Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2017

Chemistry

Higher level

Paper 2

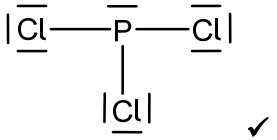
International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

Question			Answers	Notes	Total
1.	a	i	$n(Ag) = «\frac{3.275\,g}{107.87\,g\,mol} =» 0.03036$ «mol» ***AND*** $n(O) = «\frac{3.760\,g - 3.275\,g}{16.00\,g\,mol^{-1}} = \frac{0.485}{16.00} =» 0.03031$ «mol» ✓ $«\frac{0.03036}{0.03031} \approx$ 1 / ratio of Ag to O approximately 1 : 1, so» AgO ✓	*Accept other valid methods for M1.* *Award **[1 max]** for correct empirical formula if method not shown.*	**2**
1	a	ii	temperature too low ***OR*** heating time too short ***OR*** oxide not decomposed completely ✓ heat sample to constant mass «for three or more trials» ✓	*Accept "not heated strongly enough".* *If M1 as per markscheme, M2 can only be scored for constant mass technique.* *Accept "soot deposition" (M1) and any suitable way to reduce it (M2).* *Accept "absorbs moisture «from atmosphere» (M1) and "cool in dessicator" (M2).* *Award **[1 max]** for reference to "impurity" **AND** design improvement.*	**2**
1	b		A_r closer to 107/less than 108 «so more ^{107}Ag» ***OR*** A_r less than the average of (107 + 109) «so more ^{107}Ag» ✓	*Accept calculation that gives greater than 50% ^{107}Ag.*	**1**

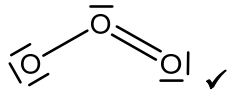
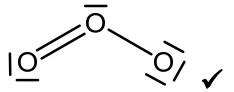
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>1</td><td>c</td><td>i</td><td>
<table>
<tr><th>Flask containing</th><th>Colour of solution</th><th>Product formula</th></tr>
<tr><td>Na_2O</td><td rowspan="2">blue
AND
yellow ✓</td><td>NaOH ✓</td></tr>
<tr><td>P_4O_{10}</td><td>H_3PO_4 ✓</td></tr>
</table>
</td><td>Do not accept name for the products.
Accept “$Na^+ + OH^-$” for NaOH.
Ignore coefficients in front of formula.</td><td>3</td></tr>
<tr><td>1</td><td>c</td><td>ii</td><td>«molten» Na_2O has mobile ions/charged particles AND conducts electricity ✓
«molten» P_4O_{10} does not have mobile ions/charged particles AND does not conducts electricity/is poor conductor of electricity ✓</td><td>Do not award marks without concept of mobile charges being present.
Award [1 max] if type of bonding or electrical conductivity correctly identified in each compound.
Do not accept answers based on electrons.
Award [1 max] if reference made to solution.</td><td>2</td></tr>
<tr><td>1</td><td>d</td><td></td><td>electrons in discrete/specific/certain/different shells/energy levels ✓
energy levels converge/get closer together at higher energies
OR
energy levels converge with distance from the nucleus ✓</td><td>Accept appropriate diagram for either M1, M2 or both.
Do not give marks for answers that refer to the lines in the spectrum.</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
2.	a	i	$Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$ ✓	*Accept equilibrium sign.* *Accept* $Sn^{2+}(aq) - 2e \rightarrow Sn^{4+}(aq)$	1
2	a	ii	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 3Sn^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3Sn^{4+}(aq)$ ✓	*Accept equilibrium sign.*	1
2	a	iii	« $[K_2Cr_2O_7] = \frac{13.239\text{ g}}{294.20\text{ g mol}^{-1} \times 0.100\text{ dm}^3}$ =» $0.450\text{ «mol dm}^{-3}$» ✓		1
2	a	iv	$n(Sn^{2+}) =$ «$0.450\text{ mol dm}^{-3} \times 0.01324\text{ dm}^3 \times \frac{3\text{ mol}}{1\text{ mol}}$ =» 0.0179 «mol» ✓ «$[Sn^{2+}] = \frac{0.0179\text{ mol}}{0.0100\text{ dm}^3}$ =» 1.79 «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	2
2	a	v	hydroxyl/OH ***OR*** aldehyde/CHO ✓	*Accept "hydroxy/alcohol" for "hydroxyl".* *Accept amino/amine/NH_2.*	1
2	b	i	«$E^\ominus$ =» $+0.85$ «V» ✓	*Accept 0.85 V.*	1
2	b	ii	$\Delta G^\ominus$ «$= -nFE^\ominus$» = -2 «mol e^-» × 96500 «C mol^{-1}» × 0.85 «V» ✓ «$\Delta G^\ominus$ =» -164 «kJ» ✓	*Accept "«+»164 «kJ»" as question states energy released.* *Award **[1 max]** for "+" or "–" 82* «kJ»**.** *Do not accept answer in J.*	2
2	b	iii	incompletely filled d-orbitals ✓ colour depends upon the energy difference between the split d-orbitals ✓ variable/multiple/different oxidation states ✓ different «nature/identity of» ligands ✓ different number of ligands ✓		3 max

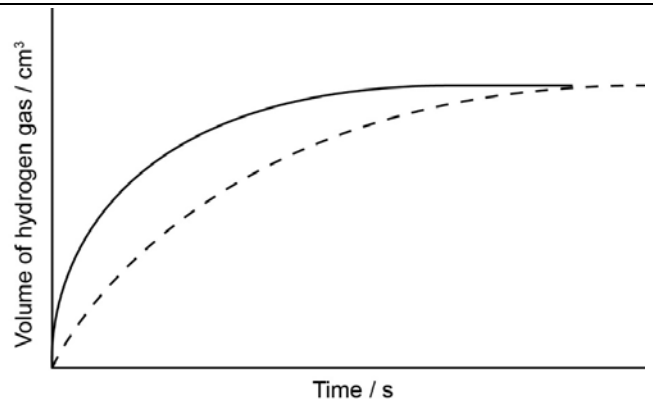
Question			Answers	Notes	Total
2	**c**		Zn/zinc is a stronger reducing agent than Fe/iron ***OR*** Zn/zinc is oxidized instead of Fe/iron ***OR*** Zn/zinc is the sacrificial anode ✓	*Accept "Zn is more reactive than Fe".* *Accept "Zn oxide layer limits further corrosion".* *Do not accept "Zn layer limits further corrosion".*	**1**

Question			Answers	Notes	Total
3.	a	i	«K_c» $= \frac{[PCl_3][Cl_2]}{[PCl_5]}$ ✓		1
3	a	ii	decrease in temperature ✓ endothermic «reaction» ***AND*** «equilibrium» shifts to the left/reactants ***OR*** endothermic «reaction» ***AND*** K_c decreases ***OR*** endothermic «reaction» ***AND*** concentration of PCl_5 increased/concentration of PCl_3 and Cl_2 decreased ***OR*** «equilibrium» shifts in the exothermic direction ✓	*Do **not** accept "temperature change".* *Accept "ΔH positive" in place of "endothermic".* *Accept "products" instead of "PCl_3 and Cl_2".*	2
3	b		*Lewis structure:*  ✓ *Molecular geometry:* trigonal/triangular pyramidal ✓ *Bond angles:* < 109.5° ✓	*Penalize missing lone pairs once only between this question and 4(b)(ii).* *Accept any combination of lines, dots or crosses to represent electrons.* *Do not apply ECF.* *Do not accept answer equal to or less than 90°.* *Literature value is 100.1°.*	3

Question			Answers	Notes	Total
4.	**a**	**i**	triple bond in nitrogen **«**molecule**»** ***AND*** single bond in hydrazine ✓ triple bond is stronger than single bond ***OR*** more shared **«**pairs of**»** electrons make bond stronger/attract nuclei more ✓	*Accept bond enthalpy values from data booklet (158 and 945 kJ mol^{-1}).*	**2**
4	**a**	**ii**	hydrogen bonding **«**between molecules, dinitrogen tetraoxide does not**»** ✓		**1**
4	**a**	**iii**	N_2H_4: −2 ***AND*** N_2O_4: +4 ✓		**1**
4	**a**	**iv**	N_2H_4 ***AND*** oxidized/oxidation state increases ***OR*** N_2H_4 ***AND*** loses hydrogen ***OR*** N_2H_4 ***AND*** reduces/removes oxygen from N_2O_4 ✓	*Accept "N_2H_4* ***AND*** *gives electrons **«**to N_2O_4**»**".*	**1**

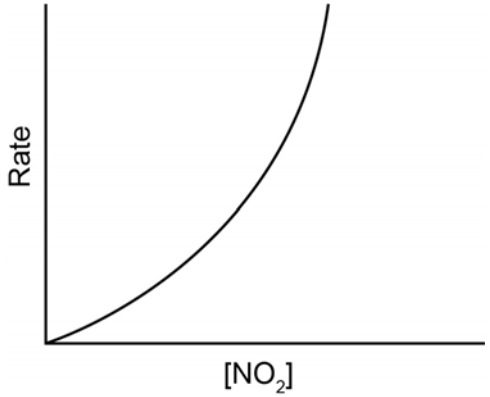
Question			Answers	Notes	Total
4	b	i	lone pair on p orbital **«**of O atom**»** overlaps/delocalizes with pi electrons **«**from double bond**»** ✓ both O–O bonds have equal bond length ***OR*** both O–O bonds have same/1.5 bond order ***OR*** both O–O are intermediate between O–O ***AND*** O=O ✓ both O–O bonds have equal bond energy ✓	*Accept "p/pi/π electrons are delocalized/not localized".*	**3**
4	b	ii	***ALTERNATIVE 1:***  ✓ FC: −1 ***AND*** +1 ***AND*** 0 ✓ ***ALTERNATIVE 2:***  ✓ FC: 0 ***AND*** +1 ***AND*** −1 ✓	*Accept any combination of lines, dots or crosses to represent electrons.* *Do not accept structure that represents 1.5 bonds.* *Do not penalize missing lone pairs if already penalized in 3(b).* *If resonance structure is incorrect, no ECF.* *Any one of the structures with correct formal charges for **[2 max]**.*	**2**

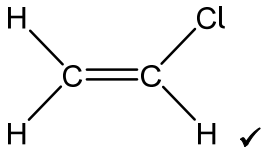
Question			Answers	Notes	Total
4	c		*Any two of:* IE_4: electron in lower/inner shell/energy level ***OR*** IE_4: more stable/full electron shell ✓ IE_4: electron closer to nucleus ***OR*** IE_4: electron more tightly held by nucleus ✓ IE_4: less shielding by complete inner shells ✓	*Accept "increase in effective nuclear charge" for M2.*	**2 max**
4	d	i	«$Q_c = \frac{0.10}{0.52^2}$ =» 0.37 ✓ reaction proceeds to the left/NO_2(g) «until $Q = K_c$» ***OR*** reverse reaction «favoured» ✓	*Do not award M2 without a calculation for M1 but remember to apply ECF.*	**2**
4	d	ii	$\Delta G = 0$ ✓ reaction at equilibrium ***OR*** rate of forward and reverse reaction is the same ***OR*** constant macroscopic properties ✓		**2**

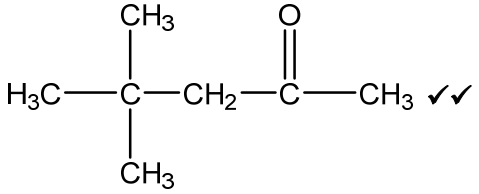
Question			Answers	Notes	Total
5.	a	i	concentration of acid decreases ***OR*** surface area of magnesium decreases✓	*Accept "less frequency/chance/rate/ probability/likelihood of collisions".* *Do **not** accept just "less acid" or "less magnesium".* *Do **not** accept "concentration of reagents decrease".*	**1**
5	a	ii	 curve starting from origin with steeper gradient ***AND*** reaching same maximum volume ✓		**1**
5	b	i	«rate =» k $[NO_2]^2$ ✓	*Accept rate = k $[NO_2]^2[CO]^0$.*	**1**
5	b	ii	«step» I ***AND*** CO does not appear in the rate law expression ***OR*** «step» I ***AND*** only «2 molecules of» NO_2 appears in rate expression ✓	*Do not allow ECF from (i).*	**1**

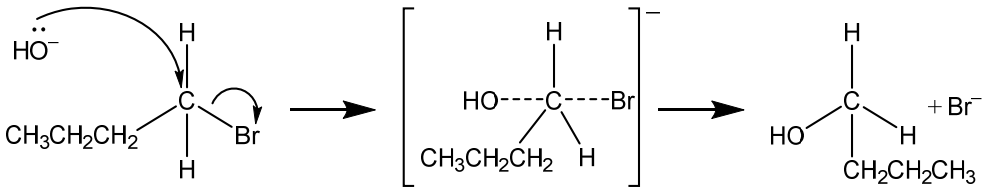
(continued…)

(Question 5b continued)

Question			Answers	Notes	Total
5	b	iii	«IR or UV-vis» spectroscopy ***OR*** colorimetry ***OR*** colour change «over time» ✓	*Accept GC/gas chromatography.*	1
5	b	iv	«$E_{a(rev)} = 226 + 132 =$» 358 «kJ» ✓	*Do not accept –358.*	1
5	b	v	 ✓	*Curve must go through origin.*	1
5	c		activation energy is independent of temperature ✓	*Accept "no relationship".*	1
5	d		$2NO_2(g) + H_2O(l) \rightarrow HNO_3(aq) + HNO_2(aq)$ ***OR*** $4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$ ✓	*Accept ionized forms of the acids.*	1

Question			Answers	Notes	Total
6.	a		*Initiation:* $Cl–Cl \rightarrow Cl\bullet + Cl\bullet$ ✓ *Propagation:* $Cl\bullet + CH_4 \rightarrow Cl–H + \bullet CH_3$ ✓ $Cl–Cl + \bullet CH_3 \rightarrow Cl–CH_3 + Cl\bullet$ ✓	*Do not penalize missing electron dot on radicals if consistent throughout.* *Accept Cl_2, HCl and CH_3Cl without showing bonds.* *Do **not** accept hydrogen radical, H• or H, but apply ECF to other propagation steps.*	**3**
6	b		«$\Delta H^{\ominus}$ =» –82.0 «kJ» – 92.3 «kJ» – (–74.0 «kJ») ✓ «$\Delta H^{\ominus}$ =» –100.3 «kJ» ✓	*Award **[2]** for correct final answer.*	**2**
6	c		$H_2C{=}CHCl$ ***OR***  ✓	*Accept "CH_2CHCl" or "$CHClCH_2$".* *Do **not** accept "C_2H_3Cl".*	**1**

Question			Answers	Notes	Total
7.	**a**	**i**	*Number of hydrogen environments:* 3 ✓ *Ratio of hydrogen environments:* 2:3:9 ✓ *Splitting patterns:* **«**all**»** singlets ✓	*Accept any equivalent ratios such as 9:3:2.* *Accept "no splitting".*	**3**
7	**a**	**ii**	carbonyl ***OR*** C=O ✓	*Accept "ketone" but not "aldehyde".*	**1**
7	**a**	**iii**	 ✓✓	*Accept $(CH_3)_3CCH_2COCH_3$.* *Award **[1]** for any aldehyde or ketone with $C_7H_{14}O$ structural formula.*	**2**
7	**b**	**i**	hexane ***AND*** hex-1-ene ✓	*Accept "benzene **AND** hexane **AND** hex-1-ene".*	**1**
7	**b**	**ii**	$CH_3CH_2CH_2CH_2CHBrCH_3$ ✓	*Accept displayed formula but **not** molecular formula.*	**1**
7	**c**	**i**	*Reagents:* **«**concentrated**»** sulfuric acid ***AND*** **«**concentrated**»** nitric acid ✓ *Name of mechanism:* electrophilic substitution ✓		**2**
7	**c**	**ii**	benzene has **«**delocalized**»** π bonds **«**that are susceptible to electrophile attack**»** ***AND*** alkanes do not ✓	*Do **not** accept "benzene has single and double bonds".*	**1**

Question			Answers	Notes	Total
7	d		 curly arrow going from lone pair/negative charge on O in $^{-}$OH to C ✓ curly arrow showing Br leaving ✓ representation of transition state showing negative charge, square brackets and partial bonds ✓	*Accept OH^{-} with or without the lone pair.* *Do not allow curly arrows originating on H in OH^{-}.* *Accept curly arrows in the transition state.* *Do not penalize if HO and Br are not at 180°.* *Do not award M3 if OH–C bond is represented.* *Award **[2 max]** if wrong isomer is used.*	**3**

Question			Answers	Notes	Total
8.	a	i	H_2O/water ✓	*Accept "hydroxide ion/OH^-".*	1
	a	ii	<table><tr><th>Acid</th><th>Base</th></tr><tr><td>HOCl AND</td><td>OCl^-</td></tr><tr><td>OR</td><td></td></tr><tr><td>H_2O AND</td><td>OH^- ✓</td></tr></table>		1
	b	i	«0.100 mol dm^{-3} × 0.0250 dm^3» = 0.00250 «mol» ✓		1
	b	ii	«$M = \frac{0.510\,g}{0.00250\,mol}$ =» 204 «g mol^{-1}» ✓		1
	b	iii	«$1.00 \times 10^{-14} = [H^+] \times 0.100$» 1.00×10^{-13} «mol dm^{-3}» ✓		1
	b	iv	weak ***AND*** pH at equivalence greater than 7 ***OR*** weak acid ***AND*** forms a buffer region ✓		1
	b	v	calorimetry ***OR*** measurement of heat/temperature ***OR*** conductivity measurement ✓	*Accept "indicator" but not "universal indicator".*	1
	b	vi	«pK_a = pH at half-equivalence =» 5.0		1

Question			Answers	Notes	Total
	c		$K_a = 10^{-4.35} / 4.46683 \times 10^{-5}$ ✓ $[H_3O^+] = \sqrt{4.46683 \times 10^{-5} \times 1.60 \times 10^{-3}} \; / \sqrt{7.1469 \times 10^{-8}} \; / 2.6734 \times 10^{-4}$ **«**mol dm^{-3}**»** ✓ pH = **«**–log $\sqrt{7.1469 \times 10^{-8}}$ =**»** 3.57 ✓	*Award **[3]** for correct final answer to two decimal places.* *If quadratic equation used, then:* *$[H_3O^+] = 2.459 \times 10^{-4}$ «mol dm^{-3}»* *and pH = 3.61*	**3**

Question			Answers	Notes	Total
9.	a	i	$\Delta H = 177.0 - \frac{189.2}{2} - 285.5$ «kJ» ✓ «ΔH =» – 203.1 «kJ» ✓	*Accept other methods for correct manipulation of the three equations.* *Award **[2]** for correct final answer.*	**2**
	a	ii	203.1 «kJ» = 0.850 «kg» × 4.18 «kJ kg^{-1} K^{-1}» × ΔT «K» ***OR*** «ΔT =» 57.2 «K» ✓ «T_{final} = (57.2 + 21.8)°C =» 79.0«°C» / 352.0 «K»✓ *If 200.0 kJ was used:* 200.0 «kJ» = 0.850 «kg» × 4.18 «kJ kg^{-1} K^{-1}» × ΔT «K» ***OR*** «ΔT =» 56.3«K» ✓ «T_{final} = (56.3 + 21.8)°C =» 78.1 «°C» / 351.1 «K»✓	*Award **[2]** for correct final answer.* *Accept two, three or four significant figures.* *Unit, if specified, must be consistent with value stated.*	**2**
	b	i	«$\Delta S^{\ominus}$ =» 270 «J K^{-1} mol^{-1}» – 267 «J K^{-1} mol^{-1}» – 131 «J K^{-1} mol^{-1}» ✓ «$\Delta S^{\ominus}$ =» –128 «J K^{-1} mol^{-1}» ✓	*Award **[2]** for correct final answer.*	**2**
	b	ii	«non spontaneous if» $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} > 0$ ***OR*** $\Delta H^{\ominus} > T\Delta S^{\ominus}$ ✓ «T above» $\frac{-124.4 \text{ «kJ mol}^{-1}\text{»}}{-0.128 \text{ «kJ K}^{-1}\text{mol}^{-1}\text{»}}$ =» 972 «K» ✓	*Award **[2]** for correct final answer.* *Accept 699 °C.* *Do not award M2 for any negative T value.*	**2**