M1. (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

<u>lowers the activation energy</u>

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

2

[7]

M2. (a) minimum energy

1

to start a reaction/ for a reaction to occur/ for a successful collision

1

(b) activation energy is high / few molecules/particles have sufficient energy to react/few molecules/particles have the required activation energy

(or breaking bonds needs much energy)

1

(c) molecules are closer together/ more particles in a given volume

1

therefore collide more often

1

(d) many

1

<u>more molecules have energy greater than activation energy</u> (QoL)

1

(e) speeds up a reaction but is chemically unchanged at the end

1

(f) increases the surface area

1

[9]

M3. (a) (i) **M1** drawn curve <u>starts at reactants</u> and <u>ends at products</u>

Tapered lines into the original curve gain credit for M1

M2 curve peak is <u>below</u> the one drawn in the question
(and may show one/two humps)

Mark M1 and M2 independently

2

(ii) Exothermic (reaction)

Ignore "ΔH is negative"

1

(iii) Σ bond (enthalpy) <u>reactants</u> < Σ bond (enthalpy) <u>products</u>

The sum for H_2 and I_2/reactants is <u>less than/lower than/smaller than</u> the sum for 2HI/products
OR
The sum for 2HI/products is <u>more than/larger than/bigger than</u> the sum for H_2 and I_2/reactants

Accept "It OR the sum will be <u>smaller</u> or <u>less</u>"

1

(iv) **M1** p

2

M2 $-(q - p)$

OR

$p - q$

OR

$-q + p$

M2 demands that the sign for an exothermic reaction is part of the outcome mathematically.
Ignore case

(b) (i) Increase/speed up/faster (rate of attainment of equilibrium)

OR

Increase/speed up/faster rate of <u>both</u> forward <u>and</u> reverse reaction

OR

Increase/speed up/faster rate of reaction

Credit "It took less time"

1

(ii) **M1** Increase/speed up/faster (rate of attainment of equilibrium)

M2 <u>More particles/molecules</u> in a <u>given volume/space</u>
OR the <u>particles</u>/<u>molecules</u> are clos<u>er</u> together
OR an increase in concentration.

M3 More/higher chance of successful/effective/productive collisions (between particles)
OR <u>more collisions/higher chance of collisions (of particles) with $E>E_{Act}$</u>

If M1 is blank, mark on and credit M1 in the text

If M1 is given as "decrease"/"no effect"/"no change" then CE = 0 for clip

In M1, if increase <u>both</u> the forward and reverse reaction, but no mention of rate, penalise M1 but mark on.

In M1, if increase <u>either</u> forward rate <u>or</u> reverse rate <u>only</u>, then penalise M1 but mark on.

Penalise M3 if an increase in the value of E_{Act}/energy of particles is stated.

Max 1 for M2 and M3 if reference to "atoms"

3

[10]

M4. (a) Equation $1/2N_2 + 3/2H_2 \rightarrow NH_3$

1

$\Delta Hf = [(945 \times 0.5) + (426 \times 1.5)] – (391 \times 3)$

1

$= –46.5 \text{ kJ mol}^{-1}$

1

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
4-5	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2-3	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

(b) The higher the temperature the faster the reaction QWC **1**

but, since the reaction is exothermic **1**

the equilibrium yield is lower QWC **1**

The higher the pressure the greater the equilibrium yield QWC **1**

because there is a reduction in the number of moles of gas in the reaction **1**

but higher pressure is expensive to produce or plant is more expensive to build QWC

1

A better catalyst would lessen the time to reach equilibrium

1

and allow more ammonia to be produced in a given time QWC

1

[11]

M5. (a) (i) Oxidation

OR

Oxidised ONLY

1

(ii) Any one from

- to provide/overcome activation energy
- to provide the minimum energy to make the reaction go/start

NOT simply to increase the (initial) reaction rate.

1

(iii) The reaction is exothermic OR releases heat (energy)

1

(iv) M1
Catalysts provide an alternative route/pathway OR an alternative mechanism

OR

(in this case) surface adsorption occurs (or a description of adsorption)

Ignore reference to "surface" alone

M2
Lowers the activation energy

OR

of lower activation energy

2

(b) M1
The (forward) reaction is exothermic OR the (forward) reaction releases heat

OR

The reverse reaction is endothermic or absorbs heat

M2 – Direction of change N.B. M2 depends on correct M1
At lower temperatures,

- the equilibrium yield of NO_2 is greater
- more NO_2 is formed
- equilibrium shifts (left) to right
- (equilibrium) favours the forward reaction

(***OR*** converse for higher temperatures)

2

(c) NO_2 (+) 4

NO_3^- (+) 5

HNO_2 (+) 3

3

[10]

M6. (a) Peak lower

1

and moved to right

1

start at the origin and curve crosses once only

1

(b) (i) (Rate of reaction) <u>increases</u>

1

(At a higher temperature) <u>more molecules/particles</u>

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]