

Mark Scheme - 2.1 Thermochemistry

1. Combustion of C and H₂ = (2 × -394) + (3 × -286)
 = -1646 kJ mol⁻¹ (1)
- $\Delta H = -1646 - (-1560) = -86 \text{ kJ mol}^{-1}$ (1) [2]

2.

- (a) (i) $2\text{C(s)} + 3\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{C}_2\text{H}_5\text{OH(l)}$ (state symbols needed)
 C(s) allowed as C(gr) or C(graphite) [1]
- (ii) (if these elements were reacted together) other products would form/
 carbon does not react with hydrogen and oxygen under standard
 conditions [1]
- (b) (i) energy = $100 \times 4.2 \times 54 = 22680$ [1]
- (ii) moles ethanol = $0.81/46 = 0.0176$ (1)
 energy change = $\frac{22.68}{0.0176}$ $\Delta H = -1290$ (1)
 -ve sign and correct to 3 sf (1) [3]
- (c) internet value numerically larger (1)
 heat losses / incomplete combustion / thermal capacity of calorimeter
 ignored (1) no credit for energy loss [2]
- (d) (i) $\text{C}_3\text{H}_7\text{OH} + 4\frac{1}{2}\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$ (ignore state symbols) [1]
- (ii) negative enthalpy change means energy in bonds broken is less than
 that in bonds made [1]
- (iii) more bonds broken and made in propanol and therefore more energy
 released [1]
- (e) any 4 from:
 both conserve carbon / non-renewable fuel sources / fossil fuels / use
 renewable sources
 (these gas / liquid) suitable for different uses e.g. ethanol to fuel cars
 atom economy gasification is less (some C lost as CO₂) / CO₂ produced in
 gasification is a greenhouse gas
 CO is toxic
 gasification at high temperature / enzymes need low temperature
 enzyme approach therefore saves fuel / gasification needs more energy [4]
 3 max if any reference to destruction of ozone layer
 QWC [2]
 The candidate has selected a form and style of writing that is appropriate to
 purpose and complexity of the subject matter (1)
 Answer has suitable structure (1)

3.

(a) Otherwise a temperature change would occur on adding the acid which had nothing to do with the reaction [1]

(b) (i) Best fit lines (1)

Temperature rise = 6.4 °C (1)
(Take value from candidate's best fit lines) [2]

(ii) Volume of acid = 26.0 cm³ [1]

[If no best fit lines award 0 in (i) and accept 25 cm³ in (ii)]

(c) Moles acid = 0.02425 (1)

Conc acid = $\frac{0.02425}{0.026} = 0.933 \text{ mol dm}^{-3}$ (1) [2]

(d) Heat = 51 × 4.18 × 6.4
= 1364 J [1]

(e) $\Delta H = \frac{-1364}{0.02425}$ (1)
= -56.2 kJ mol⁻¹ (1) [2]

(f) Pipette / burette [1]

(g) No further reaction occurs (1)

The excess acid cools the solution (1) [2]

(h) Heat/ energy is lost to the environment (1)

Insulation is improved e.g. lid on the polystyrene cup (1) [2]

Total [14]

4.

(a) The mass of one mole of compound [1]

(b) $\Delta H_f = -417 \text{ kJ mol}^{-1}$ [1]

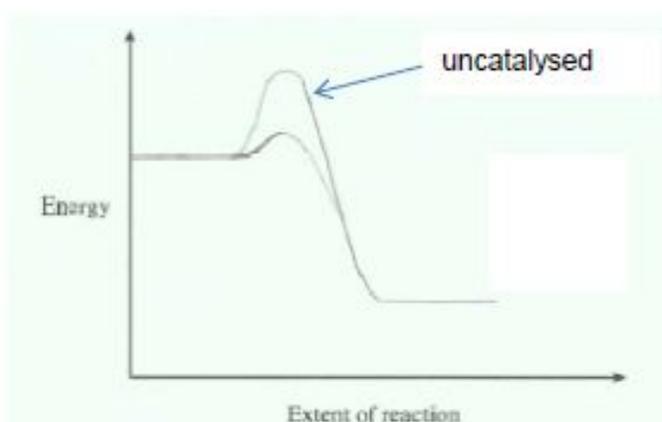
5.

(a) (i) They are both elements in their standard states. [1]

(ii) $\Delta H = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants}$ (1)
 $= (-286 + 0) - (-368 + 0)$
 $= -286 + 368 = (+)82 \text{ (kJ mol}^{-1}\text{)}$ (1) [2]

or by a cycle where correct cycle drawn (1) correct answer (1)

(b) (i)



exothermic profile drawn (1)
uncatalysed / catalysed line labelled (1) [2]

(ii) I number of moles of benzene = 2000 [1]

II mole ratio is 1 : 1 (1)

$$\therefore \text{moles of phenol produced} = \frac{2000 \times 94}{100} = 1900 \text{ (1)}$$

$$\text{mass} = M_r \times \text{number of moles} = 94 \times 1900 = 178.6 / 179 \text{ kg (1)}$$

alternatively

78 (g / kg) of benzene gives 94 (g / kg) of phenol (1)

\therefore 1 (g / kg) of benzene gives $94/78$ (g / kg) of phenol

\therefore 156 (kg) of benzene gives $94 \times 156/78$ (kg) of phenol = 188 (kg) (1)

but 95% yield $\therefore \frac{188 \times 95}{100} = 178.6 / 179$ (kg) (1) [3]

(iii) Look for at least four relevant positive points [4]

e.g.

- the process uses a (heterogeneous) catalyst, which can easily be separated from the gaseous products (thus saving energy)
- the only other product of the reaction is gaseous nitrogen, which is non-toxic / safe / not a harmful product
- the process uses nitrogen(I) oxide which is used up, rather than being released into the atmosphere from the other process (and causing global warming)
- the process is exothermic and the heat produced can be used elsewhere
- a relatively moderate operating temperature reduces overall costs
- high atom economy

Legibility of text; accuracy of spelling, punctuation and grammar;

clarity of meaning QWC [1]

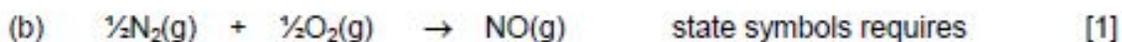
6.

- (a) (i) $M_r(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 249.7$ [1]
- (ii) I. Moles of copper(II) sulfate
 $= 0.250 \times 250/1000 = 6.25 \times 10^{-2}$ moles (1)
Mass = $6.25 \times 10^{-2} \times 249.7 = 15.6$ g (1) [2]
- II. 1 mark each for:
- Weighing method
 - Dissolve copper sulfate in a smaller volume of distilled water
 - Transfer to 250.0 cm^3 volumetric / standard flask
 - Use of funnel
 - Wash funnel / glass rod / beaker with distilled water into volumetric flask
 - Add distilled water up to mark
 - Shake solution / mix thoroughly 5 max [5]
- QWC: organisation of information clearly and coherently; use of specialist vocabulary where appropriate* [1]
- (b) (i) Powder has a greater surface area (1) so gives a higher rate of reaction (1) [2]
- (ii) Extrapolate lines from start (level at 21.3°C) and end (through points at 180-270 seconds) (1)
Temperature rise = 6.0°C (Range $5.8\text{-}6.2^\circ\text{C}$) (1) [2]
- (iii) I. Moles = $0.250 \times 0.05 = 1.25 \times 10^{-2}$ moles [1]
- II. Zinc is the limiting reagent / Copper(II) sulfate is in excess [1]
- III. $\Delta H = -(50) \times 4.18 \times 6.0 \div (6.12 \times 10^{-3})$ (1)
 $\Delta H = -204902 \text{ J mol}^{-1}$
 $\Delta H = -205 \text{ kJ mol}^{-1}$ (1) [2]
- IV. Enthalpy measures chemical energy, and as heat energy increases, chemical energy must decrease [1]

Total [18]

7.

(a) $\Delta H = \Delta H_2 + \Delta H_3 - \Delta H_1$ [1]



8.

enthalpy changes = -110 [1]

9.

(a) percentage Be by mass = 5.03% (1)

division of percentage by A_r for Be and at least one other element as shown below (1)

Al $10.04 \div 27 = 0.3719 \rightarrow 1.00$

Be $5.03 \div 9.01 = 0.5583 \rightarrow 1.50$

O $53.58 \div 16 = 3.3488 \rightarrow 9.00$

Si $31.35 \div 28.1 = 1.1566 \rightarrow 3.10$

molecular formula = $\text{Al}_2\text{Be}_3\text{O}_{18}\text{Si}_6$ or $x=3$ (1) [3]

(b) (i) Hess' Law states that where a reaction can occur by more than one route the total enthalpy change for each route will be the same [1]

(ii) $\Delta H = -393.5 - (-395.4)$ (1) = $+1.9 \text{ kJ mol}^{-1}$ (1) [2]

(iii) Kyran is incorrect as diamond is not the standard state of carbon [1]

(iv) I mass of diamond = 7.30 g [1]

II mass of graphite = $7.30 \div (93/100)$ (1) = 7.85 g (1) [2]

Total [10]

10.

- (a) (i) $\Delta H = 9 \times (-394) + 10 \times (-286) - (-275)$ (1)
 $= -6131 \text{ kJ mol}^{-1}$ (1) for correct value and (1) for correct sign [3]
- (ii) temperature 298K, 25°C (1) pressure 1 atm, 101 kPa (1) [2]
- (b) (i) $M_r = (9 \times 12) + (20 \times 1.01) = 128.2$ (1)
number of moles = $1.56 \times 10^{-3} \text{ mol}$ (1) [2]
- (ii) $\Delta H = -50 \times 4.18 \times 42 \div 1.56 \times 10^{-3}$ (1)
 $= -5626698 \text{ J mol}^{-1} = -5627 \text{ kJ mol}^{-1}$ (1) [2]
- (iii) heat loss to environment / incomplete combustion / not standard conditions [1]
- Total [10]