M1. (a) enthalpy change/ heat energy change when 1 mol of a substance **1**

is completely burned in oxygen **1**

at 298K and 100 kPa or standard conditions **1**

(not 1atm)

(b) $\Delta H = \sum$ bonds broken – $\sum$ bonds formed **1**

= (6 × 412) + 612 +348 + (4.5 × 496) – ((6 × 743) + (6 × 463)) **1**

= – 1572 kJ mol^{-1} **1**

(c) by definition ΔH_f is formation from an element **1**

(d) $\Delta H_c = \sum \Delta H_f$ products -$\sum \Delta H_f$ reactants or cycle **1**

= (3 × – 394) + (3 × –242) – (+20) **1**

= − 1928 kJ mol^{-1} **1**

(e) bond enthalpies are mean/average values **1**

from a range of compounds **1**

[12]

M2. (a) enthalpy (or energy) to break (or dissociate) a bond;

1

averaged over different molecules (environments);

1

enthalpy (or heat energy) change when one mole of a compound;

1

is formed from its elements;

1

in their standard states;

1

(b) enthalpy change = Σ(bonds broken) – Σ(bonds formed) or cycle;

1

= 4 × 388 +163 + 2 × 146 + 4 × 463 – (944 + 8 × 463);
(or similar)

1

= –789;
(+ 789 scores 1 only)

1

(c) (i) zero;

1

(ii) *AH* = Σ (enthalpies of formation of products)
–Σ (enthalpies of formation of reactants)

1

= 4 × –242-(75 + 2 × –133);

1

= –777;
(+ 777 scores one only)

1

(d) mean bond enthalpies are not exact
(or indication that actual values are different from real values)

1

[13]

M3. (a) $\Delta H = \Sigma$(bonds broken) – Σ(bonds formed) (or cycle)

1

= +146 – 496/2 (or 2 × 463 + 146 –(2 × 463 + 496/2)

1

= – 102 (kJ mol^{-1}) **(1)**

*(accept no units, wrong units loses a mark; +102 scores **(1)** only)*

1

(b) $C(s) + 2H_2(g) \rightarrow CH_4(g)$ equation **(1)** Correct state symbols **(1)**

2

(c) (i) Macromolecular

(accept giant molecule or carbon has many (4) bonds)

1

(ii) $\Delta H = \Sigma \Delta H_f$(products) – $\Sigma \Delta H_f$(reactants) (or cycle)

1

= 715 + 4 × 218 – (–74.9)

1

= 1662 (kJ mol^{-1})

(accept no units, wrong units loses one mark, allow 1660 to 1663, –1662 scores one mark only)

1

(iii) 1662/4 = 415.5

(mark is for divide by four, allow if answer to (c)(ii) is wrong)

1

[10]

M4. D

[1]

M5. (a) (Energy required) to break a given covalent bond **(1)**
averaged over a range of compounds **(1)**

Penalise first mark if 'energy' / 'enthalpy' evolved

2

(b) (i) 4 × C−H = 4 × 413 = +1652
1 × C−C = 1 × 347 = 347
1 × C=O = 1 × 736 = 736
2½ × O=O = 2.5 × 498 = 1245 **(1)**
= 2735 + 1245 = +3980 **(1)**

first mark for 4 : 1: 1 or 2735 ignore sign

(ii) 4 × H−O = -4 × 464 = –1856
4 × C−O = -4 × 736 = –2944 **(1)**
= –4800 **(1)**

First mark for 4 : 4

(iii) ΔH_R = ΣBonds broken − ΣBonds made
= +3980 − 4800 = −820 **(1)**

Conseq Mark for incorrect answers in (i) and (ii) as (i) Answer + (ii) Answer =

5

[7]

M6.(a) Enthalpy (Energy) to break a (covalent) bond **(1) OR dissociation energy**
Varies between compounds so average value used **(1) QL mark**

OR average of dissociation energies in a single molecule / e.g. CH_4

Do not allow mention of energy to form bonds but with this case can allow second mark otherwise 2nd mark consequential on first

2

(b) (i) 1/2 N_2 + 3/2 H_2 → NH_3 **(1)**

Ignore s s

(ii) $\Delta H = (\Sigma)$bonds broken $- (\Sigma)$bonds formed **(1)**
$= 1/2 \times 944 + 3/2 \times 436 - 3 \times 388$ **(1)**
$= -38$ kJ mol^{-1} **(1)**

Ignore no units, penalise wrong units
Score 2/3 for -76
1/3 for +38
Allow 1/3 for +76

4

(c) 4 (C–H) + (C=C) + (H–H) – (6 (C–H) + (C–C)) = –136 **(1)**
OR (C=C) + (H–H) – ((C–C) + 2 (C–H)) = –136
2 (C–H) = 836 **(1)**
(C–H) = 418 (kJ mol^{-1}) **(1)**

Note: allow (1) for –836
another (1) for –418

3

[9]