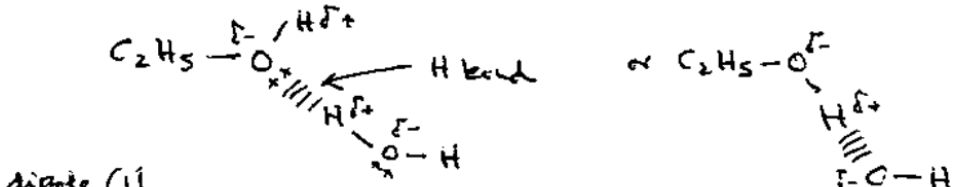
Q:1

Question Number	Mark Scheme Details	Part Mark
2 (a)	$C_2H_4 + H_2O \longrightarrow C_2H_5OH$ -1411 -1367 $\Delta H = (-)\ 44\ kJ\ mol^{-1}$	[2]
(b) (i)	* ΔH when 1 mol of element or compound (1) in 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)	 dipole (1) H bond (1)	2
	[Total 8]	
	* Some energy reference required.	

Q:2

(d) $C_2H_2(g) + {}^5/_2O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$

bonds broken:	2(H-C)	2 x 410	=	820	
	C≡C	840	=	840	
	${}^5/_2$(O=O)	${}^5/_2$ x 496	=	1240	
				2900	kJ mol^{-1} **(1)**
bonds made:	4(C=O)	4 x 740	=	2960	
	2(O-H)	2 x 460	=	920	
				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)

	$N_2H_4(l)$ +	$O_2(g)$ →	$N_2(g)$ +	$2H_2O(g)$
ΔH_f^o/kJ mol^{-1}	+50.6			–241.8

$\Delta H^o_{reaction}$ = 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^{e}_{f} of C_2H_2

$C_2H_2 + {}^{5}/_{2}O_2 \rightarrow 2CO_2 + H_2O$

ΔH^{e}_{f} **Z** 0 2(-394) -286

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

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

$= +226$ 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^{e}_{f}/kJ mol^{-1}	–394		0		–201		–242

$\Delta H^{e}_{reaction} = -201 + (-242) - (-394)$ (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)** $CH_3OH(l) + {}^{3}/_{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ (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) $\Delta H^{e}_{reaction} = -283 + 2(-286) - (-726)$ (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)

$= +8$ kJ mol^{-1} (1)

correct sign (1)

Q:9

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

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

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

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

$= 4y - 1452 + 184$

$\Delta H^{\ominus}_{reaction}$ 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 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	+	$2SO_2$	
$\Delta H_f^{\ominus}$/kJ mol^{-1}	x				–395		2(–298)	(1)

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

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

Q:11

(e)

$H_2O + Ca(NH_2)_2 \longrightarrow 2NH_3 + CO_2$

$-287 + (-320.5) \longrightarrow -162 \quad -414.5$ (1)

$-607.5 \longrightarrow -576.5$

$\Delta H = 31$ kJ mol^{-1} (1)

[2]

Q:12

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)

$= 200 \times 4.2 \times 12.2 = 10.25$ kJ (1)

(iii) $\Delta H_{reacn} = 40.1 \times (-10.25) = -411$ kJ mol^{-1} sign necessary

for ecf, $\Delta H_{reacn} = 40.1 \times$ [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)

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

$\Delta H_{reacn} = x - 2(-286) = -411$ (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)** $\Delta H_{reacn} = \Delta H$ for bonds broken – ΔH for bonds made (1)

(ii) $2H - I \rightarrow H - H + I - I$

2×299 436 151 values (1)

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

$= +11$ 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^{o} (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

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

= +119 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 $\frac{0.47 \times 2059}{23.0}$ g (1)

= 42.08g

(Use of 4.2 gives 41.89 g.)

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

Q: 16

(e) $\Delta H_f^{\ominus} = 2(-393.7) + 2(-285.9) - (-1411)$

$= +51.8 \text{ kJ mol}^{-1}$ (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	→	CH_3Cl	+	HCl
$\Delta H_f^{\ominus}$	–75		0		–82		–92

(1)

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

(ii)

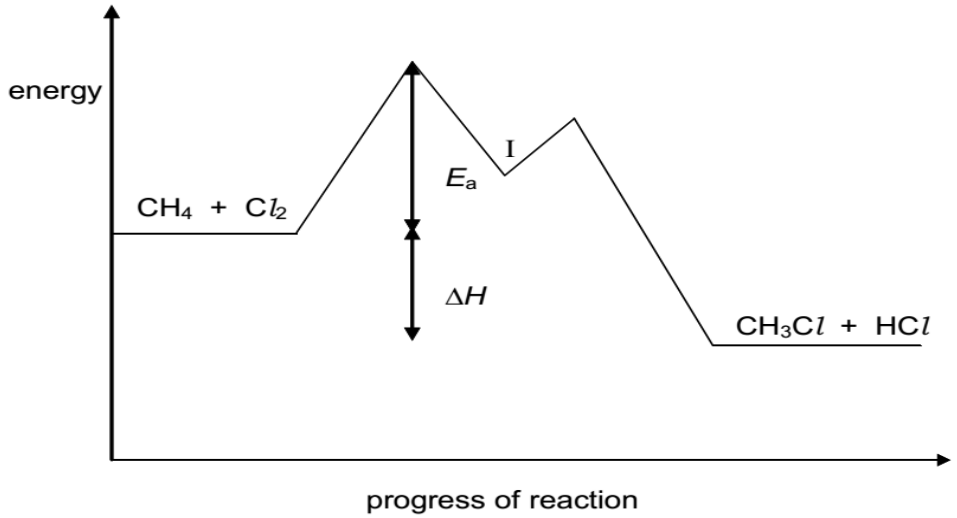
	CH_4	+	I_2	→	CH_3I	+	HI
broken	C–H		I–I	made	C–I		H–I
	410		151		240		299

(1)

$\Delta H^{\ominus}_{\text{reaction}} = -240 + (-299) + 410 + 151$
$= +22 \text{ kJ mol}^{-1}$ (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 $\frac{0.47 \times 2059}{23.0}$ 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]

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 × c × δT = 30.0 × 4.18 × 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 $K_2CO_3 \equiv \frac{652.08 \times 1}{0.0200}$ = 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 × c × δT = 30.0 × 4.18 × 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 $KHCO_3 \equiv \frac{463.98 \times 1}{0.0200}$ = 23199 J

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

(d) ΔH = 2 × (+23.20) – (–32.60) = +79.00 kJ mol^{-1} (2)

Q:21

(d) (i) $m = \frac{pVM_r}{RT} = \frac{1.01\times10^5 \times 125\times10^{-6} \times 44}{8.31\times 293}$ g (1)

= 0.228147345 g
= 0.23 g (1)

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

(iii) 0.23 g of propane produce 11.5 kJ

44 g of propane produce $\frac{11.5\times44}{0.23}$ kJ

= 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

(i) heat released = m c δT = 250 × 4.18 × 34.6 (1)
= 36157 J = 36.2 kJ (1)

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

198 g of $C_{14}H_{30}$ produce $\frac{36.2\times198}{0.763}$

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