Cambridge Pre-U

Cambridge International Examinations
Cambridge Pre-U Certificate

CHEMISTRY (PRINCIPAL) **9791/02**

Paper 2 Part A Written **For Examination from 2016**

SPECIMEN MARK SCHEME

2 hours 15 minutes

MAXIMUM MARK: 100

The syllabus is approved for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

CAMBRIDGE
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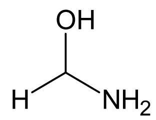
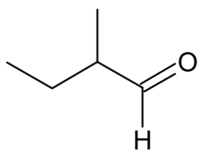
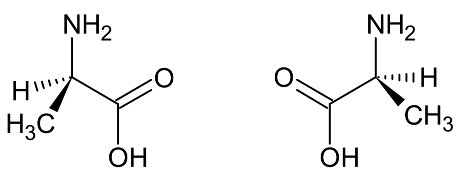
[Turn over

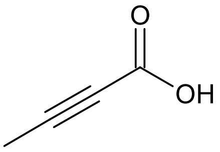
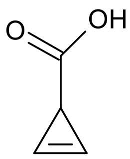
Question Number	Answer		Max marks
1 (a)	n(Mg) = 9.0 g / 24.3 g mol^{-1} = <u>0.37</u> mol Allow two or more significant figures	(1)	[1]
(b)	n(H_2O) reacted = 2 × n(Mg) = <u>0.74</u> mol Mass of water reacted = 0.74 mol × 18 g mol^{-1} = 13.3 g Mass of excess water = 30 g – 13.3 g = <u>16.7</u> g Allow two or more significant figures	(1) (1)	[2]
(c)	Vol of H_2 = 0.37 mol × 24 dm^3 mol^{-1} = <u>8.9</u> dm^3 Allow two or more significant figures	(1)	[1]
(d)	$\Delta_r H^\ominus$ = −924.5 kJ mol^{-1} − (2 × −285.8 kJ mol^{-1}) = −352.9 kJ mol^{-1} 1 mark for correct signs; 1 mark for multiplying value for water by 2 Allow two or more significant figures		[2]
(e)	Heat energy = 352.9 kJ mol^{-1} × 0.37 mol = <u>131</u> kJ Allow two or more significant figures	(1)	[1]
(f)	Heat energy = (60 − 15) K × 150 g × 4.2 J g^{-1}K^{-1} = <u>28</u> kJ Allow up to 4 significant figures	(1)	[1]
(g)	The same amount of heat energy is released from the lumps The rate of reaction (or the rate of heat generation) is slower and so a lower temperature will be reached (due to imperfect insulation)/ Allow temperature reached being the same if there is the stated assumption that the system is perfectly insulated Valid alternative: not all of the magnesium reacts as it becomes covered in insoluble magnesium hydroxide Therefore less energy released and lower temperature reached	(1) (1) (1) (1)	[2]
(h) (i)	$CaO + H_2O \rightarrow Ca(OH)_2$ 7 <pH ≤ 12	(1) (1)	[2]
(ii)	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ OR $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$ 0≤ pH < 7	(1) (1)	[2]
(iii)	$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$ OR $3CaO + P_2O_5 \rightarrow Ca_3(PO_4)_2$ Ignore state symbols.	(1)	[1]
			[Total: 15]

Question Number	Answer		Max marks
2 (a) (i)	Energy change to <u>break</u> <u>one mole of bonds</u> in the <u>gas</u> phase. 1 mark for each underlined point		[3]
(ii)	$\Delta_r H^\ominus = 2 \times (413 + 243 - 346 - 432)$ kJ mol^{-1} = –244kJ mol^{-1} 1 mark for bonds broken; 1 mark for bonds made; 1 mark for correct sign if the answer is correct		[3]
(b) (i)	Energy change = $(4405 + 3966 - (2 \times 4180))$cm^{-1} = <u>11</u> cm^{-1}		[1]
(ii)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ Superscripts must be used		[1]
(iii)	At least one K 4s atomic orbital labelled Labelled <u>sigma</u> bond below labelled <u>sigma</u> antibond (A single electron (spinning in either sense) in each atomic orbital and) two spin-paired electrons in the sigma bond Electrons must be shown with a single- or double-headed arrow	(1) (1) (1)	[3]
(iv)	The outer electron in K is closer to the nucleus than the outer electron in Rb There is less shielding of the nucleus for the K outer electron than the Rb outer electron (Despite the extra nuclear charge in rubidium) there is a weaker attraction of the electron to the nucleus Allow the opposite statements with respect to Rb	(1) (1) (1)	[3]
(v)	Labelled Rb 5s orbital shown higher in energy than labelled K 4s orbital Sigma bond is lower in energy than K 4s orbital and the antibond is higher in energy than the Rb 5s orbital The bonding and antibonding orbitals must be labelled for the second mark	(1) (1)	[2]
(vi)	E = 11 cm^{-1} $\times$ h c N_A $\times$ 100 cm m^{-1} / 1000 J kJ^{-1} = 0.13 kJ mol^{-1} Two marks for correct answer. If final answer incorrect, one mark for correct use of N_A. One mark if final answer is out by a factor of N_A i.e. 2.19×10^{-25} Allow two or more sig figs.		[2]
			[Total: 18]

Question Number	Answer	Max marks
3 (a) (i)	Point plotted corrected (must be within the correct small square in the grid)	[1]
(ii)	Bonding is intermediate-covalent-ionic-metallic	[1]
(b) (i)	$NO_2^- + 3e^- + 4H^+ \rightarrow \frac{1}{2} N_2 + 2H_2O$ OR $2NO_2^- + 6e^- + 8H^+ \rightarrow N_2 + 4H_2O$ 1 mark for correct number of electrons on the left hand side 1 mark for the rest of the balanced half equation (ignoring charge)	[2]
(ii)	$3CH_4 + 8NO_2^- + 8H^+ \rightarrow 3CO_2 + 4N_2 + 10H_2O$	[1]
(iii)	Enzyme catalysis	[1]
(c) (i)	Oxidation state = $\{(2 \times 112) - 8\} / 36 = (+)6$	[1]
(ii)	$[Mo_9O_{28}(H_2O)_4]^{2-}$ OR $[Mo_9O_{32}H_8]^{2-}$	[1]
		[Total: 8]

Question Number	Answer	Max marks
4 (a)	Carbon atom circled or otherwise indicated	[1]
(b)	Nucleophile Allow nucleophilic or Lewis base or lone-pair donor	[1]
(c)	Any unambiguous structure of the hemiaminal  No mark if atom connectivity is incorrect, e.g. $OH{-}CH_2NH_2$	[1]
(d)	Addition No credit for "electrophilic addition" Allow nucleophilic addition or reduction	[1]
(e)	Methanal (allow any carbonyl compound)	[1]
(f)	Hydrolysis Allow hydration + elimination but not substitution + elimination	[1]
(g)	Methanal: FGL 2 (1) After Reaction 2: FGL 2 (1) After Reaction 3: FGL 1 (1) Accept equivalent names for the functional group levels	[3]
(h) (i)	Allow any unambiguous structure for **Z** 	[1]
(ii)	2-methylbutanal Ignore incorrect use of spaces/hyphens but do not allow 2-methylbutan-1-al	[1]
(i)	1 mark for a correct structure  2nd mark for showing two optical isomers clearly with hashed and wedge bonds	[2]
		[Total: 13]

Question Number	Answer		Max marks
5 (a)	Mass of $HCl = \frac{1}{4} \times 55.6 \text{ mol} \times 36.5 \text{ g mol}^{-1} = \underline{507}$ g No sig figs or units penalties		[1]
(b)	Amount of NaOH = $0.02475 \text{ dm}^3 \times 0.0500 \text{ mol dm}^{-3}$ = $\underline{0.0012375}$ mol Amount of HCl in volumetric flask = 10 × 0.0012375 mol = $\underline{0.012375}$ mol $[HCl] = 0.012375 \text{ mol} / 0.00100 \text{ dm}^3 = \underline{12.4} \text{ mol dm}^{-3}$ Final answer to 3 sig figs	(1) (1) (1) (1)	[4]
(c) (i)	$H_2SO_4 + NaCl \rightarrow HCl + NaHSO_4$ Ignore state symbols Allow $H_2SO_4 + 2NaCl \rightarrow 2HCl + Na_2SO_4$		[1]
(ii)	$H_2SO_4 + 2HBr \rightarrow Br_2 + SO_2 + 2H_2O$ Ignore state symbols Allow $H_2SO_4 + 2HBr \rightarrow Br_2 + H_2SO_3 + H_2O$		[1]
(iii)	Sulfuric acid is the oxidising agent No credit for S being the oxidising agent The oxidation number of bromine increases (from −1 to 0) OR the oxidation number of sulfur decreases (from +6 to +4)	(1) (1)	[2]
(d) (i)	Bond strength decreases because the bonds gets longer OR because there is greater shielding of the bonding electrons from the halogen nucleus due to the additional inner shells of electrons No credit for answers based on electronegativity or ionic radii		[1]
(ii)	Acidic strength increases because the H−Hal bond gets weaker		[1]
(iii)	Increasing boiling point for $HCl \rightarrow HBr \rightarrow HI$ due to increasing van der Waals / instantaneous dipole – induced dipole forces HF boiling point higher than HCl due to hydrogen bonding	(1) (1)	[2]
			[Total: 13]

Question Number	Answer	Max marks
6 (a)	Molecular formula = $C_4H_4O_2$	[1]
(b)	Correct structure (1)  Name = but-2-ynoic acid (1) No mark for name if it is inconsistent with the structure given	[2]
(c)	%C = (24/42) × 100% = 57.1% %H = (2/42) × 100% = 4.8% %O = (16/42) × 100% = 38.1% 2 marks all correct, 1 mark for two out of three correct Don't penalise two or more significant figures Allow 5% for H	[2]
(d)	m/z = 84	[1]
(e) (i)	Strong absorption between 1640 and 1750 cm^{-1} (1) Very broad absorption between 2500 and 3300 cm^{-1} (1)	[2]
(ii)	Sodium chloride discs would dissolve	[1]
(f)		[1]
		[Total: 10]

Question Number			Answer		Max marks
7	(a)		alkane → ester → alcohol		[1]
	(b)		$C_3H_6O_2$ + 7/2 O_2 → 3 CO_2 + 3 H_2O or equation multiplied through by 2 Accept a structural or displayed formula for the ester but not a skeletal formula		[1]
	(c)	(i)	Use a measuring cylinder to add 300 cm^3 of water to the copper can Measure initial mass of spirit burner (+ester) on mass balance Measure initial temperature of water in copper can using thermometer Light the wick on the spirit burner (Not 'burn the ester') Extinguish the spirit burner when the temperature of the water has risen by 10 degrees Reweigh the spirit burner Subtract the final mass from the initial mass to determine mass of ester burnt	(1) (1) (1) (1) (1) (1) (1)	[Max. 6]
		(ii)	Thermal energy added to water = 4.18 J K^{-1} g^{-1} × 10.0 K × 300 g = <u>12540</u> J Thermal energy added to copper = 0.384 J K^{-1} g^{-1} × 10.0 K × 250 g = <u>960</u> J Total energy = <u>13.5</u> kJ (3 s.f. required) Answer must be in kJ, not Joules, but no penalty for omitting to write kJ	(1) (1) (1)	[3]
		(iii)	Amount of ester = 0.980 g / 74.0 g mol^{-1} = <u>0.0132</u> mol Theoretical energy released = 0.0132 mol × 1592.1 kJ mol^{-1} = <u>21.1</u> kJ Allow ecf with amount of ester 3 s.f. required in final answer, but don't penalise if penalty already sustained in previous part	(1) (1)	[2]

Question Number	Answer		Max marks
(iv)	Find thermal capacity of apparatus using: thermal capacity = theoretical energy released / observed temperature change Thermal capacity = 21.1 kJ / 10 K = <u>2.11</u> kJ K^{-1} Theoretical heat produced from combustion of ethyl ethanoate = 2.11 kJ K^{-1} × 11.5 K = <u>24.3</u> kJ VALID ALTERNATIVE: 13.5 kJ / 21.1 kJ => 64% of energy detected ∴ Divide measured energy change by 0.64 Correct calculation of measured energy change with this method as 15.5 kJ No credit for a simple additative correction for the heat loss (since there was a different temperature change) Amount of ethyl ethanoate = 0.948 g / 88 g mol^{-1} = <u>0.010773</u> mol Standard enthalpy change of combustion of ethyl ethanoate = −24.3 kJ / 0.010773 mol = <u>−2250</u> kJ mol^{-1} This mark is lost if the final answer is not negative 3 s.f. required in final answer, but don't penalise if s.f. penalty already sustained	 (1) (1) (1) (1) (1) (1)	[4]
(d)	Put a lid on the calorimeter Add insulation around the side and/or top of the calorimeter Stir the water in the copper pot Draw hot vapour from the flame through a calorimeter using suction Do repeats and **take an average** Put a cap on the spirit burner when it isn't lit to avoid evaporative losses Other sensible refinement A mark for any of the above up to a maximum of four Marks not awarded for: improving the thermometer comments about height of the can above the burner use of a different burner or different material for the can draft excluders	(1) (1) (1) (1) (1) (1) (1)	[max 4]
(e)	The methyl ethanoate will be easier to light (more volatile) The flame will be less yellow/smoky from the methyl ethanoate (less oxygen required for complete combustion)	(1) (1)	[2]
			[Total: 23]

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