 degrees Celsius, 60 atmospheres, phosphoric acid
Mode	Batch, takes days	Continuous, takes minutes
Product	About 15 per cent ethanol, needs distilling	Concentrated and clean
Atom economy	About 51 per cent	100 per cent
Equation	$C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2$	$C_2H_4 + H_2O \rightarrow C_2H_6O$

Which route the question wants is decided by the words in the stem, not by preference. Name the criterion in your first sentence.

4.2 Polymers

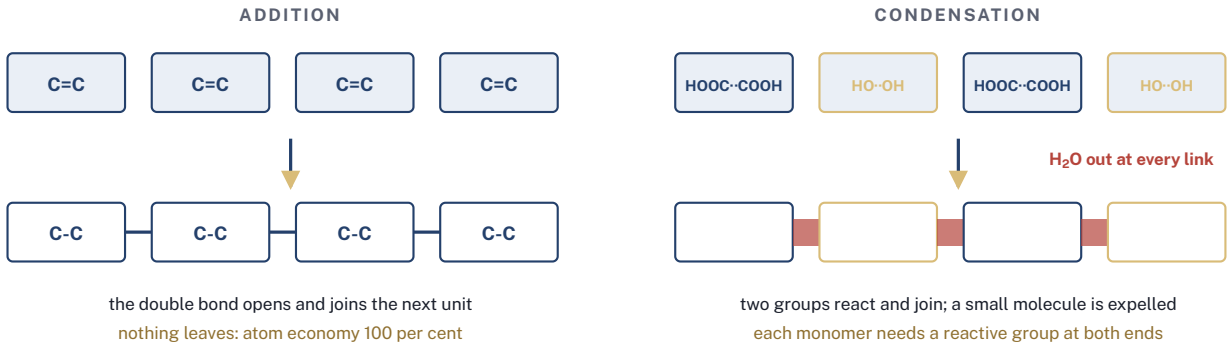


Figure 2 · The two polymerisations, told apart by whether a small molecule leaves.

	ADDITION	CONDENSATION
Monomer needs	A carbon to carbon double bond	Two functional groups, one at each end
What happens	The double bond opens and joins	Two groups react and link
What leaves	Nothing	A small molecule, usually water
Atom economy	100 per cent	Below 100 per cent
Examples	polyethene, poly(vinyl chloride), polystyrene	nylon 6,6, polyester such as PET
The link	Carbon to carbon along the chain	An amide link in nylon, an ester link in polyester

4.3 Structure and property

FEATURE	CONSEQUENCE
Long straight chains	Pack closely, so more dispersion force acts. Denser, stronger, higher melting point.
Short branches	Hold the chains apart. Less dense, flexible, lower melting point.
A polar side group	Adds dipole to dipole attraction. Rigid and tough, as in poly(vinyl chloride).
A bulky side group	Blocks regular packing. Brittle and transparent, as in polystyrene.
Cross links	Chains cannot slide. Rigid, and it will not melt: a thermosetting plastic.

Never write that one polymer has stronger bonds. The covalent bonds are identical. Write that the chains pack more closely, so more dispersion force acts over more contact area. Only the packing differs, and only the packing needs explaining.

5. The ten things most often lost

Each of these was a mark, and none of them required knowing any more chemistry.

WHAT GOES WRONG	THE FIX, IN ONE LINE
Naming the branches before finding the longest chain	Count the chain first, every time
Writing substitution where the answer is addition	Ask what left. If nothing left, it was addition
Saying the covalent bonds break on boiling	Boiling separates molecules and breaks no bonds
Giving a reagent with no conditions	Reagent and conditions are two separate marks
Forgetting the water on the right of an esterification	Condensation always expels something. Write it

WHAT GOES WRONG	THE FIX, IN ONE LINE
Confusing which alcohol names the ester	Alcohol gives yl and goes first. Acid gives anoate
Not saying whether the apparatus is reflux or distillation	That word is the whole answer in an oxidation question
Comparing two routes with no stated criterion	Name the criterion in your first sentence
Explaining a polymer property by bond strength	Explain it by packing and contact area
Leaving a yield calculation without the limiting reagent	Two reactant masses always means check which limits

About this resource

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Scope

NSW Chemistry, Year 12. Written to the NSW Chemistry Stage 6 Syllabus (2017), Module 7, for students sitting the HSC in 2027 and 2028. A new Chemistry syllabus is first examined in HSC 2029.

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Organic Chemistry: Practice Questions

07

NSW CHEMISTRY STAGE 6 SYLLABUS 2017 FOR HSC 2027 AND 2028

1. Instructions

Read this page once. It changes what the rest of the booklet is worth.

Do the questions before you read the solutions. A solution read cold gives the feeling of understanding without evidence of it. A solution read after an attempt shows what the student actually does instead.

Work under time. Allow about one and a half minutes for each multiple choice question and about two minutes a mark in Section II. Most students who lose marks in organic chemistry know the chemistry. They ran out of room to show it.

Write the formula before the numbers. In every calculation in this booklet a stated formula carries a mark even when the arithmetic that follows it slips. That is not folklore: it is how method marks are allocated in the marking guidelines, and it is the cheapest habit in the course.

1.1 Where you actually are in Module 7

Ten statements. Tick only the ones you could do right now, on paper, without a prompt. Tick what is true today. The routing below depends on accurate ticks.

- ☐ I can name a branched alkane and a substituted alkene without hesitating
- ☐ I can draw all three structural isomers of C_5H_{12} and argue that there is no fourth
- ☐ I can identify nine functional groups from a structural formula
- ☐ I can rank four compounds of similar mass by boiling point and name the force behind the order
- ☐ I can predict the major product of adding hydrogen bromide to propene
- ☐ I can classify an alcohol as primary, secondary or tertiary and say what it oxidises to
- ☐ I can choose reflux or distillation to control where an oxidation stops
- ☐ I can write an esterification including the water and name the ester correctly
- ☐ I can compare fermentation with hydration on a criterion I name first
- ☐ I can explain a polymer property from chain packing rather than bond strength

1.2 Interpreting your score

TICKS	WHAT IT MEANS	GO HERE FIRST
0 to 3	The content is not yet in place, so this booklet will feel like a test rather than a tool.	Read the Module 7 Topic Notes sections 2 to 4 first, then come back and do Section I only.
4 to 6	You know the reactions and the explaining is unreliable. This is the commonest place to be.	Section I in full, then Section II questions 13 to 17. Leave Section III for a second pass.
7 or 8	Solid. Your losses are in the production, polymer and evaluation questions.	Skip to Section II question 16, then do Section III under time before reading a single solution.
9 or 10	You are ready for the hard end. Do not reward yourself with naming exercises.	Section I challenge band only, all of Section II, then Section III in twenty minutes.

Date this. Run the same statements again at the end of term and compare the scores to measure progress.

First run Date _____ Score _____ End of term Date _____ Score _____

2. Section I · Multiple choice

Twelve questions. Allow eighteen minutes. One mark each.

Answer every question, including the ones you are unsure of. A blank scores zero and a considered guess between two options scores half the time. There is no mark for working and no penalty for a wrong answer in this section, so the only bad choice is the empty one.

2.1 How the difficulty bands work

Every question in Section I carries a band. The bands are not a prediction of your mark. They tell you what a question is testing, so that when you get one wrong you know whether the problem is recall, application or reasoning in an unfamiliar context.

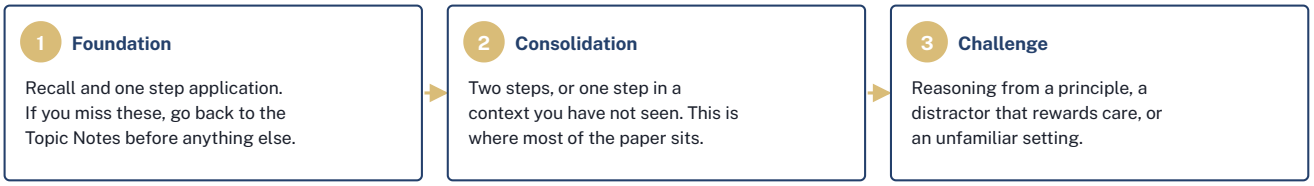


Figure 1 · The three bands. A wrong answer in each band points to a different fix.

2.2 Section I answer grid

Fill the last column when you mark it. Recall, arithmetic, misread the stem, or chose a distractor that was true but did not answer the question. Four words is enough. The pattern across twelve rows is the thing worth having.

QUESTION	YOUR ANSWER	CORRECT	IF WRONG, WHAT WENT WRONG
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

2.3 Foundation · Questions 1 to 4

Question 1 FOUNDATION — 1 MARK

Which compound is an alkene?

A C_3H_8
B C_3H_6
C C_3H_4
D C_3H_8O

Question 2 FOUNDATION — 1 MARK

The correct name for $CH_3CH(CH_3)CH_2CH_3$ is

A 2-methylbutane
B 3-methylbutane
C 2-ethylpropane
D pentane

Question 3 FOUNDATION — 1 MARK

Which reagent decolourises immediately when shaken with an alkene but not with an alkane in the dark?

A Acidified dichromate
B Bromine water
C Limewater
D Sodium hydrogencarbonate

Question 4 FOUNDATION — 1 MARK

Propan-2-ol is classified as

A a primary alcohol
B a secondary alcohol
C a tertiary alcohol
D an aldehyde

2.4 Consolidation · Questions 5 to 9

Question 5 CONSOLIDATION — 1 MARK

How many structural isomers has C_5H_{12}?

A Two
B Three
C Four
D Five

Question 6 CONSOLIDATION — 1 MARK

Butane, propanal and propan-1-ol have almost the same molar mass. Their boiling points, in increasing order, are butane, then propanal, then propan-1-ol. The best explanation is that

A the covalent bonds become progressively stronger along that order
B the strongest intermolecular force changes from dispersion to dipole-dipole to hydrogen bonding
C the molecules become progressively larger along that order
D propan-1-ol is ionic in the liquid state

Question 7 CONSOLIDATION — 1 MARK

A primary alcohol is warmed with acidified potassium dichromate in an apparatus fitted with a vertical condenser and heated for thirty minutes. The major organic product is

A an aldehyde
B a ketone
C a carboxylic acid
D an alkene

Question 8 CONSOLIDATION 1 MARK

Propene reacts with hydrogen bromide. The major product is

A 1-bromopropane
B 2-bromopropane
C 1,2-dibromopropane
D propan-2-ol

Question 9 CONSOLIDATION 1 MARK

Which reaction produces water as a second product?

A Addition of bromine to ethene
B Addition polymerisation of ethene
C Esterification of ethanol with ethanoic acid
D Hydrogenation of ethyne

2.5 Challenge · Questions 10 to 12

Question 10 CHALLENGE 1 MARK

A sample of poly(vinyl chloride) has a number average molar mass of 9.00×10^4 g/mol. The number of repeat units in an average chain is closest to

A 1440
B 1800
C 2880
D 3210

Question 11 CHALLENGE 1 MARK

Two students each make ethyl ethanoate. Student A refluxes the mixture and then distils. Student B heats the mixture in an open beaker at the same temperature for the same time. Student B obtains far less ester. The best explanation is that

A the reaction requires a sealed system to proceed at all
B the volatile ethanol and ester escape from the open beaker, so less reactant remains and less product is retained
C the sulfuric acid catalyst decomposes in an open vessel
D esterification is exothermic and the open beaker loses the heat needed

Question 12 CHALLENGE 1 MARK

Nylon 6,6 is made from a diamine and a dicarboxylic acid. Polyethene is made from ethene. Which statement correctly distinguishes the two processes?

A Nylon formation loses water at each link, while polyethene formation loses nothing
B Polyethene formation loses hydrogen at each link, while nylon formation loses nothing
C Both lose water, but nylon loses two molecules for each link
D Neither loses a small molecule, because both are addition reactions

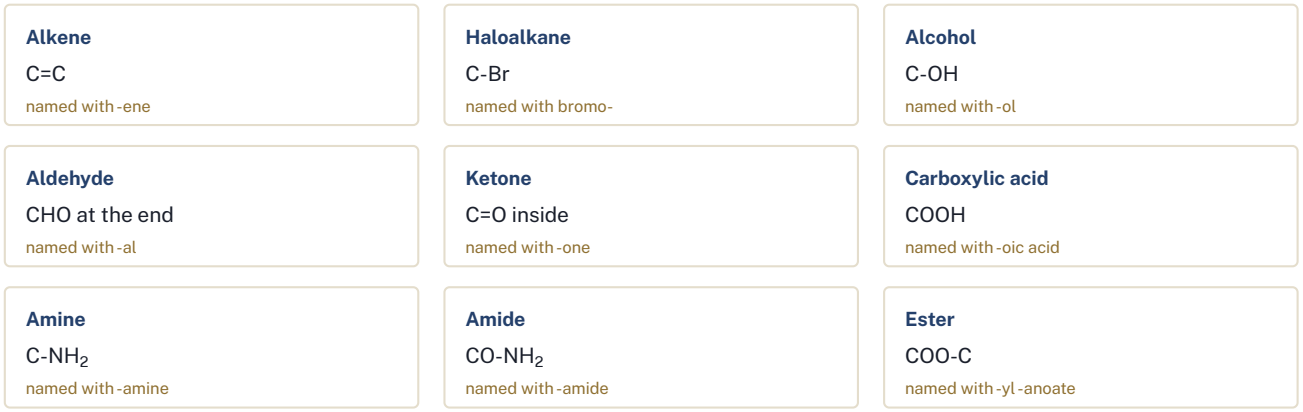


Figure 2 · The functional groups, each named on the molecule that carries it. Use this to check your Section I answers.

3. Section II · Short answer and calculation

Nine questions, 38 marks. Allow about seventy six minutes.

Show your working. In a calculation the formula you quote before substituting is worth a mark on its own, and in an explanation question the sentence that links the structure to the property is where the marks sit. If you run out of writing space, that usually means you are describing rather than explaining.

Question 13

4 MARKS

Draw and name the three structural isomers of C_5H_{12}, and explain how you know there is no fourth.

Question 14

5 MARKS

Ethene is converted to ethanol at the Kerrindal solvent plant by hydration.

(a) Write the balanced equation and state the conditions. **2 MARKS**

(b) Fermentation is an alternative route. Compare the two routes on atom economy, showing a calculation for each. **3 MARKS**

Question 15

4 MARKS

Propan-1-ol and propan-2-ol are both warmed with excess acidified potassium dichromate under reflux. Name the organic product in each case, explain why they differ, and state what would be seen if the experiment were repeated with 2-methylpropan-2-ol.

Question 16

6 MARKS

The solvent plant charges 46.0 g of ethanol with an excess of ethanoic acid and refluxes the mixture with a sulfuric acid catalyst. After distillation, 62.5 g of ethyl ethanoate is recovered.

(a) Write the balanced equation for the reaction. **1 MARK**

(b) Calculate the percentage yield. **3 MARKS**

(c) Give one chemical and one practical reason why the yield is below 100 per cent. **2 MARKS**

Question 17

4 MARKS

Explain, in terms of the apparatus and the chemistry, why a chemist wanting ethanal from ethanol distils the product off as it forms, while a chemist wanting ethanoic acid uses reflux.

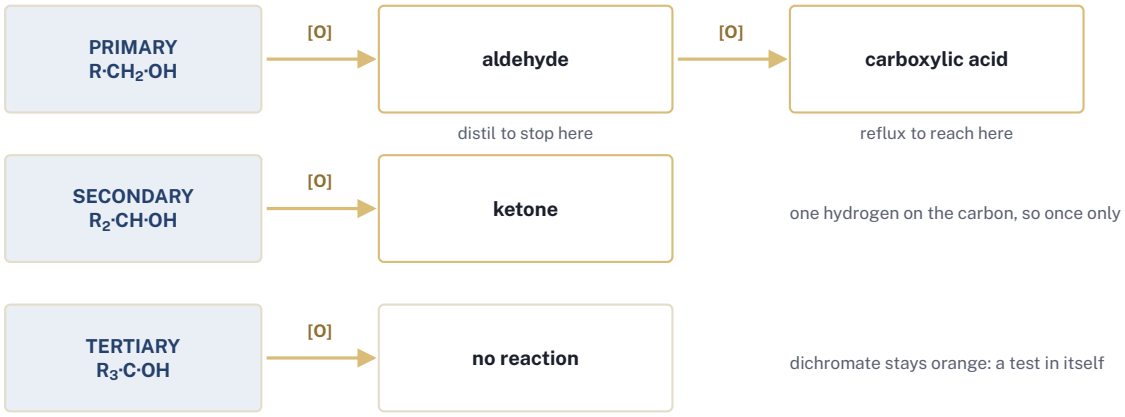


Figure 3 · The oxidation ladder, for checking your answer to question 17.

Question 18

5 MARKS

Soap is made by boiling a fat with sodium hydroxide. Name the process, name both products, and explain how the resulting molecule removes grease from a fabric.

Question 19

4 MARKS

Low density polyethene is used to line the solvent recovery tank, and high density polyethene is used for the pipework carrying the solvent away. Both are made from ethene. Explain the difference in their properties in terms of structure.

Question 20

3 MARKS

Nylon 6,6 is formed from $C_6H_{16}N_2$ and $C_6H_{10}O_4$, giving a repeat unit of $C_{12}H_{22}N_2O_2$ and two molecules of water. Calculate the atom economy of this step and explain why an addition polymerisation cannot have an atom economy below 100 per cent.

Question 21

3 MARKS

A student writes: bromine water is decolourised by an alkene because the bromine is used up in a substitution reaction, releasing hydrogen bromide. Identify the error, correct it, and describe a control the student should have run.

> Ask what left. If nothing left, it was addition. That one question settles more marks in Module 7 than any other.

4. Section III · Extended response

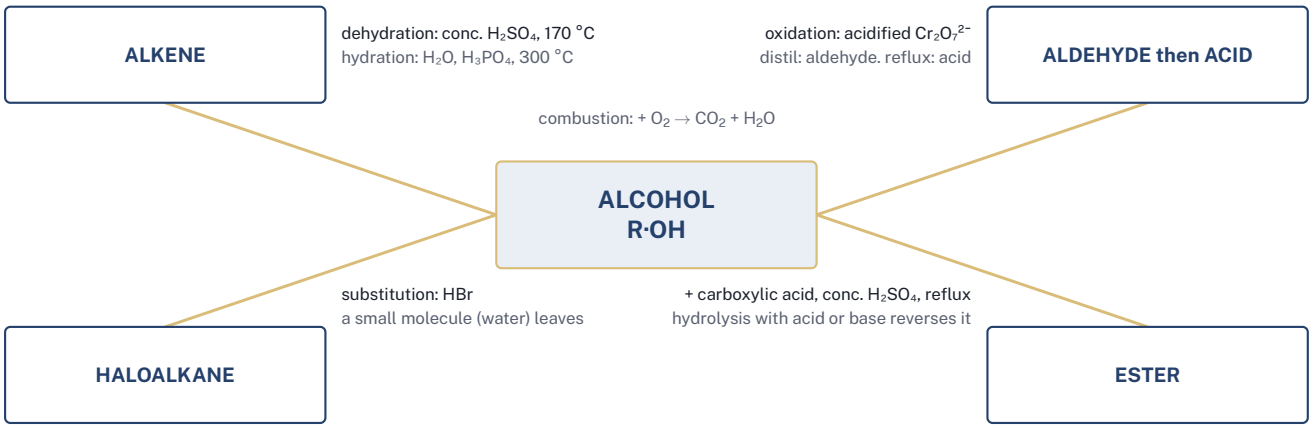
One question, 8 marks. Allow twenty minutes, including planning.

Plan before you write. Two minutes listing the compounds you will mention and the property you will link each one to buys you more than two extra minutes of writing would. A response covering three points properly outscores one mentioning six.

The situation

The Kerrindal solvent plant needs ethyl ethanoate as an extraction solvent. Ethene is available from the cracker on site. Fermentation capacity also exists, left over from an earlier process, and sugar is available locally.

The plant engineer asks you to recommend a route from raw material to finished solvent and to justify it.



Five reactions in and out of the alcohol. Learn these and the module joins up.

Figure 4 · The reactions of Module 7 as a map. Plan your route on it before you write: every step you name needs its reagent and conditions.

Question 22

8 MARKS

Describe a synthetic route from a named raw material to ethyl ethanoate, giving the reagents and conditions for each step and the equations involved. Evaluate your route against the alternative starting material on criteria you state, including atom economy and overall yield.

Plan here first. One column for each starting material, your criteria down the left. Fill the grid before you write a sentence.

CRITERION	ETHENE ROUTE	FERMENTATION ROUTE
Atom economy		
Overall yield		
Throughput		
Feedstock		

5. The drill and the audit

5.1 The twelve-minute organic drill

Run this weekly. Short is the point: the skill is the speed at which you go from a structure to a prediction, and that improves by repetition.

MINUTES	WHAT YOU DO
0 to 2	Write six structures from memory, one from each family.
2 to 5	Name all six, with every locant.
5 to 8	For each, write one reaction with its reagent and conditions.
8 to 10	Rank all six by boiling point and name the force at the top and the bottom.
10 to 12	Check, then write the one thing you got wrong and what you will check next week.

Use the solvent plant compounds: ethanol, ethanoic acid, ethyl ethanoate, ethene and polyethene. Twelve minutes a week beats three hours the night before.

5.2 The organic explanation audit, run after you mark Section II

Tick only what the written answer did, not what was meant or what would have been written with another five minutes.

- ☐ I named the functional group before describing any reaction
- ☐ I gave the conditions as well as the reagent
- ☐ I said addition or substitution by name, and said what left
- ☐ For a boiling point I named the intermolecular force rather than saying stronger bonds
- ☐ For an alcohol I identified primary, secondary or tertiary before predicting anything
- ☐ For an oxidation I named the apparatus, reflux or distillation
- ☐ For a comparison I stated my criterion in the first sentence
- ☐ For a polymer property I explained the packing rather than the bond strength

Interpreting your score

7 or 8. Your explanations are doing the work. Move on to timing and to Section III.

5 or 6. You know the chemistry and you are stating rather than linking. Rewrite two answers using because in every sentence, then compare.

0 to 4. This is the uncomfortable band and it is also the most recoverable one. Every unticked box above is a habit, not a gap in knowledge. Pick the single one you miss most and make it automatic before you attempt another explanation question.

6. Worked solutions

Every question, with the reasoning shown and not just the answer.

Mark your own working. Where your working differs from the working here but your answer agrees, check whether your route would still have earned the method marks. Sometimes it would. Sometimes the right number comes from a route a marker cannot follow.

6.1 Section I · Answers and reasoning

Q	ANSWER	BAND	WHY, AND WHAT THE DISTRACTORS WERE TESTING
1	B	Foundation	An alkene fits C_nH_{2n}, so three carbons means six hydrogens. A is the alkane, C is the alkyne, D is an alcohol. Read the hydrogen count rather than the look of the formula.
2	A	Foundation	The longest chain is four carbons, so butane. Numbering from the left puts the methyl group on carbon 2; from the right it would be carbon 3, so 2 is correct. C is the classic error of naming a branch that is longer than the chain you chose.
3	B	Foundation	Bromine water is the standard unsaturation test. Acidified dichromate tests an alcohol, limewater tests carbon dioxide, hydrogencarbonate tests a carboxylic acid.
4	B	Foundation	The carbon carrying the OH group is the middle carbon, which is attached to two other carbons. Two attached carbons means secondary. Counting the chain position instead of the attached carbons is what produces the wrong answer here.
5	B	Consolidation	Pentane, 2-methylbutane and 2,2-dimethylpropane. Students who answer C have drawn 3-methylbutane, which is 2-methylbutane written the other way round.
6	B	Consolidation	At the same molar mass the only variable is the intermolecular force, which rises from dispersion to dipole to hydrogen bonding across that order. C is the trap: the masses are deliberately almost equal, so size cannot be the explanation.
7	C	Consolidation	A vertical condenser is reflux, which returns the aldehyde to the flask to be oxidised again. A would be right only if the apparatus were set for distillation. B requires a secondary alcohol. The apparatus is the whole answer.
8	B	Consolidation	Markovnikov: the hydrogen adds to the carbon that already carries more hydrogens, which is carbon 1, putting the bromine on carbon 2. C is an addition of bromine rather than of hydrogen bromide, and D would require water.
9	C	Consolidation	Esterification is a condensation, so it expels water. A and D are additions, which lose nothing, and B is addition polymerisation, which also loses nothing. The question is really asking which of these is not an addition.
10	A	Challenge	$M(C_2H_3Cl) = 2(12.01) + 3(1.008) + 35.45 = 62.49$ g/mol, so $90000 \div 62.49 = 1440$. Option D is $90000 \div 28.05$, which uses the mass of the ethene molecule instead of the repeat unit, and option C is double the correct value, which comes from using half of the repeat unit mass.
11	B	Challenge	Ethanol boils at 78 and the ester at 77 degrees Celsius, so both escape from an open vessel at the reaction temperature. Reflux exists precisely to prevent that. A is false: the reaction proceeds fine in an open vessel, but it simply loses everything.
12	A	Challenge	Condensation expels a small molecule at each link, addition does not. B reverses the two, C invents a second water, D denies the distinction the question is testing.

6.2 Section II · Worked solutions

QUESTION 13 · THE ISOMERS OF PENTANE · 4 MARKS

Three isomers, and no more.

- **pentane:** $CH_3CH_2CH_2CH_2CH_3$, a straight chain of five carbons.
- **2-methylbutane:** $CH_3CH(CH_3)CH_2CH_3$, a four carbon chain with a methyl group on carbon 2.
- **2,2-dimethylpropane:** $C(CH_3)_4$, a three carbon chain with two methyl groups on the middle carbon.

Why there is no fourth. Work down by chain length. A five carbon chain has no branch left to place. A four carbon chain can carry one methyl group, and the only distinct position is carbon 2, because carbon 3 gives the same molecule read from the other end and carbon 1 or 4 simply extends the chain back to pentane. A three carbon chain must carry both remaining carbons, and the only position that does not extend the chain is the middle carbon. There is nothing left to try.

WHERE THE MARKS ARE

Three marks: one for each correct structure with its correct name. One mark: the argument that the list is complete, worked by chain length. A response that draws three and stops has answered draw, not explain.

QUESTION 14 · TWO ROUTES TO ETHANOL · 5 MARKS

(a) $C_2H_4(g) + H_2O(g) \rightarrow C_2H_6O(g)$. Conditions: phosphoric acid catalyst, about 300 degrees Celsius and about 60 atmospheres, run continuously with the unreacted ethene recycled.

(b) Atom economy is the molar mass of the wanted product divided by the total molar mass of the reactants. Hydration: $M(C_2H_6O) = 46.07$, and the reactants total 28.05 plus 18.02 = 46.07 g/mol, so atom economy = 46.07 ÷ 46.07 × 100 = 100 per cent. Fermentation: $C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2$, so 180.16 g/mol of glucose gives 2 × 46.07 = 92.14 g/mol of ethanol, and atom economy = 92.14 ÷ 180.16 × 100 = 51.1 per cent.

Hydration has an atom economy of 100 per cent because every atom of both reactants appears in the product. Fermentation has an atom economy of 51.1 per cent because half the mass of the glucose leaves as carbon dioxide.

WHERE THE MARKS ARE

A response that computes both numbers and does not say which is better, and why, has answered calculate rather than compare.

QUESTION 15 · TWO ALCOHOLS, ONE OXIDANT · 4 MARKS

Propan-1-ol is primary. Under reflux with excess oxidant it is oxidised twice, first to propanal and then to propanoic acid. The product is propanoic acid.

Propan-2-ol is secondary. The carbon carrying the OH group has only one hydrogen, so one oxidation is available. It gives propanone, a ketone, and stops.

Why they differ. Oxidation of an alcohol removes the hydrogen on the carbon carrying the OH group. A primary alcohol has two such hydrogens, so two oxidations are possible. A secondary alcohol has one. The number of hydrogens on that one carbon decides the whole outcome.

2-methylpropan-2-ol is tertiary. The carbon carrying the OH has no hydrogen at all, so no oxidation occurs and the dichromate remains orange. That absence of a colour change is itself the observation, and stating it is the fourth mark.

QUESTION 16 · THE SOLVENT BATCH · 6 MARKS

(a) $C_2H_6O + C_2H_4O_2 \rightleftharpoons C_4H_8O_2 + H_2O$

(b) The acid is in excess, so ethanol limits the batch. $M(C_2H_6O) = 46.07$ g/mol, so n = 46.0 ÷ 46.07 = 0.9985 mol. The ratio is one to one, so n(ester) at best is 0.9985 mol. $M(C_4H_8O_2) = 88.10$ g/mol, so the theoretical mass is 0.9985 × 88.10 = 87.97 g, and yield = 62.5 ÷ 87.97 × 100 = **71.0 per cent**.

(c) Chemical: esterification is an equilibrium, so the forward reaction never converts all the reactant, and the reverse hydrolysis runs at the same time. Practical: ester is lost mechanically, left in the flask, carried into the washings and lost in the distillation fraction that is discarded.

WHERE THE MARKS ARE

One reason must be chemical and one must be practical. Two chemical reasons scores one mark, not two. The question asked for one of each, and reading which kind of reason is wanted is worth as much here as knowing the chemistry.

QUESTION 17 · WHY THE APPARATUS DECIDES THE PRODUCT · 4 MARKS

Distillation for the aldehyde. Ethanal boils at about 20 degrees Celsius, well below ethanol at 78. If the condenser is set to lead away from the flask, the ethanal boils out as soon as it forms and is condensed in a separate receiver. It is therefore removed from the oxidising mixture before the dichromate can oxidise it a second time.

Reflux for the acid. With a vertical condenser everything that evaporates condenses and returns to the flask. The ethanal stays in contact with excess dichromate and is oxidised on to ethanoic acid, which boils at 118 degrees Celsius and stays in the flask anyway.

The controlling idea. The reagent is the same in both cases. What changes is the length of time the intermediate spends in contact with the oxidant, and the apparatus is what sets that time.

WHERE THE MARKS ARE

The sentence that earns the fourth mark names the boiling points, or at least says that the aldehyde is the most volatile species present. Without that, the explanation of why distillation removes the aldehyde and not the alcohol is missing its mechanism.

> Distil for the aldehyde. Reflux for the acid. That is the whole of question 17 and most of the oxidation marks in the paper.

QUESTION 18 · SOAP · 5 MARKS

The process is saponification, which is base hydrolysis of an ester applied to a fat.

$$C_{57}H_{110}O_6 + 3NaOH \rightarrow 3C_{18}H_{35}O_2Na + C_3H_8O_3$$

The two products are sodium stearate, which is the soap, and glycerol.

How it removes grease. A soap molecule has a long hydrocarbon tail and an ionic carboxylate head. The tail is non-polar and dissolves into the grease; the head is ionic and is attracted to water. In water the molecules arrange themselves around a grease droplet with their tails buried in it and their heads outwards, forming a micelle. The droplet now presents a charged surface to the water, so it is lifted off the fabric, suspended in the wash and carried away with the rinse.

WHERE THE MARKS ARE

One mark: naming saponification. One mark: naming both products. One mark: the two ends of the molecule, described by what each one is attracted to. One mark: the micelle, described rather than just named. One mark: the droplet being suspended and rinsed away, which is the part students stop before.

QUESTION 19 · TWO GRADES OF POLYETHENE · 4 MARKS

Both materials are made of the same repeating unit joined by the same covalent bonds, so the difference cannot be bond strength. It is the shape of the chains and how closely they can approach one another.

Low density polyethene. Its chains carry frequent short branches, which hold neighbouring chains apart. Less of each chain is in close contact with its neighbours, so fewer dispersion forces act, so the material is less dense, more flexible and melts at a lower temperature. That flexibility is why it makes a good tank liner.

High density polyethene. Its chains are largely unbranched, so they pack closely and align into crystalline regions. More surface is in contact, so more dispersion force acts in total, so the material is denser, stiffer, stronger and melts higher. That rigidity is why it makes pipe.

WHERE THE MARKS ARE

The sentence that separates a 4 from a 2: more contact area means more dispersion force in total, even though each individual dispersion force is identical. Students who write that the forces are stronger score two; students who write that more of them act score four.

QUESTION 20 · ATOM ECONOMY OF A CONDENSATION · 3 MARKS

$M(C_6H_{16}N_2)$ = 116.21 g/mol and $M(C_6H_{10}O_4)$ = 146.14 g/mol, so the reactants total 262.35 g/mol. $M(C_{12}H_{22}N_2O_2)$ = 226.32 g/mol, so atom economy = 226.32 ÷ 262.35 × 100 = **86.3 per cent**.

Why addition polymerisation cannot fall below 100 per cent. In an addition polymerisation the double bond opens and the monomers join directly. Nothing at all is expelled, so every atom of every monomer is in the product by definition. The atom economy is therefore exactly 100 per cent, and the lost 13.7 per cent in the nylon step is precisely the mass of the two water molecules.

QUESTION 21 · CORRECTING A STUDENT'S EXPLANATION · 3 MARKS

The error. The reaction of an alkene with bromine is an addition, not a substitution, and no hydrogen bromide is released.

The correction. The double bond opens and both bromine atoms attach to the two carbons that were doubly bonded. For ethene: $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$. The orange colour disappears because the bromine is consumed, not because anything is displaced.

The control. Run the same test on a known alkane, such as hexane, in the same light conditions. If the alkane leaves the bromine water orange while the unknown decolourises it, the decolourisation is evidence of unsaturation. Without that control, an alkane exposed to bright light would also fade the colour slowly by substitution, which is exactly the reaction the student was describing.

WHERE THE MARKS ARE

Why the control matters more than the correction. Substitution with a halogen is a real reaction, but it needs ultraviolet light and it is slow. The word that separates the two in an examination answer is immediately. An alkene decolourises bromine water at once and in the dark.

6.3 Section III · Marking guide and model response

CRITERION	MARKS	WHAT IT MEANS IN THIS QUESTION
Route described	2	A named starting material and a sequence of steps that actually reaches ethyl ethanoate
Reagents and conditions	2	Each step carries both. Reagent alone earns half of what is available
Equations	2	Balanced equations for every step, correctly written
Evaluation against stated criteria	2	Criteria named first, evidence for each route against each, and a judgement that refers back to them

Model response. Route chosen: ethene from the cracker. Two steps.

Step 1, hydration. $C_2H_4 + H_2O \rightarrow C_2H_6O$, with a phosphoric acid catalyst at about 300 degrees Celsius and 60 atmospheres. This gives ethanol at a hypothetical (MA99) yield of about 82 per cent, with the unreacted ethene recycled.

Step 2, esterification. $C_2H_6O + C_2H_4O_2 \rightleftharpoons C_4H_8O_2 + H_2O$, refluxed with concentrated sulfuric acid, then distilled. This gives the solvent at a hypothetical (MA99) yield of about 66 per cent. Overall yield = 0.82 × 0.66 × 100 = 54.1 per cent.

Evaluation, on three stated criteria. Atom economy: the hydration step is 100 per cent, whereas making the ethanol by fermentation would be 51.1 per cent, because half the mass of the glucose leaves as carbon dioxide. On this criterion the ethene route wins decisively. Throughput: hydration is continuous and takes minutes, while fermentation is a batch process taking days, so for a plant needing solvent every shift the ethene route wins again. Feedstock renewability: here fermentation wins, because sugar is renewable and ethene is derived from a fossil source, and the fermentation runs near room temperature rather than at 300 degrees Celsius. Judgement: for this plant, with an ethene stream already on site and a continuous solvent demand, the ethene route is the correct recommendation on atom economy and throughput, and the renewability argument would only become decisive if the site had to justify its carbon footprint or if the cracker were shut down.

WHERE THE MARKS ARE

Why that response reaches the top band. It names the criteria before comparing anything, gives numerical evidence against each criterion, concedes the criterion on which its recommendation loses, and then reaches a judgement that refers back to the stated criteria and to the specific situation in the question. A response that lists advantages of each route and stops has answered describe and caps in the middle band, however much chemistry it contains.

6.4 Module 7, tracked over the term

Date each attempt. Record which section, the mark, and the single change you will make. The same three errors recur for months in this module. Writing them down is how you find out which three are yours.

DATE	SECTION AND MARK	THE ERROR I MADE MOST, AND THE FIX

Fill one row every time you sit a set. A tracker with three rows in it is worth more than a perfect one you never started, because the pattern you are looking for only appears across attempts.

About this resource

MA99 EDUCATION

Scope

NSW Chemistry, Year 12. Written to the NSW Chemistry Stage 6 Syllabus (2017), Module 7, for students sitting the HSC in 2027 and 2028. A new Chemistry syllabus is first examined in HSC 2029. Every question uses the Kerrindal solvent plant, an invented site, and every worked solution was recomputed from its inputs before printing. Organic names are written with the hyphens the syllabus uses. The difficulty bands describe what a question tests, not what mark it predicts.

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