1. (a) (i) The energy the molecules must have to react / start the reaction 1

(ii) larger 1

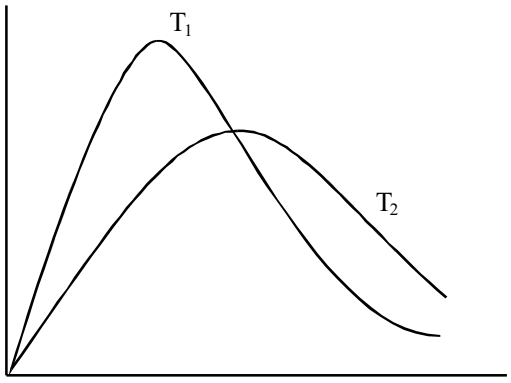
(b) (i) T_1 skewed, no intercept of y axis , must be asymptotic to x axis. **(1)**
T_2 peak lower than T_1 and to the right of T_1 **(1)** not consequential on shape.

(ii) Some comment re greater area under graph – could be shown on graph **(1)** leading to more successful **collision (1)** 5

(c) Alternative route / mechanism **(1)**
With lower activation energy **(1)**
Reaction only takes place at surface of catalyst **(1)** and (this has large surface area) which increases chance of collision with gas molecules/ more active sites **(1)** 4

[11]

2. (a) Diagram at T_1 approximately correct shape which starts near origin and does not intersect the vertical axis or the horizontal axis **(1)** At higher T_2 – flatter **(1)** and mode to right **(1)**



3

(b) Indication of activation energy **on diagram** to the right of both peaks **(1)**
Explanation of number past E_a point related to probability of reaction **(1)**
Higher T gives more molecules $\geq E_a$ **(1)**
more effective / successful collisions **(1)** 4

[7]

3. (a) (i) carbon dioxide / gas evolved **(1)**
escapes from flask / lost **(1)** **2**

(ii) reaction (is fast at first then) slows down / gives off less CO_2 per minute **(1)**
when line is horizontal the reaction has finished /
after 6 or 7 minutes the reaction has finished /
when 1 g of CO_2 lost the reaction has finished **(1)** 2

(b) Experiment 2 steeper than 1 and same mass loss **(1)**
Experiment 3 less steep than 1 and same mass loss / reaction incomplete **(1)**
Experiment 4 steeper than 1 and horizontal at twice mass loss **(1)** 3

(c) (i) 50.0 cm^3 of 0.1 mol dm^{-3} HCl $= 50 \times 1/1000$ mols
$= 5 \times 10^{-2}$ **(1)**
5×10^{-2} mol of HCl react with $\frac{5 \times 10^{-2}}{2}$ **(1)** mol of $CaCO_3$
$= 2.5 \times 10^{-2} \times 100$ g
= 2.5 g **(1)** *units must be shown*
Consequential step by step 3

(ii) Suggested mass at least twice mass calculated in (c)(i)
e.g. 5 g **(1)** twice as much needed for experiment 4 **(1)**
If mass is larger than answer to(c)(i) and a reference to an excess being needed score 1 mark
Consequential on previous answer. 2

[12]

4. (a) (i) any **two** from
concentration
pressure
surface area / particle size **(2 × 1)** 2

(ii) Pressure / concentration:
Increase of pressure/ concentration increases rate **(1)**
The particles are closer together therefore more collisions / more collisions per unit volume per unit of time **(1)**
Allow more –'frequent' collision
or
Surface area:
Increase in surface area increase the rate **(1)**
More collisions on surface of solid / more surface available for collisions **(1)** 2

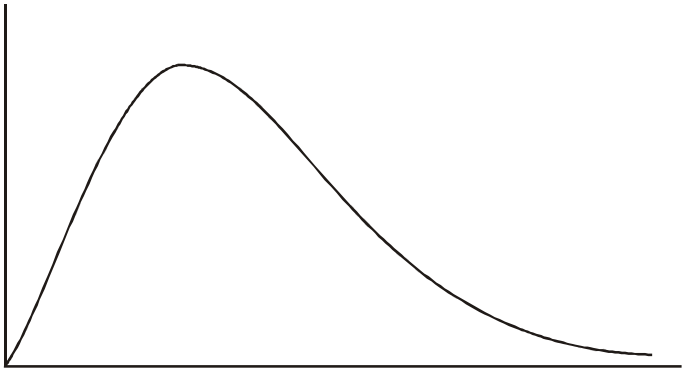
(b) (i) Similar curve with peak further **to the right (1)**
and **lower** maximum **(1)** 2
Max 1 mark if second line crosses the first more than once or crosses axis

(ii) Vertical line placed **to the right** of both of the peaks **(1)** 1

(iii) (At higher temperature average kinetic) energy of molecules is greater **(1)**
More molecules / collisions have energy greater than / equal to the activation energy **(1)**
Therefore more collisions are effective / result in reactions **(1)** 3

[10]

5. (a) (i) correct shape:
starting at/ near origin, not crossing axes, not symmetrical **(1)**



labels:
energy AND number/ fraction of molecules **(1)** 2

(ii) E_a for the uncatalysed reaction shown well to the right of the peak and E_a for catalysed reaction to the left of this, still to the right of the peak **(1)**
Some comment concerning the areas under the curve to the right of the E_a lines or labelled shading **(1)**
Greater number of collisions (or particles) have energy greater than the activation energy/ have enough energy to react **(1)**
Therefore greater number of successful/ effective collisions **(1)** 4

(b) The explanation must refer to molecules or particles:

increase temperature **(1)**
molecules have more energy **(1)**
greater proportion of collisions successful / more effective collisions per unit time / more frequent effective collisions **(1)**

OR

increase pressure/ concentration **(1)**
more molecules per unit volume or molecules closer together **(1)**
more frequent collisions / more collisions per unit time **(1)** 3

[9]

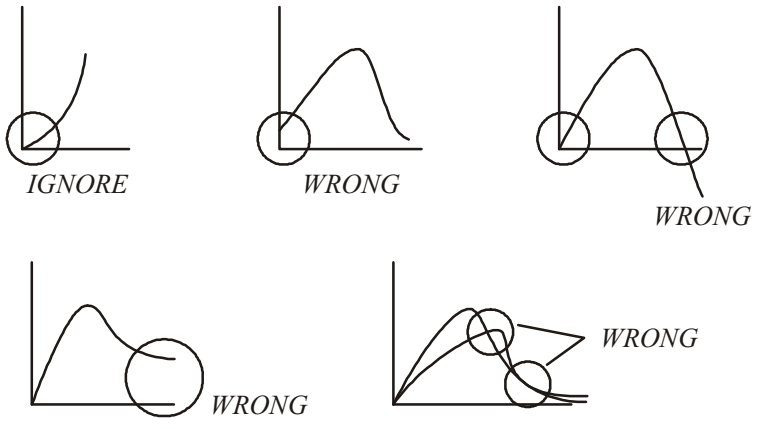
6. (a) Fine powder because it has larger surface area **(1)**

so more collisions per unit time OR greater collision frequency (between the peroxide and the catalyst) **(1)**
OR 'more active sites'
OR 'more likely for collisions to occur'
NOT 'more successful collisions'.
NOT 'more collisions' on its own 2

(b) (i) Axes labels **(1)**
ie *y*-axis = Number/"N" /fraction of molecules
x-axis = (kinetic) energy/E *NOT* potential energy

Start at or going towards origin, asymmetric, asymptotic to *x*-axis, T_1 line correct shape **(1)**

T_2 line peak lower **(1)** and to the right **(1)**
T_2 line must only cross T_1, line once, otherwise max **(1)**



4

(ii) *E*a shown well to the right of both peaks **(1)**

larger area for T_2 **shown on diagram** and related to number of collisions/molecules with E ≥ Ea **(1) -** *need to refer to shading*

Greater proportion of successful collisions
OR more of the collisions are successful **(1)**
ACCEPT more successful collisions per unit time
NOT 'more successful collisions' alone 3

(iii) Ea $_{(cat)}$ at a lower energy than E_a **(1) -** *check diagram, it is enough to draw it on the diagram*

Greater proportion of molecules have energy greater than the new activation energy OR relates areas to frequency of successful collisions **(1)** 2

[11]

7. (a) Sodium chlor**ate**(I) 1

(b) Species / particle / entity / group / atom / molecule with an unpaired / odd electron *OR* with an uneven/odd number of electrons 1

(c) Provides an alternative mechanism/route/different transition state **(1)**

of lower activation energy **(1)**

Mark independently 2

(d) A process that:

– uses materials from renewable resources/OWTTE

– consumes minimal **energy** (resources) *NOT* use a lower temperature

– does not release polluting end products/OWTTE

3 → **2**

2 → **1**

1→ 0 2

(e) (Accumulation in food chain) may mean dioxins reach high / toxic / poisonous / harmful / carcinogenic / hazardous levels. 1

Note that words appearing in the title to the summary do not count in the word total. Normally hyphenated words, numbers and chemical formulae count as one word. The question does not ask for equations in the summary, but if included they should be counted in the word total.

Sub headings do not count in the word total.
TAML = 1 word
H_2O_2 = 2 words
NaOCl = 2 words

Marking for key points

One mark should be awarded for **every** key point clearly identified in an answer.

Key points minus word penalty = maximum 6 marks

To gain the mark for a key point the wording used by the candidate must make clear the essential chemistry of the point.

Key Points

1	Stain removers contain (solid) **percarbonates** or **perborates**	**(1)**
2	which **produce hydrogen peroxide** on reaction with **water**	**(1)**
3	which **decomposes** / **breaks down** producing (free) **radicals**	**(1)**
4	that can oxidise stain molecules **and** change/alter their colour	**(1)**
		MAX 3

5	produce no **organochlorine** pollutants	**(1)**

6	(but can be unselective as) other molecules are exposed to free radicals resulting in unwanted reactions	**(1)**
7	and require longer reaction / wash time /higher temperatures / pressures ***Any two***	
	OR higher costs for **energy**, **equipment** and **labour**	**(1)**
		MAX 1

8	used in (pulp and) paper/textile /laundry industries ***Any two***	**(1)**

6 max (from 8 possible points)

To score 6, candidates need to get:
- *three from points 1- 4*
- *point 5*
- *one from points 6 – 7*
- *point 8*

Quality of Written Communication

These should *be impression* marked on a scale 2-1-0, and the mark out of 2 should be recorded in the body of the script at the end of the answer. This mark can not be lost as a result of a word penalty.

Candidates are expected to:

- show clarity of expression;

- construct and present coherent argument;
- demonstrate effective use of grammar punctuation and spelling.

The aspects to be considered are:

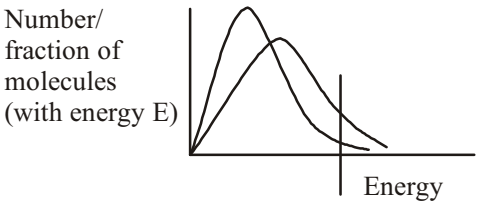
- use of technical terms; the answer should convey a correct understanding by the writer of the technical terms used in the passage which are involved in the key points.
- articulate expression; the answer should be well- organised in clear, concise English, without ambiguity. It should read fluently, with the links between key points in the original maintained.
- legible handwriting; the reader should be able to read the answer without difficulty at normal reading pace, with only the occasional difficulty with a word.
- points must be in a logical order.

Good style and use of English, with only infrequent minor faults, no use of formulae **(2)**
Frequent minor or a few major faults in style and use of English **(1)**
Very poor style and use of English **(0)** 2

NB: The quality of written communication mark cannot be lost through word penalties.

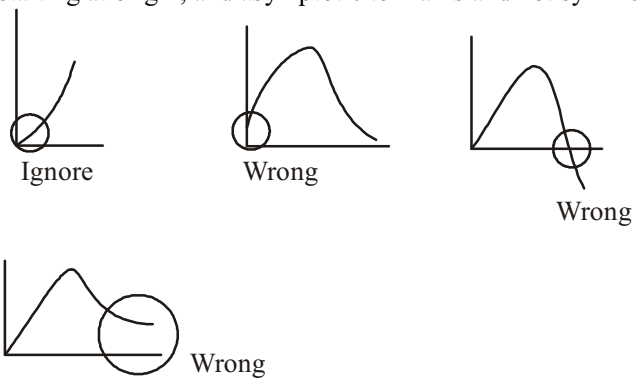
[7]

8. (a)



(i) Axes labelled **(1)**
Y: number/fraction of molecules/particles (with energy E) **and**
X: (kinetic) energy

Correct shape **(1)**
starting at origin, and asymptotic to x-axis and not symmetrical



2

(ii) line T_H with peak to the right of temp T and peak lower than temp T

because crosses twice 1

(iii) vertical line well to the right of both peaks 1

(b) (i) higher temp gives molecules higher (average kinetic) energy **(1)**

so increase in frequency of collisions **(1)**

Accept more collisions per unit time

Reject more collisions

area (under curve) to right of Ea greater at T_H **(1)**

more collisions have a greater energy $\geq E_a$
OR a greater **proportion** of collisions have energy $\geq E_a$
OR
more **of** the collisions are successful
OR a greater **proportion** of the collisions result in reaction /are successful **(1)** 4

Accept molecules/particles for collisions

Reject "more successful collisions"
"increase in frequency of successful collisions"

(ii) Energy of collisions 1

[9]

9. (a) (i) Make halogenoalkanes miscible with silver nitrate/$AgNO_3$ solution
OR to dissolve halogenoalkanes/acts as solvent **(1)** 1

(ii) Feature of water molecule:
The oxygen atom has a lone pair of electrons **(1)**

Either an S_N2 mechanism
Arrow from O of water towards C atom **(1)**
and arrow from C–I σ bond to I atom **(1)**
transition state with no charge **(1)**
Ignore final loss of H^+ and formation of I^-

Or an S_N1 mechanism
Arrow from C–I σ bond to I **(1)**
intermediate with + charge and I^- ion **(1)**
arrow from O of water to C+ of intermediate **(1)**
Ignore final loss of H^+ 4

(iii) C 1

(iv) Silver((I)) chloride **(1)**
Ignore capitals 1

(v) Precipitate dissolves/disappears/clears **(1)** 1

Reject precipitate changes colour

(vi) QWC

Must be given in a logical sequence

C–I bond is weakest (and break more easily) **(1)**
Because the iodine atom is the largest / greatest bond length **(1)**
So lowest activation energy **(1)**

Or reverse argument: e.g. C–Cl bond strongest 3

Reject Cl is more electronegative than I
OR
Cl forms a carbocation more readily than C–I

(b) QWC

Any two from three:
100 % atom economy **(1)**
higher cost of halogenoalkanes/halogenoalkanes are made from alcohols **(1)**
alkenes readily available from oil **(1)** 2

(c) (i) suck back **(1)** 1

(ii) remove delivery tube from water/add Bunsen valve **(1)** 1

[15]

10. (a) (i) Equilibrium shifts to left / lower yield **(1)** must be clear not implied
more (gas) molecules on right **(1)** 2

(ii) Equilibrium shifts to left / lower yield **(1)** *must be clear not implied*
forward reaction exothermic / shift to endothermic direction / moves to absorb heat / rate of reverse reaction increases more than rate of forward reaction **(1)** 2

(i) increased rate **(1)**
Molecules closer together / less space between molecules / higher concentration / same number of molecules in less space **(1)**
more collisions/ collide more frequently **(1)** 3

(ii) Increased rate **(1)**
More molecules /collisions have (at least) the activation energy **(1)**
More of the collisions successful / more of the collisions lead to reaction **(1)** 3

(c) (i) Platinum (plus rhodium) / Pt (Rh) **(1)** 1

(ii) Alternative route **(1)**
With lower activation energy **(1)** *this mark is consequential on previous mark*
Increase in rate because there are more successful collisions **(1)** 3

(iii) Increased surface area / more active sites **(1)** 1

[15]

11. (a) (i) *Dynamic:*
reaction occurring in both directions / rate of forward reaction and reverse reactions equal **(1)**
Equilibrium:
constant concentrations / no change in macroscopic properties **(1)** 2

(ii) all substances in same phase / are all in the gaseous state **(1)** 1

(b) (i) Higher yield of ammonia / (equilibrium position) moves to. r.h.s **(1)**
Fewer product molecules **(1)** 2

(ii) Lower yield of ammonia / (equilibrium position) moves to 1.h.s. **(1)**
since this absorbs heat/ shift in endothermic direction / the reaction is exothermic **(1)** 2

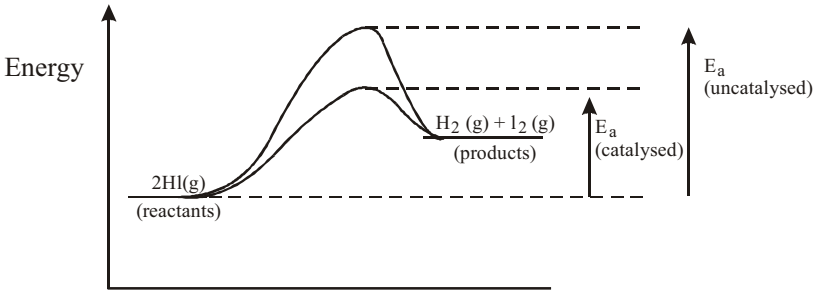
[7]

12. (a) (i) Forward and reverse reactions occur at the same rate **(1)**
so there is no change in the proportions of reactants and products **(1)** 2

(ii) Proportion of HI expected to become smaller **(1)**
because reaction will respond to temperature increase by shifting in the endothermic direction **(1)** 2

(iii) No change expected because catalysts affect only the **rate** at which equilibrium is attained. 1

(b)



Products at higher energy level than reactants **(1)**

Line going up from reactants to peak (corresponding to transition state), then down to products **(1)**

Second line with lower peak representing the catalysed reaction **(1)**
Activation energies of uncatalysed and catalysed reactions correctly marked **(1)** 4

[9]

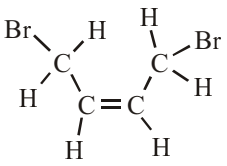
13. (a) (i) Two reactants form **one product** 1

(ii) **Substitution** reactions occur under these conditions 1

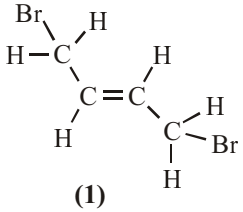
(iii) The electrons of the double / π bond polarise the Br – Br molecule **(1)**

and $Br^{\delta+}$ is the electrophile **(1)**
OR show $Br^{\delta+} - Br^{\delta-}$ *attacking in the correct orientation* 2

(b) (i)



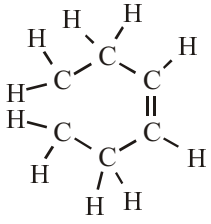
(1)



(1) 2

(ii) No rotation about a C =C double bond
OR only single bonds can rotate 1

(c) (i)



1

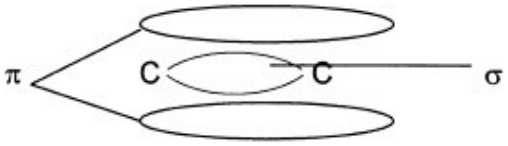
(ii) Low temperature because exothermic reaction **(1)**
High pressure because fewer molecules of product than of reactants gases are being converted into liquids **(1)** 2

[10]

14. (a) (i) $C_2H_6(g)/(l) \rightarrow C_2H_4(g) + H_2(g)$
If a state symbol is missing **(0)**
If (aq) **(0)** 1

(ii) At high pressure reaction goes in direction to reduce pressure/to oppose change by Le Chatelier's principle **(1)**
towards side with fewer molecules/moles **(1)** 2

(b) Shapes of orbitals between and above carbon



If p orbitals drawn msut show overlapping

Shapes **(1)** ACCEPT crescents for π bonds NOT lines for σ bond 2
Labels **(1)**

(c) Addition of bromine **water/solution (1)**
from yellow/brown/orange to **colourless (1)**
OR
acidified potassium manganate(VII) **(1)**
from pink/purple to **colourless (1)** 2

(d) Addition **(1)**
Elecrophilic/electrophile *OR* appropriate *explanation* **(1)** 2

[9]

15. (a) (i) rate forward = rate back **(1)**
no change in concentration/partial pressure/amount **(1)** 2

(ii) (%) increases **(1)** 1

(iii) None **(1)** 1

(b) If temperature too low, rate too slow/high temperature gives fast rate**(1),**
but if too high, yield too small/high yield needs low temperature **(1)**
therefore a compromise temperature (of 450 °C) **(1)**
and catalyst for quick rate (at temperature 450 °C)/catalyst not effective
if temperature below 400 °C **(1)** 4

[8]

16. (a) Dynamic – reaction continuing (all the time) **(1)**
ALLOW rate forward = rate back

Equilibrium – **concentrations** (of the substances) do not change /
remain the same **(1)**
NOT 'concentrations all equal'
NOT 'amounts do not change' 2

(b) (i) 350 – 450 °C *OR* 620-720 K **(1)**

$>1 \leq 5$ atm **(1)**
Values can be given in kPa or kNm^{-2} 2

(ii) High yield favoured by low temperature **(1)**
High rate favoured by high temperature **(1)**
So, temperature used is a compromise **(1)** – *conditional on first two marks*

ACCEPT correct inverse argument 3

(iii) Too costly for extra yield
OR Position of equilibrium is well to right under these conditions
OR Corrosion problems at high pressure
OR Only need elevated pressure in practice to push gases through system
OR Capital cost high
OR Maintenance cost high
OR High energy cost
OR Sulphur dioxide liquefies.
NOT "too costly" *without explanation*
NOT too dangerous 1

(c) (i) $\Delta H = 2\Delta H_f(SO_3) - 2\,\Delta H_f(SO_2) = (-395 \times 2) - (-297 \times 2)$ **(1)**

$= -196$ (kJ mol^{-1}) **(1) –** *IGNORE units*

–196 (kJ mol^{-1}) *with some working* **(2)**

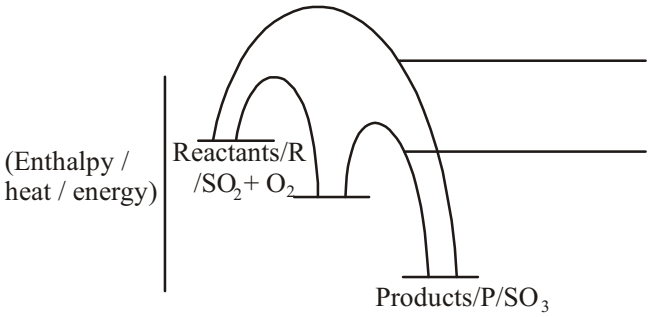
No consequential mark other than failing to multiply by two to get
–98 kJ mol^{-1} **max (1)**
Any positive answer **(0)** 2

QWC (ii) ΔH_f is **defined** as formation from elements
OR ΔH_f of an element is **defined** as 0 (in its standard state)
OR **all** elements are given the value zero

'It is an element' *on its own* **(0)** 1

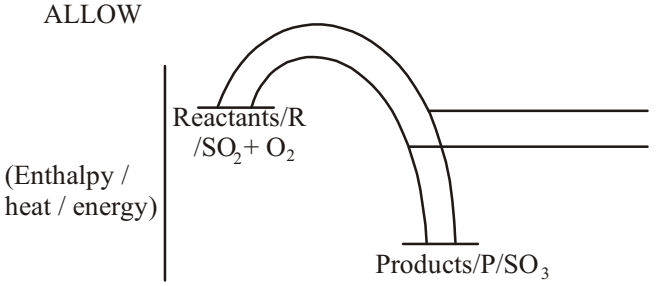
(d) (i) V_2O_5 *OR* V205
NOT name
NOT V^2O^5.
If name and formula given, ignore name. 1

(ii)



Uncatalysed (1)
Catalysed (1)
Euthalpy levels (1)

ALLOW



Uncatalysed (1)
Catalysed (1)
Euthalpy levels (1)

ALLOW endothermic intermediates
ALLOW single hump for catalysed pathway: (energy)
If the diagram shows ΔH endothermic, then can score the first two marks.

If y-axis label is wrong 3rd mark can not be awarded
Catalysed and uncatalysed labels missing scores 3rd mark only

If two diagrams drawn, full credit can be given if the catalysed E_a is clearly less than the uncatalysed.
If ΔH and E_a confused, then **max 2** 3

QWC (iii) Changes mechanism to one of lower E_a

OR to a different route with lower E_a **(1)**
NOT "Lowers E_a" *alone.*

Reactants (chemically) adsorb on catalyst surface
OR (at given T) more collisions have $E > E_a$
so more **successful** collisions **(1)** 2

(e) **Forms (a difficult to condense) mist / fog / smoke / too violent / too exothermic**
NOT "extremely reactive" 1

[18]

17. (a) Heat/enthalpy/energy **change** per mole of substance/compound/product

OR
heat/enthalpy/energy **change** for the formation of 1 mol of substance/ compound/product **(1)**
"heat released" *and* "heat required" *not allowed unless both mentioned*
NOT molecule

from its **elements** in their standard states **(1)**

at 1 atm pressure and a stated temperature/298 K **(1)**
NOT "room temperature and pressure"
NOT "under standard conditions" 3

(b) (i) (ΔH = – 306 – (–399)) = (+) **93** (kJ mol^{-1}) 1

ALLOW kJ
Incorrect units lose mark otherwise

(ii) The equilibrium moves to right hand side
OR amount of dissociation increases **(1)**

Because the (forward) reaction is endothermic **(1)**

Needs to be consistent with (i)

If (i) has a negative answer (exothermic)
equilibrium moves to left hand side **(1)**
Because (forward) reaction is exothermic **(1)**

If answer to (i) is +93 or 93 but state that this is exothermic
If reaction moves to left hand side **(1)**
If reaction moves to right hand side **(0)** 2

(iii) add chlorine **(1)**
which drives equilibrium to the left **(1)**

OR
increase the (total) pressure **(1)**
because there are fewer (gas) molecules on left hand side **(1)**

OR
add PCl_3 **(1)**
Which drives equilibrium to the left **(1)** 2

[8]

18. (a) (i) H(g) + O(g) + Cl(g) *in top RH box*

½ H_2(g) + ½ O_2(g) + ½ Cl_2(g) in lower box
Brackets around the state symbols are not required 1

(ii) $589 - 667 = -\mathbf{78}$ (kJ mol^{-1})
ALLOW final answer on its own 1

(iii) $667 - 464 = (+)\mathbf{203}$ ($kJmol^{-1}$)
ALLOW final answer on its own 1

(b) (i)

(1) **(1)** **(1)** **(1)**

ALLOW

ALLOW all dots/crosses
*ALLOW **1 max** if electrons are correct but atoms are not identified*
*If ionic dot and cross diagram **(0)*** 2

(ii) 100 – 106° **(1)**

as lone / non-bonding pairs take up **more** space/
repel **more strongly** than bonded pairs **(1)**
NOT bonds being repelled/H and Cl being repelled 2

(c) No change **(1)**

as number of **gaseous** reactant molecules = number of **gaseous** product molecules **(1)**
*ALLOW **1 max** if candidates state or imply a very small change with correct justification*
eg "hardly changes"
"doesn't change much"
"very little effect/change" 2

[9]

19. (i) QWC

Stand alone marks

Lower yield / less hydrogen produced **(1)**
IGNORE any reference to rate

More (gaseous) molecules on rhs / fewer (gaseous) molecules on lhs **(1)** 2

Reject equilibrium move left / reverse reaction favoured, if no reference to yield

(ii) QWC

Higher yield / more hydrogen produced **(1)** – if this is **only** explained in general terms of increasing rate of the reaction, do **not** award the mark

(Forward) reaction is endothermic / absorbs heat **(1)** 2

*If forward reaction is exothermic **(0 out of 2)***

(iii) No effect **(1)** 1

[5]

20. (i) higher pressure / temperature will increase rate of reaction

OR
higher pressure will increase production of methanol (as less moles of gas on the RHS) 1

Accept higher pressure faster reaction
Accept higher temperature faster reaction
Accept higher pressure greater yield

Reject no catalyst used so cheaper

(ii) Any three from:

lower temperature
increases yield / because reaction exothermic **(1)**

lower temperature costs less, (less energy used) **(1)**

Can gain 2 marks if both ideas of temperature and pressure put together in same advantage

lower pressure costs less, (pipes thinner/less energy needed to pressurise plant) **(1)**

catalyst speeds up reaction **(1)**
/allows a lower temperature to be used 3

Accept catalyst allows a lower pressure to be used

Reject lower temp/pressure easier to achieve

[4]

21. (i) Lower temperature as reaction is **exo**thermic/gives out heat /ΔH is –ve **(1)**
Higher/raise pressure as reaction moves towards fewer **gaseous** molecules **(1)** 2

Accept …as reverse reaction is endothermic

Accept … away from more gaseous molecules

*Reject …more gaseous **products***

(ii) Lowering temperature decreases reaction rate **(1)**

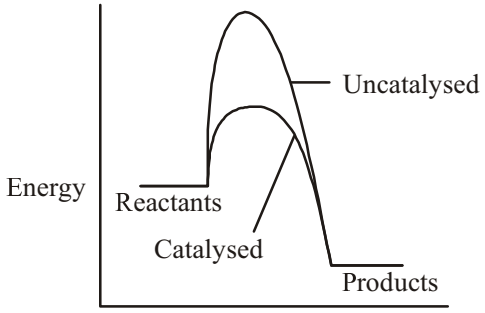
Increasing pressure increases reaction rate **(1)**

Accept increasing pressure increases number of collisions

Consequential on either/both parts of (i) 2

Check they are consistent with (i)

(iii) Energy of reactants above products 'hill' in between **(1)**
Lower 'hill' for catalysed reaction form same start to same finish **(1)**
Mark independently



2

Accept labelled activation energies
Accept double hump acceptable

[6]

22. (a) QWC
enthalpy/heat/energy **change** when 1 mole (of a substance) **(1)**

Accept "evolved" instead of "change"

Accept "sulphur" or "element" or "species" instead of "substance"

Reject heat/energy required

Reject "compound" instead of "substance"

is completely burned in oxygen /
burned in excess oxygen **(1)**

Reject reacts completely with oxygen

Any mention of specific products or specific amounts of products, other than SO2, negates 2nd mark

(all species) at 1 atm/100 kPa/105Pa/1 Bar **and** "a specified temperature" **(1)** 3

Accept ....298 K/ 25 °C /101 kPa
Or
*".....**a specified temperature** e.g. any value"*

Reject just "273 K"

Reject any mention of concentration negates third mark

(b) (i) QWC

Temperature

More molecules/collisions/ particles have
$E \geq E_{act}$ /sufficient energy to react **(1)**

Accept $E > E_{act}$
"energy barrier" instead of "E_{act}/activation energy"

Reject more atoms….

$\therefore$ a greater **proportion** of collisions are successful
Or
More **of** the collisions are successful **(1)**

*Accept collisions more **likely** to be successful*

Accept greater chance of successful…

Accept more successful collisions per second

Reject just "more successful collisions"

Reject "..fruitful collisions"

IGNORE greater frequency of collision

2nd mark dependent on 1st mark
UNLESS 1st mark is not awarded through use of "atoms"

Catalyst

EITHER:
provides alternative route of lower activation energy **(1)**

Accept "energy barrier" instead of "E_{act}/activation energy"

more molecules have $E > E_{cat}$ / a greater proportion of collisions are successful **(1)**

*Accept collisions more **likely** to be successful*

Accept greater chance of successful…

Accept more successful collisions per second

Reject just "more successful collisions"
N.B. Penalise "more collisions are successful" only once

Reject "..fruitful collisions"

2nd mark dependent on mention of lowered activation energy
Do not penalise use of "atoms" again

OR:
provides (active) sites **(1)**

where reactant molecules can bond/be adsorbed **(1)** 4

Reject where reaction can take place

(ii) QWC

reaction exothermic **(1)**

equilibrium shifts to the left decreasing the yield **(1)**
2nd mark is dependent on the 1st and is not consequential.

IGNORE Le Chatelier explanations 2

Accept ΔH negative/reverse reaction is endothermic

Reject just "equilibrium shifts to the left"

Reject just "yield decreases"

(iii) QWC

fewer (gaseous) molecules /particles/moles on the right **(1)**

equilibrium shifts to the right increasing the yield **(1)**

Reject just "equilibrium shifts to the right"

Reject just "yield increases"

2nd mark is dependent on the 1st and is not consequential.

IGNORE Le Chatelier explanations

N.B do not penalise omission of either 'equilibrium shifts' or change of yield if already penalised in (ii) 2

Reject arguments based on volume

(c) $\Delta H = \Delta H_f$ (products) – ΔH_f (reactants)
Or $(-814 \times 2) - (-286 \times 2)$ **(1)**

$= -1056$ (kJ mol^{-1}) **(1)**
IGNORE units

Correct answer with no working **(2)**

Omission of either or both of ×2 **max 1.** Hence
–242 with some working **(1)**
–1342 with some working **(1)**
–528 with some working **(1)**

(+)1056 with some working **(1)** 2

Reject ΔH_f values added scores zero overall

[13]

23. A

[1]