### Question 1

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Mark Scheme Details</th>
<th>Part Mark</th>
</tr>
</thead>
</table>
| 2. (a)          | \[ C_2H_4 \rightarrow H_2O \rightarrow C_1H_5OH \]  
\[ -1416 \]  
\[ -1567 \]  
\[ \Delta H = \frac{2}{1} \text{kJ} \text{ mol}^{-1} \] | 2 |
| (b) (i)         | *\( \Delta H \) when 1 mol \( H \) in substance is completely combusted (i) | |
|                 | Under standard conditions \( H_2O \) and \( C_2H_5OH \) are liquids (i) | |
| (ii)            | \[ C_2H_5OH + 5O_2 \rightarrow 2CO_2 + 3H_2O \] (i) | 4 |
| (c)             | \[ C_2H_5 \rightarrow O^{+} \rightarrow H^+ \]  
\[ \text{H bond} \]  
\[ \text{H bond} \]  
|                  | Dipole (i)  
\[ \text{H bond} \] (i) | 2 |

*Some energy reference required.*

**Total 8**

### Question 2

(d) \( C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(g) \)

<table>
<thead>
<tr>
<th>Bonds Broken</th>
<th>Energy (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>2(H-C)</td>
<td>2 x 410 = 820</td>
</tr>
<tr>
<td>C=C</td>
<td>840</td>
</tr>
<tr>
<td>5/2(O=O)</td>
<td>5/2 x 496 = 1240</td>
</tr>
<tr>
<td></td>
<td>2900 kJ mol(^{-1})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bonds Made</th>
<th>Energy (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4(C=O)</td>
<td>4 x 740 = 2960</td>
</tr>
<tr>
<td>2(O-H)</td>
<td>2 x 460 = 920</td>
</tr>
<tr>
<td></td>
<td>3880 kJ mol(^{-1})</td>
</tr>
</tbody>
</table>

\[ \Delta H_{\text{comb}} = -3880 + 2900 = -980 \text{ kJ mol}^{-1} \]

allow e.c.f. on incorrect bonds made/broken **[3]**
(e) (i) the enthalpy/energy change when one mole of a substance (1)
is burned in an excess of air/oxygen
or completely combusted
under standard conditions (1)
(ii) calculation in (d) includes H₂O(g) whereas ΔHₜₜₚₚ involves H₂O(l)
or average bond energy terms are used in the Data Booklet (1) [3]

Q:3

1 (a) enthalpy change when 1 mol of a compound is formed (1)
from its elements (1)
in their standard states under standard conditions (1) [3]

(b) (i) \[ \text{N}_2\text{H}_4(l) + \text{O}_2(g) \rightarrow \text{N}_2(g) + 2\text{H}_2\text{O}(g) \]
\[ \Delta H^\circ_{\text{reaction}}^o = 2(-241.8) - (+50.6) \]
\[ = -534.2 \text{ kJ mol}^{-1} \]
(ii) \( E_a \) is too high (1)
(iii) products are H₂O and N₂ which are harmless/non toxic
or are already present in the atmosphere (1) [4]

Q:4

2 (a) (i) new graph has lower maximum (1)
maximum is to the right of previous maximum (1)

(ii) \( H \) is at \( E_a \) (1) [3]

(b) the minimum amount of energy molecules must have or energy required (1)
in order for the reaction to take place (1) [2]

Q:5

d) (i) combustion
\[ \text{C}_2\text{H}_2(g) + \frac{5}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + \text{H}_2\text{O}(l) \] or
equation must be for the combustion of one mole of C₂H₂
H₂O must be shown as liquid
correct state symbols in this equation (1)

formation
\[ 2\text{C}(s) + \text{H}_2(g) \rightarrow \text{C}_2\text{H}_2(g) \]
no mark for state symbols here (1)
(ii) let \( \Delta H^\circ_f \) of \( \text{C}_2\text{H}_2 \)

\[
\text{C}_2\text{H}_2 + \frac{5}{2}\text{O}_2 \rightarrow 2\text{CO}_2 + \text{H}_2\text{O}
\]

\[
\Delta H^\circ_f \text{ C}_2\text{H}_2 = -1300 = 2(-394) + (-286) - z
\]

whence \( z = 2(-394) + (-286) - (-1300) = +226 \text{ kJ mol}^{-1} \)

Q:6

3 (a) \( \text{C}(s) + \text{O}_2(g) \rightarrow \text{CO}_2(g) \)

the enthalpy change/energy change/heat change when

one mole of a compound/\( \text{CO}_2 \)

is formed from its elements in their standard states

(b) (i) \( \text{CO}_2(g) + 3\text{H}_2(g) \rightleftharpoons \text{CH}_3\text{OH}(g) + \text{H}_2\text{O}(g) \)

\[
\Delta H^\circ/\text{kJ mol}^{-1} = -394 + 0 -201 -242
\]

\[\Delta H^\circ_{\text{reaction}} = -201 + (-242) - (-394) = -49 \text{ kJ mol}^{-1}\]

(ii) removal of \( \text{CO}_2 \) from the atmosphere

\( \text{CO}_2 \) is a greenhouse gas/causes global warming

Q:7

2 (a) \( \text{CH}_3\text{OH}(l) + \frac{3}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(l) \)

the enthalpy change/heat change/heat evolved when

one mole of \( \text{CH}_3\text{OH} \)

is completely burned or

is burned in an excess of air/oxygen

(b) \( \Delta H^\circ_{\text{reaction}} = -283 + 2(-286) - (-726) = -129 \text{ kJ mol}^{-1} \)
Q:8

(a) $\text{CH}_3\text{OCH}_3(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$

The enthalpy change/heat change/heat evolved when one mole of CH$_3$OCH$_3$/a compound is completely burned or burned in an excess of air/oxygen

(b) $2\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OCH}_3(\text{g}) + \text{H}_2\text{O}(\text{l})$

$\Delta H^\circ_\text{f} / \text{kJ mol}^{-1}$

\[\begin{align*}
\Delta H^\circ_\text{f} & = \begin{array}{c}
2(-239) \\
-184 \\
-286
\end{array} \\
\Delta H^\circ_{\text{reaction}} & = -184 + (-286) - 2(-239) \\
& = +8 \text{ kJ mol}^{-1}
\end{align*}\]

Correct sign

Q:9

(c) Let $\Delta H^\circ$ for NO be $y$ kJ mol$^{-1}$

\[\text{4NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightleftharpoons 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})\]

$\Delta H^\circ$ $4 \times (-46.0) \\
\Delta H^\circ_{\text{reaction}} = 4y + [6 \times (-242)] - [4 \times (-46.0)] \\
= 4y - 1452 + 184

\Delta H^\circ_{\text{reaction}}$ is $-906 \text{ kJ mol}^{-1}$ so

\[\begin{align*}
4y & = -906 + 1452 - 184 \\
& = 362
\end{align*}\]

Whence $y = \Delta H^\circ$ for NO $= +90.5 \text{ kJ mol}^{-1}$

+ sign is required
Q:10

1 (a) (i) 

S atom has 6 and C atom has 4 electrons (1)
S=O double bonds (4 electrons) clearly shown (1)
(ii) linear and 180° (1)

(b) (i) \( \text{CS}_2 + 3\text{O}_2 \rightarrow \text{CO}_2 + 2\text{SO}_2 \) (1)
(ii) enthalpy change when 1 mol of a substance
is burnt in an excess of oxygen/air
or is completely combusted
under standard conditions (1)

(c) \[
\begin{align*}
\Delta H^\circ/\text{kJ mol}^{-1} & \quad \text{CS}_2 + 3\text{O}_2 \rightarrow \text{CO}_2 + 2\text{SO}_2 \\
\Delta H_{\text{reaction}} & \quad = -395 + 2(-298) - x = -1110 \text{kJ mol}^{-1} \\
gives & \quad x = -395 + (-596) + 1110 = +119 \text{kJ mol}^{-1}
\end{align*}
\]

Q:11

\[
\begin{align*}
\text{H}_2\text{O} + \text{Ca}(\text{NH}_2)_2 & \rightarrow 2\text{NH}_3 + \text{CO}_2 \\
-287 & \quad + (-322.5) \quad \rightarrow -162 - 414.5 \quad (1) \\
-607.5 & \quad \rightarrow -576.5
\end{align*}
\]
\[ \Delta H = 31 \text{ kJ mol}^{-1} \quad (1) \]

Q:12
3 (a) (i) energy/enthalpy change when 1 mol of a compound is formed from its elements at 25°C and 1 atm

\[ \text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \]

(b) (i) \[ \text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2 \]

(ii) heat released = \( mc \Delta T \)

\[ = 200 \times 4.2 \times 12.2 = 10.25 \text{ kJ} \]

(iii) \( \Delta H_{\text{reacn}} = 40.1 \times (-10.25) = -411 \text{ kJ mol}^{-1} \) sign necessary for ecf, \( \Delta H_{\text{reacn}} = 40.1 \times [\text{answer to (b)(ii)]} \)

(c) (i) The enthalpy (energy) change for converting reactants into products is the same regardless of the route taken

(ii) \[ \text{Ca(s)} + 2\text{H}_2\text{O(}l) \rightarrow \text{Ca(OH)}_2(\text{aq}) + \text{H}_2(\text{g}) \]

\( \Delta H_{\text{f}} = 2 \times (-286) \)

\[ \Delta H_{\text{reacn}} = x - 2(-286) = -411 \]

x = \(-411 + 2(-286) = -983 \text{ kJ mol}^{-1} \) sign necessary for ecf, x = answ. to (b)(iii) + (572)

(d) 40.1 g of Ca give 24000 cm\(^3\) of \( \text{H}_2 \)

1 g of Ca gives \( \frac{24000}{40.1} \) = 598.5 cm\(^3\) units needed allow 40 g of Ca giving 600 cm\(^3\)

Q: 13

(d) (i) \( \Delta H_{\text{reacn}} = \Delta H \) for bonds broken – \( \Delta H \) for bonds made

(ii) \[ 2\text{H} - \text{I} \rightarrow \text{H} - \text{H} + \text{I} - \text{I} \]

\[ 2 \times 299 \]

436 151 values

\[ \Delta H = 2 \times 299 - (436 + 151) \]

\[ = + 11 \text{ kJ mol}^{-1} \]
Q: 14

2

(a)

sulphur atom has 6 /carbon atom has 4 electrons

S=C double bonds (4 electrons) clearly shown

(b) linear

180°

(c) the enthalpy change when 1 mol of a compound

is formed from its elements in their standard states

under standard conditions (may be quoted)

(d)

\[
\begin{align*}
C + O_2 & \rightarrow CO_2 & -395 \\
S + O_2 & \rightarrow SO_2 & -298 \\
CS_2 + 3O_2 & \rightarrow CO_2 + 2SO_2 & -1110 \\
C + 2S & \rightarrow CS_2 & \Delta H = -395 + 2(-298) - (-1110) \\
\end{align*}
\]

\[= +119 \text{ kJ mol}^{-1}\]

cycle (1) use of 2 for S/\text{SO}_2 (1) answer (1)

Q: 15

(d) enthalpy change when 1 mol of a substance

is burnt in an excess of oxygen/air

or undergoes complete combustion

under standard conditions

(e) (i) heat released = mc \delta T = 200 \times 4.18 \times 27.5

\[= 22990 \text{ J} = 23.0 \text{ kJ}\]

(If candidate uses 4.2 answer is 23.1 kJ.)

(ii) 23.0 kJ produced from 0.47 g

\[2059 \text{ kJ produced from } \frac{0.47 \times 2059}{23.0} \text{ g}\]

\[= 42.08 \text{ g}\]

(Use of 4.2 gives 41.89 g.)

allow ecf from (i) (1)
Q: 16

(e) \( \Delta H^\circ = 2(-393.7) + 2(-285.9) - (-1411) \)

\[ = +51.8 \text{ kJ mol}^{-1} \text{(units given in equiv.)} \]  

penalise errors:
- no 2 for -393.7
- no 2 for -285.9
- wrong sign for -(-1411)  

Q: 17

(c) (i) enthalpy change when
- 1 mol of a compound is formed (1)
- from its elements (1)
- in their standard states under standard conditions (1)

(ii) \[ \begin{array}{ll}
\text{C} + \text{O}_2 & \rightarrow \text{CO}_2 \\
\text{H}_2 + \frac{1}{2}\text{O}_2 & \rightarrow \text{H}_2\text{O} \\
\text{C}_2\text{H}_2\text{O} + 2\text{O}_2 & \rightarrow 2\text{CO}_2 + \text{H}_2\text{O} \\
2\text{C} + \text{H}_2 + \frac{1}{2}\text{O}_2 & \rightarrow \text{C}_2\text{H}_2\text{O} \quad \Delta H = 2(-395) + (-286) - (-1028) \\
& = -48 \text{ kJ mol}^{-1} \\
\end{array} \]

- correct cycle (1)
- use of 2 for C/CO\textsubscript{2} (1)
- answer (1)

Q: 18

3 (a) (i) \( \begin{array}{ll}
\Delta H^\circ & \text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl} \\
-75 & 0 \\
-82 & -92
\end{array} \)  

\[ \Delta H^\circ_{\text{reaction}} = -82 + (-92) - (-75) \]

\[ = -99 \text{ kJ mol}^{-1} \]  

(ii) \( \begin{array}{ll}
\text{CH}_4 + \text{I}_2 & \rightarrow \text{CH}_3\text{I} + \text{HI} \\
\text{broken} & \text{made} \\
\text{C}–\text{H} & \text{C}–\text{I} \\
410 & 240 \\
\text{I}–\text{I} & \text{H}–\text{I} \\
151 & 299
\end{array} \)  

\[ \Delta H^\circ_{\text{reaction}} = -240 + (-299) + 410 + 151 \]

\[ = +22 \text{ kJ mol}^{-1} \]  

(iii) activation energy is too great
Q:19

(d) enthalpy change when 1 mol of a substance (1)

is burnt in an excess of oxygen/air under standard conditions
or is completely combusted under standard conditions (1) [2]

(e) (i) heat released = m c \delta T = 200 \times 4.18 \times 27.5 (1)

= 22990 \text{ J} = 23.0 \text{ kJ} (1)

(ii) 23.0 \text{ kJ produced from 0.47 g of E}

2059 \text{ kJ produced from } \frac{0.47 \times 2059}{23.0} \text{ g of E} (1)

= 42.08 \text{ g of E} (1)

allow ecf in (i) or (ii) on candidate’s expressions [4]

(f) \text{C}_3\text{H}_6 = 42

\text{E is C}_3\text{H}_6

for ecf, \text{E must be unsaturated and be no larger than C}_3 (1) [1]
Q:20

3. (a) the overall enthalpy change/energy change/$\Delta H$ for a reaction

is independent of the route taken or
is independent of the number of steps involved
provided the initial and final conditions are the same

(b) (i) $\text{K}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O} + \text{CO}_2$

(ii) heat produced $= m \times c \times \delta T = 30.0 \times 4.18 \times 5.2$

$= 652.08$ J per 0.0200 mol of $\text{K}_2\text{CO}_3$

(iii) 0.0200 mol $\text{K}_2\text{CO}_3 = 652.08$ J

$1$ mol $\text{K}_2\text{CO}_3 = \frac{652.08 \times 1}{0.0200} = 32604$ J

enthalpy change $= -32.60$ kJmol$^{-1}$

(iv) to prevent the formation of $\text{KHCO}_3$ or
to ensure complete neutralisation

(c) (i) $\text{KHCO}_3 + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2$

(ii) heat absorbed $= m \times c \times \delta T = 30.0 \times 4.18 \times 3.7$

$= 463.98$ J per 0.0200 mol of $\text{KHCO}_3$

(iii) 0.0200 mol $\text{KHCO}_3 = 463.98$ J

$1$ mol $\text{KHCO}_3 = \frac{463.98 \times 1}{0.0200} = 23199$ J

enthalpy change $= +23.20$ kJmol$^{-1}$

(d) $\Delta H = 2 \times (+23.20) - (-32.60) = +79.00$ kJ mol$^{-1}$
Q:21

\[
(d) \quad (i) \quad m = \frac{pV}{RT} = \frac{1.01 \times 10^5 \times 125 \times 10^{-6} \times 44}{8.31 \times 293} \quad \text{g}
\]

\[
= 0.228147345 \quad \text{g}
\]

\[
= 0.23 \quad \text{g}
\]

(ii) heat released = m c \delta T = 200 \times 4.18 \times 13.8 \quad \text{J}

\[
= 11536.8 \quad \text{J} = 11.5 \quad \text{kJ}
\]

(iii) 0.23 g of propane produce 11.5 kJ

\[
44 \quad \text{g of propane produce} \quad \frac{11.5 \times 44}{0.23} \quad \text{kJ}
\]

\[
= 2200 \quad \text{kJ mol}^{-1}
\]

Q:22

(c) enthalpy change when 1 mol of a substance
is burnt in an excess of oxygen/air under standard conditions
or is completely combusted under standard conditions

(d) working must be shown

(i) heat released = m c \delta T = 250 \times 4.18 \times 34.6

\[
= 36157 \quad \text{J} = 36.2 \quad \text{kJ}
\]

(ii) \[ M_r \] of \[ \text{C}_{14}\text{H}_{30} = 198 \]

mass of \[ \text{C}_{14}\text{H}_{30} = 1.00 \times 0.763 = 0.763 \quad \text{g} \]

0.763 g of \[ \text{C}_{14}\text{H}_{30} \] produce 36.2 kJ

\[
198 \quad \text{g of} \quad \text{C}_{14}\text{H}_{30} \quad \text{produce} \quad \frac{36.2 \times 198}{0.763}
\]

\[
= 9394 \quad \text{kJ mol}^{-1}
\]