M1. (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]

M2. (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]

M3. (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) ΔH = 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]

M4.A

[1]

M5.B

[1]

M6. (a) (i) <u>enthalpy change</u> when 1 mol of a substance (or compound) (QL mark)

1

is (completely) burned in oxygen (or reacted in <u>excess</u> oxygen)

1

at 298 K and 100 kPa (or under standard conditions)

1

(ii) heat produced = mass of water × Sp heat capacity $x\Delta T$ (or $mc\Delta T$)

1

= 150 × 4.18 × 64 (note if mass = 2.12 lose first 2 marks then conseq) = 40100 J or = 40.1 kJ (allow 39.9 - 40.2 must have correct units)

1

moles methanol = mass/M_r = 2.12/32 (1)
= 0.0663

1

ΔH = – 40.1/0.0663 = – 605 kJ (mol^{-1})

1

(allow –602 to –608 or answer in J)

(note allow conseq marking after all mistakes but note use of 2.12 g loses 2 marks

(b) (i) equilibrium shifts to left at high pressure

1

because position of equilibrium moves to favour fewer moles (of gas)

1

(ii) at high <u>temperature</u> reaction yield is low (or at low <u>*T*</u> yield is high)

1

at low <u>temperature</u> reaction is slow (or at high <u>*T*</u> reaction is fast)

1

therefore use a balance (or compromise) between <u>rate</u> and <u>yield</u>

1

(c) $\Delta H = \Sigma\Delta H_c^{\ominus}$(reactants) – $\Sigma\Delta H_c^{\ominus}$(products) (or correct cycle)

1

$\Delta H_c^{\ominus}(CH_3OH) = \Delta H_c^{\ominus}(CO) + 2 \times \Delta H_c^{\ominus}(H_2) - \Delta H$

1

= (–283) + (2 × –286) – (–91) (mark for previous equation or this)
= –764 (kJ mol^{-1}) (*units not essential but lose mark if units wrong)*
(note + 764 scores 1/3)

1

[15]