AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.9 RATE EQUATIONS

SCORE	PERCENTAGE
/412	%

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Q1.

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

Only the concentration 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

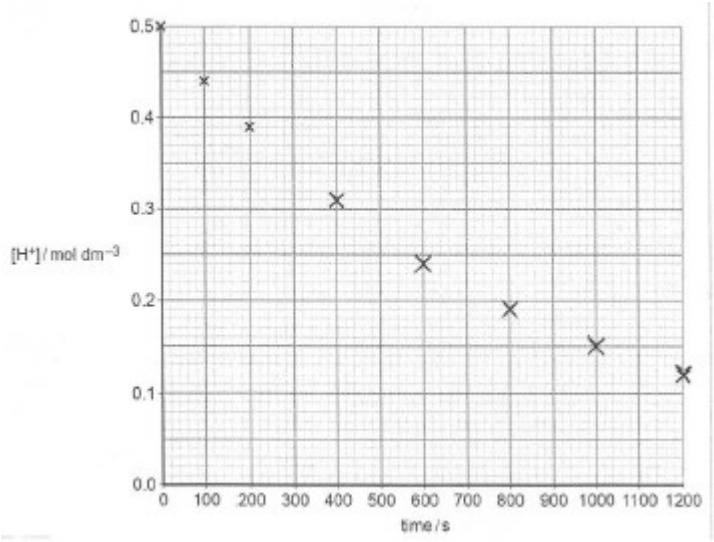
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units = <u>mol dm^{-3} s^{-1}</u>

M3 mark independently

3

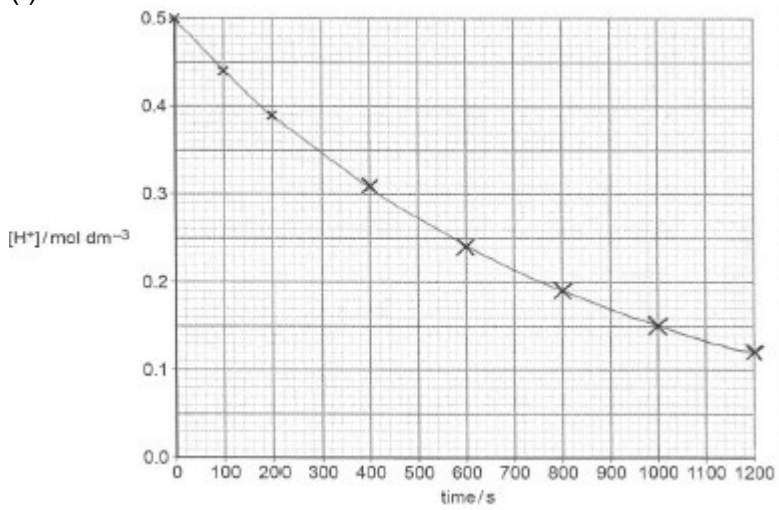
(e) 5 points correctly plotted



Allow ±half a small square for each point

1

(f)



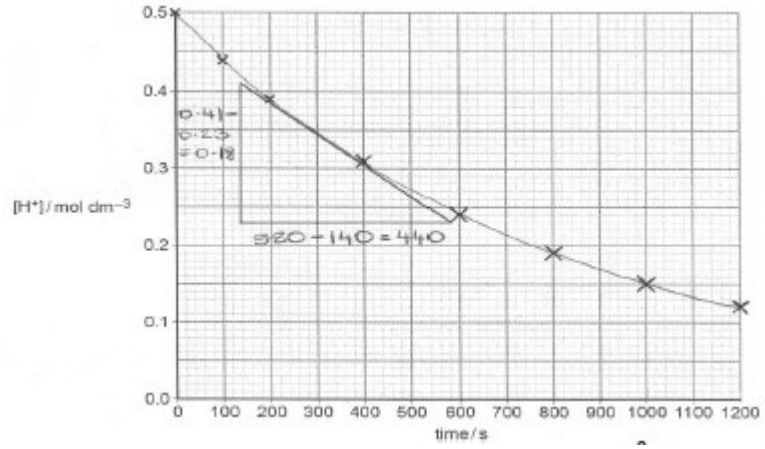
Smooth curve only within one small square of all points (ecf on part (e))

Not a series of straight lines between points

1

(g)

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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 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** only one stage is covered but the explanation is

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	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

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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]

Q2.

D

[1]

Q3.

(a) **Stage 1: Calculates value of $[C_6H_5CHO]^2$:**

M1 for the values (0, 0.0625; 0.25; 0.56 and 1) in the table.

Ignore precision.

1

Stage 2: Plots graph:

M2 for the graph labels with units and appropriate scales and using sensible proportion of graph (plotted points must cover at least half the printed grid).

$[C_6H_5CHO]^2$ on x-axis (with units) $mol^2\ dm^{-6}$

Initial rate on y-axis (with units) $mol\ dm^{-3}\ s^{-1}$

1

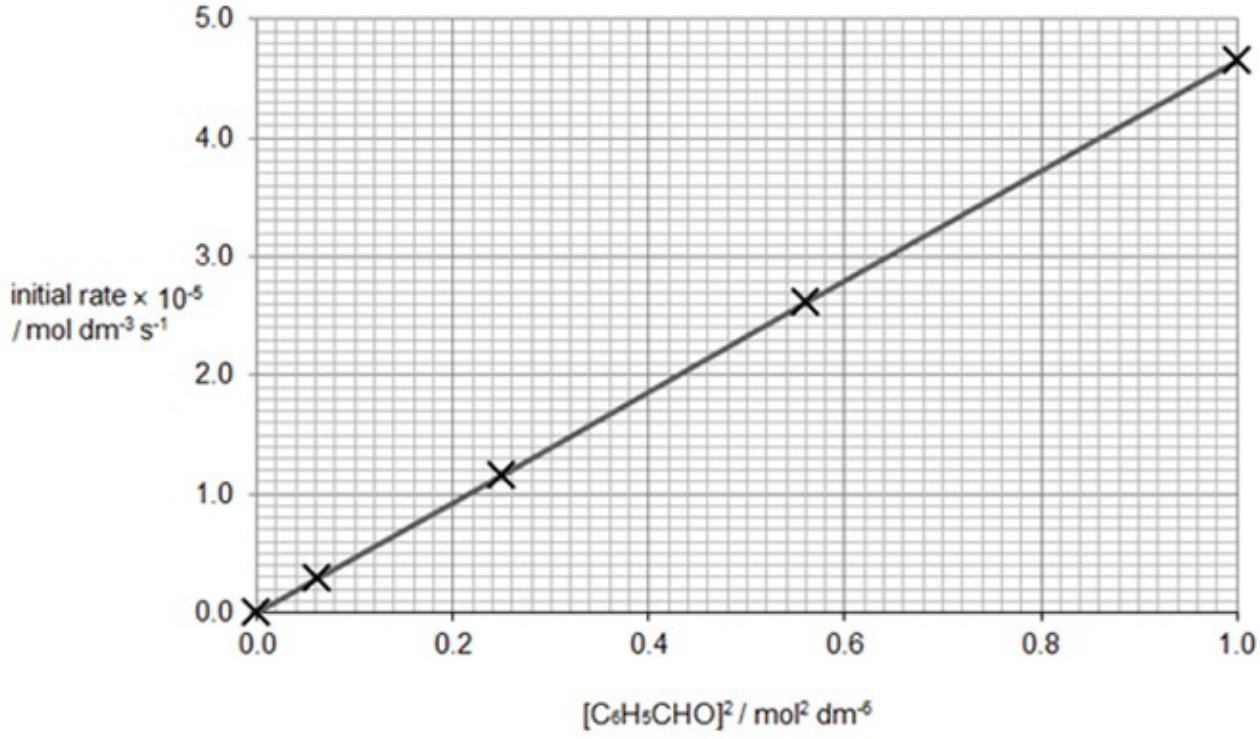
M3 for the plotting of 5 points.

1

Stage 3: Line of best fit:

M4 for the line of best fit.

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1

(b) 2nd order

1

(since) $[C_6H_5CHO]^2$ plotted against rate is straight line / directly proportional.

1

(c) (Role of CN^-) catalyst

Ignore nucleophile.

1

CN^- appears in the rate equation but is not in the reaction equation.

1

[8]

Q4.

(a) Amount of propanone = (25.0 × 1) / 1000 = 0.025 mol

1

Concentration in mixture **A** = 0.025 / (90.0/1000) = 0.278 mol dm^{-3}

1

(b) To make volumes constant for all mixtures.

1

So that volume of propanone is proportional to concentration.

1

(c) Amount of iodine in mixture **E** = (40.0 × 0.02) / 1000 = 8.0×10^{-4} mol

1

Amount of iodine in sample = $8.0 \times 10^{-4} \times (10 / 90) = 8.89 \times 10^{-5}$ mol

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As 10 cm^3 sample taken from total volume of 90 cm^3

1

Amount of thio required = $2 \times 8.89 \times 10^{-5} = 1.78 \times 10^{-4}$ mol

1

Volume of thio = $(1.78 \times 10^{-4} / 0.01) \times 1000 = 17.8\ cm^3$

1

(d) Scale

Graph must cover at least half the grid and axes must be plotted in correct orientation but ignore labeling.

1

Points

Must be correctly plotted to within ± half a small square.

1

Best-fit straight line

Must be the best-fit line possible if point(s) are plotted incorrectly.
Penalise doubled or kinked lines.

1

Gradient = y / x

1

= −0.060

Allow −0.059 to −0.061
Ignore any units given.

1

(e) Gradients / rates are proportional to volumes / concentrations of propanone **or** B to D show that gradient / rate halves when vol / concentration halves.

1

So first order with regard to propanone.

1

(f) To stop / quench the reaction at that time.

Ignore $NaHCO_3$ reacts with the HI produced.

1

By removing the acid catalyst for the reaction (by neutralisation).

1

[17]

Q5.

B

[1]

Q6.

D

[1]

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Q7.

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

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

1

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

1

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

1

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

1

$$k = \frac{7.2\times10^{-4}}{\left(1.9\times10^{-2}\right)^2 \times \left(3.5\times10^{-2}\right)} = 57.0$$

Allow consequential marking on incorrect transcription

1

mol^{-2} dm^{+6} s^{-1}

Any order

1

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

1

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

1

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

1

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

1

(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 × 300 (23.97 – (–5.03)) / 1000 = 72.3 (kJ mol^{-1})

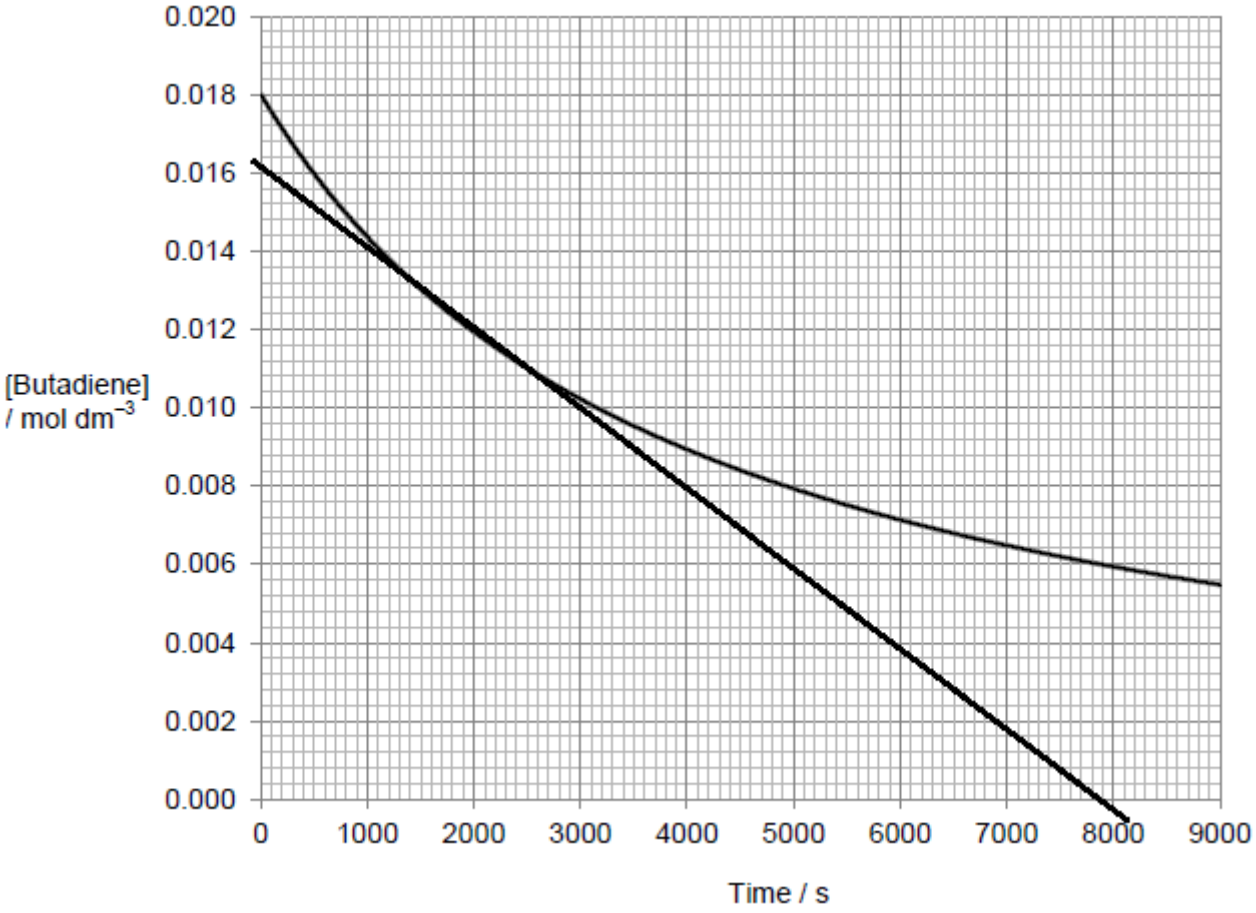
1

[12]

Q8.

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(a) Gradient drawn on graph



Line must touch the curve at 0.012 but must not cross the curve.

1

(b) Stage 1: Rate of reaction when concentration = 0.0120 mol dm^{-3}

From the tangent

Change in [butadiene] = –0.0160 – 0 and change in time = 7800 – 0

Extended response

1

Gradient = –(0.0160 – 0) / (7800 – 0) = –2.05 × 10^{-6}

Rate = 2.05 × 10^{-6} (mol dm^{-3} s^{-1})

1

Stage 2: Comparison of rates and concentrations

Initial rate / rate at 0.0120 = (4.57 × 10^{-6}) / (2.05 × 10^{-6}) = 2.23

Marking points in stage 2 can be in either order

1

Inital concentration / concentration at point where tangent drawn = 0.018 / 0.012 = 1.5

1

Stage 3: Deduction of order

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If order is 2, rate should increase by factor of $(1.5)^2 = 2.25$ this is approximately equal to 2.23 therefore order is 2nd with respect to butadiene

1

[6]

Q9.

(a) Order wrt **D** = 1 OR first OR [D] OR $[D]^1$

Ignore working

1

Order wrt **E** = 2 OR second OR $[E]^2$

1

(b) (At time zero/start) the concentrations are known

1

(c) M1 (Calculate) gradient (of tangent/curve/graph)

Allow description of gradient calculation:

Change in conc / time

1

M2 at t=0 or at start of graph/curve

M2 scored only if M1 gained

Ignore the word initial

1

[5]

Q10.

(a) (i) 2 or two or second or $[E]^2$

1

(ii) 1 or one or first or $[F]^1$ or [F]

1

(b) (i) $k = \dfrac{8.6 \times 10^{-4}}{(3.8 \times 10^{-2})^2 \times (2.6 \times 10^{-2})}$

mark is for insertion of numbers into a correctly rearranged rate equ , k = etc.

AE (−1) for copying numbers wrongly or swapping two numbers.

1

= 22.9 (Allow 22.9 − 24 after correct rounding)

1

$\underline{mol^{-2}dm^{+6}\ s^{&8722;1}}$

Any order.

1

(ii) $6.8(2) \times 10^{-3}$ (mol $dm^{&8722;3}s^{-1}$)

OR if their k is wrong, award the mark consequentially

a quick check can be achieved by using

$\underline{\text{their answer}}$ = 2.9768×10^{-4} Allow $2.9 - 3.1 \times 10^{-4}$ for the mark

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their *k*

Allow 6.8 × 10^{-3} to 6.9 × 10^{-3}
Ignore units.

1

[6]

Q11.

(a) Iodine is not involved in (or before) the rate determining / slow(est) / limiting step (in the mechanism)

Ignore, iodine does not appear in the rate equation or iodine concentration does not affect the rate

1

(b) $k = \left(\frac{8.64 \times 10^{-7}}{(5.82 \times 10^{-2}) \times (4.76 \times 10^{-1})}\right) = 3.1(2) \times 10^{-5}$

Mark for answer

1

$\underline{mol^{-1}\ dm^{+3}\ s^{-1}}$

Mark units separately, i.e. only these units but can be in any order

1

(c) Rate = *k* $[H^+]$

If wrong or missing CE = 0

1

(Large excess of propanone) so $\underline{[CH_3COCH_3]\ is}$ (effectively) $\underline{constant}$

1

[5]

Q12.

(a) Exp 2 14.(4) ×10^{-3} ***OR*** 1.4(4) ×10^{-2} or 0.014

Allow 2sf

1

Exp 3 0.1(0)

1

Exp 4 0.3(0)

If three wrong answers, check their value of k in 1(b).
They can score all 3 if they have used their (incorrect) value of k. see below.
Exp 2 rate = 0.096 × k
*Exp 3 **[Q]** = 0.015/k*
*Exp 4 **[P]** = 0.116/√k*

1

(b) $K = \frac{1.8 \times 10^{-3}}{(0.20)^2 \times 0.30}$

mark is for insertion of numbers into a correctly rearranged

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rate equ , k = etc

1

= 0.15 (min 2sfs) (allow $\frac{3}{20}$)

if upside down, score only units mark

AE (–1) for copying numbers wrongly or swapping two numbers

1

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

Any order

If k calculation wrong, allow units conseq to their k

1

(c) G

1

[7]

Q13.

(a) (i) $k = \frac{8.4\times10^{-5}}{(4.2\times10^{-2})^2\times2.6\times10^{-2}}$ ***OR*** $\frac{8.4\times10^{-5}}{(1.76\times10^{-3})\times2.6\times10^{-2}}$

Mark is for insertion of numbers into a correctly rearranged rate equ , k = etc.

If upside down, score only units mark from their k

AE (−1) for copying numbers wrongly or swapping two numbers

1

= 1.8(3)

1

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

Any order

If k calculation wrong, allow units consequential to their k = expression

1

(ii) 5.67×10^{-4} ($mol\ dm^{-3}\ s^{-1}$) ***OR*** their $k \times 3.1 \times 10^{-4}$

Allow 5.57×10^{-4} to 5.7×10^{-4}

1

(b) (i) 2 or second or $[D]^2$

1

(ii) 0 or zero or $[E]^0$

1

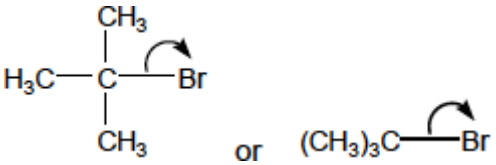
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(c) (i) Step 1 or equation as shown

Penalise Step 2 but mark on

1

(ii)



Ignore correct partial charges, penalise full / incorrect partial charges

If Step 2 given above, can score the mark here for



allow: OH^- (must show lp)

If S_N2 mechanism shown then no mark (penalise involvement of $:OH^-$ in step 1)

Ignore anything after correct step 1

1

[8]

Q14.

(a) (i)

$$k = \frac{6.2 \times 10^{-6}}{(2.9 \times 10^{-2})^2 \times 2.3 \times 10^{-2}}$$

mark is for insertion of numbers into a correctly rearranged rate equ, k = etc

AE (-1) for copying numbers wrongly or swapping two numbers

1

= 0.32 (min 2sfs)

1

mol^{-2} dm^6 s^{-1} Units must be conseq to their *k*

Any order

If k calculation wrong, allow units conseq to their k

1

(ii) 4.95×10^{-5} to 4.97×10^{-5} or 5.0×10^{-5} (min 2 sfs)

(ignore units)

rate = their k × 1.547 × 10^{-4}

1

(b) Step 2

If wrong no further mark

1

One H_2 (and two NO) (appear in rate equation)
or species (in step 2) in ratio/proportion as in the rate equation

1

[6]

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Q15.

(a) (i) propyl methanoate

must be correct spelling

1

(ii) rate = k[X][OH^-]

allow $HCOOCH_2CH_2CH_3$ (or close) for X

allow ( ) but penalise missing minus

1

(iii) $k = \frac{8.5 \times 10^{-6}}{(0.024)(0.035)}$

In (a)(iii), if wrong orders allow

mark is for insertion of numbers in correct expression for k

If expression for k is upside down, only score units conseq to their expression

1

= 0.10(12) 2sf minimum

1 for conseq answer

1

$mol^{-1}\ dm^3\ s^{-1}$

1 for conseq units

any order

1

(iv) $2.1(3) \times 10^{-5}$

or $2.1(2) \times 10^{-5}$ ignore units

allow 2 sf

NB If wrong check the orders in part (a)(iii) and allow (a)(iv) if conseq to wrong k

See * below

1

(v) 1.3×10^{-4} (1.28×10^{-4})

allow (1.26×10^{-4}) to (1.3×10^{-4}) *ignore units*

allow 2 sf

NB If wrong check the orders in part (a)(iii) and allow (a)(iv) if conseq to wrong k

See ** below

1

For example, if orders given are 1st in X and second in OH^-
[The mark in a(ii) and also first mark in a(iii) have already been lost]

So allow mark * in (iv) for rate = their k × $(0.012)(0.0175)^2$ = their k × (3.7×10^{-6}) (allow answer to 2sf)

** in (v) for rate = their k × $(0.012)(0.105)^2$ = their k × (1.32×10^{-4}) (allow answer to 2sf)

The numbers will of course vary for different orders.

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(vi) Lowered

if wrong, no further mark

1

fewer particles/collisions have energy > E_a
OR
fewer have sufficient (activation) energy (to react)

not just fewer successful collisions

1

(b) Step 2

1

(this step with previous) involves one mol/molecule/particle
A and two Bs

or 1:2 ratio or same amounts (of reactants) as in rate equation

if wrong, no further mark

1

[11]

Q16.

(a) Log (1 / time) on the y-axis + log (vol) on x-axis

If axes unlabelled use data to decide that log (1 / time) is on the y-axis

1

Sensible scales

Lose this mark if the plotted points do not cover at least half of the paper

Lose this mark if the graph plot goes off the squared paper

Lose this mark if plots a non-linear / broken scale

Lose this mark if uses an ascending y-axis of negative numbers

1

Plots points correctly ± one square

1

Line through the points is smooth

Lose this mark if the candidate's line is doubled

1

Line through the points is best fit – ignores last point

Must recognise that point at 25 cm^3 is an anomaly

If wrong graph, mark consequentially on anomaly if correctly plotted.

*A kinked graph loses smooth **and** best fit marks*

1

(b) Uses appropriate x and y readings

Allow taken from table or taken or drawn on graph

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Must show triangle on graph or such as $\frac{1.65-1.2}{1.4-0.9}$

1

Correctly calculates gradient 0.95 ± 0.02

Ignore positive or negative sign

Correct answer only with no working scores this mark

1

Answer given to 2 decimal places

1

(c) First order or order is 1

Allow consequential answer from candidate's results

1

(d) Thermostat the mixture / constant temperature / use a water bath
or Colorimeter / uv-visible spectrometer / light sensor to monitor colour change

1

Reaction / rate affected by temperature change
or Eliminates human error in timing / more accurate time of colour change

1

[11]

Q17.

(a) 2 or two or second

1

(b) $k = \frac{1.24 \times 10^{-4}}{(4.40)(0.82)}$

mark is for insertion of numbers into a correctly rearranged rate equ, k = etc

if upside down, (or use of I_2 data) score only units mark

1

$= 3.4\underline{4} \times 10^{-5}$ (min 3sfs)

1

$mol^{-1}\ dm^3\ s^{-1}$

any order

1

(c) no change or no effect or stays the same or 1.24×10^{-4}

1

(d) 1 or 2 or 1 and 2

if wrong no further mark but mark on from no answer

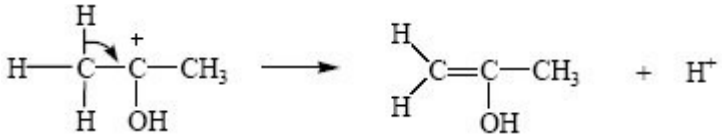
1

rate equ doesn't involve I_2 or only step which includes 2 species in rate equ

1

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(e)



any second arrow loses the mark

1

[8]

Q18.

(a) (i) 2

1

(ii) 0

1

(b) (i) rate/$[NO_2]^2[O_2]$

1

13

1

mol dm^{-3}

1

(ii) 1.9×10^{-3}

1

(iii) Step 2

1

[7]

Q19.

(a) order with respect to **P** is 2

1

order with respect to **Q** is 1

1

(b) (i) rate = k**[R][S]**^{2}

(if wrong expression, no further marks)

1

rate = $(4.2 \times 10^{-4}) \times 0.16 \times 0.84^2$

1

= 4.7×10^{-5} (mol dm^{-3} s^{-1})

ignore units even if wrong

1

(ii) $k = \frac{\text{rate}}{[R][S]^2} = \frac{8.1 \times 10^{-5}}{0.76 \times 0.98^2}$

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1

= 1.1×10^{-4}

1

(iii) T_1

**If calculated value for $k > 4.2 \times 10^{-4}$, then answer to (iii) is T_2*

1

[8]

Q20.

(a) Power (or index or shown as *x* in $[\ ]^x$) of concentration term (in rate equation) **(1)**

1

(b) 2 **(1)**

1

(c) (i) *Order with respect to **A**:* 2 **(1)**

*Order with respect to **B***: 0 **(1)**

(ii) *Rate equation:* (rate =) k $[A]^2$ **(1)**

Allow conseq on c(i)

Units for rate constant: $mol^{-1}\ dm^3\ s^{-1}$ **(1)**

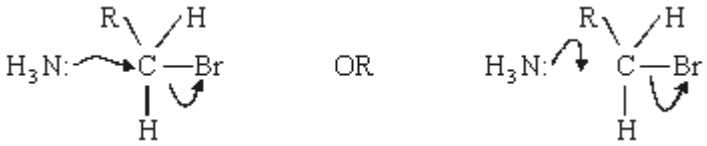
conseq on rate equation

4

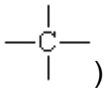
[6]

Organic points

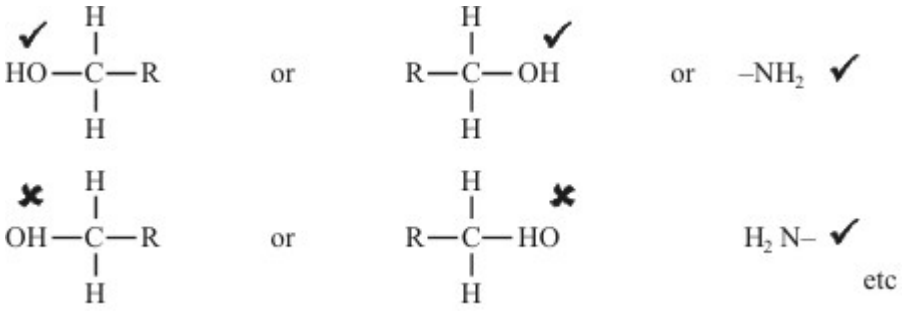
(1) Curly arrows: must show movement of a pair of electrons, i.e. from bond to atom or from lp to atom / space
e.g.



(2) Structures

penalise sticks (i.e. ) once per paper

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Penalise once per paper

allow CH_3– or $-CH_3$ or  or CH_3
or H_3C–

Q21.

(a) (i) Experiment 2: $0.4(0) \times 10^{-3}$ **(1)**
Experiment 3: 0.15 **(1)**
Experiment 4: 0.28 **(1)**

(ii) $k = \frac{4.8 \times 10^{-3}}{(0.20)^2 \times (0.30)} = 0.4(0)\ mol^{-2}\ dm^6\ s^{-1}$

(1) **(1)** **(1)**

6

(b) (change in) temperature **(1)**

1

[7]

Q22.

(a) (i) (Experiment 1 → 2) [A] doubled, ([B] constant,)
rate doubled **(1)**
stated or shown numerically

(ii) 2 **(1)**
or shown as ... $[B]^2$

2

(b) (i) $k = \frac{9.30 \times 10^{-5}}{(0.75)^2 \times (1.50)} = 1.1(0) \times 10^{-4}$

(1) **(1)**

units of k: $mol^{-2}\ dm^6\ s^{-1}$ **(1)**

(ii) rate = $(1.10 \times 10^{-4}) \times (0.20)^2 \times (0.10)$
$= 4.4(1) \times 10^{-7}$ $(mol\ dm^{-3}\ s^{-1})$
(1) for the answer
Ignore units
Conseq on (i)

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Upside down expression for k scores zero in (i) for 9073
but rate = 9073 × $(0.2)^2$ × (0.1) = 36(.3)
conseq scores (1) in (ii)

4

[6]

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Q1.

(a) This proved to be a tougher starter question than anticipated (63.4% of students failed to score). In many cases, the question was repeated as an attempt at the answer with students suggesting that "the rate only depends on $[H^+]$". Since this information had been given in the question, answers such as this could not be credited. The expected answer, that 'a large excess makes the concentrations effectively constant so that they do not affect the rate', was seldom seen.

(b) As with part (a), not many students were able to achieve both marks (only 9.7%), with few suggesting 'quenching'. Given how frequently quenching was, unnecessarily, suggested in answers to (h), this was surprising. In many cases, students described the process of titration itself rather than what should be done to the sample *before* titration. 74% of students failed to score here.

(c) This question proved easier, with just over a third of students achieving both marks for appreciating that the line indicated a constant rate, showing that the falling concentration of hydrogen ions was having no effect.

(d) A common error here was for students to start by (correctly) calculating the gradient of the line but then to divide it by a value for the $[H^+]$ (usually 0.5) or even by $[H^+]^2$ – despite having been told in part (c) that the order with respect to $H^+(aq)$ is zero. 36% of students, however, did gain all three marks.

(e) 97.3% of students were able to plot the points correctly onto the given grid.

(f) A significant number of students assumed that the instruction to 'draw a line of best fit' meant that the line must be straight. Students must learn that a best-fit line must be the best-fit to the points as plotted, so may be either straight or curved depending on the relationship between the plotted points; at A-level, students are expected to make this decision for themselves. Just under 40% of students did not gain this mark.

(g) The idea of drawing a tangent (or, for award of 'error carried forward', simply constructing a 'triangle' on a straight line) proved tricky, with a significant minority of students simply dividing 0.35 by the corresponding time value from their line.

(h) Fewer students than expected recognised the clue in the information given in the question that this was best done as a 'clock' reaction. Many students suggested answers that did not include 'X' in the initial mixture, as suggested, while many others used a variety of convoluted procedures involving what were essentially 'continuous monitoring' methods to generate concentration versus time graphs. In some cases, this was followed by a description of finding the gradient at $t = 0$, which addressed the requirement of the question to calculate an initial rate for each experiment. However, a direct measurement would have been much easier, both to do and to describe.

Credit was given for a wide variety of suggestions because, although a particular approach was hoped for, there are indeed several alternative approaches that would work. However, many students seemed to think that actual measurements of concentration (of what substance was often unclear from the descriptions) are needed, which led to suggestions that samples should be removed at timed intervals and titrated against X or placed into a colorimeter (the need to quench these samples was often over-looked). If a colorimeter was used, then the best approach

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for continuous monitoring is simply to allow the reaction to proceed in the colorimeter and take a series of readings at timed intervals – much easier than sampling. The mean mark on this question was only 1.8 out of 6.

The extra answer space available this year meant that fewer students needed additional pages for this question, but many confused, badly ordered and muddled answers were seen that took up far more space than necessary through repetition and unnecessary elaboration.

Reading the question is always key, but here many students could have saved a lot of time and space by noticing that the question asked only about a method to determine the order of this reaction with respect to A. This would have avoided the need for them to repeat most of the procedure, looking at successively changing the concentrations of A, then B, then C, while keeping each of the other two constant. Levels-of-response questions are marked using 'levels' and the key to success is for students to concentrate first on the inclusion of as much correct Chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). This is probably best achieved using a 'bullet point' approach to structuring the answer. Within a level, the mark awarded depends on the clarity and coherence of an answer, together with there being a clear, logical progression through the description.

Appropriate apparatus and quantities should be mentioned as necessary. For example, rather than stating "add A, B and C to a container", a good start to the answer would be to write, "A measuring cylinder was used to measure known volumes, of known concentrations, of A, B and C into separate beakers". Unless specifically asked to suggest suitable volumes/concentrations, then it is sufficient for students to indicate that they would make a measurement without needing to state a value.

Q2.

A was the commonest incorrect response here, suggesting that those students thought it was a concentration v time graph rather than a rate v concentration graph. 76.5% of students were successful.

Q9.

Part (a) was answered well and two thirds of students scored both marks. By contrast, part (b) was a hard question with few correct answers. Many students spoke about the changing concentrations but few mentioned the importance of knowing the initial concentration. The first mark in part (c) for mentioning a gradient was often gained but the location of where to measure the gradient was only given by a third of students.

Q10.

This question was answered well. A few students lost marks through the incorrect use of calculators in the division necessary in part (b)(i) to find the rate constant, k, or by omitting s-1 from the units of the rate calculated in part (b)(ii).

Q11.

Part (a) was answered correctly by just over half of the students. The majority of incorrect answers were because students didn't answer the question and simply just repeated what the rate equation told them.

Calculation of a rate constant in part (b) was answered very well as usual but part (c)

proved to be very difficult. A large number of students could not deduce the correct rate equation. Those who did gain this mark were not often able to give a reason for their answer and the second mark was rarely seen.

Q12.

The kinetics question was, as usual, answered well with only Experiment **4** in part (a) causing much difficulty. However, in part (c) fewer than half of the students identified graph G as that correctly showing how the rate constant *k* varies with temperature.

Q13.

This question was answered well by most students and over 80% scored full marks in part (a). Part (c)(ii) was found slightly harder and, of those who correctly identified Step 1 as the slower step, most gained the mark for the curly arrow. Those who suggested Step 2 could also gain a mark for a correct arrow for that step. However, many gave a full S_N2 mechanism in both cases.

Q14.

Part (a) was well done with many candidates scoring full marks. Although most gave the correct answer to part (a)(ii), many did it by the long route, having failed to see that the answer was simply 8x the initial rate.

Candidates found part (b) more difficult. Many of those who correctly chose step 2 could not offer a full explanation.

Q15.

Most parts of this question were answered well. The ester was named correctly by over two thirds of the candidates but a surprising number attempted to write a stoichiometric equation in part (a)(ii) rather than a rate equation. Part (a)(iii) was answered very well but in part (a)(iv) the effect of dilution on the concentration of both reagents was missed by a large majority. However, when the exact concentrations were given in part (a)(v) most candidates were able to calculate the new rate of reaction correctly. The effect on the rate constant of lowering the temperature was well known in part (a)(vi), but few candidates were able to give a correct explanation and many offered a mathematical rather than a kinetic explanation. In part (b), the requirement to use the rate equation to identify the rate determining step proved difficult for the majority.

Q16.

In this Section, the graphs seen showed the usual range of mistakes seen in this type of question as mentioned in the marking scheme. The main difficulty was in ensuring that the **plotted** graph covered at least half the printed grid.

In part (b), most candidates were able to find an appropriate gradient and full marks were common. Allowance was made for consequential errors from the drawing of the graph but in part (c) the order quoted needed to be based on the final answer to part (b).

Candidates had some trouble with part (d), many thinking that a ‘white tile’ would improve the precision of time measurement.

Q17.

As usual for questions on kinetics, this was answered well. It was also pleasing that, in

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part 3(d), over half of the candidates gained both marks on a question which required understanding of a new part of the specification. Application in part (e) of their understanding of the use of curly arrows in organic mechanisms was, however, less well done.

Q19.

As is normal, the use of rate equations is well understood and almost all candidates can answer these questions well. Very few failed to score the marks for deducing the orders with respect to **P** and **Q**. The calculation in part (b) using the given orders of reaction was well done by all except those candidates who could not rearrange the equation correctly. The same applied in part (b)(ii). In the few cases where the calculated value of the rate constant was incorrect, and greater than 4.2×10^{-4} mol^{-2} dm^{6} s^{-1} the usual answer of T_1 for part (b)(iii) was replaced by the answer T_2 consequential on their incorrect value of *k.*

Q20.

In part (a) few candidates were able to explain correctly what the term ‘order of reaction’ means. However, despite this most were able to use the idea itself and scored highly in the rest of the question. The fact that the rate of reaction increased by a factor of nine, 32 , when the concentration of A increased by three times led some candidates to think that the order with respect to A was three rather than two.

Q21.

This question was generally answered well even by weaker candidates. Calculation of the concentration of P in part (a)(i) was the only part found difficult by many. Most answers to part (a)(ii) were correct, including the units. A change in temperature was the usual and correct answer in part (b).

Q22.

This question on rate equations was answered well by most candidates. Part (a)(i) required that the candidate stated or showed mathematically that the rate doubled when the concentration of A doubled when considering experiments 1 and 2. Part (a)(ii) was usually answered correctly. Problems arose in part (b) where some candidates had difficulty in rearranging the rate equation correctly. However the mark in part (b)(ii) could still be gained for correct working despite using a wrong rate constant calculated in part (b)(i).

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Q1.

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

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

1

= 13 (must be 2 sfs)

1

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

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 × k

Ex 4 $[H^+]$ = square root of (2.7/k)

1

(c) 1/T value $3.31(1) \times 10^{-3}$ 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 = $– 6.64 \times 10^3$ (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

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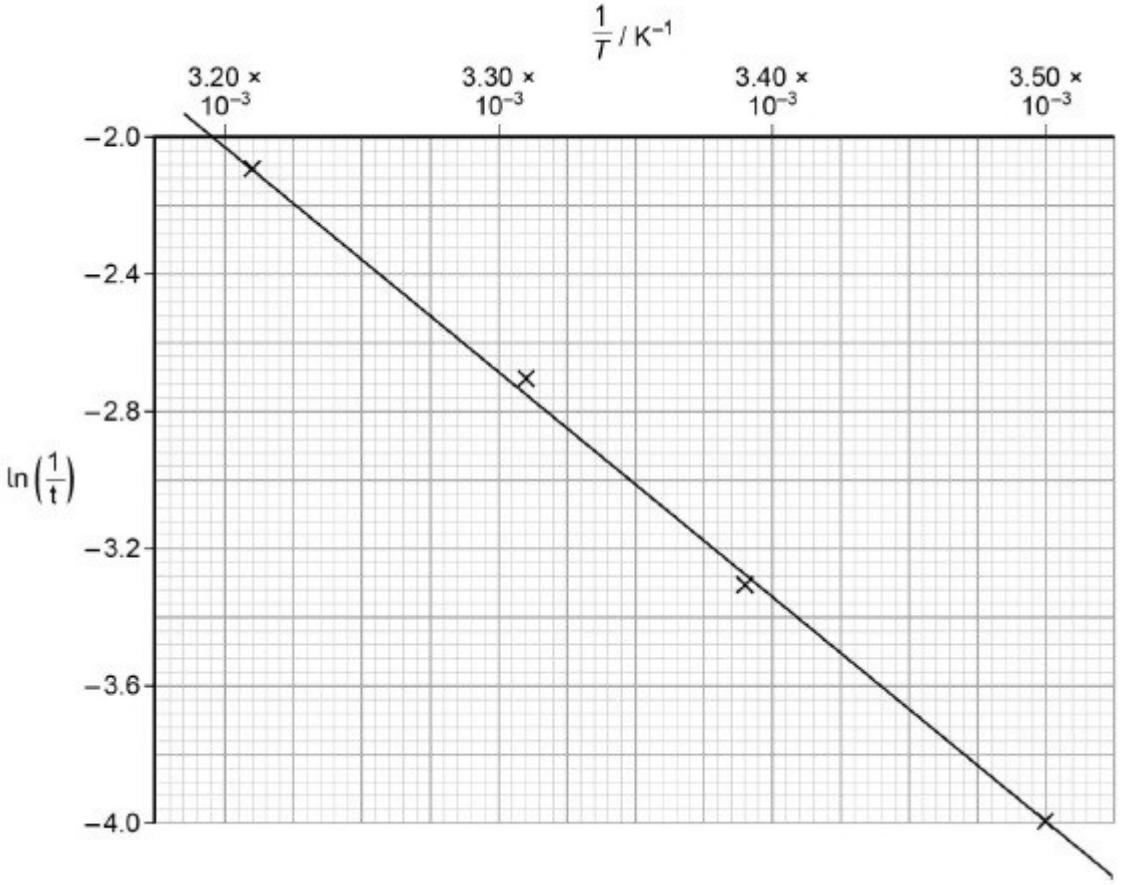
If gradient outside range then max 4 for M1, M2, M3 and M5

1

M6 = 55.2 kJ mol^{-1}

Range 54.0 - 56.5

1



[14]

Q2.

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

Only the concentration 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

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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

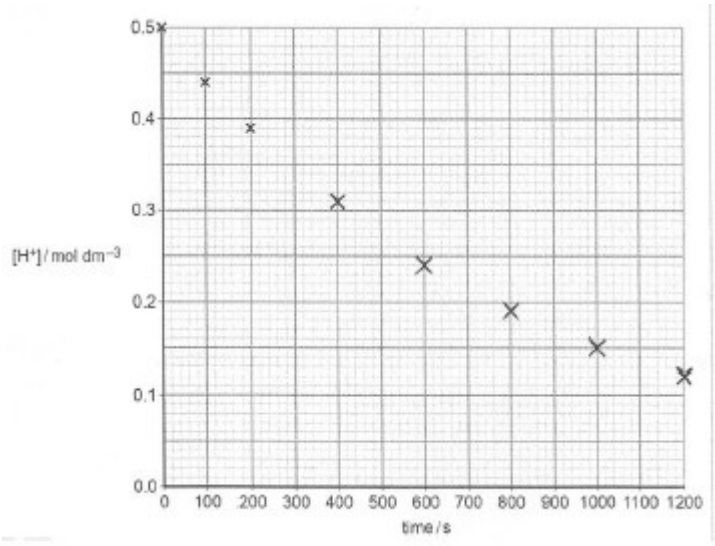
Additional processing of data such as including $[H^+]$ loses M2

units = $\underline{\text{mol dm}^{-3}\ \text{s}^{-1}}$

M3 mark independently

3

(e) 5 points correctly plotted

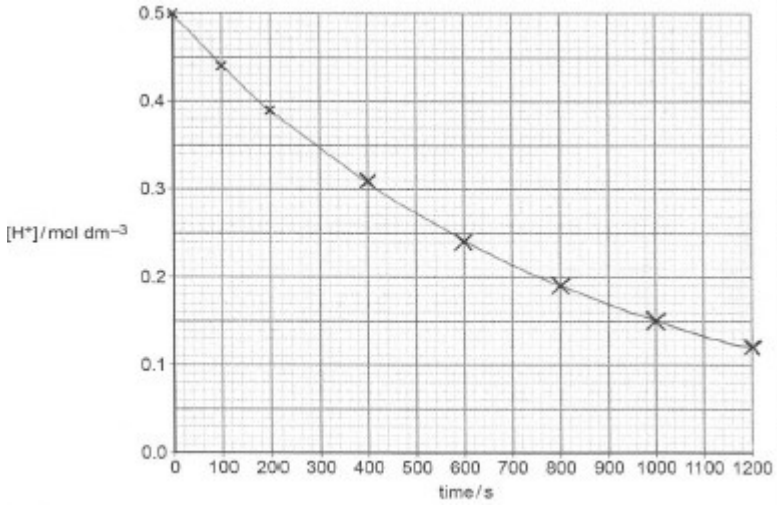


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Allow ±half a small square for each point

1

(f)

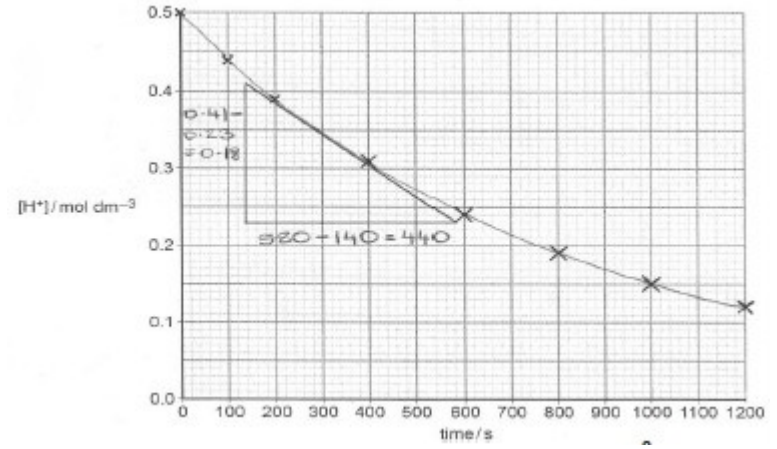


Smooth curve only within one small square of all points (ecf on part (e))

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

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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 1-2 marks	Two stages are covered but the explanation of each 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)

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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]

Q3.

C

[1]

Q4.

(a)

$$k = (\text{rate}/[C][D]) = \frac{3.1 \times 10^{-3}}{(0.48) \times (0.23)}$$

Mark is for insertion of numbers into correctly rearranged rate equation

1

$= 2.8 \times 10^{-2}$ min 2sfs

1

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$mol^{-1}\ dm^3\ s^{-1}$

Mark units separately in any order.

1

(b) $\ln k = \ln 2.8 \times 10^{-2}$ (= - 3.58)

M1 = ln (their k)
If incorrect then award M2 and M3 only

Alternative value
ln k = ln 3.2 × 10^{-3} = - 5.74

M1

$E_a = RT(\ln A - \ln k)$

OR

$-E_a = RT(\ln k - \ln A)$

If ln 16.9 used max 3
If temp used 25 max 2
Incorrect rearrangement then M1 only

M2

$E_a = 8.31 \times 298\ (16.9 + 3.58)$ (= 50716 J mol^{-1})

Alternative value
E_a = 8.31 × 298 (16.9 + 5.74)
(= 56076 J mol^{-1})

M3

E_a = 51 kJ mol^{-1}

– 50.7 or -51 scores max 2

Alternative value
E_a = 56 kJ mol^{-1}

M4

[7]

Q5.

(a) **Stage 1: Calculates value of $[C_6H_5CHO]^2$:**

M1 for the values (0, 0.0625; 0.25; 0.56 and 1) in the table.

Ignore precision.

1

Stage 2: Plots graph:

M2 for the graph labels with units and appropriate scales and using sensible proportion of graph (plotted points must cover at least half the printed grid).

$[C_6H_5CHO]^2$ on x-axis (with units) $mol^2\ dm^{-6}$

Initial rate on y-axis (with units) $mol\ dm^{-3}\ s^{-1}$

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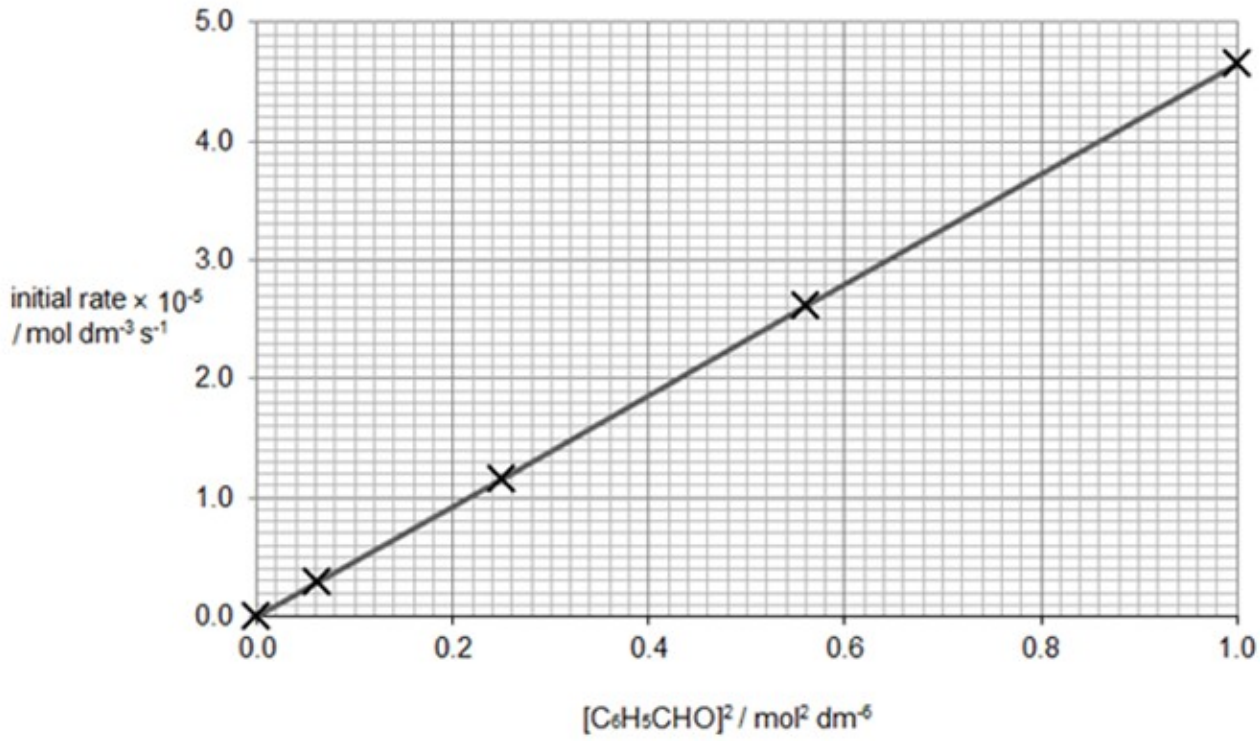
1

M3 for the plotting of 5 points.

1

Stage 3: Line of best fit:

M4 for the line of best fit.



1

(b) 2nd order

1

(since) $[C_6H_5CHO]^2$ plotted against rate is straight line / directly proportional.

1

(c) (Role of CN^-) catalyst

Ignore nucleophile.

1

CN^- appears in the rate equation but is not in the reaction equation.

1

[8]

Q6.

Stage 1: Complete table and draws graph:

Rate constant k/s^{-1}	**ln k**	**Temperature /k**	$\frac{1}{T}$
6.13×10^{-5}	**−9.7(0)**	700	**1.43×10^{-3}**

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2.75×10^{-4}	**−8.2(0)**	727	**1.38×10^{-3}**
8.25×10^{-4}	**−7.1(0)**	746	**1.34×10^{-3}**
8.23×10^{-3}	**−4.8(0)**	793	**1.26×10^{-4}**

Extended response question

M1 *Calculates (four) values of* $\frac{1}{T}$ **1**

M2 *Calculates (four) values of ln k* **1**

M3 *Plots points on graph* **1**

M4 *Draws line of best fit.* **1**

Stage 2: Calculates gradient:

M5 working = $\frac{\Delta y}{\Delta x}$ (such as $\frac{-6.9}{0.24 \div 1000}$ **OR** $\frac{-5.5}{0.19 \div 1000}$

Stage 2 *can only be accessed if the table has been completed correctly and a straight line graph is drawn.* **1**

M6 answer = -2.88×10^4

Correct answer with or without working scores M5 and M6. **1**

Stage 3: Calculates E_a:

M7 (recognises that gradient = $-2.88 \times 10^4 \propto \frac{-Eact}{R}$)

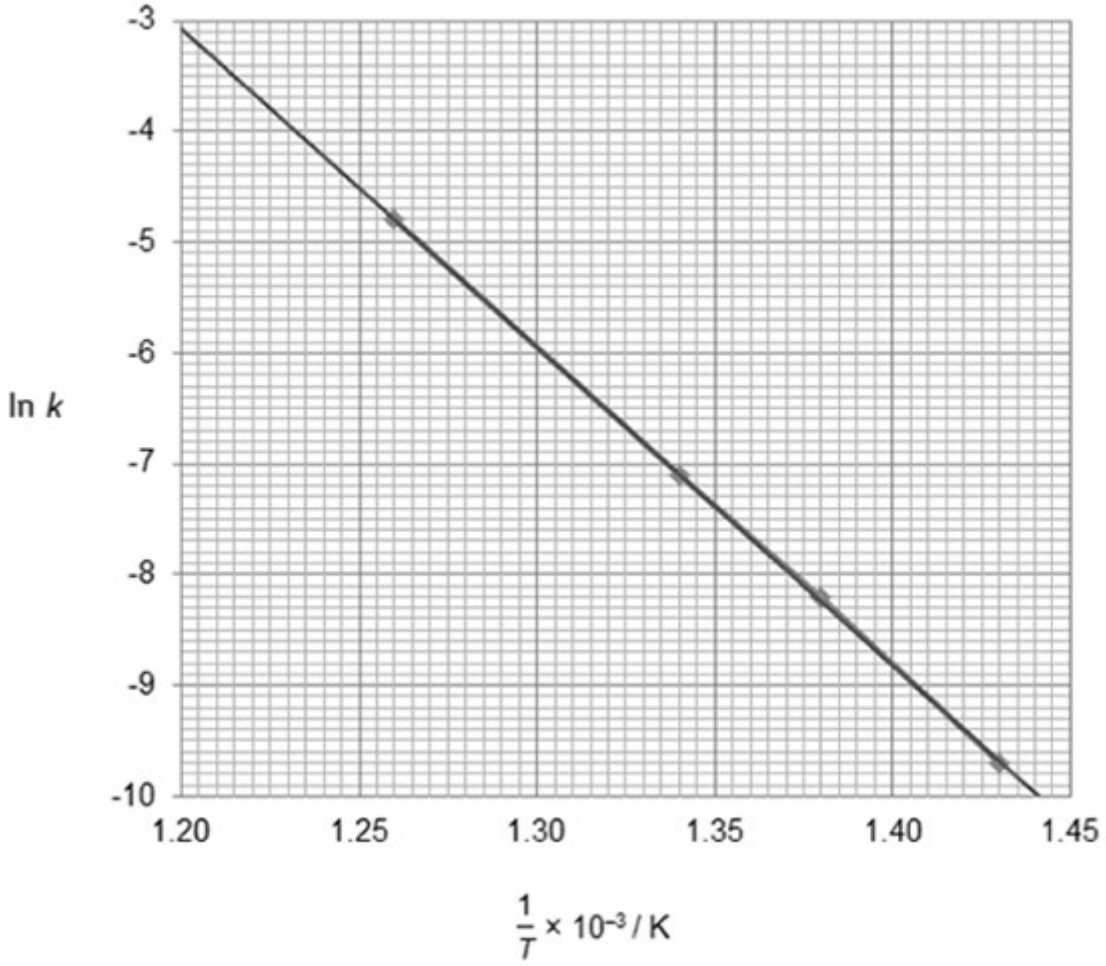
$E_a = 2.88 \times 10^4 \times 8.314$)

Stage 3 *can only be accessed if the student has correctly calculated a gradient from their line graph.* **1**

M8 (÷1,000 =) E_a = 239 kJ mol^{-1}

Correct answer with or without working scores M7 and M8.
Answer to correct number of significant figure (3 sf). **1**

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[8]

Q7.

D

[1]

Q8.

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

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

1

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

1

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

1

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

1

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$$k = \frac{7.2\times10^{-4}}{\left(1.9\times10^{-2}\right)^2 \times \left(3.5\times10^{-2}\right)} = 57.0$$

Allow consequential marking on incorrect transcription

1

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

Any order

1

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

1

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

1

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

1

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

1

(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]

Q9.

B

[1]

Q10.

(a) Order wrt **D** = 1 OR first OR [D] OR $[D]^1$

Ignore working

1

Order wrt **E** = 2 OR second OR $[E]^2$

1

(b) (At time zero/start) the concentrations are known

1

(c) M1 (Calculate) gradient (of tangent/curve/graph)

Allow description of gradient calculation:

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Change in conc / time

1

M2 at t=0 or at start of graph/curve

M2 scored only if M1 gained

Ignore the word initial

1

[5]

Q11.

(a) Iodine is not involved in (or before) the rate determining / slow(est) / limiting step (in the mechanism)

Ignore, iodine does not appear in the rate equation or iodine concentration does not affect the rate

1

(b) $k = \left(\frac{8.64 \times 10^{-7}}{(5.82 \times 10^{-2}) \times (4.76 \times 10^{-1})}\right) = 3.1(2) \times 10^{-5}$

Mark for answer

1

$\underline{mol^{-1}\ dm^{+3}\ s^{-1}}$

Mark units separately, i.e. only these units but can be in any order

1

(c) Rate = k $[H^+]$

If wrong or missing CE = 0

1

(Large excess of propanone) so $\underline{[CH_3COCH_3]\ is}$ (effectively) $\underline{constant}$

1

[5]

Q12.

(a) (i) 2

1

(ii) 0

1

(b) (i) $K = \frac{6.64 \times 10^{-5}}{(4.55 \times 10^{-2}) \times (1.70 \times 10^{-2})^2}$

Correct answer for k with or without working scores 2.

First mark is for insertion of numbers into a correctly rearranged rate equ , k = etc.

1

= 5.05 (range allowed 5.03−5.07)

AE (−1) for copying numbers wrongly or swapping two numbers.

1

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

Mark units separately, ie only these units but can be in any order.

1

(ii) 8.3×10^{-6} (mol dm^{-3} s^{-1})

Allow 0.83×10^{-5}.

Ignore units.

OR if not 8.3×10^{-6}, look at their *k* in part(i) and if not 5.05

Allow ecf for their (incorrect) $k \times (1.64 \times 10^{-6})$

1

[6]

Q13.

(a) k = rate / $[A]^2$ or $\frac{3.3 \times 10^{-5}}{(4.2 \times 10^{-3})^2}$

1

= 1.87 or 1.9

Answer scores 2

1.90 scores first mark only (incorrect rounding)

1

$mol^{-1}dm^3s^{-1}$

Any order and independent of calculation

1

(b) Expt 2 rate = $1.167 \times 10^{-4} - 1.2 \times 10^{-4}$ (mol dm^{-3} s^{-1})

If answers in table are not those given here, check their value of k in part (a) or use of alternative k.

1

Expt 3 [A] = $9.7 \times 10^{-3} - 9.8(1) \times 10^{-3}$ (mol dm^{-3})

If their k is incorrect in part (a) mark this part consequentially e.g. if $k = 7.9 \times 10^{-3}$ due to lack of squaring in (a)

Using alternative value for *k*

expt 2 4.9×10^{-7}

Expt 2 rate = $1.4(4) \times 10^{-4}$ (mol dm^{-3} s^{-1})

expt 3 1.5×10^{-1}

Expt 3 [A] = 8.85×10^{-3} (mol dm^{-3})

(expt 2 6.24×10^{-5} × their k)

(expt 3 $0.0134 / \sqrt{k}$)

1

(c) Slow step or rds involves only A

OR

B does not appear in the slow step or the rds

OR

B only appears after the slow step or the rds

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Not B has no effect on the rate or B is not in the rate equation

Allow "it" for B

1

[6]

Q14.

(a) (i) 2 or two or second or $[E]^2$

1

(ii) 1 or one or first or $[F]^1$ or [F]

1

(b) (i) $k = \dfrac{8.6 \times 10^{-4}}{(3.8 \times 10^{-2})^2 \times (2.6 \times 10^{-2})}$

mark is for insertion of numbers into a correctly rearranged rate equ , k = etc.

AE (−1) for copying numbers wrongly or swapping two numbers.

1

= 22.9 (Allow 22.9 − 24 after correct rounding)

1

$\underline{mol^{-2}dm^{+6}\ s^{\&8722;1}}$

Any order.

1

(ii) $6.8(2) \times 10^{-3}$ ($mol\ dm^{\&8722;3}s^{-1}$)

OR if their k is wrong, award the mark consequentially

a quick check can be achieved by using

$\underline{\text{their answer}}$ = 2.9768×10^{-4} Allow $2.9 - 3.1 \times 10^{-4}$ for the mark

their *k*

Allow 6.8×10^{-3} to 6.9×10^{-3}

Ignore units.

1

[6]

Q15.

(a) (i) $k = \dfrac{8.4 \times 10^{-5}}{(4.2 \times 10^{-2})^2 \times 2.6 \times 10^{-2}}$ ***OR*** $\dfrac{8.4 \times 10^{-5}}{(1.76 \times 10^{-3}) \times 2.6 \times 10^{-2}}$

Mark is for insertion of numbers into a correctly rearranged rate equ , k = etc.

If upside down, score only units mark from their k

AE (−1) for copying numbers wrongly or swapping two numbers

1

= 1.8(3)

1

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

Any order

If k calculation wrong, allow units consequential to their k = expression

1

(ii) 5.67×10^{-4} (mol dm^{-3} s^{-1}) ***OR*** their $k \times 3.1 \times 10^{-4}$

Allow 5.57×10^{-4} to 5.7×10^{-4}

1

(b) (i) 2 or second or $[D]^2$

1

(ii) 0 or zero or $[E]^0$

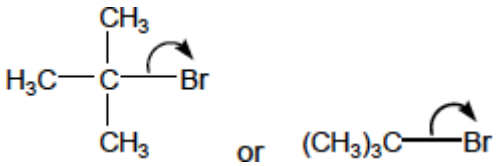
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(c) (i) Step 1 or equation as shown

Penalise Step 2 but mark on

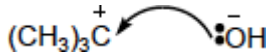
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(ii)



Ignore correct partial charges, penalise full / incorrect partial charges

If Step 2 given above, can score the mark here for



allow: OH^- (must show lp)

If S_N2 mechanism shown then no mark (penalise involvement of $:OH^-$ in step 1)

Ignore anything after correct step 1

1

[8]

Q16.

(a) Exp 2 4.5×10^{-4}

Min 2sf

1

Exp 3 4.5×10^{-3}

If three wrong answers, check their value of k in (b).

1

Exp 4 0.043 OR 4.3×10^{-2} OR 0.044 OR 4.4×10^{-2}

They can score all 3 if they have used their (incorrect) value of k. see below.

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Exp 2 rate = k × (1.0125 × 10^{-4})

*Exp 3 [**Q**] = 0.02/k*

*Exp 4 [**P**] = 0.0913/√k*

1

(b) $k = \frac{5.0 \times 10^{-5}}{(2.5 \times 10^{-2})^2 \times (1.8 \times 10^{-2})}$

Mark is for insertion of numbers into a correctly rearranged rate equ , k = etc

If upside down, score only units mark from their k

AE (-1) for copying numbers wrongly or swapping two numbers

1

= 4.4(4) (allow 40/9)

1

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

Any order

If k calculation wrong, allow units conseq to their k expression

1

[6]

Q17.

(a) Exp 2 14.(4) ×10^{-3} ***OR*** 1.4(4) ×10^{-2} or 0.014

Allow 2sf

1

Exp 3 0.1(0)

1

Exp 4 0.3(0)

If three wrong answers, check their value of k in 1(b).

They can score all 3 if they have used their (incorrect) value of k. see below.

Exp 2 rate = 0.096 × k

*Exp 3 [**Q**] = 0.015/k*

*Exp 4 [**P**] = 0.116/√k*

1

(b) $K = \frac{1.8 \times 10^{-3}}{(0.20)^2 \times 0.30}$

mark is for insertion of numbers into a correctly rearranged rate equ , k = etc

1

= 0.15 (min 2sfs) (allow $\frac{3}{20}$)

if upside down, score only units mark

AE (–1) for copying numbers wrongly or swapping two

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numbers

1

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

Any order
If k calculation wrong, allow units conseq to their k

1

(c) G

1

[7]

Q18.

(a) (i)

$$k = \frac{6.2 \times 10^{-6}}{(2.9 \times 10^{-2})^2 \times 2.3 \times 10^{-2}}$$

mark is for insertion of numbers into a correctly rearranged rate equ, k = etc
AE (-1) for copying numbers wrongly or swapping two numbers

1

= 0.32 (min 2sfs)

1

mol^{-2} dm6 s^{-1} Units must be conseq to their *k*
Any order
If k calculation wrong, allow units conseq to their k

1

(ii) 4.95×10^{-5} to 4.97×10^{-5} or 5.0×10^{-5} (min 2 sfs)

(ignore units)
rate = their k $\times$ *1.547* $\times$ 10^{-4}

1

(b) Step 2
If wrong no further mark

1

One H_2 (and two NO) (appear in rate equation)
or species (in step 2) in ratio/proportion as in the rate equation

1

[6]

Q19.

(a) (i) propyl methanoate
must be correct spelling

1

(ii) rate = $k[X][OH^-]$
allow $HCOOCH_2CH_2CH_3$ (or close) for X

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allow ( ) but penalise missing minus

1

(iii) $k = \frac{8.5 \times 10^{-6}}{(0.024)(0.035)}$

In (a)(iii), if wrong orders allow
mark is for insertion of numbers in correct expression for k
If expression for k is upside down, only score units conseq to their expression

1

= 0.10(12) 2sf minimum
1 for conseq answer

1

$mol^{-1}\ dm^3\ s^{-1}$

1 for conseq units
any order

1

(iv) $2.1(3) \times 10^{-5}$

or $2.1(2) \times 10^{-5}$ ignore units
allow 2 sf
NB If wrong check the orders in part (a)(iii) and allow (a)(iv) if conseq to wrong k
See * below

1

(v) 1.3×10^{-4} (1.28×10^{-4})
allow (1.26×10^{-4}) to (1.3×10^{-4}) ignore units
allow 2 sf
NB If wrong check the orders in part (a)(iii) and allow (a)(iv) if conseq to wrong k
See ** below

1

For example, if orders given are 1st in X and second in OH^-
[The mark in a(ii) and also first mark in a(iii) have already been lost]

So allow mark * in (iv) for rate = their k × $(0.012)(0.0175)^2$ = their k × (3.7×10^{-6})
(allow answer to 2sf)
** in (v) for rate = their k × $(0.012)(0.105)^2$ = their k × (1.32×10^{-4})
(allow answer to 2sf)

The numbers will of course vary for different orders.

(vi) Lowered
if wrong, no further mark

1

fewer particles/collisions have energy > E_a
OR
fewer have sufficient (activation) energy (to react)

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not just fewer successful collisions

1

(b) Step 2

1

(this step with previous) involves one mol/molecule/particle
A and two Bs

or 1:2 ratio or same amounts (of reactants) as in rate equation
if wrong, no further mark

1

[11]

Q20.

(a) 3-hydroxybutanal
ignore number 1 i.e. allow 3-hydroxybutan-1-al
not hydroxyl

1

(b) $k = \frac{2.2 \times 10^{-3}}{(0.10)(0.02)}$

1

= 1.1

1

$mol^{-1}\ dm^3\ s^{-1}$

1

(c) planar or flat C=O or molecule
allow planar molecule

1

<u>equal</u> probability of attack from above or below
must be equal; not attack of OH^-

1

(d) (i) Step 1 if wrong – no mark for explanation.

1

involves ethanal and OH^- or species/ "molecules"
in rate equation

1

(ii) (B-L) acid or proton donor
not Lewis acid

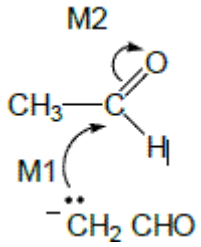
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(iii) nucleophilic addition
QOL

1

(iv)

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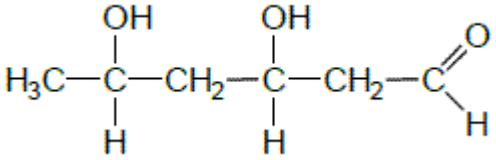


not allow M2 before M1, but allow M1 attack on C+ after non-scoring carbonyl arrow

ignore error in product

2

(e)



1

[13]

Q21.

(a) 2 or two or second

1

(b) $k = \frac{1.24 \times 10^{-4}}{(4.40)(0.82)}$

mark is for insertion of numbers into a correctly rearranged rate equ, k = etc
if upside down, (or use of I_2 data) score only units mark

1

$= 3.44 \times 10^{-5}$ (min 3sfs)

1

$mol^{-1}\ dm^3\ s^{-1}$

any order

1

(c) no change or no effect or stays the same or 1.24×10^{-4}

1

(d) 1 or 2 or 1 and 2

if wrong no further mark but mark on from no answer

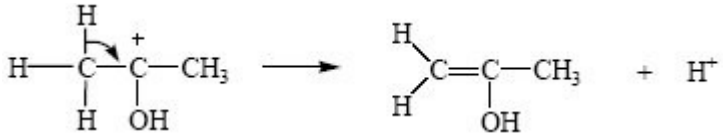
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rate equ doesn't involve I_2 or only step which includes 2 species in rate equ

1

(e)

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any second arrow loses the mark

1

[8]

Q22.

(a) (i) 2

1

(ii) 0

1

(b) (i) rate/$[NO_2]^2[O_2]$

1

13

1

mol dm^{-3}

1

(ii) 1.9×10^{-3}

1

(iii) Step 2

1

[7]

Q23.

(a) k = rate/$[CH_3CH_2COOCH_3][H^+]$

1

or

$$= \frac{1.15 \times 10^{-4}}{(0.150)(0.555)}$$

= 1.38×10^{-3} to 1.4×10^{-3}

1

$mol^{-1}\ dm^3\ s^{-1}$

1

(b) ans = rate constant × (½ × 0.150) × (½ × 0.555)

ignore units

= rate constant × 0.0208

2.88×10^{-5} (1.38×10^{-3} gives 2.87×10^{-5})

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Allow 2.87 – 2.91 × 10^{-5} (1.4 × 10^{-3} gives 2.91 × 10^{-5})

1

(c) $[H^+]$ = rate/ k$[CH_3COOCH_2CH_3]$

1

$$= \frac{4.56 \times 10^{-5}}{(8.94 \times 10^{-4})(0.123)}$$

= 0.415 (0.4146)

1

pH = 0.38 mark independently

$[H^+]$ = 0.41 gives pH = 0.39

1

[7]

Q24.

(a) exp2 4.0×10^{-3}

1

exp3 0.45×10^{-5}

1

exp4 9.0×10^{-3}

1

(b) $$\frac{1.8 \times 10^{-5}}{(3.0 \times 10^{-3})^2 (1.0 \times 10^{-3}}$$

1

2000

1

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

1

[6]

Q25.

(a) propyl methanoate;

$HCOOC_3H_7 + OH^- \rightarrow HCOO^- + C_3H_7OH$

1

OR

$HCOOC_3H_7 + NaOH \rightarrow HCOONa + C_3H_7OH$;

1

(b) order wrt A = 1;

1

order wrt NaOH = 1;

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1

Initial rate in Exp 4 = 2.4×10^{-3};

1

(c) (i) r(ate) = k[A]

OR

r(ate) = k[A][NaOH]^0;

(penalise missing [ ] but mark on)
(penalise missing [ ] once per paper)
(if wrong order, allow only units mark conseq on their rate eqs)
(penalise k_a or k_w etc)

1

(ii) $k = \frac{9.0 \times 10^{-3}}{0.02}$;

1

= 0.45;

1

s^{-1};

1

(iii) (large) excess of OH^- or $[OH^-]$ is large/high;

1

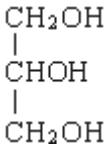
$[OH^-]$ is (effectively) constant

OR

[A] is the limiting factor *(Q of L mark)*

1

(d) (i)



1

propan(e)-1,2,3-triol

OR

1,2,3-propan(e)triol

OR

Glycerol;

1

(ii) $CH_3(CH_2)_{16}COONa$ or $C_{17}H_{35}COONa$ or $C_{18}H_{35}O_2Na$;
(ignore 3 in front of formula but not if indicating trimer)

1

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(not just anion and penalise Na shown as covalently bonded) soap - allow with detergent but not detergent alone;

1

[15]

Q26.

(a) order with respect to **P** is 2

1

order with respect to **Q** is 1

1

(b) (i) rate = k**[R][S]**^{2}

(if wrong expression, no further marks)

1

rate = $(4.2 \times 10^{-4}) \times 0.16 \times 0.84^2$

1

$= 4.7 \times 10^{-5}$ (mol dm^{-3} s^{-1})

ignore units even if wrong

1

(ii) $k = \frac{\text{rate}}{[R][S]^2} = \frac{8.1 \times 10^{-5}}{0.76 \times 0.98^2}$

1

$= 1.1 \times 10^{-4}$

1

(iii) T_1

**If calculated value for k > 4.2 × 10^{-4}, then answer to (iii) is T_2*

1

[8]

Q27.

(a) (i) Experiment 2 2.60×10^{-3}

1

Experiment 3 0.60×10^{-2}

1

Experiment 4 11.4×10^{-2}

1

(ii) $k = \frac{10.4 \times 10^{-3}}{(4.80 \times 10^{-2})(6.60 \times 10^{-2})^2}$

1

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= 49.7

(Allow 49.8 and 50)

1

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

1

(b) No change

1

[7]

Q28.

(a) (i) 2 **(1)**

(ii) 0 **(1)** 2

(b) (i) *Value of k*: $k = \frac{\text{rate}}{[NO]^2[O_2]} = \frac{6.5 \times 10^{-4}}{(5.012 \times 10^{-2})^2 (2.0 \times 10^{-2})} = 13$

Units of k: $mol^{-2}\ dm^6\ s^{-1}$ **(1)**

(ii) rate = $13\ (6.5 \times 10^{-2})^2\ (3.4 \times 10^{-2})$
$= 1.9 \times 10^{-3}$ $(mol\ dm^{-3}\ s^{-1})$ **(1)**

If k wrong, the mark in (ii) may be gained conseq for their k × 1.437 × 10^{-4}

4

[6]

Q29.

(a) Power (or index or shown as *x* in $[\ ]^x$) of concentration term (in rate equation) **(1)**

1

(b) 2 **(1)**

1

(c) (i) *Order with respect to **A**:* 2 **(1)**

*Order with respect to **B***: 0 **(1)**

(ii) *Rate equation:* (rate =) $k\ [A]^2$ **(1)**

Allow conseq on c(i)

Units for rate constant: $mol^{-1}\ dm^3\ s^{-1}$ **(1)**

conseq on rate equation

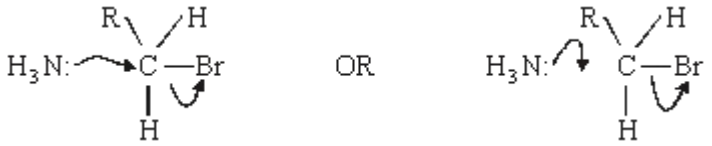
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[6]

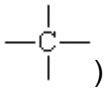
Organic points

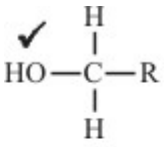
(1) Curly arrows: must show movement of a pair of electrons, i.e. from bond to atom or from lp to atom / space
e.g.

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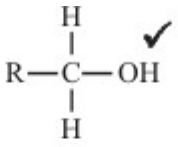


(2) Structures

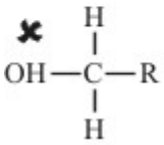
penalise sticks (i.e. ) once per paper



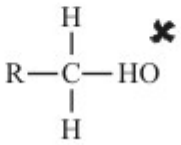
or



or $-NH_2$ ✓



or



H_2N- ✓ etc

Penalise once per paper

allow CH_3- or $-CH_3$ or  or CH_3 or H_3C-

Q30.

(a) (i) Experiment 2: $0.4(0) \times 10^{-3}$ **(1)**
Experiment 3: 0.15 **(1)**
Experiment 4: 0.28 **(1)**

(ii) $k = \frac{4.8 \times 10^{-3}}{(0.20)^2 \times (0.30)} = 0.4(0)\ mol^{-2}\ dm^6\ s^{-1}$

(1) **(1)** **(1)**

6

(b) (change in) temperature **(1)**

1

[7]

Q31.

C

[1]

Q32.

(a) *Order with respect to iodine*: 0 **(1)**
Overall order: 2 **(1)**

2

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(b) *Rate constant*: k = $\frac{2 \times 10^{-5}}{(1.5) \times (3 \times 10^{-2})}$ = 4.4(4) × 10^{-4} **(1)**

Units: mol^{-1} dm^3 s^{-1} **(1)**

3

(c) Appears in rate equation **(1)**

OR implied by mention of concentration or order

does not appear in (stoichiometric / overall) equation (1)

2

(d) pH = $-\log_{10}$ $[H^+]$ **(1)**
= 1.25
$[H^+]$ = 0.056(2) **(1)**

∴ rate = (4.44 × 10^{-4}) × (1.50) × (0.0562)

= 3.75 × 10^{-5} **(1)** (mol dm^3 s^{-1})

(3.7 — 3.8)

Can score all 3 conseq on k from part (b)

3

[10]

Q33.

(a) (i) (Experiment 1 → 2) [A] doubled, ([B] constant,)
rate doubled **(1)**

stated or shown numerically

(ii) 2 **(1)**
or shown as ... $[B]^2$

2

(b) (i) k = $\frac{9.30 \times 10^{-5}}{(0.75)^2 \times (1.50)}$ = 1.1(0) × 10^{-4}

(1) **(1)**

units of k: mol^{-2} dm^6 s^{-1} **(1)**

(ii) rate = (1.10 × 10^{-4}) × $(0.20)^2$ × (0.10)
= 4.4(1) × 10^{-7} (mol dm^{-3} s^{-1})

(1) for the answer

Ignore units
Conseq on (i)
Upside down expression for k scores zero in (i) for 9073 but rate = 9073 × $(0.2)^2$ × (0.1) = 36(.3)
conseq scores (1) in (ii)

4

[6]

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Q34.

D

[1]

Q35.

C

[1]

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Q1.

(a) 28.5% of students scored full marks in this question, but others failed to gain marks either by giving the answer to three significant figures (or as the fraction 40/3), or for incorrect signs for the powers in the units.

(b) Almost all students gave the correct answer to Experiment 2. Over 60% of students also scored the other two marks but some found these two other parts harder. There were also some who rounded their answer to one figure and failed to gain the mark.

(c) The two values in **Table 2** were given correctly by 82% of students. Of the others, some gave values that were incorrectly rounded.

(d) The best students scored full marks for answers which included carefully drawn graphs. However, there was a spread of marks down to those who were unable to plot the graph correctly or those few who made no attempt. An appreciable number of students chose a wrong scale for the y-axis and only used half of the grid provided. This small graph often led to an inaccurate gradient and so an activation energy that was outside the expected range.

Q2.

(a) This proved to be a tougher starter question than anticipated (63.4% of students failed to score). In many cases, the question was repeated as an attempt at the answer with students suggesting that “the rate only depends on $[H^+]$”. Since this information had been given in the question, answers such as this could not be credited. The expected answer, that ‘a large excess makes the concentrations effectively constant so that they do not affect the rate’, was seldom seen.

(b) As with part (a), not many students were able to achieve both marks (only 9.7%), with few suggesting ‘quenching’. Given how frequently quenching was, unnecessarily, suggested in answers to (h), this was surprising. In many cases, students described the process of titration itself rather than what should be done to the sample *before* titration. 74% of students failed to score here.

(c) This question proved easier, with just over a third of students achieving both marks for appreciating that the line indicated a constant rate, showing that the falling concentration of hydrogen ions was having no effect.

(d) A common error here was for students to start by (correctly) calculating the gradient of the line but then to divide it by a value for the $[H^+]$ (usually 0.5) or even by $[H^+]^2$ – despite having been told in part (c) that the order with respect to $H^+(aq)$ is zero. 36% of students, however, did gain all three marks.

(e) 97.3% of students were able to plot the points correctly onto the given grid.

(f) A significant number of students assumed that the instruction to ‘draw a line of best fit’ meant that the line must be straight. Students must learn that a best-fit line must be the best-fit to the points as plotted, so may be either straight or curved depending on the relationship between the plotted points; at A-level, students are expected to make this decision for themselves. Just under 40% of students did not gain this mark.

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(g) The idea of drawing a tangent (or, for award of 'error carried forward', simply constructing a 'triangle' on a straight line) proved tricky, with a significant minority of students simply dividing 0.35 by the corresponding time value from their line.

(h) Fewer students than expected recognised the clue in the information given in the question that this was best done as a 'clock' reaction. Many students suggested answers that did not include 'X' in the initial mixture, as suggested, while many others used a variety of convoluted procedures involving what were essentially 'continuous monitoring' methods to generate concentration versus time graphs. In some cases, this was followed by a description of finding the gradient at $t = 0$, which addressed the requirement of the question to calculate an initial rate for each experiment. However, a direct measurement would have been much easier, both to do and to describe.

Credit was given for a wide variety of suggestions because, although a particular approach was hoped for, there are indeed several alternative approaches that would work. However, many students seemed to think that actual measurements of concentration (of what substance was often unclear from the descriptions) are needed, which led to suggestions that samples should be removed at timed intervals and titrated against X or placed into a colorimeter (the need to quench these samples was often over-looked). If a colorimeter was used, then the best approach for continuous monitoring is simply to allow the reaction to proceed in the colorimeter and take a series of readings at timed intervals – much easier than sampling. The mean mark on this question was only 1.8 out of 6.

The extra answer space available this year meant that fewer students needed additional pages for this question, but many confused, badly ordered and muddled answers were seen that took up far more space than necessary through repetition and unnecessary elaboration.

Reading the question is always key, but here many students could have saved a lot of time and space by noticing that the question asked only about a method to determine the order of this reaction with respect to A. This would have avoided the need for them to repeat most of the procedure, looking at successively changing the concentrations of A, then B, then C, while keeping each of the other two constant. Levels-of-response questions are marked using 'levels' and the key to success is for students to concentrate first on the inclusion of as much correct Chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). This is probably best achieved using a 'bullet point' approach to structuring the answer. Within a level, the mark awarded depends on the clarity and coherence of an answer, together with there being a clear, logical progression through the description.

Appropriate apparatus and quantities should be mentioned as necessary. For example, rather than stating "add A, B and C to a container", a good start to the answer would be to write, "A measuring cylinder was used to measure known volumes, of known concentrations, of A, B and C into separate beakers". Unless specifically asked to suggest suitable volumes/concentrations, then it is sufficient for students to indicate that they would make a measurement without needing to state a value.

Q3.

43% of students chose correctly. A was the commonest incorrect response, perhaps suggesting that those students were expecting the orders in the rate equation to match the balancing in the reaction equation instead of working out the orders from the rate data given.

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Q4.

(a) This kinetics question was answered well apart from occasional slips in deducing the units.

(b) It was pleasing to see that 47% of students scored full marks in this topic which is new to the specification. The others made one or more errors in reading the given value of ln *A* as *A*, in wrongly rearranging the equation, or in using incorrect units.

Q10.

Part (a) was answered well and two thirds of students scored both marks. By contrast, part (b) was a hard question with few correct answers. Many students spoke about the changing concentrations but few mentioned the importance of knowing the initial concentration. The first mark in part (c) for mentioning a gradient was often gained but the location of where to measure the gradient was only given by a third of students.

Q11.

Part (a) was answered correctly by just over half of the students. The majority of incorrect answers were because students didn't answer the question and simply just repeated what the rate equation told them.

Calculation of a rate constant in part (b) was answered very well as usual but part (c) proved to be very difficult. A large number of students could not deduce the correct rate equation. Those who did gain this mark were not often able to give a reason for their answer and the second mark was rarely seen.

Q12.

Most students scored highly on this question. Only part (b)(ii) proved difficult for some who were unable to calculate the new initial rate in part (b)(ii) either by dividing the given rate by 8 or by using their rate constant to calculate the new rate.

Q13.

The calculation in part (a) was well answered and there were few errors although the units mark was occasionally lost. In part (b) the calculations were again well answered: experiment 3 involving a square root was the least well done. Marks were awarded consequentially on an incorrect value of k. Few students used the value of k of 2.3 supplied.
Here as elsewhere, students should be encouraged to keep their answer in their calculator as they work through a question and then write the final answer to the appropriate number of significant figures (usually 3).

The mark in part (c) proved elusive for many students, who referred to the rate of the reaction and not the mechanism as required by the question. It was well known that the concentration of **B** would not affect the rate, but how **B** was involved in the mechanism and the rate determining step was not well known.

Q14.

This question was answered well. A few students lost marks through the incorrect use of calculators in the division necessary in part (b)(i) to find the rate constant, k, or by omitting s-1 from the units of the rate calculated in part (b)(ii).

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Q15.

This question was answered well by most students and over 80% scored full marks in part (a). Part (c)(ii) was found slightly harder and, of those who correctly identified Step 1 as the slower step, most gained the mark for the curly arrow. Those who suggested Step 2 could also gain a mark for a correct arrow for that step. However, many gave a full S_N2 mechanism in both cases.

Q16.

As is usual with kinetics questions, this produced some high marks, with many students scoring full marks. In part (a), the more tricky calculation for Expt 4 was least well done and in part (b) the most common mistake in calculating the value of *k* was to forget to square the concentration of **P**.

Q17.

The kinetics question was, as usual, answered well with only Experiment **4** in part (a) causing much difficulty. However, in part (c) fewer than half of the students identified graph G as that correctly showing how the rate constant *k* varies with temperature.

Q18.

Part (a) was well done with many candidates scoring full marks. Although most gave the correct answer to part (a)(ii), many did it by the long route, having failed to see that the answer was simply 8x the initial rate.

Candidates found part (b) more difficult. Many of those who correctly chose step 2 could not offer a full explanation.

Q19.

Most parts of this question were answered well. The ester was named correctly by over two thirds of the candidates but a surprising number attempted to write a stoichiometric equation in part (a)(ii) rather than a rate equation. Part (a)(iii) was answered very well but in part (a)(iv) the effect of dilution on the concentration of both reagents was missed by a large majority. However, when the exact concentrations were given in part (a)(v) most candidates were able to calculate the new rate of reaction correctly. The effect on the rate constant of lowering the temperature was well known in part (a)(vi), but few candidates were able to give a correct explanation and many offered a mathematical rather than a kinetic explanation. In part (b), the requirement to use the rate equation to identify the rate determining step proved difficult for the majority.

Q20.

This question was generally well done although in part (a), fewer candidates than expected could name compound **X** correctly. Part (b) was answered very well but in part (c) many candidates did not read the full question and described what a racemic mixture contains rather than how one is formed in this reaction. Part (d) was answered very well except for part (d)(ii) where fewer than 50% of candidates could deduce that ethanal was acting as a proton donor in the reaction. The deduction required in part (e) was also found difficult despite the hint given that the required product contained six carbon atoms.

Q21.

As usual for questions on kinetics, this was answered well. It was also pleasing that, in part 3(d), over half of the candidates gained both marks on a question which required

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understanding of a new part of the specification. Application in part (e) of their understanding of the use of curly arrows in organic mechanisms was, however, less well done.

Q23.

As usual with questions involving rate equations, this question was answered well, particularly parts (a) and (c). Part (b) however was poorly answered and only the very best candidates gained this mark. Many of the rest only divided the original rate by 2 instead of by 4 as the concentrations of both the ester and of If" ions were halved. Again it was disappointing to see the number of candidates who did not give the pH to two decimal places despite being asked to do so.

Q24.

This question was answered well by most candidates and full marks were often gained. The value of the concentration of NO in experiment 4 was the least well answered part of section (a). Only a few candidates failed to calculate the answer 2000 for the rate constant in part (b). The few errors seen usually involved a failure to square the NO concentration or problems with the powers of 10. The units were usually correctly given.

Q25.

The first three parts of this question were well answered. In part (a), most candidates were able to name the ester *propyl methanoate* correctly although the equation for its reaction with sodium hydroxide was less well answered. The orders and the initial rate in part (b) were correctly deduced by most candidates and many were able to deduce the correct rate equation in part (c) and to use it correctly to calculate the rate constant. Those who gave an incorrect rate equation were awarded a mark for units which were consistent with their rate equation. By comparison, few were able to answer part (c)(iii) correctly by stating that the large excess of sodium hydroxide meant that its concentration was effectively constant. Part (b) distinguished fairly well between those who recognised the alcohol formed by hydrolysis of the ester drawn and were able to deduce that it would distil easily. Either the systematic name, propane-1,2,3-triol, or its common name glycerol, were accepted. The formula of the sodium salt of the acid was accepted in several forms and its use as soap was well known by most, even those who gained no other marks in part (c).

Q26.

As is normal, the use of rate equations is well understood and almost all candidates can answer these questions well. Very few failed to score the marks for deducing the orders with respect to **P** and **Q**. The calculation in part (b) using the given orders of reaction was well done by all except those candidates who could not rearrange the equation correctly. The same applied in part (b)(ii). In the few cases where the calculated value of the rate constant was incorrect, and greater than 4.2×10^{-4} mol^{-2} dm^{6} s^{-1} the usual answer of T_1 for part (b)(iii) was replaced by the answer T_2 consequential on their incorrect value of *k.*

Q27.

This question was generally answered well as is usual in questions about rates of reaction. As expected, the value required in experiment 4 was the least well answered section in part (a)(i). In part (a)(ii), the major problem for some was to rearrange the rate equation to produce *k* as the subject of an equation. Disappointing numbers of candidates were unable to do this correctly. The units were usually correctly given as was the answer to part (b).

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Q28.

As is usual in this type of question, high marks were obtained by most candidates. Part (a)(ii) caused the most problems with the answer 2 being common from the weaker candidates. Occasionally in part (b) the value of the concentration of NO was not squared in the calculation and the units were sometimes not given correctly. The value of the initial rate in part (b)(ii) was allowed consequential to an incorrect answer in part (b)(i).

Q29.

In part (a) few candidates were able to explain correctly what the term 'order of reaction' means. However, despite this most were able to use the idea itself and scored highly in the rest of the question. The fact that the rate of reaction increased by a factor of nine, 32 , when the concentration of A increased by three times led some candidates to think that the order with respect to A was three rather than two.

Q30.

This question was generally answered well even by weaker candidates. Calculation of the concentration of P in part (a)(i) was the only part found difficult by many. Most answers to part (a)(ii) were correct, including the units. A change in temperature was the usual and correct answer in part (b).

Q32.

This question on rate equations was answered well by most candidates even those who scored less well elsewhere in the paper. In part (a) most candidates deduced the overall order correctly, but to deduce that the order with respect to iodine was zero proved more difficult. Part (b) was well answered by most students, but only the better candidates were able to gain both marks in part (c). Many gave a general description of the role of a catalyst rather than the evidence that hydrogen ions appear in the rate equation but not in the overall stoichiometric equation. The use of pH to show a change of hydrogen ion concentration was understood by most candidates although some were unable to convert a pH value into a hydrogen ion concentration. Full marks were available for correct use in part (d) of an incorrect rate constant calculated in part (b).

Q33.

This question on rate equations was answered well by most candidates. Part (a)(i) required that the candidate stated or showed mathematically that the rate doubled when the concentration of A doubled when considering experiments 1 and 2. Part (a)(ii) was usually answered correctly. Problems arose in part (b) where some candidates had difficulty in rearranging the rate equation correctly. However the mark in part (b)(ii) could still be gained for correct working despite using a wrong rate constant calculated in part (b)(i).

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