Access Tuition

A-Level Chemistry

Maxwell-Boltzmann Curves

Mark Scheme

Time available: 60 minutes
Marks available: 58 marks

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Mark schemes

1.   (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

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2.   (a)   energy

> *Ignore reference to*
>
> - *any units (e.g. J, kJ, J mol^{-1}, kJ mol^{-1})*
> - *particles*
> - *molecules*
> - *kinetic*
>
> ***NOT** mean energy or average energy*
>
> ***NOT** E*

1

(b)   **M1**   maximum peak height is lower and displaced to the right of the original

1

M2   all of the following
- starts at the origin but does not follow the original line
- shows separation as soon as possible from the original line
- crosses the original curve once only
- similar area to original curve
- an attempt has been made to draw the new curve correctly towards the energy axis above the original curve but not to touch the original curve (or axis)

1

(c)   **M1**   an increase in the number/amount/proportion/fraction of molecules with
              $E \geq E_a$ / with activation energy
      or   more molecules have $E \geq E_a$ / with activation energy
      or   more molecules have enough / sufficient energy (to react)

                  M1
                  Ignore
                  •   *Molecules have more energy*
                  •   *More energetic collisions*
                  •   *More collisions*

                  Allow $E > E_a$ in place of $E \geq E_a$

                  Credit particles for molecules (but not atoms)

                  Penalise for M1 reference to increased activation energy

                                                                                                 1

      M2   more successful / effective / productive collisions in a given time / period
      or   higher rate of successful / effective / productive collisions
      or   higher frequency of successful / effective / productive collisions

                  M2
                  Must refer to both idea of successful / effective / productive
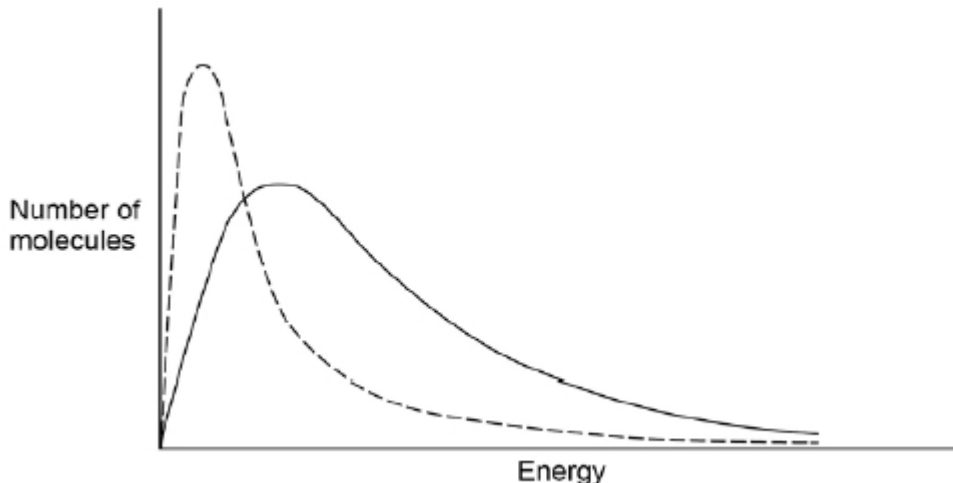   *collisions and the rate / frequency of collisions*
                  Ignore 'chance of collision'

                                                                                                 1
                                                                                               [5]

3.   (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 <u>successful</u> collisions in a given time
                  Less frequent <u>successful</u> 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 <u>successful</u> collisions

1

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4.

(a)   <u>Amount / number / proportion / percentage / fraction / moles</u> of <u>molecules / particles</u>

Penalise an incorrect qualification of the number eg NOT number of molecules with E greater than Ea.

Not 'atoms'.

1

(b)   There are no molecules / particles with zero energy

OR

All of the molecules / particles are moving / have some energy

Not 'atoms'.

The answer should relate the energy to the molecules.

1

(c)   **C** (The most probable energy)

1

(d)   **M1** The peak of the new curve is <u>displaced to the right</u> and <u>lower</u> than the original

M2 All of the following needed

- The new curve starts at the origin and should begin to separate from the original almost immediately

- <u>and</u> the new curve only crosses the original curve once

- <u>and</u> the total area under the new curve is <u>approximately</u> the same as the original

- <u>and</u> an attempt has been made to draw the new curve correctly towards the axis <u>above the original curve</u> but not to touch the original curve

2

(e)   None / no effect / stays the same

1

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5. (a) M1 On the <u>energy axis</u> E_{mp} at the maximum of <u>the original peak</u>

> **M1** *The limits for the horizontal position of E_{mp} are defined as above the word "the" in the sentence below the graph.*

M2 The peak of their new curve is <u>displaced to the left</u> and <u>higher</u> than the original.

M3 All of the following are required

- The new curve starts at the origin and should begin to separate from the original almost immediately

- <u>and</u> the new curve crosses the original curve <u>once</u>

- <u>and</u> an attempt has been made to draw the new curve correctly towards the energy axis <u>below the original curve</u> but not to touch the original curve or the axis

3

(b) **The rate of reaction decreases as the temperature decreases because**

M1 <u>A decrease</u> in the <u>number</u> / <u>proportion</u> of <u>molecules</u> <u>with $E \geq E_a$</u>
OR <u>fewer molecules have $E \geq E_a$</u>
OR <u>fewer molecules have sufficient / enough energy to react / decompose</u>

> **In M1**
> *Ignore "molecules have less energy".*
> *Ignore "less energetic collisions".*
> *Ignore "molecules do not gain activation energy".*
> *Ignore "fewer collisions".*
> *Credit "particles" for "molecules" but NOT "atoms".*

M2 <u>Fewer effective / productive / successful collisions in a given time / given period</u>
OR <u>fewer frequent effective / productive / successful collisions</u>
OR <u>lower rate of effective / productive / successful collisions</u>

> *Ignore "chance of collision"; this alone does not gain* **M2**

2

[5]

6. (a) (i) Curve drawn from origin with peak clearly lower and to right.

> *New curve crosses original once only, finishes above original and does **not** clearly curve up*
> **IGNORE** *relative areas*

1

(ii) (Relative areas under curves indicate) <u>many</u> (owtte) more molecules with E greater than or equal to Ea (at higher T) or reverse argument

> **ALLOW** *'particles'*
> **IGNORE** *'atoms'*

1

(Large) increase in (number of) <u>successful</u> (owtte) <u>collisions per unit</u> time

> **OR** *'<u>frequency</u> of successful <u>collisions</u>'*

1

(b) (i) Yield increases

Yield decreases/stays the same CE = 0

If not answered mark on

1

More moles/molecules (of gas) on left/fewer on right/3 on left 1 on right

1

Equilibrium shifts/moves (to right) to reduce pressure/oppose higher pressure

No M3 if 'more moles on right' in M2

IGNORE *'favours'*

NOT *just 'oppose the change'*

*QoL means that M3 is only awarded if these ideas are clearly linked
in one statement*

1

(ii) Higher T would increase rate but decrease yield/make less
methanol
OR
Lower T decreases rate but increases yield;

*If no mention of both rate **AND** (idea of) yield max 1*

1

Chosen T is a compromise/balance (between rate and yield) owtte

1

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7. (a) Number / proportion / percentage / fraction of molecules

Ignore "particles"

1

(b) None **OR** no effect **OR** no change

1

(c) **X**

1

(d) **Answers in either order**

M1 collision **OR** collide

Mark independently

M2 collision / molecules / particles

Ignore "correct" amount of energy

with the activation energy

OR with $E \geq E_{act}$

OR with sufficient /enough energy

OR with the minimum energy

OR with the correct orientation

2

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(e) A small increase in temperature results in <u>many more / much higher proportion of / a lot more / significantly more</u> <u>molecules / particles / collisions</u> with <u>$E \geq E_{act}$/ energy greater than the activation energy / sufficient energy / enough energy / minimum energy to react</u>
(compared with a small increase in concentration)

Not just "more molecules with $E \geq E_{act}$"

*The answer must convey that the increase is **significant***

Accept reference to "atoms", "molecules", "particles"

Ignore "species"

1

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8. (a) (i) **M1** The peak of the new curve is <u>displaced to the right</u>.

M2 All of the following are required

• The new curve starts at the origin

• The peak of the new curve is <u>lower</u> than the original

• <u>and</u> the new curve only crosses the original curve <u>once</u>

• <u>and</u> an attempt has been made to draw the new curve correctly towards the energy axis but not to touch the original curve

• the new curve must not start to diverge from the original curve

M1 is low demand

M2 is higher demand.

2

(ii) **M1** Increase in the number/proportion of molecules with $E \geq E_a$

OR <u>more molecules have $E \geq E_a$</u>

OR <u>more molecules</u> have <u>sufficient energy to react</u>

M2 <u>More effective/productive/successful collisions</u>

Ignore "molecules have more energy"

Ignore "more energetic collisions"

Ignore "molecules gain activation energy"

Ignore "more collisions"

Accept "particles" for "molecules" but NOT "atoms"

Ignore "chance of collision"; this alone does not gain M2

2

(b) (i) Iron **OR** Fe

1

(ii) **M1** Catalysts provide an alternative route/pathway/mechanism

OR

(in this case) surface adsorption/surface reaction occurs.
  For M1, not simply "provides a surface" alone

M2 that has a lower activation energy

OR

lowers the activation energy
  For M2, the candidate may use a definition of activation energy without referring to the term

2

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9. (a) (i) Z (1)

1

(ii) Collisions (1)

Cause some molecules to slow down or lose energy (1)

2

(b) Curve starts at origin and is displaced to the right (1)

Curve lower and does not touch energy axis (1)

2

(c) (i) Only a small percentage/very few collisions have $E > E_a$ (1)

1

(ii) Add a catalyst (1)

Lowers E_a (1)

More collisions/molecules have energy $> E_a$ (1)

3

[9]