Cambridge Chemistry Challenge Lower 6th

June 2022

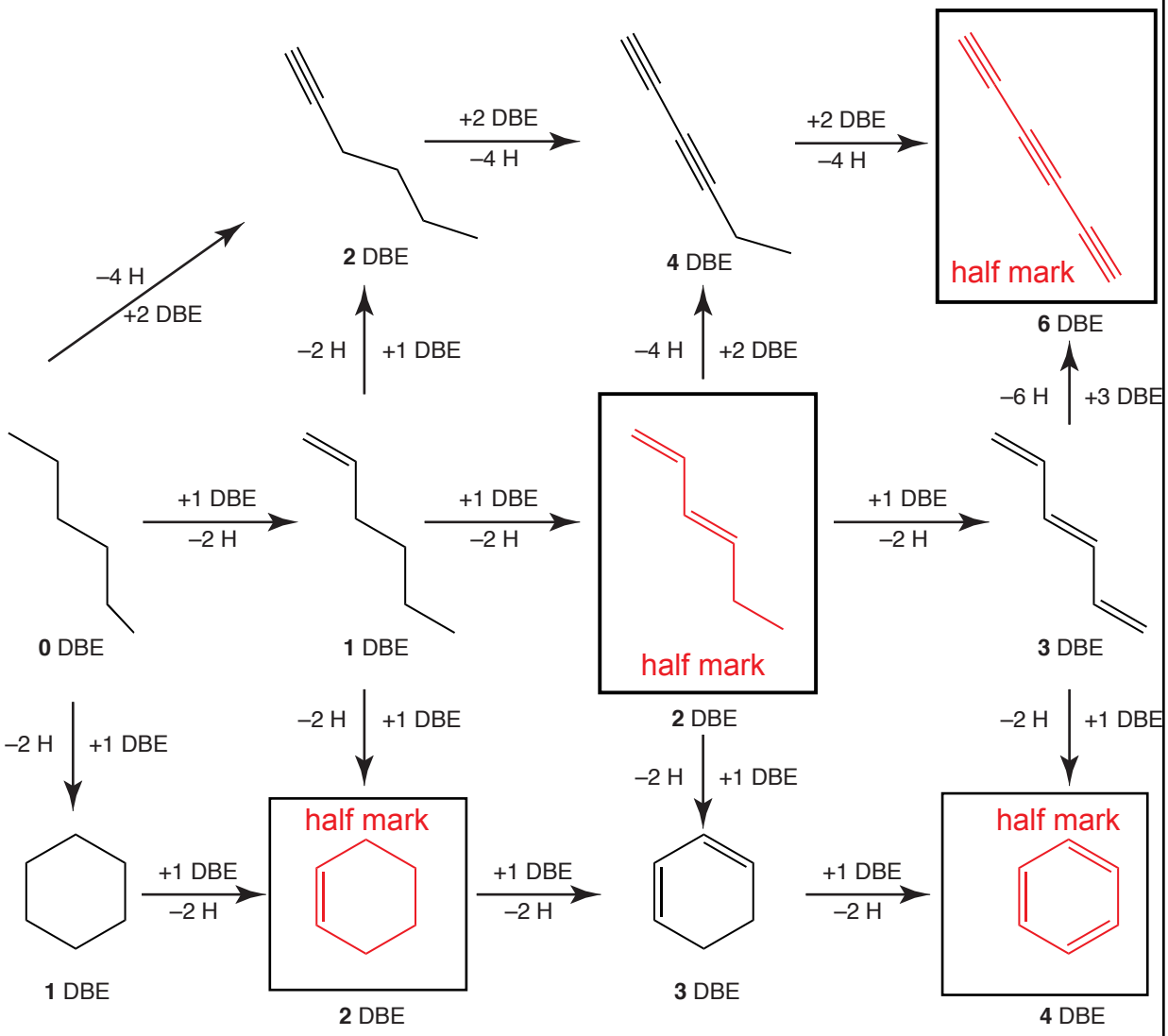
Marking scheme for teachers

(please also read the additional instructions)

	p2	p3	p4	p5	p6	p7	p8	p9	Total
mark	6	5	11	17	11	8	7	10	75

Marks available

1(a) (i) Complete the diagram below by filling in the missing structures. 1/2



1/2

1

(ii) Number of DBE Dame Bond has: (Circle the correct answer.)

004 005 006 007 (008) 009

half mark

1/2

1(b) General formulae for:

(i) an alkene or cycloalkane

C_nH_{2n} half mark

(ii) an alkyne

C_nH_{2n-2} half mark

1

(iii) a cycloalkene half mark

C_nH_{2n-2}

(iv) a tri-alkyne half mark

C_nH_{2n-10}

1

(v) hydrocarbon containing n carbons with x DBE

$C_nH_{2n-2x+2}$ half mark

1/2

1(c) Expression for the number of DBE in the hydrocarbon with formula CnHy

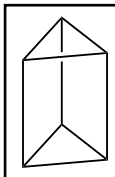
$DBE = (2n + 2 - y) / 2$ ✓

1

Page total 6

Marks available

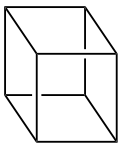
1(d) Number of DBE in:



prismane

4

half mark

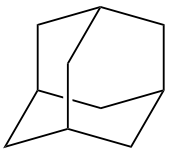


cubane

5

half mark

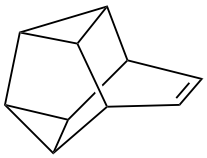
1



adamantane

3

half mark



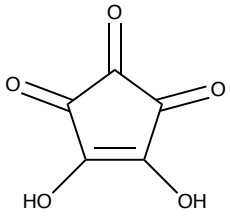
snoutene

6

half mark

1

1(e)



croconic acid

Number of DBE:

5

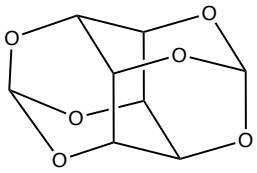
half mark

Formula:

$C_5H_2O_5$

half mark

1



hexaoxadiamantane

Number of DBE:

5

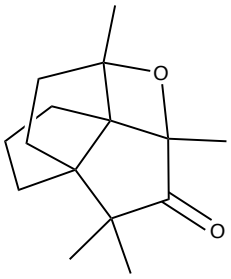
half mark

Formula:

$C_8H_8O_6$

half mark

1



dichrocephone-B

Number of DBE:

5

half mark

Formula:

$C_{15}H_{22}O_2$

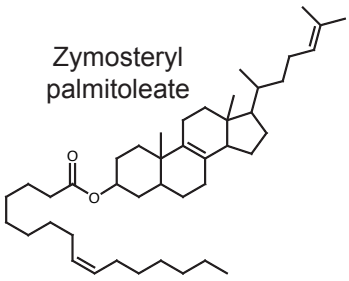
half mark

1

Page total 5

Marks available

1(f)

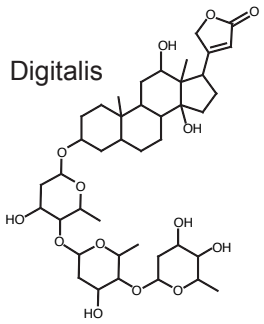


Number of DBE: 8 ✓

Formula: $C_{43}H_{72}O_{2}$ ✓

1 mark if both correct
1/2 mark if only H correct
0 marks if wrong H

2

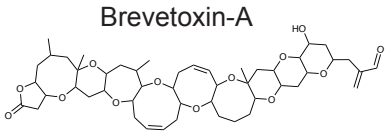


Number of DBE: 10 ✓

Formula: $C_{41}H_{64}O_{14}$ ✓

1 mark if both correct
1/2 mark if only H correct
0 marks if wrong H

2



Number of DBE: 15 ✓

Formula: $C_{49}H_{70}O_{13}$ ✓

1 mark if both correct
1/2 mark if only H correct
0 marks if wrong H

2

1(g) Complete the table of functional group combinations for 2 DBE.

DBE	Rings	C≡C	C=C	C=O	Alcohols	Ethers
2	**2**				**1**	
	2					**1**
		1			**1**	
		1				**1**
	1		**1**		**1**	
	1		**1**			**1**
	1			**1**		
			2		**1**	
			2			**1**
			1	**1**		

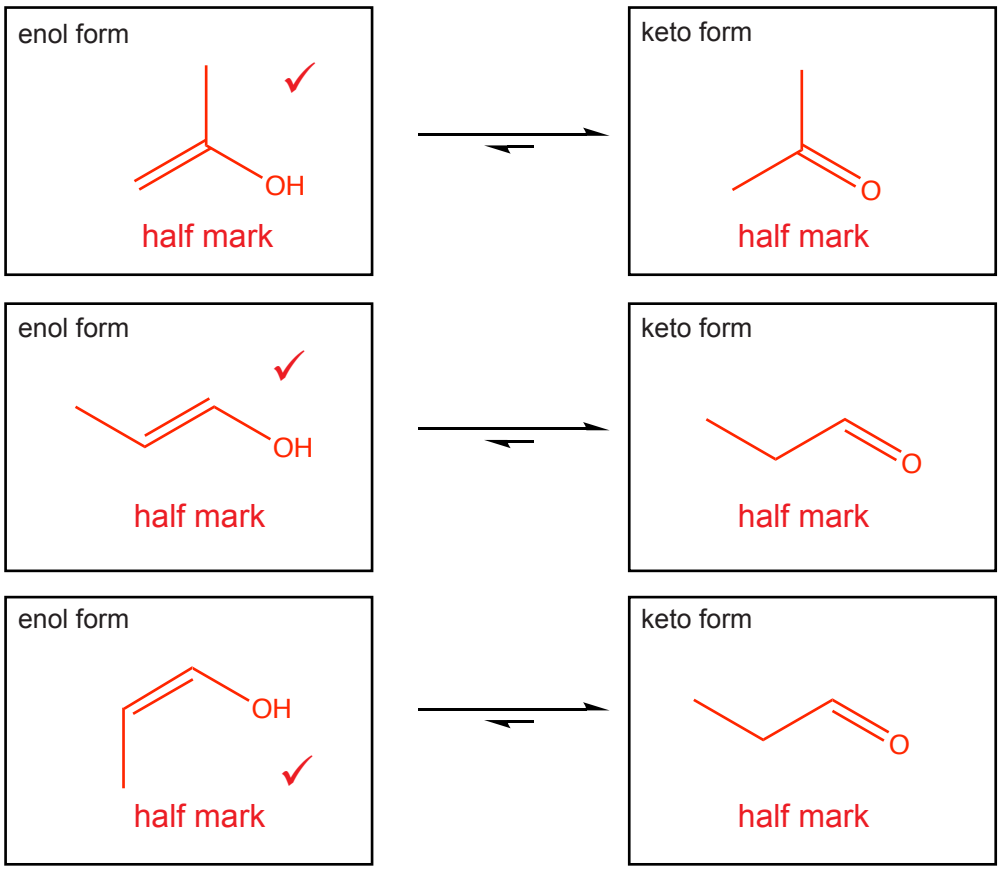
5

5 marks in total.
1/2 mark for each correct row
0 marks for repeats or incorrect rows.

Page total 11

Marks available

1(h) THREE keto-enol isomers of C_3H_6O

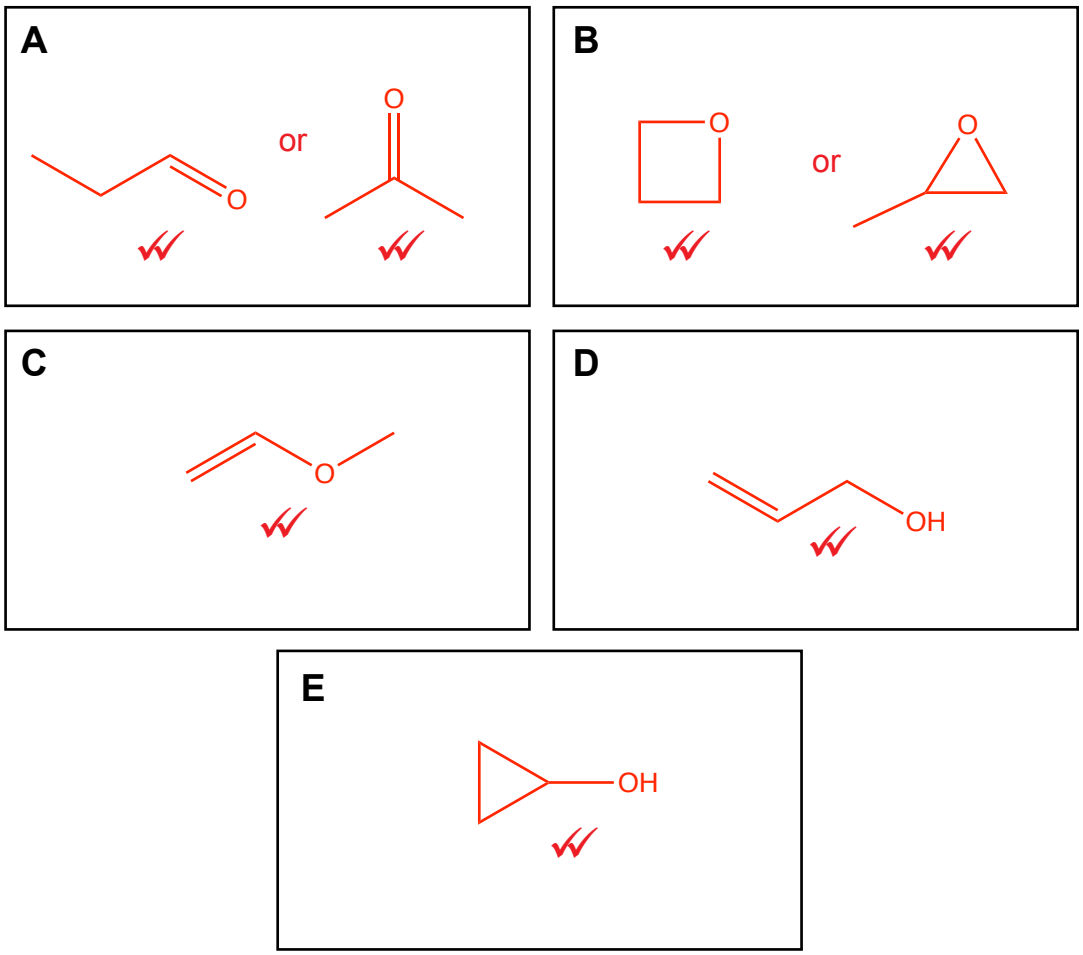


1

1

1

1(i) The structure(s) that could possibly correspond to each of the spectra:



2 for each correct structure

Page total 17

Marks available

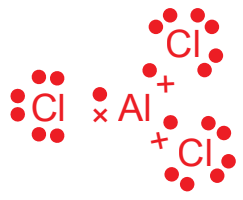
2(a) (i) Electron configuration:

$1s^2\ 2s^2$ ... $2p^6\ 3s^2\ 3p^1$ ✓ — 1

(ii) Gain: 5 Half a mark — Lose: 3 Half a mark ✓ — 1

2(b) Empirical formula: $AlCl_3$ ✓ — 1

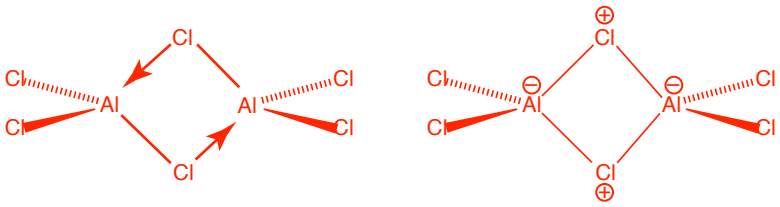
2(c) (i) Dot & Cross:



✓

(ii) Angle: 120° ✓ — 2

(iii) Structure — 1



(Either structure is fine. Accept without wedge & hash bonds.)

2(d) (i) Phases: — 1

P = LIQUID **Q =** SOLID **R =** GAS

(No partial cred. All or nothing!)

(ii) Temperature: ✓ Allow between 190-200 °C — Pressure / kPa: Allow between 220-240 °C ✓ — 2

(iii) Unique property: — 1

All three phases are in equilibrium at this point. ✓

(Half mark for ALL THREE PHASES;
a second half mark for saying IN EQUILIBRIUM)

(iii) Most likey structure (tick one): — 1

a) mixture of aluminium and chloride ions

b) a molecule of Mr 133.33

✓c) a molecule of Mr 266.66

Page total 11

Marks available

2(e) (i)

moles of $AlCl_3$ = 0.500 / (26.98 + (3 x 35.45)) = 0.00375 mol

moles of Al = 0.202 / 26.98 = 0.00749 mol

∴ ratio of $AlCl_3$: Al = 1:2 ✓

1 mol of $AlCl_3$ reacts with 2 mol Al

since molecular formula = empirical formula,
final equation is:

[moles of AlCl formed = 3 x 0.00375 = 0.01125 mol]

Equation for the formation of **B**:

$$AlCl_3(g) + 2\,Al(l) \longrightarrow 3\,AlCl(g)$$ ✓

2

(ii)

Dot & cross diagram for **B**:



✓

1

(ii)

Average bond energy in **A**:

$$AlCl_3(g) \xrightarrow{\Delta H} Al(g) + 3\,Cl(g)$$

$$Al(s) + \tfrac{3}{2}\,Cl_2(g)$$

-584.6 ; $+330$; $1.5(242.6)$

$\Delta H = 584.6 + 330 + 1.5(242.6) = 1278.5$ kJ mol^{-1} ✓

ΔH = 3 × average Al–Cl bond strength

∴ bond strength in $AlCl_3$ = 1278.5/3 = 426 kJ mol^{-1} ✓

2

Average bond energy in **B**:

$$AlCl_3(g) + 2\,Al(l) \xrightarrow{\Delta H(\text{reaction})} 3\,AlCl(g)$$

$$3Al(g) + 3\,Cl(g)$$

$3x$; $2(+10.56)$; -584.6 ; $+3(330)$; $1.5(242.6)$ ✓

$$3Al(s) + \tfrac{3}{2}\,Cl_2(g)$$

$\Delta H(\text{reaction}) = (1.532 / 0.01125) \times 3 = 408.5$ kJ mol^{-1}

$3x = -408.5 + 584.6 - 2(10.56) + 3(330) + 1.5(242.6) = 1509$ kJ mol^{-1} ✓

x = 1509 / 3 = 503 kJ mol^{-1} ✓

3

Page total 8

Marks available

2(f) (i) Decomposition reaction:

$2AlCl_3 \cdot 6H_2O(s) \longrightarrow Al_2O_3(s) + 6\,HCl(g) + 9H_2O(g)$ ✓ — 1

2(g)

x = 6, y = 0

formula: $[\,Al(H_2O)_6\,]^{3+}$ pH: 3 ✓ (half mark each) — 1

x = 4, y = 2

formula: $[\,Al(H_2O)_4(OH)_2\,]^{1+}$ pH: 9 ✓ (half mark each) — 1

x = 0, y = 4

formula: $[\,Al(OH)_4\,]^{-1}$ pH: 12 ✓ (half mark each) — 1

2(h)

No. of moles of Cl^- in 25.0 cm^3 = No. of moles of Ag^+
= (20.75 / 1000) × 0.05

No. of moles of Cl^- in 250.0 cm^3 = No. of moles of Cl^- in 1g
= (20.75 / 1000) × 0.05 × 10 = $\underline{\underline{0.010375}}$ ✓

Formula mass of $Al_2(OH)_{(6-x)}Cl_x$ =
= 2(26.98) + (6 – x)(16.00 +1.008) + x(35.45 = 156.008 +18.442x

1 mol of $Al_2(OH)_{(6-x)}Cl_x$ = [156.008 +18.442x] g gives x moles of Cl^-

so 1 g of $Al_2(OH)_{(6-x)}Cl_x$ gives:

$\dfrac{x}{156.008 + 18.442x}$ moles of Cl^- = 0.010375 (from above) — 3

$x = (156.008)(0.010375) + (18.442)(0.01375)x$ ✓

$x = \dfrac{(156.008)(0.010375)}{1 - (18.442)(0.01375)} = \underline{\underline{2.00}}$

so formula is $\underline{\underline{Al_2(OH)_4Cl_2}}$ ✓

Other methods possible, e.g. trial and error:
if x = 1, $M_r\,[\,Al_2(OH)_5Cl\,]$ = 174.444, so 1.000 g
= 5.732×10^{-3} moles ≡ moles Cl^-, therefore wrong formula

if x = 2, $M_r\,[\,Al_2(OH)_4Cl_2\,]$ = 192.888, so 1.000 g
= 5.184×10^{-3} moles ≡ 0.01037 moles Cl^-, which is correct

Page total 7

Marks available

2(j) (i)

100 mg of mineral contains:
41.1 mg H_2O

26.5 mg of CO_2 contains 26.5 x 12.01 / (12.01 +2(16)) = 7.232 mg C

4.1 mg of CO contains 4.1 x 12.01 / (12.01 +16) = 1.758 mg C

28.3 mg of residue contains 28.3 x 0.4487 = 12.698 mg C

So 100 mg of mineral contains 7.232 + 1.758 + 12.698 mg of C = 21.688 mg ✓

28.3 mg of residue contains
28.3 x 0.5513 x 2(26.98) / (2(26.98) + 3x16) mg of Al = 8.259 mg ✓

mass of oxygen in the 100 mg = 100 – 21.688 – 8.259 – 41.1 = 28.953 mg ✓

mole ratio Al : C : O : H_2O =
(8.259 / 26.98) : (21.688 / 12.01) : (28.953 / 16) : 41.1 / (16 + 2(1.008))

= 0.3061 : 1.806 : 1.81 : 2.281

divide by smallest gives = 1 : 5.9 : 5.9 : 7.5 ✓

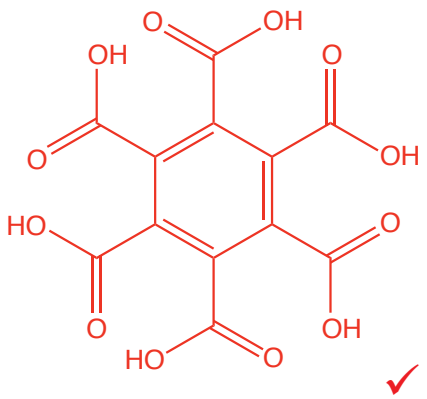
doubling & rounding up gives = 2 : 12 : 12 : 15

Formula: $Al_2C_{12}O_{12}\cdot 15H_2O$ ✓ — 5

(ii) Formula of anion:

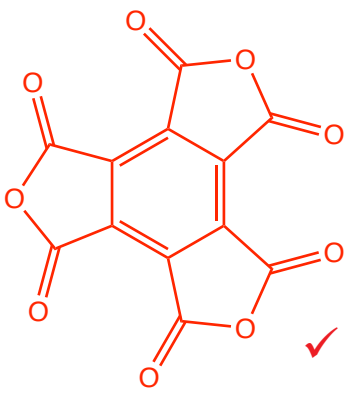
$C_{12}O_{12}^{6-}$ ✓ — 1

(iii) Structure of mellitic acid:



✓

(iv) Structure of mellitic anhydride:



✓

Formula: $C_{12}O_9$ ✓ DBE: 13 ✓ — 4

Page total 10