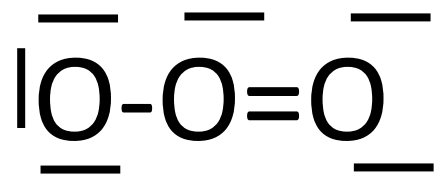
Mark scheme 2023 HL Prelim P1 P2

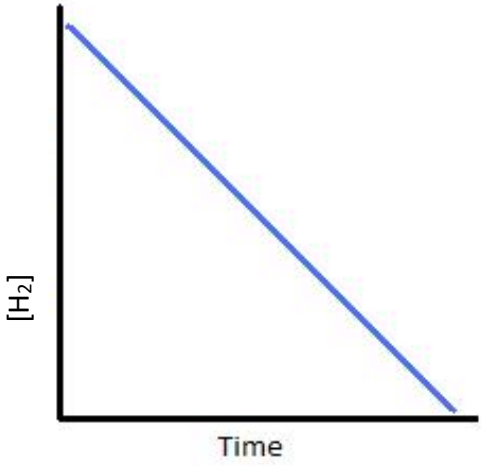
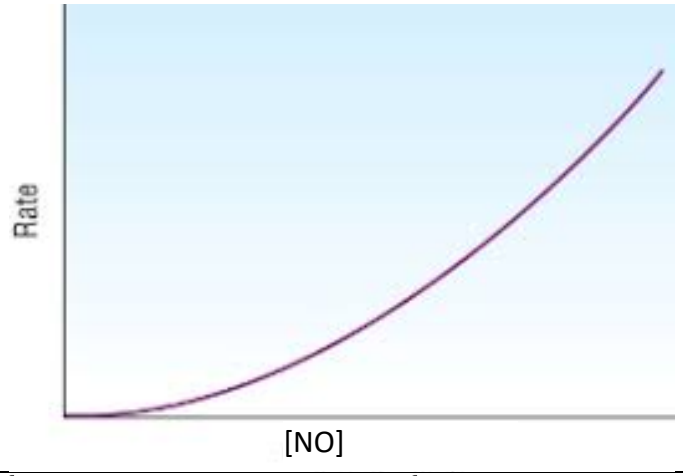
Question	1	2	3	4	5	6	7	8	9	10
Answer	**D**	**C**	**D**	**A**	**B**	**D**	**B**	**B**	**B**	**A**
Question	11	12	13	14	15	16	17	18	19	20
Answer	**A**	**A**	**D**	**B**	**A**	**D**	**D**	**B**	**C**	**D**
Question	21	22	23	24	25	26	27	28	29	30
Answer	**B**	**C**	**D**	**C**	**C**	**D**	**D**	**C**	**B**	**D**
Question	31	32	33	34	35	36	37	38	39	40
Answer	**A**	**C**	**C**	**A**	**C**	**B**	**B**	**A**	**C**	**C**

Qn	Mark scheme	Remark
1a	chromium: n(Cr) = $\frac{68.4\text{g}}{52.00\ \text{g mol}^{-1}}$ = 1.32 mol ***OR*** oxygen: n(O) = $\frac{31.6}{16.00}$ = 1.98 mol ✓ ratio n(Cr) : n(O) = 1.32 : 1.98 = 1 : 1.5 = 2 : 3 empirical formula: Cr_2O_3 ✓	

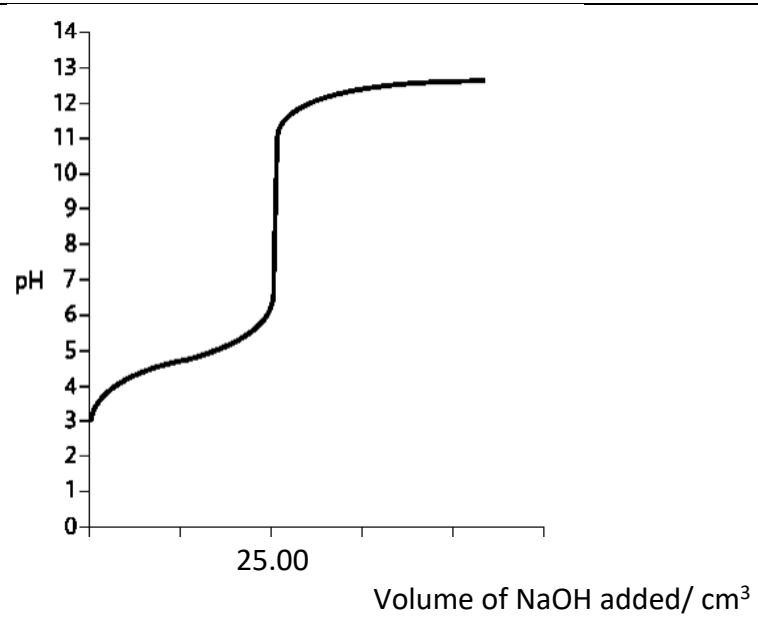
	Let the molecular formula be $Cr_{2x}O_{3x}$. 156 = 2(52.00)x + 3(16.00)x x = 1 molecular formula: Cr_2O_3 ✓ *Allow ecf for empirical and molecular formula.* *Award **[3]** for correct final answer.*	
1b i	«promoted» electrons fall back to lower energy level✓ Energy difference between levels is different✓ *Accept "Cu, Ca and Cr have different nuclear charge" for M2*	
1bii	energy levels are closer together at high energy / high frequency / short wavelength✓	
1bili	IE = $\Delta E = h\nu = 6.63 \times 10^{-34}$ J s × 1.64×10^{15} s^{-1} = 1.09×10^{-18} J✓	
1ci	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ ***OR*** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$ ✓ *Do not accept condensed electron configuration like* [Ar] $3d^5\ 4s^1$	
1cii	Both are paramagnetic.✓ «both» contain unpaired electrons ***OR*** each chromium atom has 6 unpaired electrons and each chromium(III) ion has 3 unpaired electrons.✓ *Accept orbital diagrams showing unpaired electrons.*	

1ciii	H_2O is LB as it donates electron pair OR Cr^{3+} is LA as it accepts electron pair	
iv	*Any* **THREE** *from:* partially filled d-orbitals ligands/water cause d-orbitals to split red light is absorbed as electrons move to a higher energy orbital «in d–d transitions» ***OR*** light is absorbed as electrons are promoted «green» colour observed is the complementary colour «of red»	
2ai.	CH_4 (g) + $2O_2$ (g) → CO_2 (g) + $2H_2O$ (l) ✓	
aii.	[(-393.50 + (2 x – 285.8) – (-74.0)] ; ✓ -891.1 <<kJmol^{-1}>>✓	Award 2m for correct final answer; Award 1 m for <<+>> 891.1 kJmol^{-1}
aiii.	BE assume all bonds are in gaseous state / H_2O formed is in liquid form for literature value/ OWTTE✓	
bi.	Methane AND tetrachloromethane is non-polar AND Dichloromethane is polar; ✓ C-Cl bond is polar <<C-H bond is non-polar>>;✓ In dichloromethane, dipole moment/bond polarities does not cancel out OR In tetrachloromethane, dipole moment/bond polarities cancels out; ✓	
bii.	London dispersion forces is stronger in tetrachloromethane due to greater number of electrons <<larger molecular mass>>✓	
biii.	Methane cannot form hydrogen bond/favourable intermolecular forces of attraction/interaction with water. ✓	
ci.	(3 x 498) – (4 x O-O in ozone) = <<+>> 285.4; ✓ (O-O in ozone) = << [(3 x 498) - 285.4] / 4 >> = <<+>> 302 <<kJ>>✓	Award 2m for correct final answer

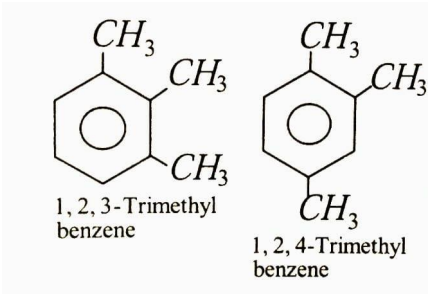
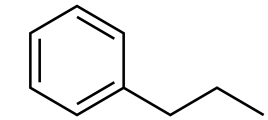
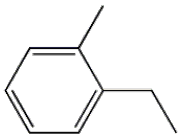
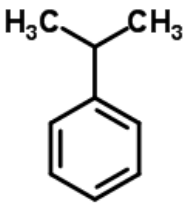
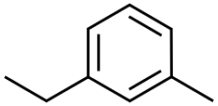
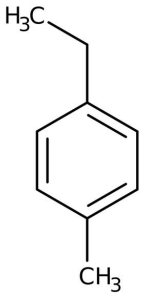
cii.	 ; ✓ FC (-1 +1 0) ✓	
ciii.	<<Bond energy is greater than O-O single but weaker than O=O double bond>> Both bonds are identical in bond length << due to resonance>>, longer than O=O single bond AND shorter than O-O single bond; ✓ Bond order is 1.5/ between 1 and 2✓	
di.	$\Delta H_1^{\ominus}$: enthalpy change of formation <<of MgO>> ✓ $\Delta H_2^{\ominus}$: lattice energy << of MgO>>✓	
dii.	3791 = 602 + 249 + 148 + 738 + 2nd IE + 612; ✓ 2nd IE = <<+>> 1442 <<kJ mol^{-1}>>✓	Award 2m for correct final answer Award 1m for -1442
diii.	2nd IE more endothermic than 1st IE as it is more difficult/ energy needed to remove an electron from a cation/ OWTTE✓	
div.	Down the group, lattice enthalpy decreases/less endothermic; ✓ Radius of M^{2+} increases; ✓	

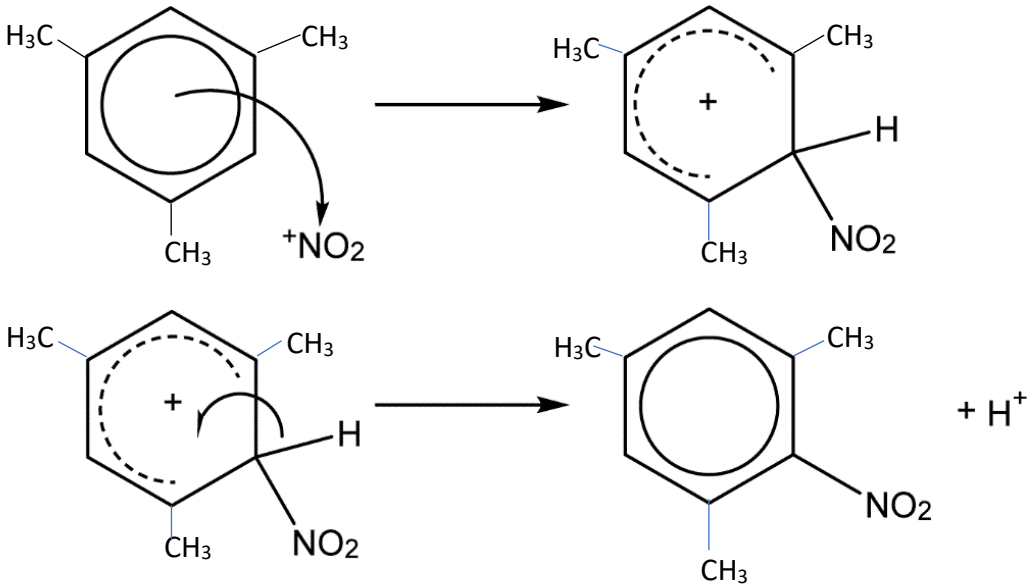
3a	(i)  (ii) 	
b	Pressure/Concentration of NO will double ; ✓ rate increases by 4 times; ✓	
c	Rate = k $[NO]^2$ mol dm^{-3} s^{-1} = k (mol dm^{-3})^2 units of k = $mol^{-1}dm^3s^{-1}$; ✓	
d	Increases in <<average>> kinetic energy of the particles; ✓ More particles have energy > E_a ; ✓ Increase in frequency of effective collisions ; ✓	
4ai	$C_5H_5N + HCl \rightarrow C_5H_5NHCl / C_5H_5NH^+Cl^-$ ✓	
aii	pyridinium ion is a Brønsted-Lowry acid as it the conjugate acid of the weak Brønsted base, pyridine. / pyridinium ion is a Brønsted-Lowry acid as it can act as a pro*ton donor.* ✓	

bi	$C_5H_5NH^+Cl^-$ + NaOH → C_5H_5N + NaCl + H_2O Amount of C_5H_5N = 25.00/1000 x 0.100 = 2.50×10^{-3} <<mol>>✓ Concentration of C_5H_5N at the equivalence point = 2.50×10^{-3}/ (50.00/1000) = 0.0500 <<mol dm^{-3}>>✓ $C_5H_5N + H_2O \rightleftharpoons C_5H_5NH^+ + OH^-$ $K_b = \frac{[C_5H_5NH^+][OH^-]}{[C_5H_5N]}$ $1.4 \times 10^{-9} = \frac{[OH^-]^2}{0.0500}$ [OH-] = 8.367×10^{-6}<<mol dm^{-3}>>✓ pOH =5.08 pH = 14 -pOH= 8. 92✓	*Award **[4]** for correct final answer.*

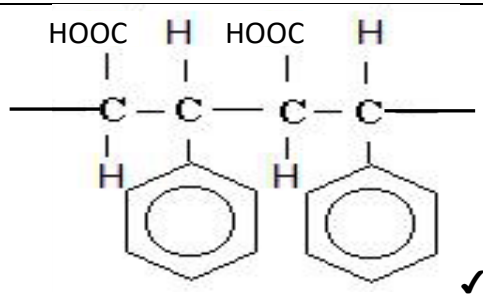
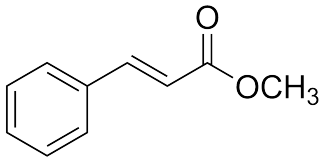
bii	 non-symmetrical sigmoidal curve, starting pH 2–7 ***AND*** terminating pH>12 ✓ equivalence point pH approximately 8.92 ***AND*** at a volume 25.00 cm^3 ✓	ECF (acid or base) from a(ii)
c	(I) The position of the equilibrium will shift to the right hand side with the smaller number of moles of gaseous particles to decrease the total pressure✓ (II) The position of the equilibrium remains unchanged as the rates of the forward and backward reactions are increased by the same extent. ✓	
di	Yield is very small as POE lies to the left/equilibrium constant is <<1/very small number. ✓	
dii	$\Delta G = -RT \ln K = - 8.31 \times 500 \times \ln (3.80 \times 10^{-16})$✓ = <<+>>148 000 J mol^{-1} = <<+>>148 kJ mol^{-1} ✓	[1] for correct working [1] for conversion to kJ

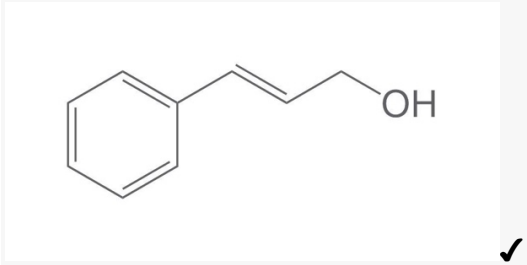
5a.	Left electrode is anode AND right electrode is cathode✓	
b.	Electrons through the wires/ cables; ✓ Ions towards the electrodes in the electrolyte/cation towards cathode and anion towards anode✓	
ci.	Cathode: $Pb^{2+} + 2e- \rightarrow Pb$ ✓ Anode: $H_2O \rightarrow ½\ O_2 + 2H^+ + 2e-$ ✓	[1] for reversed equations at electrodes Accept if student shows reduction of OH^- instead of H_2O
cii.	$Pb^{2+} + H_2O \rightarrow ½\ O_2 + 2H^+ + Pb$ OR $2Pb^{2+} + 2H_2O \rightarrow O_2 + 4H^+ + 2Pb$✓	
d.	Hydrogen gas would be formed at cathode/ water will be reduced at cathode ; ✓ Reduction potential of water is less negative (-0.83V) than manganese (-1.18V) ✓	

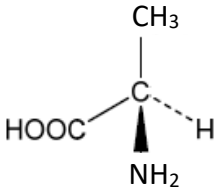
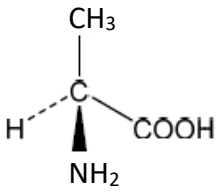
6a	Signals : 2✓ Ratio: 9:3 or 3:9 or 3: 1 or 1:3✓	
b	Any one of the following:       ✓	
ci	$HNO_3 + 2H_2SO_4 \rightleftharpoons H_3O^+ + NO_2^+ + 2HSO_4^-$✓ *Accept: $HNO_3 + H_2SO_4 \rightleftharpoons NO_2^+ + HSO_4^- + H_2O$.* *Accept: $HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$.* *Accept single arrow instead of equilibrium sign.* *Accept equivalent two step reactions in which sulfuric acid first behaves as strong acid and protonates nitric acid, before behaving as dehydrating agent removing water from it.*	

<table>
<tr>
<td>cii</td>
<td>


curly arrow going from benzene ring to N «of $^{+}NO_2/NO_2^{+}$ » ✓
carbocation with correct formula and positive charge on ring ✓
curly arrow going from C–H bond to benzene ring of cation ✓
formation of organic product nitromesitylene AND H^{+} ✓
</td>
<td>Accept mechanism with corresponding Kekulé structures.
Do not accept a circle in M2 or M3.
Accept first arrow starting either inside the circle or on the circle.
If Kekulé structure used, first arrow must start on the double bond.
M2 may be awarded from correct diagram for M3.
M4: Accept “$C_6H_5(CH_3)_3NO_2 + H_2SO_4$” if HSO_4^- used in M3.</td>
</tr>
<tr>
<td>7ai</td>
<td>Cinnamaldehyde AND
Absence of << strong, very broad band >>peak at 2500–3000 «cm^{-1}»/peak due to O–H/hydroxyl in carboxylic acids✓</td>
<td></td>
</tr>
</table>

aii	yes ***AND*** 2 different groups on each carbon involved in the double bond ***OR*** yes ***AND*** molecule produced by rearranging groups bonded on each carbon in the double bond is different from the original ✓	
aiii	 ✓	
aiv	 ✓	
av	Electrophilic addition✓	
avi	Bromine water will be decolorized by cinnamic acid ✓	

avii	 ✓ Reagents: acidified «potassium» dichromate«(VI)»/H^+ or $K_2Cr_2O_7/H^+$ or $Cr_2O_7^{2-}/H^+$ ✓ Accept acidified <<potassium» manganate(VII)/ H^+ and $KMnO_4$ /H^+ and MnO_4^- *Accept H_2SO_4 or H_3PO_4 for H^+.* *Accept "permanganate" for "manganate(VII)".* *Condition : reflux* ✓	Accept heat
b	<<intermolecular>> hydrogen bonding Accept diagram showing hydrogen bonding✓	
ci	Trigonal pyramidal; ✓ sp^3 ✓	
cii	**A *AND*** it has a chiral centre/asymmetric carbon atom/carbon with 4 different substituents✓	

Ciii	  ✓	
civ	doublet✓	