M1.(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

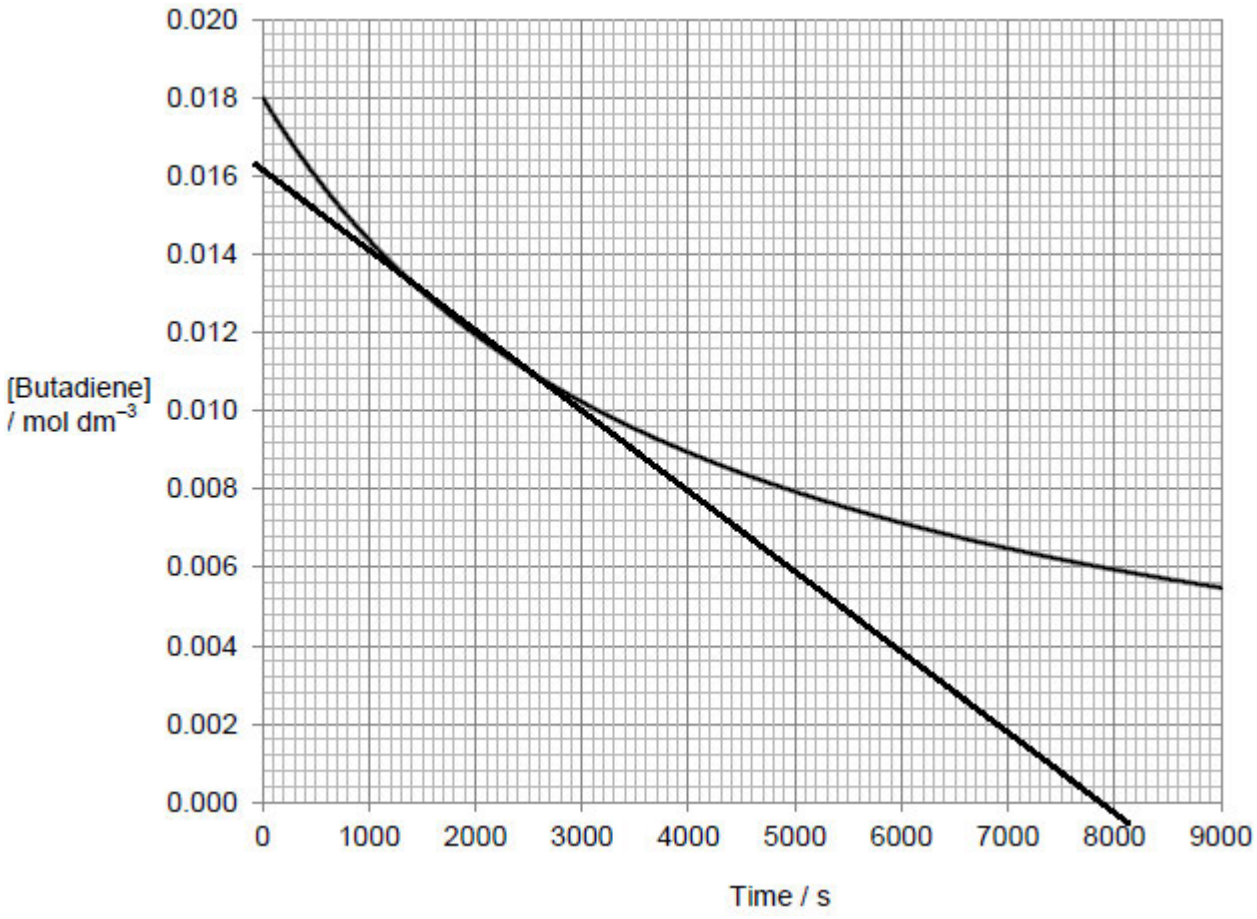
1

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

1

[12]

M2.(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

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]

M3. (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) $k = \frac{8.5 \times 10^{-5}}{(0.024)(0.035)}$

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)

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]

M4. (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]

M5.(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]

M6.(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

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

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

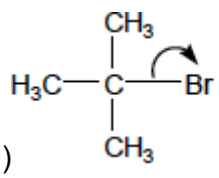
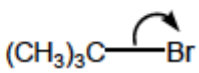
(ii) 0 or zero or $[E]^0$

1

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

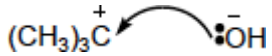
Penalise Step 2 but mark on

1

(ii)  or 

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]

M7.(a) Exp 2 $14.(4) \times 10^{-3}$ ***OR*** $1.4(4) \times 10^{-2}$ 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 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]

M1.(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

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]

M2. (a) (i) Experiment 2: 0.4(0) × 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) <u>temperature</u> **(1)**

1

[7]

M3. (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)
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]

M4. (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 $k > 4.2 \times 10^{-4}$, then answer to (iii) is T_2*

1

[8]

M5. (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)**

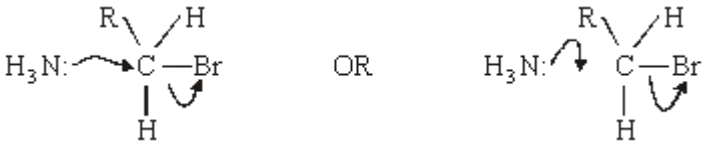
conseq on rate equation

4

[6]

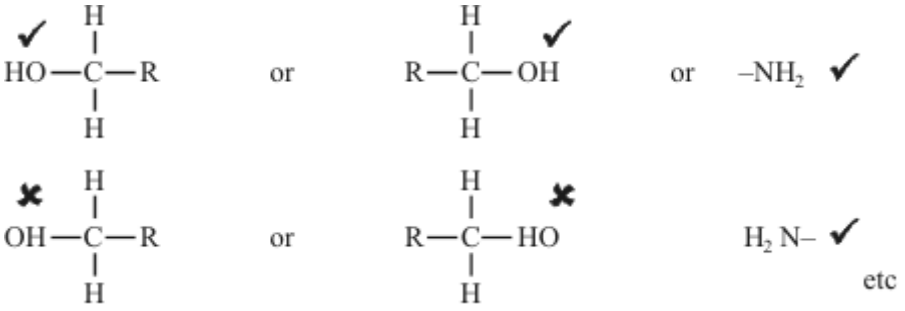
Organic points

(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



Penalise once per paper

allow CH_3– or –CH_3 or  or CH_3
or H_3C–

M6. (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

= 3.44×10^{-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

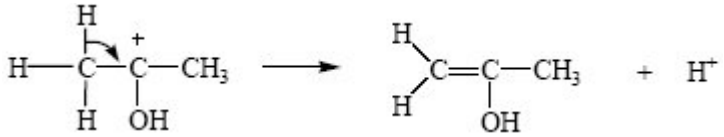
if wrong no further mark but mark on from no answer

1

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

1

(e)



any second arrow loses the mark

1

[8]

M7. (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]

M1.(a) k = rate / $[A]^2$ or $\frac{3.3\times10^{-5}}{(4.2\times10^{-3})^2}$

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 = 7.9×10^{-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 / √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

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

Allow "it" for B

1

[6]

M2. (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]

M3.(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

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

1

[12]

M4.(a) Exp 2 $14.(4) \times 10^{-3}$ ***OR*** $1.4(4) \times 10^{-2}$ 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) $K = \dfrac{1.8 \times 10^{-3}}{(0.20)^2 \times 0.30}$

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 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]

M5.(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.

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]

M6.(a) (i) $k = \frac{8.4\times10^{-5}}{(4.2\times10^{-2})^2 \times 2.6\times10^{-2}}$ ***OR*** $\frac{8.4\times10^{-5}}{(1.76\times10^{-3}) \times 2.6\times10^{-2}}$

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

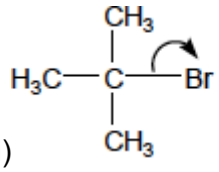
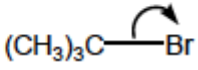
(ii) 0 or zero or $[E]^0$

1

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

Penalise Step 2 but mark on

1

(ii)  or 

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]

M7.(a) (i) 2

1

(ii) 0

1

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

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

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

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* × (1.64×10^{-6})

1

[6]

M8.(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) $k = \frac{8.6 \times 10^{-4}}{(3.8 \times 10^{-2})^2 \times (2.6 \times 10^{-2})}$

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
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]

M9.B

[1]

M1. (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) $k = \frac{8.5 \times 10^{-5}}{(0.024)(0.035)}$

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)
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]

M2. (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

equal 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

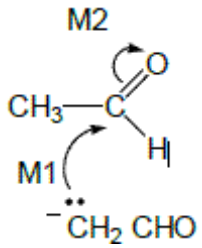
1

(iii) nucleophilic addition

QOL

1

(iv)

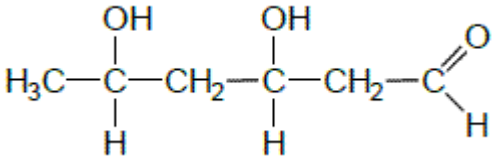


not allow M2 before M1, but allow M1 attack on C+ after non-scoring carbonyl arrow

ignore error in product

2

(e)



1

[13]

M3. (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]

M4. (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]

M5. (a) k = rate/$[CH_3CH_2COOCH_3][H^+]$

1

or

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

$= 1.38 \times 10^{-3}$ 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})

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]

M6. (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]

M7. (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

= 3.44×10^{-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

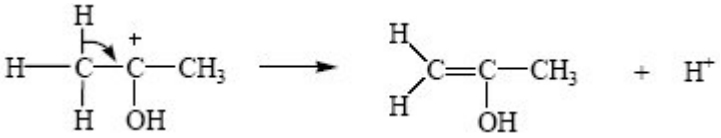
if wrong no further mark but mark on from no answer

1

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

1

(e)



any second arrow loses the mark

1

[8]

M1. (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;

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

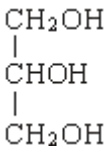
[OH^-] is (effectively) constant

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

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

1

[15]

M2.C

[1]

M3.D

[1]

M4. (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)
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]

M5. (a) *Order with respect to iodine*: 0 **(1)**
Overall order: 2 **(1)**

2

(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]

M6. (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

= 49.7

(Allow 49.8 and 50)

1

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

1

(b) No change

1

[7]

M7. (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) <u>temperature</u> **(1)**

1

[7]

M8. C

[1]

M9. (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]

M10. (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

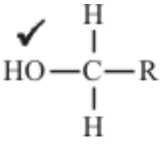
(1) Curly arrows: must show movement of a pair of electrons, i.e. from bond to atom or from lp to atom / space

e.g.

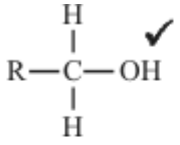


(2) Structures

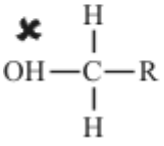
penalise sticks (i.e. ) once per paper



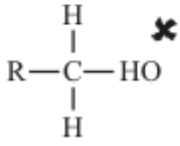
or



or –NH_2 ✓



or



H_2N– ✓

etc

Penalise once per paper

allow CH_3– or –CH_3 or  or CH_3
or H_3C–