CHEMISTRY

Stage 6

Module 7: Organic Chemistry

Alcohols

Teacher: Shane Sandot

Exam Equivalent Time: 180 minutes *(based on allocation of 1.5 minutes per mark)*

M7 Organic Chemistry

- Nomenclature
- Hydrocarbons and Associated Reactions
- Alcohols
- Reactions of Organic Acids and Bases
- Polymers

***SmarterScience analytics based on the average contribution of new syllabus content since 2019.**

HISTORICAL CONTRIBUTION

- *M7 Organic Chemistry* has contributed an average of 25.0% per HSC Chemistry exam since the new syllabus was introduced in 2019.
- This topic has been split into five sub-categories for analysis purposes which are: *1-Nomenclature (3.7%), 2-Hydrocarbons and Associated Reactions (3.4%), 3-Alcohols (9.8%), 4-Reactions of Organic Acids and Bases (6.8%) and 5-Polymers (1.3%).*
- This analysis looks at the sub-topic, *Alcohols.*

HSC ANALYSIS - What to expect and common pitfalls

- *Alcohols* is the blue whale in the *M7 Organic Chemistry* ocean, responsible for approximately 10% of the exam just on its own. A key revision focus area!
- *Reactions of Alcohols* is the largest sub-category, examined each year in the period 2019-22 predominantly via high-mark cross-topic questions (see *2019 HSC 34*).
- Students are regularly required to draw the structural formulae of a given reactions (review the challenging *2020 HSC 29* and *2021 HSC 26*).
- *Combustion* has been tested in 5 of 6 new syllabus exams. Mark allocations have been significant on most occasions with difficulty typically at the band 4-5 level.
- *Oxidation of Alcohols* was last examined in 2024 via multiple-choice. Any revision should focus on the numerous questions that appeared in the 2021-22 exams.
- *Production of Alcohol* was last examined in *2023 and 2021* with 4-mark allocations on each occasion (review the challenging *2023 HSC 27* and *2021 HSC 25*).

Questions

1. CHEMISTRY, M7 2018 HSC 10 MC

Which row of the table correctly matches the reaction type with the reactant(s), catalyst and product(s)?

	Reaction type	*Reactant(s)*	*Catalyst*	*Product(s)*
A.	Hydration	$C_2H_4 + H_2O$	Dilute acid	C_2H_6
B.	Hydration	C_2H_4	Concentrated acid	C_2H_5OH
C.	Dehydration	C_2H_5OH	Dilute acid	C_2H_4
D.	Dehydration	C_2H_5OH	Concentrated acid	$C_2H_4 + H_2O$

2. CHEMISTRY, M7 2015 HSC 17 MC

What volume of carbon dioxide will be produced if 10.3 g of glucose is fermented at 25°C and 100 kPa?

A. 1.30 L

B. 1.42 L

C. 2.57 L

D. 2.83 L

3. CHEMISTRY, M7 2016 HSC 15 MC

The table lists some properties of the straight-chained carbon compounds W, X, Y and Z.

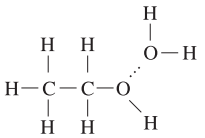
Compound	*Reactivity in bromine water*	*Solubility in water*
W	Rapidly decolourises	Insoluble
X	Unreactive	Insoluble
Y	Unreactive	Soluble
Z	Unreactive	Partly soluble

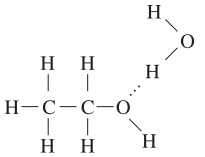
Which row of the following table best identifies the compounds W, X, Y and Z?

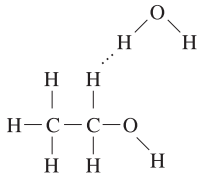
	W	X	Y	Z
A.	C_3H_6	C_3H_8	CH_3OH	C_4H_9OH
B.	C_3H_8	C_3H_6	CH_3OH	C_4H_9OH
C.	C_3H_6	C_3H_8	C_4H_9OH	CH_3OH
D.	C_3H_8	C_3H_6	C_4H_9OH	CH_3OH

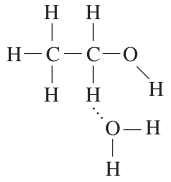
4. CHEMISTRY, M7 2016 HSC 5 MC

Which of the following diagrams best represents the bonding between molecules of water and ethanol?

(A) 

(B) 

(C) 

(D) 

5. CHEMISTRY, M7 2019 HSC 9 MC

All of the following compounds have similar molar masses.

Which has the highest boiling point?

A. Butane

B. Ethanoic acid

C. Propan-1-ol

D. Propane

6. CHEMISTRY, M7 2021 HSC 13 MC

A chemist synthesises a substance using the following pathway.

$$\mathrm{X} \xrightarrow{\text{hydration}} \mathrm{Y} \xrightarrow{\text{oxidation}} \mathrm{Z}$$

What are compounds X, Y, Z ?

	X	Y	Z
A.	propane	propan-1-ol	propan-2-one
B.	propane	propan-1-ol	propanoic acid
C.	prop-1-ene	propan-2-ol	propan-2-one
D.	prop-1-ene	propan-2-ol	propanoic acid

7. CHEMISTRY, M7 2021 HSC 7 MC

Methanol undergoes a substitution reaction using hydrogen bromide.

Compared to methanol, the product of this reaction has a

A. lower boiling point.

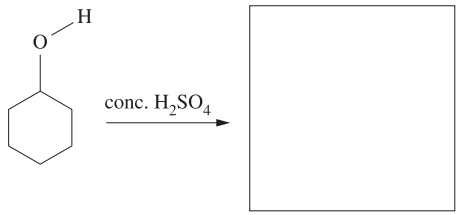
B. lower molecular mass.

C. greater solubility in water.

D. different molecular geometry at the carbon atom.

8. CHEMISTRY, M7 2022 HSC 11 MC

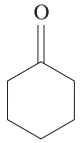
Cyclohexanol is an alcohol and undergoes a dehydration reaction with sulfuric acid as shown.

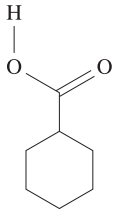


What is the major organic product of this reaction?

A. 

B. 

C. 

D. 

9. CHEMISTRY, M7 2023 HSC 10 MC

Which of the following correctly lists the compounds in order of increasing boiling point?

A. Heptane < heptan-2-one < heptan-1-o1 < heptanoic acid

B. Heptane < heptan-1-o1 < heptan-2-one < heptanoic acid

C. Heptanoic acid < heptan-2-one < heptan-1-o1 < heptane

D. Heptanoic acid < heptan-1-o1 < heptan-2-one < heptane

10. CHEMISTRY, M7 2023 HSC 15 MC

The table gives the heat of combustion of three different alcohols at 25°C.

Alcohol	*Heat of combustion* (Kj g^{-1})
Methanol	22.68
Ethanol	29.67
Butan-1-ol	36.11

Which of the following gives the best approximation for the molar heat of combustion of propan-1-ol, expressed in kJ g^{-1}?

A. $\left(\frac{22.68 + 29.67 + 36.11}{3}\right)$

B. $\left(\frac{29.67 + 36.11}{2}\right)$

C. $\left(\frac{22.68 + 29.67}{2}\right)$

D. $\left(\frac{3 \times 36.11}{4}\right)$

11. CHEMISTRY, M7 2024 HSC 13 MC

A fuel has these enthalpies of combustion: −2057.8 kJ mol^{-1} and −48.9 kJ g^{-1}.

Which of the following correctly identifies the fuel?

A. Ethanol $\left(MM = 46.1 \text{ g mol}^{-1}\right)$

B. Propane $\left(MM = 44.1 \text{ g mol}^{-1}\right)$

C. Propene $\left(MM = 42.1 \text{ g mol}^{-1}\right)$

D. Hydrogen $\left(MM = 2.02 \text{ g mol}^{-1}\right)$

12. CHEMISTRY, M7 2024 HSC 5 MC

Which would be the best reagent to use to determine whether an unknown substance was 2-methylpropan-1-ol or 2-methylpropan-2-ol?

A. Bromine water

B. Potassium nitrate solution

C. Sodium carbonate solution

D. Acidified potassium permanganate solution

13. CHEMISTRY, M7 2015 HSC 10 MC

Which of the equations correctly describes incomplete combustion?

A. $C_2H_5OH(l) + 2O_2(g) \rightarrow 2CO(g) + 3H_2O(l)$

B. $C_2H_5OH(l) + \frac{7}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

C. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

D. $C_2H_5OH(l) + 2O_2(g) \rightarrow C(s) + CO(g) + 3H_2O(l)$

14. CHEMISTRY, M7 2015 HSC 20 MC

The table shows the heat of combustion of four straight chain alkanols.

Number of C atoms in straight chain alkanol	*Heat of combustion* (kJ mol^{-1})
1	726
3	2021
5	3331
7	4638

What is the mass of water that could be heated from 20°C to 45°C by the complete combustion of 1.0 g of heptan-1-ol?

A. 0.032 kg

B. 0.044 kg

C. 0.36 kg

D. 0.38 kg

15. CHEMISTRY, M7 2016 VCE 24 MC

Methanol is a liquid fuel that is often used in racing cars. The thermochemical equation for its complete combustion is

$$2\,CH_3OH\,(l) + 3\,O_2(g) \rightarrow 2\,CO_2\,(g) + 4\,H_2O\,(l) \qquad \Delta H = -1450\,kJ\,mol^{-1}$$

Octane is a principal constituent of petrol, which is used in many motor vehicles. The thermochemical equation for
the complete combustion of octane is

$$2\,C_8H_{18}\,(l) + 25\,O_2(g) \rightarrow 16\,CO_2\,(g) + 18\,H_2O\,(l) \qquad \Delta H = -10\,900\,kJ\,mol^{-1}$$

The molar mass of methanol is 32 g mol^{-1} and the molar mass of octane is 114 g mol^{-1}. Which one of the following statements is the most correct?

A. Burning just 1.0 g of octane releases almost 96 kJ of heat energy.

B. Burning just 1.0 g of methanol releases almost 23 kJ of heat energy.

C. Octane releases almost eight times more energy per kilogram than methanol.

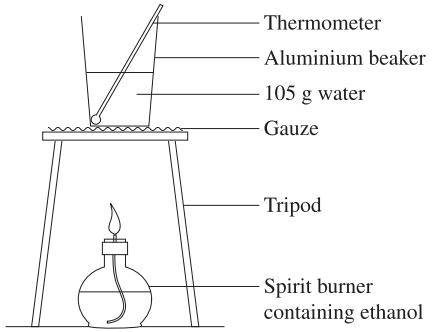
D. The heat energy released by methanol will not be affected if the oxygen supply is limited.

16. CHEMISTRY, M7 2015 VCE 5b

Draw the full structural formula of an isomer of butan-2-ol. ***(1 mark)***

17. CHEMISTRY, M7 2019 HSC 23

The following apparatus was used in an experiment to determine the molar enthalpy of combustion of ethanol.



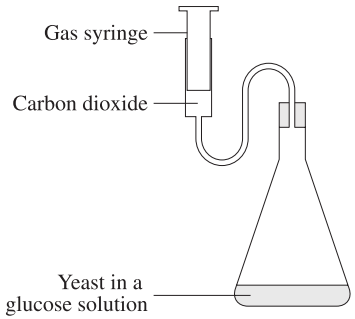
a. Calculate the experimental molar enthalpy of combustion $(\Delta_c H)$ of ethanol when 0.370 g ethanol was used to raise the water temperature from 18.5°C to 30.0°C. ***(4 marks)***

b. Upon replication, the molar enthalpy of combustion obtained in the experiment was consistently much lower than the accepted value.

Explain ONE change that could be made to the experiment that would improve the accuracy of the obtained value. ***(2 marks)***

18. CHEMISTRY, M7 2018 HSC 24

The following apparatus was set up to test the reaction rate of fermentation of glucose at different temperatures.



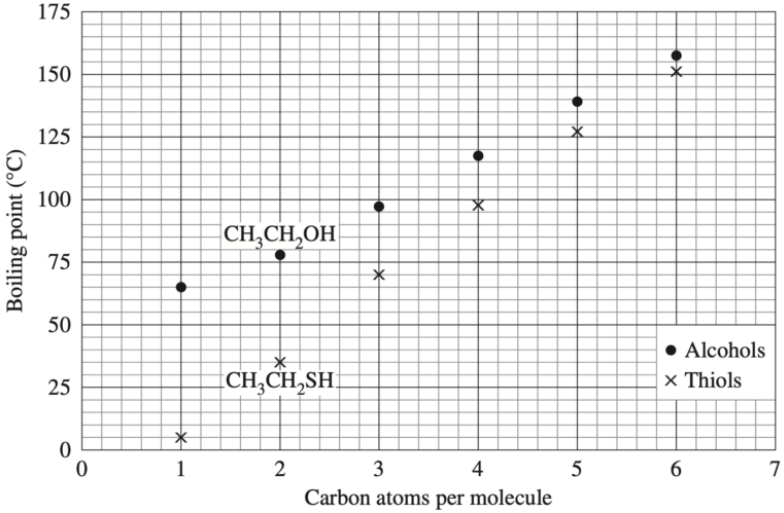
a. Write a balanced equation for the fermentation of glucose. ***(1 mark)***

b. After 24 hours, 5.5 mL of gas was collected at 25°C and 100 kPa.

Calculate the mass of glucose that would have been reacted. ***(3 marks)***

19. CHEMISTRY, M7 2019 HSC 32

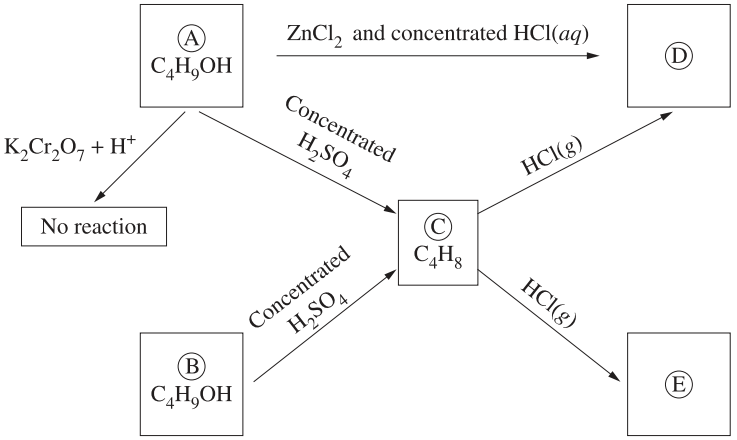
Thiols are the sulfur analogues of alcohols in that the oxygen atom of the alcohol is replaced by a sulfur atom. For example, methanethiol (CH_3SH) is the analogue of methanol (CH_3OH). The boiling points of some straight chain alcohols and thiols are given in the following graph.



Explain the patterns of the boiling points shown in the graph. ***(4 marks)***

20. CHEMISTRY, M7 2020 HSC 29

The flow chart shows reactions involving five different organic compounds, Ⓐ to Ⓔ



Draw the structure of each compound Ⓐ to Ⓔ in the corresponding space provided. ***(5 marks)***

Ⓐ

Ⓑ

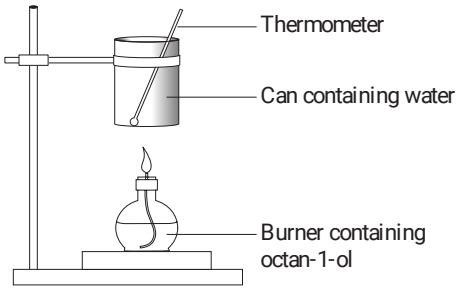
Ⓒ

Ⓓ

Ⓔ

21. CHEMISTRY, M7 2023 HSC 25

A student used the apparatus shown to investigate the combustion of octan-1-ol.



The following results were obtained by the student.

Mass of water heated	= 205 g
Initial temperature of water	= 23.7°C
Final temperature of water	= 60.4°C

The following data are given.

Molar enthalpy of combustion of octan-1-ol	= – 5294 kJ mol^{-1}
Molar mass of octan-1-ol	= 130.23 g kJ mol^{-1}

a. Assuming that no energy released by this combustion is lost to the surroundings, calculate the mass of octan-1-ol burnt. ***(3 marks)***

b. Explain ONE advantage of using a biofuel compared to fossil fuels. ***(2 marks)***

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22. CHEMISTRY, M7 2023 HSC 27

A student has been asked to produce 185 mL of ethanol (MM = 46.068 g mol^{-1}) by fermenting glucose using yeast, as shown in the equation.

$$C_6H_{12}O_6\,(aq) \rightarrow 2\,C_2H_5OH\,(aq) + 2\,CO_2\,(g)$$

Given that the density of ethanol is 0.789 g mL^{-1}, calculate the volume of carbon dioxide gas produced at 310 K and 100 kPa. ***(4 marks)***

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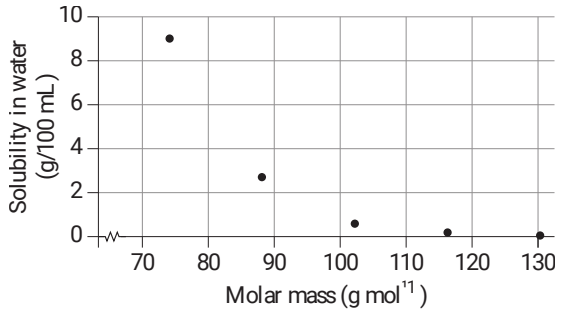
23. CHEMISTRY, M7 2023 HSC 29

The following graph shows the solubility of some alkan-1-ols in water at 20°C.



Explain the relationship between the trend shown in the graph and the relevant intermolecular forces. ***(3 marks)***

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24. CHEMISTRY, M7 EQ-Bank 22

Calculate the mass of methanol that must be burnt to increase the temperature of 325 g of water by 65°C, if exactly half of the heat released by this combustion is lost to the surroundings.

The heat of combustion of methanol is 726 kJ mol^{-1}. ***(3 marks)***

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25. CHEMISTRY, M7 EQ-Bank 24

Primary, unbranched alcohols and alkanes of the same carbon length have quite different boiling points.

Explain the difference in boiling point of these organic compounds, showing all intermolecular forces. Support your answer with diagrams. ***(4 marks)***

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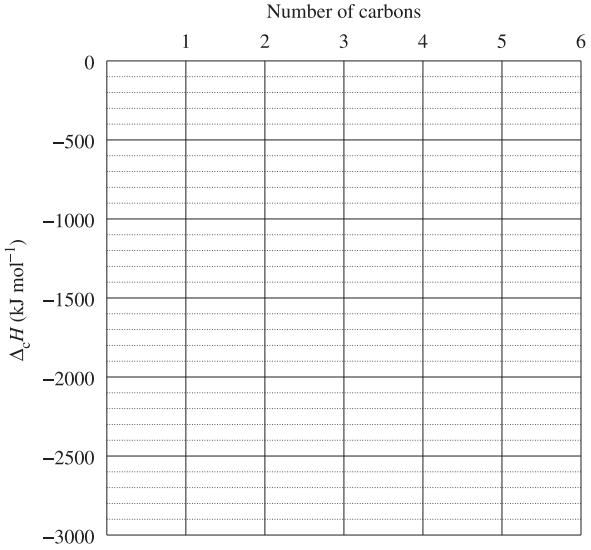
26. CHEMISTRY, M7 2022 HSC 29

The enthalpies of combustion of four alcohols were determined in a school laboratory.

The results are shown in the table.

Alcohol	$\Delta_c H$ (kJ mol^{-1})
Methanol	–596
Ethanol	–978
Propan-1-ol	–1507
Pentan-1-ol	–2910

a. Plot the results, including a curved line of best fit, to estimate the enthalpy of combustion of butan-1-ol. ***(3 marks)***



Enthalpy of combustion of butan-1-ol ____

b. The published value for the enthalpy of combustion of pentan-1-ol is closer to -3331 kJ mol^{-1}.

Justify ONE possible reason for the difference between the school's results and published values. ***(2 marks)***

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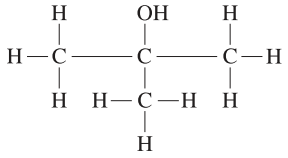
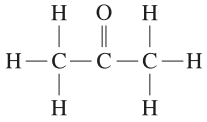
27. CHEMISTRY, M7 2019 HSC 21

a. The structural formula for 2-methylpropan-2-ol is shown in the table.

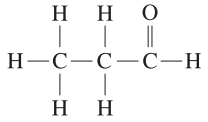
Draw one structural isomer of this alcohol and state its name. ***(2 marks)***

	Alcohol	*Isomer*
Structure		
Name	2-methylpropan-2-ol	

b. The structural formulae for two compounds are shown below.



Isomer A



Isomer B

Why are these two compounds classed as functional group isomers? ***(2 marks)***

c. A chemical test is required to distinguish between the isomers in part (b).

Identify a suitable test and explain the expected observations. ***(3 marks)***

28. CHEMISTRY, M8 2022 HSC 27

A bottle labelled 'propanol' contains one of two isomers of propanol.

a. Draw the TWO isomers of propanol. ***(2 marks)***

b. Describe how ^{13}C NMR spectroscopy might be used to identify which isomer is in the bottle. ***(2 marks)***

c. Each isomer produces a different product when oxidised.

Write equations to represent the oxidation reactions of the two isomers. Include reaction conditions. ***(3 marks)***

29. CHEMISTRY, M7 2016 HSC 23

A spirit burner containing ethanol was used to heat water in a conical flask for three minutes to measure the molar heat of combustion of ethanol.

The results from the investigation are shown.

Time (min)	0	0.5	1.5	2.0	2.5	3.0	3.5	4.5	5.0
Temperature of water (°C)	18.5	20.5	25.0	27.0	29.5	31.0	30.5	28.5	27.5

a. On the grid, draw a line graph to represent the data contained in the table. ***(3 marks)***

b. The following values were also recorded during the investigation:

Initial mass of spirit burner = 236.14 g

Final mass of spirit burner = 235.56 g

Calculated experimental molar heat of combustion of ethanol = – 827 kJ mol^{-1}.

Using information from the previous page and the above values, determine the mass of water that was in the conical flask. ***(3 marks)***

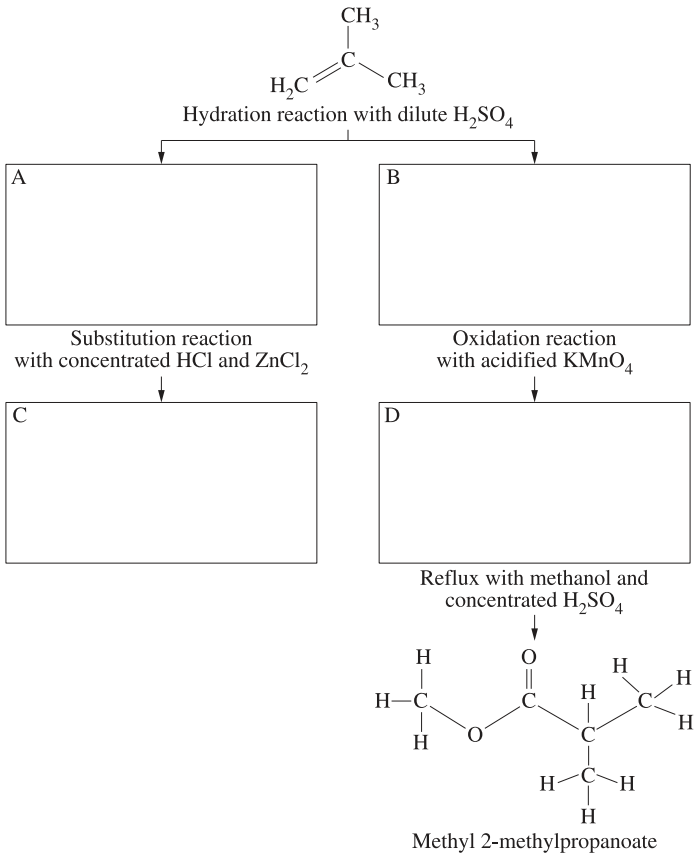
30. CHEMISTRY, M7 2017 HSC 28a

Outline TWO advantages and TWO disadvantages of using ethanol as an alternative fuel for motor vehicles. ***(4 marks)***

31. CHEMISTRY, M7 2021 HSC 26

A sequence of chemical reactions, starting with 2-methylprop-1-ene, is shown in the flow chart.

a. Complete the flow chart by drawing structural formulae for compounds A, B, C, and D. ***(4 marks)***



b. Reflux is used in the synthesis of methyl 2-methylpropanoate.

Provide TWO reasons for using this technique. ***(2 marks)***

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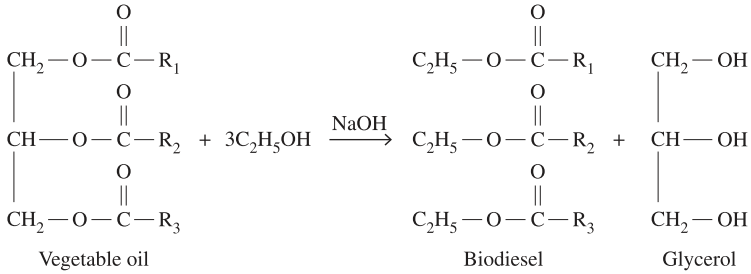
32. CHEMISTRY, M7 2020 HSC 24

Biodiesel, an alternative fuel to diesel, may be produced from vegetable oil. The chemical reaction which converts oils from biomass into biodiesel is shown. R_1, R_2 and R_3 are alkyl chains which may vary from 10 to 22 carbons in length.



a. Which functional group is present in both the oil and the biodiesel? ***(1 mark)***

b. Explain why biodiesel $(C_{14}H_{30}O_2)$ produces less soot than diesel $(C_{18}H_{38})$ when combusted under the same conditions. Support your answer with balanced chemical equations. ***(3 marks)***

c. The energy densities of biodiesel and diesel are 38 MJ kg^{-1} and 43 MJ kg^{-1} respectively. The densities of biodiesel and diesel are 0.90 kg L^{-1} and 0.83 kg L^{-1} respectively.

When 60.0 L of diesel is combusted in a typical engine, 2141 MJ of energy is released.

What volume of biodiesel would be required to produce the same amount of energy? ***(2 marks)***

d. Explain TWO advantages and TWO disadvantages of using bioethanol (ethanol produced from biomass) as an alternative to a fossil fuel. ***(4 marks)***

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33. CHEMISTRY, M7 2017 HSC 28b

The molar heat of combustion (ΔH_c) for ethanol is 1360 kJ mol^{-1}.

Calculate the energy generated per kg of CO_2 released by the combustion of ethanol. ***(3 marks)***

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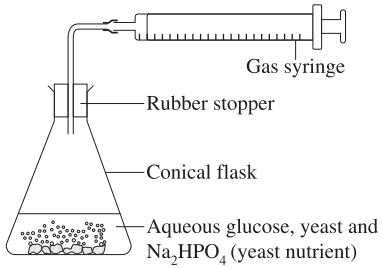
34. CHEMISTRY, M7 2021 HSC 25

A student conducted an experiment in the school laboratory under standard laboratory conditions (25°C, 100 kPa) to determine the volume of carbon dioxide gas produced during the fermentation of glucose. The following apparatus was set up.



The following data were collected.

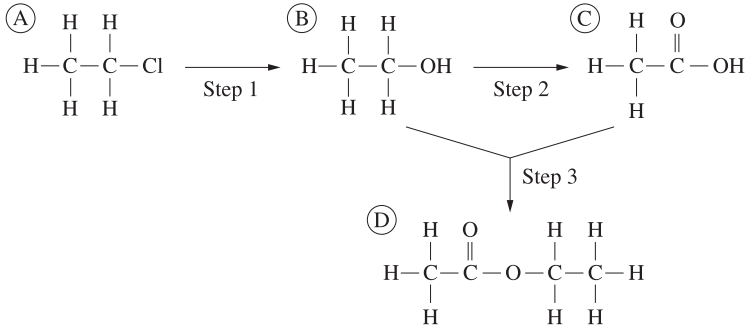
Day	*Total volume of gas* (mL)
1	489
2	677
3	899
4	1006
5	1006

Assume the total volume of gas produced was due to the production of carbon dioxide.

Calculate the mass of ethanol produced by the fermentation reaction. Include a relevant chemical equation in your answer. ***(4 marks)***

35. CHEMISTRY, M7 2019 HSC 34

The following reaction scheme can be used to synthesise ethyl ethanoate.



Outline the reagents and conditions required for each step and how the product of each step could be identified. ***(7 marks)***

36. CHEMISTRY, M6 2021 HSC 35

A manufacturer requires that its product contains at least 85% v/v ethanol.

The concentration of ethanol in water can be determined by a back titration. Ethanol is first oxidised to ethanoic acid using an excess of acidified potassium dichromate solution.

$$3\,C_2H_5OH(aq) + 2\,Cr_2O_7^{2-}(aq) + 16\,H^+(aq) \longrightarrow 3\,CH_3COOH(aq) + 4\,Cr^{3+}(aq) + 11\,H_2O(l)$$

The remaining dichromate ions are reacted with excess iodide ions to produce iodine (I_2)

$$Cr_2O_7^{2-}(aq) + 14\,H^+(aq) + 6I^-(aq) \longrightarrow 2\,Cr^{3+}(aq) + 7\,H_2O(l) + 3\,I_2(aq)$$

The iodine produced is then titrated with sodium thiosulfate $(Na_2S_2O_3)$.

$$I_2(aq) + 2\,S_2O_3^{2-}(aq) \longrightarrow 2\,I^-(aq) + S_4O_6^{2-}(aq)$$

A 25.0 mL sample of the manufacturer's product was diluted with distilled water to 1.00 L. A 25.0 mL aliquot of the diluted solution was added to 20.0 mL of 0.500 mol L^{-1} acidified potassium dichromate solution in a conical flask. Potassium iodide (5.0 g) was added and the solution titrated with 0.900 mol L^{-1} sodium thiosulfate. This was repeated three times.

The following results were obtained.

Time	*Volume of* $Na_2S_2O_3(aq)$ *added* (mL)
1	29.9
2	28.7
3	28.4
4	28.6

The density of ethanol is 0.789 g mL^{-1}.

Does the sample meet the manufacturer's requirements? Support your answer with calculations. ***(7 marks)***

Worked Solutions

1. CHEMISTRY, M7 2018 HSC 10 MC

→ The dehydration of an alkanol $(\mathrm{C_2H_5OH})$ uses a concentrated acid catalyst to produce an alkene $(\mathrm{C_2H_4})$ and water.

$\Rightarrow D$

---

2. CHEMISTRY, M7 2015 HSC 17 MC

$\mathrm{C_6H_{12}O_6} \longrightarrow 2\,\mathrm{CO_2} + 2\,\mathrm{C_2H_5OH}$

$$\mathrm{n(C_6H_{12}O_6)} = \frac{10.3}{6 \times 12.01 + 12 \times 1.008 + 6 \times 16} = \frac{10.3}{180.156} = 0.057\,\mathrm{mol}$$

$\mathrm{n(CO_2)} = 2 \times \mathrm{n(C_6H_{12}O_6)} = 0.114\,\mathrm{mol}$

$\mathrm{Volume\ (CO_2)} = 0.114 \times 24.79 = 2.83\,\mathrm{L}$

$\Rightarrow D$

---

3. CHEMISTRY, M7 2016 HSC 15 MC

→ Compound W is unsaturated (C–C multiple bonds exist).

→ Compound X is saturated (all C–C bonds are single bonds).

→ Shorter alcohols, such as $\mathrm{CH_3OH}$ are more soluble.

$\Rightarrow A$

---

4. CHEMISTRY, M7 2016 HSC 5 MC

→ In a solution of ethanol and water, hydrogen bonding (strongest intermolecular force) occurs between the partially negative oxygen end of the ethanol molecule and the partially positive hydrogen end of a water molecule.

$\Rightarrow B$

---

5. CHEMISTRY, M7 2019 HSC 9 MC

→ Carboxyllic acids have a high affinity for hydrogen bonding, the strongest molecular force.

→ They therefore require more heat to break the intermolecular forces to convert liquid to gas versus other substances.

$\Rightarrow B$

Worked Solutions

6. CHEMISTRY, M7 2021 HSC 13 MC

By elimination:

→ Hydration reaction is an addition reaction that can only occur on alkenes, thus X = prop-1-ene (eliminate A and B)

→ Y = propan-2-ol

→ The oxidation of secondary alcohol creates a ketone, thus Z = propanone

$\Rightarrow C$

---

7. CHEMISTRY, M7 2021 HSC 7 MC

→ The product of the substitution reaction between methanol and hydrogen bromide is bromomethane.

→ Methanol contains an OH functional group and thus can form strong hydrogen bonds.

→ Bromomethane can only form dipole-dipole forces which are weaker than hydrogen bonds. As a result, bromomethane requires less energy to break these intermolecular forces, resulting in a lower boiling point than methanol.

$\Rightarrow A$

---

8. CHEMISTRY, M7 2022 HSC 11 MC

When alcohols are dehydrated using concentrated $\mathrm{H_2SO_4}$, an OH group and a H atom from the adjacent carbon is eliminated to form an alkene.

$\Rightarrow B$

---

9. CHEMISTRY, M7 2023 HSC 10 MC

→ Compounds with functional groups capable of hydrogen bonding have higher boiling points (due to stronger bonds, more energy is required to break)

$\Rightarrow A$

---

10. CHEMISTRY, M7 2023 HSC 15 MC

→ The boiling point of straight-chained alcohols increases with their chain length.

→ Therefore the boiling point of Propan-1-ol will exist between Ethanol and Butan-1-ol

$\Rightarrow B$

---

11. CHEMISTRY, M7 2024 HSC 13 MC

$$\frac{-2057.8 \text{ kJ mol}^{-1}}{x \text{ g mol}^{-1}} = -48.9 \text{ kJ g}^{-1}$$

$$x \text{ g mol}^{-1} = \frac{-2057.8 \text{ kJ mol}^{-1}}{-48.9 \text{ kJ g}^{-1}}$$

$$= 42.1 \text{ g mol}^{-1}$$

$\Rightarrow C$

---

12. CHEMISTRY, M7 2024 HSC 5 MC

→ Can use an oxidation reaction to determine the unknown substance.

→ 2-methylpropan-1-ol is a primary alcohol whereas 2-methylpropan-2-ol is a tertiary alcohol.

→ Hence when undergoing oxidation with acidified potassium permanganate solution, the solution containing the primary alcohol will oxidise and experience a colour change from purple to colourless. The tertiary alcohol will not undergo oxidation.

$\Rightarrow D$

---

13. CHEMISTRY, M7 2015 HSC 10 MC

→ Incomplete combustion produces carbon and/or carbon monoxide (eliminate B and C).

♦ Mean mark 44%.

→ Option D is not balanced (oxygen atoms do not equate)

$\Rightarrow A$

---

14. CHEMISTRY, M7 2015 HSC 20 MC

$q = mC\Delta T \quad \Rightarrow \quad m = \dfrac{q}{C\Delta T}$

♦ Mean mark 51%.

$$m = \frac{4638 \times 10^3}{\left(4.18 \times 10^3\right) \times (45 - 20)}$$

$$= 44.38 \text{ J per } 116.2 \text{ g heptan-1-ol}$$

$$= \frac{44.38}{116.2}$$

$$= 0.38 \text{ kg}$$

$\Rightarrow D$

---

15. CHEMISTRY, M7 2016 VCE 24 MC

♦ Mean mark 40%.

Consider option B:

→ 1 mole of CH_3OH produces 725 kJ of heat energy

→ $\text{MM } (\text{CH}_3\text{OH}) = 32.0 \text{ grams}$

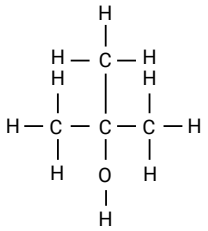
→ Heat energy of 1 gram $\text{CH}_3\text{OH} = \dfrac{725}{32.0} = 22.7$ kJ

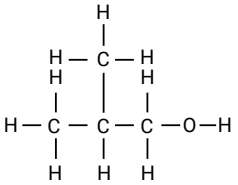
$\Rightarrow B$

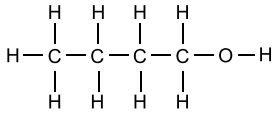
---

16. CHEMISTRY, M7 2015 VCE 5b

Possible images include:







17. CHEMISTRY, M7 2019 HSC 23

a. $$\begin{aligned} \text{n(ethanol)} &= \frac{\text{m}}{\text{MM}} \\ &= \frac{0.370}{46.068} \\ &= 0.008032 \text{ mol} \end{aligned}$$

$$q = mC\Delta T = 105 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ K}^{-1} \times (30 - 18.5) \text{ K} = 5047.35 \text{ J}$$

$$\begin{aligned} (\Delta_c H) &= -\frac{q}{n} \\ &= -\frac{5047.35}{0.008032} \\ &= -628\ 405 \text{ J mol}^{-1} \\ &= -628 \text{ kJ mol}^{-1} \quad (3 \text{ sig fig}) \end{aligned}$$

b. Improvement to experiment accuracy (one of many possible answers):

→ The molar enthalpy of combustion measured in the experiment was not very accurate due to heat being lost to the surroundings.

→ To improve the accuracy, it would be helpful to move the spirit burner closer to the beaker to reduce heat loss.

18. CHEMISTRY, M7 2018 HSC 24

a. $\text{C}_6\text{H}_{12}\text{O}_6\,(\text{aq}) \longrightarrow 2\,\text{C}_2\text{H}_5\text{OH}\,(\text{l}) + 2\,\text{CO}_2\,(\text{g})$

Mean mark (a) 57%.

b. $\text{Vol}(\text{CO}_2) = 5.5 \div 1000 = 0.0055\,\text{L}$

$$\text{n}(\text{CO}_2) = \frac{\text{V}(\text{CO}_2)}{24.79} = 2.2186 \times 10^{-4}\,\text{mol}$$

$$\text{n}(\text{C}_6\text{H}_{12}\text{O}_6) = \frac{1}{2} \times \text{n}(\text{CO}_2) = 1.1093 \times 10^{-4}\,\text{mol}$$

$$\text{MM}(\text{C}_6\text{H}_{12}\text{O}_6) = (6 \times 12.01 + 12 \times 1.008 + 6 \times 16.00) = 180.156$$

$$\text{m}(\text{C}_6\text{H}_{12}\text{O}_6) = 1.1093 \times 10^{-4} \times 180.156 = 0.020\,\text{g}$$

19. CHEMISTRY, M7 2019 HSC 32

→ The boiling point of a compound increases with an increase in the number of carbon atoms due to the increase in dispersion forces.

→ Alcohols have higher boiling points than thiols with the same number of carbon atoms due to the stronger hydrogen bonding in alcohols compared to the weaker dispersion forces in thiols.

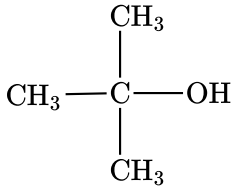
→ As the chain length increases, the difference in boiling point between alcohols and thiols decreases because hydrogen bonding becomes a smaller contributor to the total intermolecular forces and the increasing strength of dispersion forces becomes more significant.

→ Methanol has hydrogen bonding as the dominant intermolecular force, while methanethiol has dipole-dipole forces as the dominant intermolecular force, resulting in a lower boiling point for methanethiol.

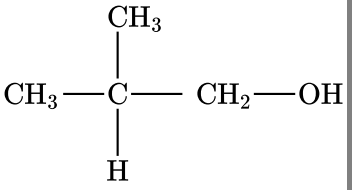
→ As the chain length increases, the thiols have a greater increase in boiling point due to their higher molecular mass and stronger dispersion forces compared to the alcohols.

20. CHEMISTRY, M7 2020 HSC 29

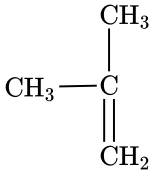
(A)



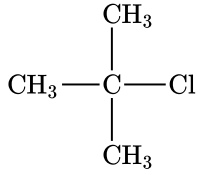
(B)



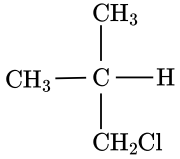
(C)



(D)



(E)



21. CHEMISTRY, M7 2023 HSC 25

a. Find the heat absorbed by the water ((\q\)):

$$
\begin{aligned}
q &= mc\Delta T \\
&= 205 \times 4.18 \times 36.7 \\
&= 31\ 488.23\ \text{J} \\
&= 31.448\ \text{kJ}
\end{aligned}
$$

$$
\begin{aligned}
&\text{octan-1-ol} \Rightarrow \text{C}_8\text{H}_{18}\text{O} \\
&\text{MM}(\text{C}_8\text{H}_{18}\text{O}) = 12.01 \times 8 + 1.008 \times 18 + 16 = 130.224
\end{aligned}
$$

$$
\begin{aligned}
\text{n}(\text{octan-1-ol}) &= \frac{-31.448\ \text{kJ}}{-5294\ \text{kJ mol}^{-1}} \\
&= 5.94 \times 10^{-3}\ \text{mol}
\end{aligned}
$$

$$
\begin{aligned}
\text{m}(\text{octan-1-ol}) &= 5.94 \times 10^{-3} \times 130.224 \\
&= 0.774\ \text{g}
\end{aligned}
$$

b. Advantage of biofuel vs fossil fuel

→ Combustion of biofuels derived from plants will have a lower greenhouse impact as the carbon dioxide released during combustion will replace that used in photosynthesis, unlike fossil fuels.

Other answers could include:

→ Biofuels are biodegradable and therefore pose a much reduced environmental threat than fossil fuels which are not.

→ Biofuels are more sustainable than fossil fuels as they are produced from renewable resources.

---

22. CHEMISTRY, M7 2023 HSC 27

$$
\begin{aligned}
&\text{Density}(\rho) = \frac{\text{m}}{\text{V}} \quad \Rightarrow \quad \text{m} = \rho \times \text{V} \\
&\text{m}(\text{ethanol}) = 0.789 \times 185 = 146\ \text{g} \\
&\text{n}(\text{ethanol}) = \frac{\text{m}}{\text{MM}} = \frac{146}{46.068} = 3.17\ \text{mol} \\
&\text{V} = \frac{\text{n}RT}{P} \\
&\quad = \frac{3.17 \times 8.314 \times 310}{100} \\
&\quad = 81.7\ \text{L}
\end{aligned}
$$

---

23. CHEMISTRY, M7 2023 HSC 29

→ The graph shows a non-linear relationship with the following clear trend, as the molar mass increases, solubility decreases.

→ When molar mass increases, the chain length of a molecule increases. Hence, as the chain length of alkan-1-ols increase, their solubility in water decreases.

→ Shorter chain alcohols dissolve more readily in water. This is due to the formation of hydrogen bonds between the hydroxyl group of the alcohol and water molecules.

→ However, as the chain length of alkan-1-ols increase, the dispersion forces between the alkyl groups become stronger, decreasing their solubility.

my solution

→ The graph shows a non-linear relationship with the following clear trend, as the molar mass increases, solubility decreases.

→ When molar mass increases, the chain length of a molecule increases. In alkan-1-ols this increases the length of their carbon backbone, increasing their non-polar nature (increased dispersion forces), thus solubility in polar solvents (eg: water) decreases

→ Shorter chain alcohols dissolve more readily in water. This is due to the formation of hydrogen bonds between the hydroxyl group of the alcohol and water molecules and the comparatively polar nature of the molecule compared top long-chained alkan-1-ols

→ However, as the chain length of alkan-1-ols increase, the dispersion forces between the alkyl groups become stronger and mitigate the polarity of the hydroxyl group, decreasing their solubility.

---

24. CHEMISTRY, M7 EQ-Bank 22

Using $q = mc\Delta T$:

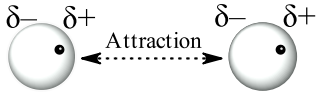
$$
\begin{aligned}
&q = 325 \times 10^{-3} \times 4.18 \times 10^{3} \times 65 = 88\ 302.5\ \text{J} = 88.3025\ \text{kJ} \\
&\text{Methanol heat combustion} = 726\ \text{kJ mol}^{-1}\ \text{(given)} \\
&\text{n}(\text{CH}_3(\text{OH})) = \frac{88.3025}{726} \\
&\text{MM}(\text{CH}_3(\text{OH})) = 12.01 + 3 \times 1.008 + 16 + 1.008 = 32.042 \\
&\text{m}(\text{CH}_3(\text{OH})) = \frac{88.3025}{726} \times 32.042 \\
&\text{Since } 50\% \text{ of heat is lost} \rightarrow \text{twice as much methanol is needed} \\
&\text{m}(\text{CH}_3(\text{OH}))\ \text{initial} = 2 \times \frac{88.3025}{726} \times 32.042 = 7.79\ \text{g}
\end{aligned}
$$

---

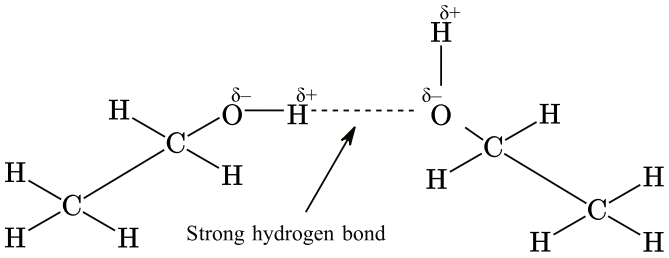
25. CHEMISTRY, M7 EQ-Bank 24

→ Alkanes are saturated hydrocarbons – i.e. they are made up of carbon and hydrogen atoms only and all atoms are joined together by single covalent bonds which are non-polar.

→ Weak intermolecular forces (Van der Waals) are therefore the only forces holding alkane molecules together and as a result, alkanes have low boiling points.



→ In contrast, alcohols have an OH functional group. The OH bond is polar with an oxygen "pole" that is slightly negatively charged and hydrogen "pole" that is slightly positively charged.

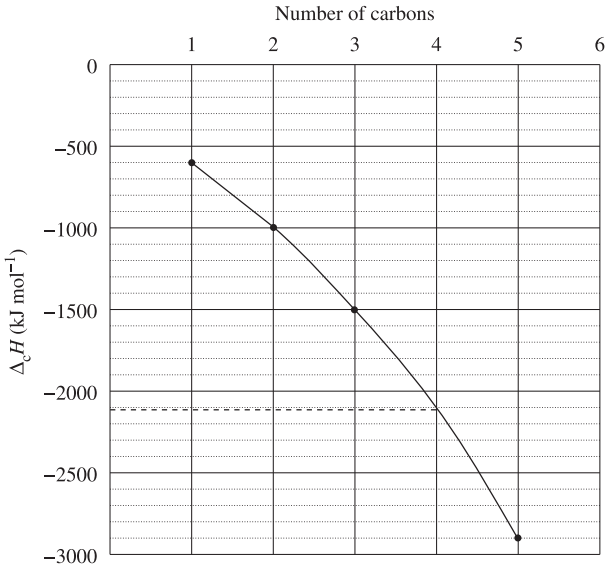


→ The hydrogen atom on one molecule will form an electrostatic bond with the oxygen atom on another atom creating a hydrogen bond.

→ Since hydrogen bonds are much stronger intermolecular forces than dispersion forces, the boiling points of alcohols are significantly higher than those of alkanes with the same carbon lengths.

26. CHEMISTRY, M7 2022 HSC 29

a.



From interpolating the graph, the enthalpy of combustion of butan-1-ol is –2120 kJ mol $^{-1}$.

b. Heat loss to the surroundings.

♦ Mean mark (b) 48%.

→ The school's results are lower in magnitude than the published values because heat is lost to the surroundings, making the measured change in temperature smaller.

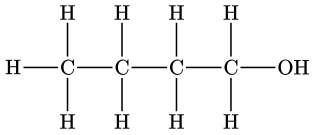
Other possible answers:

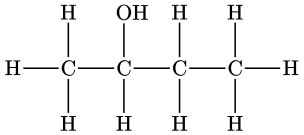
→ Incomplete combustion

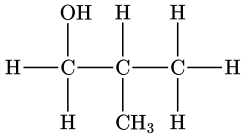
→ Temperature change will be reduced if combustion is incomplete as less heat is released. Enthalpy of combustion will be lower as a result.

27. CHEMISTRY, M7 2019 HSC 21

a. Successful answers should have one of the following:


butan-1-ol


butan-2-ol


2-methylpropan-1-ol

b. Functional Group isomers

→ Both isomers have the same number and type of atoms, but they have different arrangements of those atoms and therefore have different functional groups.

→ Isomer A has a ketone functional group, while isomer B has an aldehyde functional group.

c. Tollens' Test:

♦♦ Mean mark (c) 39%.

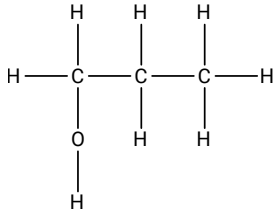
→ The Tollens' test can be used to differentiate between Isomer A (a ketone) and Isomer B (an aldehyde).

→ Isomer B will be readily oxidised to a carboxylic acid, whereas isomer A will not.

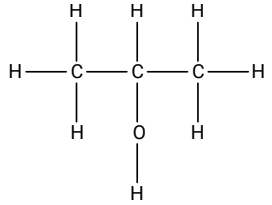
→ As a result, Isomer B will reduce the silver-ions in Tollens' reagent to form a silver mirror inside the test tube, while Isomer A will not react.

28. CHEMISTRY, M8 2022 HSC 27

a. Isomer 1:



Isomer 2:



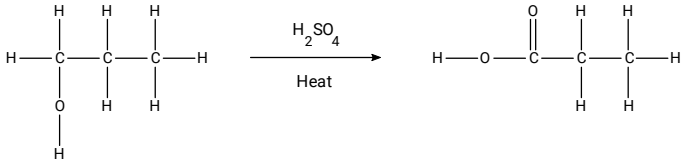
b. Identifying isomers with $^{13}\text{C NMR}$ spectroscopy:

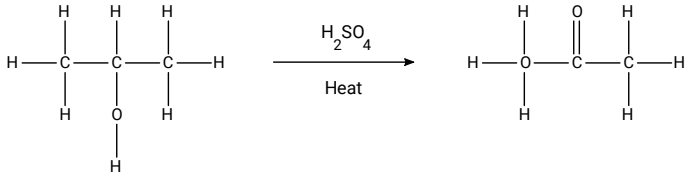
→ this can be used to identify the isomers in the bottle because they show a different number of signals which helps deduce the carbon environment.

→ Propan-1-ol contains 3 C environments so it would have 3 peaks on a $^{13}\text{C NMR}$ spectrum whereas propan-2-ol only contains 2 C environments (due to symmetry), so it would only have 2 signals on a $^{13}\text{C NMR}$ spectrum.

c.

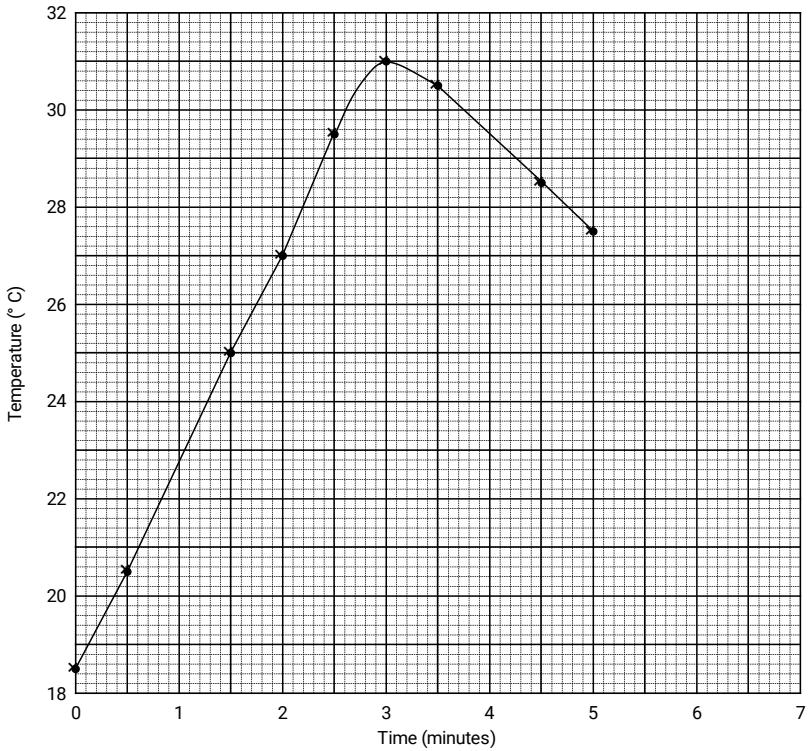
♦ Mean mark (c) 52%.





29. CHEMISTRY, M7 2016 HSC 23

a.



b. Using the graph:

Mean mark (b) 53%.

$\triangle T = 31.0 - 18.5 = 12.5^{\circ}\text{C}$

$\text{m(Ethanol burnt)} = 236.14 - 235.56 = 0.58\ \text{g}$

$$\text{n(Ethanol)} = \frac{\text{m}}{\text{MM}} = \frac{0.58}{2\ \times 12.01 + 6\ \times 1.008 + 16.00} = 0.0126\,\text{mol}$$

$\text{Energy released } (q) = 0.0126\ \times 827 = 10.420\,\text{kJ}$

$$q = -\,mC\triangle T \ \ => \ \ m = -\,\frac{q}{C\triangle T}$$

$$\therefore m(\text{water}) = \frac{10\ 420}{4.18 \times 10^3 \times 12.5} = 0.00019927\ \text{g}$$
$$= 0.199\ \text{kg}$$

30. CHEMISTRY, M7 2017 HSC 28a

♦ Mean mark 52%.

Advantages:

→ Ethanol can be produced from biomass. These renewable sources include crops such as sugarcane as opposed to other fuels such as petrol which come from non-renewable fossil fuels, which are finite resources.

→ Ethanol undergoes complete combustion more easily than octane, producing less soot $(\text{C}\,(\text{s}))$ which can adversely affect the efficiency and running of motors, and less $\text{CO}\,(\text{g})$ which is poisonous.

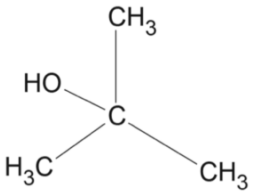
Disadvantages:

→ Ethanol releases less energy, on a mole or per kilogram basis, than octane. This results in a greater mass of fuel being required to supply an equivalent amount of energy.

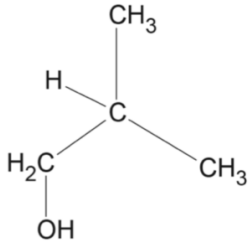
→ Producing ethanol from renewable crops requires a huge amount of arable land. This reduces the availability of land for other crops.

31. CHEMISTRY, M7 2021 HSC 26

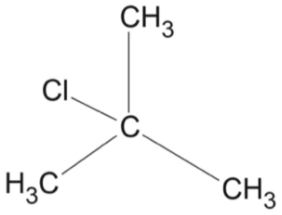
a. Compound A:



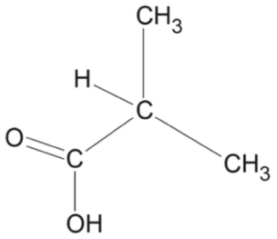
Compound B:



Compound C:



Compound D:



b. Reasons for reflux technique:

♦ Mean mark (b) 46%.

→ Reflux heats the reaction mixture which increases the average kinetic energy, and thus increases the reaction rate.

→ Heating causes the volatile substances to form vapour molecules. Refluxing uses a condenser to cool the vapour molecules into liquids, and thus retains the substances.

32. CHEMISTRY, M7 2020 HSC 24

a. Ester functional group.

♦♦ Mean mark (a) 39%, (b) 49%.

b. $\mathrm{C_{14}H_{30}O_2\,(l)} + \frac{41}{2}\,\mathrm{O_2\,(g)} \longrightarrow 14\,\mathrm{CO_2\,(g)} + 15\,\mathrm{H_2O\,(l)}$

$\mathrm{C_{18}H_{38}\,(l)} + \frac{55}{2}\,\mathrm{O_2\,(g)} \longrightarrow 18\,\mathrm{CO_2\,(g)} + 19\,\mathrm{H_2O\,(l)}$

→ Soot is produced when a fuel source undergoes incomplete combustion due to insufficient oxygen.

→ Since biodiesel already contains oxygen atoms within its structure, it would require less oxygen to undergo complete combustion compared to diesel, and is therefore less likely to produce soot.

c. $\mathrm{m(biodiesel)} = \dfrac{2141}{38} = 56.3\ \mathrm{kg}$

$\mathrm{V(biodiesel)} = \dfrac{56.3}{0.90} = 63\ \mathrm{L}\ \ (\text{nearest L})$

d. Advantages of bioethanol (two examples needed only):

♦ Mean mark (d) 55%.

→ Bioethanol is sustainable because it is produced from renewable resources, whereas petrol is produced from nonrenewable crude oil reserves.

→ Additionally, bioethanol is biodegradable whereas petrol isn't. As a result, bioethanol would pose less of an environmental threat in comparison to petrol.

→ Ethanol produces less airborne particulates that are associated with lung cancer.

Disadvantages of bioethanol (two examples needed only):

→ Bioethanol requires a large amount of arable land in order to grow crops to produce bioethanol. Thus, it would lead to soil erosion and environmental pollution.

→ More energy is also required to produce bioethanol because of the requirement for labour, fertilisation, and distillation of ethanol from fermentation.

→ If fossil fuels are used as the energy source within the manufacturing process of biofuel, it will not achieve carbon neutrality and will contribute to global warming.

33. CHEMISTRY, M7 2017 HSC 28b

$$\mathrm{C_2H_5OH\,(l) + 3\,O_2\,(g) \longrightarrow 2\,CO_2\,(g) + 3\,H_2O\,(g)}$$

♦ Mean mark 48%.

$$\mathrm{m(CO_2) = 12.01 + 2 \times 16.00 = 44.01\,g\,mol^{-1}}$$

$$\mathrm{n(CO_2) = \frac{1000}{44.01} = 22.72\,mol}$$

$$\mathrm{n(C_2H_5OH) = \frac{22.72}{2} = 11.36\,mol}$$

$$\therefore \text{ Energy per kg } \mathrm{CO_2} = 11.36 \times 1360$$

$$= 15\ 450 \text{ kJ}$$

34. CHEMISTRY, M7 2021 HSC 25

The fermentation reaction:

$$\mathrm{C_6H_{12}O_6}(aq) \rightarrow 2\mathrm{C_2H_5OH}(aq) + 2\mathrm{CO_2}(g)$$

♦ Mean mark 55%.

$$\mathrm{v_{(CO_2)} = 1006\ mL = 1.006\ L}$$

$$\mathrm{n_{(CO_2)} = \frac{v}{V_m} = \frac{1.006}{24.79} = 0.04058087939\ mol}$$

$$\mathrm{n_{(C_2H_5OH)} = n_{(CO_2)} = 0.04058087939\ mol}$$

$$\mathrm{m_{(C_2H_5OH)} = n \times MM}$$

$$= 0.04058087939 \times 46.068$$

$$= 1.869 \text{ g}$$

35. CHEMISTRY, M7 2019 HSC 34

♦♦ Mean mark 38%.

Step 1:

→ To synthesise chloroethane (A) into ethanol (B), NaOH is added and heated. $\mathrm{KMnO_4\ /\ H^+}$ is then added and heated.

→ The mixture is then treated with concentrated sulfuric acid and refluxed.

→ Ethanol (B) can be identified using infrared spectroscopy by looking for a broad absorption between 3230 $\mathrm{cm^{-1}}$ and 3550 $\mathrm{cm^{-1}}$, which indicates the presence of an $\mathrm{O-H}$ bond. This absorption would not be present in chloroethane (A).

→ Alternative ways to identify ethanol include: mass spectrum analysis (single ion peak at m/z = 46), reactivity tests, and $^1\mathrm{H\ NMR}$ spectrum analysis (3 signals vs 2 for chloroethane).

Step 2:

→ Ethanol (B) can be converted into ethanoic acid (C) by combining it with a strong oxidant like sodium carbonate, which produces carbon dioxide bubbles, confirming the presence of a carboxylic acid.

→ Ethanol will not react as above and the compounds can be distinguished.

→ Alternative ways to identify ethanoic acid include: IR or $^{13}\mathrm{C\ NMR}$ spectrum analysis, litmus indicators, mass spectrum analysis (ion peak at m/z = 60 vs m/z = 46)

Step 3

→ Ethyl ethanoate (D) can be synthesised by heating a mixture of ethanol, ethanoic acid and concentrated sulfuric acid under reflux.

→ A $^1\mathrm{H\ NMR}$ spectrum can be used to identify ethyl ethanoate as it will have 3 signals versus ethanol and ethanoic acid that will only have 2 each.

→ Alternative ways to identify ethyl ethanoate include: a distinct smell, no $\mathrm{O-H}$ peaks in the IR spectrum or mass spectrum analysis (ion peak at m/z = 102).

$$\begin{aligned}\text{V}_{\text{avg}}\ (\text{Na}_2\text{S}_2\text{O}_3) &= \frac{28.7 + 28.4 + 28.6}{3} \\ &= 28.5666\ldots\ \text{mL} \\ &= 0.0285666\ldots\ \text{L}\end{aligned}$$

♦♦♦ Mean mark 39%.

→ The first titration is an outlier and so is excluded from the average.

$\text{n}(\text{Na}_2\text{S}_2\text{O}_3) = \text{c} \times \text{V} = 0.900 \times 0.0285666\ldots = 0.02571\ \text{mol}$

$\text{n}({\text{S}_2\text{O}_3}^{2-}) = \text{n}(\text{Na}_2\text{S}_2\text{O}_3) = 0.02571\ \text{mol}$

I_2 and ${\text{S}_2\text{O}_3}^{2-}$ are in a $1:2$ ratio:

$\text{n}(\text{I}_2) = \frac{1}{2} \times \text{n}(\text{S}_2\text{O}_3^{2-}) = \frac{1}{2} \times 0.02571 = 0.012855\ \text{mol}$

Excess ${\text{Cr}_2\text{O}_7}^{2-}$ and I_2 are in $1:3$ ratio:

$\text{n}({\text{Cr}_2\text{O}_7}^{2-})\ \text{excess} = \frac{1}{3} \times \text{n}(\text{I}_2) = \frac{1}{3} \times 0.012855 = 0.004285\ \text{mol}$

$\text{n}({\text{Cr}_2\text{O}_7}^{2-})\ \text{initial} = \text{c} \times \text{V} = 0.500 \times \frac{20}{1000} = 0.01\ \text{mol}$

$\text{n}({\text{Cr}_2\text{O}_7}^{2-})\ \text{reacted with ethanol}$

$= \text{n}({\text{Cr}_2\text{O}_7}^{2-})\ \text{initial} - \text{n}({\text{Cr}_2\text{O}_7}^{2-})\ \text{excess}$

$= 0.01 - 0.004285$

$= 0.005715\ \text{mol}$

$\text{n}(\text{C}_2\text{H}_5\text{OH}) = \frac{3}{2} \times \text{n}({\text{Cr}_2\text{O}_7}^{2-}) = \frac{3}{2} \times 0.005715 = 0.0085725\ \text{mol}$

$\text{m}(\text{C}_2\text{H}_5\text{OH}) = \text{n} \times \text{MM} = 0.0085725 \times (2 \times 12.01 + 6 \times 1.008 + 16.00) = 0.3949\ \text{g}$

→ Thus, 0.3949 g of ethanol is in a diluted 25 mL solution.

Find the mass of ethanol in the original solution:

$\text{m}(\text{C}_2\text{H}_5\text{OH})\ \text{original} = 0.3949\ldots \times \frac{1000}{25} = 15.796\ldots\ \text{g}$

$\text{D} = \frac{\text{m}}{\text{V}} \quad \Rightarrow \quad \text{V} = \frac{\text{m}}{\text{D}}$

$\text{V}(\text{C}_2\text{H}_5\text{OH}) = \frac{15.796}{0.789} = 20.021\ \text{mL}$

$\%\ (\text{C}_2\text{H}_5\text{OH}) = \frac{\text{V(ethanol)}}{\text{V(sample)}} = \frac{20.021}{25.0} = 80.08\ldots\%\ \text{v/v}$

→ Therefore, the product doesn't meet the manufacturer's requirement as the concentration is less than 85%.