Mark schemes

Q1.
  C

<div align="right">[1]</div>

Q2.
  (a) Consider experiments 1 and 2: [B constant]

[A] increases × 3: rate increases by 3^2 therefore 2nd order with respect to A

<div align="right">1</div>

Consider experiments 2 and 3:

[A] increases × 2: rate should increase × 2^2 but only increases × 2

Therefore, halving [B] halves rate and so 1st order with respect to B

<div align="right">1</div>

Rate equation: rate = $k[A]^2[B]$

<div align="right">1</div>

  (b) rate = $k\,[C]^2[D]$ therefore k = rate $/ [C]^2[D]$

<div align="right">1</div>

$$k = \frac{7.2 \times 10^{-4}}{\left(1.9 \times 10^{-2}\right)^2 \times \left(3.5 \times 10^{-2}\right)} = 57.0$$

Allow consequential marking on incorrect transcription

<div align="right">1</div>

$mol^{-2}\ dm^{+6}\ s^{-1}$
      Any order

<div align="right">1</div>

  (c) rate = $57.0 \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2} = 3.99 \times 10^{-3}$ (mol dm^{-3} s^{-1})

OR

Their $k \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2}$

<div align="right">1</div>

  (d) Reaction occurs when molecules have $E \geq E_a$

<div align="right">1</div>

Doubling T by 10 °C causes <u>many</u> more molecules to have this E

<div align="right">1</div>

Whereas doubling [**E**] only doubles the number with this E

<div align="right">1</div>

(e) $E_a = RT(\ln A - \ln k) / 1000$

Mark is for rearrangement of equation and factor of 1000 used correctly to convert J into kJ

1

$E_a = 8.31 \times 300 (23.97 - (-5.03)) / 1000 = 72.3$ (kJ mol^{-1})

1

[12]

Q3.
   B

[1]

Q4.
   C

[1]

Q5.
   B

[1]

Q6.
   (a)   The sodium hydrogencarbonate solution neutralises the acid (catalyst)

M1

So stops the reaction

M2

   (b)   The concentration/amount of propanone is much larger than/200 times larger than the concentration/amount of iodine
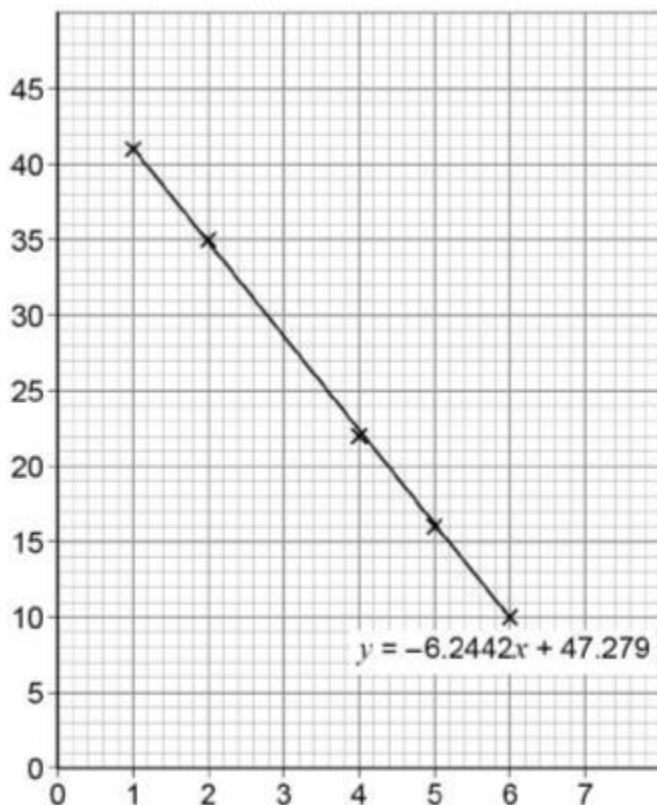
M1

<u>Concentration</u> of propanone is (almost) constant

The change in concentration in propanone is negligible

M2

   (c)

$y = -6.2442x + 47.279$

M1

Suitable axes (plotted points must take up at least half of the grid)

M2

For all points correctly plotted to ± ¹/₂ small square

For straight line of best fit which avoids the anomalous plot M1

M3

(d)   The graph is a straight line / has a constant gradient

M1

So the rate of reaction does not change as the concentration
(of iodine) changes / the iodine is being used up at a constant
rate.
            Correct rate vs conc graph scores M2

M2

(e)   Gradient = (−14.1 − −2.8) / (0.00180 − 0.00128)
            = −11.3 / 0.00052
            = −21731
                Allow -21330 to -22130

M1

Gradient = −E_a / R
−E_a = their answer x 8.31 (= 180583 J mol⁻¹)

M2

E_a = M2 ÷ 1000 (= 181 kJ mol⁻¹)

M3

[12]

Q7.

(a) **M1**   tangent drawn to the curve at 0,0

*If tangent not drawn at 0,0 then allow conseq
gradient calculation*

1

M2   Evidence of value used in calculation leading to initial rate = 5.5

Note allow 5 – 7

1

M3 $cm^3 \ s^{-1}$

NOT cm³ / s

1

(b) **M1** $[H_2PO_2^-]^2 \ \alpha \ 1/t$

*Accept time argument eg if conc doubled time is
quartered*

*Accept suitable words that implies a square or
square root relationship*

1

M2   Order = 2

*Not simple description of as conc increases time
decreases 1*

1

(c)
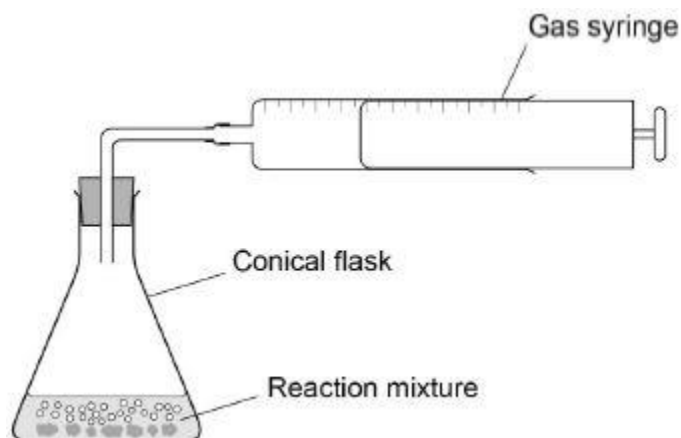
Either gas syringe or measuring cylinder over water
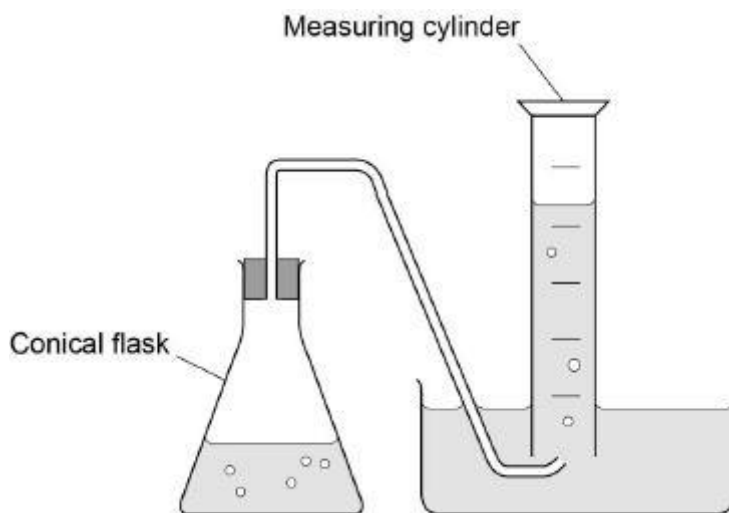
Tubing shown should not be closed
Syringe should have a plunger shown
Allow lack of graduations

1

(d) Falls by a factor of 8

OR Multiplied by $^1/8$
   OR Divided by 8
   Allow halved then quartered / Decreases by 2^3

1

(e) **M1** $[M]^2 = \underline{Rate}$
         Re-arrangement

1

M2 $[M]^2 = \dfrac{0.0250}{21.3 \times 0.0155}$ $(=7.57 \times 10^{-2})$
      Inserts correct numbers into their rearranged expression

1

M3 $[M] = \sqrt{7.57 \times 10^{-2}} = 0.275$ mol dm^{-3} (min 2 sf)
      Takes square root (allow ecf for square root of their M2)
      Common error is to use 0.25 rather than 0.025. This leads to an answer of 0.870. Scores 2
      Upside-down expression leads to an answer of 3.63. Scores 2

1

(f) The sum of powers/indices (to which the concentrations are raised in the rate equation)
      All the orders added/ sum of the (individual) orders
      This can be explained using a general rate equation stated as an example
      e.g. Rate = $k[A]^x[B]^y$ and the overall order is $x + y$

1

[11]

Q8.

(a)   <u>DNA</u> Replication

>   *NOT mitosis*
>   *NOT DNA synthesis*
>   *Ignore terms relating to cell division processes*
>   *Ignore 'damages DNA'*
>   *Ignore DNA transcription*
>   *Ignore 'cell replication'*

1

(b) $[Pt(NH_3)_2Cl_2] + H_2O \rightarrow [Pt(NH_3)_2Cl(H_2O)]^+ + Cl^-$

>   **M1** *Correct formula **and** charge of B*
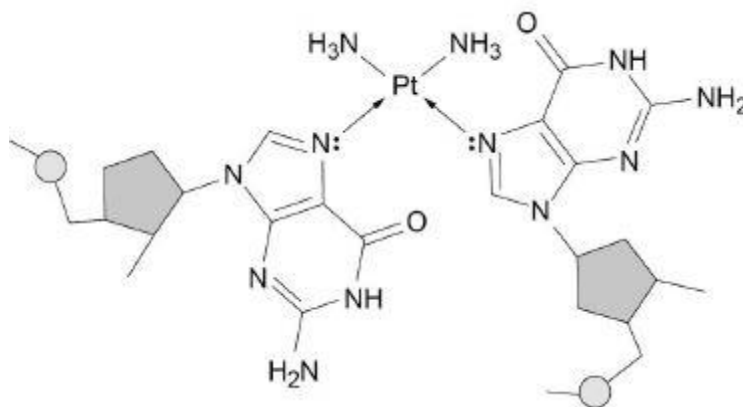
1

>   **M2** *Correct balancing **and** charges in equation*

1

>   *Allow **M2** if the **only** error in complex B is the charge*
>   *(**M1** not awarded) with Cl⁻ **only***
>   *ALLOW complexes without [ ] and/or ( ) around H_2O*
>   *IGNORE ( ) around Cl*
>   *NOT any additional different species (loses **M2**)*
>   *(allow uncancelled water on both sides)*

(c)

>   **M1** *Pt in a cis-diammine complex bonded to the correct nitrogen atoms*
>   *Pt must have the two ammonia ligands shown*
>   *NOT if drawn as trans*
>   *IGNORE any charge on Pt*
>   *Ignore any wedges and dashes (3D representations)*

1

>   **M2** *both lone pairs shown **OR** two arrows indicating co-ordinate bonds*

*Allow **M2** if bonds to platinum are from the incorrect nitrogen atoms*

1

(d) **M1** plot concentration (y-axis) against time (x-axis) **and** take tangents / (calculate the) gradients (to calculate rates)

Allow concentration-time graph

NOT time-concentration graph (unless clarified in words or sketch) but mark on

1

M2 Plot rate/gradients against conc

1

M3 straight line through origin / directly proportional confirms first order

allow first order if rate halves/doubles when conc halves/doubles

1

*Alternatives to **M2** and **M3**:*

***M2** Plot a graph of log rate vs log conc*
***M3** (Straight) line of gradient = 1*

***M2** measure (at least) two half-lives (in this case, tangents not required for M1)*
***M3** constant half-life means first order*

***M2** compare rates/gradients at different concentrations*
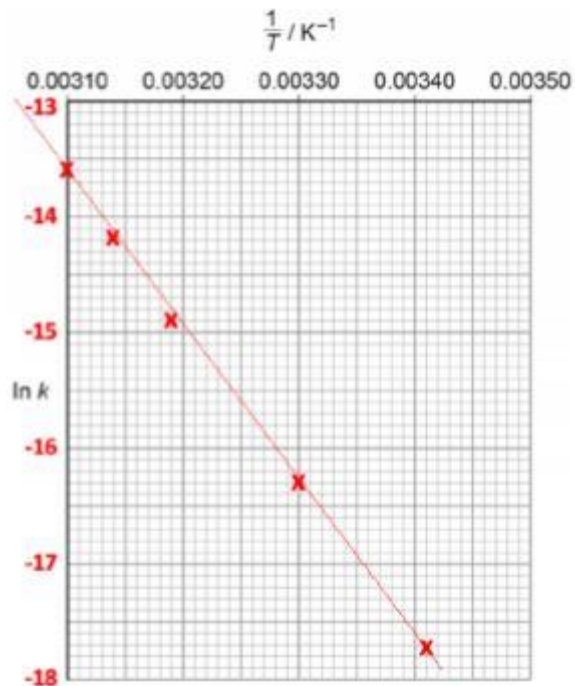***M3** first order if rate halves when conc halves*

(e)

temperature, T / K	$\frac{1}{T}$ / K^{-1}	rate constant, k / s^{-1}	ln k
318	0.00314	6.63×10^{-7}	−14.2

Allow 3.14 x 10^{-3}

2

(f)

Gradient = −13 125

$$\left(-13125 = \frac{-E_a}{R}\right)$$

E_a = 13 125 x 8.31 = 109 069

= 109 (kJ mol^{-1})

> *Vertical axis with sensible scales (plotted points must take up more than half the grid) NOT M1 if y-axis in wrong direction*

1

> *all points plotted correctly (within ±0.5 small square)*

1

> *Best fit straight line based on the student's data (ignoring anomalous point if relevant)*

1

> *Gradient calculated within range: 12876 - 13598*

1

> *Mark is for their (gradient x 8.31) **and** conversion into kJmol^{-1}*
> *E_a in the range: 107 – 114 kJ mol^{-1}*
> *NOT a negative activation energy*

1

[15]

Q9.

$$A = k / e^{-E_a/RT}$$

$$= (3.46 \times 10^{-8}) / e^{-96200/(8.31 \times 298)}$$

$$= 2.57 \times 10^9$$

s^{-1}

OR using $\ln k = \ln A - E_a/RT$

$\ln A \rightarrow = \ln k + E_a/RT$

$\rightarrow = -17.179 + 38.847 = 21.667$

$A \rightarrow = 2.57 \times 10^9$

s^{-1}

> *M1 Rearrangement (if wrong can only score M2 & M4)*
>
> 1
>
> *M2 Correct conversions of both E_a and T*
>
> 1
>
> *M3 Answer allow 2.45×10^9 to 2.6×10^9*
>
> 1
>
> *M4 Units*
>
> 1
>
> *If use 96.2kJ, $A = 3.60 \times 10^{-8}$*
> *If use 96.2kJ and 25°C, $A = 5.50 \times 10^{-8}$*

[4]

Q10.

(a)
$$k = \frac{2.4 \times 10^{-2}}{0.10 \times 0.20 \times (0.30)^2}$$

> *Mark is for insertion of numbers into a correctly re-arranged equation.*
>
> 1

= 13 (must be 2 sfs)

> 1

Units mol^{-3} dm^{+9} s^{-1}

> *Can be in any order*
>
> 1

(b) Experiment 2 $[BrO_3^-] = 0.15$

> 1

Experiment 3 rate = 0.26 or 0.27

> 1

Experiment 4 $[H^+] = 0.45$ or 0.46

> *If k wrong in (a) : allow the expected answer OR values conseq to their k (allow mix & match)*
> *Ex 2 $[BrO_3^-] = 2/k$*
> *Ext 3 rate = $0.02 \times k$*
> *Ex 4 $[H^+]$ = square root of (2.7/k)*
>
> 1

(c) 1/T value 3.31(1) × 10^{-3} or 0.00331(1)

> *Must be 3 sig figs or more*
>
> 1

ln(1/t) value –3.30 or –3.297
    Not allow –3.29

1

(d) **M1** y axis labelled with values (no units) and plotted points use over half of the axis

1

M2 points plotted correctly (see graph below)

1

M3 best fit straight line (minimum 3 points plotted)
    + - one small square for line of best fit

1

M4 gradient = – 6.64×10^3 (K) or -6640 (K)
    Range - 6.5×10^3 to - 6.8×10^3 or -6500 to -6800

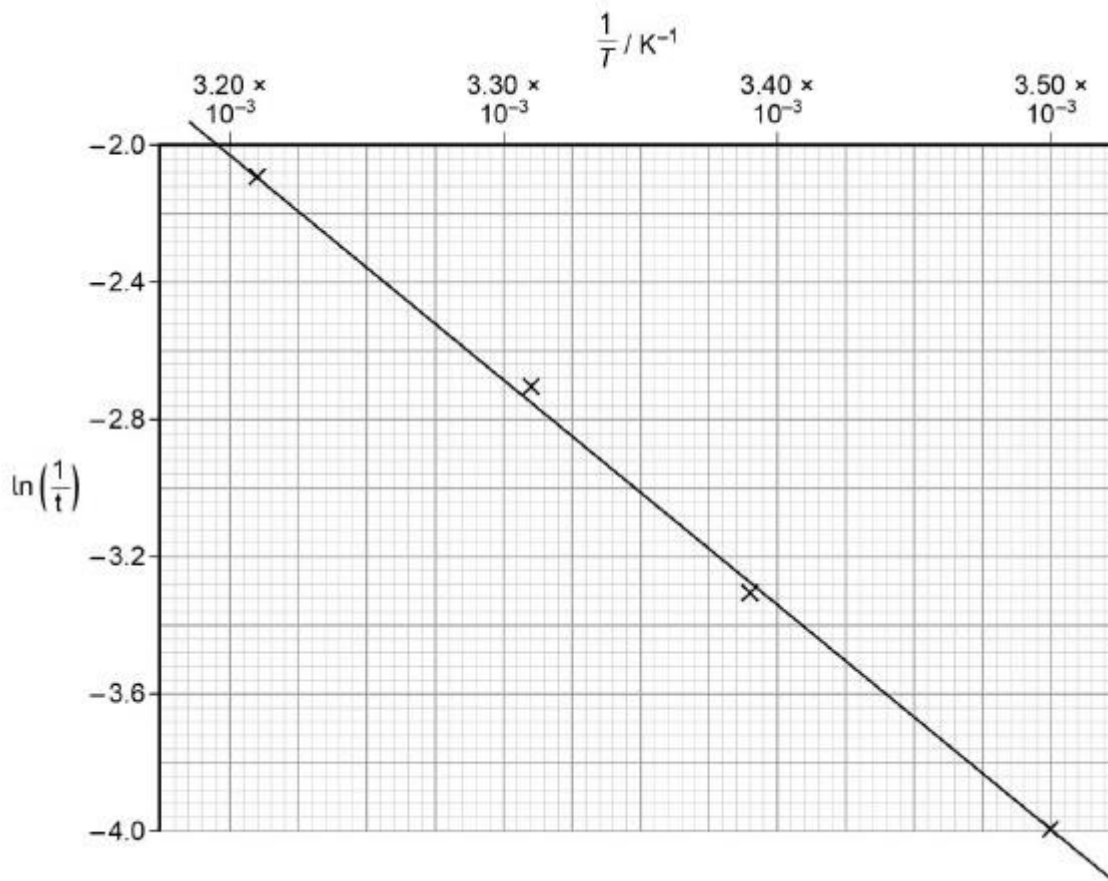**1**

M5 E_a = M4 × 8.31
    If gradient outside range then max 4 for M1, M2, M3 and M5

1

M6 = 55.2 kJ mol^{-1}
    Range 54.0 - 56.5

1

[14]

Q11.

(a) H_2O_2 and/or I^- <u>concentration</u> change is negligible /
H_2O_2 and/or I^- <u>concentration</u> (effectively) constant

> *Only the <u>concentration</u> of H^+ changes.*

so have a constant/no effect on the rate / so is zero order (w.r.t. H_2O_2 and I^-) / a and b are zero

> *Ignore references to H^+ is limiting reagent / rds /*
> *H_2O_2/I^- not in rate equation*
>
> *Do not allow reference to catalyst.*

2

(b) Stop the reaction / quench

By dilution / cooling / adding a reagent to react with H_2O_2/I^-

> *Allow valid suggestions about how to stop the*
> *reaction.*
>
> *Do not allow reaction with acid/alkali / neutralisation*
> *for M2*
>
> *Do not penalise other named reagents.*
>
> *Ignore references to measuring volume and adding*
> *indicator*

2

(c) M1: constant gradient

OR

change/decrease in concentration is proportional to time

> *Allow constant rate / rate = k*
>
> *Ignore reference to straight line*
>
> *Not increase in concentration / concentration is*
> *inversely proportional / concentration (on its own) is*
> *proportional*

M2: as $[H^+]$ changes/decreases

> *M2 dependent on correct M1*
>
> *Allow rate v concentration graph would give*
> *horizontal straight line owtte*
>
> *Allow so $[H^+]$ has no effect on the rate*

2

(d) evidence of attempt at calculation of gradient via $\Delta y/\Delta x$

> *allow construction lines on graph*

$k_1 = 0.0012 / 1.2 \times 10^{-3}$

> *At least 2 sf (0.00118 – 0.00122)*
>
> *Correct answer scores 2/2*

No ecf from incorrect or inverted numbers in M1
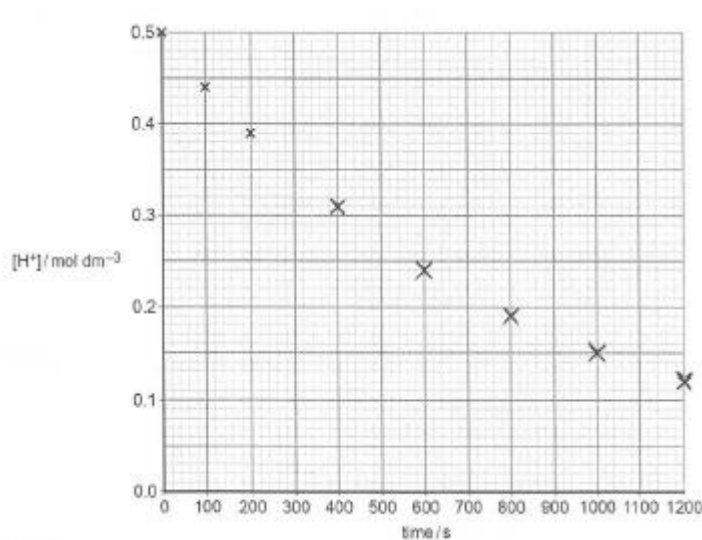
$k_1 = -0.0012$ scores 1/2

Additional processing of data such as including $[H^+]$ loses M2

units = <u>mol dm^{-3} s^{-1}</u>

M3 mark independently
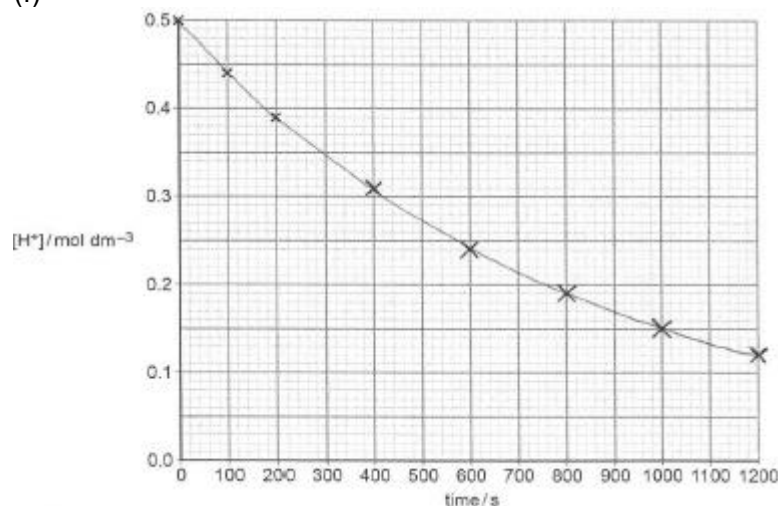
3

(e)   5 points correctly plotted

Allow ±half a small square for each point
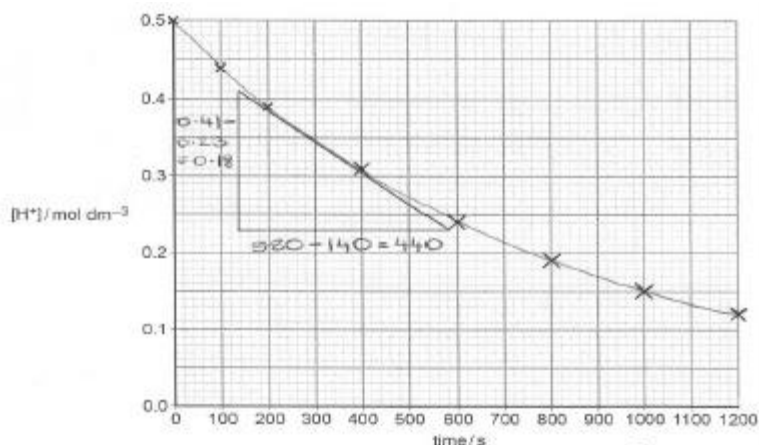
1

(f)

Smooth curve only within one small square of all points
(ecf on part (e))
Not a series of straight lines between points

1

(g)

M1: Tangent to curve drawn at $[H_3O^+] = 0.35$ mol dm^{-3}
e.g. 0.18/440

> *M1 for a tangent / triangle / other suitable working*
>
> *Allow ECF for both M1 and M2 following on from straight line drawn in 01.6, but must show suitable construction on graph for M1*

M2: Rate = 4.09×10^{-4} (mol dm^{-3} s^{-1})

> *Ignore negative signs*
>
> *Allow value in range 3.70×10^{-4} - 4.50×10^{-4}*
>
> *At least 2sf*
>
> *ecf from any straight line for correctly calculated gradient*

2

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

Level 3 5-6 marks	All stages are covered and the explanation of each stage is correct and virtually complete. Answer is coherent and shows progression through all three stages. A clear explanation of how the order is determined from the results is needed to show coherence.
Level 2 3-4 marks	All stages are covered (NB 'covered' means min 2 from stage 2) but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages covered and the explanations are generally correct and virtually complete Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete
Level 1	Two stages are covered but the explanation of each

| 1-2 marks | stage may be incomplete or may contain inaccuracies

OR only one stage is covered but the explanation is generally correct and virtually complete

Answer shows some progression between two stages |
|---|---|
| Level 0

0 marks | Insufficient correct Chemistry to warrant a mark |

Indicative Chemistry content Method 1

Stage 1 Preparation

1a   Measure (suitable/known volumes of) some reagents
        (ignore quoted values for volume)
1b   Measure (known amount of) **X** / use a colorimeter
1c   into separate container(s) – (allow up to two reagents and **X**
        measured together into one container); reference to **A**, **B** or **C** added
        last. NOT if **X** added last.

Stage 2 Procedure

2a   Start clock/timer at the point of mixing (don't allow if only 2 reagents
        mixed)
        (allow even if **X** not added or added last)
2b   Time recorded for appearance of blue colour/specific reading on
        colorimeter/disappearing cross
2c   Use of same concentration of **B** and **C** / same total volume / same
        volume/amount of **X**
2d   Same temperature/use water bath
2e   Repeat with different concentrations of A (can be implied through
        different volumes of A and same total volume)

Stage 3 Use of Results

3a   1/time taken is a measure of the rate
3b   plot of 1/time against volumes/concentrations of **A** or plot log(1/time)
        vs log(volume or concentration of **A**)
3c   description of interpreting order from shape of 1/time vs volume or
        concentration graph / gradient of log plot gives order / allow
        interpretation of time vs concentration graph / ratio between change
        in concentration and change in rate (e.g, 2x[A] = 2 × rate so 1st order)

**Indicative Chemistry content – Alternative Method Using Colorimetry
and repeated Continuous Monitoring**

Stage 1 Preparation

1a   Measure (suitable/known volumes of) **A**, **B** and **C** (ignore quoted
        values for volume)
1b   Use of colorimeter
1c   into separate container(s) – (allow up to two reagents measured

together into one container) – ignore use of **X**

Stage 2 Procedure

2a Start clock/timer at the point of mixing
2b Take series of colorimeter readings at regular time intervals
2c Use of same concentration of **B** and **C** / same total volume / (same volume/amount of **X**)
2d Same temperature
2e Repeat with different concentrations of **A** (can be implied through different volumes of **A** and same total volume)

Stage 3 Use of Results

3a Plot absorbance vs time and measure/calculate gradient at time=0
3b plot of gradient against volumes/concentrations of **A** or plot log(1/time) vs log(volume or concentration of A)
3c description of interpreting order from shape of 1/time vs volume or concentration graph / gradient of log plot gives order

6

[19]