RIVER VALLEY HIGH SCHOOL

JC 2 PRELIM PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

PAPER 4

SUGGESTED SOLUTION

1 **(a)** $K_{sp} = [Ca^{2+}][IO_3^-]^2$

(b) **Results**

titration	1	2
final burette reading / cm^3	19.60	39.20
initial burette reading/ cm^3	0.00	19.60
volume of **FA 2** used / cm^3	19.60	19.60

(c) **(i)** average volume of **FA 2** used $= \frac{19.60 + 19.60}{2}$

$= 19.60\ cm^3$

$V_{\mathbf{FA\ 2}} = \underline{19.60\ cm^3}$

(ii) amount of $S_2O_3^{2-} = 0.100 \times \frac{19.60}{1000}$

$= 0.00196$ mol

$IO_3^- \equiv 3I_2 \equiv 6S_2O_3^{2-}$

amount of IO_3^- in 25.0 cm^3 of **FA 1** $= 0.00196 \div 6$

$= 3.267 \times 10^{-4}$

$= 3.27 \times 10^{-4}$ mol

amount of IO_3^- in 25.0 cm^3 of **FA 1** $= \underline{3.27 \times 10^{-4}\ mol}$

(iii) amount of dissolved IO_3^- in the mixture from **(b)** at equilibrium

$= 3.267 \times 10^{-4} \times \frac{100.0}{25.0}$

$= 1.307 \times 10^{-3}$ mol

amount of IO_3^-(aq) in the mixture $= \underline{1.307 \times 10^{-3}\ mol}$

(d) **(i)** amount of IO_3^- from $KIO_3 = 0.0100 \times \frac{100.0}{1000}$

$= 0.00100$ mol

amount of IO_3^- from dissolved $Ca(IO_3)_2 = 1.307 \times 10^{-3} - 0.00100$

$= 3.07 \times 10^{-4}$ mol

amount of IO_3^-(aq) from dissolved $Ca(IO_3)_2 = \underline{3.07 \times 10^{-4} \text{ mol}}$

(ii) amount of Ca^{2+} in mixture $= \frac{3.07 \times 10^{-4}}{2}$

$= 1.535 \times 10^{-4}$

$= 1.54 \times 10^{-4}$ mol (to 3 s.f.)

amount of Ca^{2+}(aq) in the mixture $= \underline{1.54 \times 10^{-4} \text{ mol}}$

(e) $[Ca^{2+}]_{eqm} = \frac{1.535 \times 10^{-4}}{0.100}$

$= 1.535 \times 10^{-3}$ mol dm^{-3}

$[IO_3^-]_{eqm} = \frac{1.307 \times 10^{-3}}{0.100}$

$= 1.307 \times 10^{-2}$ mol dm^{-3}

$K_{sp} = [Ca^{2+}][IO_3^-]^2$

$= (1.535 \times 10^{-3})(1.307 \times 10^{-2})^2$

$= 2.62 \times 10^{-7}$ mol^3 dm^{-9} (to 3 s.f.)

$K_{sp} = \underline{2.62 \times 10^{-7} \text{ mol}^3 \text{ dm}^{-9}}$

(f) <u>**FA 1** would be diluted/ $[IO_3^-]$ in **FA 1** is lowered/ lower amount of IO_3^- in 25.0 cm^3 of **FA 1**</u>. This <u>forms less I_2 for reaction with $S_2O_3^{2-}$.</u> Therefore, the mean titre would be <u>lower</u>.

(g) The student did not carry out the experiment at 25 °C. Hence, the position of equilibrium for $Ca(IO_3)_2(s) \ll Ca^{2+}(aq) + 2IO_3^-(aq)$ shifted to the left.

OR

When the student carried out the experiment, equilibrium has not been reached before filtering in **(b)** step 4. Hence, the $[Ca^{2+}]$ and $[IO_3^-]$ is lower.

2 (c) Results

Shift 1 and timed practice

Experiment	$V_{\mathbf{FA\,5}}$ / cm^3	V_{H_2O} for **solution A** / cm^3	$V_{\mathbf{FA\,6}}$ / cm^3	V_{H_2O} for **solution B** / cm^3	t /s	$\frac{1}{t}$ /s^{-1}
1	5.0	30.0	20.0	10.0	22.1	0.0425
2	10.0	25.0	20.0	10.0	11.1	0.0901
3	5.0	30.0	10.0	20.0	48.1	0.0208

Shift 2

Experiment	$V_{\mathbf{FA\,5}}$ / cm^3	V_{H_2O} for **solution A** / cm^3	$V_{\mathbf{FA\,6}}$ / cm^3	V_{H_2O} for **solution B** / cm^3	t /s	$\frac{1}{t}$ /s^{-1}
1	10.0	25.0	20.0	10.0	15.4	0.0649
2	20.0	15.0	20.0	10.0	8.0	0.125
3	10.0	25.0	10.0	20.0	28.3	0.0353

Shift 3

Experiment	$V_{\mathbf{FA\,5}}$ / cm^3	V_{H_2O} for **solution A** / cm^3	$V_{\mathbf{FA\,6}}$ / cm^3	V_{H_2O} for **solution B** / cm^3	t /s	$\frac{1}{t}$ /s^{-1}
1	10.0	25.0	20.0	7.0	11.8	0.0847
2	20.0	15.0	20.0	7.0	6.1	0.163
3	10.0	25.0	10.0	17.0	23.0	0.0435

(d) (Using results from shift 1)

- IO_3^-

(Let rate = $k[IO_3^-]^n[H^+]^m[SO_3^{2-}]^p$.

Since k, $[H^+]$ and $[SO_3^{2-}]$ are constant, $\frac{\text{rate}_1}{\text{rate}_2} = \left(\frac{V_{\mathbf{FA\,5}} \text{ in experiment 1}}{V_{\mathbf{FA\,5}} \text{ in experiment 2}}\right)^n$.)

$$\frac{\text{rate}_1}{\text{rate}_2} = \frac{0.0425}{0.0901} = \left(\frac{5.0}{10.0}\right)^n$$

n = 1.08
= 1 (nearest integer)

OR

(Concentration is directly proportional to the volume used when total volume is kept constant.)

Comparing experiments 1 and 2, $V_{FA\,6}$ (and $V_{FA\,7}$) are kept constant, relative rate is doubled when $V_{FA\,5}$ is doubled. Therefore, the reaction is first order with respect to IO_3^-.

order of reaction with respect to IO_3^- = 1

- H^+

(Since k, $[IO_3^-]$ and $[SO_3^{2-}]$ are constant, $\frac{\text{rate}_1}{\text{rate}_3} = \left(\frac{V_{FA\,6} \text{ in experiment 1}}{V_{FA\,6} \text{ in experiment 3}}\right)^m$.)

$$\frac{\text{rate}_1}{\text{rate}_3} = \frac{0.0425}{0.0208} = \left(\frac{20.0}{10.0}\right)^m$$

m = 1.03

= 1 (nearest integer)

OR

(Concentration is directly proportional to the volume used when total volume is kept constant.)

Comparing experiments 1 and 3, $V_{FA\,5}$ (and $V_{FA\,7}$) is kept constant, relative rate is halved when $V_{FA\,6}$ is halved. Therefore, the reaction is first order with respect to H^+.

order of reaction with respect to H^+ = 1

(e) Repeat each experiment and take average of the timings for the dark blue colour to appear. Use the average ***t*** to calculate the relative rate.

OR

Conduct the experiment with other $V_{FA\,5}$, keeping $V_{FA\,6}$ and $V_{FA\,7}$ constant. Plot the graph of relative rate ($\frac{1}{t}$) against $(V_{FA\,5})^n$ to obtain a best fit straight line. Use the best fit straight line to obtain the relative rate ($\frac{1}{t}$) at various $V_{FA\,5}$.

Then, conduct the experiment with other $V_{FA\,6}$, keeping $V_{FA\,5}$ and $V_{FA\,7}$ constant. Plot the graph of relative rate ($\frac{1}{t}$) against $(V_{FA\,6})^m$ to obtain a best fit straight line. Use the best fit straight line to obtain the relative rate ($\frac{1}{t}$) at various $V_{FA\,6}$.

(f) (i) Shift 1, 2 and timed practice ($V_{\mathbf{FA\,7}}$ = 5.0 cm^3)

$$[SO_3^{2-}]_{initial} = \frac{0.0400 \times 5.0}{75.0}$$

$$= 2.667 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{rate of experiment 1} = \frac{2.667 \times 10^{-3}}{22.1}$$

$$= 1.21 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$$

rate of experiment 1 = $\underline{1.21 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}}$

Shift 3 ($V_{\mathbf{FA\,7}}$ = 8.0 cm^3)

$$[SO_3^{2-}]_{initial} = \frac{0.0400 \times 8.0}{75.0}$$

$$= 4.267 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{rate of experiment 1} = \frac{4.267 \times 10^{-3}}{15.4}$$

$$= 2.77 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$$

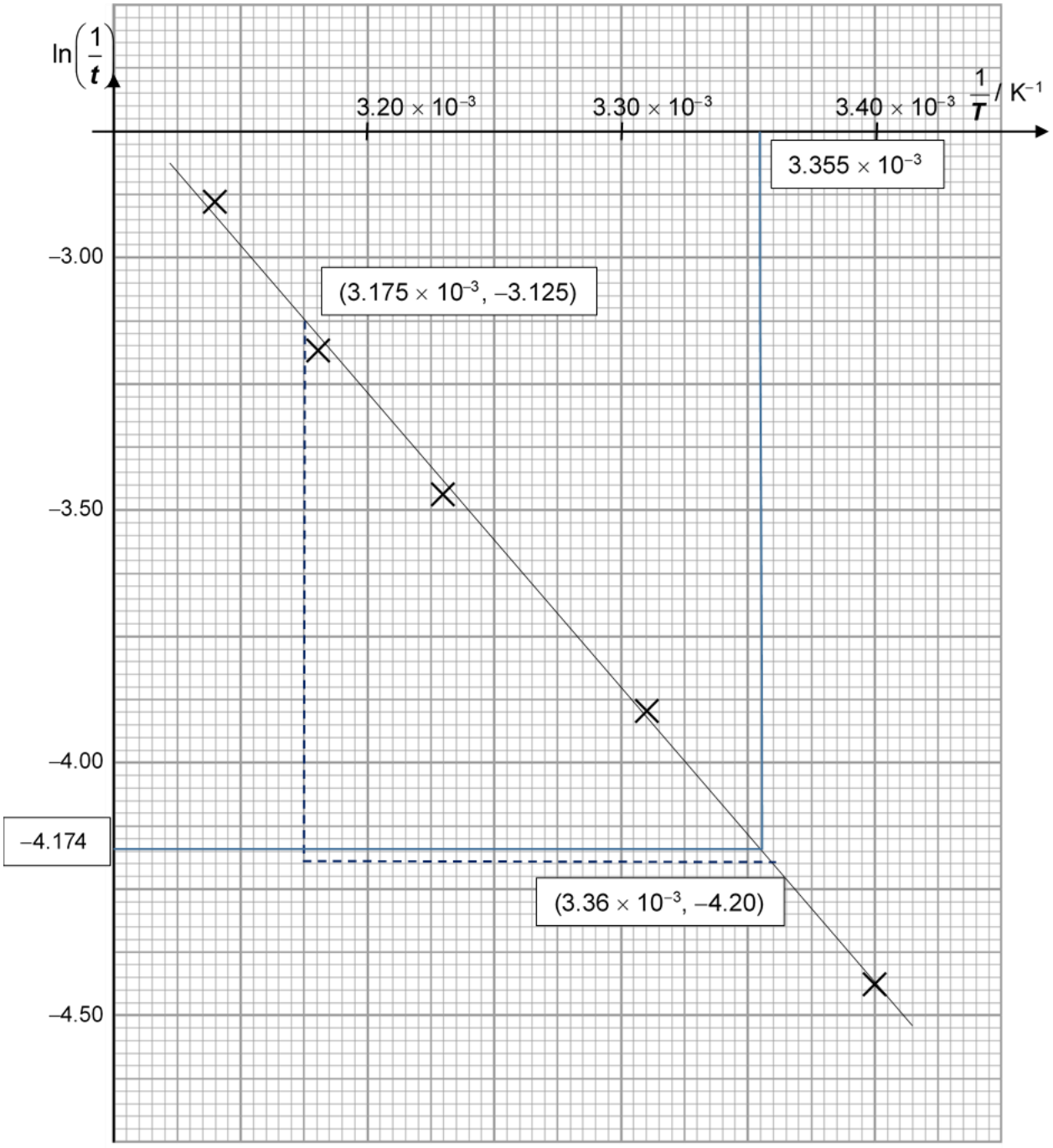
rate of experiment 1 = $\underline{2.77 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}}$

(ii) When total volume is unchanged, $\underline{[SO_3^{2-}] \propto V_{\mathbf{FA\,7}}}$. Since the reaction is first order with respect to SO_3^{2-}, $\underline{\text{when the } [SO_3^{2-}] \text{ is doubled, the rate of reaction is doubled}}$.

(iii) $\frac{1}{t}$ cannot be used as relative rate.

t measured is the time taken for $\underline{\text{varying amount of } SO_3^{2-} \text{ to react completely/ } [SO_3^{2-}]_{initial} \text{ to fall till 0 mol dm}^{-3}}$.

(g) (i) Plot, on the grid provided in page **13**, a graph of $\ln\left(\frac{1}{t}\right)$ on the *y-axis* against $\frac{1}{T}$ on the *x-axis.* Draw a line of best-fit taking into account all your plotted points.



(ii) gradient of line = $\frac{-4.20-(-3.125)}{3.36\times10^{-3}-3.175\times10^{-3}}$

$= -5.81 \times 10^{3}\ \text{K}$

gradient of line = $\underline{-5.81 \times 10^{3}\ \text{K}}$

(iii) $-5.81 \times 10^3 = -\left(\frac{E_a}{R}\right)$

$E_a = 5.81 \times 10^3 \times 8.314$

$= 48.3 \text{ kJ mol}^{-1}$

E_a = <u>48.3 kJ mol^{-1}</u>

(iv) At $\boldsymbol{t}$ = 65.0 s, $\ln\left(\frac{1}{65.0}\right) = -4.174$

From graph, $\frac{1}{\boldsymbol{T}} = 3.355 \times 10^{-3} \text{ K}^{-1}$

temperature = $\frac{1}{3.355 \times 10^{-3}} - 273$

= 25.1 °C

temperature = <u>25.1 °C</u>

3 (a) **FA 8** is a <u>black</u> solid. **FA 9** is a <u>colourless</u> solution.

FA 8 dissolved/ react to give a <u>green/ bluish green solution</u>.

Green/ bluish green filtrate and black residue are obtained.

(b) Unless otherwise stated, use a 1 cm depth of the filtrate from **(a)** in separate test tubes for each of the following tests.

	Test	Observations
(i)	To a portion of the filtrate from **(a)**, add aqueous ammonia till no more change is observed. To a portion of the resultant mixture, add dilute sulfuric acid till no more change is observed.	(Pale/ Light) <u>green/blue ppt</u> formed dissolved in excess NH_3(aq) to give a <u>dark blue/ deep blue solution</u>. (Pale/ Light) <u>blue ppt</u> formed dissolved in excess H_2SO_4(aq) to give a <u>light/pale blue</u> <u>solution</u>.
(ii)	To a portion of **FA 3** in a large test tube, add a few drops of filtrate from **(a)**, followed by 3 cm height of **FA 2**. Shake for a few minutes.	<u>Cream/off-white ppt formed in brown solution</u>. <u>Brown solution decolourised/ turned colourless</u> when **FA 2** is added leaving a cream/off-white ppt. (Cream/off-white) <u>ppt dissolved to give a colourless solution</u> after shaking for a few minutes.

(iii)	To a portion of the filtrate from **(a)**, add aqueous sodium carbonate. To a portion of **FA 9**, add aqueous sodium carbonate.	(Pale/ Light) blue/ green ppt formed. **(**Since **FA 8** was in excess in **(a)**, the filtrate should not contain H^+ and CO_2 should not be formed.**)** With **FA 9**, effervescence observed. Colourless, odourless gas evolved which formed a white ppt with limewater. CO_2 gas evolved.
(iv)	To a portion of deionised water in a large test tube, dilute 5 drops of **FA 9**. Add aqueous silver nitrate, followed by aqueous ammonia.	White ppt formed when a few drops of $AgNO_3$(aq) was added. Ppt dissolved in NH_3(aq) to give a colourless solution.

(c) **(i)** Cu^{2+}

(ii) The ion (Cu^{2+}) in the filtrate is acting as an oxidising agent as it oxidised the colourless iodide in **FA 3** to brown iodine.

(d) **(i)** hydrochloric acid

(ii) Any two of the following ionic equations.

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

$2H^+(aq) + CuO(s) \rightarrow H_2O(l) + Cu^{2+}(aq)$

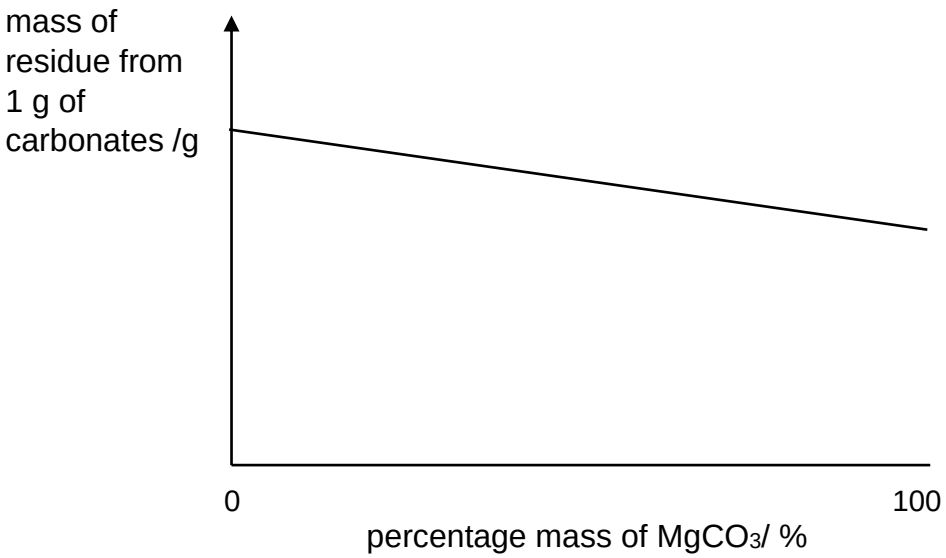
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

(e) To a portion of filtrate, add excess NaOH(aq) to precipitate the cation as insoluble hydroxide($Cu(OH)_2$).

Or To a portion of filtrate, add excess Na_2CO_3(aq) to precipitate the cation as insoluble carbonate($CuCO_3$).

Filter to remove the ppt as residue and collect the filtrate which contains the halide ions.

4 (a)



(Note: graph is a straight line with negative gradient, does not meet horizontal axis at 100% and ends at 100%)

As <u>percentage mass of $MgCO_3$ increases</u>, percentage mass of $CaCO_3$ decreases. The residue will now be made up of a <u>greater proportion of MgO</u> compared to CaO. Since <u>MgO has a smaller molar mass</u> than CaO, the <u>mass of the residue decreases</u>.

(b) percentage by mass of $MgCO_3$(s) in the sample = 100 – 67.5

= 32.5%

$$\text{amount of } MgCO_3 \text{ in 1.000 g} = \frac{1.000 \times \frac{32.5}{100}}{84.3}$$

$$= 3.855 \times 10^{-3} \text{ mol}$$

(= amount of dolomite ($CaCO_3 \bullet MgCO_3$))

$$\text{percentage by mass of dolomite} = \frac{3.855 \times 10^{-3} \times (84.3 + 100.1)}{1.000} \times 100\%$$

= 71.1%

percentage by mass of dolomite = <u>71.1%</u>

(c) $$\text{amount of } CO_2 \text{ in 0.400 g} = \frac{0.400}{12.0 + 2 \times 16.0}$$

= 0.009091 mol

Assuming that thermal decomposition was complete,

minimum total mass of carbonates required = $0.009091 \times (40.1 + 12.0 + 3 \times 16.0)$

= 0.910 g

(Note that the molar mass of $CaCO_3$ was used in the calculations as it has a higher molar mass as compared to $MgCO_3$.)

minimum total mass of carbonates required = <u>0.910 g</u>

(d) **(i)** Quantities of reactants

Total mass of carbonates = 1.000 g

Table 4.1

experiment	(Percentage mass of $MgCO_3$(s)/ %)	mass of $MgCO_3$(s)/ g	mass of $CaCO_3$(s)/ g
1	0	0	1.000
2	25	0.250	0.750
3	50	0.500	0.500
4	75	0.750	0.250
5	100	1.000	0

(ii) Preparation of the mixture of carbonates:

1. Weigh and record the mass of a clean, dry crucible.
2. Add about 0.250 g of $MgCO_3$(s) into the crucible, weigh and record the mass of the crucible with $MgCO_3$(s).
3. Add about 0.750 g of $CaCO_3$(s) into the same crucible, weigh and record the mass of the crucible with $MgCO_3$(s) and $CaCO_3$(s).

(iii) Thermal decomposition:

4. Heat the crucible and its content strongly for about 10 minutes to decompose the carbonates.
5. Stop heating and place the lid on the crucible. (To reduce contact with moisture and carbon dioxide in air to avoid formation of metal hydroxides or metal carbonates.)
6. When the crucible and the content cools to room temperature, weigh and record the mass of crucible and its content/ residue.
7. Repeat step 4 to 6 until the mass of crucible and its content is consistent within 0.050 g in difference.

Experiment 2 to 5:

8. Repeat steps 1 to 7 using masses of $MgCO_3$(s) and $CaCO_3$(s) stated in **Table 4.1** for experiment 2 to 5.

(iv) Experimental Results

(Experiment)	1	…
mass of crucible/ g	**A**	
mass of crucible and $MgCO_3$(s)/ g	**B**	
mass of crucible, $MgCO_3$(s) and $CaCO_3$(s)/ g	**C**	
mass of $MgCO_3$(s)/ g	**B – A**	
mass of $MgCO_3$(s) and $CaCO_3$(s)/ g	**C – A**	
mass of crucible and its content/residue after 1st heating/ g	**D**	
mass of crucible and its content/residue after 2nd heating/ g	**E**	

Weighings after heating and cooling may be recorded in a separate table as follow:

		1st heating	2nd heating
(Experiment 1)	mass of crucible and its content/ g	**D**	**E**
….			

where **D** – **E** < 0.050 g

M48: Mass of carbonates used for 5 experiments

- 5 experiments with different % mass of $MgCO_3$
- Accept total mass ≥ minimum mass calculated in **(b)** up to 3 g.
- mass of each carbonate ≥ 0.100 g

M49: Weighing by subtraction method

- Weigh crucible
- Weigh crucible with either one of the carbonates
- Weigh crucible with both carbonates

M50: Ensure complete decomposition

- Heat for at least 5 min in each heat-cool-weigh cycle
- Repeat heat-cool-weigh cycle until consecutive masses of crucible and contents are consistent within 0.050 g in difference
- Ignore if crucible is not cooled before weighing
- Reject “mass of crucible and carbonates” after heating.

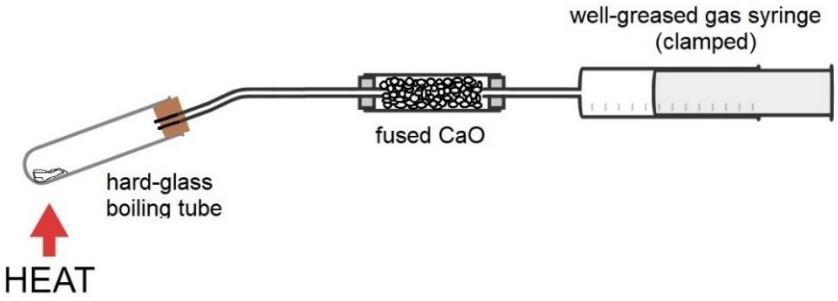
M51: Ensure accuracy

- Use clean, dry crucible
- Cool the crucible and its content before weighing.
- Place a lid on the crucible during cooling
- Boiling tube can be used in lieu of crucible and stopper used during cooling

M52: Tabulate results for one experiment.

- Clear headers and units
- Cells need not be populated
- Accept results presented in two tables.
- Accept if calculated masses are not in the table

(e) (i)



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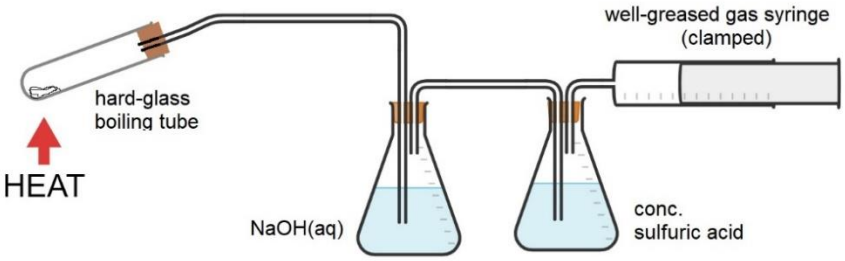

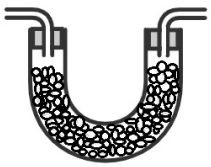

U-tube may be used for solid drying agent

M53: Apparatus set up

- <u>channelled the gases evolved through</u> appropriate apparatus (tube has to be packed with solid chemical or gas has to be bubbled into solutions)
- gas collected into a (well-greased) <u>gas syringe</u>
- heat source must be shown
- reject collection of gas over water.

M54: identity of reagents to remove NO_2 and moisture

- <u>an alkali/ basic compound (to remove NO_2)</u>, <u>then</u> into <u>any drying agent</u> and finally into a gas syringe.
- Or <u>any basic drying agent</u> and then into a gas syringe
- identity of alkali and drying agent is required

(ii) Gas collected in the gas syringe is colourless/ not coloured/ not brown.

Or

Take a sample of gas collected and bubble into water with a drop of universal indicator. The universal indicator will turn red if NO_2 is present.

Or

Dip moist blue litmus paper into the gas sample. Moist blue litmus will turn red if NO_2 is present.