3. The reaction of sodium thiosulfate with hydrochloric acid is described by the following balanced chemical equation: $Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + SO_2 + S + H_2O$
To investigate the effect of *concentration* on the rate of this reaction, the experiment was carried out for a number of different concentrations of sodium thiosulfate solution. For each run, a stopwatch was started when 100 cm^3 of $Na_2S_2O_3$ were mixed with 10 cm^3 of 3 M HCl.
For each run, the reaction was carried out at room temperature and the time taken for the same mass of sulfur to precipitate was measured. The inverse of that time was taken as a measure of the initial rate of reaction.
The results are shown in the table below.

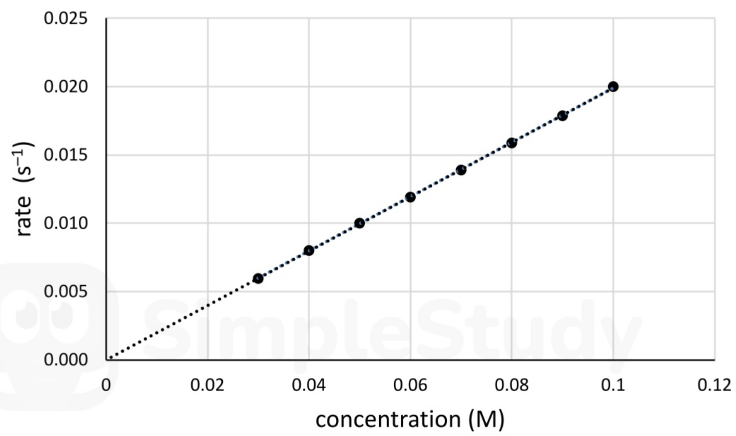
Concentration of $Na_2S_2O_3$ (M)	0.10	0.09	0.08	0.07	0.06	0.05	0.04	0.03
Time (s)	50	56	63	72	84	100	125	168
Rate = $\frac{1}{\text{Time}}$ (s^{-1})	0.020	0.018						

(*a*) (*i*) Describe a method that could be used to know when the same mass of sulfur had been precipitated in each run.
X placed under flask **// light-meter** **(3)**
(time measured until) X not visible **// (time measured until) same value** **(3)**

(*ii*) Describe how a 0.10 M solution of $Na_2S_2O_3$ could be used to prepare a 100 cm^3 portion of 0.09 M $Na_2S_2O_3$ solution.
90 cm^3 of (0.10 M) solution **(3)**
made up (to 100 cm^3) with water **(3)**

(*b*) (*i*) Copy and complete the third row of the table into your answerbook by filling in the missing rate values, correct to three decimal places.
0.016, 0.014, 0.012, 0.010, 0.008, 0.006 **(6 × 1)**

(*ii*) Draw a graph on graph paper to show how the rate of the reaction varies with the concentration of sodium thiosulfate solution.



axes labelled **(3)**
points plotted ***[–1 for each incorrectly plotted point]*** **(6)**
[maximum of 3 marks for points plotted on paper other than graph paper]
line of best fit **(2)**

(*iii*) What can be concluded from your graph?
rate proportional to concentration / time inversely proportional to concentration **(3)**

(*c*) (*i*) Use your graph to estimate the rate of reaction if 100 cm^3 of 0.015 M $Na_2S_2O_3$ solution had been used.
≈ 0.003 (s^{-1}) **(4)**

(*ii*) Calculate the time taken for the sulfur to precipitate in this case.

$\frac{1}{0.003}$ **= 333 (s)** **(4)**

(*d*) To investigate the effect of *temperature* on the rate of this reaction, the time taken for the same mass of sulfur to precipitate was measured at three different temperatures, using fixed volumes and concentrations of the reactants.
The results are shown in the table below.

Temperature (°C)	T_1	T_2	T_3
Time (s)	40	10	25

(*i*) Describe a suitable method for heating the reactants and measuring the reaction temperature. A labelled diagram may help your answer.
heat source / water bath / hotplate / Bunsen burner **(3)**
thermometer **(3)**

(*ii*) Which temperature (T_1, T_2 or T_3) was the highest? Justify your answer.
T_2 **(2)**
greatest rate / least time **(2)**

Question 2

1. A student carried out an experiment to determine the iron(II) content of an iron supplement tablet. Six iron tablets with a total mass of 2.496 g were dissolved in dilute sulfuric acid. The solution and the washings were transferred to a 250 cm^3 volumetric flask and made up to the mark using deionised water. A 25.0 cm^3 portion of this solution was transferred into a conical flask and some sulfuric acid was added. The solution was then titrated against a previously standardised solution of potassium manganate(VII) ($KMnO_4$). A number of titrations were carried out. The titration reaction is described by the following balanced equation:

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

(*a*) Identify a primary standard that the student could have used to standardise the solution of potassium manganate(VII).

ammonium iron(II) sulfate / $(NH_4)_2SO_4.FeSO_4.6H_2O$ **(5)**

(*b*) (*i*) Outline the correct procedure for bringing the solution in the volumetric flask precisely to the 250 cm^3 mark.

add (deionised water) drop by drop / slowly **(3)**

bottom of meniscus on the mark **(3)**

(*ii*) Explain why using more than one iron tablet in the 250 cm^3 of solution increases the accuracy of the analysis.

smaller % error / large volume of potassium manganate(VII) / high concentration of iron solution / one tablet error **(3)**

(*c*) (*i*) Name the piece of apparatus used to accurately measure and transfer the 25.0 cm^3 portion of iron(II) solution into the conical flask.

pipette / burette **(3)**

(*ii*) Describe how this piece of apparatus was rinsed before use.

with deionised water **(3)**

with iron(II) solution / solution it will contain **(3)**

(*d*) (*i*) Explain why the addition of an indicator into the conical flask was not required.

potassium manganate(VII) acts as the indicator **(3)**

(*ii*) Describe what the student observed at the end point.

(pale) pink **(3)**

(*iii*) Describe what would be observed in the conical flask if insufficient acid was present during the titration. Explain your answer.

brown / precipitate **(3)**

MnO_2 / Mn^{4+} **(3)**

(*e*) On average, 22.5 cm^3 of 0.010 M potassium manganate(VII) solution were required for complete reaction with 25.0 cm^3 of the solution of the iron(II) in excess acid.

(*i*) Calculate the number of moles of manganate(VII) ions present in 22.5 cm^3 of 0.010 M potassium manganate(VII) solution.

$\frac{0.010}{1000} \times 22.5 = 0.000225$ / 2.25×10^{-4} (moles per 22.5 cm^3) **(3)**

(*ii*) Calculate the number of moles of iron(II) present in the 250 cm^3 solution in the volumetric flask.

$0.000225 \times 5 = 0.001125$ (moles per 25 cm^3) **(2)**

$0.001125 \times 10 = 0.01125$ (moles per 250 cm^3) **(2)**

(*iii*) Calculate the average mass of iron(II) in one tablet.

$0.01125 \div 6 = 0.001875$ (moles per tablet) **(2)**

$\times 56 = 0.105$ (g per tablet) **(2)**

(*iv*) Calculate the percentage by mass of iron(II) in one tablet.

$\frac{0.105}{0.416} = 0.2524, \times 100 = 25.24$ (%) // $\frac{0.630}{2.496} = 0.2524, \times 100 = 25.24$ (%) **(4)**

[Allow 3 marks for 0.2524]

Question 3

1. A student carried out an experiment to determine the concentration of ethanoic acid in vinegar. A 10.0 cm^3 portion of the vinegar was first diluted to exactly 50.0 cm^3. The diluted vinegar solution was titrated against a 0.09 M sodium hydroxide solution in a conical flask. On average, 12.4 cm^3 of the *diluted* vinegar were required to neutralise 25.0 cm^3 of the NaOH solution.
The titration reaction is described by the following balanced chemical equation:

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

(*a*) (*i*) Name the piece of apparatus used to measure accurately the 10.0 cm^3 portion of the original vinegar.

pipette / burette ***[accept graduated cylinder / syringe]*** **(3)**

(*ii*) Describe how this piece of apparatus was rinsed before use.

with deionised water **(3)**

with vinegar **(3)**

(*iii*) Describe a suitable method to dilute the 10.0 cm^3 portion of the original vinegar to exactly 50.0 cm^3.

add (10.0 cm^3 of original) vinegar to (50 cm^3) volumetric flask **(3)**

to mark with deionised water / (add water to) bring bottom of meniscus to mark **(3)**

(*b*) (*i*) Calculate the volume of *undiluted* vinegar which would be required to neutralise 25.0 cm^3 of the 0.09 M NaOH solution.

reference to a factor of 5 ***[state/imply]*** **(3)**

12.4 ÷ 5 = 2.48 (cm^3) ***[accept 2.5 (cm^3)]*** **(3)**

(*ii*) Outline an advantage of diluting the vinegar before carrying out the titration.

smaller (%) error / more accurate (volume) / less (concentrated) NaOH **(3)**

(*c*) (*i*) Name a suitable indicator for this titration.

phenolphthalein **(3)**

(*ii*) State the colour change observed at the end point.

pink ***[do not accept purple]*** **(3)**

to colourless ***[do not accept clear]*** **(3)**

[award 3 marks for both correct colours reversed]

(*d*) (*i*) Calculate the number of moles of sodium hydroxide in each 25.0 cm^3 portion.

$\frac{0.09 \times 25.0}{1000}$ **= 0.00225 (moles)** **(4)**

(*ii*) Calculate the number of moles of ethanoic acid in each cm^3 of the *diluted* vinegar.

0.00225 ÷ 12.4 = 0.00018 (moles) **(4)**

(*iii*) Calculate the concentration of ethanoic acid in the original vinegar in moles per litre.

0.00018 × 1000 **(2)**

× 5 = 0.91 (M) **(2)**

(*iv*) Calculate the concentration of ethanoic acid in the original vinegar in % (w/v).

$M_r = 60$ **(2)**

$\frac{0.91 \times 60}{10}$ **= 5.44 (%)** **(3)**

QUESTION 4

Eight items to be answered. Six marks to be allocated to each item and one additional mark to be added to each of the first two items for which the highest marks are awarded.

(*a*) REFER: Li, Na, and K (groups) have similar chemical **properties //**
atomic mass (weight) of Na (one) is **average of (midway between)** those of **Li and K (of other two) / mass number of one (Na) is average** of the mass numbers **of** the **others (Li and K) / 23 = (7 + 39) ÷ 2** (2 × 3)

(*b*) WHY: electron in **outer** energy **level (shell, *n* = 3) has more energy /**
electron in **excited (higher, outer)** state **has more energy /**
electron in **inner** energy **level (shell, *n* = 2) has less energy /**
electron **loses energy /** electron moves **from higher to lower energy** level **/**
$E_2 - E_1 = hf$ (6)

(*c*) WHY: second **electron** comes **from full (new, closed) shell (**main **energy level, 1*s* sublevel, 1*s* orbital) /**
second **electron** comes **from shell (**main **energy level) closer to nucleus /**
second outermost **electron** comes **from 1st** main **energy level (shell)**
while first electron comes **from 2nd /**
1st electron removed (lost) is only electron in outer (2nd) shell (main **energy level) /**
second **electron** comes **from** a species with **a stable helium (noble gas)**
electron **configuration /**
second **electron less (not) shielded (screened)** from nucleus than first (6)

Where 6 marks not awarded above 5 marks may be awarded any *one* of the following.
more difficult to remove electron from positive ion than from neutral atom **/**
greater electrostatic force (attraction) between Li^+ **ion and electron /**
1st electron farther from nucleus / 2nd **electron closer to nucleus /**
ionic radius smaller than atomic radius **/**
effective nuclear charge increased when 1st electron is removed /
more protons than electrons in the ion

(*d*) WHAT: (*i*) **red / crimson //**
(*ii*) **blue-green / green** (4 + 2)
[Allow blue/green for blue-green]

(*e*) STATE: **at the same temperature and pressure //**
equal volumes of gases have **equal (the same) number(s) of particles (atoms, molecules, moles)** (2 × 3)
[Do not allow s.t.p for ‘same temperature and pressure’.]

(*f*) CALCULATE: 0.**2**00 g (6)

18.3 × 12 = **219.6** g C (3)
1098 carats = 219.6 g
⇒ one carat = $\frac{219.6}{1098}$ = 0.**2**00 g (3)

or

$\frac{18.3}{1098} = \frac{\mathbf{1}}{\mathbf{60}}$ (0.**016667)** moles C per carat (3)
⇒ one carat = 0.016667 × 12
= 0.**2**00 g (3)

or

$\frac{1098}{18.3}$ = **60** carats per mole C (per 12 g C) (3)
⇒ one carat = $\frac{\mathbf{12}}{\mathbf{60}}$
= 0.**2**00 g (3)

(*g*) WHAT: **iron(II) sulfate (**$FeSO_4$, ammonium **iron(II) sulfate) /**

$(C_6H_5)_2NH$ (diphenylamine) and **NH_4Cl (ammonium chloride) /**
copper (Cu) //
concentrated **sulfuric acid (H_2SO_4)**
or
sodium hydroxide (NaOH) solution **//**
aluminium (Al) / copper (Cu) / zinc (Zn) (4 + 2)

(*h*) IDENTIFY: (*i*) **aluminium sulfate (alum, $Al_2(SO_4)_3$) / polyacrylamide ($\text{-}CH_2CHCONH_2\text{-})_n$ / sodium silicate (Na_2SiO_3, Na_4SiO_4, $Na_6Si_2O_7$, etc) / sodium aluminate ($NaAlO_2$, $NaAl(OH)_4\cdot(H_2O)_x$, $Na_2O\cdot Al_2O_3$, $Na_2Al_2O_4$) / aluminium chlorohydrate ($Al_nCl_{3n\text{-}m}(OH)_m$) / iron(II) sulfate ($FeSO_4$) / iron(III) chloride ($FeCl_3$) / calcium oxide (CaO) / calcium hydroxide ($Ca(OH)_2$)**
[Allow polyelectrolyte]

(*ii*) **sodium fluoride (NaF) / hexafluorosilicic acid (H_2SiF_6) / sodium fluorosilicate (Na_2SiF_6) /**
[Allow **fluoride** ion **(F^-), fluoride** salt.]
(4 + 2)

(*i*) WHAT: **iodine (I_2) //**
hydrogen (H_2) (4 + 2)
[Allow I and H]

(*j*) WHICH: **ethyne (C_2H_2)** (6)

(*k*) CALCULATE: **72**.0 mg (6)

M_r aspirin ($C_9H_8O_4$) = 180		M_r aspirin ($C_9H_8O_4$) = 180
0.146 × 180* = **26.28**0 g aspirin (3)	*or*	0.146 ÷ 365 = **4 × 10⁻⁴ (1/2500)** mol per day (2)
26.28 ÷ 365 = 0.**072**0 **(9/125)** g per day (2)		4 × 10⁻⁴ × 180* = 0.**072**0 **(9/125)** g per day (3)
⇒ 0.0720 × 1000 = **72**.0 mg per day (1)		⇒ 0.0720 × 1000 = **72**.0 mg aspirin per day (1)

[**Addition must be shown for error to be treated as slip.*]

(*l*) **A** WRITE: $CO_2 + H_2O \rightarrow H_2CO_3$
$\mathbf{H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+ / H_2CO_3 + H_2O \rightleftharpoons (\rightarrow) HCO_3^- + H_3O^+}$ **//**
$\mathbf{HCO_3^- \rightleftharpoons (\rightarrow) CO_3^{2-} + H^+ / HCO_3^- + H_2O \rightleftharpoons (\rightarrow) CO_3^{2-} + H_3O^+}$ (2 × 3)
or
$\mathbf{H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+ \rightleftharpoons (\rightarrow) CO_3^{2-} + 2H^+}$ (6)
[Allow $\mathbf{2H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H^+}$ or
$\mathbf{2H_2CO_3 + 3H_2O \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H_3O^+}$]

or

B WHAT: **molecules occupy (at) lattice points //**
held together by (contain) **intermolecular (van der Waals, London, dispersion, dipole-dipole, hydrogen) bonds (forces, interactions)** (2 × 3)

QUESTION 4

Eight items to be answered.

Six marks to be allocated to each item and one additional mark to be added for each of the first two items attempted.

(*a*) HOW: (*i*) **18** electrons
(*ii*) **16** neutrons (2 × 3)
[Take order of question unless answers clearly labelled.]

(*b*) DEFINE: **space (volume, region)** around nucleus of an atom **//**
where there is a relatively **high probability (possibility) of finding an electron /**
where an electron is likely to be found (2 × 3)
['Area' around nucleus not acceptable.]

(*c*) WRITE: $\mathbf{1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^8}$ **/**
$\mathbf{1s^2\,2s^2\,2p_x{}^2 2p_y{}^2\,2p_z{}^2\,3s^2\,3p_x{}^2 3p_y{}^2\,3p_z{}^2 4s^2\,3d^8}$ **/**
[Ar] $\mathbf{4s^2\,3d^8}$ (6)
[*Allow subscripts instead of superscripts.*]
[*Arrows to represent numbers of electrons acceptable but sub-level labels must be given.*]

(*d*) WHICH: $\mathbf{CO_2}$ container **/ last (third) one //**
EXPLAIN: **equal numbers of molecules (moles) /** according to **Avogadro's law /**
$\mathbf{CO_2}$ **triatomic (three atoms in** $\mathbf{CO_2}$ molecule**) /** $\mathbf{CO_2}$ **molecule has more atoms** (2 × 3)
[Award second (3) only if first (3) is given.]

(*e*) DEFINE: number expressing the **relative (measure of)** force of **attraction (affinity) of an atom (nucleus** of an atom**)** of an element **//**
for shared pair(s) of **electrons / for electrons in a covalent bond** (2 × 3)

(*f*) WHY: **C-C is a sigma** bond and **C≡C is a sigma and 2 pi** bonds **//**
sigma stronger than pi **/ pi weaker** than sigma (2 × 3)

(*g*) DEDUCE: $\mathbf{N_2O}$ (6)

(*h*) FIND: **3 /** $\mathbf{KBrO_3}$ (6)

$$\frac{80}{39+80+16x} = 0.479 \quad * \;/\; \frac{80}{119+16x} \times 100 = 47.9 \quad * \qquad (3)$$

$80 = 57.001 + 7.664x \;\Rightarrow\; x = \mathbf{3}$ (3)

or

$\frac{39}{80} \times 47.9 = 23.35\%\ (23.4\%)$ K* and

$100 - (47.9 + 23.4) =$ **28.7% (28.8%, 29%)** O (3)

$\frac{47.9}{80} = 0.598 \qquad \frac{23.4}{39} = 0.6 \qquad \frac{28.7}{16} = 1.794$

$0.598 : 0.6 : 1.794 = 1 : 1 : 3 \;\Rightarrow x =$ **3** (3)

or

$80 = 47.9\,\% \;\Rightarrow$ **167.01** $= 100 = M_r$ (3)

$167.01 - 80 - 39 = 48.01 = 16x$

$\Rightarrow\quad x =$ **3** (3)

[**Work based on Ar values in Formula and Tables booklet acceptable.*]

(*i*) SHOW: $\mathbf{H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-}$ **/** $\mathbf{2H_2O \rightleftharpoons H_3O^+ + OH^-}$ FORMULAE: (3) BALANCED (3)
Allow $\mathbf{H_2O \rightleftharpoons H^+ + OH^-}$
[non equilibrium arrow unacceptable....(–1)]

(*j*) GIVE: **preservative (antifungal** agent**, pH adjuster) / food additive / flavour**ing agent (6)

(*k*) WHAT: (*i*) **2** (3)
(*ii*) **3** (3)
[Take order of question unless answers clearly labelled.]

(*l*) **A** GIVE: *advantage:* **suits slower reactions / suits pharmaceutical industry (research) /**

flexible (adaptable) reaction vessels **/ suits small quantities / capital (building, installation) costs** of plant **small / loss isolated to single batch / etc**

disadvantage: **contamination** from previous batch **possible / labour costs high / costly (unit cost higher) / filling (emptying, cleaning, recharging, calibration, maintenance of)** reaction vessel takes **time / etc**

(2 × 3)

or

B WHAT: **low-**density poly(ethene) **(L**DPE**)** carbon chains **more branched (has branching) / high**-density poly(ethene) **(H**DPE**)** carbon chains have **less (no) branching** (6)

Question 6

(*a*) (*i*) WHAT: **elements** listed **according to** relative **atomic mass (weight)** and chemical **properties repeat periodically (at** regular **intervals) /** **elements** listed **according to** relative **atomic mass (weight)** and **in groups with similar properties**

(*ii*) CMNT: **listed (positioned)** correctly **according to** chemical **properties /** **listing (positioning)** these **by** relative **atomic mass (weight) would not group them with elements of similar** chemical **properties /** chemical **properties matched (fitted) better when** order **reversed /** **it was thought** relative **atomic mass**es **(weight**s**) had been incorrectly measured**

(*iii*) WHY: **undiscovered (unknown)** in 1869 **/ discovered after (later than)** 1869

(5 + 4 + 2)

(*b*) (*i*) DEFINE 1: *Atomic number:*
number of protons in the nucleus of an atom (3)

DEFINE 2: *Relative atomic mass:*
average mass of atom of the element **/**
average of mass of isotopes of the element **taking abundances into account (as they occur naturally) /**
average of mass numbers of isotopes of the element **taking abundances into account (as they occur naturally) //**
compared to (relative to, based on) 1/12th **carbon–12** isotope

(2 × 3)

(*ii*) GIVE: **more fundamental property** of element **/**
no need to reverse order to force elements into correct groups **/**
tellurium (Te) and iodine (I) positions on table **justified /**
tellurium (Te) and iodine (I) in correct groups / elements **in correct groups /**
elements **in groups with similar properties / properties repeat periodically /**
identifies gaps in periodic table / **indicates undiscovered elements** (3)

(*c*) (*i*) WHY: **stable arrangement of electrons / do not lose or gain electrons /**
2 or 6 electrons in outer subshell /
have **stable** outer **octet (**$ns^2\,np^6$**)** except He **/ satisfy octet rule** (3)
[Full outer shell unacceptable but does not cancel.]

(*ii*) HOW: **less reactive** down group **/ less likely to gain an electron** down group /
less easily reduced down group **/ more difficult to attract (gain) electron(s)** down group/
reduction more difficult down group

WHY: **increasing (greater) atomic radius (number of shells) / more shells /**
nucleus farther from outer electrons /
increasing (more) screening of nucleus by electrons in inner shells **/**
more difficult to achieve stable octet (ns^2np^6**) /**
more difficult to achieve full outer sub-level (subshell) /
decreasing (smaller) electron affinity /
decreasing (smaller) electronegativity
[HOW and WHY not linked.] (6 + 3)

(*d*) (*i*) HOW: **violently / vigorously / explosively / dangerously / rapidly / burns (goes on fire,** makes coloured **flame) / fizzes** (6)
[Allow 'very reactive'.]

JUSTIFY: **reactivity increases down group / small ionisation energy /**
easily loses one (outer, most loosely bound) electron / easily oxidised (6)
[Allow (6) for any of 'large atomic radius' or 'number of shells' or 'much screening of nucleus by electrons in inner shells' or 'unstable' or 'alkali metal' or 'Group 1 element'.]
[HOW and JUSTIFY not linked.]

(*ii*) PREDICT: **FrOH (francium hydroxide) //**
H_2 (hydrogen) (2 + 1)

Question 7

(*b*) (*i*) WRITE: $(CH_2)_n(COOH)_2$: $\mathbf{14n + 90}$ (3)

$(CH_2)_n(COONa)_2$: $\mathbf{14n + 134}$ (3)

[Take order of question unless answers clearly labelled.]

(*ii*) WRITE: $\frac{1.77}{14n+90}$ moles $(CH_2)_n(COOH)_2$ (3)

$\frac{2.43}{14n+134}$ moles $(CH_2)_n(COONa)_2$ (3)

[Take order of question unless answers clearly labelled.]

(*iii*) FIND:

$\frac{1.77}{14n+90} = \frac{2.43}{14n+134}$ **/**
$24.78n + 237.18 = 34.02n + 218.7$ **/**
$\Rightarrow 18.48 = 9.24n$ **//** (2)
$\Rightarrow n = \mathbf{2}$ **//** (2)
molar mass of $(CH_2)_n(COOH)_2$ = **118** g (3)

[Allow correct answers obtained by trial and error method below, i.e. letting n = 2 and showing n = 2 gives equal moles of succinic acid and disodium succinate as shown below. Do not allow mixing and matching of marks between boxes.]

Letting $n = \mathbf{2} \Rightarrow M_r\ (CH_2)_n(COOH)_2 = \mathbf{118}$ and $M_r\ (CH_2)_n(COONa)_2 = 162$ (2 + 3)
Show moles $(CH_2)_n(COOH)_2$ = moles $(CH_2)_n(COONa)_2$
$\frac{1.77}{118}$ = 0.**015** moles $(CH_2)_n(COOH)_2$ = $\frac{2.43}{162}$ = 0.**015** moles $(CH_2)_n(COONa)_2$ (2)

(*iv*) WHAT: **250** cm^3 (6)

$\frac{1.77}{118}$ = 0.**015** moles $(CH_2)_n(COOH)_2$ (2)
$\Rightarrow$ 0.**03** moles NaOH (2)
$0.03 = \frac{0.12 \times V}{1000} \Rightarrow V = \mathbf{250}\ cm^3$ (2)

Question 8

(*c*) CALCULATE: (*i*) 0.**036** moles H or 0.**018** moles H_2 (3)

$0.018 \times 2 =$ 0.**036** mol H or 0.**018** moles H_2	(3)

CALCULATE: (*ii*) 0.**032** moles C (8)

$\frac{3.584}{56^*} =$ 0.**064** moles KOH	(4)
$\Rightarrow 0.064 \div 2 = 0.032$ moles CO_2	
$\Rightarrow$ 0.**032** moles C	(4)

[**Addition must be shown for error to be treated as slip.*]

CALCULATE: (*iii*) 0.**002 / 2 × 10^{-3} / 1/500** moles S (4)

$\frac{44.8}{22400} = 0.002$ / 2×10^{-3} / 1/500 moles SO_2	
$\Rightarrow$ 0.**002 / 2 × 10^{-3} / 1/500** moles S	(4)

CALCULATE: (*iv*) 0.**004 / 4 × 10^{-3} / 1/250** moles N or 0.**002 / 2 × 10^{-3} / 1/500** moles N_2 (4)

$\frac{2.4 \times 10^{21}}{6 \times 10^{23}} = 0.004$ / 4×10^{-3} / 1/250 moles NO_2	
$\Rightarrow$ 0.**004 / 4 × 10^{-3} / 1/250** moles N or 0.**002 / 2 × 10^{-3} / 1/500** moles N_2	(4)

WHAT: $\mathbf{C_{16}H_{18}N_2O_4S}$ (6)

C : H : N : O : S = 0.**032 :** 0.**036 :** 0.**004 :** 0.**008 :** 0.**002**	(2)
[Number of **moles H atoms** and number of **moles of N atoms** essential.]	
Divide C : H : N : O : S **ratio by smallest number of moles**	(3)
$\Rightarrow \mathbf{C_{16}H_{18}N_2O_4S}$	(1)
[Last mark available **ONLY** for $\mathbf{C_{16}H_{18}N_2O_4S}$]	

[Full marks available where elements are not in alphabetical order.]

Question 9

7. (*a*) (*i*) Explain how an acid differs from a base according to the Brønsted-Lowry theory.

proton donor **(2)**

proton acceptor **(2)**

(*ii*) Explain how a strong acid differs from a weak acid according to the Brønsted-Lowry theory.

good proton donor **(2)**

poor proton donor **(2)**

(*iii*) What is a conjugate acid-base pair?

two species that differ by a H^+ **(2)**

(*iv*) Identify the conjugate acid-base pairs in the following reaction:

$$HCO_3{}^{-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} + OH^{-}{}_{(aq)}$$

HCO_3^- and H_2CO_3, H_2O and OH^- **(3)**

(*b*) (*i*) Explain what is meant by pH.

$-\log_{10}$ **(2)**

$[H^+]$ / moles per litre of H^+ ions **(2)**

(*ii*) Calculate the H_3O^+ ion concentration, in moles per litre, of a solution of a strong acid with pH = 1.4.

$[H^+] = 10^{-1.4}$ **(2)**

0.0398 (mol L^{-1}) **(2)**

(*iii*) Calculate the pH of a 0.015 M solution of a weak monobasic acid with $K_a = 3.2 \times 10^{-4}$ at 25 °C.

$\sqrt{K_a M_{acid}} = [H^+]$ / $-\log_{10}\sqrt{K_a M_{acid}}$ **(2)**

$K_a M_{acid} = 0.0000048$ / $\sqrt{K_a M_{acid}} = 0.00219$ **(2)**

pH = 2.66 / 2.7 **(3)**

(*c*) (*i*) Write an expression for the ionic product of water (K_w).

$K_w = [H^+][OH^-]$ **(6)**

The ionic product of water (K_w) at 60 °C is 9.61×10^{-14} mol^2 l^{-2}.

(*ii*) Calculate the pH of pure water at 60 °C.

$[H^+] = \sqrt{9.61 \times 10^{-14}}$ / $[H^+] = 3.1 \times 10^{-7}$ **(3)**

pH = $-\log_{10}(3.1 \times 10^{-7})$ = 6.5 **(3)**

(*d*) A certain water-soluble acid-base indicator, represented by HA, is a weak acid which dissociates in water as described by the following balanced equation:

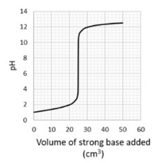
$$\underset{\text{yellow}}{HA} + H_2O \rightleftharpoons H_3O^+ + \underset{\text{blue}}{A^-}$$

(*i*) State the colour you would expect to observe when a few drops of HA are added to a solution of a strong base. Justify your answer.

blue **(3)**

H_3O^+ concentration decreases / (equilibrium position) moves to the right / system opposes stress **(3)**

The pH curve on the right shows the change of pH as 50 cm^3 of a solution of a strong base were added to 25 cm^3 of a solution of a strong monobasic acid.



The indicator HA changes colour in the pH range of 4.2 to 5.4.

(*ii*) Would the indicator HA be a suitable choice of indicator for the titration? Justify your answer.

yes **(2)**

(pH range of indicator) coincides with vertical portion of the curve **(2)**