

## 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    |

1(a) oxidation states of titanium in ilmenite (FeTiO<sub>3</sub>):

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



leave blank

1

1(b)

(i) reaction between rutile (TiO<sub>2</sub>), chlorine and carbon:



[ Do not penalise lack of state symbols]

1

(ii) reaction between ilmenite (FeTiO<sub>3</sub>), chlorine and carbon:



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

1

1(c) type of structure and bonding:

ionic

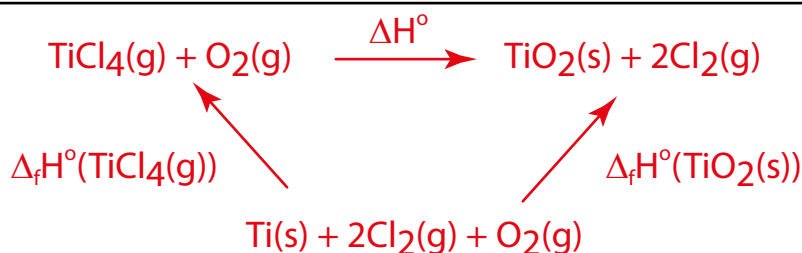
giant covalent

simple molecular (simple covalent)



1

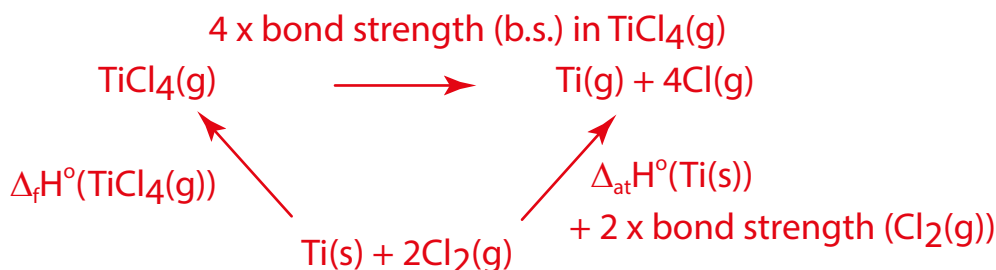
1(d) average bond strength TiCl<sub>4</sub>:



$$\Delta_f H^\circ(\text{TiCl}_4(\text{g})) = \Delta_f H^\circ(\text{TiO}_2(\text{s})) - \Delta H^\circ$$

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

$$= -764 \text{ kJ mol}^{-1}$$



$$4 \times \text{b.s. in TiCl}_4(\text{g}) = \Delta_{\text{at}} H^\circ(\text{Ti}(\text{s})) + 2 \times \text{b.s. Cl}_2(\text{g}) - \Delta_f H^\circ(\text{TiCl}_4(\text{g}))$$

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

$$= 1721 \text{ kJ mol}^{-1}$$

average bond strength in TiCl<sub>4</sub> is therefore: 430 kJ mol<sup>-1</sup> (3 sig. fig.)



4

Page total  
8

1(e)

(i) dot and cross diagram for NO<sub>2</sub>

leave blank



1

(ii) bond angle in NO<sub>2</sub>:

90°    105°    109°    115°    120°    135°    180°    ✓

[No ECF from part (i)]

1

1(f)

(i) reaction between NO<sub>2</sub> and HO•:



the product is named: Nitric Acid ✓

2

(ii) reaction between superoxide and NO:



1

(iii) net reaction with species being reduced underlined:



2

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



1

1(h)

(i) what happens to the titanium:

oxidation    reduction    disproportionation    nothing    ✓

1

Page total  
9

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  $-\frac{\Delta H^\circ}{R}$  ✓

$$-\frac{\Delta H^\circ}{R} = \frac{-12 - (-9)}{0.001572 - 0.001412} = \frac{-3}{0.00016} = -18750$$

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

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

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

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

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

5

1(k)

ionic

giant covalent

simple molecular (simple covalent) ✓

1

2(a) molecular formula of Pyrethrin I:



leave  
blank

1

2(b)

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

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



There are 4 double bonds in Pyrethrin I

$$\text{Number of moles of bromine reacting} = 4 \times 0.001523 = 0.00609 \text{ moles}$$



2

(ii) volume of bromine water reacting:

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



1

2(c)

(i) concentration of Cypermethrin in the sample:

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

[Accept correct answers given in mol dm<sup>-3</sup> or mmol dm<sup>-3</sup>]



2

(ii) mass of Cypermethrin in the sample:

$$\begin{aligned} \text{Mass} &= \text{moles of Cypermethrin} \times \text{Mr Cypermethrin} \\ &= [\text{Cypermethrin}] \times \text{volume of sample} \times \text{Mr Cypermethrin} \\ &= 0.0538 \times 10^{-6} \times 15 \times 10^{-3} \times 416.3 \\ &= 3.36 \times 10^{-7} \text{ g (equivalent to } 3.36 \times 10^{-4} \text{ mg or } 0.336 \mu\text{g or } 336 \text{ ng)} \end{aligned}$$



2

[accept error carried forward; 1 mark if answer is out by a factor of 10<sup>3</sup>]

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

A 15 kg child can safely consume  $0.02 \times 15 = 0.3$  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  $(0.3/84 \times 10^{-6}) = 3571.3$  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

2(d) ways of forming Br<sub>2</sub>:

<sup>79</sup>Br<sup>79</sup>Br    <sup>79</sup>Br<sup>81</sup>Br    <sup>81</sup>Br<sup>79</sup>Br    <sup>81</sup>Br<sup>81</sup>Br ✓  
[do not penalise if only one of <sup>79</sup>Br<sup>81</sup>Br or <sup>81</sup>Br<sup>79</sup>Br is given]

leave  
blank  
1

2(e) Spectrum matching that of Br<sub>2</sub>:

Spectrum A    Spectrum B    Spectrum C    Spectrum D ✓

1

2(f)

(i) m/z values of Cl<sub>2</sub>:

70, 72 & 74 ✓

1

(ii) intensities of peaks corresponding to Cl<sub>2</sub>:

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,            |
| 9:6:1                      | 1:2:1               | 667 & 669 ✓               |
| (or 56.25 : 37.5 : 6.25) ✓ | (or 25 : 50 : 25) ✓ | 1:4:6:4:1 ✓               |
|                            |                     | (or 6.25:25:37.5:25:6.25) |

4

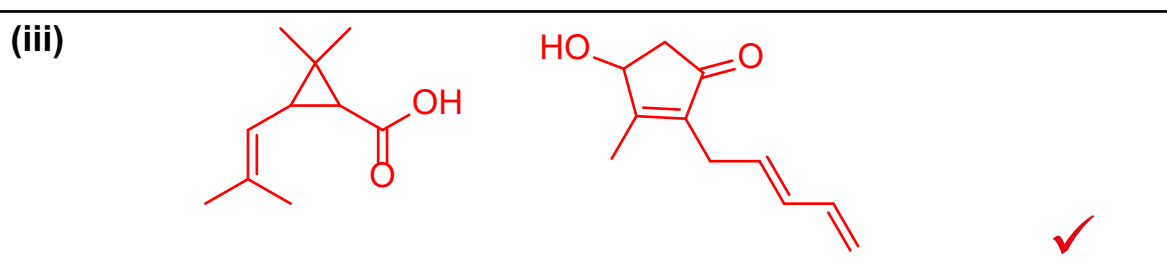
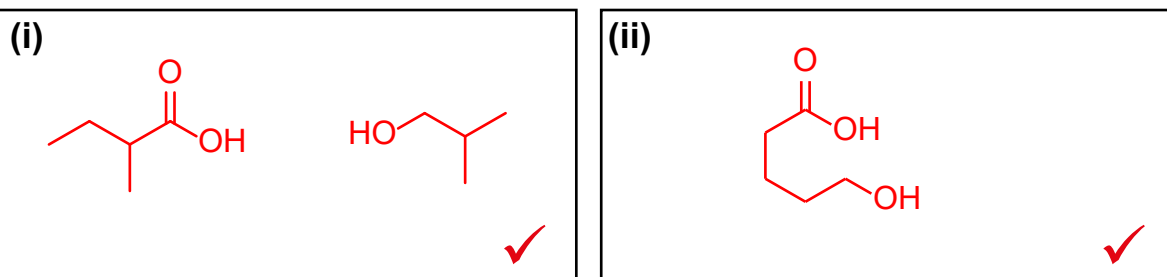
2(h)

(i) volume of Deltamethrin solution:

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

1

2(j) products of ester hydrolysis:



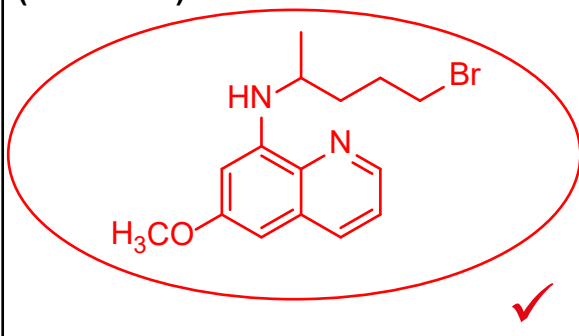
3

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13

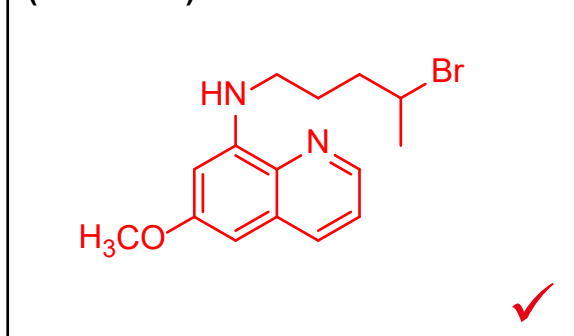
2(k) Four possible products:

leave blank

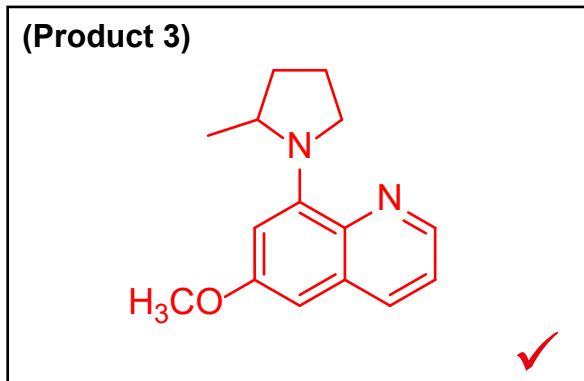
(Product 1)



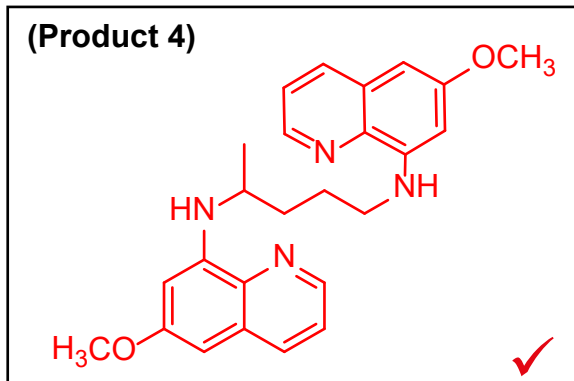
(Product 2)



(Product 3)



(Product 4)



2(l)

(i) Circle the correct structure in your answer above

✓

4

(ii) The reagent is:

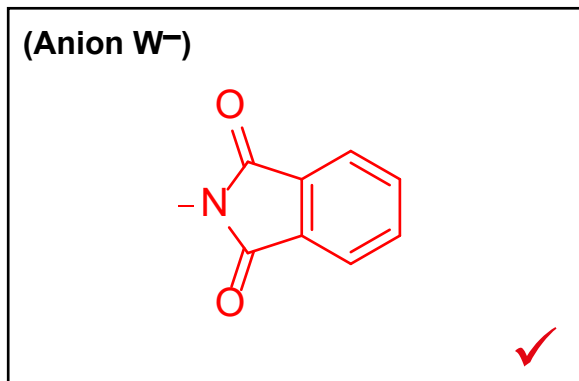
NH<sub>3</sub>

✓

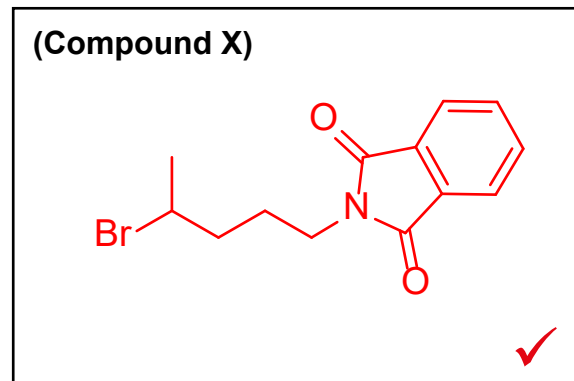
1

2(m) Structures:

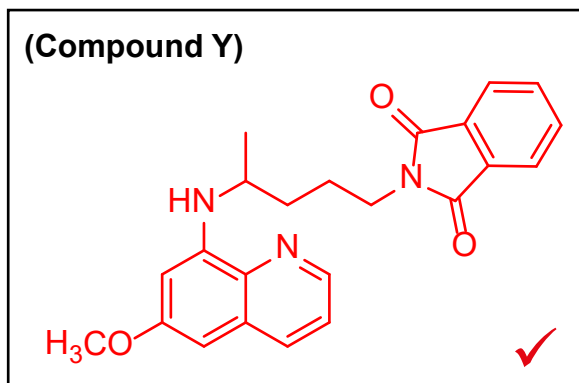
(Anion W<sup>-</sup>)



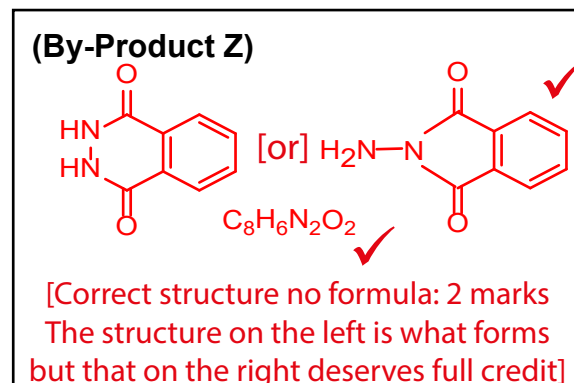
(Compound X)



(Compound Y)



(By-Product Z)



5

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