

Question	Marking Guidance	Mark	Comments
2(a)	<i>One from</i> <ul style="list-style-type: none">• Ti is not produced• TiC / <u>carbide</u> is produced OR titanium reacts with carbon• Product is brittle• Product is a poor engineering material	1	Penalise "titanium carbonate" Ignore "impure titanium" Credit "titanium is brittle"
2(b)	<u>Heat (energy) change at constant pressure</u>	1	QoL
2(c)	The <u>enthalpy change</u> in a reaction is independent of the route taken (and depends only on the initial and final states)	1	Credit "heat change at constant pressure" as an alternative to "enthalpy change"

2(d)	<p>M1 The <u>enthalpy change / heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / product</p> <p>M2 is formed from its (constituent) <u>elements</u></p> <p>M3 with <u>all reactants and products / all substances in standard states</u> OR <u>all reactants and products / all substances in normal states under standard conditions / 100 kPa / 1 bar and any specified T</u> (usually 298 K)</p>	3	<p>For M1, credit correct reference to molecule/s or atom/s</p> <p>Ignore reference to 1 atmosphere</p>
2(e)(i)	<p>Na / it is not in its <u>standard state / normal state under standard conditions</u></p> <p>OR</p> <p><u>Standard state / normal state under standard conditions</u> for Na is solid / (s)</p>	1	<p>QoL</p> <p>Ignore “sodium is a liquid or sodium is not a solid”</p>

2(e)(ii)	<p>M1 $\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$</p> <p>M2 $\Delta H_r = 4(-411) - (-720) - 4(+3)$ $= -1644 + 720 - 12$ (This also scores M1)</p> <p>M3 $= -936 \text{ (kJ mol}^{-1}\text{)}$</p>	3	<p>Correct answer gains full marks</p> <p>Credit 1 mark for +936 (kJ mol⁻¹)</p> <p>Credit 1 mark for -924 (kJ mol⁻¹) i.e. assuming value for Na(l) = 0</p> <p>For other incorrect or incomplete answers, proceed as follows</p> <ul style="list-style-type: none"> check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) If no AE, check for a correct method; this requires either a correct cycle with 2Cl₂ and 4Na OR a clear complete statement of M1 which could be in words and scores <u>only M1</u>
2(e)(iii)	<p>Reducing agent OR reductant OR reduces TiCl₄ OR electron donor</p>	1	<p>Ignore “reduces titanium”</p>

B

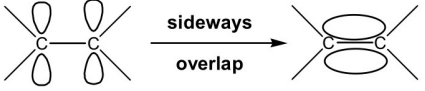
D

F322

Mark Scheme

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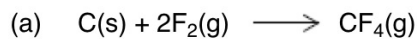
Question	Answer	Mark	Guidance
3 (a)	(enthalpy change when) the number of moles of reactants ✓ as specified in the (balanced) equation react together ✓	2	ALLOW (enthalpy change when) the number of moles of products ALLOW molar quantities / amounts Enthalpy change that occurs during a reaction is not sufficient
(b) (i)	$Q = 50 \times 4.2 \times 11.0$ ✓ 2.3 ✓	2	ALLOW 2310 J ✓ 2300j ALLOW use 4.18 for c which gives 2.299 J ALLOW two marks for 2.31 / 2.310 with no working out ALLOW ECF ie Q divided by 1000 IGNORE any sign quoted
(ii)	moles = 0.200 ✓	1	ALLOW 0.2 / 0.20
(iii)	$\Delta H_r = 2 \times (2.3 \div 0.200)$ ✓ 23 ✓ + sign ✓	3	ALLOW ECF from answer from $2 \times [(i) \div \text{answer to (ii)}]$ Answer from $2 \times [(i) \div \text{answer to (ii)}]$ must have only 2 sig figs + sign must be written for 'sign mark' + sign is independent of answer ALLOW answers per mole of NH_4SCN $\Delta H_r = 2.3 \div 0.200$ for one mark 12 for the second mark + sign for the third mark NOTE If c = 4.18 has been used in b(i) , $\Delta H_r = +11$ by ECF for calculation per mole of NH_4SCN

Question	Answer	Mark	Guidance
3 (c) (i)	(Enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	ALLOW energy required rather than enthalpy change DO NOT ALLOW energy released DO NOT ALLOW bonds formed
(ii)	(Sideways) overlap of p orbitals ✓ Forming a π /pi bond ✓	2	IGNORE reference to σ bonds IGNORE incorrect diagram This diagram would score one mark – the π bond needs to be labelled for second mark  2p orbitals
(iii)	π bond is weaker (than the σ bond) OR σ bond is stronger (than the π bond) ✓	1	There are two types of bonds is not sufficient DO NOT ALLOW π bond is stronger than the σ bond ALLOW the two bonds in double bond are not the same strength
(iv)	bonds broken = (+)4010 AND bonds formed = (-)3931 Overall enthalpy change = +79 ✓	2	ALLOW Bonds broken = (+)690 AND bonds formed = (-)611 ✓ ALLOW 79 without a sign ALLOW -79 for one mark overall ALLOW ECF from incorrect enthalpy changes calculated for bonds broken and made

Question	Answer	Mark	Guidance
3 (c) (v)	Bond enthalpies may not be the same as the average bond enthalpy OR The idea that bonds have different strengths in different environments ✓	1	DO NOT ALLOW answers involving heat loss OR the use of non standard conditions Average bond enthalpies are used is NOT sufficient
Total		16	

Mark schemes

1



State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma \Delta_f H \text{ products} - \Sigma \Delta_f H \text{ reactants}$ or a correct cycle

1

$$\text{Hence} = (2 \times -680) + (6 \times -269) - (x) = -2889$$

1

$$x = 2889 - 1360 - 1614 = -85 \text{ (kJ mol}^{-1}\text{)}$$

1

Score 1 mark only for +85 (kJ mol⁻¹)

(d) Bonds broken = $4(\text{C-H}) + 4(\text{F-F}) = 4 \times 412 + 4 \times \text{F-F}$

Bonds formed = $4(\text{C-F}) + 4(\text{H-F}) = 4 \times 484 + 4 \times 562$

Both required

1

$$-1904 = [4 \times 412 + 4(\text{F-F})] - [4 \times 484 + 4 \times 562]$$

$$4(\text{F-F}) = -1904 - 4 \times 412 + [4 \times 484 + 4 \times 562] = 632$$

1

$$\text{F-F} = 632 / 4 = 158 \text{ (kJ mol}^{-1}\text{)}$$

1

The student is correct because the F-F bond energy is much less than the C-H or other covalent bonds, therefore the F-F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F-F bond)

1

[10]

Question	Answers	Mark	Additional Comments/Guidance
2a)	<p>The <u>enthalpy / heat energy change</u> when <u>1 mol</u> (of a substance)</p> <p>is <u>burned/reacts completely in oxygen</u></p> <p>with all reactants and products in their <u>standard states</u></p> <p>OR</p> <p>With all reactants and products in their normal states at 298K/given temp & 100kPa</p>	<p>1</p> <p>1</p> <p>1</p>	<p>If enthalpy of formation definition given CE=O</p> <p>NOT just 'energy'</p> <p>ALLOW alternatives for substance e.g. molecule/compound/element</p> <p>ALLOW reacts in excess oxygen</p> <p>ALLOW 'everything' for 'reactants and products'</p> <p>Penalise incorrect conditions if given</p> <p>ALLOW 'normal states under standard conditions'</p>
2b)	<p>$\Delta H = \Sigma \Delta H_c(\text{reactants}) - \Sigma \Delta H_c(\text{products})$</p> <p>OR</p> <p>correctly and fully balanced cycle</p> <p>$\Delta H = [3(-394) + 4(-286)] - (-2010)$</p> <p>OR</p> <p>$\Delta H = -2326 + 2010$</p> <p>$\Delta H = -316 \text{ (kJ mol}^{-1}\text{)}$</p> <p>+316 scores 1 mark only</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Correct answer scores 3</p> <p>M2 also scores M1</p> <p>IGNORE units</p> <p>Check for AE in working – can award M3 as ecf (error carried forward) from M2 if M2 not given due to AE</p>

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2c)	<p>$\Delta H/-1893 = \Sigma B(\text{reactants}) - \Sigma B(\text{products})$</p> <p>OR</p> <p>$\Delta H/-1893 = \Sigma \text{Bonds broken} - \Sigma \text{Bonds formed}$</p> <p>OR</p> <p>$\Delta H/-1893 = 2B(\text{C-C}) + 7B(\text{C-H}) + B(\text{C-O}) + B(\text{O-H}) + 4\frac{1}{2}B(\text{O=O}) - 6B(\text{C=O}) - 8B(\text{O-H})$</p> <p>$-1893 = 2B(\text{C-C}) + 7(412) + 360 + 463 + 4\frac{1}{2}(496) - 6(805) - 8(463)$</p> <p>OR</p> <p>$-1893 = 2B(\text{C-C}) + 5939 - 8534$</p> <p>OR</p> <p>$-1893 = 2B(\text{C-C}) - 2595$</p> <p>OR</p> <p>$2B(\text{C-C}) = 702$</p> <p>$B(\text{C-C}) = (+)351 \text{ (kJ mol}^{-1}\text{)}$</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Correct answer gains 3 marks</p> <p>M2 also scores M1</p> <p>May see no 463 in bonds broken and 7x463 in made (gives 5476 – 8071)</p> <p>If NOT 351 check for AE. This would lose M2, but could gain M1 and M3 (+)234 scores 1 (due to 3(C-C))</p> <p>NOT M3 from incorrect M2 unless incorrect M2 is due to AE</p> <p>IGNORE Units</p> <p>If no other mark awarded then ALLOW 1 if 5939 or 5476 or 8534 or 8071 seen</p>
Total		9	

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Question	Marking Guidance	Mark	Comments
6(a)	$3\text{N}_2\text{H}_4 \longrightarrow 4\text{NH}_3 + \text{N}_2$	1	Or multiples Ignore state symbols
6(b)	M1 <u>enthalpy / heat (energy) change / required / needed to break / dissociate a covalent bond (or a specified covalent bond)</u> M2 <u>average / mean over different molecules / compounds / substances</u>	2	Ignore bond making Ignore standard conditions M2 requires an attempt at M1
6(c)	M1 $\sum (\text{bonds broken}) - \sum (\text{bonds formed}) = \Delta H$ OR Sum of bonds broken – Sum of bonds formed = ΔH M2 (also scores M1) $4(+388) + 163 + 2(146) + 4(463) - 944 - 8(463) = \Delta H$ OR broken +3859 (2007) formed – 4648 (2796) M3 $\Delta H = -789$ (kJ mol ⁻¹) Award 1 mark for + 789 Students may use a cycle and gain full marks	3	M1 could stand alone <u>Award full marks for correct answer</u> Ignore units Two marks can score with an arithmetic error in the working Credit one mark only for calculating <u>either</u> the sum of the bonds broken <u>or</u> the sum of the bonds formed provided this is <u>the only mark that is to be awarded</u>

Question	Marking Guidance	Mark	Comments
3(a)(i)	M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the \sum or SUM) M1 $\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$ OR a <u>correct cycle of balanced equations</u> M2 $\Delta H = 3(-394) - 3(-111) - (-971)$ (This also scores M1) M3 = (+) 122 (kJ mol ⁻¹) Award 1 mark ONLY for -122	3	Correct answer gains full marks Credit 1 mark ONLY if -122 (kJ mol ⁻¹) For other incorrect or incomplete answers, proceed as follows <ul style="list-style-type: none"> check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) If no AE, check for correct method; this requires either a correct cycle of balanced equations OR a clear statement of M1 which could be in words and scores M1 only
3(a)(ii)	By definition OR Because it is an element / elemental	1	Ignore reference to “standard state”
3(b)(i)	$\text{TiO}_2 + 2\text{Cl}_2 + 2\text{C} \longrightarrow \text{TiCl}_4 + 2\text{CO}$ OR $\text{TiO}_2 + 2\text{Cl}_2 + \text{C} \longrightarrow \text{TiCl}_4 + \text{CO}_2$ M1 use of <u>Cl₂ and C</u> M2 a correct balanced equation	2	Allow multiples Ignore state symbols

3(b)(ii)	$\text{TiCl}_4 + 4\text{Na} \longrightarrow \text{Ti} + 4\text{NaCl}$ OR $\text{TiCl}_4 + 2\text{Mg} \longrightarrow \text{Ti} + 2\text{MgCl}_2$ M1 use of Na OR Mg M2 a correct balanced equation	2	Allow multiples Ignore state symbols
3(c)(i)	$4\text{FeCr}_2\text{O}_4 + 8\text{Na}_2\text{CO}_3 + 7\text{O}_2 \longrightarrow 8\text{Na}_2\text{CrO}_4 + 2\text{Fe}_2\text{O}_3 + 8\text{CO}_2$	1	Allow multiples Ignore state symbols
3(c)(ii)	$\text{Cr}_2\text{O}_3 + 2\text{Al} \longrightarrow \text{Al}_2\text{O}_3 + 2\text{Cr}$	1	Allow multiples Ignore state symbols

Question	Marking Guidance	Mark	Comments
4(a)(i)	reduction OR reduced OR redox OR reduction-oxidation	1	Not "oxidation" alone
4(a)(ii)	$\text{Fe}^{3+} + 3\text{e}^- \longrightarrow \text{Fe}$	1	Ignore state symbols Do not penalise absence of charge on electron Credit $\text{Fe}^{3+} \longrightarrow \text{Fe} - 3\text{e}^-$ Credit multiples
4(b)(i)	Because (one of the following) CO is not the only product OR (Some) complete combustion (also) occurs OR CO ₂ is (also) formed Further oxidation occurs	1	Reference to "incomplete combustion to form CO" does not answer the question
4(b)(ii)	The <u>enthalpy change / heat (energy) change at constant pressure</u> in a reaction is <u>independent of the route / path taken</u> (and depends only on the initial and final states)	1	

4(b)(iii)	<p>M1 The <u>enthalpy change / heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element</p> <p>M2 is <u>burned completely / undergoes complete combustion</u> in (excess) <u>oxygen</u></p> <p>M3 with <u>all reactants and products / all substances in standard states</u></p> <p>OR <u>all reactants and products / all substances in normal / specified states under standard conditions / 100 kPa / 1 bar and specified T / 298 K</u></p>	3	<p>For M1, credit correct reference to molecule/s or atom/s</p> <p>For M3 Ignore reference to 1 atmosphere</p>
4(c)	<p>M1 (could be scored by a correct mathematical expression which <u>must have all ΔH symbols and the Σ</u>)</p> <p>M1 $\Delta H_r = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$</p> <p>OR correct cycle of balanced equations with 2Fe, 3C and 3O₂</p> <p>M2 $\Delta H_r = 2(+14) + 3(-394) - (-822) - 3(-111)$ $= 28 - 1182 + 822 + 333$ (This also scores M1)</p> <p>M3 = (+) 1 (kJ mol⁻¹)</p> <p>(Award 1 mark ONLY for – 1) (Award 1 mark ONLY for – 27)</p>	3	<p>Correct answer gains full marks Credit 1 mark ONLY for –1 (kJ mol⁻¹) Credit 1 mark ONLY for – 27 (kJ mol⁻¹) i.e. assuming value for Fe(l) = 0</p> <p>For other incorrect or incomplete answers, proceed as follows</p> <ul style="list-style-type: none"> • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) • If no AE, check for a correct method; this requires either a correct cycle with 2Fe, 3C and 3O₂ OR a clear statement of M1 which could be in words and scores <u>only M1</u>
4(d)(i)	$\text{C(s)} + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$	1	<p>State symbols essential Possible to include C(s, graphite)</p>

4(d)(ii)	<p>These two enthalpy changes are for <u>the same reaction / same equation / same reactants and products</u></p> <p>OR</p> <p>They <u>both make one mole of carbon dioxide only from carbon and oxygen</u> (or this idea clearly implied)</p> <p>OR</p> <p>The <u>same number and same type of bonds are broken and formed</u></p>	1	<p>Penalise reference to CO₂ being produced by a different route</p> <p>“both form CO₂” is not sufficient (since other products might occur e.g.CO)</p>
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A