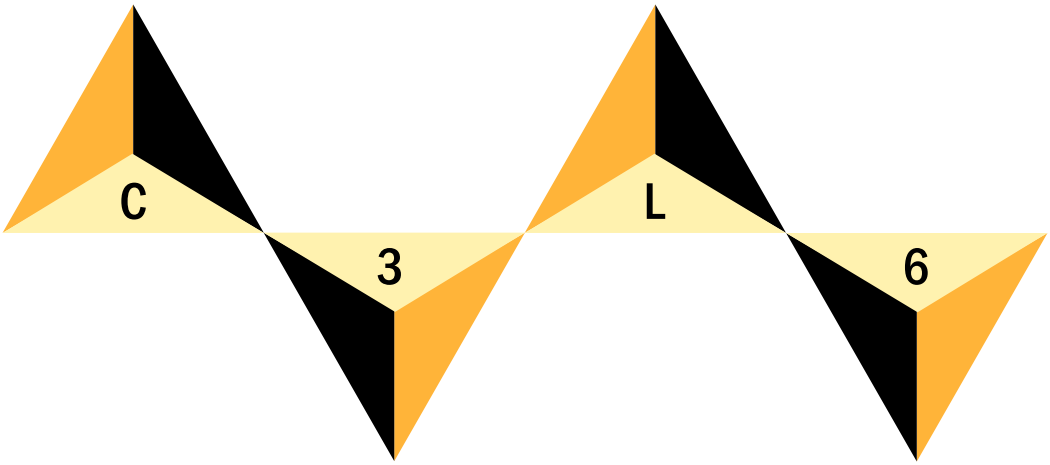


Cambridge Chemistry Challenge Lower 6th

June 2013

Marking scheme for teachers

(please also read the additional instructions)

	p2	p3	p4	p5	p6	p7	p8	p9	Total
mark	7	7	7	8	5	11	6	9	**60**

leave blank

1(a) C (34.6 / 12.01) : H (3.85 / 1.008) : O (61.5 / 16.00)

2.88	:	3.82	:	3.84
1	:	1.33	:	1.33
3	:	4	:	4

empirical formua of A	**molecular formua of A**
$C_3H_4O_4$ ✓	$C_3H_4O_4$ ✓

2

(b) **functional group contained in A**

carboxylic acid ✓

[allow COOH]

1

[accept C=O and O–H]

(c)(i) moles of A = (8.00/104) x (25/1000) = 0.00192 mol

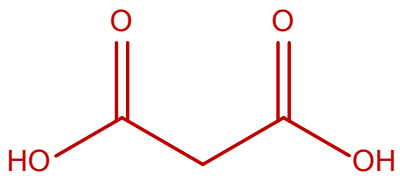
moles of NaOH = (0.200/1000) x 19.2 = 0.00384 mol ✓

∴ moles of NaOH per mole of A
= 0.00384 / 0.00192
= 2

number of moles
2 ✓

2

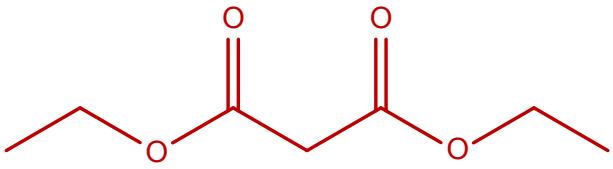
(c)(ii) **structure of A:**



✓

1

(d) **structure of B:**



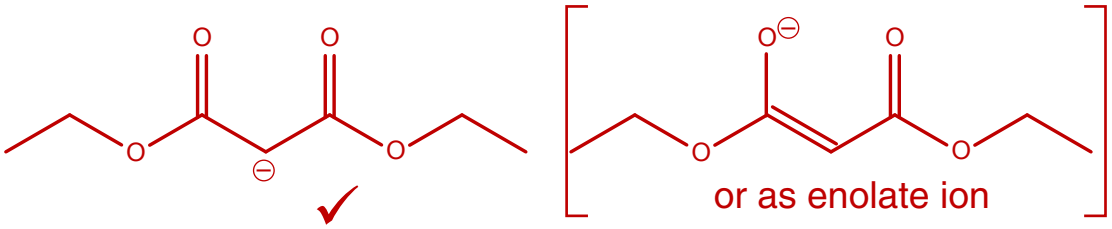
✓

1

Page total 7

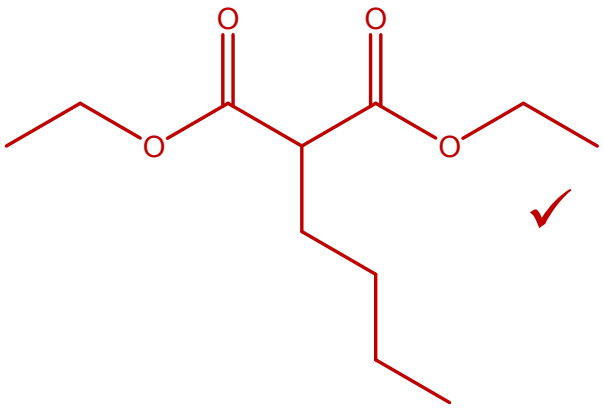
leave blank

1(e) **structure of ion C**



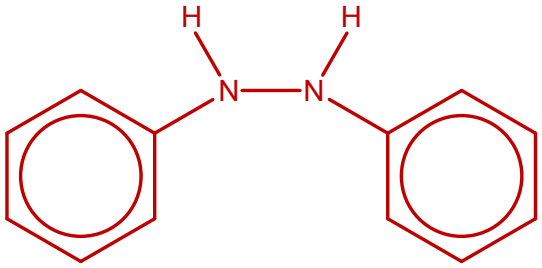
1

structure of D



1

(f) **structure of E**



2

(g) **molecular formula for phenylbutazone:** $C_{19}H_{20}N_2O_2$

1

(h)

(i)	The M_r of phenylbutazone is 309.	☐
(ii)	The molecule fragments.	☐
(iii)	Naturally occurring carbon contains a small proportion of ^{13}C.	✓
(iv)	Naturally occurring hydrogen contains a large proportion of deuterium (^2H).	☐
(v)	One of the nitrogen atoms has been protonated.	✓

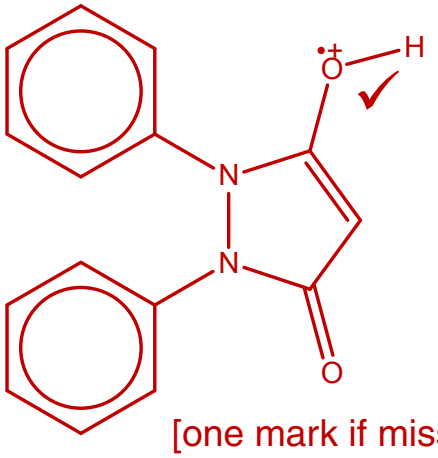
1

1 mark for each correct
–1 mark for each other box ticked down to zero.

Page total 7

leave blank

1(i) **structure of fragment at m/z 252:**



[one mark if missing + fullmarks if only missing •]

2

structure of other fragment:



1

(j) **number of burgers needed:**

mass of PB per burger = $4.0 \times 10^{-9} \times 250$ g = 1.0×10^{-6} g ✓

therapeutic dose = (3.0 / 1000) × 75 g = 0.225 g

∴ number of burgers needed = (0.225 / 1.0×10^{-6}) = 225,000

[allow two or three sig. figs.] ✓

2

(k)(i) **mass of azobenzene produced:**

reading from graph, absorption of 0.997 corresponds

to concentration of 10.4 μg / cm^3 of heptane ✓

[allow between 10.0 - 10.5 μg / cm^3]

∴ in 10 cm^3 of heptane extracted from the blood ✓

10.4×10 μg = 104 μg or 1.04×10^{-4} g

[allow between 1.00 - 1.05×10^{-4} g]

2

Page total 7

leave blank

1(k)(ii) mass of phenylbutazone oxidised:

RMM of azobenzene = 182.22 ✓

RMM of phenylbutazone = 308.55

moles of azobenzene = $\frac{1.04 \times 10^{-4}}{182.22}$ ($= 5.71 \times 10^{-7}$)

$\therefore$ mass of phenylbutazone = $308.55 \times \frac{1.04 \times 10^{-4}}{182.22}$

$= 1.76 \times 10^{-4}$ g or 176 μg ✓

[allow e.c.f. from part (i)] 2

(iii) concentration of phenylbutazone in the blood:

moles of azobenzene = moles of phenylbutazone in 10 cm^3 blood

$= \frac{1.04 \times 10^{-4}}{182.22}$

$\therefore$ concentration of phenylbutazone in the blood ✓ 1

$= 100 \times \frac{1.04 \times 10^{-4}}{182.22} = 5.7 \times 10^{-5}$ mol dm^{-3}

[allow e.c.f.]

(l) number of peaks in carbon NMR spectra:

1,2-dimethylbenzene	1,3-dimethylbenzene	1,4-dimethylbenzene
4 ✓	5 ✓	3 ✓

3

(m) number of peaks in carbon NMR spectra of phenylbutazone:

10 ✓✓

2

Page total 8

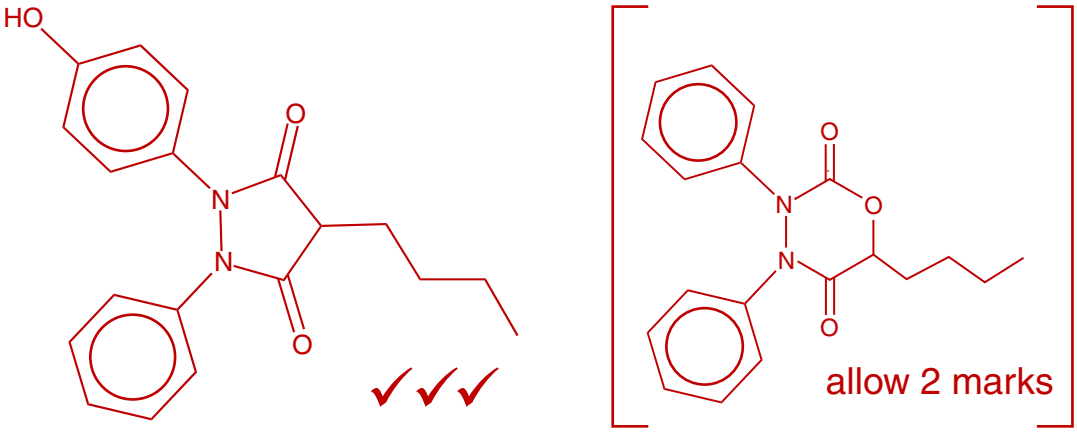
leave blank

1(n)(i) atom introduced:

oxygen ✓

1

(n)(ii) structure of metabolite:



✓✓✓

allow 2 marks

3

3 marks if OH group drawn on correct position in one ring

[1 mark if OH drawn on other position on benzene ring

or if oxygen atom inserted to give a reasonable structure]

(o) missing letters in scrabble answer:

O	X	Y	P	H$_4$	E$_1$	N	B$_3$	U$_1$	T$_1$	A	Z	O$_1$	N$_1$	E$_1$

1

✓

1 mark if all correct

Page total 5

leave blank

2(a) standard enthalpy change:

$\Delta H° = (-89.10) + 2(-286.0) - (-121.0) - 4(-4.187)$ ✓

$= -523.4 \text{ kJ mol}^{-1}$ ✓ 2

[1 mark if correct number but wrong sign]

(b)(i) equation:

$CH_4(aq) + 2O_2(aq) \longrightarrow CO_2(aq) + 2H_2O(l)$ ✓ 1

[no penalty if missing state symbols]

(b)(ii) standard enthalpy change:

$\Delta H° = (-121.0) + 2(-286.0) - (-89.10) - 2(-11.72)$ ✓

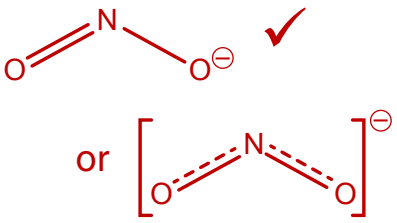
$= -580.5 \text{ kJ mol}^{-1}$ ✓ 2

[1 mark if correct number but wrong sign]

(c)(i) formula of nitrate(III): NO_2^-

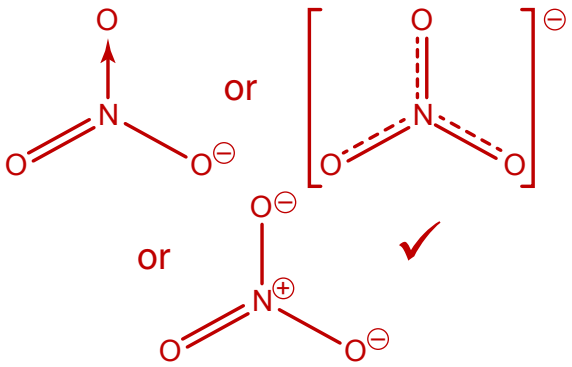
formula of nitrate(V): NO_3^- ✓ 2

(c)(ii) structure of nitrate(III):



✓

structure of nitrate(V):



✓ 2

bond angle in nitrate(III): allow between 110-119° ✓

bond angle in nitrate(V): 120° (exactly) ✓ 2

Page total 11

leave blank

2(c)(iii) equation between iodide and nitrate(III) in acid:

$2NO_2^-(aq) + 6I^-(aq) + 8H^+(aq) \longrightarrow N_2(g) + 3I_2(aq) + 4H_2O(l)$ ✓

1

[no penalty if missing state symbols]

(c)(iv) sulfur-containing ion:

1

SO_4^{2-} ✓

(c)(v) equation between sulfate(IV) and and iodine in acid:

$SO_3^{2-}(aq) + I_2(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2I^-(aq) + 2H^+(aq)$ ✓✓

2

[no penalty if missing state symbols]

(d) (i) **The ^{40}K emits an alpha particle.** ☐

(ii) **A neutron in the ^{40}K decays into a proton, a positron (positive electron) and a neutrino.** ☐

(iii) **A proton in the ^{40}K decays into a neutron, a positron (positive electron) and a neutrino.** ☑

(iv) **A neutron in the ^{40}K decays into a proton, an electron, and a neutrino.** ☐

(v) **A proton in the ^{40}K captures an electron, and decays into a neutron and a neutrino.** ☑

2

1 mark for each correct
–1 mark for each other box ticked down to zero.

Page total 6

leave blank

2(e)(i) atoms of ^{40}Ar in 1cm^3 of water:

1 cm^3 water contains 0.0445 cm^3 of ^{40}Ar

$$= \frac{0.0445 \times 6.022 \times 10^{23}}{22400} = 1.20 \times 10^{18} \text{ atoms}$$ ✓ 1

(e)(ii) mass of rock:

since 1.0% by volume of rock is water

100 cm^3 of rock contains 1.0 cm^3 of water = 270 g ✓ 1

(e)(iii) mass of potassium:

mass of potassium = 2.0% by mass of rock

$= 270 \times (2.0/100) = 5.4$ g 1

(e)(iv) atoms of ^{40}K:

moles of potassium in rock = 5.4 / 39.102 = 0.138

moles of ^{40}K is $(0.0117/100) \times 0.138 = 1.62 \times 10^{-5}$ ✓

$\therefore$ number of atoms of ^{40}K = 2

$$(5.4/39.102) \times (0.0117/100) \times 6.022 \times 10^{23} = 9.7 \times 10^{18}$$ ✓

[if assumed proportion of ^{40}K is 0.0117% by mass, answer comes out as 9.5 $\times 10^{18}$ and 1 mark should be given]

(f) age of sample:

$$N_{^{40}Ar} = 0.105 \times N_{^{40}K} \times (e^{\lambda t} - 1)$$

rearranging:

$$e^{\lambda t} = \frac{N_{^{40}Ar}}{0.105 \times N_{^{40}K}} + 1 \qquad \therefore t = \frac{1}{\lambda} \times \ln\left(\frac{N_{^{40}Ar}}{0.105 \times N_{^{40}K}} + 1\right)$$ ✓✓ 4

$$\therefore t = \frac{1}{5.54 \times 10^{-10}} \times \ln\left(\frac{1.2 \times 10^{18}}{0.105 \times 9.73 \times 10^{18}} + 1\right) = 1.4 \times 10^9 \text{ years}$$ ✓✓

$= 1.4$ billion years

[give 2 marks if equation has been correctly (and usefully) rearranged in some form]

Page total 9