Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2017

Chemistry

Higher level

Paper 2

16 pages

International Baccalaureate®
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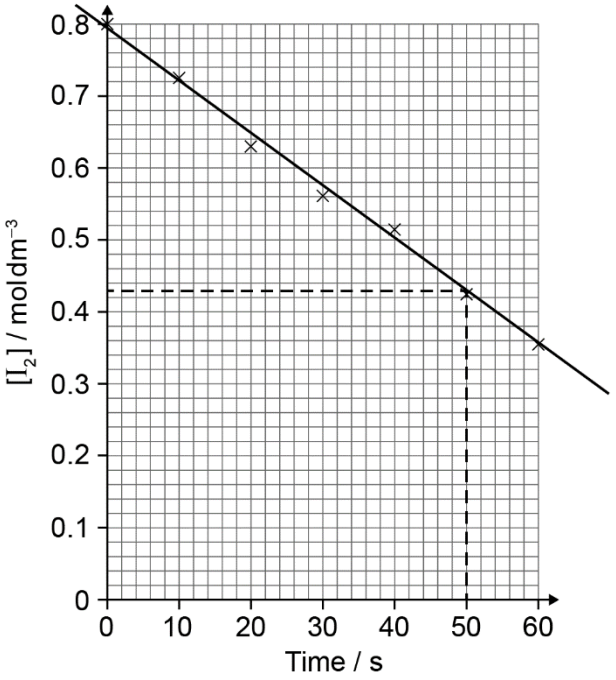
Question			Answers	Notes	Total
1.	a	i	use a colorimeter/monitor the change in colour ***OR*** take samples ***AND*** quench ***AND*** titrate «with thiosulfate» ✓	*Accept change in pH.* *Accept change in conductivity.* *Accept other suitable methods.* *Method must imply "change".*	**1**
1	a	ii	 best fit line ✓ relative rate of reaction = « $\frac{-\Delta y}{\Delta x} = \frac{-(0.43 - 0.80)}{50}$ =» $0.0074/7.4 \times 10^{-3}$ ✓	*Best fit line required for M1.* *M2 is independent of M1.* *Accept range from 0.0070 to 0.0080.*	**2**
1	b		*Relationship:* rate of reaction is «directly» proportional to $[H^+]$ ***OR*** rate of reaction α $[H^+]$ ✓ *Order of reaction with respect to $[H^+]$:* first ✓	*Accept "doubling the concentration doubles the rate".* *Do **not** accept "rate increases as concentration increases".*	**2**

Question			Answers	Notes	Total
1.	c		zero order ✓ rate of reaction is the same for all concentrations of iodine ✓	*Accept "all graphs have same/similar gradient".*	2
1.	d		slow rate of reaction which gradually increases ✓ as H^+ ions are produced «to catalyse the reaction» ***OR*** reaction is autocatalytic ✓	*M1 should mention "rate of reaction".*	2

2.	a		electrostatic attraction ✓ between «a lattice of» metal/positive ions/cations ***AND*** «a sea of» delocalized electrons ✓	*Accept "mobile electrons".* *Do **not** accept "metal atoms/nuclei".*	2
2.	b		$\frac{(46 \times 7.98) + (47 \times 7.32) + (48 \times 73.99) + (49 \times 5.46) + (50 \times 5.25)}{100}$ ✓ $= 47.93$ ✓	*Answer must have two decimal places with a value from 47.90 to 48.00.* *Award [2] for correct final answer.* *Award [0] for 47.87 (data booklet value).*	2
2.	c		*Protons:* 22 ***AND*** *Neutrons:* 26 ***AND*** *Electrons:* 22 ✓		1
2.	d	i	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$ ✓		1
2.	d	ii	vanadium has smaller ionic radius «leading to stronger metallic bonding» ✓	*Accept vanadium has «one» more valence electron«s» «leading to stronger metallic bonding».* *Accept "atomic" for "ionic".*	1

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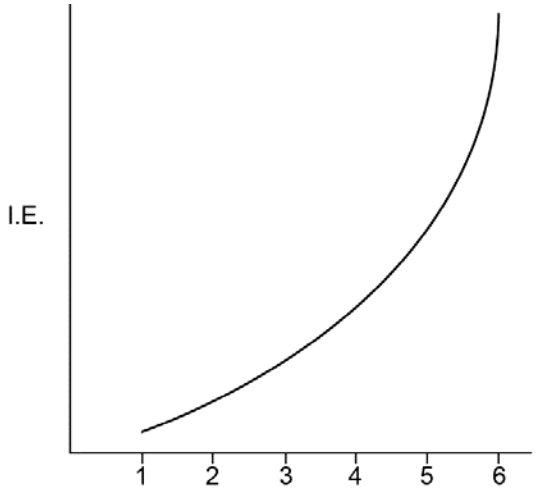
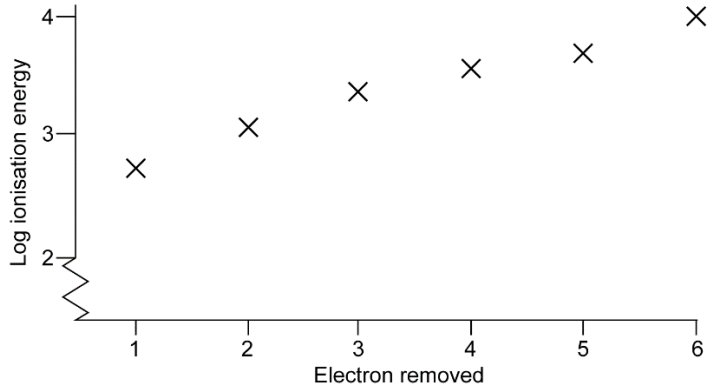
Question			Answers	Notes	Total
2.	d	iii	  regular increase for first five ***AND*** sharp increase to the 6th ✓	*A log graph is acceptable.* *Accept log plot on given axes (without amendment of y-axis).* *Award mark if gradient of 5 to 6 is greater than "best fit line" of 1 to 5.*	**1**
2.	d	iv	titanium atoms/ions distort the regular arrangement of atoms/ions ***OR*** titanium atoms/ions are a different size to aluminium «atoms/ions» ✓ prevent layers sliding over each other ✓	*Accept diagram showing different sizes of atoms/ions.*	**2**

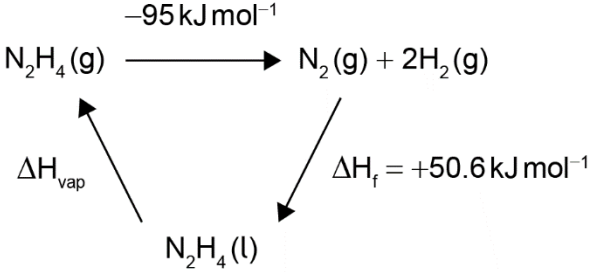
Question			Answers	Notes	Total
2.	e		pair of electrons provided by the ligand ✓	*Do **not** accept "dative" or "co-ordinate bonding" alone.*	1
2.	f		partially filled d-orbitals ✓ «ligands cause» d-orbitals «to» split ✓ light is absorbed as electrons transit to a higher energy level «in d–d transitions» ***OR*** light is absorbed as electrons are promoted ✓ energy gap corresponds to light in the visible region of the spectrum ✓ colour observed is the complementary colour ✓		4 max
2.	g	i	ionic ***OR*** «electrostatic» attraction between oppositely charged ions ✓		1
2.	g	ii	«simple» molecular structure ***OR*** weak«er» intermolecular bonds ***OR*** weak«er» bonds between molecules ✓	*Accept specific examples of weak bonds such as London/dispersion and van der Waals.* *Do **not** accept "covalent".*	1
2.	h	i	$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(aq)$ correct products ✓ correct balancing ✓	*Accept ionic equation.* *Award M2 if products are HCl and a compound of Ti and O.*	2
2.	h	ii	HCl causes breathing/respiratory problems ***OR*** HCl is an irritant ***OR*** HCl is toxic ***OR*** HCl has acidic vapour ***OR*** HCl is corrosive ✓	*Accept TiO_2 causes breathing problems/is an irritant.* *Accept "harmful" for both HCl and TiO_2.* *Accept "smoke is asphyxiant".*	1

Question			Answers	Notes	Total
3.	**a**		V_2O_5: +5 ✓ VO^{2+}: +4 ✓	*Do **not** penalize incorrect notation twice.*	**2**
3.	**b**	**i**	H_2SO_3 (aq) ***OR*** Pb (s) ✓		**1**
3.	**b**	**ii**	Zn (s) ✓		**1**
3.	**c**	**i**	VO^{2+} (aq) + V^{2+} (aq) + $2H^+$ (aq) → $2V^{3+}$ (aq) + H_2O (l) ✓	*Accept equilibrium sign.*	**1**
3.	**c**	**ii**	$E^{\ominus}$ **«**= +0.34 V – (–0.26 V)**»** = +0.60 **«**V**»** ✓ $\Delta G^{\ominus}$ = **«**$-nFE^{\ominus}$ = -9.65×10^4 C mol^{-1} × 0.60 J C^{-1} =**»** – 57 900 **«**J mol^{-1}**»** / –57.9 **«**kJ mol^{-1}**»** ✓ spontaneous as $\Delta G^{\ominus}$ is negative ✓	*Do **not** award M3 as a stand-alone answer.* *Accept "spontaneous" for M3 if answer given for M2 is negative.* *Accept "spontaneous as $E^{\ominus}$ is positive" for M3.*	**3**

Question			Answers	Notes	Total
4.	a		$2NiS\ (s) + 3O_2\ (g) \rightarrow 2NiO\ (s) + 2SO_2\ (g)$ ✓		1
4.	b		formation of «gaseous» pentacarbonyliron is slower ***OR*** «gaseous» complexes form at different rates ***OR*** gases have different rates of diffusion «due to difference in masses» ***OR*** difference in thermal stability of «gaseous» complexes ***OR*** difference in boiling points of «gaseous» complexes ***OR*** difference in solubility of «gaseous» complexes ***OR*** difference in surface affinity «onto solid absorbent» ***OR*** difference in chemical properties of «gaseous» complexes ✓	*Accept any other valid answer.*	1
4.	c	i	$\sum S^{\ominus}_{RHS} = 313.4$ «J K^{-1}» ***AND*** $\sum S^{\ominus}_{LHS}$ = «$(4 \times 197.6) + 29.9$ J K^{-1} =» 820.3 «J K^{-1}» ✓ $\Delta S^{\ominus}$ «$= \sum S^{\ominus}_{RHS} - \sum S^{\ominus}_{LHS} = 313.4 - 820.3$» = –506.9 «J K^{-1}» ✓	*Award [2] for correct final answer.*	2
4.	c	ii	$\Delta H^{\ominus}$ «$= -633.0 - 4 \times (-110.5)$» = –191 «kJ» ✓		1
4.	c	iii	«when» $\Delta G = 0$ «forward and backward reactions are equally favourable» ✓ «when $\Delta G = 0$, $T = \frac{\Delta H}{\Delta S}$», T = «$\frac{191\ kJ}{0.5069\ kJ\ K^{-1}}$ =» 377 «K» ✓ «temperature =» 104 «°C» ✓	*Award [3] for correct final answer. Use of –500 J K^{-1} and –200 kJ gives 127 °C.* *Award [2 max] for T < 104 «°C».* *Accept $\Delta G < 0$ and T > 104 «°C».*	3

Question			Answers	Notes	Total
4.	**d**		CO is toxic/poisonous ***OR*** $Ni(CO)_4$ decomposition deposits nickel in the lungs ***OR*** tetracarbonylnickel is toxic/poisonous ***OR*** tetracarbonylnickel is highly flammable **«**auto-ignition temperature of 60 °C**»** ✓		**1**

Question			Answers	Notes	Total
5.	a		107° ✓	*Accept 100° to <109.5°.* *Literature value = 105.8°*	1
5.	b		tetrahedral ✓ sp^3 ✓	*No ECF allowed.*	2
5.	c		removes/reacts with OH^- ✓ moves to the right/products «to replace OH^- ions» ✓	*Accept ionic equation for M1.*	2
5.	d	i	$K_b = 10^{-5.77} / 1.698 \times 10^{-6}$ ***OR*** $K_b = \frac{[N_2H_5^+] \times [OH^-]}{[N_2H_4]}$ ✓ $[OH^-]^2$ «$= 1.698 \times 10^{-6} \times 0.0100$» $= 1.698 \times 10^{-8}$ ***OR*** $[OH^-]$ «$= \sqrt{1.698 \times 10^{-8}}$» $= 1.303 \times 10^{-4}$ «mol dm^{-3}» ✓ pH «$= -\log_{10} \frac{1 \times 10^{-14}}{1.3 \times 10^{-4}}$» $= 10.1$ ✓	*Award [3] for correct final answer.* *Give appropriate credit for other methods containing errors that do not yield correct final answer.*	3
5.	d	ii	methyl red ***OR*** bromocresol green ***OR*** bromophenol blue ***OR*** methyl orange ✓		1
5.	e		bubbles ***OR*** gas ***OR*** magnesium disappears ✓ $2NH_4^+ (aq) + Mg (s) \rightarrow Mg^{2+} (aq) + 2NH_3 (aq) + H_2 (g)$ ✓	*Do **not** accept "hydrogen" without reference to observed changes.* *Accept "smell of ammonia".* *Accept $2H^+ (aq) + Mg (s) \rightarrow Mg^{2+} (aq) + H_2 (g)$* *Equation must be ionic.*	2

Question			Answers	Notes	Total
5.	f		*bonds broken*: E(N–N) + 4E(N–H) ***OR*** 158 «kJ mol^{-1}» + 4 × 391 «kJ mol^{-1}» / 1722 «kJ» ✓ *bonds formed*: E(N≡N) + 2E(H–H) ***OR*** 945 «kJ mol^{-1}» + 2 × 436 «kJ mol^{-1}» / 1817 «kJ» ✓ «ΔH = bonds broken – bonds formed = 1722 – 1817 =» –95 «kJ» ✓	*Award [3] for correct final answer.* *Award [2 max] for +95 «kJ».*	**3**
5.	g		 ***OR*** $\Delta H_{vap} = -50.6\ kJ\ mol^{-1} - (-95\ kJ\ mol^{-1})$ ✓ «ΔH_{vap} =» +44 «kJ mol^{-1}» ✓	*Award [2] for correct final answer. Award [1 max] for –44 «kJ mol^{-1}».* *Award [2] for:* *ΔH_{vap} = – 50.6 kJ mol^{-1} – (–85 J mol^{-1}) = +34 «kJ mol^{-1}».* *Award [1 max] for –34 «kJ mol^{-1}».*	**2**
5.	h	i	total mass of oxygen «= 8.0 × 10^{-3} g dm^{-3} × 1000 dm^3» = 8.0 «g» n(O_2) «$= \frac{8.0\,g}{32.00\,g\,mol^{-1}}$ =» 0.25 «mol» ***OR*** n(N_2H_4) = n(O_2) ✓ «mass of hydrazine = 0.25 mol × 32.06 g mol^{-1} =» 8.0 «g» ✓	*Award [3] for correct final answer.*	**3**

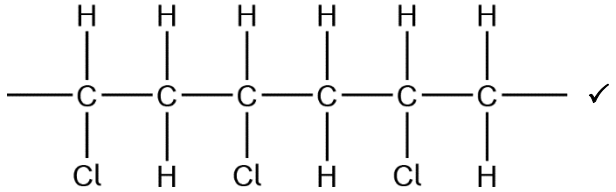
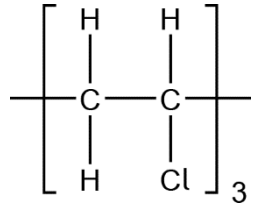
continued…

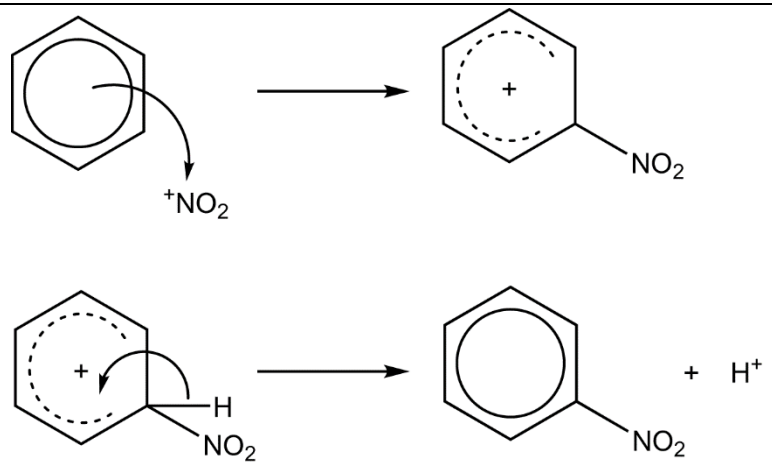
(Question 5h continued)

Question			Answers	Notes	Total
5.	**h**	**ii**	«$n(N_2H_4) = n(O_2) = \frac{8.0\,g}{32.00\,g\,mol^{-1}}$ =» 0.25 «mol» «volume of nitrogen = 0.25 mol × 24.8 $dm^3\ mol^{-1}$» = 6.2 «dm^3» ✓	*Award [1] for correct final answer.*	**1**

Question			Answers	Notes	Total
6.	a		substitution ***AND*** «free-»radical ***OR*** substitution ***AND*** chain ✓	*Award [1] for "«free-»radical substitution" or "S_R" written anywhere in the answer.*	**1**
6.	b	i	*Two propagation steps:* $C_2H_6 + \bullet Cl \rightarrow C_2H_5\bullet + HCl$ ✓ $C_2H_5\bullet + Cl_2 \rightarrow C_2H_5Cl + \bullet Cl$ ✓ *One termination step:* $C_2H_5\bullet + C_2H_5\bullet \rightarrow C_4H_{10}$ ***OR*** $C_2H_5\bullet + \bullet Cl \rightarrow C_2H_5Cl$ ***OR*** $\bullet Cl + \bullet Cl \rightarrow Cl_2$ ✓	*Accept radical without • if consistent throughout.* *Allow ECF for incorrect radicals produced in propagation step for M3.*	**3**
6.	b	ii	triplet ***AND*** quartet ✓		**1**
6.	b	iii	chemical shift/signal outside range of common chemical shift/signal ✓ strong signal/12/all H atoms in same environment ***OR*** singlet/no splitting of the signal ✓ volatile/easily separated/easily removed ***OR*** inert/stable ✓ contains three common NMR nuclei/^{1}H and ^{13}C and ^{29}Si ✓	*Do **not** accept chemical shift = 0.*	**2 max**

continued…

Question			Answers	Notes	Total
6.	c	i	$C = \frac{24.27}{12.01} = 2.021$ ***AND*** $H = \frac{4.08}{1.01} = 4.04$ ***AND*** $Cl = \frac{71.65}{35.45} = 2.021$ ✓ **«**hence**»** CH_2Cl ✓	*Accept* $\frac{24.27}{12.01} : \frac{4.08}{1.01} : \frac{71.65}{35.45}$. *Do **not** accept $C_2H_4Cl_2$.* *Award [2] for correct final answer.*	**2**
6.	c	ii	molecular ion peak(s) **«**about**»** *m/z* 100 ***AND*** **«**so**»** $C_2H_4Cl_2$ **«**isotopes of Cl**»** ✓ two signals **«**in ^{1}H NMR spectrum**»** ***AND*** **«**so**»** CH_3CHCl_2 ***OR*** **«**signals in**»** 3:1 ratio **«**in ^{1}H NMR spectrum**»** ***AND*** **«**so**»** CH_3CHCl_2 ***OR*** one doublet and one quartet **«**in ^{1}H NMR spectrum**»** ***AND*** **«**so**»** CH_3CHCl_2 ✓ 1,1-dichloroethane ✓	*Accept "peaks" for "signals".* *Allow ECF for M3 if the formula of an incorrect chlorohydrocarbon is identified.*	**3**
6.	c	iii	base ***OR*** proton acceptor ✓		**1**
6.	d		 ✓	*Continuation bonds must be shown.* *Ignore square brackets and "n".* *Accept*  . *Accept other versions of the polymer, such as head to head and head to tail.* *Accept condensed structure provided all C to C bonds are shown (as single).*	**1**

Question			Answers	Notes	Total
7.	a		*Any two of:* planar «X-ray» ✓ C to C bond lengths all equal ***OR*** C to C bonds intermediate in length between C–C and C=C ✓ all C–C–C bond angles equal ✓		**2 max**
7.	b		*benzene:* «electrophilic» substitution/S_E ***AND*** *cyclohexene:* «electrophilic» addition/A_E ✓	*Accept correct equations.*	**1**
7.	c		«concentrated» nitric ***AND*** sulfuric acids ✓ $^+NO_2$ ✓	*Accept NO_2^+.*	**2**
7.	d		 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 ***AND*** H^+ ✓	*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.* *M2 may be awarded from correct diagram for M3.* *M4: Accept $C_6H_5NO_2 + H_2SO_4$ if HSO_4^- used in M3.*	**4**

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Question			Answers	Notes	Total
7.	e		Fe/Zn/Sn ***AND*** $HCl/H_2SO_4/CH_3COOH$ ✓ NaOH/KOH ✓	*Accept other suitable metals and acids.* *Accept other suitable bases.* *Award [1 max] for single-step reducing agents (such as H_2/Pt, Na_2S etc.).* *Accept formulas or names.*	**2**

8.	a		$NO\bullet\ (g) + O_3\ (g) \rightarrow NO_2\bullet\ (g) + O_2\ (g)$ ✓ $NO_2\bullet\ (g) + O\bullet\ (g) \rightarrow NO\bullet\ (g) + O_2\ (g)$ ***OR*** $NO_2\bullet\ (g) + O_3\ (g) \rightarrow NO\bullet\ (g) + 2O_2\ (g)$ ✓	*Allow representation of radicals without • if consistent throughout.*	**2**
8.	b		«loss of ozone» allows UV radiation to penetrate atmosphere/reach earth ✓ UV radiation causes skin cancer ***OR*** UV radiation causes tissue damage ✓		**2**