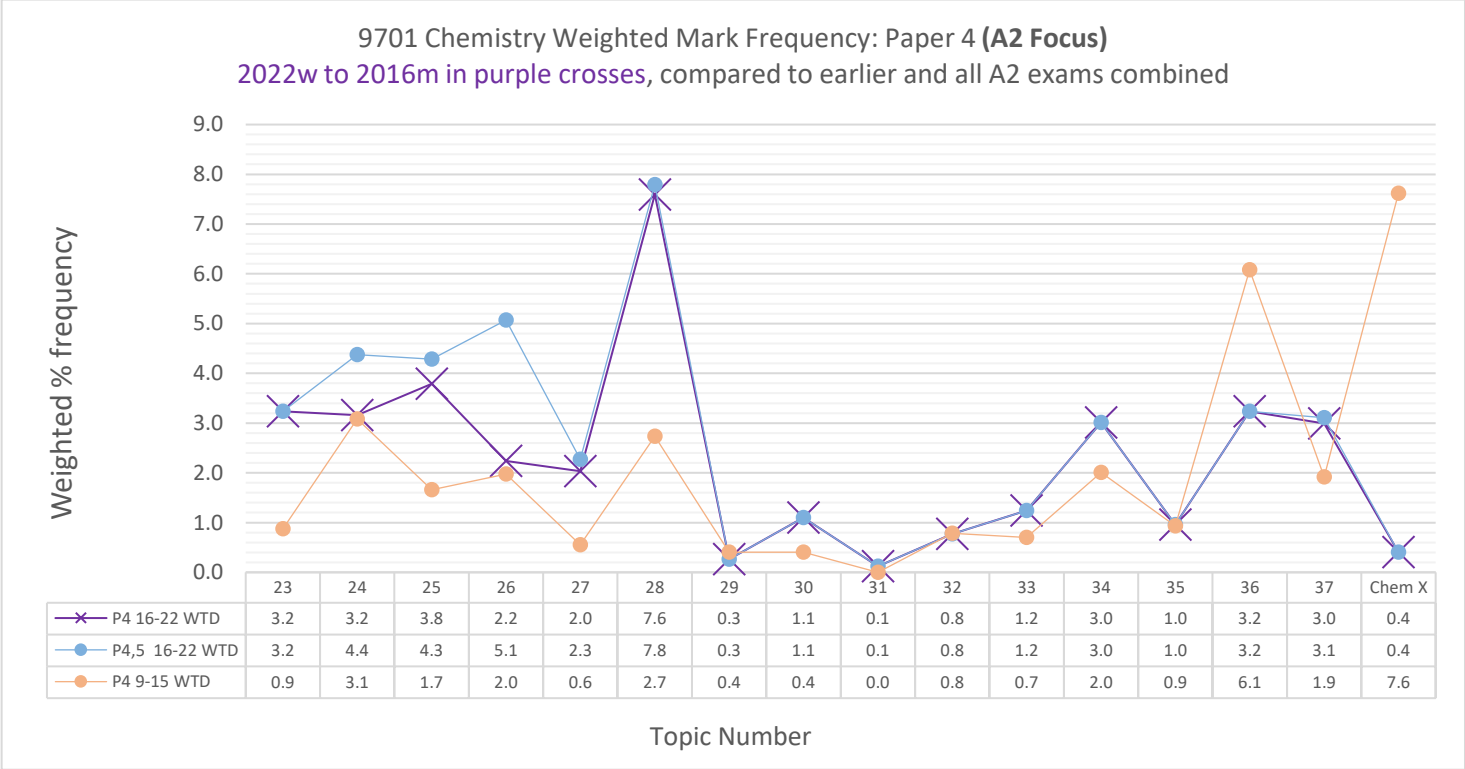
Name: Class: Date:

A Level Chem 33 EQ 22m to 09w **Paper 4** Carboxylic acids and derivatives 85 marks

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 3 minutes to complete.

Paper 4 Topic Checklist Tick each task off as you go along	RANK:	P4 Noob	P4 Novice	P4 Bronze	P4 Silver	P4 Gold	P4[1] Winner	P4 Hero	P4 Legend
	Marks	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 33 (marks)	85		5	9	21	34	43	64	85
Time - 72 seconds per mark (minutes)	103		6	10	26	41	52	78	103



	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Chem X
P4 16-22 WTD	3.2	3.2	3.8	2.2	2.0	7.6	0.3	1.1	0.1	0.8	1.2	3.0	1.0	3.2	3.0	0.4
P4,5 16-22 WTD	3.2	4.4	4.3	5.1	2.3	7.8	0.3	1.1	0.1	0.8	1.2	3.0	1.0	3.2	3.1	0.4
P4 9-15 WTD	0.9	3.1	1.7	2.0	0.6	2.7	0.4	0.4	0.0	0.8	0.7	2.0	0.9	6.1	1.9	7.6

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 outcome from skillful action in study is being better at any important tasks even if circumstances are do not feel ideal.

Learning how to manage oneself so we can more reliably get ambitious and successful outcomes out of our challenges in a productive and positive way is one aspect of life's most valuable 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 question, or page, 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. If you find you get a higher percentage answering short answer questions than multiple choice questions that often means you are using the marking scheme correctly; your correct answer might not be fully complete. The marks easiest to miss rely on providing more details fully described.

[1] **DO NOT** work on these higher levels of completion unless you have also achieved at least a "Silver" (25%) in the same topic in Paper 5, if it exists.

33 Carboxylic acids and derivatives

33.1 Carboxylic acids

Learning outcomes

Candidates should be able to:

1 recall the reaction by which benzoic acid can be produced:
   (a) reaction of an alkylbenzene with hot alkaline $KMnO_4$ and then dilute acid, exemplified by methylbenzene
2 describe the reaction of carboxylic acids with PCl_3 and heat, PCl_5, or $SOCl_2$ to form acyl chlorides
3 recognise that some carboxylic acids can be further oxidised:
   (a) the oxidation of methanoic acid, HCOOH, with Fehling's reagent or Tollens' reagent or acidified $KMnO_4$ or acidified $K_2Cr_2O_7$ to carbon dioxide and water
   (b) the oxidation of ethanedioic acid, HOOCCOOH, with warm acidified $KMnO_4$ to carbon dioxide
4 describe and explain the relative acidities of carboxylic acids, phenols and alcohols
5 describe and explain the relative acidities of chlorine-substituted carboxylic acids

33.2 Esters

Learning outcomes

Candidates should be able to:

1 recall the reaction by which esters can be produced:
   (a) reaction of alcohols with acyl chlorides using the formation of ethyl ethanoate and phenyl benzoate as examples

33.3 Acyl chlorides

Learning outcomes

Candidates should be able to:

1 recall the reactions (reagents and conditions) by which acyl chlorides can be produced:
   (a) reaction of carboxylic acids with PCl_3 and heat, PCl_5, or $SOCl_2$
2 describe the following reactions of acyl chlorides:
   (a) hydrolysis on addition of water at room temperature to give the carboxylic acid and HCl
   (b) reaction with an alcohol at room temperature to produce an ester and HCl
   (c) reaction with phenol at room temperature to produce an ester and HCl
   (d) reaction with ammonia at room temperature to produce an amide and HCl
   (e) reaction with a primary or secondary amine at room temperature to produce an amide and HCl
3 describe the addition-elimination mechanism of acyl chlorides in reactions in 33.3.2(a) – (e)
4 explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and halogenoarenes (aryl chlorides)

6 Lidocaine is used as an anaesthetic. A synthesis of lidocaine is shown in Fig. 6.1.

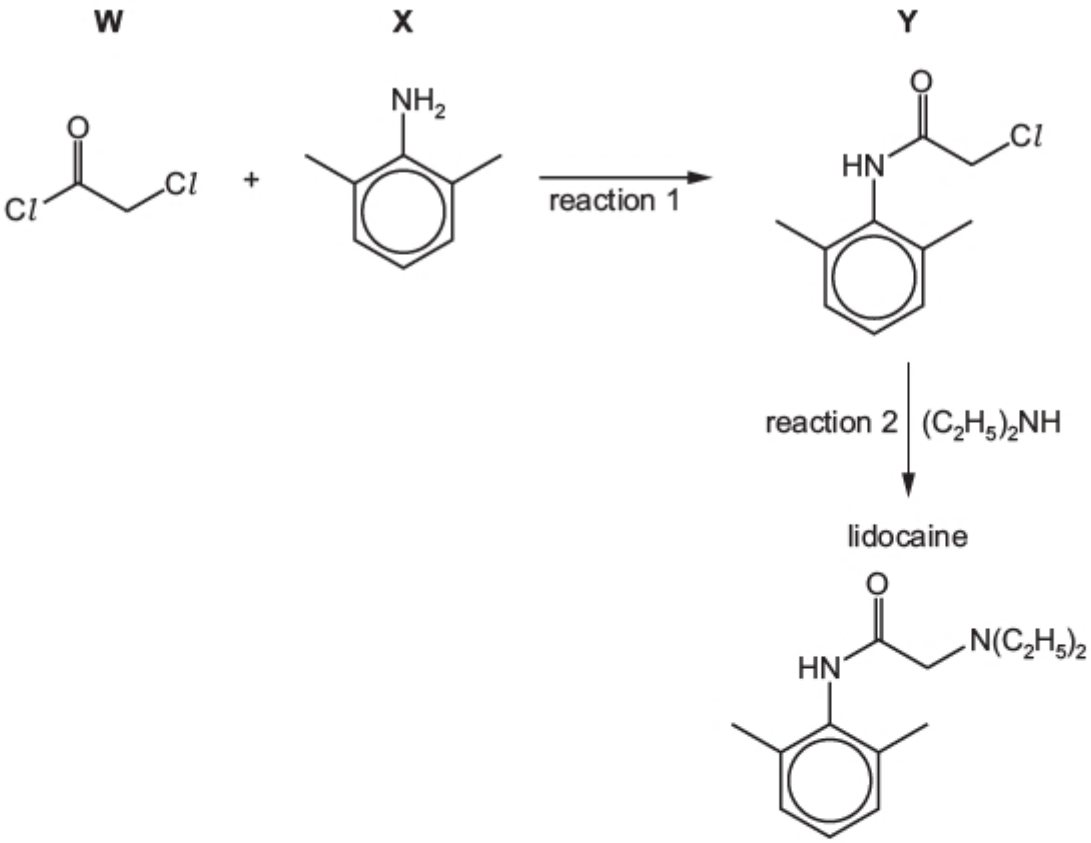


Fig. 6.1

(a) **W** can be formed by reacting $HOCH_2COOH$ with an excess of $SOCl_2$.

Write an equation for this reaction.

..... [1]

(b) After **W** and **X** have reacted together, an excess of $CH_3COONa(aq)$ is added to the reaction mixture.

Suggest why.

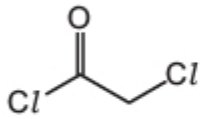
.....

..... [1]

(c) The reaction of **W** with **X**, reaction 1, follows an addition–elimination mechanism.

Complete the mechanism for the reaction of **W** with **X**.
Include all relevant curly arrows, lone pairs of electrons, charges and partial charges.

Use Ar–NH_2 to represent **X**.



Ar—NH_2

[4]

(d) $(C_2H_5)_2NH$ reacts with **Y** in reaction 2.

Explain why $(C_2H_5)_2NH$ can act as a nucleophile.

.....

..... [1]

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(d) **K** can also be synthesised from phenol, C_6H_5OH.

Fig. 4.4 shows several reactions of phenol.

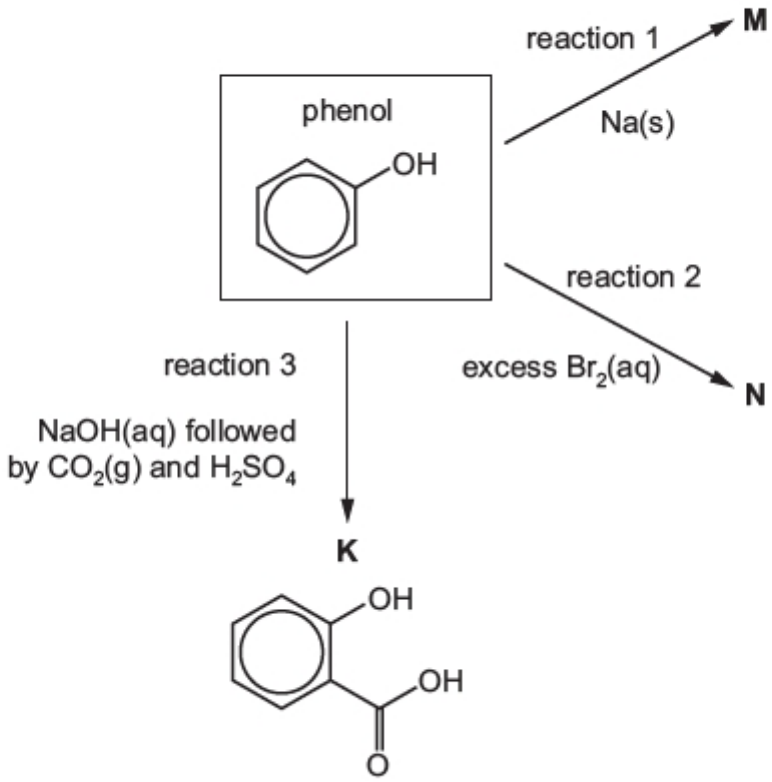

Fig. 4.4

(iii) Explain why phenol is a weaker acid than **K**.

.....

.....

.....

..... [2]

Q# 370/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 6 /www.SmashingScience.org :o)

6 **(a)** Compare and explain the relative acidities of butanoic acid, ethanol, ethanoic acid and water.

..... > ..... > ..... > .....

most acidic least acidic

.....

.....

.....

.....

.....

..... [4]

(b) Three carboxylic acids, methanoic acid, HCO_2H, ethanedioic acid, HO_2CCO_2H, and butanedioic acid, $HO_2CCH_2CH_2CO_2H$, are compared. Two tests were carried out on separate samples of each organic acid, as shown.

The following results were obtained. ✓ = observed change ✗ = no observed reaction

test	reagents and conditions	HCO_2H	HO_2CCO_2H	$HO_2CCH_2CH_2CO_2H$	observed change
1		✓	✗	✗	
2		✓	✓	✗	

(i) Complete the table with the reagents and conditions and the observed change for a positive test.
Assume these organic acids all have a similar acid strength. [3]

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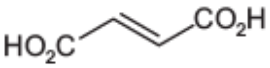
6 Fumaric acid is a naturally occurring dicarboxylic acid.

fumaric acid



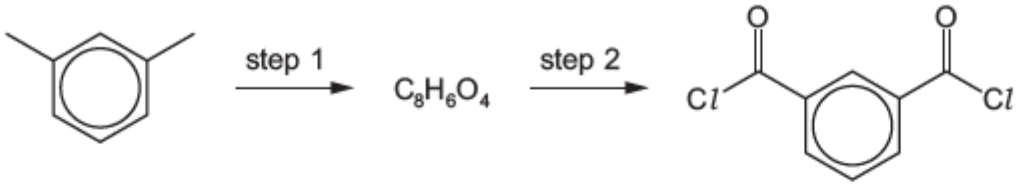
(a) Identify the products of the reaction between fumaric acid and an excess of hot, concentrated, acidified manganate(VII).

..... [1]

Q# 372/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 5 /www.SmashingScience.org :o)

(b) Compound **M** is made from 1,3-dimethylbenzene in a two-step synthesis.

1,3-dimethylbenzene **L** **M**



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

[1]

(ii) Suggest reactants and conditions for each step of this synthesis.

step 1 .....

step 2 .....

[2]

(iii) Write an equation for step 2.

..... [1]

6 **(a)** Compare and explain the relative acidities of 2-chloropropanoic acid, 3-chloropropanoic acid, and propanoic acid. Explain your answer.

..... > ..... > .....

most acidic least acidic

explanation .....

.....

.....

.....

.....

.....

[3]

(c) Three tests were carried out on separate samples of the organic acids shown in the table.
The following results were obtained.
✓ = observed change
✗ = no observed reaction

test	reagent(s) and conditions	HCO_2H	CH_3COCO_2H	HO_2CCO_2H	observed change
1	....	✓	✗	✗	
2	....	✗	✓	✗	
3	....	✓	✗	✓	

Complete the table with the reagent(s) and conditions and the observed change for each test.
Assume these organic acids all have a similar acid strength. [5]

(iii) $[Fe(C_2O_4)_2Cl_2]^{4-}$ contains ligands which are anions of ethanedioic acid, HO_2CCO_2H.

Complete the table to show any observations for the reactions of HO_2CCO_2H with the named reagents.

Where no change is observed, write 'none'.

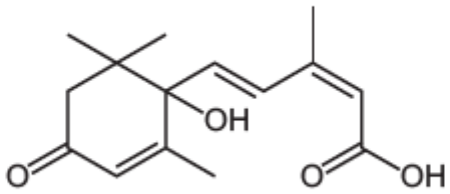
reagent	observations with HO_2CCO_2H
warm acidified manganate(VII)	
2,4-dinitrophenylhydrazine	
warm Tollens' reagent	

[2]

[Total: 20]

Q# 375/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 8 /www.SmashingScience.org :o)

8 Abscisic acid, $C_{15}H_{20}O_4$, is a plant hormone.



abscisic acid, $C_{15}H_{20}O_4$

(b) Abscisic acid is reacted with an excess of $NaBH_4$.

Give the molecular formula of the organic product formed.

..... [1]

(c) If abscisic acid is treated with an excess of hot, concentrated, acidified $KMnO_4$, three different carbon-containing products are formed.

(i) Draw the skeletal formula of the carbon-containing product with the **largest** molecular mass.

[1]

(ii) Identify the carbon-containing product with the **smallest** molecular mass. Explain how this product arises.

.....

.....

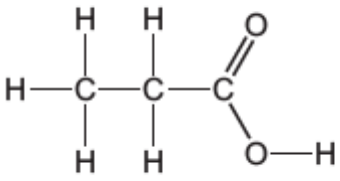
..... [2]

(iii) Identify the third carbon-containing product of this reaction by giving its displayed or structural formula.

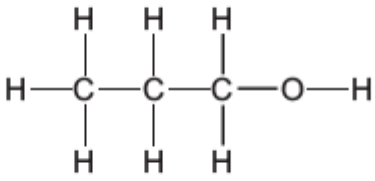
[1]

Q# 376/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 7 /www.SmashingScience.org :o)

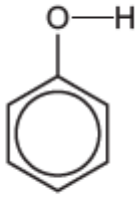
7 The three substances shown all have some acidic properties.



propanoic acid



propan-1-ol



phenol

(b) (i) Give the order of the relative acidities of propanoic acid, propan-1-ol and phenol, stating the most acidic first.

..... [1]

(ii) Explain your answer to **(i)**.

.....

.....

.....

.....

.....

..... [2]

(c) Methanoic acid, HCO_2H, has a similar acid strength to propanoic acid.

Describe a chemical test to distinguish between these two acids. Name the acid which gives a positive result in this test and describe the observations that would be made.

.....

.....

.....

..... [2]

(d) The ester phenyl propanoate, $C_2H_5CO_2C_6H_5$, can be made from phenol and propanoic acid in a **two-step** synthesis. The first step produces an acyl chloride.

For this **two-step** synthesis,

- draw the structure of the product of the first step,
- state the reagents and conditions needed for each step of the synthesis.

.....

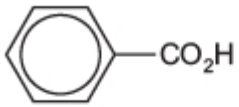
.....

.....

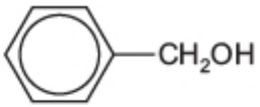
..... [3]

Q# 377/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 9 /www.SmashingScience.org :o)

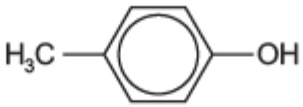
(b) Describe and explain the relative acidities of benzoic acid, phenylmethanol and 4-methylphenol.



benzoic acid



phenylmethanol



4-methylphenol

.....

.....

.....

.....

.....

..... [3]

Q# 378/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 1 /www.SmashingScience.org :o)

(d) (i) The ethanedioates of the Group 2 elements, MC_2O_4, decompose on heating to produce a mixture of two different gases and the solid oxide, MO, only.

(ii) Describe **two** observations you would make during the reaction when ethanedioic acid, $H_2C_2O_4$, is warmed with acidified manganate(VII) ions.

.....

.....

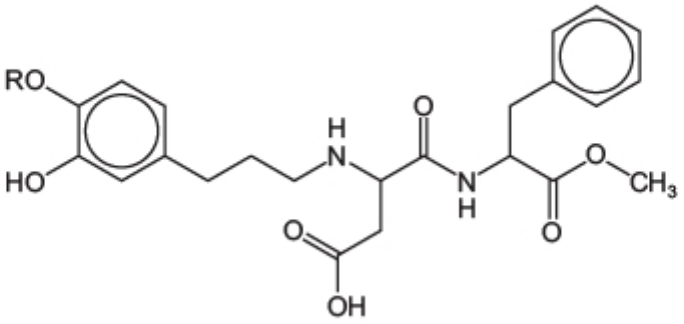
.....

..... [2]

[Total: 14]

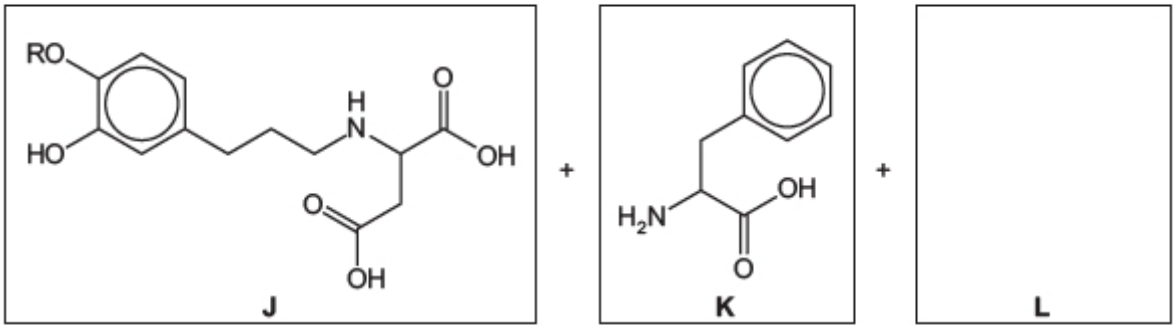
Q# 379/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 7 /www.SmashingScience.org :o)

7 The compound *Advantame* is a sweetener that tastes approximately 25 000 times sweeter than sucrose.



Advantame

(b) The decomposition of *Advantame* produces three molecules, **J**, **K** and **L**. The RO– group in *Advantame* is unreactive.



(i) Suggest possible reagents and conditions for this decomposition.

..... [1]

(ii) Name the *type of reaction* occurring.

..... [1]

(iii) Draw the structure of **L** in the box above. [1]

10 (a) Ethanedioic acid, $C_2O_4H_2$, occurs in many vegetables. The amount that occurs in spinach can be estimated as follows.

- 40.0 g of spinach leaves are crushed and mixed with distilled water, using a mortar and pestle.
- The mixture is filtered, and the leaves are washed with a little more water.
- The combined filtrate and washings are made up to 100.0 cm^3 with water.
- A 25.0 cm^3 portion of the resulting solution is added to a conical flask, along with an excess of dilute sulfuric acid.
- The acidified solution is warmed, and then titrated with 0.0200 mol dm^{-3} $KMnO_4$.

The equation for the reaction between ethanedioic acid and acidified manganate(VII) ions is shown.

$$2MnO_4^- + 6H^+ + 5C_2O_4H_2 \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

In the titration, 15.20 cm^3 of $KMnO_4$ was required to reach the end-point.

Calculate the percentage by mass of ethanedioic acid in the spinach leaves.

percentage of ethanedioic acid = ... % [3]

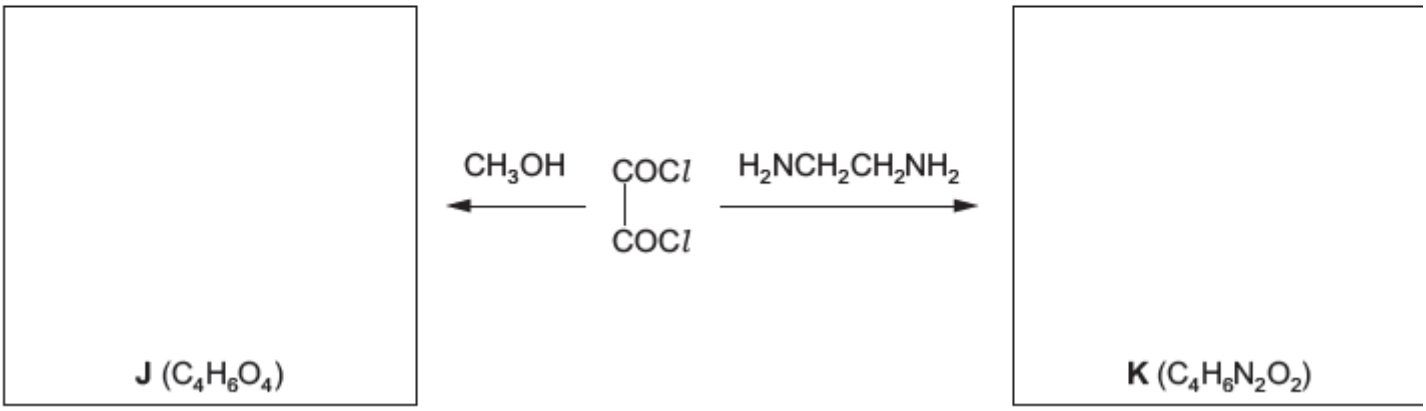
(b) Ethanedioic acid can be converted into ethanedioyl chloride:

$$HO_2CCO_2H \rightarrow ClOCCOCl$$

(i) State a suitable reagent for this reaction.

..... [1]

(ii) For the reactions of ethanedioyl chloride below, suggest the structures of compounds **J** and **K** and draw them in the boxes.



[2]

Q# 381/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 2 /www.SmashingScience.org :o)

2 **(a)** Both chloroalkanes and acyl chlorides react with water, but only acyl chlorides fume in moist air.

(i) State which product causes the fumes in this reaction.

..... [1]

(ii) Explain why the reactivities of chloroalkanes and acyl chlorides differ.

.....

.....

..... [1]

Q# 382/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 5 /www.SmashingScience.org :o)

5 (a) Organohalogen compounds can undergo hydrolysis.

$$R\text{–}Cl + H_2O \rightarrow R\text{–}OH + HCl$$

State the relative rates of hydrolysis of the following compounds.

$CH_3CH_2CH_2Cl$ CH_3CH_2COCl C_6H_5Cl

Explain your answer.

.....

.....

.....

.....

.....

..... [3]

Q# 383/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 4 /www.SmashingScience.org :o)

(b) (i) Describe and explain the relative acidities of chloroethanoic acid and ethanoic acid.

.....

.....

.....

(ii) Describe and explain the relative acidities of phenol and ethanol.

.....

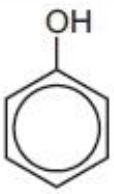
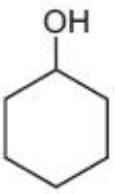
.....

.....

[3]

Q# 384/ ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 5 /www.SmashingScience.org :o)

5 (a) A series of experiments is carried out in which the reagent shown at the top of the column of the table is mixed, in turn, with each of the reagents at the side.
Complete the following table by writing in each box the formula of any gas produced.
Write **x** in the box if no gas is produced.
The first column has been completed as an illustration.

	H_2O			
Na	H_2			
KOH(aq)	x			
$Na_2CO_3(aq)$	x			

[5]

6 Acyl chlorides are useful intermediates in organic syntheses.

(a) (i) State a suitable reagent for converting carboxylic acids into acyl chlorides.

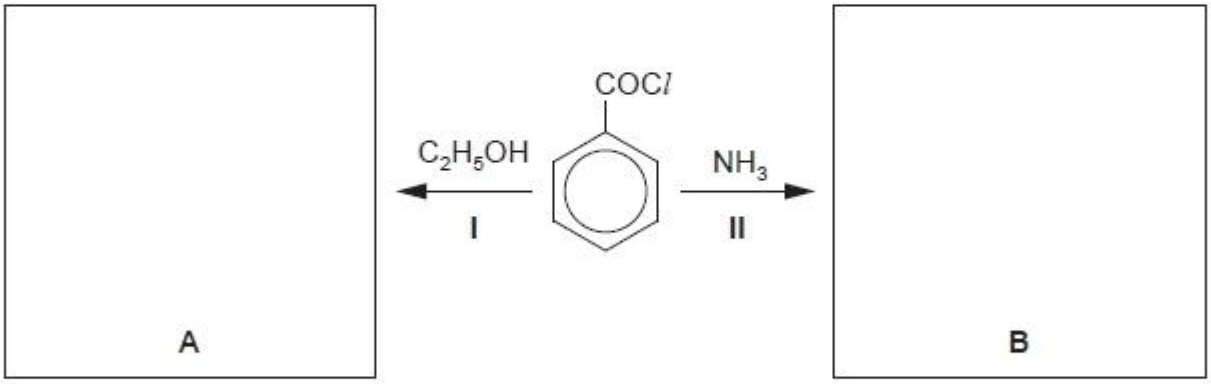
.....

(ii) Construct an equation for the reaction between ethanoic acid, CH_3CO_2H, and the reagent you have stated in **(i)**.

.....

[2]

(b) (i) In the boxes provided draw the structures of the compounds formed when benzoyl chloride undergoes the following reactions.



(ii) Name the functional group in

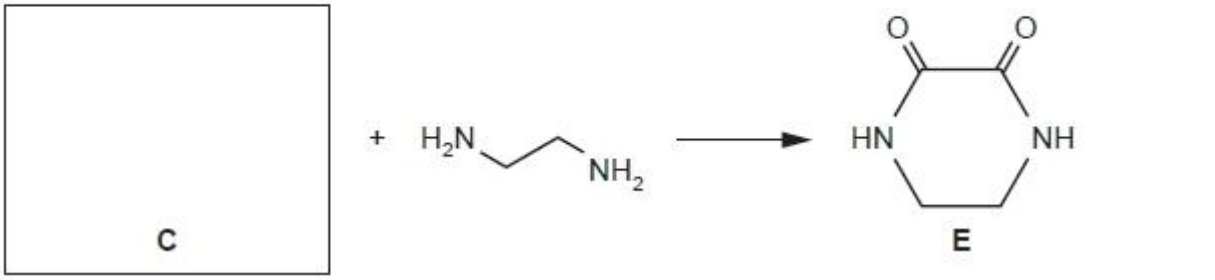
- compound **A** .....
- compound **B** .....

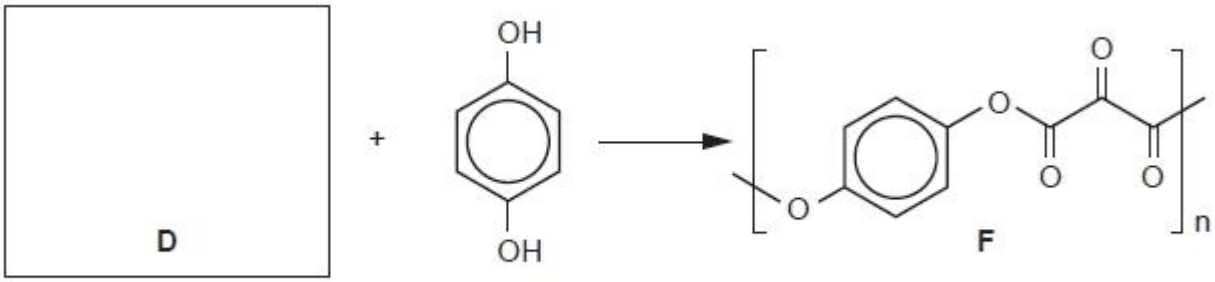
(iii) What *type of reaction* is reaction **II**?

.....

[5]

(c) (i) Suggest suitable acyl chlorides to use in the following reaction. Draw their structures in the boxes provided.





Compound **E** dissolves in, but does not react with, cold water.

(iv) What type of polymer is compound **F**?

..... [3]

Mark Scheme A Level Chem 33 EQ 22m to 09w **Paper 4** Carboxylic acids and derivatives 85 marks

Q# 368/ ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 6 /www.SmashingScience.org :o)

6(a)	$HOCH_2COOH + 2SOCl_2 \rightarrow ClCH_2COCl + 2SO_2 + 2HCl$	1
6(b)	to remove / neutralise excess H^+ / acid produced OR to react with any acidic by-products / HCl / SO_2 OR to react with any unreacted **W**	1
6(c)	 M1: curly arrow from **lone pair** on :NH_2 to carbonyl $C^{(\delta+)}$=O M2: correct dipole on $^{\delta+}C=O^{\delta-}$ **AND** curly arrow from bond C=O to $O^{(\delta-)}$ M3: correct structure of the intermediate (inc. charges) M4: curly arrow from lone pair on $:O^-$ to C=O **AND** curly arrow from C—Cl to Cl	4
6(d)	N / nitrogen can donate its lone pair / LP / pair of electrons	1

Q# 369/ ALvl Chemistry/2022/m/TZ 1/Paper 4/Q# 4 /www.SmashingScience.org :o)

4(d)(iii)	• (CO)O—H bond **weaker** / more easy to donate H^+ in **K** • owing to negative inductive / electron withdrawing effect of C=O / COOH group • carboxylate anion stabilised / phenoxide anion is less stabilised *All three for two marks*	2

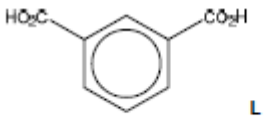
Q# 370/ ALvl Chemistry/2021/s/TZ 1/Paper 4/Q# 6 /www.SmashingScience.org :o)

6(a)	**M1:** ethanoic acid > butanoic acid > water > ethanol **M2:** a reason given in terms of an electron donating or an electron withdrawing group for one of: strengthening of O–H bond OR weakening of O–H bond OR stability of anion *Two out of the three alternatives M3, M4 and M5:* M3: ethanol: positive inductive effect / electron donating effect of ethyl / alkyl / R group M4: butanoic acid: positive inductive effect / electron donating effect of propyl / alkyl / R group M5: (either ethanoic or butanoic) acid: negative inductive effect of either C=O or carbonyl OR negative charge delocalised over COO^-	4
6(b)(i)	<table><tr><th></th><th>reagents and conditions</th><th>observed change</th></tr><tr><td>test 1</td><td>Tollen's reagent, warm OR Fehling's solution, warm</td><td>silver mirror (brick) red ppt / solid</td></tr><tr><td>test 2</td><td>acidified MnO_4^-, warm</td><td>decolourises OR bubbles</td></tr></table> **M1 / M2:** reagents and conditions × 2 **M3:** observations both correct	3

Q# 371/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 6 /www.SmashingScience.org :o)

6(a)	CO_2 and H_2O / in words	1

Q# 372/ ALvl Chemistry/2021/m/TZ 2/Paper 4/Q# 5 /www.SmashingScience.org :o)

5(b)(i)	 L	1
5(b)(ii)	**M1:** heat / reflux with acidified / alkaline KMnO4 (then acidify) **M2:** PCl_5 **OR** $SOCl_2$ / (heat with) PCl_5	2
5(b)(iii)	$C_8H_6O_4 + 2PCl_5 \rightarrow C_8H_4O_2Cl_2 + 2POCl_3 + 2HCl$ **OR** $C_8H_6O_4 + 2SOCl_2 \rightarrow C_8H_4O_2Cl_2 + 2SO_2 + 2HCl$ **OR** $3C_8H_6O_4 + 2PCl_3 \rightarrow 3\ C_8H_4O_2Cl_2 + 2H_3PO_3$	1

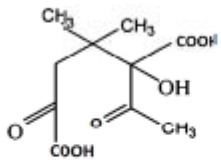
Q# 373/ ALvl Chemistry/2020/s/TZ 1/Paper 4/Q# 6 /www.SmashingScience.org :o)

6(a)	**M1** 2-chloropropanoic acid > 3-chloropropanoic acid > propanoic acid [1] **M2** $CH_3CHClCO_2H$ / $ClCH_2CH_2CO_2H$ (are more acidic) as they contain an electronegative *Cl* atom so weaken O-H bond / stabilise carboxylate anion [1] **M3** $CH_3CHClCO_2H$ (is more acidic than $ClCH_2CH_2CO_2H$) as the *Cl* atom is closer to CO_2H so weaken O-H bond more / stabilise carboxylate anion more [1]	3
6(c)	<table><tr><th></th><th>reagents and conditions</th><th>observed change</th></tr><tr><td>test 1</td><td>**M1** Tollen's reagent, warm OR Fehling's solution, warm</td><td>silver mirror (brick)-red ppt.</td></tr><tr><td>test 2</td><td>**M2** aqueous alkaline iodine OR 2,4-DNPH</td><td>yellow ppt. orange ppt.</td></tr><tr><td>test 3</td><td>**M3** acidified MnO_4^-, warm</td><td>decolourises (and bubbles)</td></tr></table> Two correct observations = 1 mark Three correct observations = 2 marks	5

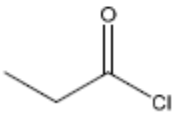
Q# 374/ ALvl Chemistry/2020/m/TZ 2/Paper 4/Q# 1 /www.SmashingScience.org :o)

1(c)(iii)	<table><tr><th>reactant</th><th>observation with $(CO_2H)_2$</th></tr><tr><td>warm H^+/MnO_4^-</td><td>decolourised **OR** effervescence / bubbling / fizzing</td></tr><tr><td>2,4-DNPH</td><td>none / no reaction</td></tr><tr><td>warm Tollens' reagent</td><td>none / no reaction</td></tr></table>	2

Q# 375/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 8 /www.SmashingScience.org :o)

8(b)	$C_{15}H_{22}O_4$	1
8(c)(i)		1
8(c)(ii)	CO_2	1
	oxidation / oxidative cleavage	1
8(c)(iii)	CH_3COCO_2H	1

Q# 376/ ALvl Chemistry/2018/s/TZ 1/Paper 4/Q# 7 /www.SmashingScience.org :o)

7(b)(i)	propanoic acid, phenol, propan-1-ol	1
7(b)(ii)	• propan-1-ol: O-H bond strengthened by positive inductive effect of alkyl group OR propoxide ion is destabilised by positive inductive effect of alkyl group • phenol: O-H bond weakened by negative inductive effect of ring OR phenoxide ion is stabilised by delocalisation of oxygen lone pair into ring • propanoic acid: O-H bond weakened by negative inductive effect of C=O OR propanoate ion is stabilised by delocalisation of minus charge by C=O 1 mark for a correct explanation, max 2 marks	2
7(c)	Tollens' reagent or Fehling's reagent	1
	methanoic acid gives a silver mirror/solid with Tollen's reagent OR red / orange ppt / solid with Fehlings' reagent	1
7(d)	PCl_5 or PCl_3 (+heat) or $SOCl_2$ (added to propanoic acid)	1
	product of first step: 	1
	add product of first step to phenol in NaOH	1

Q# 377/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 9 /www.SmashingScience.org :o)

9(b)	benzoic acid > methylphenol > phenylmethanol methylphenoxide anion has delocalisation of the lone pair on oxygen over the ring benzoic acid has an (extra) electronegative oxygen or electron withdrawing C=O	3

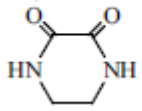
Q# 378/ ALvl Chemistry/2018/m/TZ 2/Paper 4/Q# 1 /www.SmashingScience.org :o)

1(d)(ii)	the $KMnO_4$ would decolourise bubbles / gas evolution would be seen	2

Q# 379/ ALvl Chemistry/2017/m/TZ 2/Paper 4/Q# 7 /www.SmashingScience.org :o)

7(b)(i)	$H^+(aq)$ + heat	1
7(b)(ii)	hydrolysis	1
7(b)(iii)	CH_3OH	1

Q# 380/ ALvl Chemistry/2016/s/TZ 1/Paper 4/Q# 10 /www.SmashingScience.org :o)

10 (a)	$n(MnO_4^-)$ = $0.02 \times 15.2/1000 = 3.04 \times 10^{-4}$ mol $n(C_2O_4H_2)$ = $3.04 \times 10^{-4} \times 5/2 = 7.6 \times 10^{-4}$ (in 25cm^3) = 3.04×10^{-3}mol in 100cm^3 $M_r = 24 + 64 + 2 = 90$ mass of $C_2O_4H_2 = 3.04 \times 10^{-3} \times 90$ = 0.2736 g (0.274) percentage = $0.2736 \times 100/40 = 0.68\%$	[1] [1] [1]
(b) (i)	$SOCl_2$ *or* PCl_5 *or* PCl_3	[1]
(ii)	**J** is $CH_3OCO–COOCH_3$ **K** is 	[1] [1]

Q# 381/ ALvl Chemistry/2015/s/TZ 1/Paper 4/Q# 2 /www.SmashingScience.org :o)

2 (a) (i)	hydrogen chloride ***or*** HCl	1
(ii)	***either*** (RCOCl) has two electron-withdrawing groups/atoms, making the **more** δ+/electron deficient ***or*** (RCOCl) has an oxygen, making the **carbon more** δ+/electron deficient ***or*** (RCOCl) has two electron-withdrawing groups, **weakening** the **C–Cl** bond	1

Q# 382/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 5 /www.SmashingScience.org :o)

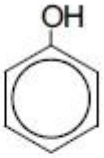
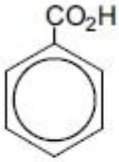
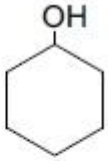
5 (a)	$CH_3CH_2COCl > CH_3CH_2CH_2Cl > C_6H_5Cl$ **any two** *of:* • C-Cl bond strength is weakest in CH_3CH_2COCl ora • In C_6H_5Cl (no hydrolysis) C-Cl bond is part of delocalised system **OR** p-orbital on Cl overlaps with π system **OR** electrons from Cl overlap with π system • CH_3CH_2COCl carbon in C-Cl bond is more electron deficient since it is also attached to an oxygen atom ora	1 1+1	[3]

Q# 383/ ALvl Chemistry/2014/w/TZ 1/Paper 4/Q# 4 /www.SmashingScience.org :o)

(b) (i)	acidity of $ClCH_2CO_2H > CH_3CO_2H$ **AND** ($ClCH_2CO_2H$) as an electronegative/electron withdrawing Cl	1	
(ii)	acidity of phenol > CH_3CH_2OH **AND** electrons on oxygen (on phenol) delocalised into ring **OR** benzene ring withdraws electrons from oxygen stronger acid linked to weakening O-H bond/anion being stabilised	1 1	[3]

Q# 384/ ALvl Chemistry/2013/s/TZ 1/Paper 4/Q# 5 /www.SmashingScience.org :o)

5 (a)

	H_2O			
Na	H_2	H_2	H_2	H_2
KOH(aq)	X	X	X	X
Na_2CO_3(aq)	X	X	CO_2	X

[5]

6 (a) (i) $SOCl_2$ *or* PCl_5 *or* PCl_3 (1)

(ii) $CH_3CO_2H + SOCl_2 \longrightarrow CH_3COCl + SO_2 + HCl$
or $CH_3CO_2H + PCl_5 \longrightarrow CH_3COCl + POCl_3 + HCl$
or $3CH_3CO_2H + PCl_3 \longrightarrow 3CH_3COCl + H_3PO_3$ (1)
[2]

(b) (i) **A** is $C_6H_5CO_2C_2H_5$ (1)
B is $C_6H_5CONH_2$ (1)

(ii) ester (1)
amide (1)

(iii) nucleophilic substitution / condensation (1) [5]

(c) (i) **C** is $ClCOCOCl$ (1)
D is $ClCOCOCOCl$ (1)