Q1.

This question is about acid–base titrations.

Citric acid reacts with sodium hydroxide.

$$C_6H_8O_7(aq) + 3\ NaOH(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(l)$$

(a) A student makes a solution of citric acid by dissolving some solid citric acid in water.

Describe a method to add an accurately known mass of solid to a beaker to make a solution.

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(2)

(b) The student dissolves 0.834 g of citric acid in water and makes the solution up to 500 cm^3

Calculate the concentration, in mol dm^{-3}, of citric acid in this solution.

Concentration _______________ mol dm^{-3}

(3)

(c) The student uses this method to complete a titration.

- Rinse a burette with distilled water.
- Fill the burette with sodium hydroxide solution.
- Use a measuring cylinder to transfer 25 cm^3 of the citric acid solution into a conical flask.
- Add 5 cm^3 of indicator.
- Slowly add the sodium hydroxide solution from the burette into the conical flask.
- Add the sodium hydroxide solution dropwise near the end point until the indicator just changes colour.
- Repeat the titration to get concordant results.

The method used by the student includes three practical steps that will lead to an inaccurate final result.

For each of these three steps

- identify the mistake
- explain why it is a mistake
- suggest how the mistake can be overcome.

(6)

(d) The table below shows the student's burette readings after the mistakes in the practical procedure have been corrected.

	Rough	Run 1	Run 2	Run 3
Final reading / cm^3	23.65	22.95	46.05	26.30
Start reading / cm^3	0.00	0.00	22.95	3.40
Titre / cm^3	23.65			

Complete the table.

Use the data in the table above to calculate the mean titre.

Mean titre ____________ cm^3

(2)

(e) The total uncertainty in the use of the burette is ±0.15 cm^3

Calculate the percentage uncertainty in the use of the burette in **Run 1**.

Percentage uncertainty ________________

(1)

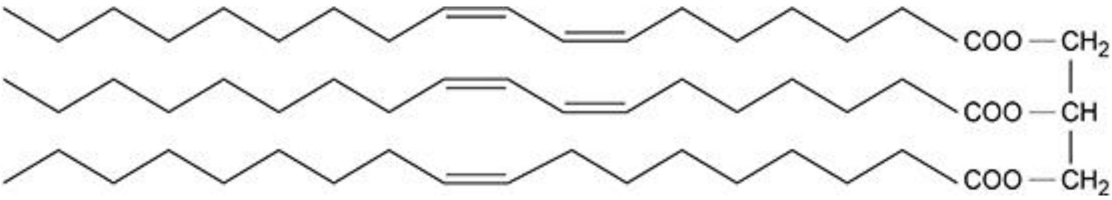
(Total 14 marks)

Q2.

This question is about olive oil.

A sample of olive oil is mainly the unsaturated fat **Y** mixed with a small amount of inert impurity.

The structure of **Y** in the olive oil is shown.
Y has the molecular formula $C_{57}H_{100}O_6$ (M_r = 880).



The amount of **Y** is found by measuring how much bromine water is decolourised by a sample of oil, using this method.

- Transfer a weighed sample of oil to a 250 cm^3 volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 cm^3 samples of the olive oil solution with 0.025 mol dm^{-3} Br_2(aq).

(a) A suitable target titre for the titration is 30.0 cm^3 of 0.025 mol dm^{-3} Br_2(aq).

Justify why a much smaller target titre would **not** be appropriate.

Calculate the amount, in moles, of bromine in the target titre.

Justification ____

____

____

____

Amount of bromine ____________________ mol

(2)

(b) Calculate a suitable mass of olive oil to transfer to the volumetric flask using your answer to part (a) and the structure of **Y**.
Assume that the olive oil contains 85% of **Y** by mass.

(If you were unable to calculate the amount of bromine in the target titre, you should assume it is 6.25×10^{-4} mol. This is **not** the correct amount.)

Mass of olive oil _______________ g

(5)

The olive oil solution can be prepared using this method.

- Place a weighing bottle on a balance and record the mass, in g, to 2 decimal places.
- Add olive oil to the weighing bottle until a suitable mass has been added.
- Record the mass of the weighing bottle and olive oil.
- Pour the olive oil into a 250 cm^3 volumetric flask.
- Add organic solvent to the volumetric flask until it is made up to the mark.
- Place a stopper in the flask and invert the flask several times.

(c) Suggest an extra step to ensure that the mass of olive oil in the solution is recorded accurately. Justify your suggestion.

Extra step ____

____

Justification ____

____

____

(2)

(d) State the reason for inverting the flask several times.

____

____

____

(1)

(e) A sample of the olive oil was dissolved in methanol and placed in a mass spectrometer. The sample was ionised using electrospray ionisation. Each molecule gained a hydrogen ion (H^+) during ionisation.

The spectrum showed a peak for an ion with $\frac{m}{z}$ = 345 formed from an impurity in the olive oil.

The ion with $\frac{m}{z}$ = 345 was formed from a compound with the empirical formula $C_5H_{10}O$

Deduce the molecular formula of this compound.

Show your working.

Molecular formula ______________________________________

(2)

(Total 12 marks)

Q3.

A student is provided with a 5.60 g sample of ethanoic acid (CH_3COOH) contaminated with sodium ethanoate (CH_3COONa).

The student dissolves the sample in deionised water and makes the volume up to 200 cm^3

The student removes 25.0 cm^3 samples of the solution and titrates them with 0.350 mol dm^{-3} sodium hydroxide solution.

The table below shows the results of these titrations.

	Rough	**1**	**2**	**3**
Final volume / cm^3	20.85	41.10	20.50	40.80
Initial volume / cm^3	0.00	20.85	0.00	20.50
Titre / cm^3	20.85	20.25	20.50	20.30

(a) Use the results in the table above to calculate the mean titre value.

Use the mean titre to calculate the percentage by mass of sodium ethanoate in the original sample.

Mean titre value _______________ cm^3

Percentage by mass ____________________

(6)

(b) The student rinses the burette with deionised water before filling with sodium hydroxide solution.

State and explain the effect, if any, that this rinsing will have on the value of the titre.

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___

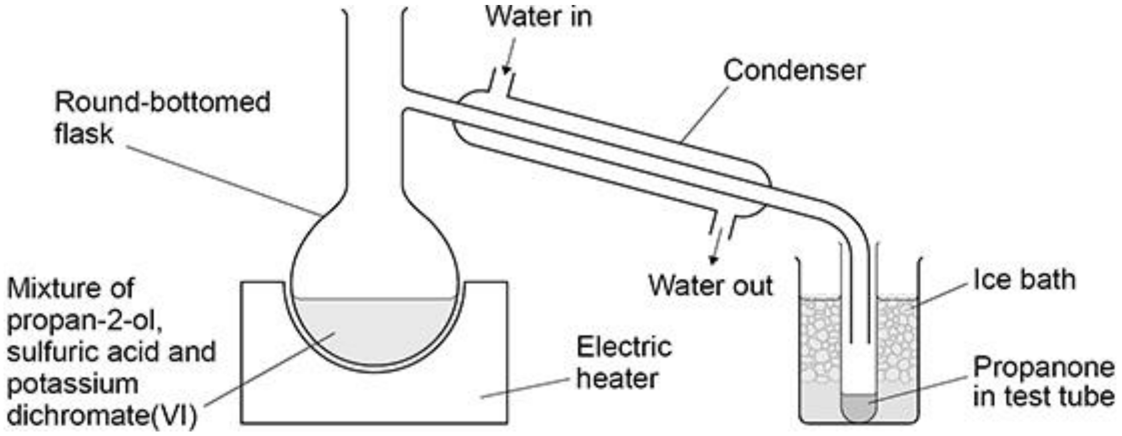
(2)
(Total 8 marks)

Q4.

Propanone can be made by reacting propan-2-ol with an excess of acidified potassium dichromate(VI).

The propanone is removed from the reaction mixture by distillation.

(a) The figure below shows the apparatus set up by a student to make propanone by this method. Suitable clamps are used to hold all the apparatus firmly in place.



There are **three** problems with the apparatus set up in the figure above.

For each problem:

- identify the problem
- describe the issue it would cause
- suggest how the problem can be solved.

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___

___

(6)

Another student completes the experiment using apparatus that is set up correctly.

(b) The student reacts 2.0 cm^3 of propan-2-ol ($CH_3CH(OH)CH_3$) with an excess of acidified potassium dichromate(VI).

The student obtains 0.954 g of propanone (CH_3COCH_3).

Calculate the percentage yield of propanone in this experiment.
Give your answer to the appropriate number of significant figures.

Density of propan-2-ol = 0.786 g cm^{-3}

Percentage yield ______________________

(4)

(c) Molecules of propan-2-ol and propanone each contain three carbon atoms.

Complete the table below to suggest the shape and a bond angle around the central C atom in a molecule of each compound.

Compound	propan-2-ol $CH_3CH(OH)CH_3$	propanone CH_3COCH_3
Shape around central C atom		
Bond angle around central C atom		

(2)

(d) Explain why propanone has a lower boiling point than propan-2-ol.

____

____

____

____

____

____

____

____

____

(3)
(Total 15 marks)

Q5.

This question is about a titration.

A student dissolves an unknown mass of sodium hydroxide in water to make 200 cm^3 of an aqueous solution.

A 25.0 cm^3 sample of this sodium hydroxide solution is placed in a conical flask and is titrated with 0.150 mol dm^{-3} sulfuric acid.

The equation for this reaction is shown.

$$2\,NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2\,H_2O(l)$$

The table shows the results of the titrations.

Titration	**Rough**	**1**	**2**	**3**
Final reading / cm^3	20.75	40.35	21.05	40.60
Initial reading / cm^3	0.00	20.75	1.20	21.05
Titre / cm^3	20.75	19.60	19.85	19.55

(a) Calculate the mass of sodium hydroxide used to make the original solution.

Mass of sodium hydroxide ________________ g

(5)

(b) The student uses a funnel to fill the burette with sulfuric acid before starting the titration. After filling, the student forgets to remove the funnel from the top of the burette.

Suggest why this might affect the titre volume recorded.

____

____

____

(1)

(c) State **one** advantage of using a conical flask rather than a beaker for the titration.

___

___

___

(1)

(Total 7 marks)

Q6.

Aspirin can be produced by reacting salicylic acid with ethanoic anhydride.
An incomplete method to determine the yield of aspirin is shown.

1. Add about 6 g of salicylic acid to a weighing boat.
2. Place the weighing boat on a 2 decimal place balance and record the mass.
3. Tip the salicylic acid into a 100 cm^3 conical flask.
4. ___
5. Add 10 cm^3 of ethanoic anhydride to the conical flask and swirl.
6. Add 5 drops of concentrated phosphoric acid.
7. Warm the flask for 20 minutes.
8. Add ice-cold water to the reaction mixture and place the flask in an ice bath.
9. Filter off the crude aspirin from the mixture and leave it to dry.
10. Weigh the crude aspirin and calculate the yield.

(a) Describe the instruction that is missing from step **4** of the method.

Justify why this step is necessary.

Instruction ___

Justification ___

___

___

(2)

(b) Suggest a suitable piece of apparatus to measure out the ethanoic anhydride in step **5**.

___

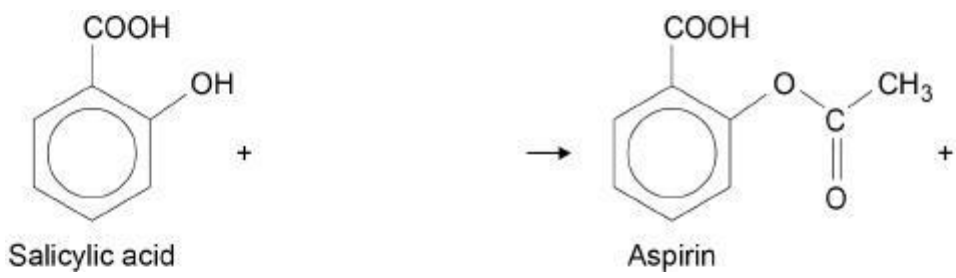
(1)

(c) Identify a hazard of using concentrated phosphoric acid in step **6**.

___

(1)

(d) Complete the equation for the reaction of salicylic acid with ethanoic anhydride to produce aspirin.



(1)

(e) A 6.01 g sample of salicylic acid (M_r = 138.0) is reacted with 10.5 cm^3 of ethanoic anhydride (M_r = 102.0).
In the reaction the yield of aspirin is 84.1%

The density of ethanoic anhydride is 1.08 g cm^{-3}

Show by calculation which reagent is in excess.

Calculate the mass, in g, of aspirin (M_r = 180.0) produced.

Reagent in excess ________________

Mass of aspirin ___________ g

(5)

(f) Suggest **two** ways in which the melting point of the crude aspirin collected in step **9** would differ from the melting point of pure aspirin.

Difference 1 ____

____

Difference 2 ____

____

(2)

(g) The crude aspirin can be purified by recrystallisation using hot ethanol (boiling point = 78 °C) as the solvent.

Describe **two** important precautions when heating the mixture of ethanol and crude aspirin.

Precaution 1 ____

____

Precaution 2 ____

____

(2)

(h) The pure aspirin is filtered under reduced pressure.
A small amount of cold ethanol is then poured through the Buchner funnel.

Explain the purpose of adding a small amount of cold ethanol.

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____

____

(1)

(i) A sample of the crude aspirin is kept to compare with the purified aspirin.

Describe **one** difference in appearance you would expect to see between these two solid samples.

____

____

____

(1)

(Total 16 marks)

Mark schemes

Q1.

(a) **M1** measure the mass of the weighing boat (or similar) and solid

1

M2 Add the solid to a beaker (or other suitable container) and then reweigh the weighing boat (and subtract to find the mass of solid added.)

1

OR

M1 Place weighing boat on a balance and zero the balance

M2 Add the solid to a beaker (or other suitable container), wash out weighing boat and transfer washing to the beaker.

M1 place (an empty) beaker on balance and zero
M2 add the solid to the beaker and record the mass

OR

M1 place (an empty) beaker on balance and measure its mass
M2 add the solid to the beaker and subtract mass of empty beaker from the total mass

(b) **M1** M_r citric acid = 192.0

1

M2 Amount of citric acid = Mass / M_r
= 0.834 / 192
= 0.0043438 (mol)

M2 conseq on M1

1

M3 Concentration = moles / volume
= 0.0043438 / 0.5
= 0.00869 (mol dm^{-3})

M3 conseq on M2

1

Alternative Method

M1 Concentration (g/dm^3) = 0.834 / 0.50 = 1.668

M2 M_r citric acid = 192.0

M3 Concentration (mol/dm^3) = M1/M2 = 0.00869

(c) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3 Three stages are covered and the explanation of each stage is generally correct and virtually complete Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.	5-6 marks

Level 2 Three stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete Answer shows some attempt at structure. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.	3-4 marks
Level 1 Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order or show some confusion. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.	1-2 marks
Level 0 Insufficient correct chemistry to gain a mark.	0 marks

Use best three of these four stages

Stage 1
a. Problem – using a measuring cylinder
b. Explanation – large uncertainty / not accurate enough
c. Improvement – use a (volumetric) pipette (Not dropping pipette)

Stage 2
a. Problem – too much indicator
b. Explanation – may react and affect the endpoint reading
c. Improvement – use a smaller volume (2-6 drops)

Stage 3
a. Problem – rinsing the burette with distilled or deionised water
b. Explanation – will slightly dilute the alkali solution
c. Improvement – rinse the burette with alkali solution

Stage 4
a. Problem – adding alkali solution until the indicator "just" changes colour
b. Explanation – acid may not have fully reacted (as mixture not swirled)
c. Improvement – add alkali solution until a permanent colour change is seen.

6

(d) Calculates the titres for each of 1,2,3 as

1	2	3
22.95	23.10	22.90

1

Averages concordant titres:
(22.95 + 22.90) ÷ 2 = 22.93 cm^3

Allow 22.9(25) cm^3

1

(e) (0.15 / 22.95) × 100 = 0.65%

0.15 / (Their Run 1) × 100

1

[14]

Q2.

(a) Smaller titre will increase (%) uncertainty / error

1

amount Br_2 = $0.025 \times \frac{30}{1000} = 7.5 \times 10^{-4}$ mol

Or 0.00075

1

(b) Ratio Y :bromine

M1 1 : 5

Alternative calc using supplied answer

M1

M2 n Y in 25 cm^3 oil = $\frac{7.5 \times 10^{-4}}{5} = 1.5 \times 10^{-4}$

n Y in 25 cm^3 oil = $\frac{6.25 \times 10^{-4}}{5} = 1.25 \times 10^{-4}$

If no ratio must state n Y for M2

M2

M3 n Y in 250 cm^3 = M2 × 10 = (1.5×10^{-3})

n Y in 250 cm^3 = $1.25 \times 10^{-4} \times 10$ = (1.25×10^{-3})

M3

M4 Mass = M3 × 880 = (1.32 g)

Mass = $1.25 \times 10^{-3} \times 880$ = (1.1 g)

M4

M5 Total mass oil needed = M4 × $\frac{100}{85}$ = 1.55 g

Total mass oil needed = $1.1 \times \frac{100}{85}$ = 1.29g

M5

If wrong ratio used treat as AE and mark ECF

(c) Extra step: Weigh the bottle after oil transfer (and record the mass)

OR Rinse the bottle with solvent after transfer and add the washings (to the volumetric flask)

M1

Justification: Not all of the oil is transferred
Or so that the mass of oil left in the bottle is accounted for Or find the exact mass of oil used

To ensure all the oil is transferred

M2 is dependent on M1

M2

(d) To ensure the solution is homogeneous

Allow evenly mixed/ distributed OWTTE

Uniform solution

1

(e) M_r = 345 – 1

Must show workings in both M1 and M2

M1

M_r ($C_5H_{10}O$) = 86

$\frac{M1}{86}$ = 4 Hence $C_{20}H_{40}O_4$

M2

[12]

Q3.

(a) M1: Mean titre = $\frac{20.25+20.30}{2}$ = 20.275 cm^3

Allow M1 = 20.28 cm^3

1

M2 Amount of NaOH = 0.35 × (20.275 ÷ 1000) = 0.00709625 mol

Amount of ethanoic acid in 25 cm^3 = 0.00709625 mol

M2 = M1 × 10^{-3} × 0.35

1

M3 Amount of ethanoic acid in 200 cm^3 = 0.05677 mol

M3 = M2 × 8

1

M4 Mass of ethanoic acid in sample = 60.0 × 0.05677 = 3.4062 g

M4 = M3 × 60.0

1

M5 Mass of sodium ethanoate = 5.6 – 3.4062 = 2.1938 g

M5 = 5.6 – M4

1

M6 percentage CH_3COONa = (2.1938 ÷ 5.6) × 100 = 39.1 %

M6 = (M5 ÷ 5.6) × 100

(39.1 – 39.2)

Accept alternative methods

M5 = (M4 ÷ 5.6) × 100) followed by M6 = 100 – M5 1

1

(b) M1 Titre value would increase / larger value

1

M2 Because the sodium hydroxide solution would be more dilute

1

[8]

Q4.

(a)

This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 marks**	**All stages are covered and each stage is generally correct and virtually complete** (6 v 5) Answer is well structured, with no repetition or irrelevant points, and covers all aspects of the question. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete** (4 v 3) Answer has some structure and covers most aspects of the question. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only minor errors in use of technical terms.
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete** (2 v 1) Answer includes statements which are presented in a logical order and/or linked.
Level 0	Insufficient correct chemistry to gain a mark.

Stage 1
Anti-bumping granules
1a no anti-bumping granules / add anti-bumping granules
1b to create smaller bubbles / to prevent large bubbles / to prevent mixture jumping into condenser

Stage 2
Open system with no thermometer
2a system should be closed (above flask) to prevent gases escaping
2b should be closed with (bung +) thermometer
2c to allow collection of propanone (only) / to prevent distillation of other components / to stay in suitable temperature range

Stage 3
The water direction in the condenser
3a water flows in wrong direction through condenser / change water direction
3b condenser not cool enough / not full of water
3c product may not condense / comes through as gas

6

(b) **M1** mass of propan-2-ol = 2.0 x 0.786 (= 1.572 g to at least 2sf)

M2 amount of propan-2-ol = $\frac{1.572}{60.0}$ (= 0.0262 to at least 2 sf) mol

M3 mass of propanone expected = 0.0262 x 58.0 (= 1.52 g to at least 2sf)

M4 % yield = $\left(\frac{0.954}{1.52} x\ 100\right)$ = 63% (2sf only)

Alternative for M3/4

M3 *amount of propanone formed =* $\frac{0.954}{58.0}$ *(= 0.0164) mol*

M4 *% yield =* $\left(\frac{0.0164}{0.0262} x\ 100\right)$ *= 63% (2sf only)*

Allow ECF at each step

4

(c) **M1** propan-2-ol: tetrahedral and 109.5°

M1 *allow 104–110°*

1

M2 propanone: trigonal planar and 120°

M2 *allow 115–123°*

Any two correct boxes scores one mark

1

(d) **M1** propan-2-ol has stronger intermolecular forces

Penalise ***M1*** *and* ***M2*** *for any reference to breaking covalent bonds, (but* ***M3*** *could score)*

1

M2 propan-2-ol has hydrogen bonds between molecules

For ***M2*** *ignore reference to dipole-dipole forces in propan-2-ol*

1

M3 propanone has dipole-dipole forces and/or van der Waals' forces

1

[15]

Q5.

(a) **M1** Volume of H_2SO_4 = (19.60 + 19.55) / 2 =

= (19.575 cm^3 / 19.58 cm^3)

M1 *= calculation of mean titre*

M2 Moles of H_2SO_4 = concentration x volume

= 0.150 x (19.575 / 1000)

(= 2.936×10^{-3} mol)

M2 *= **M1** x 10^{-3} x 0.150*

M3 Moles of NaOH in 25 cm^3 = 2.936×10^{-3} x 2 = (5.87×10^{-3} mol)

M3 *= **M2** x 2*

M4 Moles of NaOH in original 200 cm^3 sample = 5.87×10^{-3} x 8

(= 0.04698 mol)

M4 *= **M3** x 8*

M5 Mass of NaOH = Mr x moles = 40.0 x 0.04698

= 1.88 g (1.9 g)

M5 *= 1.879g*

Allow correct alternative approaches

5

(b) Additional drops of solution could have entered the burette from the funnel, (making the value on the burette lower).

Must imply that solution from funnel drips into burette

1

(c) Less chance of splashing/losing any solution using a conical flask (when swirling)

Allow easier to swirl

1

[7]

Q6.

(a) **M1** (Re)weigh the empty boat

1

M2 In order to calculate the (exact) mass of salicylic acid added to the reaction mixture

1

(b) 10 cm^3 measuring cylinder (if volume given – allow between 10 to 50 cm^3)
Or a 10 cm^3 pipette

Or burette / graduated pipette

Or 10 cm^3 syringe

1

(c) Corrosive

Allow skin burn / permanent eye damage

Ignore irritant / toxic

1

(d) LHS + $(CH_3CO)_2O$ RHS + CH_3COOH

1

(e) **M1** Amount salicylic acid = $^{6.01}/_{138}$ = 4.36×10^{-2} mol

Allow conseq from wrong mole ratio in (d)

Must show and state that ethanoic anhydride is in excess

1

M2 Mass $(CH_3CO)_2O$ = 10.5 × 1.08 = 11.34 g

1

M3 Amount $(CH_3CO)_2O$ = $^{11.34}/_{102}$ = 1.11×10^{-1} mol

For M4/M5 ecf from M1/M3

1

M4 $(CH_3CO)_2O$ is in excess

1

M5 Mass aspirin = M1 × 0.841 × 180 = 6.59 g

Allow 2 sf or more.

1

(f) **M1** Value lower

1

M2 Range of values

For M2 allow mpt not sharp or a larger range of melting points

1

(g) **M1** (Ethanol is flammable so) use a water bath to heat / do not use a Bunsen burner

Must give practical step, not just state hazard

1

M2 Heat to temp below bp (so ethanol does not boil away)

Allow use min vol solvent

1

(h) To remove any soluble impurities

Allow To avoid aspirin dissolving (small amount cold solvent used)

Allow To remove/(wash away) any ethanolic solution on the product.

1

(i) Pure product will have (larger) crystals / needle-like crystals / lighter in colour

Allow whiter, less grey, more crystalline, less powdery, shinier, single colour

Must be tied to pure product

Allow opposite points tied to the crude product

1

[16]