42nd INTERNATIONAL CHEMISTRY OLYMPIAD

UK Round One - 2010

MARKING SCHEME

Notes

Chemical equations may be given as sensible multiples of those given here.

Formulae can be given by any conventional method (i.e. structural or molecular).

State symbols do not need to be included in the chemical equations to obtain the mark(s).

Answers should be given to an appropriate number of significant figures although the marker should only penalise this once in the whole paper.

Total 61 marks.

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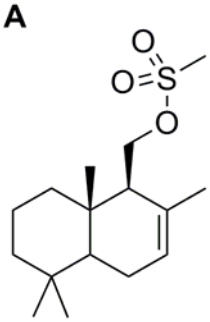
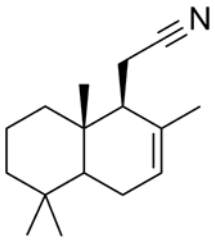
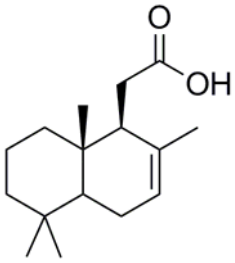
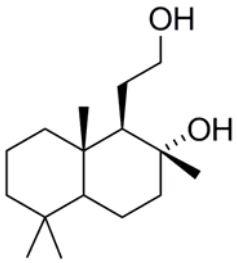
<table>
<tr><th colspan="5">Question 1</th></tr>
<tr><th></th><th></th><th colspan="2">Answer</th><th>Marks</th></tr>
<tr><td>(a)</td><td></td><td colspan="2">Ambrox ($C_{16}H_{28}O$) has a molar mass of ((16*12.01)+(28*1.008)+(1*16)) = 236.384 g mol^{-1}.

10000000 g produced every year, therefore (10000000/236.384) = $4.2x10^4$ moles of Ambrox are produced each year.</td><td>1 mark</td></tr>
<tr><td rowspan="2">(b)</td><td rowspan="2"></td><td>A
 
$C_{16}H_{28}O_3S$</td><td>B
 
$C_{16}H_{25}N$
Accept structures with the nitrile group shown as CN</td><td rowspan="2">1 mark per correct structure</td></tr>
<tr><td>C
 
$C_{16}H_{26}O_2$
Accept structures with the carboxyl group shown as COOH.</td><td>D
 
$C_{16}H_{30}O_2$</td></tr>
<tr><td>(c)</td><td>i)</td><td colspan="2">The percentage yields for each step are combined to give an overall yield of 24.87 %.</td><td>1 mark</td></tr>
<tr><td></td><td>ii)</td><td colspan="2">Number of moles of (-)-drimenol needed = (number of moles of Ambrox produced in a year)/(overall yield) = (42304.5/0.2487) = 170102.5 moles of (-)-drimenol

(-)-drimenol has a molar mass of ((15*12.01)+(26*1.008)+(1*16)) = 222.358 g mol^{-1}.

The mass of (-)-drimenol needed is therefore (222.358*170102.5) = 38 tonnes.

Also accept correctly worked solutions using the candidate's answers to (a) and (c) i).

Do not penalise candidates for rounding values in the intermediate part of the calculation.</td><td>1 mark</td></tr>
<tr><td></td><td>iii)</td><td colspan="2">The mass of bark needed = (mass of (-)-drimenol)/(proportion of (-)-</td><td>1 mark</td></tr>
</table>

		drimenol in bark) = 37.825/0.005 = $\underline{7.6x10^3}$ $\underline{\text{tonnes}}$. Also accept correctly worked solutions using the candidate's answer to (c) ii).	

Question 2			
		Answer	**Marks**
(a)		% Cu = 27.58%	2 marks
(b)	**i)**	$Ag^+ + Cl^- \rightarrow AgCl$ **OR** $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$	1 mark
	ii)	% Cl = 38.46%	2 marks
(c)	**i)**	Oxygen	1 mark
	ii)	C:H:N:Cu:Cl = 8:24:2:2:5 2 marks or nothing.	2 marks
	iii)	$[Cu_4Cl_{10}O]^{4-}$	1 mark

Question 3			
		Answer	**Marks**
(a)		$U + 3ClF_3 \longrightarrow UF_6 + 3ClF$	1 mark
(b)		The Ag and Cl in AgCl should be circled.	1 mark
(c)	**i)**	$3IF \longrightarrow I_2 + IF_3$ $5IF_3 \longrightarrow I_2 + 3IF_5$ $7IF_5 \longrightarrow I_2 + 5IF_7$	3 marks
	ii)	$3IF \longrightarrow I_2 + IF_3$ $\Delta_rH^\theta = -3\Delta_fH^\theta(IF) + \Delta_fH^\theta(IF_3) = (286.2 - 486)$ kJ mol^{-1} = –199.8 kJmol^{-1} $5IF_3 \longrightarrow I_2 + 3IF_5$ $\Delta_rH^\theta = -5\Delta_fH^\theta(IF_3) + 3\Delta_fH^\theta(IF_5) = (2430 - 2529)$ kJ mol^{-1} = –99 kJ mol^{-1} $7IF_5 \longrightarrow I_2 + 5IF_7$ $\Delta_rH^\theta = -7\Delta_fH^\theta(IF_5) + 5\Delta_fH^\theta(IF_7) = (5901 - 4812.5)$ kJ mol^{-1} = +1088.5 kJ mol^{-1}	3 marks
	iii)	IF_5 doesn't disproportionate.	1 mark

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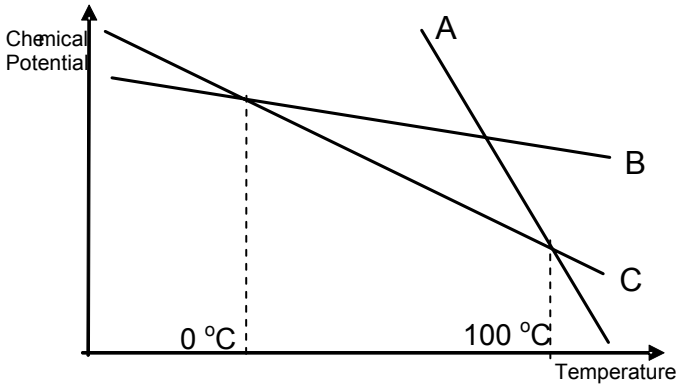
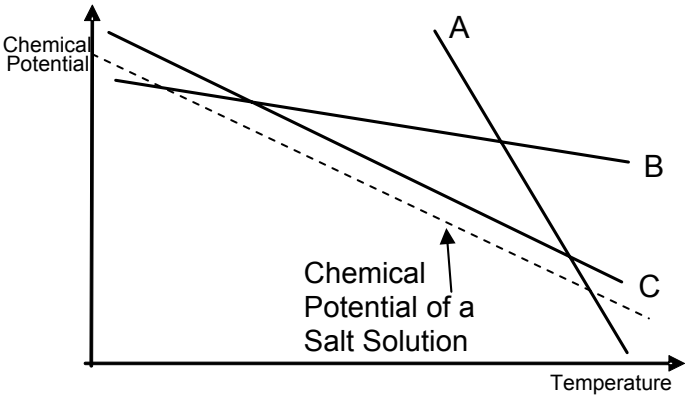
Question 4			
		Answer	**Marks**
(a)	**i)**	A = Water vapour (or gas), B = Ice (or solid), C = Liquid water (or liquid)	1 mark
	ii)	 Both correct (**2 marks**). One mark for each correct temperature (can be either in °C or K). Must indicate clearly that temperatures correspond to the point on the graph where the lines intersect to get the marks.	2 marks
(b)	**i)**	 (**1 mark**) Accurate positioning is not required but line they have drawn must be below line C at all points.	1 mark
	ii)	Higher than Water	1 mark
(c)	**i)**	RMM (H_2O) = 18.016 Density of H_2O = 1000 g dm^{-3} Concentration of Water = Density/RMM = 55.5 mol dm^{-3}	1 mark
	ii)	Concentration of NaCl = 3.00 mol dm^{-3} Concentration of ions = 6.0 mol dm^{-3} Concentration of H_2O = 55.5 mol dm^{-3} Mole fraction of ions (x_i) = 6.0/(6.0 + 55.5) = 0.10	1 mark

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(d)	**i)**	$\Delta T = \frac{x_i R T_m^{\ 2}}{\Delta_m H^{\Theta}}$ ΔT = (0.0976 x 8.314 x 273 x 273)/6010 ΔT = 10.1 K Freezing Point = −10.1 ^{o}C or 262.9 K All correct (**2 marks**) [Error Carried Forward – Answer should be 103.1 x Answer to part c) ii)] If enthalpy is used in kJ without converting then **1 mark**.	2 marks
	ii)	$x_i = \frac{\Delta T \Delta_m H^{\Theta}}{R T_m^{\ 2}}$ x_i = (21.1 x 6010)/(8.314 x 273 x 273) x_i = 0.205 x_i = [ions]/([ions] + [water]) 0.205 = [ions]/([ions] + [55.5]) Rearranging, [ions] = 14.31 mol dm^{-3} Concentration of NaCl = 7.16 mol dm^{-3} All correct (**2 marks**) Correct calculation of x_i (**1 mark**). If x_i incorrect but correct calculation to work out [NaCl] from x_i (**1 mark**)	2 marks
(e)		Concentration of $CaCl_2$ = 3.0 mol dm^{-3} Concentration of ions = 9.0 mol dm^{-3} Concentration of H_2O total = 55.5 mol dm^{-3} Concentration of Free H_2O = 55.5 – (9 x 3.0) = 28.5 mol dm^{-3} Mole fraction of ions (x_i) = 9.0/(9.0 + 28.5) = 0.240 $\Delta T = \frac{x_i R T_m^{\ 2}}{\Delta_m H^{\Theta}}$ ΔT = (0.240 x 8.314 x 273 x 273)/6010 ΔT = 24.7 K Freezing Point = −24.74 ^{o}C or 248.3 K All correct (**2 marks**). If [ions] of 6.0 mol dm^{-3} used or failure to account for bound water but all else correct (**1 mark**). (Final answer should be x_i x 103.1). If more than one mistake made in calculation of x_i no marks.	2 marks

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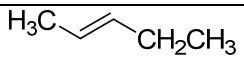
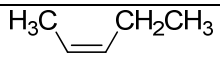
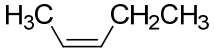
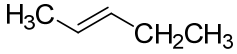
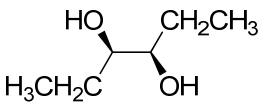
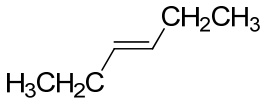
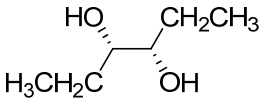
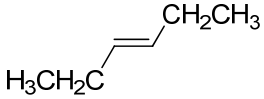
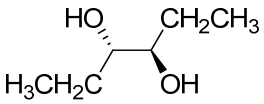
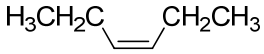
Question 5				
		Answer		**Marks**
(a)		i) +4 ii) +8 iii) +6		All correct = 1 2 correct = ½
(b)		Oxidation		1 mark
(c)		OsO_4		1 mark
(d)		+6		1 mark
(e)	**i)**		**ii)** 	All correct = 2 2 correct = ½
	iii)		**iv)** 	
(f)	**i)**	3		1 mark
(f)	**ii)**	**DIOL** 	**ALKENE** 	
				
				
		(1 mark) for each correct pair of diol and alkene to a maximum of (**3 marks)** if all correct. If meso compound is drawn twice do not penalise again if answer to f) i) is 4. No marks are awarded for correct diol with incorrect or missing alkene, or for alkene on its own.		3 marks
(g)		**5 8 9 12**		
		All correct (**2 marks**); (**½ mark** for each correct number). If more than four numbers are given then (**minus ½ mark)** for each additional answer above the first four down to a minimum of zero.		2 marks

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Question 6			
		Answer	**Marks**
(a)		Mass of a gold atom = 197 g mol^{-1} / 6.02 ×10^{23} mol^{-1} = 3.27 × 10^{-22} g	1 mark
(b)		Number of atoms in unit cell = (8 × 1/8) + (6 × 1/2) = 4	1 mark
(c)	**i)**	If *a* is the length of the unit cell edge and *r* is the radius of an atom: $a\sqrt{2} = 4r$ length AB = $4r / \sqrt{2} = 2\sqrt{2} \times r$	1 mark
	ii)	volume of unit cell = $32r^3 / \sqrt{2} = 16\sqrt{2} \times r^3$	1 mark
	iii)	length of body diagonal $a\sqrt{3} = 2\sqrt{6} \times r$	1 mark
(d)		Molar volume of gold = 197 g mol^{-1} / 19.3 g cm^{-3} = 10.2 cm^3 mol^{-1}	1 mark
(e)		Fraction = 4 × volume of gold atom / unit cell volume = $(4 \times 4/3\ \pi r^3) / (16\sqrt{2} \times r^3) = \pi\sqrt{2} / 6 = 0.74$ Can accept $\pi\sqrt{2} / 6$	1 mark
(f)		Radius of gold atom = $[(\text{volume of gold atom}) / (4/3)\pi]^{1/3}$ = $[(10.2\ cm^3\ mol^{-1} / 6.02 \times 10^{23}\ mol^{-1}) \times 0.74 / (4/3)\pi]^{1/3}$ = 1.44 × 10^{-8} cm	1 mark
(g)	**i)**	Surface area of dome = ½ × $4\pi(21\ m / 2)^2$ = 693 m^2 Volume of gold = 80 000 g / 19.3 g cm^{-3} = 4 145 cm^3 = 0.004 145 m^3 Average thickness of gold = 0.004 145 m^3 / 693 m^2 = 6.0 × 10^{-6} m = 6.0 × 10^{-4} cm	1 mark
	ii)	Thickness of a layer of gold atoms = $(2\sqrt{6} \times r) / 3$ = 2.35 × 10^{-8} cm Number of layers of gold atoms = 6.0 × 10^{-4} cm / 2.35 × 10^{-8} cm = 2.5 × 10^4	1 mark
		Only penalise once for error carried forward	

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