3.2.2 Kinetics

Maxwell Boltzmann distribution

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128 minutes

128 marks

M1. (a) M1 On the energy axis E_{mp} at the maximum of the original peak

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 displaced to the left and higher 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
- and the new curve crosses the original curve once
- and an attempt has been made to draw the new curve correctly towards the energy axis below the original curve but not to touch the original curve or the axis

3

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

M1 A decrease in the number / proportion of molecules with $E \geq E_a$

OR fewer molecules have $E \geq E_a$

OR fewer molecules have sufficient / enough energy to react / decompose

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

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

2

[5]

M2. (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

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

[6]

M3. (a) **M1** The activation energy is the minimum / least / lowest energy

Mark independently

Ignore "heat" and ignore "enthalpy"

M2 (energy) for a reaction to occur / to go / to start

OR (energy) for a successful / effective collision

Ignore "breaking the bonds"

2

(b) **M1** Catalysts provide an alternative route OR an alternative mechanism OR alternative / different path(way)

M2 Lowers the activation energy

Mark independently

Ignore reference to "surface"

2

(c) (i) Stay(s) the same

1

(ii) Increases

Credit "increase" or "increased"

1

(iii) Increases

Credit "increase" or "increased"

1

(iv) Stay(s) the same

1

(d) (i) **M1** yeast or zymase

M2 ethanol

Ignore "enzyme"

In M2, ignore "alcohol" and ignore any formula

2

(ii) **M1** (Concentrated) H_3PO_4 OR (Concentrated) H_2SO_4

M2 butan-2-ol

Credit correct names

Ignore "hydrogenphosphate or hydrogensulfate"

Ignore "dilute" or "aq"

Do not penalise absence of hyphens in name.

In M2, ignore any formula

2

[12]

M4. (a) (i) **M1** The peak of the new curve is displaced to the right.

M2 All of the following are required

- The new curve starts at the origin
- The peak of the new curve is lower than the original
- and the new curve only crosses the original curve once
- and 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 more molecules have $E \geq E_a$

OR more molecules have sufficient energy to react

M2 More effective/productive/successful collisions

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

[7]

M5. (a) Peak lower

1

and moved to right

1

start at the origin and curve crosses once only

1

(b) (i) (Rate of reaction) increases

1

(At a higher temperature) more molecules/particles

1

have the minimum energy needed to react/have activation energy/have successful collisions

Mark CE if incorrect effect given

1

(ii) (Rate of reaction) <u>increases</u> 1

lowers activation energy 1

so that more molecules are able to react 1

Mark CE if incorrect effect given

[9]

M6. (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]

M7. (a) the minimum energy;

1

<u>Energy</u> required for a reaction to occur;

(or to start a reaction or for successful collisions)

1

(b) axes labelled:- y: number *(or fraction or %)* of molecules *(or particles)*
x: energy *(or KE);*

1

curve starts at origin;

1

skewed to right;

1

approaches x axis as an asymptote;

(penalise a curve that levels off > 10% of max peak height or a curve that crosses the energy axis)

1

second curve displaced to the left (and does not cross T_1 curve for a second time)

1

and peak higher;

1

many fewer molecules;

1

fewer molecules have $E > E_a$;

(can score this mark from suitably marked curves)

1

(c) molecules *(or particles or collisions)* do not have enough energy;

(or orientation may be wrong)

1

increase the pressure;

1

(or increase the concentration or reduce the volume)
increases the collision frequency;

(or more collisions)
(do not allow if stated to be due to increase in energy implied by temperature increase)

1

add a catalyst;

1

lowers activation energy (or E_a) *(Q of L mark);*

1

[15]

M8. (a) Graph starts at origin

1

Graph skewed to left and has decreasing gradient to maximum

1

Graph after maximum decreases in steepness, never touches *x* axis, levels out less than 5 mm from *x* axis.

1

(b) Minimum energy

1

To start a reaction (*or for a reaction to occur*)

1

(c) Molecules gain energy (*or always some molecules have* $E > E_a$)

1

Due to collisions

1

(d) Decreases

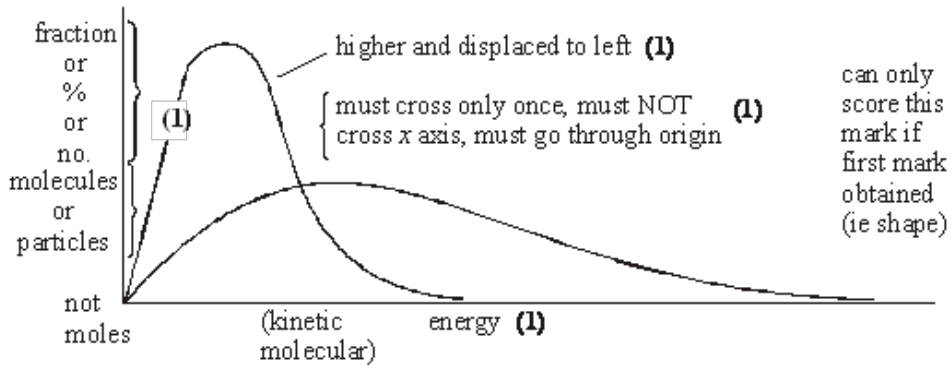
1

E_a lowered **(1)**
By alternative route **(1)**
So more molecules have energy > E_a **(1)**

max 2

[10]

M9. (a)



2

(b) See above

2

(c) Energy < E_a or must have enough energy (to react) **(1)**

1

(d) Increase concentration (or pressure) **(1)**

1

(e) Many **(1)** more molecules have $E > E_a$ / enough energy **(1)**

NOT KE increases with T

2

(f) Lowers E_a **(1)**

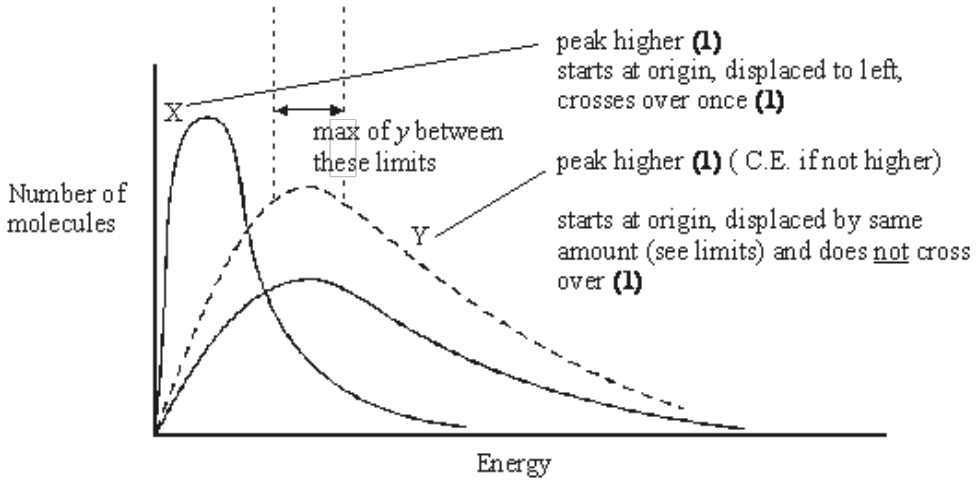
alternative route **(1)**

2

[10]

M10. (a) (i) (ii)

4



(b) (i) collide **(1)**

with sufficient energy (or $E \geq E_a$) **(1)** (*or with correct orientation*)

(ii) molecules (or particles) have more energy (or move faster) **(1)**

more molecules (or collisions) have $E \geq E_a$ (or sufficient energy) **(1)**

4

(c) (i) equilibrium reached **(1)**

(or rate forward reaction = rate backward)

(ii) Reaction is endothermic **(1)**

or ΔH +ve

or reverse reaction is exothermic

endothermic reaction favoured **(1)**

(or reaction shifts to R

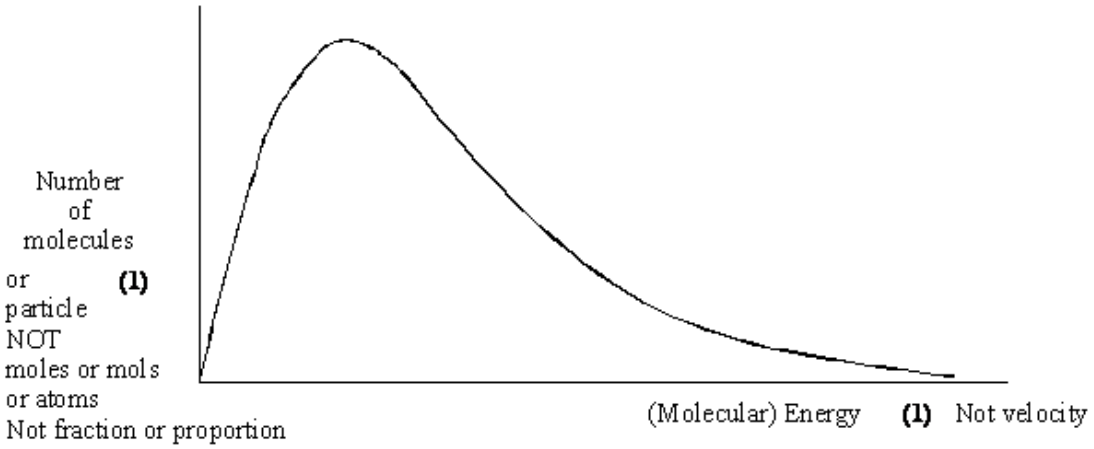
or moves forward

or more products formed)

3

[11]

M11. (a) (i)



(ii) The total number of particles (or molecules) in the sample

OR the number of molecules present

(iii) No molecules have no energy

OR all molecules have some energy

Do not allow "if there are no molecules there is no energy"

4

(b) (i) The minimum energy required **(1)**

for a reaction to occur **(1)**

OR to start reaction or for a successful collision

(ii) Changes: Catalyst **(1)**

Explanation: Alternative route **(1),** with a lower activation energy **(1)**

OR a lower activation energy (1)
so more molecules can react (1)/more molecules have this energy

If change incorrect CE = 0

Allow answers anywhere in b (ii)

5

[9]

M12. (a) **Increase in temperature:**

Yield is increased **(Allow if for H_2 (g) or products) (1)**

Reaction endothermic **(1)**

Equilibrium moves to the right **OR** forward, **OR** Equilibrium moves to oppose change **OR** to absorb heat **(1)**

If "Yield statement" incorrect allow max one if reaction stated to be endothermic

Increase in pressure:

Yield is decreased **(Allow if for H_2 (g) or products) (1)**

Increase in moles of gas **or** 2 moles increased to 4 moles **or** more moles on right **(1)**
Equilibrium moves to the left **OR** backwards, **OR** Equilibrium moves to oppose change **OR** to reduce pressure **(1)**

If "Yield statement" incorrect allow max one if number of moles change is correct.

6

(b) **Equilibrium yield:**
Unaffected **or** equilibrium unchanged **(1)**
Rate or speed increased **(1)**
Forward and backwards reactions equally or by the same amount **(1)**

Amount of hydrogen produced:
More hydrogen produced (1)

4

[10]

M13. (a) Activation energy;-
The minimum energy needed for a reaction to occur / start **(1)**

1

(b) Catalyst effect:-
Alternative route (or more molecules have Ea) **(1)**
Lower activation energy **(1)**

2

(c) Increase in moles of gas:-
Position of E_{mp} unchanged **(1)**
More molecules with E_{mp} **(1)**
Area under curve increases **(1)**
Molecules with $E \geq E_a$ increased **(1)**

Temperature decreased:-
Position of E_{mp} moves to the left **(1)**
More molecules with E_{mp} **(1)**
Area under curve unchanged **(1)**
Molecules with $E \geq E_a$ decreased **(1)**

Catalyst introduced:-
Position of E_{mp} unchanged **(1)**
Molecules with E_{mp} unchanged **(1)**
Area under curve unchanged **(1)**
Molecules with $E \geq E_a$ increased **(1)**

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[15]