M1. (a) (i) $\Delta H = \Sigma$ bonds broken $-\Sigma$ bonds formed

1

= 944/2 + 3/2 × 436 –3 × 388

1

= –38 (kJ mol^{-1})

ignore units even if incorrect
correct answer scores 3
–76 scores 2/3
+38 scores 1/3

1

(ii) mean / average bond enthalpies are from a range of compounds
or
mean / average bond enthalpies differ from those in a single compound / ammonia

1

(b) $\Delta S = \Sigma S$ products $-\Sigma S$ reactants

1

= 193 – (192/2 + 131 × 3/2)

1

= –99.5 J K^{-1} mol^{-1}

units essential for M3
correct answer with units scores 3
–199 J K^{-1} mol^{-1} & –99.5 score 2/3
–199 and + 99.5 J K^{-1} mol^{-1} score 1/3

1

(c) (i) $\Delta G = \Delta H - T\Delta S$ = –46 + 800 × 99.5/1000

mark is for putting in numbers with 1000
if factor of 1000 used incorrectly CE = 0

1

= 33.6 or 33600

allow 33 to 34 (or 33000 to 34000)

1

kJ mol^{-1} with J mol^{-1}

correct units for answer essential

if answer to part (b) is wrong or if -112 used, mark consequentially e.g.

- *–199 gives 113 to 114 kJ mol^{-1} (scores 3/3)*
- *–112 gives 43 to 44 kJ mol^{-1} (scores 3/3)*

1

(ii) If answer to (c) (i) is positive: not feasible / not spontaneous

If answer to (c) (i) is negative: feasible / spontaneous

if no answer to (c) (i) award zero marks

1

[11]

M2. (a) **Three conditions <u>in any order</u> for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$
OR
$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

Penalise "bacteria" and "phosphoric acid" using the list principle

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 <u>6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up</u> (to form glucose or in photosynthesis)

1

M3 <u>6 (mol/molecules) CO_2/carbon dioxide</u> given out <u>due to</u>

2 (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

(c) **M1 (could be scored by a correct mathematical expression)**

(Sum of) bonds broken – (Sum of) bonds made/formed = Δ*H*

OR

$(\Sigma)\ B_{reactants} - (\Sigma)\ B_{products} = \Delta H$

(where B = bond enthalpy/bond energy)

For M1 there must be a correct mathematical expression using ΔH or "enthalpy change"

M2 Reactants = (+) 4719
OR
Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.

Ignore units.

M2 is for either value underlined

M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are not specific for this reaction *OR* they are average values from many different compounds/molecules

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol
therefore ΔH = **– 669** kJ mol^{-1} OR – **670** $kJmol^{-1}$

OR **–668.8** kJ mol^{-1}

Award M1, M2 and M3 for correct answer to the calculation

Penalise M3 ONLY if correct answer but sign is incorrect

In M1, do not penalise incorrect cases in the formula

If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3

If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770

Ignore incorrect units in M2

M4 Incomplete combustion

Do not forget to award this mark. Mark independently

4

[15]

M3. (a) (i) Reducing agent

OR

Reduce(s) (WO_3/tungsten oxide)

OR

electron donor

OR

to remove oxygen (from WO_3/tungsten oxide or to form water);

1

(ii) $WO_3 + \mathbf{3}H_2 \rightarrow W + \mathbf{3}H_2O$

Or multiples

1

(iii) *One from*

H_2 is

- explosive
- flammable or inflammable

- easily ignited

Ignore reference to pressure or temperature

1

(b) (i) Addition

Ignore "electrophilic"

Penalise "nucleophilic addition"

OR

(catalytic) hydrogenation

OR

Reduction

1

(ii) Geometric(al)

OR

cis/trans OR E Z OR E/Z

1

(c) (i) (If any factor is changed which affects an equilibrium), the position of equilibrium will shift/move/change/respond/act so as to oppose the change.

OR

(When a system/reaction in equilibrium is disturbed), the equilibrium shifts/moves in a direction which tends to reduce the disturbance

A variety of wording will be seen here and the key part is the last phrase and must refer to movement of the equilibrium.

QoL

1

(ii) **M1 – Statement of number of moles/molecules**

There are more moles/molecules (of gas) on the left/of reactants

OR

fewer moles/molecules (of gas) on the right./products

OR

there are 4 moles/molecules (of gas) on the left and 2 moles/ molecules on the right.

Ignore "volumes" for M1

Mark independently

M2 – Explanation of response/movement in terms of pressure
Increase in pressure is opposed (or words to that effect)

OR

pressure is lowered by a shift in the equilibrium (from left) to right/favours forward reaction.

2

(d) ΣB(reactants) – ΣB(products) = Δ*H* (**M1**)

OR

Sum of bonds broken – Sum of bonds formed = ΔH (**M1**)

B(H–H) + ½B(O=O) – 2B(O–H) = – 242 (**M1**)

B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**)

B(H–H) = (+)436 (kJ mol^{-1}) (**M3**)

Award 1 mark for – 436

Candidates may use a cycle and gain full marks.

M1 could stand alone

Award full marks for correct answer.

Ignore units.

Two marks can score with an arithmetic error in the working.

3

[11]

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

$= –46.5$ 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]