Chemistry:
Transition from GCSE to AS level

Part 11 - Required Practical

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There are 12 required practicals:
6 for AS (Y12) and 6 for A2 (Y13)

The first required practical is divided into 2 parts:
(a) making a standard solution
(b) titrations the standard solution

1. Making up a standard solution.

Watch these videos:

University of Edinburgh: https://youtu.be/MeOAPbMvubE

Rugby School: https://youtu.be/iPYyRNjXkgY

Note: wash solid off weighing boat rather than weighing by difference

WORK SHEET 1a

To prepare a solution of sodium hydrogensulfate that has a known concentration.

Requirements

- weighing bottle or boat
- one 250 cm^3 volumetric (graduated) flask
- sodium hydrogensulfate solid (see below)
- filter funnel
- spatula
- de-ionised or distilled water in a wash bottle
- one 250 cm^3 beaker
- glass rod
- digital mass balance (reading to 2 or 3 decimal places)

The composition of the sodium hydrogensulfate should be known; either anhydrous (and the purest available) or the monohydrate. Students need to be advised which they are using. Suppliers can also call this reagent sodium bisulfate.

Suggested Method

The task is to prepare 250 cm^3 of a solution of sodium hydrogensulfate with a known concentration in the range 0.0900 to 0.110 mol dm^{-3}

The procedure is as follows

a) Calculate the mass of sodium hydrogensulfate solid needed to produce 250 cm^3 of a 0.100 mol dm^{-3} solution. Show your working. If you are using the anhydrous solid, the mass to weigh out will be between 2.7 and 3.3 g, and if you are using the monohydrate, the mass to weigh out should be between 3.1 and 3.8 g
b) Weigh a clean dry weighing bottle (or weighing boat).
c) Place the weighing bottle on the pan of a digital balance and, using a spatula, place into the bottle **approximately** the mass of sodium hydrogensulfate that you have calculated to be necessary.
d) Weigh the weighing bottle and its contents accurately and record the **precise** mass.
e) Pour the contents of the weighing bottle into a beaker and re-weigh the weighing bottle (which may still contain traces of sodium hydrogensulfate).
f) Calculate the mass of sodium hydrogensulfate that you have transferred. Remember to record all weighings to the precision of the balance that you have used.
g) Add approximately 100 cm^3 of de-ionised (or distilled) water to the beaker containing the solid and using a glass rod, stir the contents of the beaker until all of the sodium hydrogensulfate dissolves.
h) Using a funnel, pour the contents of the beaker into a 250 cm^3 volumetric (graduated) flask and then using the wash bottle rinse the beaker and funnel into the same volumetric flask. Rinse the glass rod into these washings.
i) Make the volumetric flask up to the graduated mark by carefully adding de-ionised water from the wash bottle. You will need to be careful so that you do not over-shoot the mark.
j) Stopper the volumetric flask and shake it thoroughly to mix the contents of the flask.
k) Calculate the exact concentration in mol dm^{-3} of your solution quoting the value to the appropriate precision. Show all of your working.

2. Titration technique.

Watch these 2 videos:

Note: don't show filling the air space below the burette tap
titres are written to 2dp but 2nd do is either 0 or 5

Uni of Edinburgh https://youtu.be/rK7Egs-SJus
Rugby School https://youtu.be/RI14t0R1wMY

WORK SHEET 1b

To determine the concentration of a solution of sodium hydroxide by titration using a sodium hydrogensulfate solution that has a known concentration.

Whenever possible, students should work individually.
If it is essential to work in a pair or in a small group, because of the availability of apparatus, supervisors must be satisfied that they are able to assess the contribution from each student to the practical activity.

Requirements

- burette
- stand and clamp
- 25 cm^3 pipette
- pipette filler
- Two 250 cm^3 conical flasks
- Two 250 cm^3 beakers
- funnel
- wash bottle
- phenolphthalein indicator
- standard sodium hydrogensulfate solution (150 cm^3)
- sodium hydroxide solution (150 cm^3)

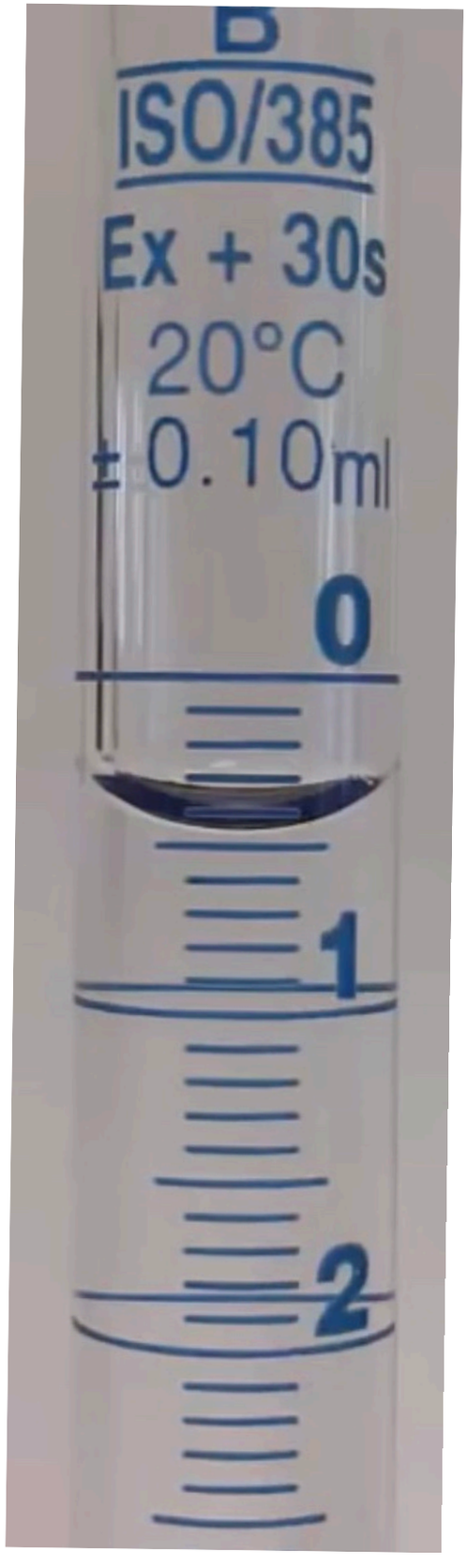
The sodium hydrogensulfate solution needs to be a solution with an accurately known concentration between 0.0900 and 0.100 mol dm^{-3} or could be the solution which the student prepared as part of Work Sheet 1a.

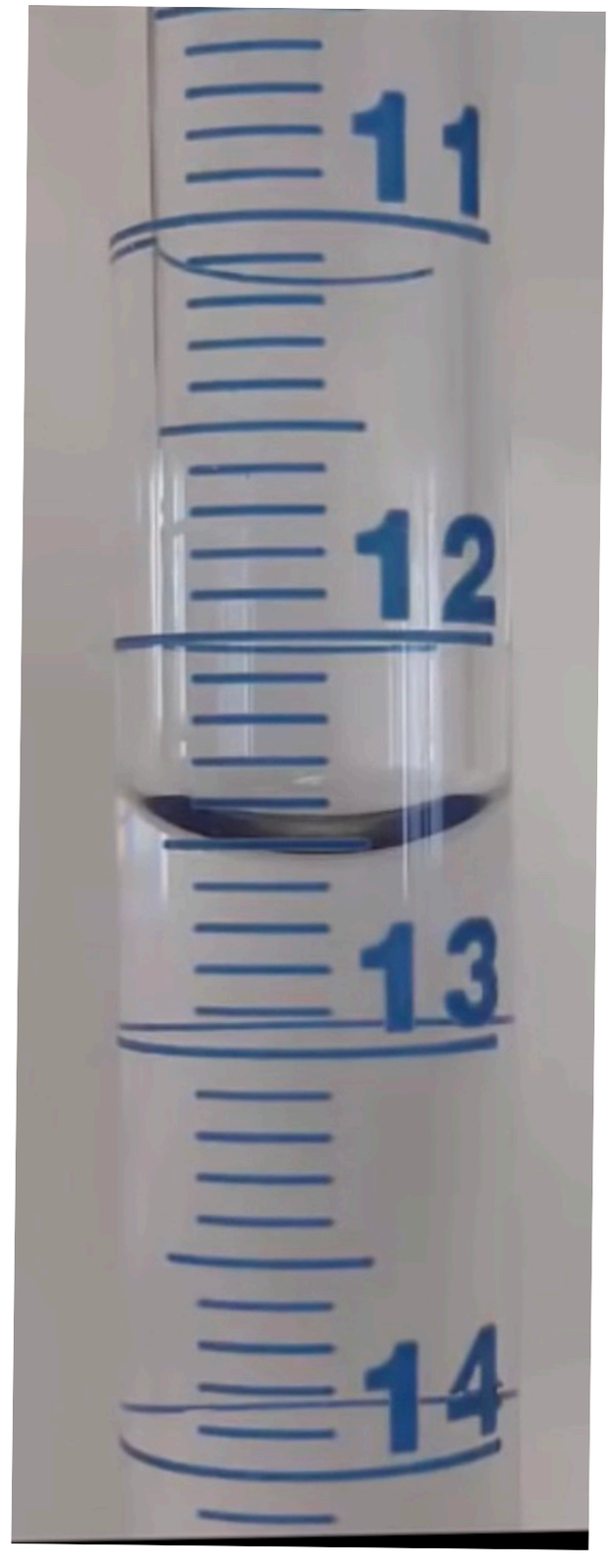
Students should use a sodium hydroxide solution with an accurately known concentration between 0.0900 and 0.100 mol dm^{-3} but labelled as “Sodium hydroxide solution of unknown concentration”.

Suggested Method

a) Pour approximately 100 cm^3 of the sodium hydrogensulfate solution into a clean, dry beaker that is labelled 'sodium hydrogensulfate'. Use a small volume of this solution to rinse the burette before filling it with the sodium hydrogensulfate solution.
b) Pour approximately 100 cm^3 of the sodium hydroxide solution into a second clean, dry beaker labelled 'sodium hydroxide'.
c) Rinse a 25 cm^3 pipette with the sodium hydroxide solution provided and then, using a pipette filler, pipette exactly 25.0 cm^3 of sodium hydroxide solution into a 250 cm^3 conical flask (which has been rinsed with de-ionised water).
d) Add **two to three drops** of phenolphthalein indicator to the solution in the conical flask and note the colour of the indicator in alkali.
e) **Before you start** to titrate, construct a Table ready to record your results.
f) Record the initial burette reading. Make sure that all your burette readings are to the appropriate precision.
g) Titrate the contents of the conical flask by adding sodium hydrogensulfate solution to it from the burette. Add the sodium hydrogensulfate solution slowly, swirling the flask gently to mix the solution. Add the sodium hydrogensulfate solution dropwise near the end-point until the indicator undergoes a definite colour change; this is the end-point of the titration. Record the colour change in your results. Record the final burette reading in your Table of results.
h) Calculate and record in your Table of results the volume of sodium hydrogensulfate solution used.
i) Repeat the titration until you obtain **two** results, which are **concordant.** You should normally carry out **at least three** titrations. **Record all of the results** that you obtain.
j) Calculate and record the mean volume of sodium hydrogensulfate solution used in the titration. Show your working.

What are the burette readings?





The Periodic Table of the Elements

1	2											3	4	5	6	7	0
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	96.0 Mo molybdenum 42	[97] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La * lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac † actinium 89	[267] Rf rutherfordium 104	[270] Db dubnium 105	[269] Sg seaborgium 106	[270] Bh bohrium 107	[270] Hs hassium 108	[278] Mt meitnerium 109	[281] Ds darmstadtium 110	[281] Rg roentgenium 111	[285] Cn copernicium 112	[286] Nh nihonium 113	[289] Fl flerovium 114	[289] Mc moscovium 115	[293] Lv livermorium 116	[294] Ts tennessine 117	[294] Og oganesson 118

Key

relative atomic mass
symbol
name
atomic (proton) number

140.1 Ce cerium 58	140.9 Pr praseodymium 59	144.2 Nd neodymium 60	[145] Pm promethium 61	150.4 Sm samarium 62	152.0 Eu europium 63	157.3 Gd gadolinium 64	158.9 Tb terbium 65	162.5 Dy dysprosium 66	164.9 Ho holmium 67	167.3 Er erbium 68	168.9 Tm thulium 69	173.0 Yb ytterbium 70	175.0 Lu lutetium 71
232.0 Th thorium 90	231.0 Pa protactinium 91	238.0 U uranium 92	[237] Np neptunium 93	[244] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[247] Bk berkelium 97	[251] Cf californium 98	[252] Es einsteinium 99	[257] Fm fermium 100	[258] Md mendelevium 101	[259] No nobelium 102	[262] Lr lawrencium 103

* **58 – 71** Lanthanides

† **90 – 103** Actinides

Use this for the task on the next page

The following question is from a past AS paper

3 This question is about a white solid, $MHCO_3$, that dissolves in water and reacts with hydrochloric acid to give a salt.

$$MHCO_3 + HCl \rightarrow MCl + H_2O + CO_2$$

A student was asked to design an experiment to determine a value for the M_r of $MHCO_3$. The student dissolved 1464 mg of $MHCO_3$ in water and made the solution up to 250 cm^3.
25.0 cm^3 samples of the solution were titrated with 0.102 mol dm^{-3} hydrochloric acid. The results are shown in **Table 1**.

Table 1

	Rough	**1**	**2**	**3**
Initial burette reading / cm^3	0.00	10.00	19.50	29.25
Final burette reading / cm^3	10.00	19.50	29.25	38.90
Titre / cm^3	10.00	9.50	9.75	9.65

0 3 . 1 Calculate the mean titre and use this to determine the amount, in moles, of HCl that reacted with 25.0 cm^3 of the $MHCO_3$ solution.

[3 marks]

0 3 . 2 Calculate the amount, in moles, of $MHCO_3$ in 250 cm^3 of the solution.
Then calculate the experimental value for the M_r of $MHCO_3$.
Give your answer to the appropriate number of significant figures.

[3 marks]

0 3 . 3 The student identified use of the burette as the largest source of uncertainty in the experiment.

Using the same apparatus, suggest how the procedure could be improved to reduce the percentage uncertainty in using the burette.

Justify your suggested improvement.

[2 marks]

Suggestion

Justification

0 3 . 4 Another student is required to make up 250 cm^3 of an aqueous solution that contains a known mass of $MHCO_3$. The student is provided with a sample bottle containing the $MHCO_3$.

Describe the method, including apparatus and practical details, that the student should use to prepare the solution.

[6 marks]

Pause this presentation while you complete the exercise on the previous page.

When complete move to the next page where you can check your answers.

03.1	Selects correct titres $\text{mean titre} = \frac{9.75 + 9.65}{2}$ = 9.7(0) cm^3 mol HCL = 0.102 × $^{9.70}/_{1000}$ = 9.89×10^{-4} (allow 9.9x10-4 for M3 but check not via 4 titres in which case only 1 mark)	1 1 1	If 3 or more titres used them MAX 1 for conseq M3 Calculates mean Calculates mol (working or result gains credit) 9.92×10^{-4} scores 1 if all 4 titres used 9.83×10^{-4} scores 1 if titres 1,2,and 3 used

03.2	mol $MHCO_3$ = ANS 3.1 x 10 (= 9.89×10^{-3}) $\text{Mr} = \frac{1464/1000}{M1}$ Mr = 148 (3sf)	1 1 1	Use ecf if wrong mean calculated above Allow ecf following wrong mass conversion

03.3	Suggestion: Use a larger mass of solid OR use a more concentrated solution of $MHCO_3$ OR less concentrated / more dilute solution of HCl OR more $MHCO_3$ Justification: So a larger titre/reading will be needed OR larger volume of HCl	1 1	Cannot score justification mark unless suggestion correct, but suggestion could be after justification Assume reference to the solution means the $MHCO_3$

03.4 **Stage 1:** transfers known mass of solid

a) Weigh the sample bottle containing the solid on a (2 dp) balance
b) Transfer to beaker* and reweigh sample bottle
c) Record the difference in mass

Or

d) Place beaker* on balance and tare
e) Transfer solid into beaker
f) Record mass

Or

g) Known mass provided
h) Transfers (known) mass into beaker*
i) Wash all remaining solid from sample bottle into beaker

Allow use of weighing boat

*Allow other suitable glassware including volumetric flask

Stage 2: Dissolves in water

a) Add distilled / deionised water
b) Stir (with a glass rod) or swirl
c) Until all solid has dissolved

Stage 3: Transfer, washing and agitation

a) Transfer to <u>volumetric / graduated</u> flask. Allow if a clear description/diagram given eg long necked flask with $250cm^3$ mark
b) With washings
c) Make up to $250cm^3$ / mark with water
d) Shakes/inverts/mixes

Having checked your work you will have either:

1. Completed the task correctly - well done :)

2. Made some mistakes - which you now understand (having seen the correct answer) - that's OK as you have 'learned from your mistakes'

3. Do not understand the answer - if this is the case you **must** seek assistance from your teacher (if you do not then you will ***never*** understand this and this may be a building block for later work!)

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The following question is from a past AS paper

Q1.

Citric acid, $C_3H_5O(COOH)_3$, occurs naturally in many fruits and can also be synthesised in the laboratory for use as a food flavouring. A student analysed a sample of citric acid to determine its percentage purity.

The student dissolved 784 mg of impure citric acid in water to prepare 250 cm^3 of solution in a volumetric flask.

The student titrated 25.0 cm^3 samples of this solution with 0.0500 mol dm^{-3} sodium hydroxide solution using phenolphthalein as the indicator.

$$C_3H_5O(COOH)_3(aq) + 3NaOH(aq) \rightarrow C_3H_5O(COO)_3Na_3(aq) + 3H_2O(l)$$

(a) The student rinsed the burette before filling it with the sodium hydroxide solution.

State why the student should use sodium hydroxide solution rather than water for the final rinse of the burette.

_____

_____

_____

(1)

(b) The student carried out several titrations. The results are shown in the table.

Complete the table to show the titre in each titration.

Titration	**Rough**	**1**	**2**	**3**
Final reading / cm^3	25.2	23.95	47.65	24.10
Start reading / cm^3	0.0	0.05	23.95	0.10
Titre / cm^3				

(1)

(c) Calculate the mean titre using the concordant results.

Give your answer to the appropriate number of significant figures.

Mean titre _____ cm^3

(2)

(d) The total uncertainty when using the burette is ±0.15 cm^3. This is the combination of uncertainties in the start reading, final reading and the determination of the end point.

Use your answer to part (c) to calculate the percentage uncertainty for the use of the burette in this experiment.

Percentage uncertainty _____ %

(1)

(e) Use your answer to part (c) to find the mass, in mg, of citric acid dissolved in 250 cm^3 of the solution.

The relative molecular mass (M_r) of citric acid is 192.0

mass _____ mg

(3)

(f) Calculate the percentage purity of this sample of citric acid.

Percentage purity _____ %

(1)

(Total 9 marks)

Pause this presentation while you complete the exercise on the previous page.

When complete move to the next page where you can check your answers.

Mark schemes

Q1.

(a) use of water would <u>dilute</u> the NaOH OR
use of water would change the <u>concentration</u> of NaOH OR
to ensure the <u>concentration</u> of the NaOH is not changed OR

Ignore reference to weakening the solution, watering down the solution, contaminate

Allow

it would gives a titre value that is larger

it would decrease the pH of the NaOH

(any additional qualifying reason given must be correct)

1

(b) Rough = 25.2, 1= 23.90, 2 = 23.70, 3 = 24.00.

Need all four (with rough to 1dp and the other three to 2dp)

1

(c) **M1** use of titrations 1 & 3 only

***M1** is for choosing correct titres*

1

M2 23.95 (cm^3)

***M2** is for calculating the mean to 2dp for their chosen titres*

24.0 cm^3 = 1 mark (wrong number of decimal places)

24 cm^3 = 1 mark (only if it is clear that titration 2 is not included)

23.86 cm^3 = 1 mark (used all three titrations)

23.9 cm^3 = 0 marks (used all three titrations and wrong number of decimal places)

If error(s) made in 2.2, allow ECF from 2.2, where they choose concordant titres and find the mean (can score M1 and M2)

1

(d) $\left(\frac{0.15}{23.95} \times 100\right) = 0.63\%$

(0.6263%)

Allow any correct value with at least 2 significant figures based on their answer to 2.3. Rounding must be correct.

1

(e) **M1** moles NaOH = $\frac{23.95}{1000} \times 0.0500$ (=0.001198)

1

M2 moles acid in flask = $\frac{M1}{3} \times 10$ (= 0.003992)

1

M3 mass acid (= 0.003992 x 192.0 = 0.766 g) = 766 (mg)

Correct answer to at least 2sf = 3 marks (allow 760-770 mg)

Correct value in grams (lose M3) = 2 marks (allow 0.76-0.77 g)

Allow ECF at each stage (including those based on value from 2.3)

Incorrect answers that are a factor of 10 too small lose M2 (76-77 mg = 2 marks, 0.076-0.077 g = 1 mark)

*(if use 25 cm^3 for volume of NaOH, then max 2 marks (**M2** and **M3** for 800 mg)*

1

(f) $\left(\frac{\text{Answer to Q (e)}}{784} \times 100\right) = 97.7$ or 97.8%

Allow any correct value to at least 2 significant figures based on their answer to Q(e)

(values may be over 100% if 2.5 is incorrect)

1

[9]

Examiner reports

Q1.

(a) Only a minority of students (42.3%) could explain why the final rinse of a burette in a titration should be done with the solution going into the burette rather than with water. This showed the importance of students understanding *why* they are doing what they are doing in a practical procedure rather than just following instructions.

(b) Very few students (only 15%) could give the volumes in each titration to the appropriate precision, for example writing 23.9 instead of 23.90 cm^3.

(c) The calculation of the uncertainty in the use of the burette in the titration was answered well, but a significant number of students did double the uncertainty perhaps because they did not appreciate the origins of the ±0.15 cm^3 uncertainty.

(d) Many students could identify the concordant titres to use to find the mean, although many did not, but few students quoted the mean to the appropriate precision.

(e) This calculation was done well, but some students used the wrong volume of alkali, using the volume of the acid instead. The conversion of g to mg was done well. This question discriminated particularly well.

(f) Nearly half of students could find the percentage purity based on their answer to question (e). Worryingly, just over 20% of students made no attempt at all at this question.

Having checked your work you will have either:

1. Completed the task correctly - well done :)

2. Made some mistakes - which you now understand (having seen the correct answer) - that's OK as you have 'learned from your mistakes'

3. Do not understand the answer - if this is the case you **must** seek assistance from your teacher (if you do not then you will ***never*** understand this and this may be a building block for later work!)

Instrumental Errors

There are two types of errors involved in experimental measurement:

(i) Human errors – which can be minimised through good practical technique.
(ii) Apparatus errors – errors in the apparatus used which cannot be avoided.

Apparatus errors can be quantified, giving us a measure of confidence in our results.

Apparatus errors

There are two types of apparatus errors, fixed errors and variable errors.

(i) Fixed errors – these errors are always the same for a particular piece of apparatus and occur for pieces of apparatus which measure a fixed amount of substance.
The error is expressed as a percentage of the amount measured.

Pipette 25ml pipettes are most commonly used and have an error of +/- 0.06 ml.

$$\% \text{ error in 25ml pipette} = \frac{0.06}{25} \times 100 = 0.24\%$$

Graduated flask 250 ml flask generally used when preparing standard solutions; they have an error of 0.15ml.

$$\% \text{ error in graduated flask} = \frac{0.15}{250} \times 100 = 0.06\%$$

These errors would change if you used a 10 ml pipette or a 100 ml graduated flask, for example.

(ii) Variable errors - these errors depend upon the amount of substance being measured e.g. balance, burette.

Balance 2 d.p. error in reading = +/- 0.005
3 d.p. error in reading = +/- 0.0005

These errors would be doubled. Why ? _____

_____

$$\% \text{ total error in balance (2dp)} = \frac{\text{_____}}{\text{Mass measured}} \times 100$$

$$\% \text{ total error in balance (3dp)} = \frac{\text{_____}}{\text{Mass measured}} \times 100$$

Example 3.452 g of solid were weighed by difference using a 3dp balance. What is the % error in this measurement ?

Burette The error in a burette reading can be quantified by considering the scale divisions on a burette.

The divisions are ___ml apart, so we can measure to the nearest ___ ml.

A titre value is given by subtracting initial volume from final volume, so two readings are used giving a combined error of +/-0.1 ml.

We must also allow for the volume of one drop (0.05 ml) as an error in the endpoint.

So total burette error is +/- 0.15 ml.

$$\% \text{ error burette} = \frac{0.15}{\text{Titre value}} \times 100$$

Example A titration gave an average titre value of 24.55 cm^3. What is the percentage error in this value ?

When we do titrations, we do not want the titre values to be small e.g. 8.00 cm^3

Why ?

Total error in an experiment

To find the total % error in an experiment, we add the % errors for all pieces of apparatus used.

You are expected to:

take into account errors and limitations of the experiment and identify areas for improvement.

i.e. in a practical which involves measurement you will be expected to discuss quantitatively:

- the errors inherent in your measurements and techniques
- the difference between your calculated ‘answer’ and the expected value where available
- improvements you could make to the experiment to limit these errors and improve your answer.

For example, you may be asked to weigh out about 5g of material using a balance which reads to 2 decimal places.
The error in your reading will be 0.01 g in say 5.00 g, i.e. 0.2 %
If the mass required was only 1.00 g the percentage error would be 1.0 %

It is sometimes important to:

- consider how the error in your measurements might change during an experiment,
  e.g. if the times measured for a reaction at different temperatures get longer.
-
- consider which pieces of apparatus are the most important in seeking to reduce your error.
  e.g. it is not important to measure a mass of substance to 0.2% accuracy if you can only measure a temperature change to 2% accuracy.

- identify the largest source of error.

Possible errors in the use of other pieces of apparatus are listed below:

Apparatus	Actual error	percentage error
volumetric flask	0.6 cm^3 in 250 cm^3	0.24 %
pipette	0.05 cm^3 in 25 cm^3	0.2 %
burette: reading volume at start **and** end	0.05 cm^3 (1 drop) at **each** end of a 25 cm^3 titre	0.2 x 2 = 0.4 %
burette: end point	0.05 (1 drop) in 25cm^3 titre	0.2 %
thermometer (0-100°C)	0.5 °C in 10 °C at **each** end of change	2 x 5 = 10 %
thermometer (0-50°C)	0.1 °C in 10 °C at **each** end of change	2 x 1 = 2 %
stopwatch	0.1 sec in 20 sec 0.1 sec in 100 sec	0.5 0.1

Note

- *accuracy* strictly refers to how close you are to the correct answer;
- *precision* refers to how carefully your readings are made (to the nearest gram, 0.1 g, or 0.01 g)
- You are expected always to be as precise as necessary for the experiment; accuracy comes with increased skill.
- You will be rewarded for concordancy in a series of titration readings (precision); these may however give you a very inaccurate result if you have made the same mistake in procedure every time.
- If you take an average of two readings, you should not quote the mean to a greater degree of accuracy than is possible to read, e.g. the mean of 24.50 cm^3 and 24.55 cm^3 should be given as 24.53 cm^3 (and not 24.525 cm^3).

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	96.0 Mo molybdenum 42	[97] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La * lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac † actinium 89	[267] Rf rutherfordium 104	[270] Db dubnium 105	[269] Sg seaborgium 106	[270] Bh bohrium 107	[270] Hs hassium 108	[278] Mt meitnerium 109	[281] Ds darmstadtium 110	[281] Rg roentgenium 111	[285] Cn copernicium 112	[286] Nh nihonium 113	[289] Fl flerovium 114	[289] Mc moscovium 115	[293] Lv livermorium 116	[294] Ts tennessine 117	[294] Og oganesson 118

Key

relative atomic mass
symbol
name
atomic (proton) number

140.1 Ce cerium 58	140.9 Pr praseodymium 59	144.2 Nd neodymium 60	[145] Pm promethium 61	150.4 Sm samarium 62	152.0 Eu europium 63	157.3 Gd gadolinium 64	158.9 Tb terbium 65	162.5 Dy dysprosium 66	164.9 Ho holmium 67	167.3 Er erbium 68	168.9 Tm thulium 69	173.0 Yb ytterbium 70	175.0 Lu lutetium 71
232.0 Th thorium 90	231.0 Pa protactinium 91	238.0 U uranium 92	[237] Np neptunium 93	[244] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[247] Bk berkelium 97	[251] Cf californium 98	[252] Es einsteinium 99	[257] Fm fermium 100	[258] Md mendelevium 101	[259] No nobelium 102	[262] Lr lawrencium 103

* **58 – 71** Lanthanides

† **90 – 103** Actinides

Use this for the task on the next page

Questions on Errors

In each of the following, assume that the standard maximum apparatus errors were as follows:

Balance (3 dp)	± 0.0005g
250 cm^3 volumetric flask	± 0.5 cm^3
25 cm^3 pipette	± 0.05 cm^3
burette	± 0.15 cm^3

For each exercise estimate the percentage maximum error in using each piece of apparatus, and hence the maximum overall apparatus error.

Use the average titre to estimate the error in using the burette.

1. In a titration 25cm^3 of the alkali solution were transferred to a conical flask by means of a pipette. An acid solution was added from a burette until the alkali was exactly neutralised. The average of the concordant titres was 24.45 cm^3 of the acid solution.

   Estimate the percentage maximum error in using each piece of apparatus, and hence the maximum overall apparatus error.

2. 2.343 g of a solid alkali were measured out on a three-figure balance (the technique used was 'weighing by difference'). The sample was dissolved in water and the volume made up to 250 cm^3. In a titration 25cm^3 of this alkali solution was added to were transferred to a conical flask by means of a pipette. An acid solution was added from a burette until the alkali was exactly neutralised. the average of the concordant titres was 19.80 cm^3 of the acid solution.

Estimate the percentage maximum error in using each piece of apparatus, and hence the maximum overall apparatus error.

Having checked your work you will have either:

1. Completed the task correctly - well done :)

2. Made some mistakes - which you now understand (having seen the correct answer) - that's OK as you have 'learned from your mistakes'

3. Do not understand the answer - if this is the case you **must** seek assistance from your teacher (if you do not then you will ***never*** understand this and this may be a building block for later work!)

Pause this presentation while you complete the exercise on the previous page.

When complete move to the next page where you can check your answers.

(1) Pipette (alkali) $\frac{0.05}{25} \times 100 = 0.2\%$

Burette (acid) $= \frac{0.15}{24.45} \times 100 = 0.61\%$

Maximum overall apparatus error $= 0.2 + 0.61 = \underline{0.81\%}$

(2) Balance (solid) $= \frac{0.0005}{2.343} \times 2 \times 100 = 0.043\%$

↑ weighing by difference (ie 2 readings)

Graduated flask $= \frac{0.5}{250} \times 100 = 0.2\%$

Pipette $= \frac{0.05}{25} \times 100 = 0.2\%$

Burette $= \frac{0.15}{19.8} \times 100 = 0.76\%$

Maximum overall apparatus error $= 0.043 + 0.2 + 0.2 + 0.76$

$= \underline{1.20\%}$

When you’re confident with this topic move onto part 12:

More practice !