Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2018

Chemistry

Higher level

Paper 2

23 pages

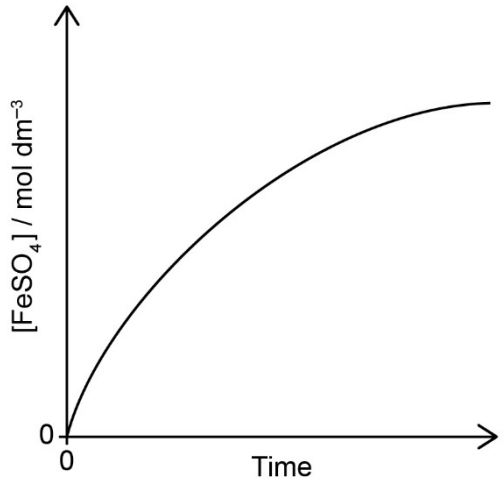
Question			Answers	Notes	Total
1.	a	i	n_{CuSO4} «$= 0.0800\,dm^3 \times 0.200\,mol\,dm^{-3}$» $= 0.0160$ mol ***AND*** n_{Fe} «$= \frac{3.26\,g}{55.85\,g\,mol^{-1}}$» $=$ 0.0584 mol ✓ $CuSO_4$ is the limiting reactant ✓	*Do **not** award M2 if mole calculation is not shown.*	**2**
1.	a	ii	***ALTERNATIVE 1:*** «$0.0160\,mol \times 63.55\,g\,mol^{-1} =$» 1.02 «g» ✓ «$\frac{0.872\,g}{1.02\,g} \times 100 =$» 85.5 «%» ✓ ***ALTERNATIVE 2:*** «$\frac{0.872\,g}{63.55\,g\,mol^{-1}} =$» 0.0137 «mol» ✓ «$\frac{0.0137\,mol}{0.0160\,mol} \times 100 =$» 85.6 «%» ✓	*Accept answers in the range 85–86 %.* *Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
1.	b	i	***ALTERNATIVE 1:*** $q = «80.0\ g \times 4.18\ J\ g^{-1}\ K^{-1} \times 7.5\ K =» 2.5 \times 10^3$ **«**J**»**/2.5 **«**kJ**»** ✓ **«**per mol of $CuSO_4 = \frac{-2.5\ kJ}{0.0160\ mol} = -1.6 \times 10^2\ kJ\ mol^{-1}$**»** **«**for the reaction**»** $\Delta H = -1.6 \times 10^2$ **«**kJ**»** ✓ ***ALTERNATIVE 2:*** $q = «80.0\ g \times 4.18\ J\ g^{-1}\ K^{-1} \times 7.5\ K =» 2.5 \times 10^3$ **«**J**»**/2.5 **«**kJ**»** ✓ **«**$n_{Cu} = \frac{0.872}{63.55} = 0.0137\ mol$**»** **«**per mol of $CuSO_4 = \frac{-2.5\ kJ}{0.0137\ mol} = -1.8 \times 10^2\ kJ\ mol^{-1}$**»** **«**for the reaction**»** $\Delta H = -1.8 \times 10^2$ **«**kJ**»** ✓	*Award **[2]** for correct final answer.*	**2**
1.	b	ii	density **«**of solution**»** is $1.00\ g\ cm^{-3}$ ***OR*** specific heat capacity **«**of solution**»** is $4.18\ J\ g^{-1}\ K^{-1}$/that of **«**pure**»** water ***OR*** reaction goes to completion ***OR*** iron/$CuSO_4$ does not react with other substances ✓	*The mark for "reaction goes to completion" can only be awarded if 0.0160 mol was used in part (b)(i).* *Do **not** accept "heat loss".*	**1**

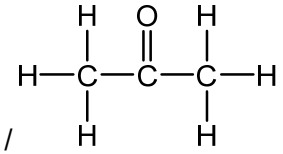
(continued…)

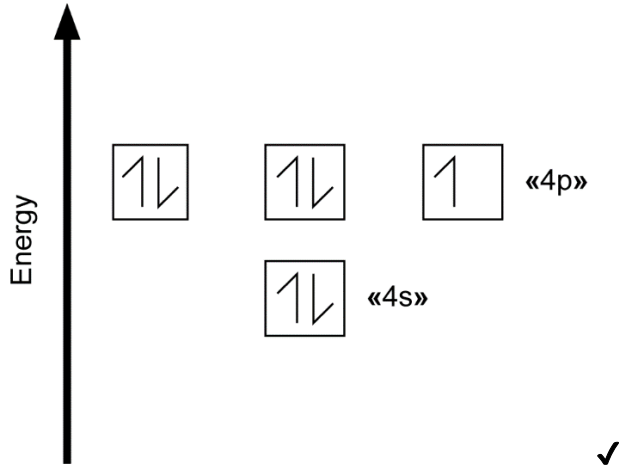
(Question 1b continued)

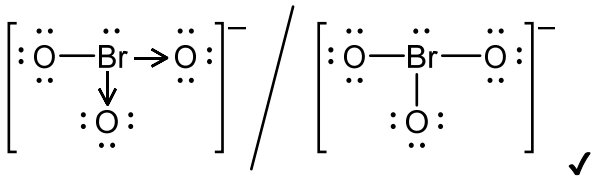
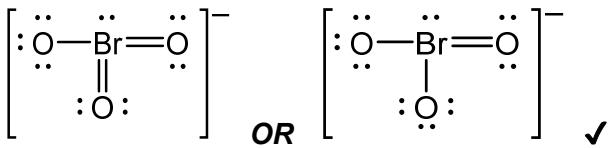
Question			Answers	Notes	Total
1.	b	iii	***ALTERNATIVE 1:*** «$0.2\,°C \times \frac{100}{7.5\,°C}$ =» 3 %/0.03 ✓ «0.03 × 160 kJ» = «±» 5 «kJ» ✓ ***ALTERNATIVE 2:*** «$0.2\,°C \times \frac{100}{7.5\,°C}$ =» 3 %/0.03 ✓ «0.03 × 180 kJ» = «±» 5 «kJ» ✓	*Accept values in the range 4.1–5.5 «kJ».* *Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
1.	c	i	 initial concentration is zero ***AND*** concentration increases with time ✓ decreasing gradient as reaction proceeds ✓		**2**
1.	c	ii	«draw a» tangent to the curve at time = 0 ✓ «rate equals» gradient/slope «of the tangent» ✓	*Accept suitable diagram.*	**2**
1.	c	iii	piece has smaller surface area ✓ lower frequency of collisions ***OR*** fewer collisions per second/unit time ✓	*Accept "chance/probability" instead of "frequency".* *Do **not** accept just "fewer collisions".*	**2**

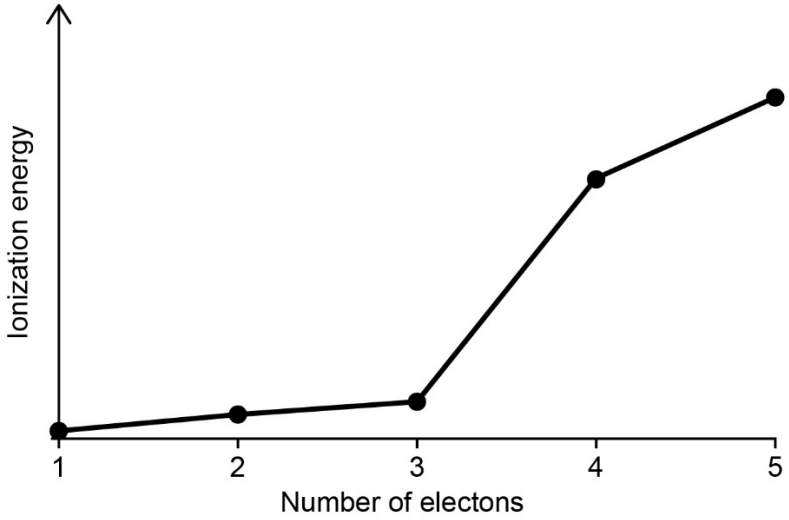
Question			Answers	Notes	Total
1.	d		*Anode (positive electrode):* $2H_2O\,(l) \rightarrow O_2\,(g) + 4H^+\,(aq) + 4e^-$ ✓ *Cathode (negative electrode):* $2H_2O\,(l) + 2e^- \rightarrow H_2\,(g) + 2OH^-\,(aq)$ ***OR*** $2H^+\,(aq) + 2e^- \rightarrow H_2\,(g)$ ✓	*Accept "$4OH^-\,(aq) \rightarrow O_2\,(g) + 2H_2O\,(l) + 4e^-$"* ***OR*** *"$Fe^{2+}\,(aq) \rightarrow Fe^{3+}\,(aq) + e^-$" for M1.* *Accept "$Fe^{2+}\,(aq) + 2e^- \rightarrow Fe\,(s)$"* ***OR*** *"$SO_4^{2-}\,(aq) + 4H^+\,(aq) + 2e^- \rightarrow 2H_2SO_3(aq) + H_2O\,(l)$" for M2.*	**2**

Question			Answers	Notes	Total
2.	a		«in 100 g sample» $\frac{62.02\text{ g}}{12.01\text{ g mol}^{-1}}$ ***AND*** $\frac{10.43\text{ g}}{1.01\text{ g mol}^{-1}}$ ***OR*** «in 100 g sample» 5.164 mol C ***AND*** 10.33 mol H ✓ 27.55 % ***OR*** 1.722 mol O ✓ «empirical formula» C_3H_6O ✓		3
2.	b		«absorption at wavenumber 1700–1750 cm^{-1}» C=O/carbonyl ✓	*Do **not** accept "ketone" or "aldehyde".*	1
2.	c		«*m*/*z* =» 58 ✓		1
2.	d		 / CH_3COCH_3 / ✓		1

Question			Answers	Notes	Total
3.	a	i	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$ ***OR*** $[Ar]\ 4s^2\ 3d^{10}\ 4p^5$ ✓	*Accept 3d before 4s.*	**1**
3.	a	ii	 ✓	*Accept double-headed arrows.*	**1**

Question			Answers	Notes	Total
3.	b	i	*Structure I – follows octet rule:*  ✓ *Structure II – does not follow octet rule:*  ***OR*** ✓	*Accept dots, crosses or lines to represent electron pairs.*	**2**
3.	b	ii	«structure I» formal charge on Br = +2 ***OR*** «structure II» formal charge on Br = 0/+1 ✓ structure II is preferred ***AND*** it produces formal charge closer to 0 ✓	*Ignore any reference to formal charge on oxygen.*	**2**

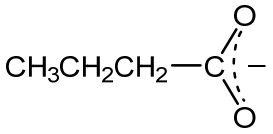
Question			Answers	Notes	Total
3.	c		*Geometry:* trigonal/pyramidal ✓ *Reason:* three bonds ***AND*** one lone pair ***OR*** four electron domains ✓ *O–Br–O angle:* 107° ✓	*Accept "charge centres" for "electron domains".* *Accept answers in the range 104–109°.*	3
3.	d	i	$BrO_3^-(aq) + 6e^- + 6H^+(aq) \rightarrow Br^-(aq) + 3H_2O(l)$ correct reactants and products ✓ balanced equation ✓	*Accept reversible arrows.*	2
3.	d	ii	$BrO_3^-(aq) + 6Fe^{2+}(aq) + 6H^+(aq) \rightarrow Br^-(aq) + 3H_2O(l) + 6Fe^{3+}(aq)$ ✓		1
3.	d	iii	$E^{\ominus}_{reaction}$ = «+1.44 V – 0.77 V =» 0.67 «V» ✓ $\Delta G^{\ominus}$ = «$-nFE^{\ominus}_{reaction} = -6 \times 96500\ C\ mol^{-1} \times 0.67\ V$ =» -3.9×10^5 «J» ✓		2
3.	e		both are paramagnetic ✓ «both» contain unpaired electrons ✓	*Accept orbital diagrams for both ions showing unpaired electrons.*	2

Question			Answers	Notes	Total
4.	a		nuclear charge/number of protons/Z_{eff} increases «causing a stronger pull on the outer electrons» ✓ same number of shells/«outer» energy level/shielding ✓	*Accept "atomic number" for "number of protons".*	2
4.	b		isoelectronic/same electronic configuration/«both» have 2.8 ✓ more protons in Na^+ ✓		2
4.	c		 *Sketch showing:* largest increase between third and fourth ionization energies ✓ $IE_1 < IE_2 < IE_3 < IE_4 < IE_5$ ✓		2

Question			Answers	Notes	Total
4.	**d**		Fe^{2+} ***AND*** smaller size/radius ***OR*** Fe^{2+} ***AND*** higher charge density ✓ stronger interaction with **«**polar**»** water molecules ✓	*M1 not needed for M2.*	**2**

5.	**a**		all **«**species**»** are in same phase ✓	*Accept "all species are in same state".* *Accept "all species are gases".*	**1**
5.	**b**		negative ***AND*** fewer moles/molecules **«**of gas**»** in the products ✓		**1**
5.	**c**		$\Delta G^{\ominus}$ =**«**–RT ln K_c =**»** –8.31 J K^{-1} mol^{-1} × 1000 K × ln 280 ***OR*** $\Delta G^{\ominus}$ = –4.7 × 10^4 **«**J**»** ✓ **«**$\Delta G^{\ominus}$ =**»** –47 **«**kJ**»** ✓	*Award **[2]** for correct final answer.*	**2**
5.	**d**		$\Delta G^{\ominus}$ < 0/spontaneous ***AND*** $\Delta S^{\ominus}$ < 0/unfavourable ✓ exothermic ***AND*** $\Delta H^{\ominus}$ **«**must be**»** negative/favourable ✓		**2**

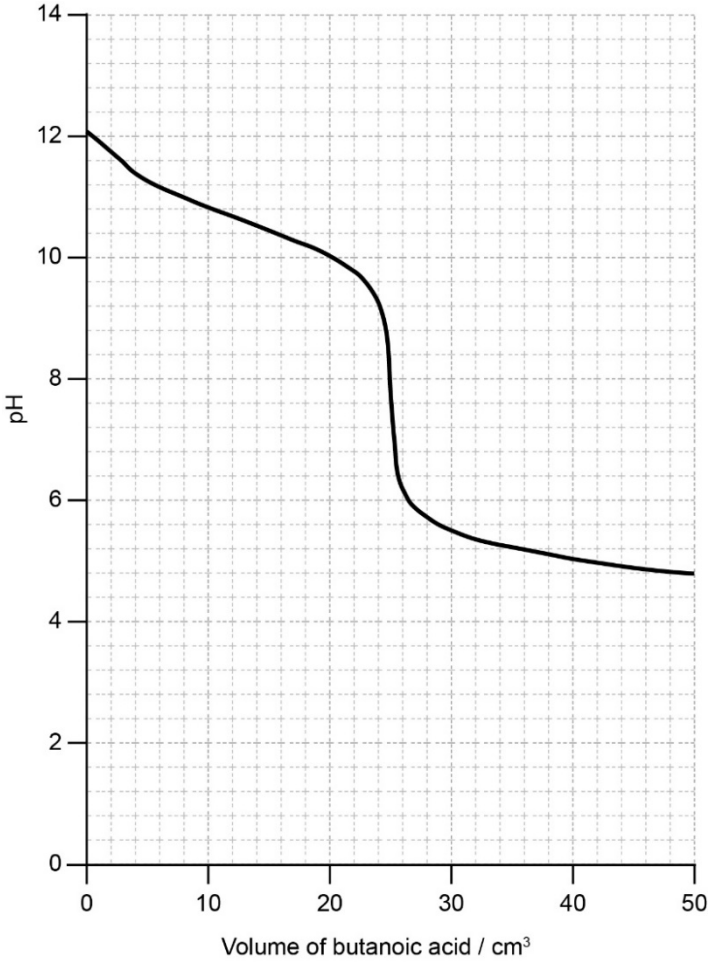
Question			Answers	Notes	Total
5.	e		«reaction quotient/Q =» $\frac{[SO_3]^2}{[SO_2]^2[O_2]} / \frac{0.500^2}{0.200^2 \times 0.300}$ /20.8 ✓ reaction quotient/Q/20.8/answer < K_c/280 ***OR*** mixture needs more product for the number to equal K_c ✓ reaction proceeds to the right/products ✓	*Do **not** award M3 without valid reasoning.*	**3**

Question			Answers	Notes	Total
6.	**a**	**i**	*Butanoic acid:* $CH_3CH_2CH_2COOH\,(aq) + H_2O\,(l) \rightleftharpoons CH_3CH_2CH_2COO^-\,(aq) + H_3O^+\,(aq)$ ✓ *Ethylamine:* $CH_3CH_2NH_2\,(aq) + H_2O\,(l) \rightleftharpoons CH_3CH_2NH_3^+\,(aq) + OH^-\,(aq)$ ✓		**2**
6.	**a**	**ii**	 *Diagram showing:* dotted line along O–C–O ***AND*** negative charge	*Accept correct diagrams with pi clouds.*	**1**
6.	**a**	**iii**	–1 ✓		**1**
6.	**b**	**i**	**«**$= \frac{1.00 \times 10^{-14}\ mol^2\ dm^{-6}}{0.00192\ mol\ dm^{-3}}$**»** $= 5.21 \times 10^{-12}$ **«**$mol\ dm^{-3}$**»** ✓		**1**

(continued…)

(Question 6b continued)

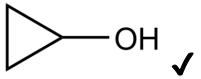
Question			Answers	Notes	Total
6.	b	ii	«pK_b = 3.35, $K_b = 10^{-3.35} = 4.5 \times 10^{-4}$» «$C_2H_5NH_2 + H_2O \rightleftharpoons C_2H_5NH_3^+ + OH^-$» $K_b = \frac{[OH^-][CH_3CH_2NH_3^+]}{[CH_3CH_2NH_2]}$ ***OR*** «K_b =» $4.5 \times 10^{-4} = \frac{[OH^-]\,[CH_3CH_2NH_3^+]}{0.250}$ ***OR*** «K_b =» $4.5 \times 10^{-4} = \frac{x^2}{0.250}$ ✓ «$x = [OH^-]$ =» 0.011 «mol dm^{-3}» ✓ «pH = $-\log \frac{1.00 \times 10^{-14}}{0.011}$ =» 12.04 ***OR*** «pH = 14.00 – (–log 0.011)=» 12.04 ✓	*Award **[3]** for correct final answer.*	**3**

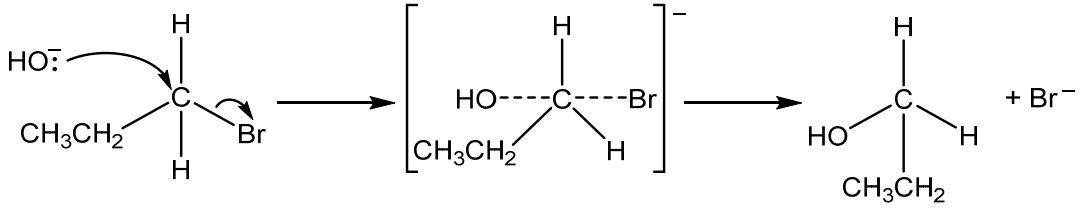
Question			Answers	Notes	Total
6.	c		 decreasing pH curve ✓ pH close to 7 (6–8) at volume of 25 cm^3 butanoic acid ✓ weak acid/base shape with no flat «strong acid/base» parts on the curve ✓		3

Question			Answers	Notes	Total
6.	**d**		*Any two of:* butanoic acid forms more/stronger hydrogen bonds ✓ butanoic acid forms stronger London/dispersion forces ✓ butanoic acid forms stronger dipole–dipole interaction/force ✓	*Accept "butanoic acid forms dimers".* *Accept "butanoic acid has larger M_r/hydrocarbon chain/number of electrons" for M2.* *Accept "butanoic acid has larger «permanent» dipole/more polar" for M3.*	**2 max**
6.	**e**	**i**	lithium aluminium hydride/$LiAlH_4$ ✓		**1**
6.	**e**	**ii**	butan-1-ol/1-butanol/$CH_3CH_2CH_2CH_2OH$ ✓		**1**

Question			Answers	Notes	Total
7.	a		«electrophilic» addition/A_E ***OR*** reduction ✓	*Accept "hydrogenation".*	**1**
7.	b		«(−286 kJ) + (−1411 kJ) =» −1697 «kJ» ✓		**1**
7.	c		«−1697 kJ + 1561 kJ =» −136 «kJ» ***OR*** «$\Delta H^{\ominus} = \Delta H_f^{\ominus}$ (products) − $\Delta H_f^{\ominus}$ (reactants) = − 84 kJ − 52 kJ =» −136 «kJ» ✓		**1**

Question			Answers	Notes	Total
7.	d		*Accurate:* no approximations were made in the cycle ***OR*** values are specific to the compounds ***OR*** Hess's law is a statement of conservation of energy ***OR*** method is based on a law ***OR*** data in table has small uncertainties ✓ *Approximate:* values were experimentally determined/had uncertainties ***OR*** each value has been determined to only three/four significant figures ***OR*** different sources have «slightly» different values for enthalpy of combustion ***OR*** law is valid until disproved ***OR*** law of conservation of energy is now conservation of mass-energy ***OR*** small difference between two quite large terms «leads to high percentage uncertainty» ✓		**2**

Question			Answers	Notes	Total
8.	a		angle between bonds is 60˚/strained/smaller than 109.5˚ ✓		1
8.	b	i	*Any two of:* CH_3COCH_3 ✓ CH_3CH_2CHO ✓ $CH_2=CHCH_2OH$ ✓ $CH_3OCH=CH_2$ ✓  ✓  ✓	*Accept displayed or condensed structural formulas or skeletal formulas.* *Accept $CH(OH)=CHCH_3$ and $CH_2=C(OH)CH_3$.*	2
8.	b	ii	no ***AND*** only one «axial/methyl/CH_3» substituent «at the ring» ***OR*** no ***AND*** two «axial» substituents required «for cis/trans-isomers» ✓	*Accept "no **AND** «O in the ring and» one carbon has two H atoms".*	1
8.	c		*Chemical shift:* 3.7–4.8 «ppm» ✓ *Splitting pattern:* doublet ✓		2

Question			Answers	Notes	Total
9.	a		polarity/polar «molecule/bond» ***OR*** carbon–halogen bond is weaker than C–H bond ✓		1
9.	b		primary ***AND*** Br/bromine is attached to a carbon bonded to two hydrogens ***OR*** primary ***AND*** Br/bromine is attached to a carbon bonded to one C/R/alkyl «group» ✓	*Accept "primary **AND** Br/bromine is attached to the first carbon in the chain".*	1
9.	c		 curly arrow going from lone pair/negative charge on O in HO^- to C ✓ curly arrow showing Br leaving ✓ representation of transition state showing negative charge, square brackets and partial bonds ✓ formation of organic product $CH_3CH_2CH_2OH$ ***AND*** Br^- ✓	*Do **not** allow curly arrow originating on H in HO^-.* *Accept curly arrow either going from bond between C and Br to Br in 1-bromopropane or in the transition state.* *Do **not** penalize if HO and Br are not at 180° to each other.* *Do **not** award M3 if OH–C bond is represented.*	4
9.	d		«Lewis» base ***AND*** donates a pair of electrons ✓		1

Question			Answers	Notes	Total
9.	**e**		*Any two of:* choose **«**most**»** appropriate reaction **«**for preparing the target compound**»** ✓ design/discover new reactions/reagents ✓ apply this knowledge to other areas of chemistry/science ✓ **«**retro-**»**synthesis **«**more effective**»** ✓ control/predict **«**desired**»** products ✓ control rate of reaction **«**more effectively**»** ✓ satisfy intellectual curiosity ✓ predicting how changing reagents/conditions might affect reaction ✓ suggesting intermediates/transition states ✓	*Accept other reasonable answers.*	**2 max**

10.	**a**		*B:* reactant ✓ *D:* intermediate ✓		**2**
10.	**b**		rate = k[A][B] ✓		**1**
10.	**c**		1.80 **«**mol dm^{-3} s^{-1}**»** ✓		**1**