Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

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Chemistry

Higher level

Paper 2

18 pages

International Baccalaureate
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Question			Answers	Notes	Total
1.	**a**		C_2H_2 (g) + 2.5O_2 (g) → 2CO_2 (g) + H_2O (l) ***OR*** 2C_2H_2 (g) + 5O_2 (g) → 4CO_2 (g) + 2H_2O (l) ✓		1
1.	**b**	**i**	H:C⋮⋮C:H / H—C≡C—H ✓	*Accept any valid combination of lines, dots and crosses.*	1
1.	**b**	**ii**	«ethyne» shorter ***AND*** a greater number of shared/bonding electrons ***OR*** «ethyne» shorter ***AND*** stronger bond ✓		1
1.	**b**	**iii**	London/dispersion/instantaneous dipole-induced dipole forces ✓	*Do **not** accept just "intermolecular forces" or "van der Waals' forces".*	1
1.	**c**	**i**	ethanal ✓		1
1.	**c**	**ii**	«sum of bond enthalpies of reactants =» 2(C–H) + C≡C + 2(O–H) ***OR*** 2 × 414 «kJ mol^{-1}» + 839 «kJ mol^{-1}» + 2 × 463 «kJ mol^{-1}» ***OR*** 2593 «kJ» ✓ «sum of bond enthalpies of A =» 3(C–H) + C=C + C–O + O–H ***OR*** 3 × 414 «kJ mol^{-1}» + 614 «kJ mol^{-1}» + 358 «kJ mol^{-1}» + 463 «kJ mol^{-1}» ***OR*** 2677 «kJ» ✓ «enthalpy of reaction = 2593 kJ − 2677 kJ» = −84 «kJ» ✓	*Award **[3]** for correct final answer.*	3

(Question 1c continued)

Question			Answers	Notes	Total
1.	c	iii	B **AND** it has a more negative/lower enthalpy/«potential» energy **OR** B **AND** more exothermic «enthalpy of reaction from same starting point» ✓		1
1.	c	iv	*Identity of product*: **«B»** *IR spectrum:* 1700−1750 «cm^{-1} band» **AND** carbonyl/CO group present **OR** no «band at» 1620−1680 «cm^{-1}» **AND** absence of double bond/C=C **OR** no «broad band at» 3200−3600 «cm^{-1} » **AND** absence of hydroxyl/OH group ✓ *^{1}H NMR spectrum:* «only» two signals **AND** A would have three **OR** «signal at» 9.4−10.0 «ppm» **AND** «H atom/proton of» aldehyde/−CHO present **OR** «signal at» 2.2−2.7 «ppm» **AND** «H atom/proton of alkyl/CH next to» aldehyde/CHO present **OR** «signal at» 2.2−2.7 «ppm» **AND** «H atom/proton of» RCOCH$_2$- present **OR** no «signal at» 4.5−6.0 «ppm» **AND** absence of «H atom/proton next to» double bond/C=C ✓	*Accept a specific value or range of wavenumbers and chemical shifts.* *Accept "two signals with areas 1:3".*	2

(continued…)

(Question 1c continued)

Question			Answers	Notes	Total
1.	**c**	**v**	2.3 ppm: doublet ✓ 9.8 ppm: quartet ✓		**2**
1.	**d**	**i**	*Reagents:* acidified/H⁺ **AND** «potassium» dichromate«(VI)»/$K_2Cr_2O_7$/$Cr_2O_7^{2-}$ ✓ *Conditions:* distil «the product before further oxidation» ✓	*Accept "«acidified potassium» manganate(VII)/KMnO₄/MnO₄⁻/permanganate".* *Accept "H_2SO_4" or "H_3PO_4" for "H⁺".* *Accept "more dilute dichromate(VI)/manganate(VII)" or "excess ethanol".* *Award M1 if correct reagents given under "Conditions".*	**2**
1.	**d**	**ii**	−1 ✓		**1**
1.	**d**	**iii**	*Any three of:* has an oxygen/O atom with a lone pair ✓ that can form hydrogen bonds/H-bonds «with water molecules» ✓ hydrocarbon chain is short «so does not disrupt many H-bonds with water molecules» ✓ «large permanent» dipole-dipole interactions with water ✓		**3 max**

Question			Answers	Notes	Total
2.	a		increase in the amount/number of moles/molecules «of gas» ✓ from 2 to 3/by 50 % ✓		**2**
2.	b		«rate of reaction decreases» concentration/number of molecules in a given volume decreases **OR** more space between molecules ✓ collision rate/frequency decreases **OR** fewer collisions per unit time ✓	*Do **not** accept just "larger space/volume" for M1.*	**2**
2.	c	i	half «of the initial rate» ✓	*Accept "lower/slower «than initial rate»".*	**1**
2.	c	ii	1 slower than 2 **OR** 1 rate determinant step/RDS ✓ 1 is unimolecular/involves just one molecule so it must be first order **OR** if 1 faster/2 RDS, second order in N_2O **OR** if 1 faster/2 RDS, first order in O ✓		**2**

Question			Answers	Notes	Total
2.	d		smaller initial gradient ✓ initial pressure is lower **AND** final pressure of gas lower «by similar factor» ✓		2
2.	e		no **AND** it is a systematic error/not a random error **OR** no **AND** «a similar magnitude» error would occur every time ✓		1
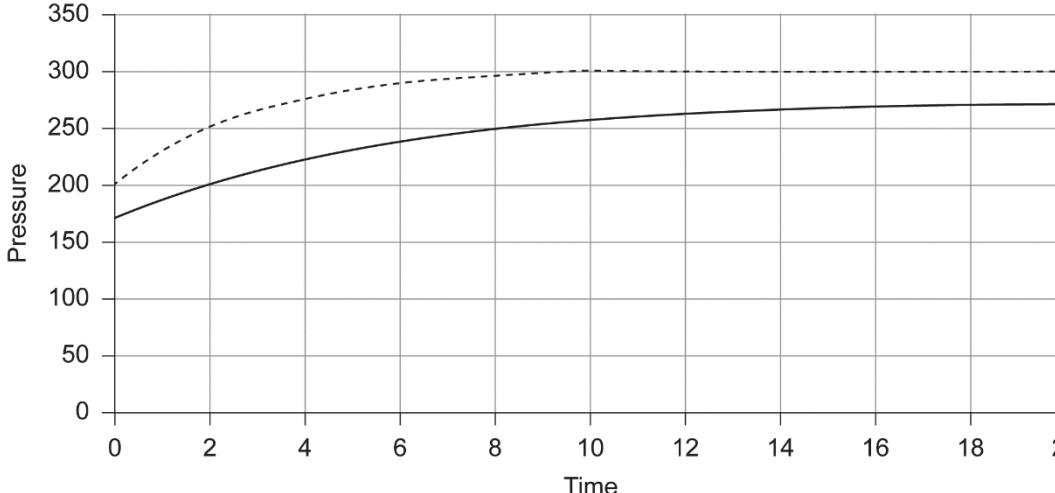
Question			Answers	Notes	Total
2.	f		catalysed and uncatalysed E_a marked on graph **AND** with the catalysed being at lower energy ✔️ «for catalysed reaction» greater proportion of/more molecules have $E \geq E_a$ / $E > E_a$ **OR** «for catalysed reaction» greater area under curve to the right of the E_a ✔️	*Accept "more molecules have the activation energy".*	2
2.	g	i	$\Delta S^{\ominus} = 2(S^{\ominus}(N_2)) + S^{\ominus}(O_2) - 2(S^{\ominus}(N_2O))$ **OR** $\Delta S^{\ominus} = 2 \times 193$ «J mol^{-1} K^{-1}» $+ 205$ «J mol^{-1} K^{-1}» $- 2 \times 220$ «J mol^{-1} K^{-1}» ✔️ «$\Delta S^{\ominus} = +$»151 «J K^{-1}» ✔️	*Award **[2]** for correct final answer.*	2

(Question 2g continued)

Question			Answers	Notes	Total
2.	g	ii	exothermic decomposition **OR** $\Delta H_{(decomposition)} < 0$ ✔ $T\Delta S^{\ominus} > \Delta H^{\ominus}$ **OR** $\Delta G^{\ominus}$ «$= \Delta H^{\ominus} - T\Delta S^{\ominus}$» < 0 «at all temperatures» ✔ reaction spontaneous at all temperatures ✔		3

	Question		Answers	Notes	Total
3.	a	i	absorbs <u>UV/ultraviolet</u> light «of longer wavelength than absorbed by O_2» ✔		**1**
3.	a	ii	$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ ✔ $NO_2(g) + O_3(g) \rightarrow NO(g) + 2O_2(g)$ ✔	*Ignore radical signs.* *Accept equilibrium arrows.* *Award **[1 max]** for $NO_2(g) + O(g) \rightarrow$ $NO(g) + O_2(g)$.*	**2**
3.	b	i	mass spectrometry/MS ✔		**1**
3.	b	ii	$«\dfrac{(98 \times 14) + (2 \times 15)}{100} =»\ 14.02$ ✔ $«M_r = (14.02 \times 2) + 16.00 =»\ 44.04$ ✔		**2**
3.	b	iii	*Any two:* same **AND** have same nuclear charge /number of protons/Z_{eff} ✔ same **AND** neutrons do not affect attraction/ionization energy/Z_{eff} **OR** same **AND** neutrons have no charge ✔ same **AND** same attraction for «outer» electrons ✔ same **AND** have same electronic configuration/shielding ✔	*Accept "almost the same".* *"Same" only needs to be stated once.*	**2 max**

Question			Answers	Notes	Total
3.	c		*Nitrogen and carbon:* N has greater nuclear charge/«one» more proton «and electrons both lost from singly filled p-orbitals» ✓ *Nitrogen and oxygen:* O has a doubly filled «p-»orbital **OR** N has only singly occupied «p-»orbitals ✓	*Accept "greater e− ⁻ e⁻ repulsion in O" or "lower e− ⁻ e⁻ repulsion in N".* *Accept box annotation of electrons for M2.*	**2**
3.	d	i	delocalization **OR** delocalized π-electrons ✓	*Accept "resonance".*	**1**
3.	d	ii	linear **AND** 2 electron domains **OR** linear **AND** 2 regions of electron density ✓	*Accept "two bonds **AND** no lone pairs" for reason.*	**1**
3.	d	iii	sp ✓		**1**

Question			Answers	Notes	Total
4.	**a**		$^{185}_{75}$Re ✓		**1**
4.	**b**	**i**	gap in the periodic table ***OR*** element with atomic number **«75»** unknown ***OR*** break/irregularity in periodic trends ✓ **«periodic table shows»** regular/periodic trends **«in properties»** ✓		**2**
4.	**b**	**ii**	electrolyze **«a solution of /molten»** rhenium salt/Re^{n+} ✓ graphite as cathode/negative electrode ***OR*** rhenium forms at cathode/negative electrode ✓	*Accept "using rhenium anode" for M1.*	**2**
4.	**b**	**iii**	*Any two of:* variable oxidation states ✓ forms complex ions/compounds ✓ coloured compounds/ions ✓ **«para»**magnetic compounds/ions ✓	*Accept other valid responses related to its* **chemical** *metallic properties.* *Do* **not** *accept "catalytic properties".*	**2 max**
4.	**c**		place **«pieces of»** Re into each solution ✓ if Re reacts/is coated with metal, that metal is less reactive **«than Re»** ✓	*Accept other valid observations such as "colour of solution fades" or "solid/metal appears" for "reacts".*	**2**

Question			Answers	Notes	Total
4.	d	i	rhenium(III) chloride **OR** rhenium trichloride ✓		1
4.	d	ii	«M_r ReCl$_3$ = 186.21 + (3 × 35.45) =» 292.56 ✓ «$100 \times \dfrac{186.21}{292.56}$ =» 63.648 «%» ✓		2
4.	e	i	same group as Mn «which forms MnO$_4^-$» **OR** in group 7/has 7 valence electrons, so its «highest» oxidation state is +7 ✓		1
4.	e	ii	ReO$_4^-$ (aq) + 6H$^+$ (aq) + 3e$^-$ $\rightleftharpoons$ [Re(OH)$_2$]$^{2+}$ (aq) + 2H$_2$O (l) ✓		1
4.	e	iii	no **AND** ReO$_4^-$ is a weaker oxidizing agent than Fe^{3+} **OR** no **AND** Fe^{3+} is a stronger oxidizing agent than ReO$_4^-$ **OR** no **AND** Fe^{2+} is a weaker reducing agent than [Re(OH)$_2$]$^{2+}$ **OR** no **AND** [Re(OH)$_2$]$^{2+}$ is a stronger reducing agent than Fe^{2+} **OR** no **AND** cell emf would be negative/−0.41 V ✓		1

	Question		Answers	Notes	Total
5.	**a**	**i**	*Weak acid*: partially dissociated/ionized «in aqueous solution/water» **AND** *Strong acid*: «assumed to be almost» completely/100 % dissociated/ionized «in aqueous solution/water» ✓		**1**
5.	**a**	**ii**	CO_3^{2-} ✓		**1**
5.	**b**		shifts to left/reactants **AND** to increase amount/number of moles/molecules of gas/CO_2 (g) ✓	*Accept "shifts to left/reactants **AND** to increase pressure".*	**1**
5.	**c**		«$K_a =$» $10^{-6.36}/4.37 \times 10^{-7} = \dfrac{[H^+]^2}{[CO_2]}$ **OR** «$K_a =$» $10^{-6.36}/4.37 \times 10^{-7} = \dfrac{[H^+]^2}{0.200}$ ✓ $[H^+]$ «$= \sqrt{0.200 \times 4.37 \times 10^{-7}}$ » $= 2.95 \times 10^{-4}$ «mol dm^{-3}» ✓ «pH =» 3.53 ✓	*Award [3] for correct final answer.*	**3**

	Question		Answers	Notes	Total
5.	**d**	**i**	*Between sodium and hydrogencarbonate:* ionic ✓ *Between hydrogen and oxygen in hydrogencarbonate:* «polar» covalent ✓		**2**
5.	**d**	**ii**	«additional HCO_3^-» shifts position of equilibrium to left ✓ pH increases ✓	*Do **not** award M2 without any justification in terms of equilibrium shift in M1.*	**2**
5.	**d**	**iii**	«molar mass of $NaHCO_3$ =» 84.01 «g mol^{-1}» ✓ «concentration $= \dfrac{3.0 \times 10^{-2} g}{84.01 \text{ g mol}^{-1}} \times \dfrac{1}{0.100 \text{ dm}^3}$ =» 3.6×10^{-3} «mol dm^{-3}» ✓	*Award **[2]** for correct final answer.*	**2**
5.	**d**	**iv**	«$1.0 - 0.6 = \pm$» 0.4 «%» ✓		**1**
5.	**e**		*Equation (3):* OH^- donates an electron pair **AND** acts as a Lewis base ✓ *Equation (4):* OH^- accepts a proton/H^+/hydrogen ion **AND** acts as a Brønsted–Lowry base ✓		**2**

Question			Answers	Notes	Total
5.	**f**		S-shaped curve from ~7 to between 12 and 14 ✓ equivalence point at 5 cm^3 ✓	*Accept starting point >6~7.*	**2**
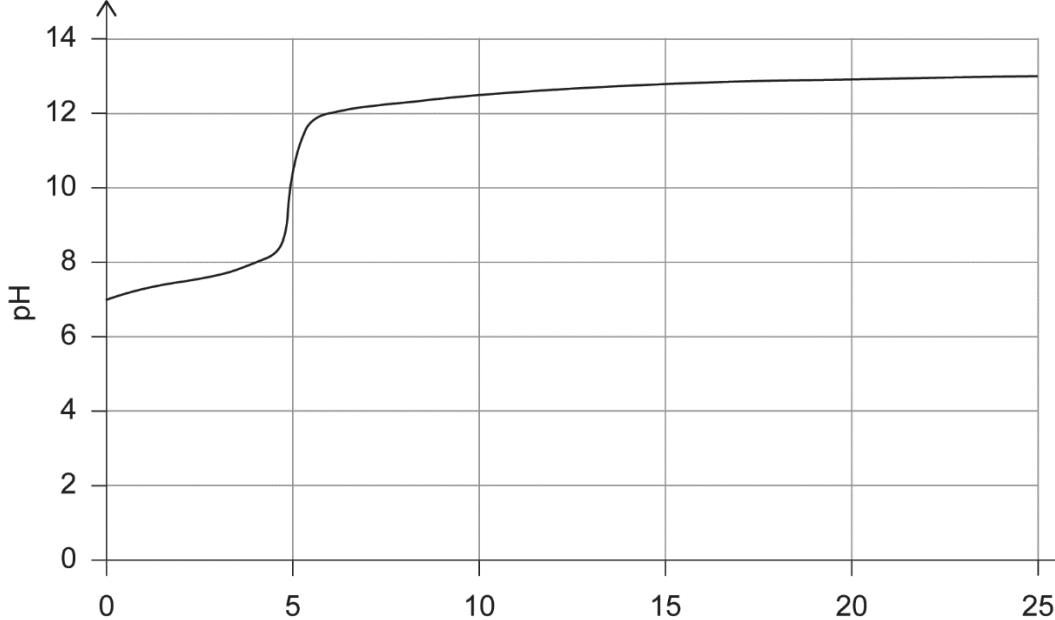
Question			Answers	Notes	Total
6.	**a**		/ $-CH_2CH(C_6H_5)-$ ✔	*Do **not** penalize the use of brackets and "n".* *Do **not** award the mark if the continuation bonds are missing.*	**1**
6.	**b**		$\ln k \ll = -\dfrac{10000}{8.31 \times 298} \gg = -4.04$ ✔ $k = 0.0176$ ✔	*Award **[2]** for correct final answer.*	**2**
6.	**c**		*Similarity:* «both» involve an electrophile **OR** «both» electrophilic ✔ *Difference:* first/reaction of ring/with NO_2^+ is substitution/$S_{«E»}$ **AND** second/reaction of C=C/with HBr is addition/$A_{«E»}$ ✔	*Answer must state which is substitution and which is addition for M2.*	**2**

Question			Answers	Notes	Total
6.	**d**	**i**	*Two forms:* chiral/asymmetric carbon **OR** carbon atom attached to 4 different groups ✓ *Relationship:* mirror images **OR** enantiomers/optical isomers ✓	*Accept appropriate diagrams for either or both marking points.*	**2**
6.	**d**	**ii**	benzene ring «of the C_6H_5–CH_2» and the bromine «on the CH_2–Br» can take up different relative positions by rotating about the «C–C, σ–»bond ✓	*Accept "different parts of the molecule can rotate relative to each other".* *Accept "rotation around σ–bond".*	**1**
6.	**e**		C_6H_5–CH_2–CH_2OH ✓		**1**