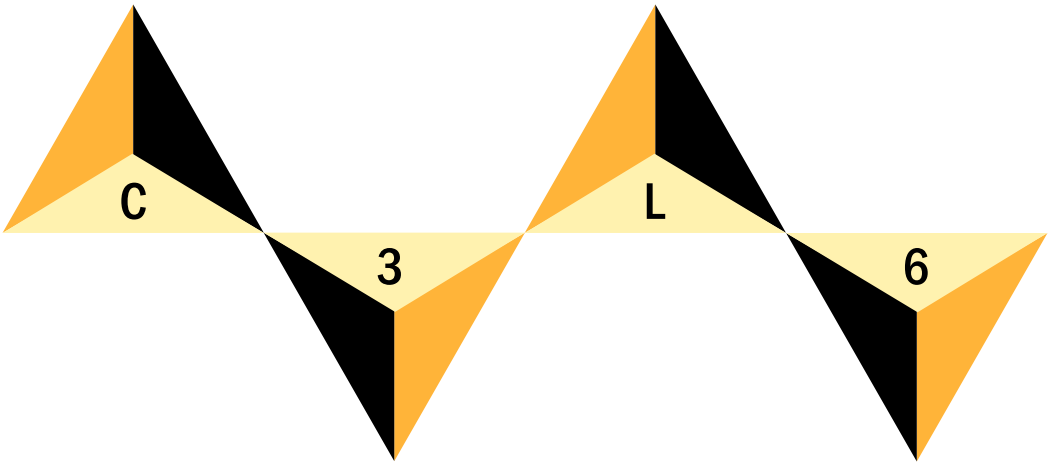

Cambridge Chemistry Challenge Lower 6th

June 2016

Marking scheme for teachers

(please also read the additional instructions)

	p2	p3	p4	p5	p6	p7	Total
mark	8	9	9	10	13	11	60

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1(a) **oxidation states of titanium in ilmenite ($FeTiO_3$):**

Ti(III) or Ti(IV); also accept +3 or +4 ✓ 1

1(b)

(i) **reaction between rutile (TiO_2), chlorine and carbon:**

$TiO_2(s) + 2Cl_2(g) + 2C(s) \longrightarrow TiCl_4(l) + 2CO(g)$ ✓

[Do not penalise lack of state symbols] 1

(ii) **reaction between ilmenite ($FeTiO_3$), chlorine and carbon:**

$2FeTiO_3(s) + 7Cl_2(g) + 6C(s) \longrightarrow 2FeCl_3(s) + 2TiCl_4(l) + 6CO(g)$ ✓ 1

[Half quantities accepted. Do not penalise lack of state symbols]

1(c) **type of structure and bonding:**

ionic **giant covalent** **simple molecular (simple covalent)** ✓ 1

1(d) **average bond strength $TiCl_4$:**

$TiCl_4(g) + O_2(g) \xrightarrow{\Delta H^\circ} TiO_2(s) + 2Cl_2(g)$

$\Delta_f H^\circ(TiCl_4(g))$ $\Delta_f H^\circ(TiO_2(s))$

$Ti(s) + 2Cl_2(g) + O_2(g)$

$\Delta_f H^\circ(TiCl_4(g)) = \Delta_f H^\circ(TiO_2(s)) - \Delta H^\circ$

$= -939 - (-175)$ kJ mol^{-1}

$= -764$ kJ mol^{-1} ✓✓

4 x bond strength (b.s.) in $TiCl_4(g)$

$TiCl_4(g) \longrightarrow Ti(g) + 4Cl(g)$

$\Delta_f H^\circ(TiCl_4(g))$ $\Delta_{at} H^\circ(Ti(s))$ + 2 x bond strength ($Cl_2(g)$)

$Ti(s) + 2Cl_2(g)$

4 x b.s. in $TiCl_4(g) = \Delta_{at} H^\circ(Ti(s)) + 2$ x b.s. $Cl_2(g) - \Delta_f H^\circ(TiCl_4(g))$

$= 473 + 2 \times 242 - (-764)$ kJ mol^{-1}

$= 1721$ kJ mol^{-1} 4

average bond strength in $TiCl_4$ is therefore: 430 kJ mol^{-1} (3 sig. fig.) ✓✓

Page total 8

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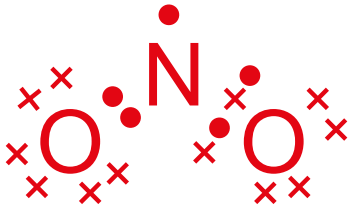
1(e)

(i) dot and cross diagram for NO_2

[accept all chemically reasonable diagrams]



✓ 1

(ii) bond angle in NO_2:

90° 105° 109° 115° 120° 135° 180° ✓ 1

[No ECF from part (i)]

1(f)

(i) reaction between NO_2 and $HO^{\bullet}$:

$NO_2 + HO^{\bullet} \longrightarrow HNO_3$ ✓

the product is named: Nitric Acid ✓ 2

(ii) reaction between superoxide and NO:

$NO + O_2^- \longrightarrow NO_3^-$ ✓ 1

(iii) net reaction with species being reduced underlined:

$H_2O + \underline{O_2} + NO_2 + NO \longrightarrow HNO_3 + H^+ + NO_3^-$ ✓✓ 2

[$2HNO_3$ accepted as product. 1 mark for equation; 1 for underlined]

1(g) the reaction for the formation of titanium(III) chloride is:

$2TiCl_4(l) + H_2(g) \longrightarrow 2TiCl_3(s) + 2HCl(g)$ ✓ 1

[Half quantities accepted.]

1(h)

(i) what happens to the titanium:

oxidation reduction disproportionation nothing ✓ 1

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1(h)

(ii) the standard entropy change is:

Positive ✓

One of the products is gaseous.

✓ 2

(iii) the position of equilibrium would:

Move towards the reactants OR shift to the left hand side.

The forward reaction is exothermic OR the reverse reaction is endothermic.

✓ 1

1(j) the standard enthalpy and entropy changes are:

The gradient of the line is equal to $-\frac{\Delta H^\circ}{R}$ ✓

$$-\frac{\Delta H^\circ}{R} = \frac{-12-(-9)}{0.001572-0.001412} = \frac{-3}{0.000016} = -18750$$

$\Delta H^\circ = 155.9 \text{ kJ mol}^{-1}$ ✓

Substitute the value for $-\frac{\Delta H^\circ}{R}$ to find ΔS°: $-12 = -18750 \times 0.001572 + \frac{\Delta S^\circ}{R}$

$$\frac{\Delta S^\circ}{R} = 17.475$$

$\Delta S^\circ = 145.3 \text{ J mol}^{-1}\text{ K}^{-1}$ ✓✓✓

[Two marks for value, the third if the units are correct]

5

1(k)

ionic **giant covalent** **simple molecular (simple covalent)** ✓ 1

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2(a) **molecular formula of Pyrethrin I:**

$C_{21}H_{28}O_3$ ✓ 1

2(b)

(i) **moles of bromine reacting with 500 mg Pyrethrin I:**

Number of moles of Pyrethrin I = $\frac{0.5}{328.4}$ = 0.001523 moles ✓

There are 4 double bonds in Pyrethrin I

Number of moles of bromine reacting = 4 x 0.001523 = 0.00609 moles ✓ 2

(ii) **volume of bromine water reacting:**

Volume of bromine water = $\frac{0.00609013}{0.05}$ = 0.122 dm^3 = 122 cm^3 ✓ 1

2(c)

(i) **concentration of Cypermethrin in the sample:**

[Cypermethrin] = $\frac{\text{Peak area} - 2.403}{44.547} = \frac{4.8 - 2.403}{44.547}$ = 0.054 μmol dm^{-3}

[Accept correct answers given in mol dm^{-3} or mmol dm^{-3}] ✓✓ 2

(ii) **mass of Cypermethrin in the sample:**

Mass = moles of Cypermethrin x Mr Cypermethrin

= [Cypermethrin] x volume of sample x Mr Cypermethrin

= 0.0538 x 10^{-6} x 15 x 10^{-3} x 416.3

= 3.36 x 10^{-7} g (equivalent to 3.36 x 10^{-4} mg or 0.336 μg or 336 ng) ✓✓ 2

[accept error carried forward; 1 mark if answer is out by a factor of 10^3]

(iii) **number of blueberries consumed without exceeding the MRL:**

A 15 kg child can safely consume 0.02 x 15 = 0.3 mg Cypermethrin per day.
Assuming all blueberries contain an equal amount of Cypermethrin, then each blueberry contains (336/4) = 84 ng of Cypermethrin.
No. of blueberries to reach MRL (0.3/84 x 10^{-6}) = 3571.3 blueberries.
A 15 kg child could eat 3571 blueberries without exceeding the MRL.
[Accept error carried forward;
award 1 mark if only the safe mass of Cypermethrin per day is given] ✓✓ 2

Page total 10

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2(d) **ways of forming Br_2:**

$^{79}Br^{79}Br$ $^{79}Br^{81}Br$ $^{81}Br^{79}Br$ $^{81}Br^{81}Br$ ✓

[do not penalise if only one of $^{79}Br^{81}Br$ or $^{81}Br^{79}Br$ is given] 1

2(e) **Spectrum matching that of Br_2:**

Spectrum A Spectrum B Spectrum C Spectrum D ✓ 1

2(f)

(i) **m/z values of Cl_2:**

70, 72 & 74 ✓ 1

(ii) **intensities of peaks corresponding to Cl_2:**

9:6:1 (or as percentages 56.25 : 37.5 : 6.25)

[award 2 or 0] ✓✓ 2

2(g) **m/z values for molecular ions and their corresponding ratios.**

Cypermethrin	Deltamethrin	Tralomethrin
415, 417 & 419	503, 505 & 507	661, 663, 665, 667 & 669 ✓
9:6:1 (or 56.25 : 37.5 : 6.25) ✓	1:2:1 (or 25 : 50 : 25) ✓	1:4:6:4:1 (or 6.25:25:37.5:25:6.25) ✓

4

2(h)

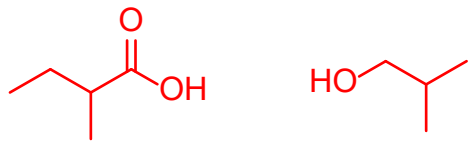
(i) **volume of Deltamethrin solution:**

12.5 x 55 = 687.5 mg of Deltamethrin will be needed on a 12.5 m^2 net.
Multiply mass in grams by 10 to give volume in cm^3: 6.9 cm^3 ✓

1

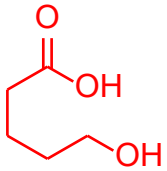
2(j) **products of ester hydrolysis:**

(i)



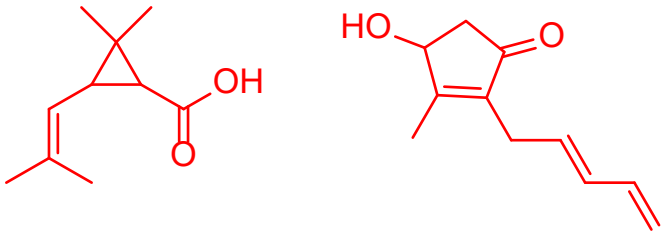
✓

(ii)



✓

(iii)



✓

3

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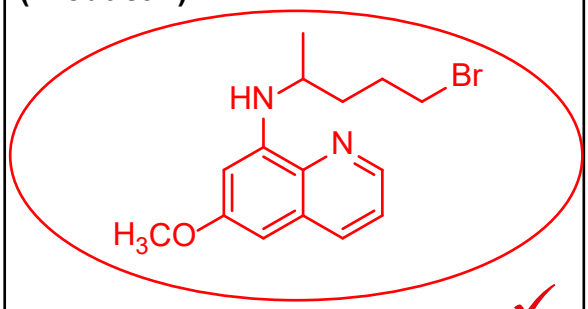
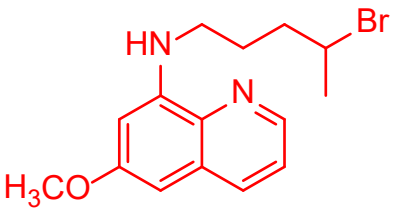
2(k) Four possible products:

(Product 1)



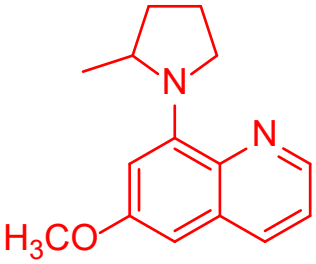
✓

(Product 2)



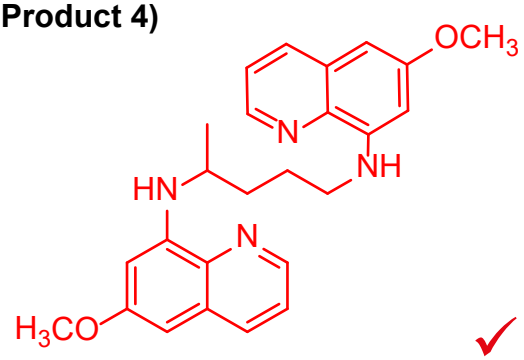
✓

(Product 3)



✓

(Product 4)



✓

4

2(l)

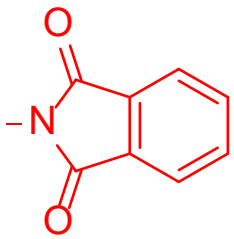
(i) Circle the correct structure in your answer above ✓ 1

(ii) The reagent is:

NH_3 ✓ 1

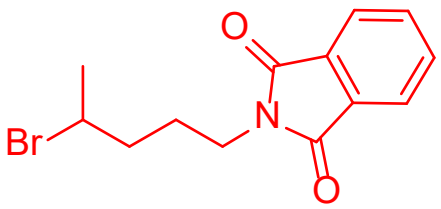
2(m) Structures:

(Anion W^-)



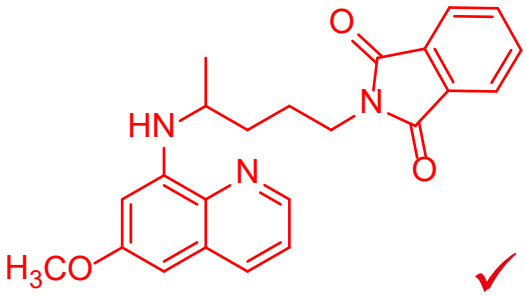
✓

(Compound X)



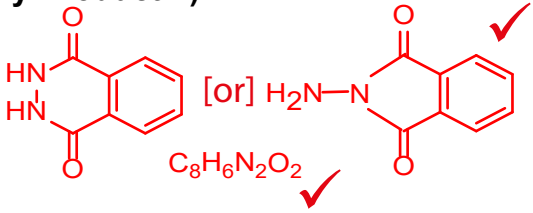
✓

(Compound Y)



✓

(By-Product Z)



✓ ✓

[Correct structure no formula: 2 marks
The structure on the left is what forms but that on the right deserves full credit]

5

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