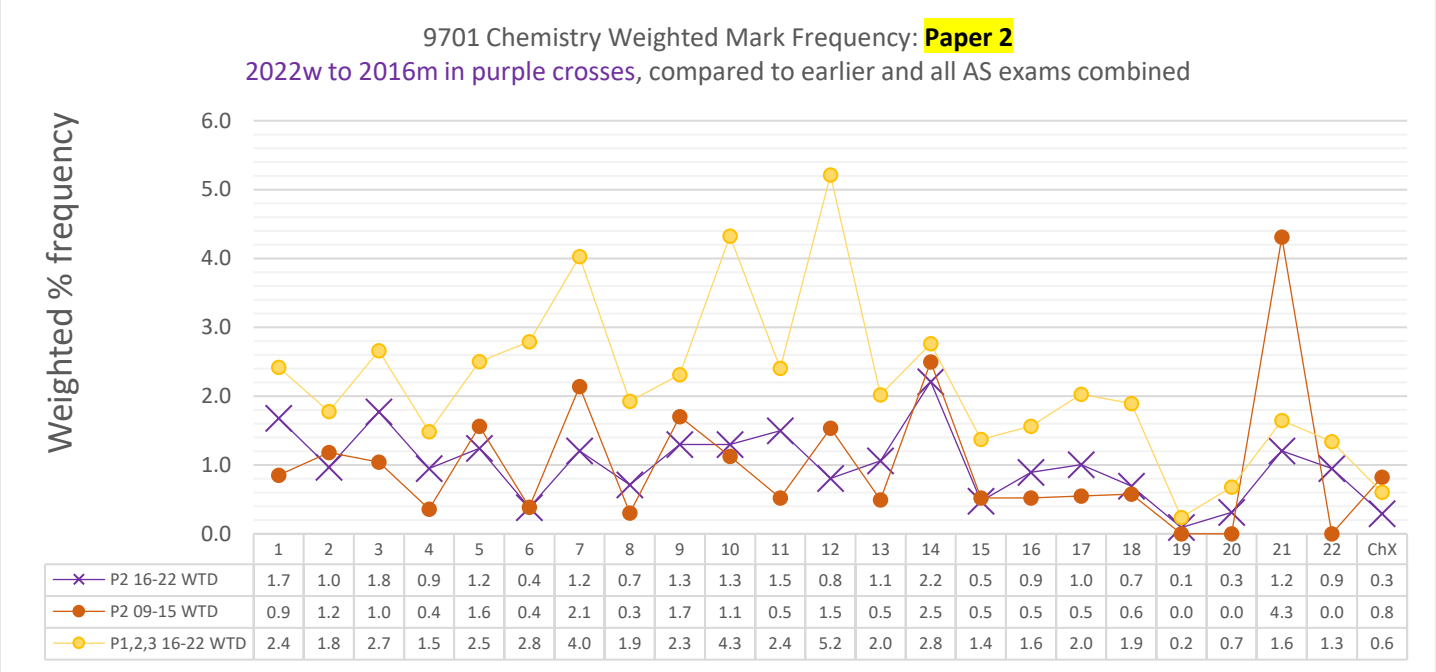
Name: Class: Date:

ALvl Chem 18 EQ P2 22w to 09s Paper 2 Carboxylic acids and derivatives 59marks

As you start and work through this worksheet you can tick off your progress to show yourself how much you have done, and what you need to do next. The first task is just to read the first question and should take you less than one minutes to complete.

Paper 2 Topic Checklist Tick each task off as you go along	RANK:	P1 Noob	P1 Novice	P1 Bronze	P1 Silver	P1 Gold	P1[1] Winner	P1 Hero	P1 Legend
		1 Q started	1 Q done	10% of marks	25% of marks	40% of marks	50% of marks	75% of marks	100% of marks
Topic (marks)	59		3	6	15	24	30	44	59
Time @75s/mark (minutes)	74		4	7	18	30	37	55	74



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	ChX
P2 16-22 WTD	1.7	1.0	1.8	0.9	1.2	0.4	1.2	0.7	1.3	1.3	1.5	0.8	1.1	2.2	0.5	0.9	1.0	0.7	0.1	0.3	1.2	0.9	0.3
P2 09-15 WTD	0.9	1.2	1.0	0.4	1.6	0.4	2.1	0.3	1.7	1.1	0.5	1.5	0.5	2.5	0.5	0.5	0.5	0.6	0.0	0.0	4.3	0.0	0.8
P1,2,3 16-22 WTD	2.4	1.8	2.7	1.5	2.5	2.8	4.0	1.9	2.3	4.3	2.4	5.2	2.0	2.8	1.4	1.6	2.0	1.9	0.2	0.7	1.6	1.3	0.6

What the most thoughtful students will get out of their extensive studying will be a capacity to do meaningful brain-based work even under stressful conditions, which is a part of the self-mastery skillset that will continue to deliver value for the whole of their lives. Outstanding grades will also happen, but the most important goal from skillful action in study is being better at any important task, even if circumstances do not feel ideal.

As you are moving through your studies you can learn more about yourself by trying out new ways to manage yourself, and analysing how effective those new techniques were. In this reflective process not only will you get better at working positively and productively to deliver ambitious and successful outcomes, but you will be working towards one aspect of life's highest pursuit, summarised and inscribed on the Temple of Apollo at Delphi: "know thyself".

1. To complete these questions, as important as your answer, is checking your answer against the mark scheme.
2. For each page or group of 10-20 marks, convert your mark score into a percentage. This will allow you to see (and feel) your progress as you get more experience and understanding with each topic.
3. Multiple choice questions, done carefully where you explain and show yourself your thinking using written notes as you move through each question, can be more useful than just Paper 2 for students aiming for a C or B grade. Paper 2 should be the larger focus for students aiming for A and A* grades, however.
4. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are NOT using the marking scheme correctly; your correct answer might not be fully complete for all the marks you are awarding. The marks easiest to miss rely on providing the largest amount of detail.

[1] **DO NOT** work on these higher levels of completion in your AS year unless you have also achieved at least a "**Silver**" (25%) in the same topic in **Paper 1**, which tend also to be easier questions, as well as ""**Silver**" (25%) in the same topic, if it exists, in Paper 3.

18 Carboxylic acids and derivatives

18.1 Carboxylic acids

Learning outcomes

Candidates should be able to:

1 recall the reactions by which carboxylic acids can be produced:
   (a) oxidation of primary alcohols and aldehydes with acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ and refluxing
   (b) hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification
   (c) hydrolysis of esters with dilute acid or dilute alkali and heat followed by acidification

2 describe:
   (a) the redox reaction with reactive metals to produce a salt and $H_2(g)$
   (b) the neutralisation reaction with alkalis to produce a salt and $H_2O(l)$
   (c) the acid–base reaction with carbonates to produce a salt and $H_2O(l)$ and $CO_2(g)$
   (d) esterification with alcohols with concentrated H_2SO_4 as catalyst
   (e) reduction by $LiAlH_4$ to form a primary alcohol

18.2 Esters

Learning outcomes

Candidates should be able to:

1 recall the reaction (reagents and conditions) by which esters can be produced:
   (a) the condensation reaction between an alcohol and a carboxylic acid with concentrated H_2SO_4 as catalyst

2 describe the hydrolysis of esters by dilute acid and by dilute alkali and heat

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(b) **V** contains two types of functional group: a carboxylic acid and an alkene.

(i) Describe a chemical test and observation which confirms the presence of a carboxyl functional group.

.....

..... [2]

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(b) **K** is used to make the addition polymer Perspex®. A synthesis of Perspex® is shown in Fig. 4.2.

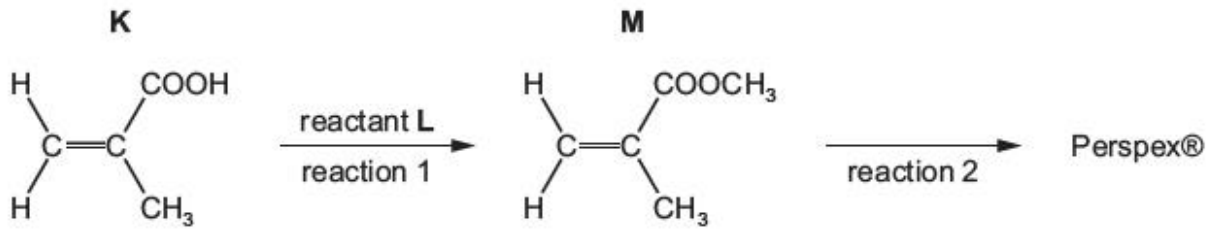

Fig. 4.2

(i) Identify **L**. State the conditions required for reaction 1.

L = ...

conditions = ... [2]

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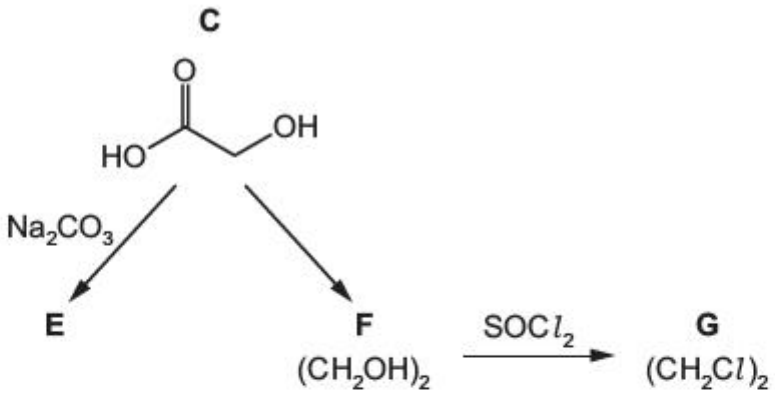
(c) Some other reactions of **C** are shown.



(i) Draw the structure of **E**.

[1]

(ii) Suggest why $NaBH_4$ is not a suitable reagent to make **F**, $(CH_2OH)_2$, from **C**.
Explain your answer.

.....

..... [1]

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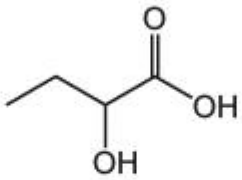
3 The reducing agent $LiAlH_4$ can be synthesised by reacting aluminium chloride with lithium hydride, LiH.

(a) (i) At 200 °C, aluminium chloride exists as $Al_2Cl_6(g)$.

(c) Two students try to prepare 2-hydroxybutanoic acid in the laboratory.

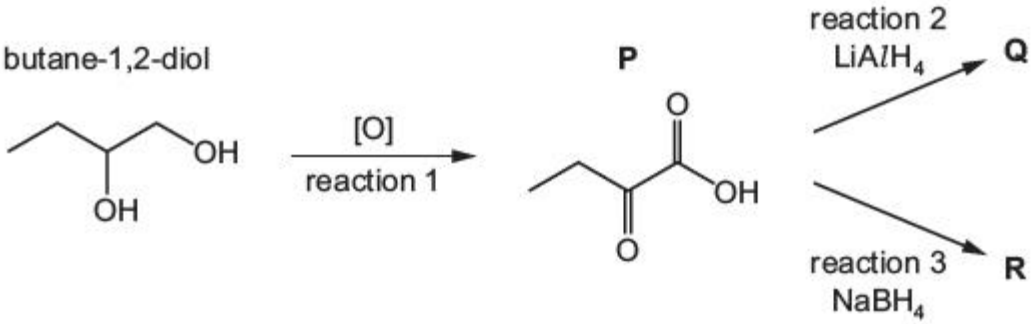
2-hydroxybutanoic acid



Both students oxidise butane-1,2-diol to form **P** in reaction 1.

One student then reduces **P** using $LiAlH_4$. **Q** is formed.

The other student reduces **P** using $NaBH_4$. **R** is formed.



(ii) Only one of the students successfully prepares 2-hydroxybutanoic acid.

Identify which of **Q** or **R** is 2-hydroxybutanoic acid and explain the difference between reactions 2 and 3.

.....

.....

..... [2]

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(f) Propanoic acid, $CH_3CH_2CO_2H$, is reduced by $LiAlH_4$.

(i) Write an equation to show this reaction. Use [H] to represent an atom of hydrogen from the reducing agent.

..... [1]

(ii) Name the organic product formed in this reaction.

..... [1]

(g) Organic compound **W** is an ester which is a structural isomer of propanoic acid.

(i) State the molecular formula of **W**.

..... [1]

(ii) Draw a possible structure of **W**.

[1]

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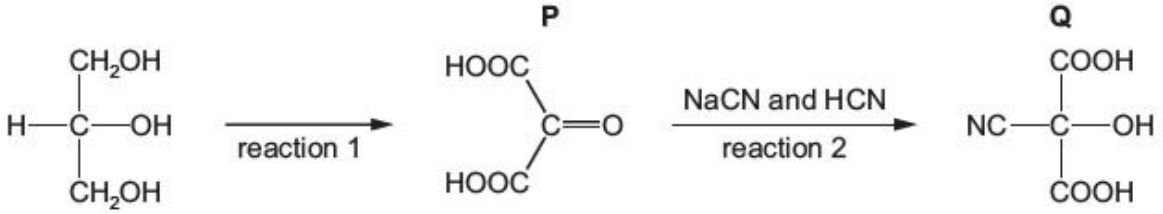
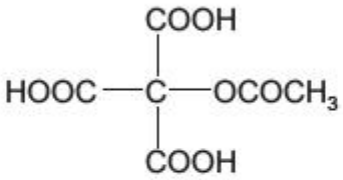
3 Glycerol, $CH_2(OH)CH(OH)CH_2OH$, is widely used in the food industry and in pharmaceuticals.

(a) A series of reactions starting from glycerol is shown.



(v) When **Q** is heated with excess aqueous ethanoic acid in the presence of a catalytic amount of sulfuric acid, two reactions take place to form compound **R**.

R



Identify the two types of reaction that occur.

1 .....

2 .....

[2]

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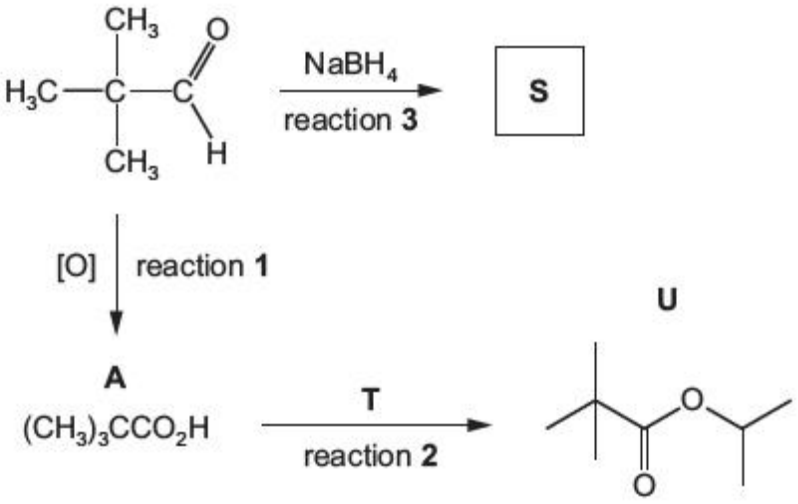
Two reaction sequences are shown.



(b)

(ii) **A**, $(CH_3)_3CCO_2H$, is a solid at room temperature.

B, $CH_3CO_2(CH_2)_2CH_3$, is an isomer of **A**. **B** is a liquid at room temperature.

Explain the difference in the physical states of **A** and **B**, with reference to any intermolecular forces that may exist.

.....

.....

.....

..... [3]

(iv) Draw the structure of the organic molecule **T** that reacts with **A**, $(CH_3)_3CCO_2H$, in reaction **2**, to form **U**.

Suggest a catalyst for reaction **2**.

T

catalyst .....

[2]

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(d) Samples of organic compounds, **A**, **B**, **C** and **D**, are placed in unlabelled bottles.

A	**B**	**C**	**D**
$CH_3CH_2COCH_3$	$CH_3(CH_2)_2CHO$	CH_3CH_2OH	CH_3CO_2H

(i) Identify all of the compound(s), **A**–**D**, that contain a carbonyl group.

..... [1]

(ii) **A**–**D** are reacted separately with the reagents given in the table.

Complete the table to:

- identify which of the compounds, **A**–**D**, reacts with the reagents
- give an appropriate observation when a reaction occurs.

reagent	compounds identified	observation when a reaction occurs
Tollens' reagent		
alkaline solution of iodine		
sodium metal		

[8]

[Total: 15]

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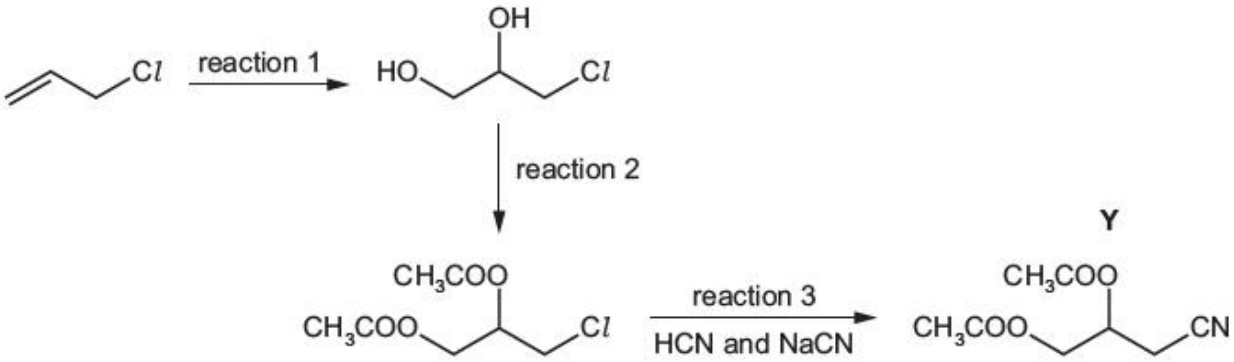
(c) A series of reactions starting from allyl chloride is shown.



(ii) In reaction 2, the organic product of reaction 1 is mixed with concentrated H_2SO_4 and an organic acid, and then heated under reflux.

State the role of the concentrated H_2SO_4. Identify the organic acid used.

role of the concentrated H_2SO_4 .....

identity of the organic acid .....

[2]

(iv) The organic product of reaction 3 is **Y**.

Y can be hydrolysed using excess aqueous H_2SO_4 to form **Z**.

The molecular formula of **Z** is $C_4H_8O_4$.

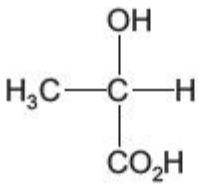
Draw the structure of **Z**.

[2]

Q# 400/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3 Calcium and its compounds have a large variety of applications.

(d) Calcium lactate is used in some medicines. It forms when lactic acid (2-hydroxypropanoic acid) reacts with calcium carbonate.



lactic acid

(i) Identify the **two** other products of the reaction of lactic acid with calcium carbonate.

..... [1]

Q# 401/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

(d) $CH_3(CH_2)_3CO_2H$ is a colourless liquid with an unpleasant odour.

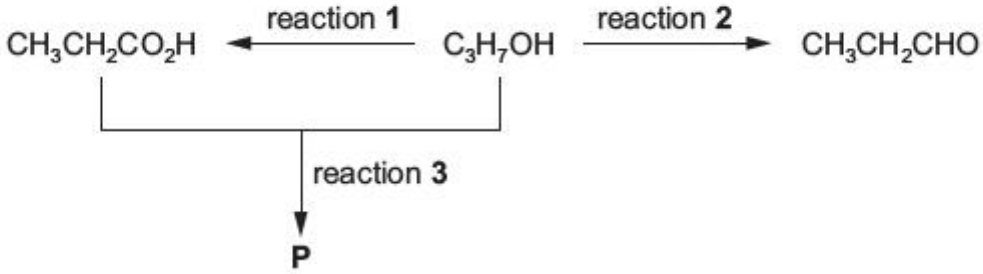
It reacts with methanol in the presence of an acid catalyst to produce an organic product **V**, which has a pleasant fruity smell.

(i) Name **V**.

..... [1]

Q# 402/ ALvl Chemistry/2016/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 A sequence of reactions is shown starting with an alcohol, C_3H_7OH.

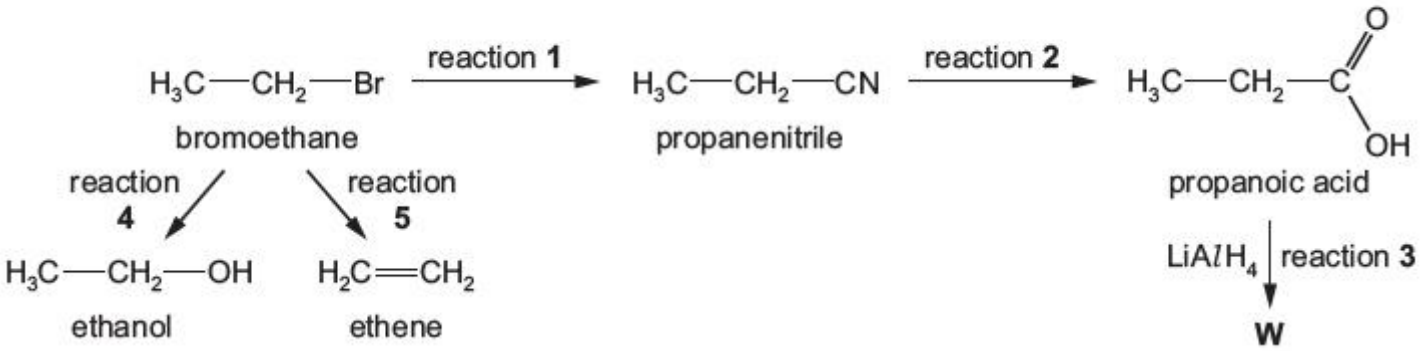


(d) Name **P**, the organic product of reaction **3**.

..... [1]

Q# 403/ ALvl Chemistry/2016/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 A reaction sequence is shown.



(d) Under appropriate conditions, ethanol and propanoic acid undergo a condensation reaction.

(i) State the condition necessary for the reaction.

..... [1]

(ii) Draw the skeletal formula of the organic product of this reaction.

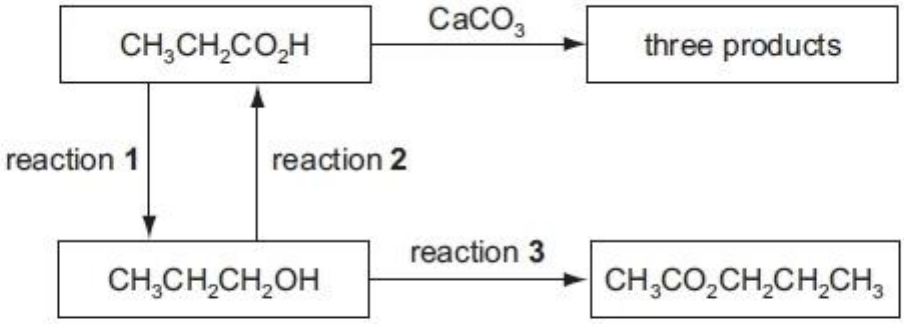
[1]

(iii) Name the organic product of this reaction.

..... [1]

Q# 404/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 A series of reactions based on propanoic acid is shown.



(a) Write an equation for reaction **1**, using [H] to represent the reducing agent.

..... [2]

(c) Write an equation for the reaction of propanoic acid with calcium carbonate, $CaCO_3$.

..... [2]

(d) **(i)** Suggest a suitable reagent and conditions for reaction **3**.

.....

..... [2]

(ii) Identify the **other** product of reaction **3**.

..... [1]

[Total: 10]

Q# 405/ ALvl Chemistry/2013/w/TZ 1/Paper 4/Q# 4/www.SmashingScience.org

4 Compound **R** is a weak diprotic (dibasic) acid which is very soluble in water.

(b) Three possible structures for **R** are shown below.

S	T	U
$HO_2CCH=CHCO_2H$	$HO_2CCH(OH)CH_2CO_2H$	$HO_2CCH(OH)CH(OH)CO_2H$

(e) The acid **S** shows stereoisomerism. Draw structures to show this isomerism. Label each isomer.

[2]

(f) When one of the isomers of **S** is heated at 110 °C in the absence of air, a cyclic compound **V**, with molecular formula $C_4H_2O_3$, is formed.
The other isomer of **S** does not react at this temperature.

Suggest the displayed formula of V.

[2]

[Total: 18]

Q# 406/ ALvl Chemistry/2012/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 Organic compounds which contain oxygen may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. The functional groups may be identified by their reactions with specific reagents.

Compound **X** has the empirical formula CH_2O and M_r of 90.

(a) There is no reaction when **X** is treated with $NaHCO_3$.

What functional group does this test show to be **not** present in **X**?

..... [1]

Q# 407/ ALvl Chemistry/2010/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5 Isomerism occurs in many organic compounds. The two main forms of isomerism are structural isomerism and stereoisomerism. Many organic compounds that occur naturally have molecules that can show stereoisomerism, that is *cis-trans* or optical isomerism.

Unripe fruit often contains polycarboxylic acids, that is acids with more than one carboxylic acid group in their molecule.

One of these acids is commonly known as tartaric acid, $HO_2CCH(OH)CH(OH)CO_2H$.

(b) Give the structural formula of the organic compound produced when tartaric acid is reacted with an excess of $NaHCO_3$.

[1]

A third polycarboxylic acid present in unripe fruit is a colourless crystalline solid, **W**, which has the following composition by mass: C, 35.8%; H, 4.5%; O, 59.7%.

(d) (i) Show by calculation that the empirical formula of **W** is $C_4H_6O_5$.

(ii) The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

[3]

A sample of **W** of mass 1.97 g was dissolved in water and the resulting solution titrated with 1.00 mol dm^{-3} NaOH. 29.4 cm^3 were required for complete neutralisation.

(e) (i) Use these data to deduce the number of carboxylic acid groups present in one molecule of **W**.

(ii) Suggest the displayed formula of **W**.

[5]

[Total: 13]

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4(b)(i)	**M1** (add) group 1 carbonate / group 1 bicarbonate / Na_2CO_3 / $NaHCO_3$ etc. **M2** effervescence / fizzing / bubbling	2

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4(b)(i)	L = CH_3OH / methanol [1] conditions = acid(ic) / H^+ / H_2SO_4 **AND** (heat under) reflux [1]	2

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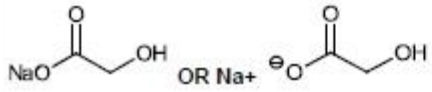
4(c)(i)		1
4(c)(ii)	Not a strong (enough) reducing agent	1

Q# 394/ ALvl Chemistry/2020/w/TZ 1/Paper 4/Q# 3/www.SmashingScience.org

3(c)(ii)	(**M1:** *correct identity of R and statement re: reaction 3 ONLY ketone reduced*) R (is 2-hydroxybutanoic acid) **AND** as (only) C=O / ketone reduced	2
	(**M2:** *correct explanation re: strength of reducing agents*) $NaBH_4$ cannot reduce the COOH / **carboxylic acid** OR $LiAlH_4$ can reduce the COOH / **carboxylic acid**	

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6(c)	*Structural formula of X:* HCO_2H OR HCOOH	1
6(d)	**M1** *reagent* (2,4–) DNPH / (2,4)-dinitrophenylhydrazine **M2** *observation* yellow / orange / red precipitate	2
6(e)	*Predict two differences, with reasons, between spectra of Y, $CH_3CH_2COCH_3$ and 2-methylbut-1-ene (shown)* *first difference* **M1** absence of peak/ absorption at 3100 (cm^{-1}) as no longer any =C–H present (in Y) *second difference* **M2** peak at 1650 (cm^{-1}) moves to the left to any value / range of values between 1670 and 1740) due to disappearance of C=C (in Y) and appearance of C=O (in Y) OR absence of peak at 1650 (cm^{-1}) as no longer any C=C present (in Y) AND appearance of peak (in Y) at (any value / range of values) between 1670-1740(cm^{-1}) due to C=O	2
6(f)(i)	$CH_3CH_2CO_2H + 4[H] \rightarrow CH_3CH_2CH_2OH + H_2O$	1
6(f)(ii)	propan-1-ol ALLOW propan-2-ol as error carried forward from **6f(i)**	1
6(g)(i)	*Molecular formula of W* $C_3H_6O_2$	1
6(g)(ii)	*Possible structure of W* CH_3COOCH_3 OR $HCOOCH_2CH_3$	1

Q# 396/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(a)(v)	**M1** hydrolysis **M2** esterification / condensation	2

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4(b)(ii)	**M1:** A has **H-bonding** (between molecules) **M2:** B only has dipole–dipole / **VdW** forces (between molecules) **M3:** H-bonding is stronger / requires more energy to overcome	3
4(b)(iv)	HO **M1:** / $CH_3CH(OH)CH_3$ **M2:** H_2SO_4 / sulfuric acid	2

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4(c)(iii)	<table><tr><td></td><td>alcohol group present in Z</td></tr><tr><td>primary</td><td>✓</td></tr><tr><td>secondary</td><td>✓</td></tr><tr><td>tertiary</td><td></td></tr></table>	1
4(d)(i)	A and B	1
4(d)(ii)	<table><tr><td></td><td>Compound(s)</td><td>Observation</td></tr><tr><td>Reaction with Tollens' reagent</td><td>B ✓</td><td>silver mirror OR grey / black / brown / silver precipitate ✓</td></tr></table>	2
	<table><tr><td></td><td>Compound(s)</td><td>Observation</td></tr><tr><td>Reaction with alkaline aq. iodine</td><td>A ✓ and C ✓</td><td>(Pale) yellow precipitate /solid ✓</td></tr></table>	3
	<table><tr><td></td><td>Compound(s)</td><td>Observation</td></tr><tr><td>Reaction with sodium metal</td><td>C ✓ and D✓</td><td>Effervescence / sodium/solid disappears ✓</td></tr></table>	3

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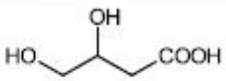
4(c)(ii)	**M1** catalyst **M2** ethanoic acid / CH_3CO_2H	2
4(c)(iii)	nucleophilic substitution / S_N2	1
4(c)(iv)	 **M1** hydrolysed nitrile on straight-chain 4C backbone **M2** 3,4-diol	2

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3(d)(i)	carbon dioxide **AND** water	1

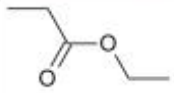
Q# 401/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 3/www.SmashingScience.org

3(d)(i)	methyl pentanoate	1

Q# 402/ ALvl Chemistry/2016/w/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

5(d)	(1-)propyl propanoate	1	1
	Total:		6

Q# 403/ ALvl Chemistry/2016/s/TZ 1/Paper 4/Q# 5/www.SmashingScience.org

(d) (i)	(conc) H^+ / (conc) acid / (conc)H_2SO_4 / (conc)H_3PO_4	[1]	[1]
(ii)		[1]	[1]
(iii)	ethyl propanoate	[1]	[1]

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4 (a)	$CH_3CH_2CO_2H + 4[H] \rightarrow CH_3CH_2CH_2OH + H_2O$	1+1	[2]

(c)	$2\ CH_3CH_2CO_2H + CaCO_3 \rightarrow (CH_3CH_2CO_2)_2Ca + H_2O + CO_2$	1+1	[2]
(d) (i)	CH_3CO_2H	1	
	warm / hot / high temperature / heat / reflux **AND** concentrated sulfuric acid	1	[2]
(ii)	water (or hydrogen chloride or ethanoic acid)	1	[1]
			[10]

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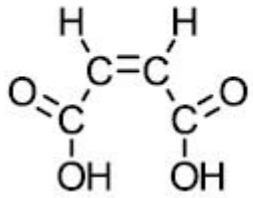
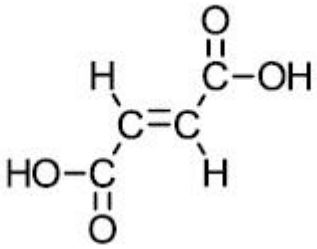
(e)



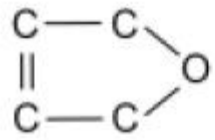
cis **or** Z



trans **or** E

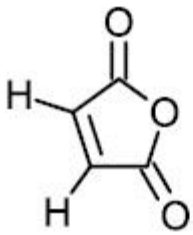
two correct structures (1)
correct labels (1) [2]

(f) correct ring of C and O atoms, i.e.



(1)

correct compound, i.e.



(hydrogen atoms do not need to be shown) (1) [2]

[Total: 18]

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5 **(a)** carboxylic acid **or** $-CO_2H$ **or** $-COOH$ (1) [1]

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(b) $NaO_2CCH(OH)CH(OH)CO_2Na$ (1) [1]

(d) **(i)** $C : H : O = \frac{35.8}{12} : \frac{4.5}{1} : \frac{59.7}{16}$ this mark is for correct use of A_r values (1)

$C : H : O = 2.98 : 4.5 : 3.73$

$C : H : O = 1 : 1.5 : 1.25$ this mark is for evidence of correct calculation (1)

gives empirical formula of **W** is $C_4H_6O_5$

(ii) $C_4H_6O_5 = 12 \times 4 + 1 \times 6 + 16 \times 5 = 134$

molecular formula of **W** is $C_4H_6O_5$ (1) [3]

(e) (i) $n(OH^-) = \frac{29.4 \times 100}{1000} = 0.0294$ (1)

$n(\mathbf{W}) = \frac{1.97}{134} = 0.0147$ (1)

no. of $-CO_2H$ groups present

in one molecule of **W** $= \frac{0.0294}{0.0147} = 2$ (1)

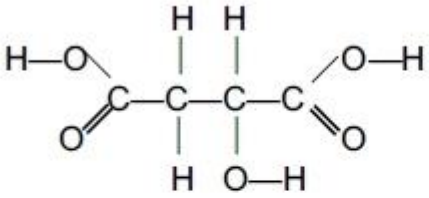
or $n(OH^-) = \frac{29.4 \times 1.00}{1000} = 0.0294$ (1)

1.97 g **W** ≡ 0.0294 mol NaOH

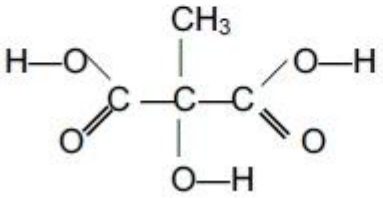
134 g **W** ≡ $\frac{0.0294 \times 134}{1.97} = 1.999 \approx 2$ mol NaOH (1)

no. of $-CO_2H$ groups present in 1 molecule of **W** = 2 (1) [3]

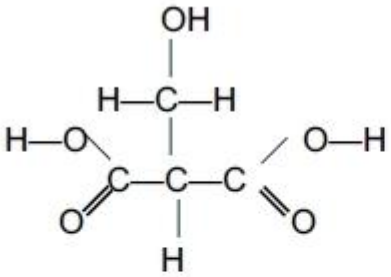
(ii)



or



or



one correct structure (1)
correctly displayed (1)
allow any **correct** ether [2]

[Total: 13]