

Cambridge Chemistry Challenge Lower 6th

June 2017

Student Answer Booklet

Student name _____

male female

Date of exam _____

Email _____

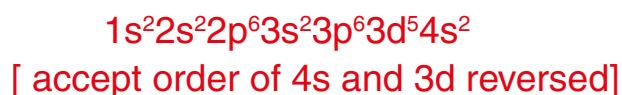
School _____

School year (eg year 12) _____

A-level (or equiv) subjects taken _____

	p2	p3	p4	p5	p6	p7	p8	p9	Total
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1(a) The electron configuration of manganese:



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blank

1

1(b)

(i) The highest oxidation state of manganese:

+7 or (VII) ✓

1

(ii) Briefly justify your answer to b(i):

There is a large jump in the ionisation energy graph for manganese between the 7th and 8th ionisations.

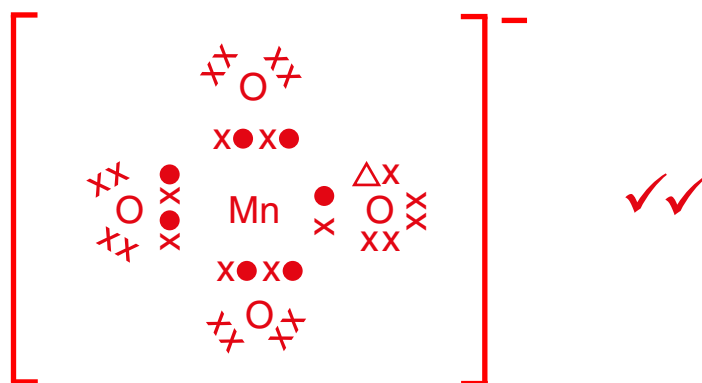
or ✓

+7 corresponds to the loss of all of the 4s and 3d electrons, losing an electron from the 3p shell requires considerably more energy.

1

1(c)

(i) Dot and cross diagram for MnO_4^- :



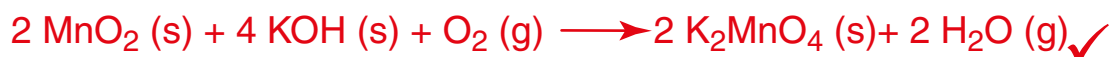
2

(ii) Bond angle in MnO_4^- :

109.5° ✓

1

1(d) Balanced equation for the reaction of pyrolusite:



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

1

1(e)

(i) Half equation for the reduction of water:



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

1

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1(e)

(ii) Half equation for the oxidation of potassium manganate(VI):



1

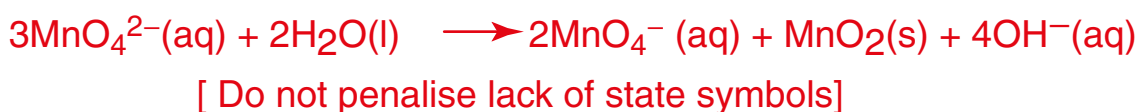
(iii) Reaction for production of potassium manganate(VII):



[Half quantities accepted. Do not penalise lack of state symbols.
Also accept correct ionic equation.]

1

1(f) Disproportionation reaction:



1

1(g) Units of ϵ : $\text{mol}^{-1} \text{dm}^3 \text{cm}^{-1}$

[SI unit is actually $\text{m}^2 \text{mol}^{-1}$: allow other derivatives such as $\text{dm}^2 \text{mol}^{-1}$]

\checkmark

1

1(h) Value of ϵ :

$$\epsilon = \Delta \text{Absorbance} / \Delta[\text{KMnO}_4] = 1 / 0.00045 = 2222 \text{ mol}^{-1} \text{dm}^3 \text{cm}^{-1}$$

Accept 2200 to 2300 $\text{mol}^{-1} \text{dm}^3 \text{cm}^{-1}$ (2 sig. fig)

\checkmark

1

1(i) Absorbance of solution:

$$\text{Concentration (mol dm}^{-3}\text{)} = \frac{\text{Concentration (g dm}^{-3}\text{)}}{M_r(\text{KMnO}_4)}$$

$$= \frac{(0.05 / 1000)}{158.034} = 3.16 \times 10^{-7} \quad \checkmark$$

2

$$A = 2222 \times 3.16 \times 10^{-7} = 7.0 \times 10^{-4} \text{ (2 sig. fig.)}$$

Accept $A = 6.6 \times 10^{-4}$ to 7.4×10^{-4} \checkmark

1(j)

(i) Concentration of potassium manganate(VII):

$$\text{Concentration (mol dm}^{-3}\text{)} = \text{Absorbance} / \epsilon l = 0.4 / 2222 = 0.000178 \quad \checkmark$$

$$\text{Concentration (mg dm}^{-3}\text{)} = \text{Concentration (mol dm}^{-3}\text{)} \times M_r(\text{KMnO}_4) \times 1000$$

$$= 0.000178 \times 158.034 \times 1000$$

$$= 28 \text{ mg (2 sig. fig.)}$$

Accept 27 to 30 mg dm^{-3} \checkmark

2

1(j)

(iii) Amount of water for a toxic dose:

The toxic dose for a 75 kg resident is $75 \times 1000 = 75000$ mg.
 This is $75000/28.44 = 2600$ litres of contaminated water. (2 sig. fig) ✓
 Accept 2500 to 2800 litres.

1

1(k)

(i) Molecular formula of Compound X:

Element	Ar	Percentage	Percentage/ Ar	Divide by smallest	Whole numbers
Mn	54.938	49.5	0.90101569	1	2
O	15.999	50.5	3.156447278	3.50321011	7

1

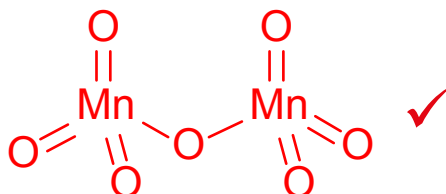


(ii) Balanced equation for reaction of $KMnO_4$ with H_2SO_4 :



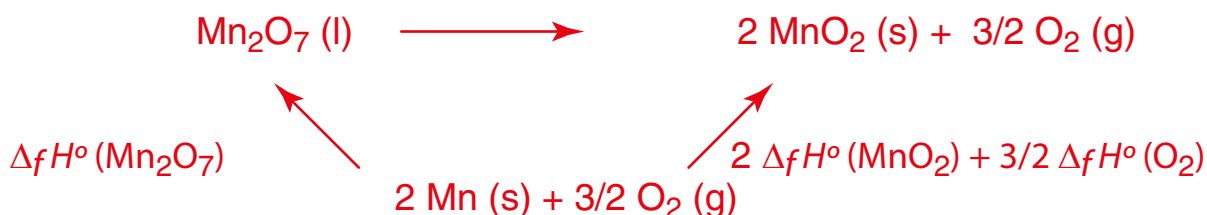
1

(iii) Structure of Compound X:



1

1(l) Standard change enthalpy of reaction:



2

$$\begin{aligned}
 \Delta_r H^\circ &= 2 \times \Delta_f H^\circ(MnO_2) + 3/2 \Delta_f H^\circ(O_2) - \Delta_f H^\circ(Mn_2O_7) \quad \checkmark \\
 &= (2 \times -520) + (3/2 \times 0) - (-742) \\
 &= -298 \text{ kJ mol}^{-1} \quad \checkmark
 \end{aligned}$$

1(m) Mass of KMnO_4 needed:

$$\begin{aligned}\text{No. moles heptanoic acid} &= \text{mass (heptanoic acid)} / M_r (\text{heptanoic Acid}) \\ &= 300 / 130.182 \\ &= 2.304 \quad \checkmark\end{aligned}$$

$$\begin{aligned}\text{No. moles of heptanal} &= 2.304 / 77 \times 100 \\ &= 2.993 \quad \checkmark\end{aligned}$$

$$\begin{aligned}\text{No. moles of } \text{KMnO}_4 &= 2.993 \times (2/3) \times 1.1 \\ &= 2.195 \quad \checkmark\end{aligned}$$

$$\begin{aligned}\text{Mass } \text{KMnO}_4 &= \text{No. moles } (\text{KMnO}_4) \times M_r (\text{KMnO}_4) \\ &= 2.195 \times 158.042 \\ &= 347 \text{ g} \quad \checkmark\end{aligned}$$

4

1(n) How many times more expensive:

500 ml of NaMnO_4 contains $0.4 \times 500 = 200 \text{ g NaMnO}_4$

200 g of NaMnO_4 contains $200 / 141.95 = 1.41 \text{ moles NaMnO}_4$

Cost per mole is $\text{£}67.80 / 1.41 = \text{£}48.12 \quad \checkmark$

3

1 kg of KMnO_4 contains $1000 / 158.03 = 6.33 \text{ moles KMnO}_4$

Cost per mole is $\text{£}54.20 / 6.33 = \text{£}8.57 \quad \checkmark$

It is $\text{£}48.12 / \text{£}8.57 = \underline{\underline{5.62}}$ times more expensive to use $\text{NaMnO}_4 \quad \checkmark$

2(a)

(i) Equation for bromination of ethane:



leave
blank

1

(ii) Classification of this reaction:

Addition Elimination Substitution Hydrolysis Cracking Polymerisation \checkmark

1

(iii) The bond broken by light:

The Br—Br bond is broken. \checkmark

1

2(b) Smallest proportion bromoalkane: B \checkmark

Systematic name: 2-bromo-2-methylbutane. \checkmark

2

[Allow ECF for correct name but wrong choice.]

2(c) Expected percentages A–D:

A: (6/12) 50%	B: (1/12) 8.3%	C: (2/12) 16.7%	D: (3/12) 25%
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2

[Award 0.5 marks per correct answer] $\checkmark\checkmark$

2(d) Relative reactivity between B and C:

Compound B: Actual percentage/predicted percentage = $93.5/8.3 = 11.2$ \checkmark

Compound C: Actual percentage/predicted percentage = $6.3/16.7 = 0.378$

Relative reactivity Compound B vs Compound C = $11.2 / 0.378 = 29.7$ \checkmark
[Accept ECF from part (c)]

2

2(e) Number of structural isomers:

(i) 3 \checkmark ^{1/2}	(ii) 1 \checkmark ^{1/2}	(iii) 3 \checkmark ^{1/2}
(iv) 4 \checkmark ^{1/2}	(v) 3 \checkmark	(vi) 2 \checkmark

4

[Award 0.5 marks for (i), (ii), (iii) & (iv). Award 1 mark for (v) and (vi)]

2(f)

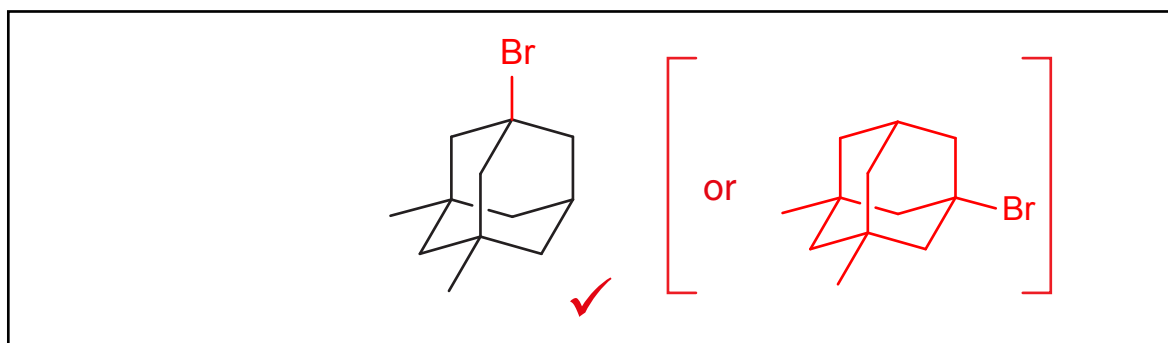
(i) Number of structural isomers of compound E: 5 $\checkmark\checkmark$

2

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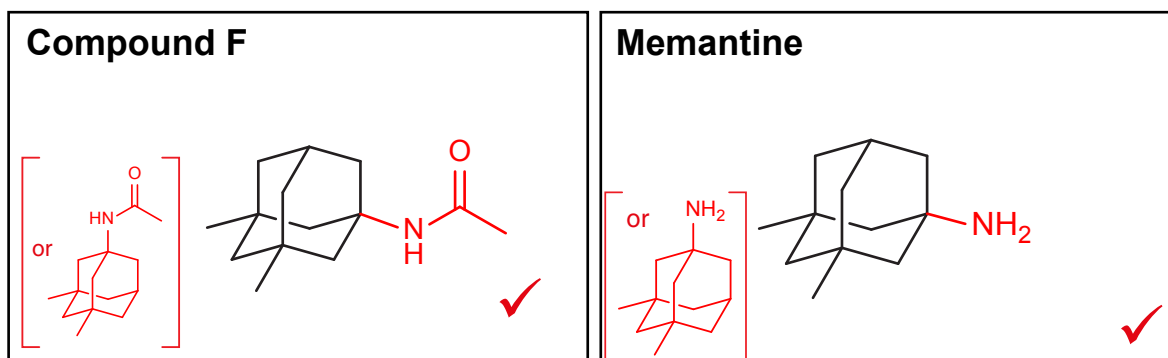
2(f)

(ii) Structure of Compound E (carbon skeleton given):

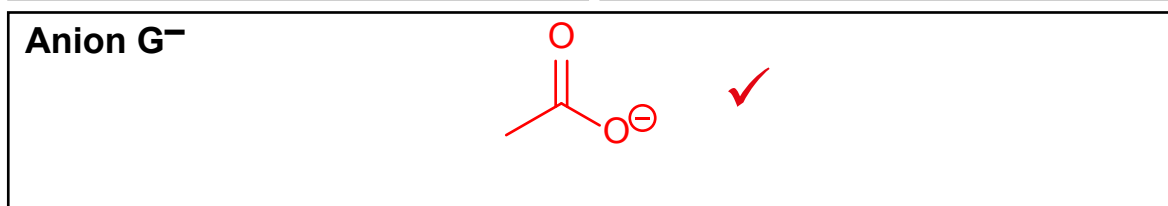


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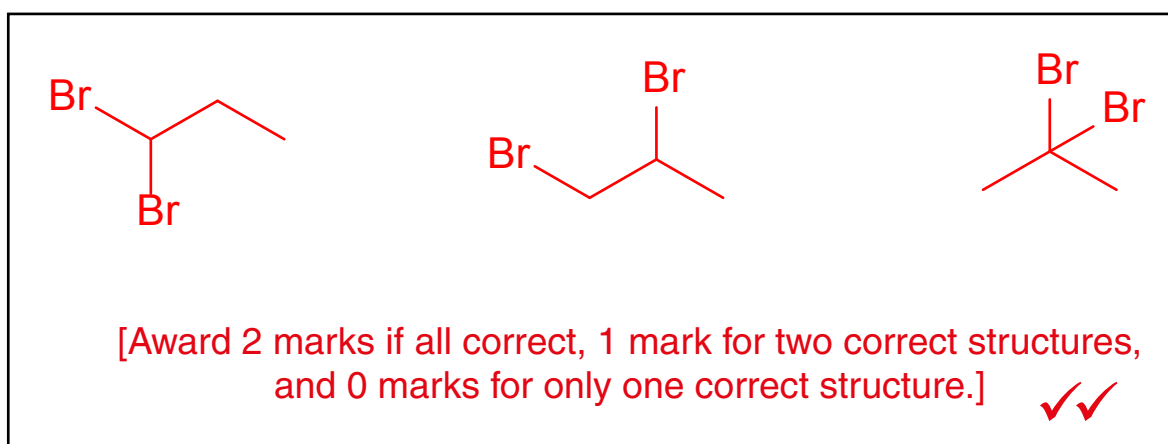
2(g) Structures in memantine synthesis:



3



2(h) Structural isomers of dibromopropane:



2

2(i) Percentage of 1,3-dibromopropane:

Probability of first bromination occurring at a terminal C atom = $6/8 = 0.75$.

Probability of second bromination occurring at the opposite terminal C atom = $3/7 = 0.43$. ✓

Probability of formation of 1,3-dibromopropane = $0.75 \times 0.43 = 0.32$.

If the probability of all hydrogen atoms being replaced was equal then 32% of the products would be 1,3-dibromopropane. ✓

2

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2(j)

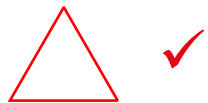
(i) Structure of Compound H:

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Element	Ar	Percentage	Percentage/ Ar	Divide by smallest
C	12	85.63	7.13583333	1
H	1.008	14.37	14.2559524	2

3 carbon atoms, therefore C₃H₆ ✓

[NOT propene as it gives the 1,2 bromination product. Give 2 marks if just give correct structure with no calculation.]



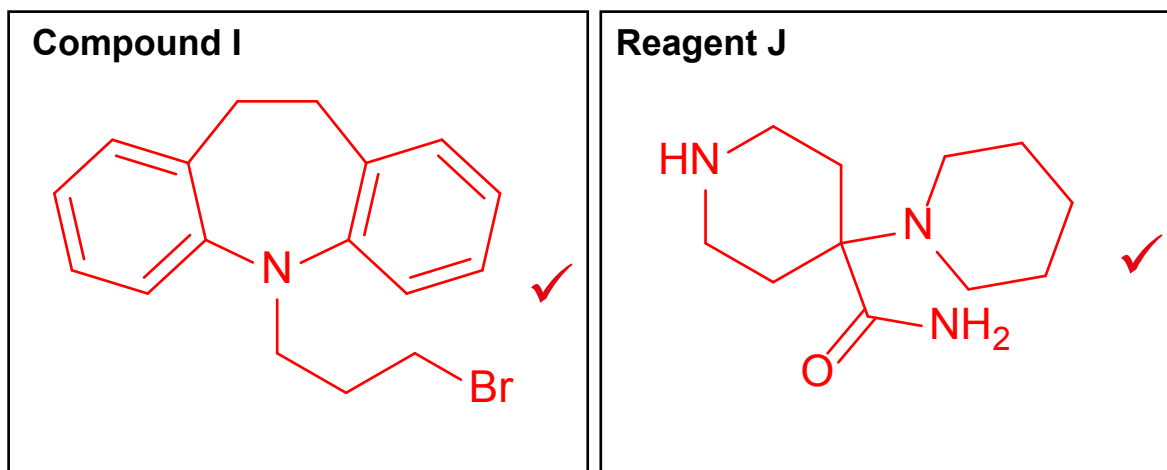
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(ii) Classification of this reaction:

Addition Elimination Substitution Hydrolysis Cracking Polymerisation ✓

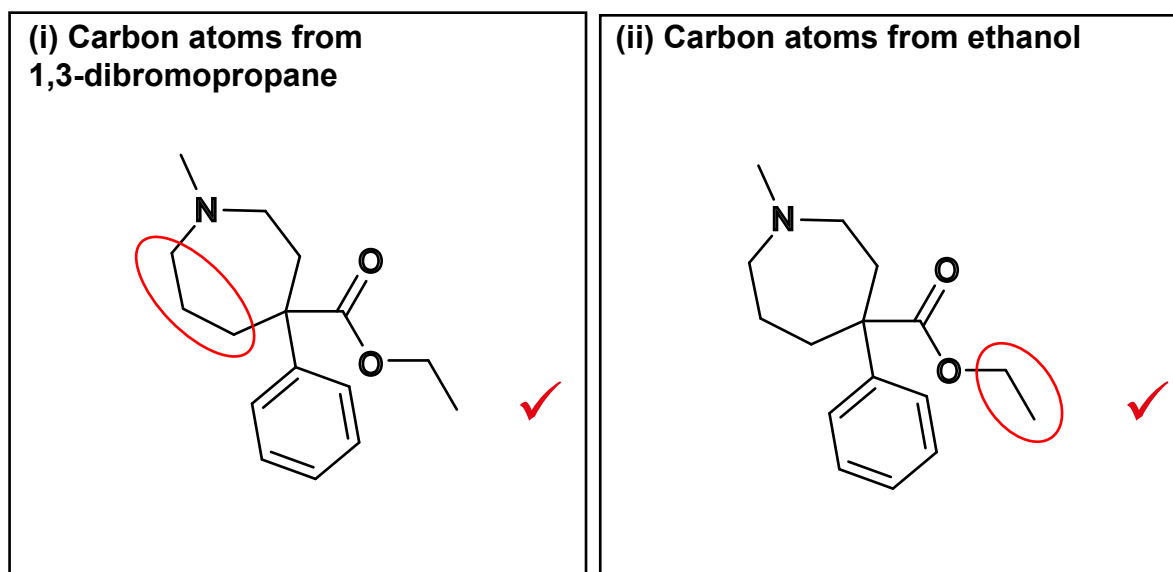
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2(k) Structures in memantine synthesis:



2

2(l) Structures:



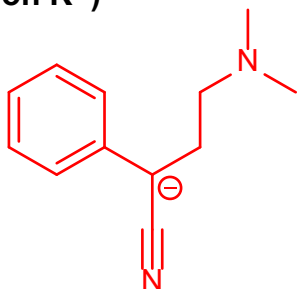
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2(m) Structures:

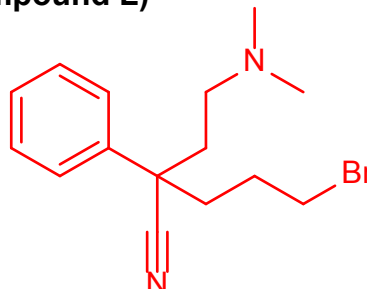
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(Anion K⁻)



✓✓

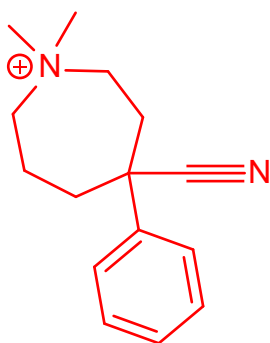
(Compound L)



✓✓

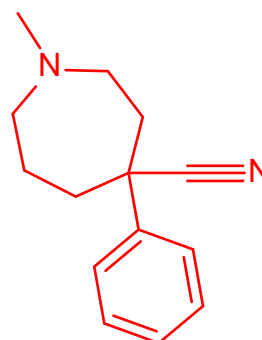
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(Cation M⁺)



✓✓

(Compound N)



✓✓