Q:1

Question Number	Mark Scheme Details	Part Mark
2 (a)	$C_2H_4 + H_2O \longrightarrow C_2H_5OH$ -1411 -1367 $\Delta H = ^{(1)} 44^{(1)} kJ mol^{-1}$	[2]
(b) (i)	*ΔH when 1 mol of element or compound(1) a substance is completely combusted (1)	
(ii)	Under standard conditions H_2O & C_2H_5OH are liquids(1)	
(iii)	$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$ (1)	4

(c)	$C_2H_5 - O \overset{\delta-}{} \cdots H^{\delta+}$ H bond or $C_2H_5 - O^{\delta-}$
	
	dipole (1)
	H bond (1) $O - H$ $H^{\delta+}$
	                             $O - H$
	                             H
	
	$[Total\ 8]$
	
	* Some energy reference required.
		2

Q:2

(d) $C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$
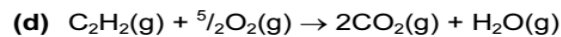
bonds broken: 2(H-C)   2 x 410   =   820
                 C≡C   840   =   840
                 $\frac{5}{2}$(O=O) $\frac{5}{2}$ x 496   =   <u>1240</u>
                                       2900   kJ mol^{-1} **(1)**

bonds made: 4(C=O)   4 x 740   =   2960
                 2(O-H)   2 x 460   =   <u>920</u>
                                       3880   kJ mol^{-1} **(1)**

ΔH_{comb} = -3880 + 2900 = -980 kJ mol^{-1} **(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 $H_2O(g)$ whereas ΔH_{comb} involves $H_2O(l)$
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)** $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$
$\Delta H_f^{\circ}/kJ\ mol^{-1}$ +50.6   −241.8
$\Delta H^{\circ}_{reaction} = 2(-241.8) - (+50.6)$ (1)
                  $= -534.2\ kJ\ mol^{-1}$ (1)

(ii) E_a is too high (1)

(iii) products are H_2O and N_2 which are harmless/non toxic
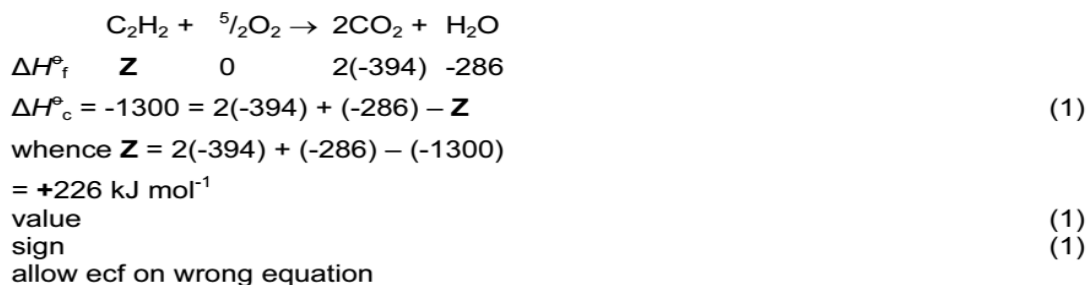**or** are already present in the atmosphere (1)   **[4]**

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**
$C_2H_2(g) + {}^5/_2O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ **or**
equation must be for the combustion of one mole of C_2H_2
 H_2O must be shown as liquid   (1)
correct state symbols in this equation   (1)

formation
$2C(s) + H_2(g) \rightarrow C_2H_2(g)$
no mark for state symbols here   (1)

(ii) let **Z** be ΔH°_f of C_2H_2

$$C_2H_2 + \tfrac{5}{2}O_2 \rightarrow 2CO_2 + H_2O$$

ΔH°_f **Z**   0   2(-394)   -286

$\Delta H^\circ_c = -1300 = 2(-394) + (-286) - \mathbf{Z}$ (1)

whence $\mathbf{Z} = 2(-394) + (-286) - (-1300)$

$= \mathbf{+226}$ kJ mol^{-1}
value   (1)
sign   (1)
allow ecf on wrong equation   [6]

Q:6

3   **(a)** $C(s) + O_2(g) \rightarrow CO_2(g)$ (1)
the enthalpy change/energy change/heat change when
one mole of a compound/CO_2 (1)
is formed from its elements in their standard states   (1)

(b) (i) $CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$
ΔH°_f/kJ mol^{-1} -394 0 -201 -242

$\Delta H^\circ_{reaction} = -201 + (-242) - (-394)$ (1)
-49 kJ mol^{-1} (1)
correct sign   (1)

(ii) removal of CO_2 from the atmosphere   (1)
CO_2 is a greenhouse gas/causes global warming   (1)

Q:7

2   **(a)** $CH_3OH(l) + \tfrac{3}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ (1)
the enthalpy change/heat change/heat evolved when
one mole of CH_3OH (1)
is completely burned **or**
is burned in an excess of air/oxygen   (1)

(b) $\Delta H^\circ_{reaction} = -283 + 2(-286) - (-726)$ (1)
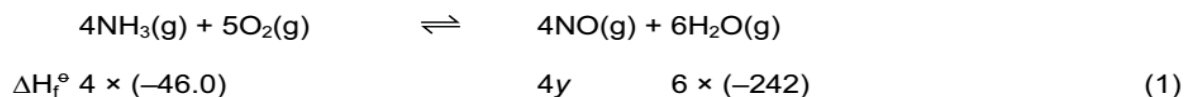$= -129$ kJ mol^{-1} (1)
correct sign   (1)

Q:8

(a) $CH_3OCH_3(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ (1)

the enthalpy change/heat change/heat evolved when
one mole of CH_3OCH_3/a compound (1)
is completely burned **or**
burned in an excess of air/oxygen (1)

(b)

	$2CH_3OH(l)$	$\rightarrow$	$CH_3OCH_3(g)$	$+$	$H_2O(l)$
$\Delta H^{\ominus}_f$ /kJ mol^{-1}	2(–239)		–184		–286

$\Delta H^{\ominus}_{reaction} = -184 + (-286) - 2(-239)$ (1)
$\quad\quad\quad\quad = +8$ kJ mol^{-1} (1)
correct sign (1)

Q:9

(c) let $\Delta H_f^{\ominus}$ for NO be y kJ mol^{-1}

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

$\Delta H_f^{\ominus}$ 4 × (–46.0) $4y$ 6 × (–242) (1)

$\Delta H^{\ominus}_{reaction} = 4y + [6 \times (-242)] - [4 \times (-46.0)]$ (1)
$\quad\quad\quad\quad = 4y - 1452 + 184$

$\Delta H^{\ominus}_{reaction}$ is –906 kJmol^{-1} so
$4y = -906 + 1452 - 184 = 362$ (1)
whence $y = \Delta H_f^{\ominus}$ for NO = +90.5 kJ mol^{-1}
+ sign is required (1)

Q:10

1 (a) (i)

$$S \overset{\circ\ \circ}{\underset{\circ\ \circ}{\times\!\!\times}} C \overset{\circ\ \circ}{\underset{\circ\ \circ}{\times\!\!\times}} S$$

       S atom has 6 **and C** atom has 4 electrons   (1)

       S=C double bonds (4 electrons) clearly shown   (1)

    (ii)   linear **and** 180°   (1)

  (b) (i) $CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$ (1)
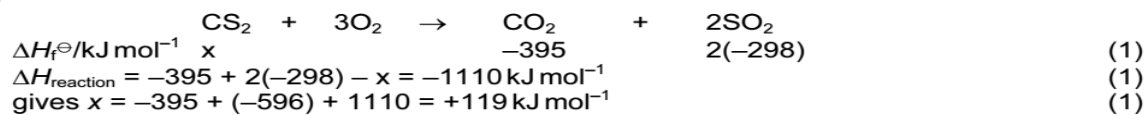
    (ii)   enthalpy change when 1 mol of a substance   (1)

       is burnt in an excess of oxygen/air
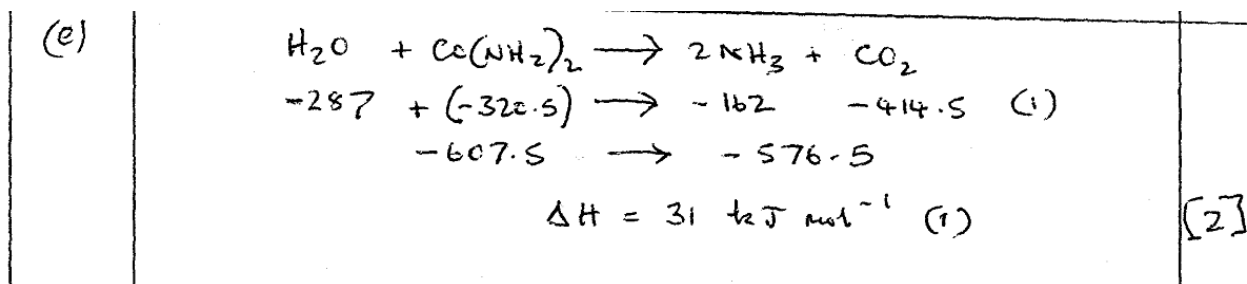
       or is completely combusted

   under standard conditions   (1)

  (c)

	CS_2	+	$3O_2$	$\rightarrow$	CO_2	+	$2SO_2$
$\Delta H_f^{\ominus}/\text{kJ mol}^{-1}$	x				−395		2(−298)

$\Delta H_{\text{reaction}} = -395 + 2(-298) - x = -1110 \text{ kJ mol}^{-1}$ (1)

gives $x = -395 + (-596) + 1110 = +119 \text{ kJ mol}^{-1}$ (1)

                                                        (1)

Q:11

(e)

$$H_2O + Co(NH_2)_2 \longrightarrow 2NH_3 + CO_2$$
$$-287 + (-320.5) \longrightarrow -162 \quad -414.5 \quad (i)$$
$$-607.5 \longrightarrow -576.5$$
$$\Delta H = 31 \text{ kJ mol}^{-1} \quad (1)$$

[2]

Q:12

5

3 (a) (i) energy/enthalpy change when 1 mol of a compound is
formed from its elements (1)

at 25°C and 1 atm (1)

(ii) $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ (1)

(b) (i) $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ (1)

(ii) heat released = $mc\Delta T$ (1)

= 200 x 4.2 x 12.2 = 10.25 kJ (1)

(iii) ΔH_{reacn} = 40.1 x (–10.25) = –411 kJ mol^{-1} sign necessary

for ecf, ΔH_{reacn} = 40.1 x [answer to **(b)(ii)**]

(1) **[4]**

(c) (i) The enthalpy (energy) change for converting reactants into
products (1)

is the same regardless of the route taken (1)

(ii) $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ ΔH = –411
$\Delta H^{\ominus}_f$ 2 x (–286)   x

ΔH_{reacn} = x – 2(–286) = –411 (1)

x = –411 + 2(–286) = –983 kJ mol^{-1} (1)
sign necessary

for ecf, x = ans. to (b)(iii) + (–572) **[4]**

(d) 40.1 g of Ca give 24000 cm^3 of H_2 (1)

1 g of Ca gives $\frac{24000}{40.1}$ = 598.5 cm^3 units needed

allow 40 g of Ca giving 600 cm^3 (1) **[2]**

Q: 13

(d) (i) ΔH_{reacn} = ΔH for bonds broken – ΔH for bonds made (1)

(ii) $2H – I \rightarrow H – H + I – I$
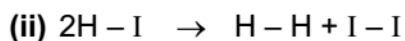
2 x 299   436 151 values (1)
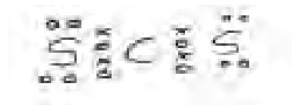
ΔH = 2 x 299 – (436 + 151)

= + 11 kJ mol^{-1} (1) **[3]**

Q: 14

2 **(a)**

sulphur atom has 6 /carbon atom has 4 electrons (1)

S=C double bonds (4 electrons) clearly shown (1) **[2]**

(b) linear (1)

$180°$ (1) **[2]**

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

is formed from its elements in their standard states (1)

under standard conditions (may be quoted) (1) **[3]**

(d) $C + O_2 \rightarrow CO_2$ -395

$S + O_2 \rightarrow SO_2$ -298

$CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$ -1110

$C + 2S \rightarrow CS_2$ $\Delta H = -395 + 2(-298) - (-1110)$

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

cycle (1)   use of 2 for S/SO$_2$ (1)   answer (1) **[3]**

Q: 15

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

is burnt in an excess of oxygen/air
or undergoes complete combustion
under standard conditions (1)

(e) **(i)** heat released = m c δT = 200 x 4.18 x 27.5 (1)

= 22990 J = 23.0 kJ

(If candidate uses 4.2 answer is 23.1 kJ.) (1)

(ii) 23.0 kJ produced from 0.47 g

2059 kJ produced from $\dfrac{0.47 \times 2059}{23.0}$ g (1)

= 42.08g

(Use of 4.2 gives 41.89 g.)

allow ecf from **(i)** (1)

7

Q: 16

(e) $\Delta H_f^\circ = 2(-393.7) + 2(-285.9) - (-1411)$
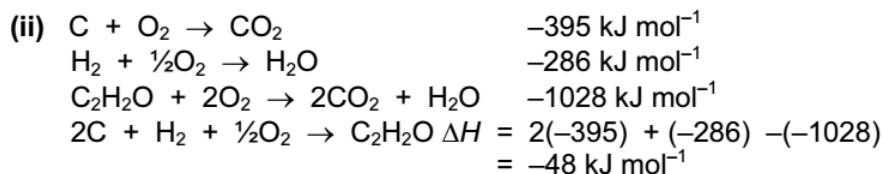
$= +51.8 \text{ kJ mol}^{-1}$(units given in qu.) (3)

penalise errors: no 2 for -393.7
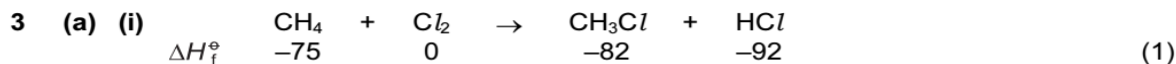no 2 for -285.9
wrong sign for $-(-1411)$ [3]

Q: 17

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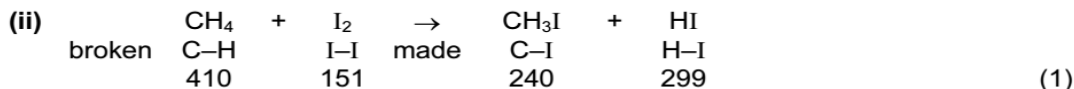in their standard states under standard conditions (1)

(ii) $C + O_2 \rightarrow CO_2$ -395 kJ mol^{-1}
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$ -286 kJ mol^{-1}
$C_2H_2O + 2O_2 \rightarrow 2CO_2 + H_2O$ $-1028 \text{ kJ mol}^{-1}$
$2C + H_2 + \frac{1}{2}O_2 \rightarrow C_2H_2O$ $\Delta H = 2(-395) + (-286) - (-1028)$
$= -48 \text{ kJ mol}^{-1}$
correct cycle (1)   use of 2 for C/CO_2 (1)   answer (1) [6]

Q: 18

3 (a) (i)

	CH_4	+	Cl_2	$\rightarrow$	CH_3Cl	+	HCl
ΔH_f°	-75		0		-82		-92

(1)

$\Delta H_{reaction}^\circ = -82 + (-92) - (-75)$
$= -99 \text{ kJ mol}^{-1}$ (1)

(ii)

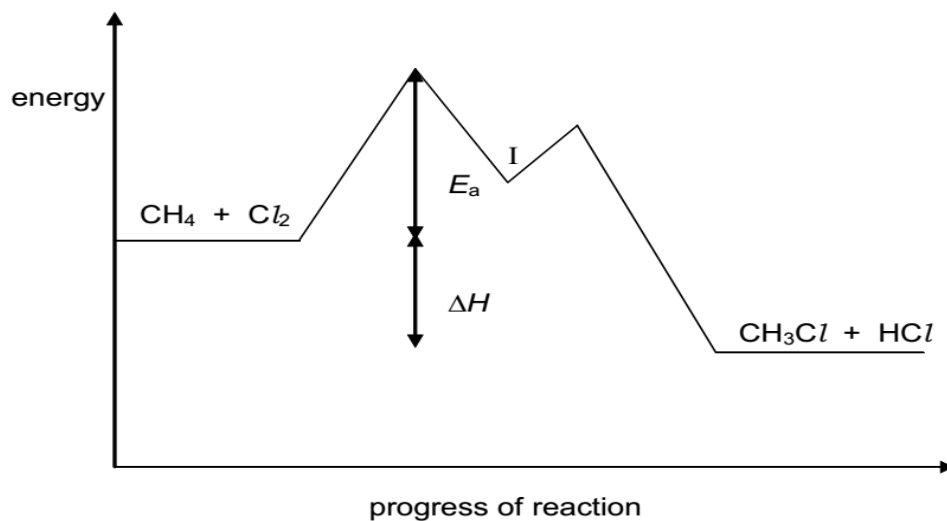|	CH_4	+	I_2	$\rightarrow$	CH_3I	+	HI
broken	C–H		I–I	made	C–I		H–I
	410		151		240		299

(1)

$\Delta H_{reaction}^\circ = -240 + (-299) + 410 + 151$
$= +22 \text{ kJ mol}^{-1}$ (1)

(iii) activation energy is too great (1) [5]

(c)

correct placement of 16 kJ   (1)
correct placement of −99 kJ (allow ecf on wrong calculation in **(a) (i)**)   (1)
intermediate clearly shown at I   (1)
correct 'double peak' shape   (1)
second peak lower than first   (1)   [5]

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 δT = 200 x 4.18 x 27.5 (1)

= 22990 J = 23.0 kJ (1)

(ii) 23.0 kJ produced from 0.47 g of **E**

2059 kJ produced from $\dfrac{0.47 \times 2059}{23.0}$ g of **E** (1)

= 42.08 g of **E** (1)

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

(f) C_3H_6 = 42

E is C_3H_6

for ecf, **E** must be unsaturated and be no larger than C_5 (1)   [1]

9

Q:20

3 **(a)** the overall enthalpy change/energy change/ΔH for a reaction (1)

is independent of the route taken **or**
is independent of the number of steps involved
provided the initial and final conditions are the same (1)

(b) (i) $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$ (1)

(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 K_2CO_3 (1)

(iii) 0.020 mol $K_2CO_3 \equiv 652.08$ J

1 mol $K_2CO_3 \equiv \dfrac{652.08 \times 1}{0.0200} = 32604$ J

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

(iv) to prevent the formation of $KHCO_3$ **or**
to ensure complete neutralisation (1)

(c) (i) $KHCO_3 + HCl \rightarrow KCl + H_2O + CO_2$ (1)

(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 $KHCO_3$ (1)

(iii) 0.020 mol $KHCO_3 \equiv 463.98$ J

1 mol $KHCO_3 \equiv \dfrac{463.98 \times 1}{0.0200} = 23199$ J

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

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

Q:21

(d) (i) $m = \dfrac{pVM_r}{RT} = \dfrac{1.01 \times 10^5 \times 125 \times 10^{-6} \times 44}{8.31 \times 293}$ g (1)

$\qquad\qquad$ = 0.228147345 g
$\qquad\qquad$ = 0.23 g (1)

(ii) heat released = m c δ T = 200 × 4.18 × 13.8 J (1)
$\qquad$ = 11536.8 J = 11.5 kJ (1)

(iii) 0.23 g of propane produce 11.5 kJ

$\qquad$ 44 g of propane produce $\dfrac{11.5 \times 44}{0.23}$ kJ

$\qquad$ = 2200 kJ mol^{-1} (1)

Q:22

(c) 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]

(d) working **must** be shown

$\quad$ **(i)** heat released = m c δT = 250 × 4.18 × 34.6 (1)
$\qquad$ = 36157 J = 36.2 kJ (1)

$\quad$ **(ii)** M_r of $C_{14}H_{30}$ = 198 (1)
$\qquad$ mass of $C_{14}H_{30}$ = 1.00 × 0.763 = 0.763 g (1)
$\qquad$ 0.763 g of $C_{14}H_{30}$ produce 36.2 kJ

$\qquad$ 198 g of $C_{14}H_{30}$ produce $\dfrac{36.2 \times 198}{0.763}$

$\qquad$ = 9394 kJ mol^{-1} (1) [5]