

M1.(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 = $57.0 \times (3.6 \times 10^{-2})^2 \times 5.4 \times 10^{-2} = 3.99 \times 10^{-3} (\text{mol dm}^{-3} \text{s}^{-1})$

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

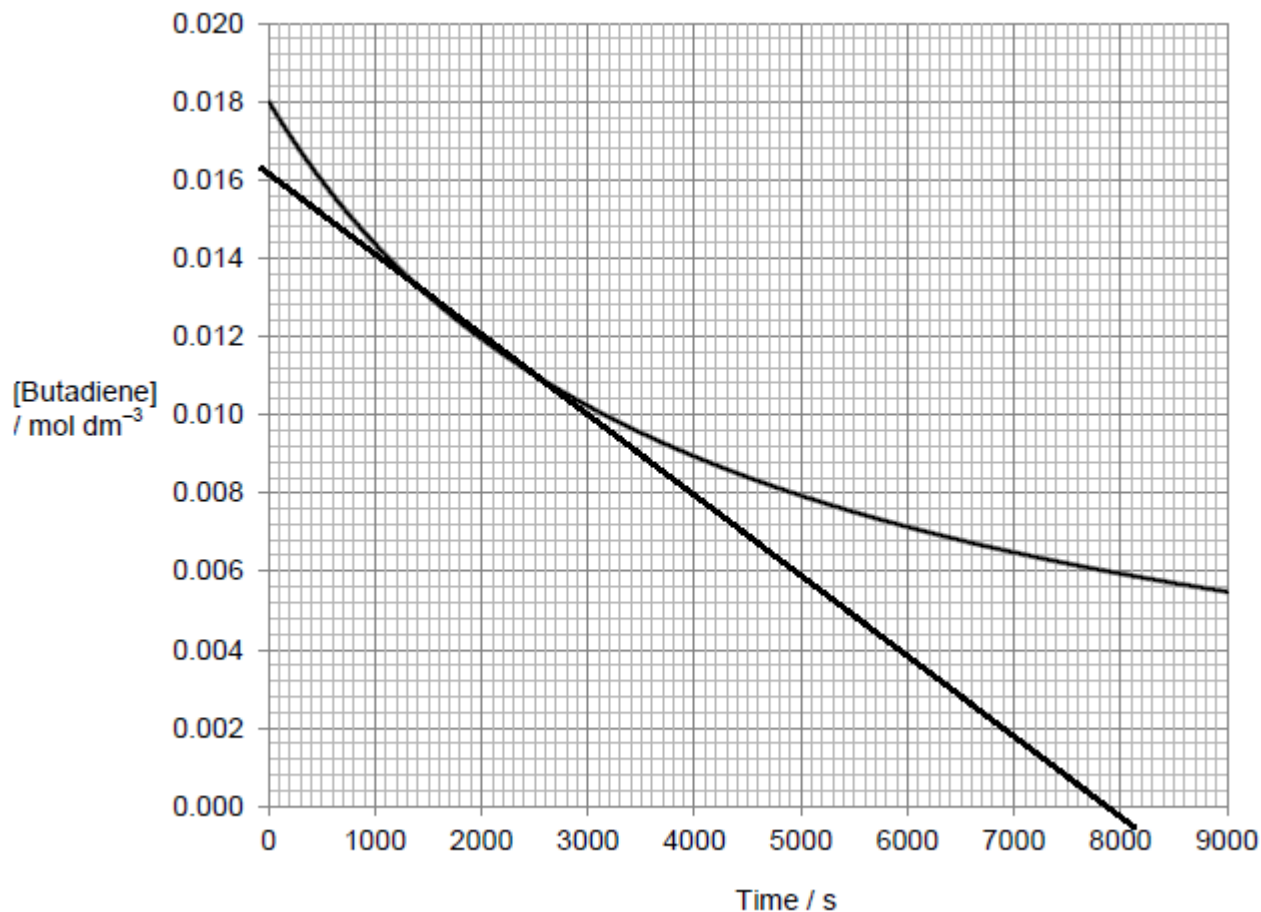
Whereas doubling [E] only doubles the number with this E 1

(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]

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 = $0.0120 \text{ mol dm}^{-3}$

From the tangent

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

Extended response

1

$$\text{Gradient} = -(0.0160 - 0) / (7800 - 0) = -2.05 \times 10^{-6}$$

$$\text{Rate} = 2.05 \times 10^{-6} \text{ (mol dm}^{-3} \text{ s}^{-1}\text{)}$$

1

Stage 2: Comparison of rates and concentrations

$$\text{Initial rate / rate at } 0.0120 = (4.57 \times 10^{-6}) / (2.05 \times 10^{-6}) = 2.23$$

Marking points in stage 2 can be in either order

1

Initial 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

$\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$
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 $k \times (0.012)(0.0175)^2 = \text{their } k \times (3.7 \times 10^{-6})$
 (allow answer to 2sf)
 ** in (v) for rate = their $k \times (0.012)(0.105)^2 = \text{their } k \times (1.32 \times 10^{-4})$
 (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

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

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

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

$$\frac{\text{mol}^{-2}\text{dm}^6 \text{ s}^{\&8722;1}}$$

Any order.

1

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

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]

M6.(a) (i)
$$k = \frac{8.4 \times 10^{-5}}{(4.2 \times 10^{-2})^2 \times 2.6 \times 10^{-2}} \quad \text{OR} \quad \frac{8.4 \times 10^{-5}}{(1.76 \times 10^{-3}) \times 2.6 \times 10^{-2}}$$

Mark is for insertion of numbers into a correctly rearranged rate equation, $k = \text{etc.}$

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

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

Any order

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

1

- (ii) $5.67 \times 10^{-4} (\text{mol dm}^{-3} \text{s}^{-1})$ **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 $[\text{D}]^2$

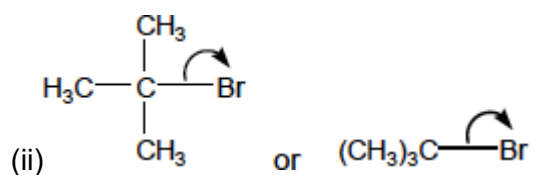
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- (ii) 0 or zero or $[\text{E}]^0$

1

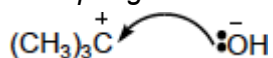
- (c) (i) Step 1 or equation as shown
Penalise Step 2 but mark on

1



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 = $0.096 \times k$

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

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

Any order

If k calculation wrong, allow units conseq to their k

1

(c) G

1

[7]