2022 H2 Chemistry Prelim Paper 4 Marks Scheme with Markers' Comments

1 Determination of a value for an enthalpy change of solution

(a)

mass of capped bottle / weighing bottle and FA 1 / g	9.514
mass of capped bottle and residual FA 1	
mass of weighing bottle with residue OR	5.519
mass of weighing bottle after transfer / g	
mass of FA 1 used / transferred / g	3.995

T₁ / °C	29.4
T _m / °C	21.0
ΔT/°C	8.4

- May record data in a single table or have one table for mass and one table for temperature
- [1]: correct headers and units.
- [1]: mass readings to 3 d.p. and temperature readings to 1 d.p.
- [1]: correctly determined maximum temperature change and mass of FA 1 used

Accuracy

2

3

Comments:

The majority of students presented their data clearly.

It is more accurate to describe the mass after reweighing as 'mass of weighing bottle <u>with residue</u>' than to describe as 'mass of empty bottle' as there might not be complete transfer of all solids into the cup.

It was disappointing that some students were still recording mass to 2 d.p. instead of 3 d.p., and surprisingly some students did not realise something must be amiss when the mass of the bottle they measured was less than 1.000 g! Students should have a judgement of the magnitude of the quantity they are measuring and make corrections if necessary.

Students could have used the notations $(T_i, T_m, \Delta T)$ given for the various temperatures measured in their tabulation instead of giving long descriptions. Descriptions of 'final' or 'maximum' temperature were not accepted as the temperature dropped in this experiment. Majority was able to score the accuracy marks.

(b)(i) Calculate heat change using result from 1(a)

heat change (q₁) = mc∆T = (**25** x 1.00) x 4.18 x (temp drop) = _____ J

Ignore sign

(b)(ii) $\Delta H_2 = + \{(q_1) / n(NaHCO_3)\} \times 2$

= + _____ J mol⁻¹ or kJ mol⁻¹ with correct sign

1

(b)(iii)
$$T_{av} = \frac{(25 \times 31.2) + (50 \times 27.6)}{(25+50)} = 28.8 \ ^{\circ}\text{C}$$

(b)(iv) heat change (q₂) = mc∆T = (25+50) x 1.00 x 4.18 x (|28.1 - 28.8|) = 219.45 J

 $n(NaHCO_3) = \frac{50}{1000} \times 1.00 = 0.050 \text{ mol}$

$$\Delta H_3 = + \{(219.45 / 0.050)\} \times 2$$

= + 8778
= + 8780 J mol⁻¹ or + 8.78 kJ mol⁻¹

Final answer to 3 s.f. and appropriate units for (b)(i), (b)(ii), (b)(iii), (b)(iii), (b)(iv).

Comments:

(b)(i): Instead of using the information given that the density of the solution is 1.00 g cm⁻³, giving the mass, m, of solution as 25 g, many students made the mistake of adding the mass of the solid to 25. Some even made the mistake of using the mass of the solid rather than the mass of the solution. A few students were still making the mistake of adding '273' to temperature change.

(b)(ii): Most students were unable to score this mark. Common mistakes include:

- Did not realise that the value of {(q₁) / n(NaHCO₃)} gives the heat absorbed for only 1 mol of NaHCO₃ used, while ΔH₂ is the enthalpy change of the reaction (per balanced equation) for <u>2</u> mol of NaHCO₃, hence the necessity to multiply by 2.
- Did not recognise the endothermic reaction (temperature dropped) and incorrectly giving a negative sign to ΔH₂.
- Dividing the heat change by the M_r instead of the number of moles of solid used.
- Wasting time to determine the limiting reagent when it was given in the question stem that 'the sulfuric acid is in excess'. Students should read questions carefully to avoid unnecessary waste of time.

(b)(iii): Most students correctly calculated the average initial temperature using the formula given.

(b)(iv): Similar errors were made in this part as in(b)(ii). Another common error made here was in using the wrong volume of 25 or 50 cm³ instead of the total volume of reaction mixture which is 75 cm³. Some students did not make use of the T_{av} they have correctly calculated to find ΔT , not understanding the purpose of the calculation in **(b)(iii)**.

1

1

1

1



Comments:

Many students attempted this part using the most straightforward method of drawing an energy cycle.

However, many were not careful in balancing the species in the cycle and not multiplying ΔH_1 by 2, leading to an incorrect value for the calculated ΔH_1 . Students need to revisit their concepts in Energetics especially on the definition of the various enthalpy changes and application of Hess' Law.

[Total: 14]

2 To determine the order of reaction with respect to the concentration of iodine in the iodination of propanone reaction

Mark

(a) Correct header with units

Include for transfer time, in min and s for each entry

t	t₀/ min	initial burette reading / cm ³	final burette reading / cm ³	Volume of FA 6 / cm ³
4 min 18 s	4.0	0.00	17.40	17.40
8 min 2 s	8.0	18.00	34.20	16.20
12 min 0 s	12.0	30.00	44.90	14.90
16 min 0 s	16.0	0.00	13.70	13.70
20 min 0 s	20.0	14.00	26.40	12.40

Records all

• volumes to 0.05 cm³

• transfer time, t, to consistent precision, i.e. nearest s

• correctly calculates decimal values of t_d and records to 1 d.p.

5 sets of titration results and 1 aliquot is taken at between 3.5 min to 5 min and 1 student choses well–spaced values of time of transfer, where the longest time ≤ 20 min

Comments:

- Some students did not follow instructions to reflect the recording of data to the appropriate significant figures/decimal places or units.
- Many wrote the units for time incorrectly as mins or sec, or did not leave t_d as 1 decimal place.
- The maximum time taken should not exceed 20 min and the 5 readings taken should be well-spaced from 4 to 20 min.
- A number of students also forgot to include t as part of the table and thus lost marks for recording.
- (b)(i) Axes correct way round + correct labels + scale + units the scale must be chosen 1 so that the *y* intercept would fall within the scale range; and, that the plotted points occupy at least half the graph grid in the *x* direction (including x = 0) and the plotted points and the *y* intercept together occupy at least half the graph grid in the *y* direction.

Plotting – within $\pm \frac{1}{2}$ small square. Check all points; put ticks if correct.

1

1

Graph line is straight and is the best-fit line with a fair scatter of points either side of the line.

Accuracy

1

Comments:

As the volume of FA 6 at $t_d = 0.00$ min is required, you should clearly indicate the coordinates of the y-intercept on the graph.

Since the question does not need you to find the x-intercept from the graph, it is unnecessary to include y=0. Students who did this usually ended up with a scale that does not fulfill the requirement for the plotted points to occupy at least half the graph grid in both x and y directions.

Please show the scale/division for every 10 small boxes to avoid plotting wrongly and also for the ease of reference by the marker.

1

As the reaction is between I_2 and CH_3COCH_3 , the amount of I_2 will be decreasing during the reaction, thus the graph of volume of $S_2O_3^{2-}$ used against time should be a decreasing graph.

(b)(ii) order with respect to [I₂] : zero explanation: the graph line is straight OR gradient of the graph is constant, so no change in rate as [I₂] decreases.
 Do not allow this mark if the graph line is not straight.

Comments:

Many students wrongly thought that the order with respect to $[I_2]$ was one upon obtaining a straight-line graph. Students will need to know that gradient of a concentration-time graph is rate. Since the rate did not change as the $[I_2]$ drop, reaction is zero order with respect to $[I_2]$.

(b)(iii) Clear indication of **correct** co-ordinates from graph (read to $\pm \frac{1}{2}$ small square) 1 and triangle drawn should be at least half the number of grids in x & y direction of the line drawn.

gradient correctly calculated

Do not award this mark if coordinates, or volume and time values not given **or** if graph not straight line.

Comments:

The 2 points used for the calculation of gradient must be far apart (i.e. gradient triangle should be large) to minimise percentage error.

(b)(iv) Line correctly extrapolated to meet *y*-axis.
 and
 V_{max} correctly read from intercept to within ± ½ small square

 $nS_2O_3^{2-} = V_{max} \times 10^{-3} \times 0.0100 = a \text{ mol}$ $nI_2 \text{ (in 10 cm}^3) = \frac{1}{2} a \text{ mol}$ $nI_2 \text{ (in 100 cm}^3 \text{ of } \textbf{reaction mixture} / \text{ in 50 cm}^3 \text{ of } \textbf{FA 5}) = (\frac{1}{2} a) \times 10 = b \text{ mol}$ $[I_2] \text{ in } \textbf{FA 5} = b \times 1000/50 \text{ mol dm}^{-3}$

Comments:

Most students made the mistake of not scaling up to find nI_2 in 100 cm³ of reaction mixture. This is a sampling method in which samples of 10 cm³ are pipetted from the 100 cm³ reaction mixture for titration.

(b)(v) Correctly calculates $t_{max} = V_{max} / |\text{gradient}| = V_{max} / b(\text{iii})$

1

Comments: Also accepted the y=mx+c method. 1

1

1

1

(c) rate = $k[CH_3COCH_3][H^+]$ Rate units = mol dm⁻³ s⁻¹; allow mol dm⁻³ min⁻¹ allow ecf if student deduces order with respect to jodine to be other than zero

Comments: Many students did not include the order with reaction wrt H⁺ though it was already mentioned in the question that it is first order wrt to both propanone and H⁺. Many students also fail to give the correct **units for rate** and wrote down the units for k instead.

(d) \

Volume of FA 6 added/cm³



Marking point for sketch: Same shape of line as in **2(b)(i)** + starts at same point + 1 new line gradient is about ½ that of original.

Explanation:

(new graph starts at the same volume as initially the amount of iodine is the same.) As reaction is 1st order with respect to $[CH_3COCH_3]$, when $[CH_3COCH_3]$ is halved,

• the rate of reaction (which is the gradient of the graph) is also halved.

1

or

• <u>so $t_{max} = 2 \times \text{original as twice the amount of time is needed to complete the reaction at half the original rate</u>.</u>$

Comments:

- Most of the students are unable to **relate the first order reaction with respect to propanone to the effect on rate** when its concentration is halved.
 - In addition, they did not realize that the **initial volume of FA6 used should remain the same** as amount of iodine is the same.
 - Question asked for **labelled graph** so there should be clear indication on the graph on the points of consideration to show the change in the gradient such as *t_{max}* and 2*t_{max}*.

(e)(i) FA 7 helps to <u>quench</u> the reaction <u>by removing H⁺</u>. Omission of it will result in the <u>further reaction</u> of the iodine with propanone, causing titre value to be <u>lower</u> than expected.

Comments:

- Many students mention FA7 'stops' the reaction which is technically not correct because quenching means to slow down the reaction till the rate is close to zero. Therefore, it is preferred that students use the word 'quench' for such question. Students also did not mention how the reaction was quenched by the removal of H⁺ which should have been mentioned together.
- 'Titre value is lower than expected' is preferred over 'titre value decreases' because the former makes comparison between what is obtained versus what we expect.

 (e)(ii) The temperature will <u>decrease/drop/fall/become lower</u>. The <u>reaction</u> between NaHCO₃(aq) and H₂SO₄(aq) is <u>endothermic</u> (from question 1). Comments: Most students were unable to relate the quenching reaction of FA7 to remove H⁺ to the reaction in guestion and information in table 1.1.

the reaction in question and information in table 1.1. The results in table 1.1 showed a decrease in temperature which means an endothermic reaction had taken place. Most of them jumped to the conclusion that it is an exothermic reaction because neutralisation has taken place.

- (f)(i) It acts as a <u>catalyst</u>, <u>consumed/reacted in step 1 and regenerated in step 3</u> and 1 hence its concentration remains unchanged.
 Comments:
 A number of students failed to recognise that H⁺ is a catalyst and did not explicitly mention the evidence on the steps that it is consumed and regenerated. Some of them even think that it is a nucleophile/electrophile.
- (f)(ii) step 3 [accept step 1]

1

1

1

Comments:

Many students are unable to relate the rate equation to the correct slow step.

In general, there are 3 main cases which you will be asked to infer the rate equation from mechanisms. Read on below to see which is the correct case for this question.

Case 1: slow step is 1st step

Step 1: $(CH_3)_3CCI \longrightarrow (CH_3)_3C^+ + CI^-$ (slow)Step 2: $(CH_3)_3C^+ + OH^- \longrightarrow (CH_3)_3COH$ (fast)

In this case, $Rate = k [(CH_3)_3CCl]$

We simply need to check the coefficient of the reactant to determine the order wrt the reactant.

<u>Case 2: slow step is not 1st step AND product formed in preceding steps are used</u> <u>up in subsequent steps</u>

Step 1:	$2NO \longrightarrow N_2O_2$	(fast)
Step 2:	$N_2O_2 + O_2 \longrightarrow 2NO_2$	(slow)

The rate equation for the rate-determining step (i.e. slow step) is: rate = $k [N_2O_2][O_2]$.

However, N_2O_2 is <u>an intermediate</u> and should not appear in the rate equation. Therefore, we must eliminate $[N_2O_2]$ from the rate equation. To do so, we express $[N_2O_2]$ in terms of [reactants] from the first step.

The rate equation for the overall third order reaction will be: $rate = k [NO]^2 [O_2]$

This question of this practical exam belongs to Case 2 and not Case 1! WHY?

The first two steps of the reaction are not slow step as they are both at equilibrium, showing that both forward and reverse reactions occur readily and likely not to have high activation energy. Furthermore, the first 2 steps do not have repulsion of like charges or breaking of strong bonds to give high E_a . The 3rd step is most likely the slow step since it involves breaking a stronger C-H sigma bond and forming a weaker pi bond.

Since the reactant of the 3rd slow step is formed from the preceding 2 steps as the only product, we can express the [reactant] in the 3rd step in terms of those in the preceding 2 steps. This hence gives us the rate equation in terms of propanone and acid only, which is in line with what we found in this experiment.

<u>Case 3: slow step is not 1st step AND not all product formed in preceding steps are</u> <u>used up</u>

5---

We see this example in N2021 Paper 3 Qn 3c.

step 1

step 1
$$O_3 \xleftarrow{k_r} O + O_2$$
 last
step 2 $O_3 + O \rightarrow 2O_2$ slow

Since the 2nd step is the slow step, we must represent the concentration of the O intermediate in terms of the reactants and products in the preceding step. Notice that at higher concentration of oxygen, it causes the POE of step 1 to shift to the left. This slows down the overall reaction as the O intermediate required for the second slow step will be present in lower concentration. This is in line with the negative order of reaction observed for O₂ in the overall rate equation: rate = k' $[O_3]^2[O_2]^{-1}$ Such substances with negative order of reaction are called inhibitors in chemistry.

[Total: 21]

3 Investigation of the chemistry of some vanadium ions

(a) $NH_4VO_3 + NaOH \rightarrow NaVO_3 + H_2O + NH_3 / NH_4^+ + OH^- \rightarrow H_2O + NH_3$ and

gas turns (moist) red litmus blue and confirms NH3 evolved

Comments: Generally well done. Some students however, incorrectly mentioned about the production of ammonium hydroxide (NH₄OH) instead of NH₃ and H₂O.

(b)

tests	observations			
(i) Using a 50 cm ³ measuring cylinder, measure about 10 cm ³ of FA 8 into a 250 cm ³ beaker.				
cylinder, measure about 40 cm ³ of FA 3 to the same beaker.	acidification $[]$			
The resulting solution obtained is solution W , which will be used in 3(b)(ii) and 3(c) .				
(ii) Transfer about 30 cm ³ of solution W into a 100 cm ³ conical flask, using the same measuring cylinder used in 3(b)(i) .	 effervescence/bubbles formed [√] solution turns blue [√] then green/turquoise/blue- green/grey-blue [√] 			
Using a spatula, slowly add all the FA 9 provided, a small spatula measure each time, into the conical flask. Swirl after each addition.	4. then lilac/purple/mauve[$$] Marks allocated as follows: 4 - 5[] = 2			
You may then leave the mixture to stand, swirling the flask from time to time and observe the solution until no further changes are seen.	2 - 3[v] = 1 0 - 1[v] = 0			
While you are waiting, continue with test 3(c).				

Comments:

Some pointers to take note.

- Gas evolved ≠ effervescence (you technically cannot see gas evolved, what you see are bubbles which is effervescence)
- There are 5 observation points in 3(b) and the observations ought to be in sequence

1

1

(c)	tests	observations
	Transfer about 10 cm ³ of solution W into a boiling tube using the same measuring cylinder used in 3(b)(i) .	 blue solution formed [√]; then green/turquoise/blue- green/grey-blue final solution [√].
	Add all the tin powder in the weighing bottle into the boiling tube and shake the mixture.	Both [√] for 1 mark
	Gently warm the boiling tube. You should not allow the mixture in the boiling tube to boil or heat to dryness.	
	To view the colour of the solution clearly, you may find it necessary, from time to time, to allow the tin to settle.	
	Observe the mixture until no further changes are seen.	

1

2

1

Comments:

Once again, the two observation points here ought to be in sequence. Many students mistakenly thought that the colour arises due to colored ppt formed. However, should you follow the instructions of the test to allow for time for the solid tin to settle, you would be able to see that the solution is the one responsible for the colours, not the solid.

(d)(i)

	tests	observations
1	To about 1 cm depth of FA 10 in a test-tube, add aqueous sodium hydroxide until no further changes are observed.	White ppt soluble in excess [1]
2	To about 1 cm depth of FA 10 in a test-tube, add aqueous ammonia until no further changes are observed.	White ppt soluble in excess [1]

(d)(ii) Zinc

(d)(iii) $Zn^{2+} + 2OH^{-} \rightarrow Zn(OH)_2$ (also accept \Rightarrow to be in line with the POE shift to explain why 1 the salt dissolves)

 $Zn^{2+} + 4NH_3 \rightarrow [Zn(NH_3)_4]^{2+} \text{ or } Zn(OH)_2 + 4NH_3 \rightarrow [Zn(NH_3)_4]^{2+} + 2OH^-$

Comments: Generally well done for d(i).

Students should note that d(ii) has to be Zn(s) only, as the question specifically mentioned on page 13 of the question paper that FA9 is a metal. Zn^{2+} is a metal **cation** and hence should students give that answer, it would be assumed that students are referring to FA10, instead of FA9 as required by the question.

d(iii) is poorly done. The relevant equations have been covered in Experiment 12 and can also be found in the Inorganic QA notes.

One way to remember is by relating to what you have learnt from similar observation for Cu^{2+} . When ammonia is added, the formation of ppt is due to the metal hydroxide formed. The ppt is soluble in excess ammonia as a complex is formed with ammonia ligands.

Extension question:

[Total: 9]

Relevant half-equations and standard electrode potential data are given below.

V ³⁺ (aq) + e⁻ ⇒	V ²⁺ (aq)	<i>E</i> [⊕] = −0.26V
Sn ²⁺ (aq) + 2e⁻ ⇒	Sn(aq)	<i>E</i> [⊕] = −0.14V
VO ²⁺ (aq) + 2H ⁺ + e ⁻ ≓	$V^{3+}(aq) + H_2O(l)$	<i>E</i> [⊕] = +0.34V
$VO_2^+(aq) + 2H^+ + e^- \rightleftharpoons$	$VO^{2+}(aq) + H_2O(I)$	<i>E</i> [⊕] = +1.00V
$MnO_4^{-}(aq)^{+} 8H^{+} + 5e^{-} \rightleftharpoons$	$Mn^{2+}(aq) + 4H_2O(I)$	<i>E</i> [●] = +1.51V
Zn ²⁺ (aq) + 2e ⁻ ⇒	Zn(s)	$E^{e} = -0.76V$

Can you explain why a series of colours is observed when Zn and Sn were added to the vanadate solution and which species is responsible for each of the colour observed?

Planning

(a) Minimum mass of Ca(IO₃)₂ required = $6.2 \times 10^{-3} \times 389.9 \times \frac{100}{1000} = 0.242$ g

Comments: Most students were able to score here. Those who got it wrong often mistook solubility for solubility product.

(b) Suggested plan

- 1. Measure <u>100.0 cm³</u> of deionised water using a <u>100.0 cm³ measuring cylinder</u> and add it to a 250 cm³ conical flask. Place the conical flask in a <u>thermostatically-controlled water bath at 20 °C</u>. Place a <u>thermometer into the</u> <u>flask</u> to monitor the temperature of the water.
- 2. Using an electronic weighing balance, weigh about $1.0 \text{ g of } Ca(IO_3)_2$ in a weighing bottle. Add some $Ca(IO_3)_2$ solid to the deionised water in the conical flask. Stir the mixture continuously with a glass rod. Continue adding $Ca(IO_3)_2$, with stirring, until some undissolved solid remains. Allow the mixture to stand for 1 hour to reach equilibrium.
- 3. <u>Filter</u> the mixture to obtain the saturated solution by using <u>dry filter paper and</u> <u>dry filter funnel</u> into a <u>dry conical flask</u> placed in a thermostatically controlled water bath at 20 °C, so that the filtrate is collected at 20 °C.
- 4. Fill a <u>burette with $Na_2S_2O_3$ </u>.
- 5. <u>Pipette 25.0 cm³ of the filtrate</u> from step 3 into a 250 cm³ conical flask.
- 6. Use a <u>measuring cylinder</u> to add about 10 cm³ of H₂SO₄ to the same conical flask.
- 7. Use another <u>measuring cylinder</u> to add about 10 cm³ of KI to the same conical flask. The solution turns brown.
- 8. Run Na₂S₂O₃ from the burette into the conical flask until a pale-yellow solution is obtained.
- 9. <u>Using a dropper, add 5 drops of starch solution</u> to the conical flask. Continue adding Na₂S₂O₃ until the <u>blue-black colour just disappears</u>. Record your titration results.
- 10. <u>Repeat titration</u> until consistent <u>titration results within 0.10 cm³</u> of each other are obtained.

1

Comments:

It was great to see the vast majority attempting this part. Most students were able to give reasonably sound plans though a few confused it with the experiment in Question 2 and started to describe plans involving timed intervals.

See the breakdown of marks scheme below and points to note:

marks	description
1	prepare saturated solution of $Ca(IO_3)_2$ in 100 cm ³ deionised water by adding excess $Ca(IO_3)_2$ (at least 0.250 g)
	 masses smaller than 0.250 g were not accepted as the uncertainty involved in using the weighing balance affects the 3rd decimal place and may not allow us to accurately ensure >0.242 g of Ca(IO₃)₂ solid has been used.
1	maintain constant temperature (use of water bath and thermometer)
	 many students forgot the use of the thermometer to check that the temperature of the saturated solution is maintained the same as that of the water bath during the entire equilibration process. This checking should ideally be done BEFORE the 1 hour to establish equilibrium so that the equilibrium is established under the correct temperature.
1	filtration: dry filter paper, funnel, conical flask(or beaker)
	• few students remembered the use of dry apparatus to prevent additional water added that will dilute the saturated solution, causing the position of equilibrium to be affected.
1	titration procedure to determine the concentration of dissolved IO_3^- : pipette a portion (25 cm ³), add H ⁺ and I ⁻ (10 cm ³) before titration, describe end-point colour change
	 As the phrasing in question is subject to different interpretations, addition of acid can be done to the bulk saturated solution or after pipetting. However, adding acid after pipetting will make subsequent calculations in (c)(ii) easier. Answers that took portions of filtrate less than 25 cm³ and top up to 25 cm³ for "acidified solution of the filtrate" were also accepted.
1	apparatus (for preparation of saturated solution and titration)
	 measuring cylinders for the volumes of deionised water, sulfuric acid and potassium iodide 10 or 25 cm³ pipotte to onsure that equal participa of filtrate ware
	 To or 25 cm pipelle to ensure that equal portions of litrate were drawn out for titration. Measuring cylinder is not accepted for this as there is greater error in volume measurement using measuring cylinder, leading to inconsistent portions and titration results may not be consistent. burette for titration
	 conical flasks for preparation of saturated solution and titration
1	ensure reliability of results.
	 (1) to equilibrate for at least 1 hour, (2) add starch indicator to make the end-point colour change more visible and (2) report titration until titra volumes are within 10.10em³ of each
	(3) repeat titration until titre volumes are within ±0.10cm° of each other.

(c)(i) K_{sp} of Ca(IO₃)₂ = [Ca²⁺] [IO₃⁻]²

(c)(ii) Amount of
$$S_2O_3^{2^-}$$
 ions = $0.100 \times V = 0.1V$ mol
Amount of I_2 reacted = $\left(\frac{1}{2}\right)(0.1V) = 0.05V$ mol

Amount of IO_3^- ions in 25.0 cm³ of filtrate = $(\frac{1}{3})(0.05V)$ = 0.016667V mol [1] Amount of IO_3^- ions in 100 cm³ of saturated solution = $(\frac{100.0}{25.0})(0.016667V) = 0.066667V$ mol Amount of Ca²⁺ ions in 100 cm³ of saturated solution = $(\frac{1}{2})(0.066667V) = 0.033333V$ mol K_{sp} of Ca(IO_3)₂ = [Ca²⁺] [IO_3^-]² K_{sp} of Ca(IO_3)₂ = $(\frac{0.033333V}{0.100})(\frac{0.0666667V}{0.100})^2$ [1] for concentrations of both ions

= 0.148V³ mol³ dm⁻⁹ [1] with correct simplified expression

OR
Amount of IO₃⁻ ions in 25.0 cm³ of filtrate =
$$\binom{1}{3}(0.05V)$$

= $\binom{1}{60}V$ mol [1]
[IO₃⁻] = $\binom{1000}{25.0} \binom{1}{60}V = \binom{2}{3}V$ mol dm⁻³
[Ca²⁺] = $\binom{1}{2}\binom{2}{3}V$ = $\binom{1}{3}V$ mol dm⁻³ [1] for concentrations of both ions
 K_{sp} of Ca(IO₃)₂ = $\binom{1}{3}V\binom{2}{3}V^{2}$

= $\left(\frac{4}{27}\right)$ V³ mol³ dm⁻⁹ [1] with correct simplified expression

Answers in word may be accepted but there must be clear indications of how the stoichiometry is applied in the working, not just quote mole ratio in the reaction equations.

Comments:

(c)(i) was generally well done. A few answers forgot to write " K_{sp} " in their expression or forgot the charges of the ions.

Solving for concentration of the ions is the most challenging part of (c)(ii). Quite a number of students forgot that the titration was performed only on 25 cm³ of the filtrate and instead calculated as though Vdm³ of sodium thiosulfate is used to react with the entire 100 cm³ filtrate.

Students who chose to add H_2SO_4 before pipetting a portion out for titration also encountered greater difficulty in performing calculations as they had to factor in that the pipetted solution is diluted and not the original saturated salt solution.

1