M1.(a) $k = \text{rate} / [A]^2$ or $\dfrac{3.3 \times 10^{-5}}{(4.2 \times 10^{-3})^2}$

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 × 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} 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 × 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

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

Allow consequential marking on incorrect transcription

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 $\underline{E \geq E_a}$

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

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) $k = \dfrac{8.4 \times 10^{-5}}{(4.2 \times 10^{-2})^2 \times 2.6 \times 10^{-2}}$ **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

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(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 $(CH_3)_3C \overset{\frown}{\quad} Br$
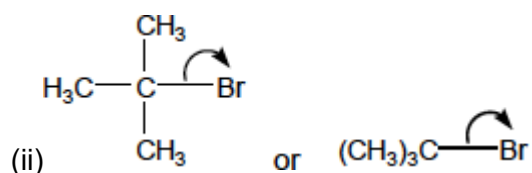
Ignore correct partial charges, penalise full / incorrect partial charges

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

$(CH_3)_3\overset{+}{C} \overset{\frown}{\quad} \overset{-}{:}\ddot{O}H$
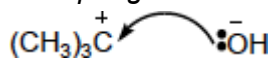
allow: OH$^-$ (must show lp)

If S$_N$2 mechanism shown then no mark (penalise involvement of :OH$^-$ 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

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

> *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

$mol^{-2}dm^{+6} s^{-1}$
> *Any order.*

1

(ii) $6.8(2) \times 10^{-3}$ (mol dm^{-3}s^{-1})
OR if their k is wrong, award the mark consequentially
a quick check can be achieved by using
<u>their answer</u> = 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]