5. Chemical energetics

5.1 Enthalpy change

Paper 2

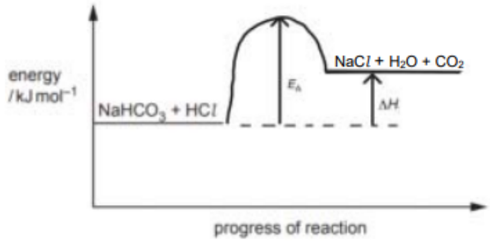
Marking Scheme

Q1.

<table>
<tr><td>(a)</td><td>M1 (enthalpy change / energy change) when one mole of a compound / substance is formed
M2 from its elements in their standard states</td><td>2</td></tr>
<tr><td>(b)(i)</td><td>
<table>
<tr><td></td><td>equation for reaction</td><td>$\Delta H_{formation}$</td></tr>
<tr><td>Fe_2O_3</td><td>$2Fe (s) + \frac{3}{2}O_2 (g) \rightarrow Fe_2O_3 (s)$</td><td>–824.2</td></tr>
<tr><td>CO</td><td>$C (s) + \frac{1}{2}O_2 (g) \rightarrow CO (g)$</td><td>–110.5</td></tr>
<tr><td>CO_2</td><td>$C (s) + O_2 (g) \rightarrow CO_2 (g)$</td><td>–393.5</td></tr>
</table>
</td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>$\Delta H_{reaction} = -\Delta H_{Fe2O3} - (3 \times -\Delta H_{CO}) + (3 \times -\Delta H_{CO2})$
$= -(-824.2) - (3 \times -110.5) + (3 \times -393.5)$
$= -24.8$ kJ mol^{-1}

• evidence of use of correct expression and / or any rearrangement of only these bond energy values
• use correct stoichiometry for these bond energy values only
• calculate their expression correctly provided the expression uses only addition / subtraction and all 3 values</td><td>2</td></tr>
</table>

Q2.

(a)	 *All three correct (2 marks) or two correct (1 mark):* • profile for endothermic reaction (include 'hump') • arrow representing E_A • arrow representing ΔH **OR** (+) 27.2	**2**
(b)(i)	no more fizzing / effervescence stops	**1**
(b)(ii)	**M1** calculate Q from = 50 × 4.18 × (26.2 – 19.6)) = 1379.(4) **M2** *Use M1 to find energy change when 1 mol Na_2CO_3 / 2 mol HC*l* reacts* **M1** ÷ 0.04 = 34485 **M3** *express Q as $\Delta H_{(1)}$ in kJ mol^{-1}* = – (value for **M2**) ÷ 1000 = –34.5 kJ mol^{-1} *Alternative method* **M1** *evidence of use* Q = $mc\Delta T$ = 50 × 4.18 / 1000 × (26.2 – 19.6) = 1.3794 **M2** *Use M1 to find energy change when 1 mol Na_2CO_3 / 2 mol HCl reacts* **M1** ÷ 0.04 = 34.485 **M3** *express Q as $\Delta H_{(1)}$ in kJ mol^{-1}* = – (value for **M2**) *(expressed in kJ)* = –34.5 kJ mol^{-1}	**3**
(b)(iii)	*Using answer from 2(b)(ii)* (=) 2ΔH_2 – (ΔH_1) (=) 2 × 27.2 – (2b(ii)) 2 × 27.2 – (–34.50) = (+) 88.9 kJ mol^{-1} *All three correct (2 marks) or two correct (1 mark):* • (27.2) – (–34.5) OR (27.2) – (2b(ii)) • 2 × 27.2 and 1 × 2b(ii) • calculate correctly their expression Using **alternative** value of ΔH_1 = –38.4 kJ mol^{-1} ΔH_r = (+)92.8 kJ mol^{-1} = 2 marks	**2**

Q3.

(b)(i)	(+)5 / V	**1**

Q4.

(a)	**M1** (enthalpy change) when 1 mole of water is formed **M2** from an (aqueous) acid and an alkali / (aqueous) base	**2**
(b)(i)	0.05 mol	**1**
(b)(ii)	**M1** *correct volume and correct temperature change* **M2** *calculation to calculate Q based on M1 volume and temp and* $Q = mc\Delta T$ $Q = mc\Delta T = 175 \times 4.18 \times (27.8 - 20) = (-)5705.7$ **M3** *energy change when 0.1 mol* H_2O *is made with appropriate unit and sign* $\Delta H =$ M2 / 0.1 = –57.1 kJ mol^{-1} OR –57100 J mol^{-1}	**3**
(c)(i)	..(1)..H_2SO_4(aq) + ..(1)..$Ba(OH)_2$(aq) → …(1)..$BaSO_4$(s) + $2H_2O$(l)…… **M1** correct state symbols for both products **M2** correctly balanced equation	**2**
(c)(ii)	precipitation (of $BaSO_4$) (also) involves an energy change	**1**

Q5.

(a)	Method 1 • identification of number and type of bonds when all are broken 2O-H + 4C-H + C=C **OR** (2 × 460) + (4 × 410) + 610 • Identification of number and type of bonds when all are made O-H + 5C-H + C-C + C-O **OR** (460 + (5 × 410) + 350 + 360) • calculation of energy to break bonds – energy to make bonds 3170 – 3220 = – 50 (kJ mol^{-1}) Two correct for one mark, three correct for two marks. **OR** Method 2 • identification of number and type of relevant bonds broken (including the new C-H only) 2O-H + C=C **OR** (2 × 460) + 610 • identification of number and type of relevant bonds made (including the new C-H only) O-H + C-H + C-C + C-O **OR** (460 + 410 + 350 + 360) • calculation using energy to break bonds – energy to make bonds 1530 – 1580 = –50 (kJ mol^{-1}) Two correct for one mark, three correct for two marks.	**2**

Q6.

(e)(i)	enthalpy change when one mole of a compound / substance is formed	**1**
	from its constituent elements in their standard states	**1**
(e)(ii)	2(–592) = 2(–289) + (496) – 2(P=O) OR (2) P=O = 2(–289) + (496) + 2(592)	**1**
	$E_{P=O}$ = ½(1102) = +551 (kJ mol^{-1})	**1**

Q7.

(b)(i)	enthalpy change when one mole of a compound / substance is formed	1
	from its constituent elements in their standard states	1
(b)(ii)	ΔH_r = +9 + 3(–1281) – 4(–972) = (+)54 (kJ mol^{-1}) (1)	2
	Any two from (1): • use correct stoichiometry for all three values • use correct expression regardless of stoichiometry for all three values • calculated correctly	
(b)(iii)	P (in H_3PO_3) is (both) oxidised and reduced (simultaneously)	1
	P (is oxidised) from (+)3 / (+)III → (+)5 / (+)V AND (reduced to) –3 / –III	1

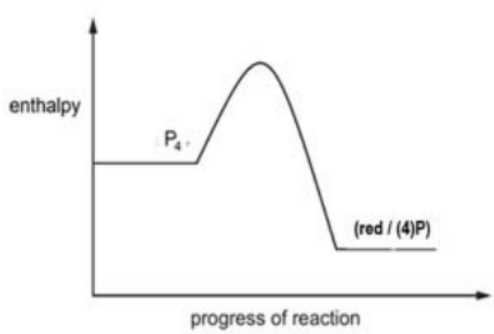
Q8.

(b)	evaluation, to give a value, based on calculation using: • all three correct bond energies [HI = 299, H_2 = 436, I_2 = 151] • correct use of stoichiometry to calculate ΔH for 1 mol HI x = 1 and y = ½ • *calculate a value for ΔH correctly* i.e. x(299) – y(436 + 151) ΔH = (+)5.5 kJ mol^{-1}	2

Q9.

(b)(i)	**M1** (enthalpy/energy change when) 1 mole of a compound **M2** *burns/combusts/reacts in **excess** oxygen/O_2* **OR** ***completely** burns/ **completely** combusts/**completely** reacts in oxygen/O_2*	2
(b)(ii)	**M1** (–394 +**2** (–297) – (+89.7) **M2** = –1080 (kJ mol^{-1})	2

Q10.

(a)(ii)		1

Q11.

(b)	(enthalpy / energy change) when one mole of a compound is formed from its elements in their standard states	**2**

Q12.

(a)	**M1** (enthalpy / energy change) when one mole of a compound/substance is formed **M2** from its elements in their standard states	**2**

Q13.

(d)(i)	**M1** (enthalpy change) when 1 mole of sucrose **M2** burns/combusts/reacts in excess air/oxygen **OR** completely burns/combusts/reacts in air/oxygen	**2**
(d)(ii)	**M1** *for finding amount of energy released per gram of sucrose using* ΔH /Q = mcΔT OR ΔH = – mcΔT = (-)250x4.18x(40.7-25) = (-)16406.5 J per gram OR(-)16.4065 kJ / g **M2** *for finding amount (mol) sucrose in1g = 1/342 mol* ***M3*** *= M1 / (M2x1000)* ΔH = - 5610 kJ mol^{-1} (3 sig figs) OR -5611 kJ mol^{-1} (4 sig figs)	**3**

Q14.

(e)	**M1** Si—H bond is (much) weaker than C—H bond	**1**
	M2 low activation energy *ORA*	**1**

Q15.

(b)(i)	$C_4H_4S(l) + 6O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l) + SO_2(g)$ • correct species • balancing • state symbols Award one mark for two correct bullet points, award two marks for all three correct.	**2**

(b)(ii)	**M1** (enthalpy change when) 1 mol of a substance **M2** EITHER burns / combusts / reacts in excess air / oxygen OR completely burns / combusts / reacts in air / oxygen	**2**
(b)(iii)	**M1** m = 200 and ΔT = 37.5–18.5 **M2** $Q = mc\Delta T$ = 200 × 4.18 × (37.5 – 18.5) = 15 884 (J)	**2**
(b)(iv)	**M1** mol of thiophene used = 0.63 / 84.1 OR 7.49(1 082 045) × 10^{-3} **M2** calculation ÷ 1000 AND negative sign $\Delta H_c = \frac{\mathbf{-(iii)}}{\mathbf{1000}} \div n = \frac{\mathbf{-(iii)}}{\mathbf{21000}} \div (0.63 / 84.1)$ = **–**2120 (–2120.39) (kJ mol^{-1})	**2**

Q16.

(b)	−196 + 6S=O = (4 × 534) + 496	**1**
	S=O = 2828 / 6 = 471(.3)	**1**