Cambridge Assessment International Education

# Cambridge Pre-U

**CHEMISTRY** **9791/02**

Paper 2 Part A Written **For examination from 2020**

MARK SCHEME

Maximum Mark: 100

**Specimen**

This specimen paper has been updated for assessments from 2020. The specimen questions and mark schemes remain the same. The layout and wording of the front covers have been updated to reflect the new Cambridge International branding and to make instructions clearer for candidates.

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

This document has **8** pages. Blank pages are indicated.

**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

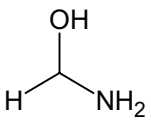
Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

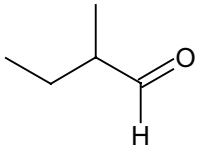
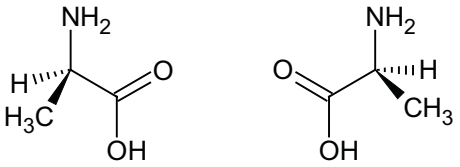
| Question | Answer | Marks |
|---|---|---|
| 1(a) | $n(Mg) = 9.0\,g / 24.3\,g\,mol^{-1} = \underline{0.37}\,mol$<br>Allow two or more significant figures | **1** |
| 1(b) | $n(H_2O)$ reacted = 2 × n(Mg) = $\underline{0.74}$ mol (1)<br>Mass of water reacted = $0.74\,mol \times 18\,g\,mol^{-1} = 13.3\,g$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

| Question | Answer | Marks |
|---|---|---|
| 2(a)(i) | Energy change to <u>break</u> <u>one mole of bonds</u> in the <u>gas</u> phase.<br>1 mark for each underlined point | **3** |
| 2(a)(ii) | $\Delta_r H^{\ominus} = 2 \times (413 + 243 - 346 - 432)\,kJ\,mol^{-1} = -244\,kJ\,mol^{-1}$<br>1 mark for bonds broken; 1 mark for bonds made;<br>1 mark for correct sign if the answer is correct | **3** |
| 2(b)(i) | Energy change = $(4405 + 3966 - (2 \times 4180))\,cm^{-1} = \underline{11}\,cm^{-1}$ | **1** |
| 2(b)(ii) | $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$<br>Superscripts must be used | **1** |
| 2(b)(iii) | At least one K 4s atomic orbital labelled (1)<br>Labelled <u>sigma</u> bond below labelled <u>sigma</u> antibond (1)<br>(A single electron (spinning in either sense) in each atomic orbital and) two spin-paired electrons in the sigma bond (1)<br>Electrons must be shown with a single- or double-headed arrow | **3** |

| Question | Answer | Marks |
|---|---|---|
| 2(b)(iv) | The outer electron in K is closer to the nucleus than the outer electron in Rb (1)<br>There is less shielding of the nucleus for the K outer electron than the Rb outer electron (1)<br>(Despite the extra nuclear charge in rubidium) there is a weaker attraction of the electron to the nucleus (1)<br>Allow the opposite statements with respect to Rb | **3** |
| 2(b)(v) | Labelled Rb 5s orbital shown higher in energy than labelled K 4s orbital (1)<br>Sigma bond is lower in energy than K 4s orbital and the antibond is higher in energy than the Rb 5s orbital (1)<br>The bonding and antibonding orbitals must be labelled for the second mark | **2** |
| 2(b)(vi) | $E = 11\,cm^{-1} \times h\ c\ N_A \times 100\,cm\,m^{-1} / 1000\,J\,kJ^{-1} = 0.13\,kJ\,mol^{-1}$<br>Two marks for correct answer.<br>If final answer incorrect, one mark for correct use of $N_A$.<br>One mark if final answer is out by a factor of $N_A$ i.e. $2.19 \times 10^{-25}$<br>Allow two or more sig figs. | **2** |

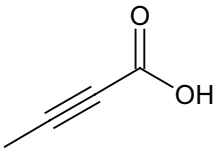
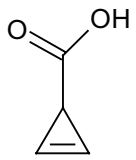
| Question | Answer | Marks |
|---|---|---|
| 3(a)(i) | Point plotted corrected (must be within the correct small square in the grid) | **1** |
| 3(a)(ii) | Bonding is intermediate-covalent-ionic-metallic | **1** |
| 3(b)(i) | $NO_2^- + 3e^- + 4H^+ \rightarrow ½\ N_2 + 2H_2O$ OR $2NO_2^- + 6e^- + 8H^+ \rightarrow N_2 + 4H_2O$<br>1 mark for correct number of electrons on the left hand side<br>1 mark for the rest of the balanced half equation (ignoring charge) | **2** |
| 3(b)(ii) | $3CH_4 + 8NO_2^- + 8H^+ \rightarrow 3CO_2 + 4N_2 + 10H_2O$ | **1** |
| 3(b)(iii) | <u>Enzyme</u> catalysis | **1** |
| 3(c)(i) | Oxidation state = $\{(2 \times 112) - 8\} / 36 =$ <u>(+)6</u> | **1** |
| 3(c)(ii) | $[Mo_9O_{28}(H_2O)_4]^{2-}$ OR $[Mo_9O_{32}H_8]^{2-}$ | **1** |

| Question | Answer | Marks |
|---|---|---|
| 4(a) | Carbon atom circled or otherwise indicated | **1** |
| 4(b) | Nucleophile<br>Allow nucleophilic or Lewis base or lone-pair donor | **1** |
| 4(c) | Any unambiguous structure of the hemiaminal<br>  <br><br>No mark if atom connectivity is incorrect, e.g. $OH{-}CH_2NH_2$ | **1** |
| 4(d) | Addition<br>No credit for “electrophilic addition”<br>Allow nucleophilic addition or reduction | **1** |
| 4(e) | Methanal (allow any carbonyl compound) | **1** |
| 4(f) | Hydrolysis<br>Allow hydration + elimination but not substitution + elimination | **1** |

| Question | Answer | Marks |
|---|---|---|
| 4(g) | Methanal: FGL 2 (1)<br>After Reaction 2: FGL 2 (1)<br>After Reaction 3: FGL 1 (1)<br>Accept equivalent names for the functional group levels | **3** |
| 4(h)(i) | Allow any unambiguous structure for **Z**<br>  <br> | **1** |
| 4(h)(ii) | 2-methylbutanal<br>Ignore incorrect use of spaces / hyphens but do not allow 2 methylbutan-1-al | **1** |
| 4(i) | 1 mark for a correct structure<br>  <br><br>2nd mark for showing two optical isomers clearly with hashed and wedge bonds | **2** |

| Question | Answer | Marks |
|---|---|---|
| 5(a) | Mass of HC$l$ = $\frac{1}{4}$ 55.6 mol × 36.5 g mol$^{-1}$ = <u>507</u> g<br>No sig figs or units penalties | **1** |
| 5(b) | Amount of NaOH = 0.02475 dm$^3$ × 0.0500 mol dm$^{-3}$ = <u>0.0012375</u> mol (1)<br>Amount of HC$l$ in volumetric flask = 10 × 0.0012375 mol = <u>0.012375</u> mol (1)<br>[HC$l$] = 0.012375 mol / 0.00100 dm$^3$ = <u>12.4</u> mol dm$^{-3}$ (1)<br>Final answer to 3 sig figs (1) | **4** |
| 5(c)(i) | $H_2SO_4$ + NaC$l$ → HC$l$ + $NaHSO_4$<br>Ignore state symbols<br>Allow $H_2SO_4$ + 2NaC$l$ → 2HC$l$ + $Na_2SO_4$ | **1** |
| 5(c)(ii) | $H_2SO_4$ + 2HBr → $Br_2$ + $SO_2$ + $2H_2O$<br>Ignore state symbols<br>Allow $H_2SO_4$ + 2HBr → $Br_2$ + $H_2SO_3$ + $H_2O$ | **1** |
| 5(c)(iii) | Sulfuric acid is the oxidising agent (1)<br>No credit for S being the oxidising agent<br>The oxidation number of bromine increases (from −1 to 0) OR the oxidation number of sulfur decreases (from +6 to +4) (1) | **2** |
| 5(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<br>No credit for answers based on electronegativity or ionic radii | **1** |
| 5(d)(ii) | Acidic strength increases because the H−Hal bond gets weaker | **1** |

| Question | Answer | Marks |
|---|---|---|
| 5(d)(iii) | Increasing boiling point for HC$l$ → HBr → HI due to increasing van der Waals / instantaneous dipole – induced dipole forces (1)<br>HF boiling point higher than HC$l$ due to hydrogen bonding (1) | **2** |

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

| Question | Answer | Marks |
|---|---|---|
| 7(a) | alkane → ester → alcohol | **1** |
| 7(b) | $C_3H_6O_2$ + 7/2 $O_2$ → 3 $CO_2$ + 3 $H_2O$ or equation multiplied through by 2<br>Accept a structural or displayed formula for the ester but not a skeletal formula | **1** |
| 7(c)(i) | Max 6 marks from:<br>Use a measuring cylinder to add 300 $cm^3$ of water to the copper can (1)<br>Measure initial mass of spirit burner (+ester) on mass balance (1)<br>Measure initial temperature of water in copper can using thermometer (1)<br>Light the wick on the spirit burner (Not 'burn the ester') (1)<br>Extinguish the spirit burner when the temperature of the water has risen by 10 degrees (1)<br>Reweigh the spirit burner (1)<br>Subtract the final mass from the initial mass to determine mass of ester burnt (1) | **6** |

| Question | Answer | Marks |
|---|---|---|
| 7(c)(ii) | Thermal energy added to water = $4.18\,J\,K^{-1}\,g^{-1} \times 10.0\,K \times 300\,g$ = 12 540 J (1)<br>Thermal energy added to copper = $0.384\,J\,K^{-1}\,g^{-1} \times 10.0\,K \times 250\,g$ = 960 J (1)<br>Total energy = 13.5 kJ (3 s.f. required) (1)<br>Answer must be in kJ, not Joules, but no penalty for omitting to write kJ | **3** |
| 7(c)(iii) | Amount of ester = $0.980\,g / 74.0\,g\,mol^{-1}$ = 0.0132 mol (1)<br>Theoretical energy released = $0.0132\,mol \times 1592.1\,kJ\,mol^{-1}$ = 21.1 kJ (1)<br>Allow ecf with amount of ester<br>3 s.f. required in final answer, but don't penalise if penalty already sustained in previous part | **2** |
| 7(c)(iv) | Find thermal capacity of apparatus using: thermal capacity = theoretical energy released / observed temperature change<br><br>Thermal capacity = $21.1\,kJ / 10\,K$ = 2.11 $kJ\,K^{-1}$ (1)<br>Theoretical heat produced from combustion of ethyl ethanoate = $2.11\,kJ\,K^{-1} \times 11.5\,K$ = 24.3 kJ (1)<br><br>VALID ALTERNATIVE: 13.5 kJ / 21.1 kJ => 64% of energy detected ∴ Divide measured energy change by 0.64 (1)<br>Correct calculation of measured energy change with this method as 15.5 kJ (1)<br><br>No credit for a simple additative correction for the heat loss (since there was a different temperature change)<br><br>Amount of ethyl ethanoate = $0.948\,g / 88\,g\,mol^{-1}$ = 0.010773 mol (1)<br>Standard enthalpy change of combustion of ethyl ethanoate = −24.3 kJ / 0.010773 mol = −2250 $kJ\,mol^{-1}$ (1)<br>This mark is lost if the final answer is not negative<br>3 s.f. required in final answer, but don't penalise if s.f. penalty already sustained | **4** |
| 7(d) | Max 4 marks from:<br>Put a lid on the calorimeter (1)<br>Add insulation around the side and/or top of the calorimeter (1)<br>Stir the water in the copper pot (1)<br>Draw hot vapour from the flame through a calorimeter using suction (1)<br>Do repeats and **take an average** (1)<br>Put a cap on the spirit burner when it isn't lit to avoid evaporative losses (1)<br>Other sensible refinement (1)<br>Marks not awarded for: improving the thermometer<br>comments about height of the can above the burner<br>use of a different burner or different material for the can<br>draft excluders | **4** |
| 7(e) | The methyl ethanoate will be easier to light (more volatile) (1)<br>The flame will be less yellow/smoky from the methyl ethanoate (less oxygen required for complete combustion) (1) | **2** |

**BLANK PAGE**