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 ________________________________

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	p2	p3	p4	p5	p6	p7	p8	p9	**Total**
mark									

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1(a) **The electron configuration of manganese:**

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$ 1

[accept order of 4s and 3d reversed]

1(b)

(i) **The highest oxidation state of manganese:**

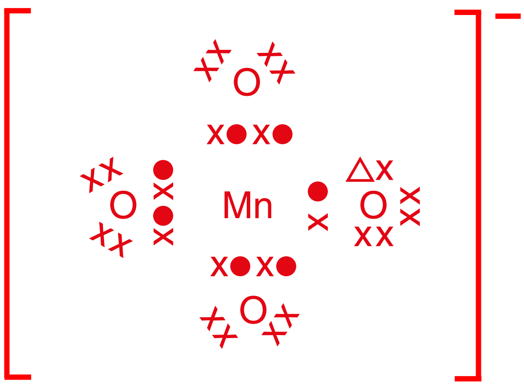
+7 or (VII) 1

(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 1
+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(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:**

$2\,MnO_2\,(s) + 4\,KOH\,(s) + O_2\,(g) \longrightarrow 2\,K_2MnO_4\,(s) + 2\,H_2O\,(g)$ 1

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

1(e)

(i) **Half equation for the reduction of water:**

$2\,H_2O\,(l) + 2e^- \longrightarrow H_2\,(g) + 2\,OH^-\,(aq)$ 1

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

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1(e)

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

MnO_4^{2-} (aq) ⟶ MnO_4^- (aq) + e^- ✓ 1

[Do not penalise lack of state symbols]

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

$2K_2MnO_4(aq) + 2H_2O(l) \longrightarrow 2KMnO_4(aq) + 2KOH(aq) + H_2(g)$ ✓

[Half quantities accepted. Do not penalise lack of state symbols. Also accept correct ionic equation.] 1

1(f) Disproportionation reaction:

$3MnO_4^{2-}(aq) + 2H_2O(l) \longrightarrow 2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq)$ ✓ 1

[Do not penalise lack of state symbols]

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

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

1(h) Value of ε:

$\varepsilon = \Delta Absorbance / \Delta[KMnO_4] = 1 / 0.00045 = 2222\ mol^{-1}\ dm^3\ cm^{-1}$

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

1(i) Absorbance of solution:

$$\text{Concentration (mol dm}^{-3}) = \frac{\text{Concentration (g dm}^{-3})}{M_r(KMnO_4)}$$

$$= \frac{(0.05 / 1000)}{158.034} = 3.16 \times 10^{-7}$$ ✓ 2

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

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

1(j)

(i) Concentration of potassium manganate(VII):

Concentration (mol dm^{-3}) = Absorbance / ε l = 0.4/2222 = 0.000178 ✓ 2

Concentration (mg dm^{-3}) = Concentration (mol dm^{-3}) × $M_r(KMnO_4)$ ×1000

= 0.000178 × 158.034 × 1000

= 28 mg (2 sig. fig.)

Accept 27 to 30 mg dm^{-3} ✓

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1(j)

(iii) Amount of water for a toxic dose:

The toxic dose for a 75 kg resident is 75 x 1000 = 75000 mg.
This is 75000/28.44 = 2600 litres of contaminated water. (2 sig. fig) ✓ 1
Accept 2500 to 2800 litres.

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

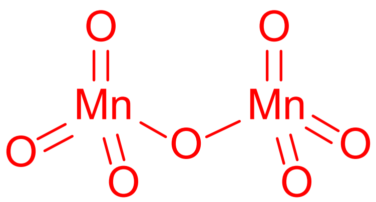
Mn_2O_7 ✓ 1

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

$2KMnO_4(aq) + H_2SO_4(l) \longrightarrow K_2SO_4(aq) + Mn_2O_7(l) + H_2O(l)$ ✓ 1

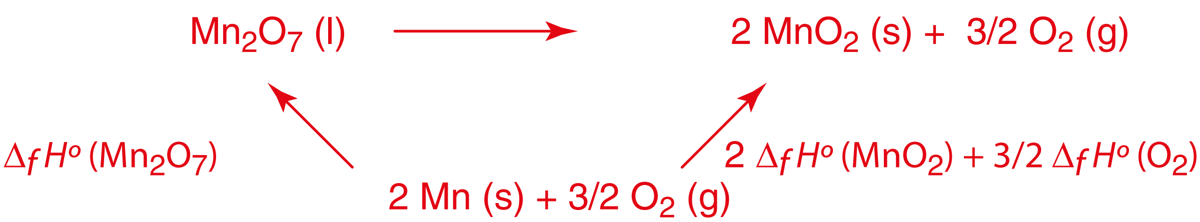
[Do not penalise lack of state symbols]

(iii) Structure of Compound X:



✓ 1

1(l) Standard change enthalpy of reaction:



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$\Delta_r H^o = 2 \times \Delta_f H^o(MnO_2) + 3/2\, \Delta_f H^o(O_2) - \Delta_f H^o(Mn_2O_7)$ ✓

$= (2 \times -520) + (3/2 \times 0) - (-742)$

$= -298\ \mathrm{kJ\ mol^{-1}}$ ✓

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1(m) Mass of $KMnO_4$ needed:

No. moles heptanoic acid = mass (heptanoic acid) / M_r (heptanoic Acid)
= 300 / 130.182
= 2.304 ✓

No. moles of heptanal = 2.304 / 77 × 100
= 2.993 ✓

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No. moles of $KMnO_4$ = 2.993 × (2/3) × 1.1 ✓
= 2.195

Mass $KMnO_4$ = No. moles ($KMnO_4$) × Mr ($KMnO_4$)
= 2.195 × 158.042
= 347 g ✓

1(n) How many times more expensive:

500 ml of $NaMnO_4$ contains 0.4 × 500 = 200 g $NaMnO_4$

200 g of $NaMnO_4$ contains 200 / 141.95 = 1.41 moles $NaMnO_4$

Cost per mole is £67.80 / 1.41 = £48.12 ✓

3

1 kg of $KMnO_4$ contains 1000 / 158.03 = 6.33 moles $KMnO_4$

Cost per mole is £54.20 / 6.33 = £8.57 ✓

It is £48.12 / £8.57 = 5.62 times more expensive to use $NaMnO_4$ ✓

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2(a)

(i) **Equation for bromination of ethane:**

$C_2H_6 + Br_2 \longrightarrow C_2H_5Br + HBr$ ✓ 1

(ii) **Classification of this reaction:**

Addition Elimination Substitution Hydrolysis Cracking Polymerisation ✓ 1

(iii) **The bond broken by light:**

The Br—Br bond is broken. ✓ 1

2(b) **Smallest proportion bromoalkane:** B ✓

Systematic name: 2-bromo-2-methylbutane. ✓ 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%

2

[Award 0.5 marks per correct answer] ✓✓

2(d) **Relative reactivity between B and C:**

Compound B: Actual percentage/predicted percentage = 93.5/8.3 = 11.2 ✓

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 ✓

[Accept ECF from part (c)] 2

2(e) **Number of structural isomers:**

(i) 3 1/2 ✓	**(ii)** 1 1/2 ✓	**(iii)** 3 1/2 ✓
(iv) 4 1/2 ✓	**(v)** 3 ✓	**(vi)** 2 ✓

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 ✓✓ 2

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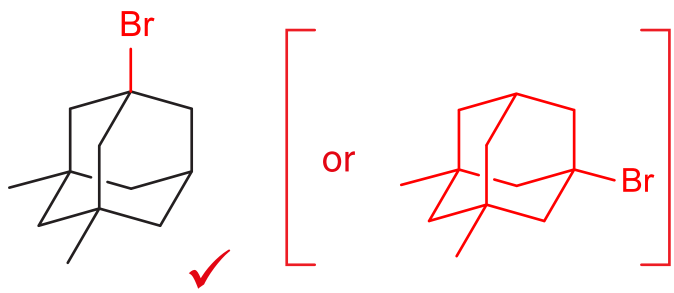
2(f)

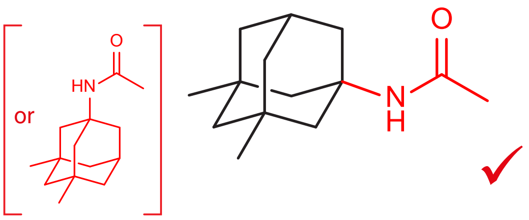
(ii) Structure of Compound E (carbon skeleton given):



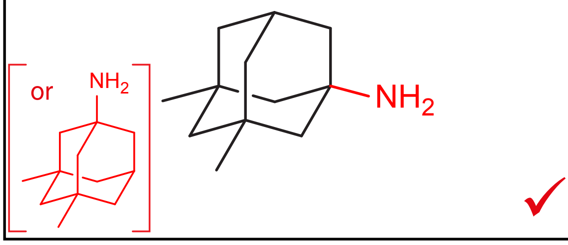
1

2(g) Structures in memantine synthesis:

Compound F

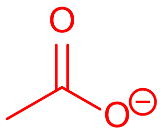


Memantine

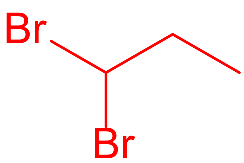


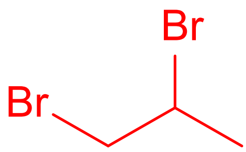
3

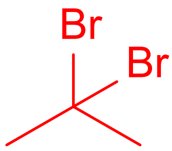
Anion G$^-$



2(h) Structural isomers of dibromopropane:







[Award 2 marks if all correct, 1 mark for two correct structures, and 0 marks for only one correct structure.] ✓✓

2

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

Probability of first bromination occuring at a terminal C atom = 6/8 = 0.75.
Probability of second bromination occuring at the opposite terminal C atom = 3/7 = 0.43. ✓
Probability of formation of 1,3-dibromopropane = 0.75 × 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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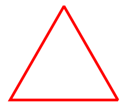
2(j)

(i) Structure of Compound H:

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 C_3H_6



[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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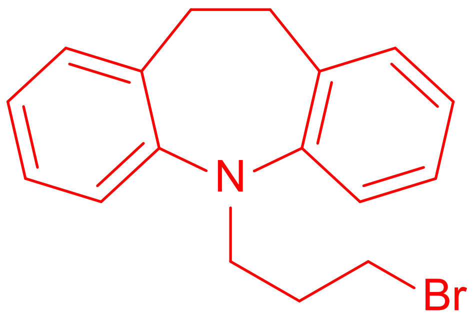
(ii) Classification of this reaction:

Addition Elimination Substitution Hydrolysis Cracking Polymerisation

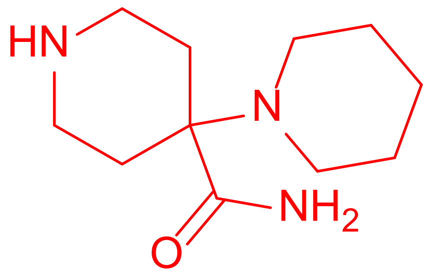
1

2(k) Structures in memantine synthesis:

Compound I



Reagent J



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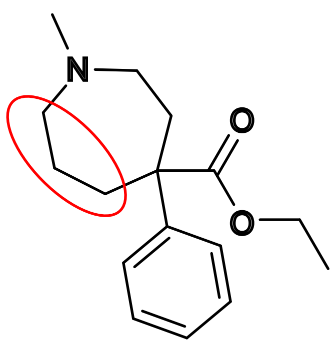
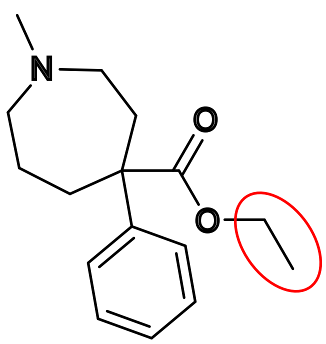
2(l) Structures:

(i) Carbon atoms from 1,3-dibromopropane



(ii) Carbon atoms from ethanol



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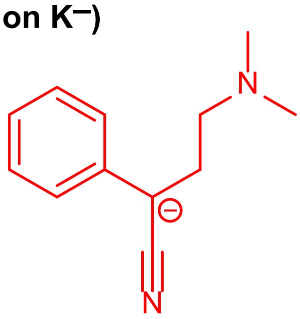
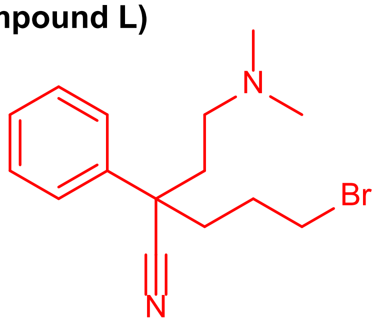
2(m) **Structures:**

(Anion K⁻)



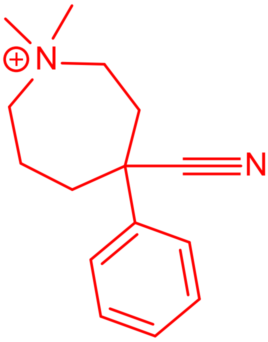
✓✓

(Compound L)



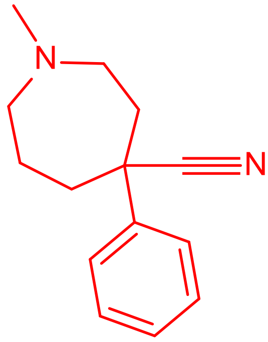
✓✓

(Cation M⁺)



✓✓

(Compound N)



✓✓

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