

Mark schemes

Q1.

- (a) Number of molecules (with a particular energy)
Ignore particles / atoms
Allow amount or fraction or proportion for number 1
- (b) There are no molecules with no energy
All molecules / particles have some energy
Allow particles / atoms 1
- (c) Most probable / common / modal energy 1
- (d) **M1** Peak should be at same energy (i.e. in line with X)
M1 and M2 marked independently 1
- M2** Overall area should be half the original area; after diverging from the origin, the second line should not touch the first line
M2 area should be about half of the original 1
- [5]

Q2.

B

[1]

Q3.

A

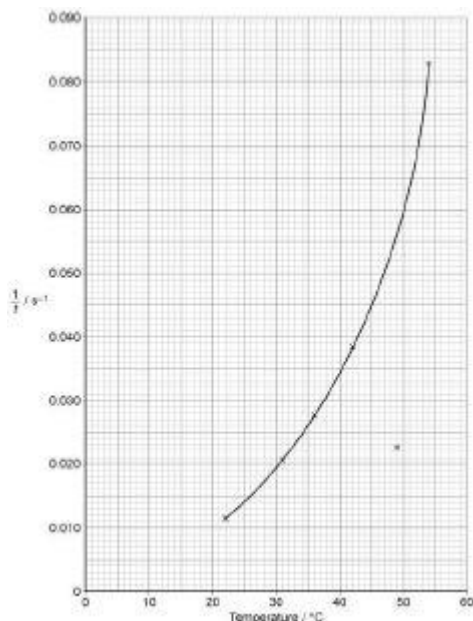
There is no reaction to form water because the molecules do not collide with sufficient energy.

[1]

Q4.

- (a) Idea that it is hard to judge to the nearest 0.01 second *or* Idea that it is hard to judge the exact moment (that it becomes too cloudy / the cross disappears) *or* the idea of reaction time
Ignore ideas relating to accuracy (unless qualified) 1
- (b) 0.083(3....) 1
- (c) **M1** points plotted correctly (allow $\pm 1/2$ small square for each)

- M2** suitable best fit curve that misses point at 49°C and passes within one small square of the other five points



If any points plotted incorrectly: best fit line based on their plotted points which may need to be more than one square away from some points

*If no value calculated in (b), then **M1** and **M2** based on the other points (except the fifth anomalous point). A straight line may be allowed for **M2** for the first four points.*

*If incorrect value calculated in (b): **M1** based on all values being plotted correctly; **M2** based on suitable best fit line for the plotted points (except the fifth anomalous point).*

*Penalise **M2** if best fit line goes to 0,0.*

2

(d)

1

value from their best fit line at 40°C

eg $\frac{1}{0.0345} = 29$ (s)

Ignore units

1

- (e) as it forms a toxic gas or
SO₂ is toxic/poisonous or
to limit amount of SO₂ formed

Ignore reference to SO₂ being harmful

Ignore reference to acid rain / pollutant

1

- (f) reaction would take too long / too slow / take a long time / very slow

Ignore reaction may not occur

Allow idea that it makes judging the moment when the cross disappears more difficult

1
[7]

Q5.

B

At a given temperature their average kinetic energy is constant

[1]

Q6.

D

The mean energy of the molecules is greater than the most probable energy of the molecules

[1]

Q7.

(a) **M1** provides a different route / mechanism / pathway
Ignore reference to (frequency of) collisions, surface area or active sites

1

M2 with lower activation energy
Penalise reference to increasing energy of particles (CE = 0)
*Allow E_a / E_{act} or definition of activation energy in **M2***

1

(b) **M1** line 2 = steeper than original and finishes at same height

1

M2 line 3 = less steep than original and finishes at half the height
If two correct lines are drawn but neither labelled, then allow 1 mark.
If two correct lines are drawn and only one is labelled, then allow 2 marks.
If only one correct line is drawn and neither are labelled, then 0 marks.
If two correct lines are drawn but line 2 is labelled 1 and line 3 is labelled 2, then allow 1 mark
Allow some unevenness in drawing of lines in terms of height it levels off at, with up to a quarter of a box of unevenness
At the start, lines must separate from the original before the first vertical line.
In terms of the origin, lines must start within one half of a square of the origin.

For each line ignore the time at which the line becomes horizontal – it is the fact it is more or less steep than the original line that matters (along with the height at which it finishes)

1

- (c) **M1** more particles/molecules/reactants/ H_2O_2 /moles in given/same volume/space OR
particles/molecules/reactants/ H_2O_2 /moles closer together

Penalise reference to changing the activation energy (CE = 0)

For M1 do not allow area

1

- M2** successful collisions are more frequent

For M2

successful collisions – allow reference to collisions with sufficient energy or collisions with the activation energy or effective collisions

more frequent – allow reference to per unit time, per second (but ignore reference to rate of collisions, ignore chance of collisions, ignore likelihood of collisions)

1

[6]

Q8.

D

[1]

Q9.

- (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 / $\text{H}_2\text{O}_2/\text{I}^-$ 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 $\text{H}_2\text{O}_2/\text{I}^-$

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

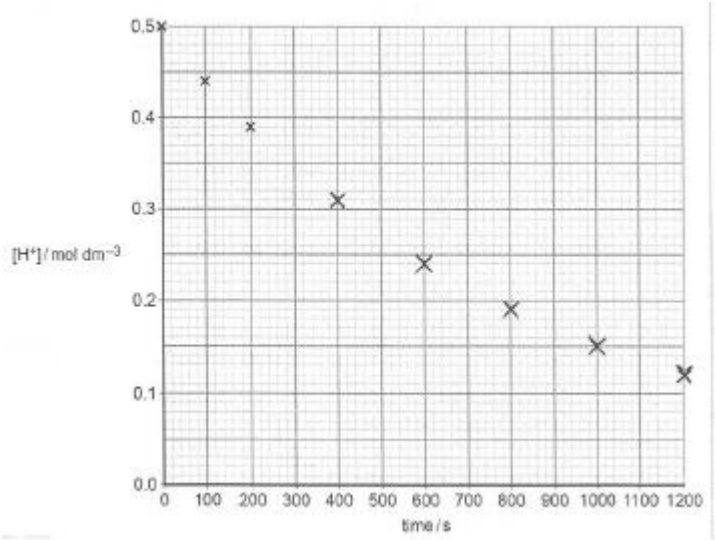
Additional processing of data such as including $[H^+]$ loses M2

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

M3 mark independently

3

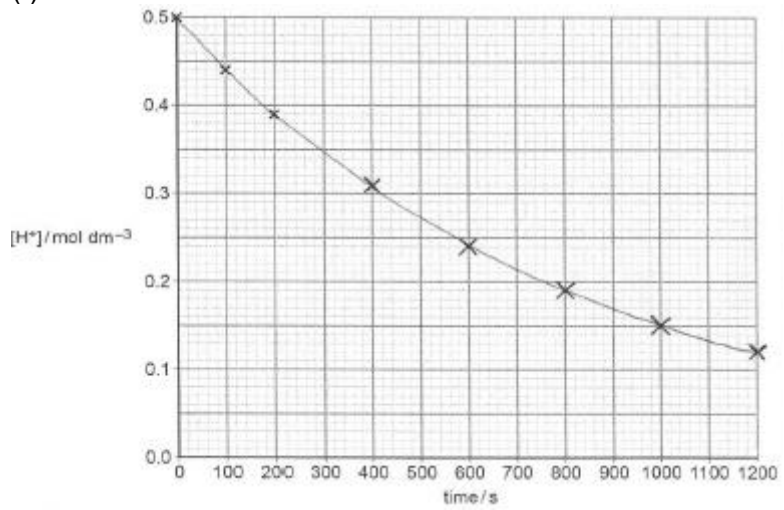
(e) 5 points correctly plotted



Allow \pm half a small square for each point

1

(f)



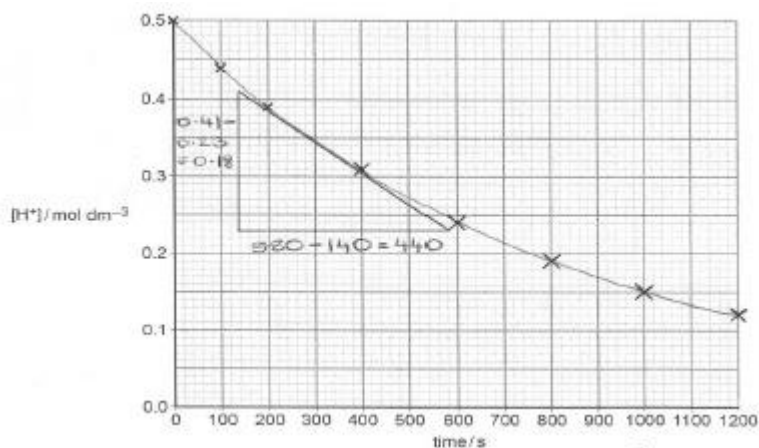
Smooth curve only within one small square of all points

(ecf on part (e))

Not a series of straight lines between points

1

(g)



M1: Tangent to curve drawn at $[\text{H}_3\text{O}^+] = 0.35 \text{ mol dm}^{-3}$
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 = $4.09 \times 10^{-4} \text{ (mol dm}^{-3} \text{ s}^{-1})$

Ignore negative signs

Allow value in range $3.70 \times 10^{-4} - 4.50 \times 10^{-4}$

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	<p>All stages are covered and the explanation of each stage is correct and virtually complete.</p> <p>Answer is coherent and shows progression through all three stages.</p> <p>A clear explanation of how the order is determined from the results is needed to show coherence.</p>
Level 2 3-4 marks	<p>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</p> <p>OR two stages covered and the explanations are generally correct and virtually complete</p> <p>Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete</p>
Level 1	Two stages are covered but the explanation of each

1-2 marks	<p>stage may be incomplete or may contain inaccuracies</p> <p>OR only one stage is covered but the explanation is generally correct and virtually complete</p> <p>Answer shows some progression between two stages</p>
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 $1/\text{time}$ taken is a measure of the rate
- 3b plot of $1/\text{time}$ against volumes/concentrations of **A** or plot $\log(1/\text{time})$ vs $\log(\text{volume or concentration of A})$
- 3c description of interpreting order from shape of $1/\text{time}$ 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. $2x[A] = 2 \times \text{rate}$ 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

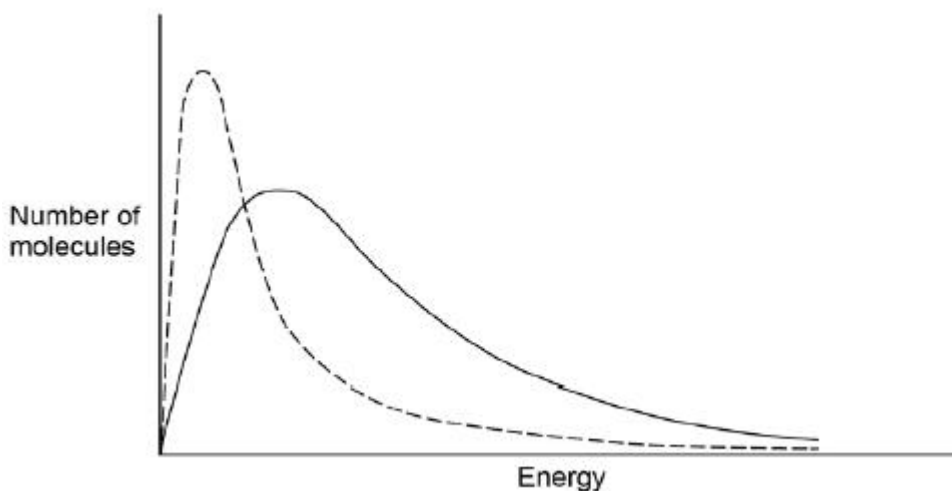
- 3a Plot absorbance vs time and measure/calculate gradient at time=0
- 3b plot of gradient against volumes/concentrations of **A** or plot $\log(1/\text{time})$ vs $\log(\text{volume or concentration of A})$
- 3c description of interpreting order from shape of $1/\text{time}$ vs volume or concentration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

6

[19]

Q10.

(a)



M1 Curve is higher and displaced to the left

M2 Only crosses the original curve once

2

(b) Rate of reaction decreases (no mark)

Fewer particles will have energy greater than or equal to the activation energy

1

Fewer successful collisions in a given time

Less frequent successful collisions

1

- (c) The amount of gas present (or number of molecules) has been reduced /
or the pressure has been reduced

1

Rate of reaction decreases (no mark)

Particles are spread further apart

1

Fewer collisions between gas particles so fewer successful collisions

1

[7]

Q11.

A

[1]

Q12.

A

[1]

Q13.

C

[1]

Q14.

B

[1]

Q15.

A

[1]

Q16.

C

[1]

Q17.

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

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

1

Consider experiments 2 and 3:

[A] increases $\times 2$: rate should increase $\times 2^2$ but only increases $\times 2$

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 $k = \text{rate} / [C]^2[D]$

1

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

Allow consequential marking on incorrect transcription

1

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

Any order

1

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

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 many 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

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

1

[12]