CAMBRIDGE
International Education

Cambridge International AS & A Level

CHEMISTRY **9701/42**

Paper 4 A Level Structured Questions **May/June 2024**

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2024 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

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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 descriptions 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.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	‘List rule’ guidance For questions that require ***n*** responses (e.g. State **two** reasons …): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked *ignore* in the mark scheme should not count towards ***n***. • Incorrect responses should not be awarded credit but will still count towards ***n***. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

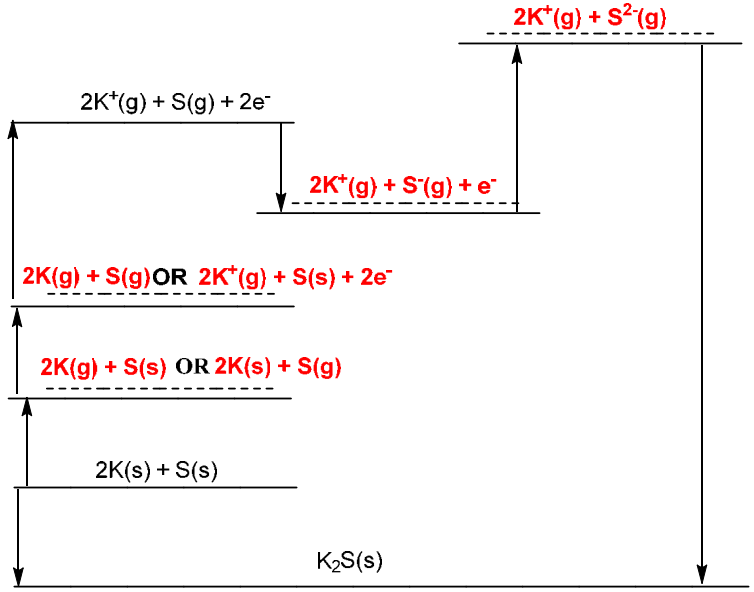
For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

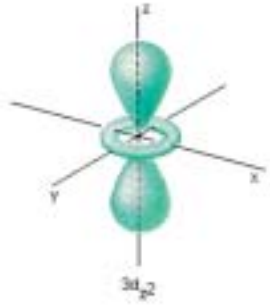
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

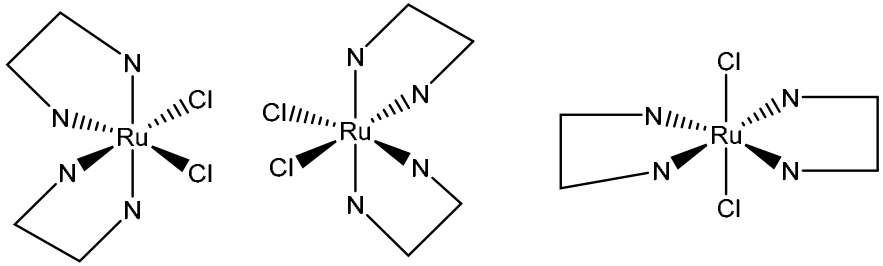
Question	Answer	Marks
1(a)	**M1** magnesium > calcium > strontium **M2** ΔH_{latt} and ΔH_{hyd} both become less exothermic / less negative **M3** ΔH_{latt} changes less **OR** ΔH_{hyd} is dominant factor **M4** ΔH_{sol} becomes less exothermic / less negative / more positive / more endothermic	**4**
1(b)	**M1** ΔH / energy change when 1 mole of an ionic solid / compound is formed **M2** from gaseous ions (under standard conditions)	**2**
1(c)	**M1** as ionic radii increases **AND** ΔH_{latt} less exothermic **M2** as ionic charge increases **AND** ΔH_{latt} increases/more exothermic	**2**
1(d)(i)	 any two [1] any three [2] all four [3]	**3**

Question	Answer	Marks
1(d)(ii)	**M1** selection of **ONLY** six correct values (–381, 89, 419, 279, –200, 640) **AND** use of × 2 as only multiplier with K **M2** correct evaluation of data used ecf $-381 = (89 \times 2) + (419 \times 2) + 279 + (-200) + 640 + \Delta H^{\ominus}_{latt}$ $\Delta H^{\ominus}_{latt} = -2116$ (kJ mol^{-1})	**2**

Question	Answer	Marks
2(a)(i)	$2LiNO_3 \rightarrow Li_2O + 2NO_2 + ½O_2$	**1**
2(a)(ii)	**M1** radius / size of cation / M^+ increases **OR** charge density of ion decreases **M2** less polarisation / distortion of anion / nitrate ion / NO_3^- / less weakening of NO bond	**2**
2(b)	**M1 M2** any two for one mark or all four for two marks: • mol total MnO_4^- = $0.125 \times 0.0500 = 6.25 \times 10^{-3}$ • mol Fe^{2+} = $0.0400 \times 0.0225 = 9.00 \times 10^{-4}$ • mol unreacted MnO_4^- = $9.00 \times 10^{-4} \div 5 = 1.80 \times 10^{-4}$ ecf • mol reacted MnO_4^- = $6.25 \times 10^{-3} - 1.80 \times 10^{-4} = 6.07 \times 10^{-3}$ ecf **M3** mol NO_2^- = $2.5 \times 6.07 \times 10^{-3} = 1.5175 \times 10^{-2}$ conc $NaNO_2$ = $4 \times 1.5175 \times 10^{-2} = 6.07\text{-}6.08 \times 10^{-2}$ mol dm^{-3} ecf min 2sf	**3**
2(c)(i)	$3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ **M1** MnO_4^{2-} as a reactant and MnO_4^- + MnO_2 products identified **M2** correct equation	**2**
2(c)(ii)	(E_{cell}) decreases / becomes less positive **AND** as $[H^+]$ decreases **AND** equilibrium shifts to the left **OR** in alkali the E_{cell} = 0.60 – 0.56 = 0.04 V (working required)	**1**

Question	Answer	Marks
3(a)	**M1** $\Delta S^{\ominus}$ = (213.8 + 2 × 248.2) – (237.8 + 3 × 205.2) $\Delta S^{\ominus}$ = –143.2 (J K^{-1} mol^{-1}) **M2** $\Delta H^{\ominus}$ = (–393.5 + 2 × –296.8) – (116.7) $\Delta H^{\ominus}$ = –1103.8 (kJ mol^{-1}) **M3** $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ $\Delta G^{\ominus}$ = –1103.8 – (298 × –0.1432) = –1061.1 to –1061.4 (kJ mol^{-1}) ecf min 3sf	**3**
3(b)	**M1** $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ **AND** $\Delta G^{\ominus}$ = 0 **OR** $T = \Delta H^{\ominus} / \Delta S^{\ominus}$ [1] **M2** T = 261.6 ÷ 0.3655 = 715.7 / 716 / 715 K min 3sf	**2**

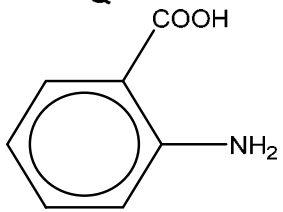
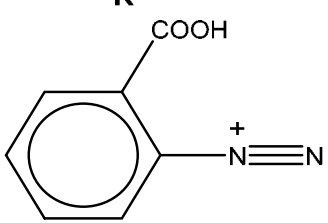
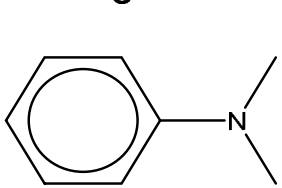
Question	Answer	Marks
4(a)(i)	the (3)d and (4)s (sub-shells/orbitals) are close/similar in energy	**1**
4(a)(ii)		**1**

Question	Answer	Marks
4(b)	• precipitation solution **A**: e.g. NaOH / OH^- • observations: (pale) blue ppt. / solid • product: $Cu(OH)_2$ **OR** $[Cu(OH)_2(H_2O)_4]$ ecf from **A** • ligand substitution solution **B**: e.g. HCl / Cl^-, NH_3 • observations: dark/deep blue solution (with NH_3) **OR yellow** solution (with Cl^-) • product: $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **OR** $[CuCl_4]^{2-}$ any two [1] any four [2] all six [3]	**3**
4(c)	**M1** (Ag^+) d-subshell is full / complete **OR** d^{10} **OR** d-orbitals are full **M2** no d-d(*) transition **OR** no d electrons promoted/excited	**2**
4(d)	**M1** species with two lone pairs (of electrons) **M2** that form dative (covalent) / co-ordinate bond(s) to a (central) metal atom / ion	**2**
4(e)(i)		**3**
4(e)(ii)	optical **AND** cis-trans / geometical	**1**
4(e)(iii)	trans isomer / trans isomer correctly identified **AND** dipoles cancel / partial charges cancel / ion dipoles cancel	**1**

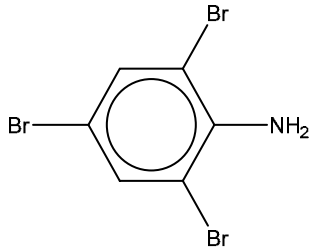
Question	Answer	Marks
5(a)(i)	**M1** (using exp 1 and 2) [NO] × 3, rate × 9 so 2nd order to NO **M2** (using exp 1 and 3) [NO] × 2, [Cl_2] × 4, rate × 16 so 1st order to Cl_2 **OR** (using exp 2 and 3) [NO] × 2 / 3, [Cl_2] × 4, rate × 1.8 so 1st order to Cl_2 **M3** (rate =) k [NO]^2 [Cl_2] ecf	**3**
5(a)(ii)	**M1** rate = k [NO]^2[Cl_2] k = (3.68 × 10^{-2}) ÷ (0.025^2 × 0.015) = 3925.33 ecf (a)(i) min 2sf **M2** dm^6 mol^{-2} min^{-1} ecf (a)(i)	**2**
5(b)	initiation $NO_2Cl \rightarrow Cl\bullet + NO_2\bullet$ step 1 $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ step 2 $ClO\bullet + O_3 \rightarrow Cl\bullet + 2O_2$ Any two [1] all three [2]	**2**
5(c)	**M1** $O_3 + NO_2 \rightarrow NO_3 + O_2$ **ALLOW** $O_3 + NO_2 \rightarrow NO_5$ **M2** $NO_3 + NO_2 \rightarrow N_2O_5$ **ALLOW** $NO_5 + NO_2 \rightarrow N_2O_5 + O_2$	**2**

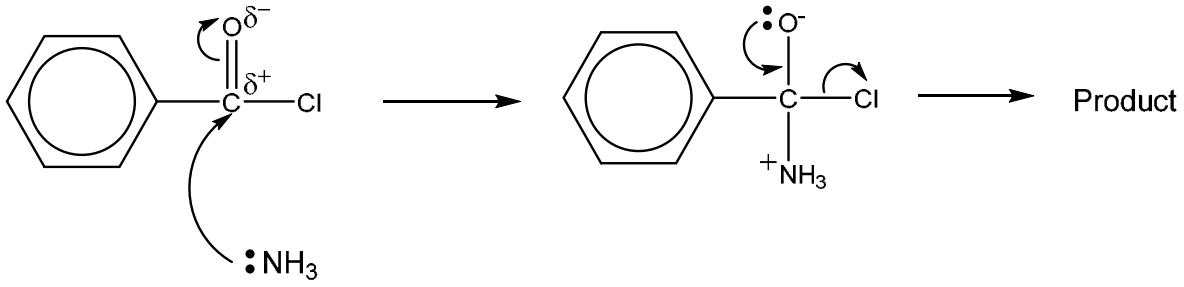
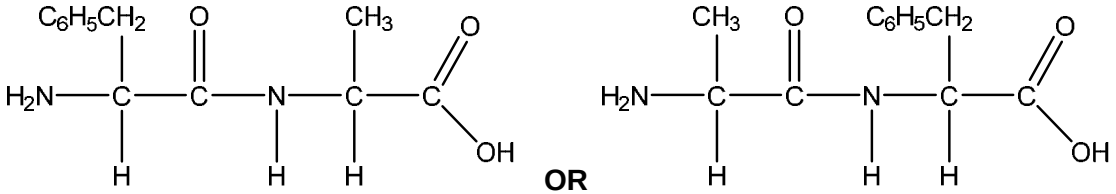
Question	Answer	Marks
6(a)(i)	species / molecules / pair that differ (by the presence or absence) of a H^+ ion / proton	**1**
6(a)(ii)	$HCOOH + H_2O \rightleftharpoons H_3O^+ + HCOO^-$	**1**
6(b)(i)	$K_a = \frac{[H^+]\,[CH_3CH_2CH_2COO^-]}{[CH_3CH_2CH_2COOH]}$	**1**

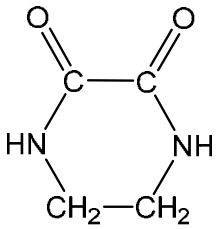
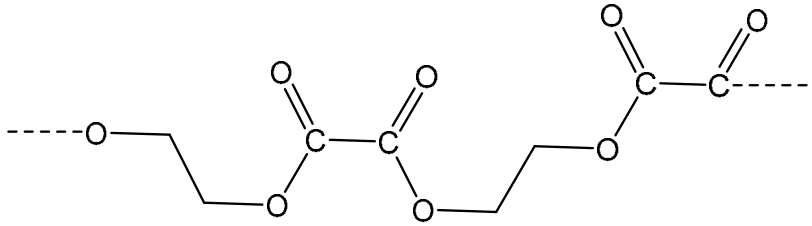
Question	Answer	Marks
6(b)(ii)	**M1** $K_a = 10^{-4.82} = 1.51 \times 10^{-5}$ **OR** $[H^+] = 10^{-3.25} = 5.62 \times 10^{-4}$ **M2** $[HA] = (10^{-3.25})^2 \div 1.51 \times 10^{-5} = 0.021 / 0.0209 / 0.02089$ (mol dm^{-3}) ecf min 2sf	**2**
6(c)(i)	**M1** a solution that resists / opposes / minimises changes in pH **M2** when small amounts of acid / H^+ and base / alkali / OH^- are added to it	**2**
6(c)(ii)	Method 1 **M1** $[H^+] = 10^{-5.70}$ **OR** 2.00×10^{-6} **OR** 1.99526×10^{-6} **M2** moles $CH_3COONa = 0.400 \times 0.125 = 5.00 \times 10^{-2}$ moles $CH_3COOH_{eqm} = (5.00 \times 10^{-2} \times 2.00 \times 10^{-6}) \div 1.78 \times 10^{-5}$ **OR** 5.60×10^{-3} **M3** $[CH_3COOH]_{initial} = 5.60 \times 10^{-3} \times 1000 / 600$ $[CH_3COOH]_{initial} = 0.00933$–$0.00936$ (mol dm^{-3}) ecf min 2sf Method 2 **M1** $pK_a = -\log(1.78 \times 10^{-5})$ **OR** 4.75 **M2** $pH = pK_a + \log[B^-] / [HA]$ $5.7 = 4.75 + \log (0.05 / (0.6x)$ $0.95 = \log (0.05 / (0.6x)$ **M3** $10^{0.95} = (0.05 / (0.6x)$ $5.348x = 0.05$ $x = 0.00935$-0.00937 (mol dm^{-3}) ecf min 2sf	**3**
6(d)(i)	$HCOOH \rightarrow CO_2 + 2H^+ + 2e^-$	**1**
6(d)(ii)	**M1** $Q = 3.75 \times 40 \times 60$ **OR** 9000 C **AND** use of 96500 **OR** $1.6 \times 10^{-19} \times 6.02 \times 10^{23}$ **M2** moles of oxygen = $9000 \div 386000 = 0.0233$ volume of $O_2 = 0.0233 \times 24000 = 559.6 / 559.8 / 560$ cm^3 ecf min 2sf **ALLOW** [use of $Q \div (1.6 \times 10^{-19} \times 6.02 \times 10^{23})$] = 560.6 cm^3	**2**

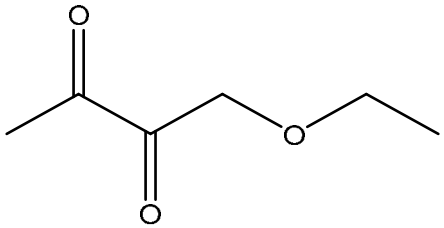
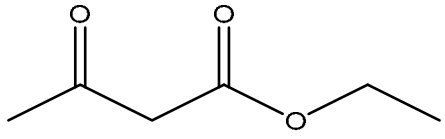
Question	Answer	Marks
7(a)(i)	2-nitrobenzoic acid **OR** 2-nitrobenzenecarboxylic acid	**1**
7(a)(ii)	hot / reflux / heat **AND** (alkaline / acidified / neutral) MnO_4^- / $KMnO_4$	**1**
7(a)(iii)	COOH / carboxyl group is electron-withdrawing / electronegative **AND** 3- and 5- / meta- directing	**1**
7(b)(i)	**Q**  **R**  **S** 	**3**
7(b)(ii)	**M1** step 1: Fe / Sn, conc. HC*l* **M2** step 2: HNO_2 **OR** $NaNO_2$ **AND** HC*l* **M3** step 1: heat / reflux / hot **AND** step 2: ⩽10 °C	**3**

Question	Answer	Marks
8(a)	**M1** benzylamine > ammonia > phenylamine **M1 M2** *Any two for one mark, all three for two marks:* • (basicity linked to) p orbital of N / lone pair on N **AND** being able to bond / accept / donate to / coordinate to a proton / H^+ • (benzylamine) R / alkyl / CH_2 group **AND** is electron donating / positive inductive effect / has + I effect • (phenylamine) p orbital of N / lone pair on N is overlaps / incorporated / delocalised in the ring / π-bond system	**3**

Question	Answer	Marks
8(b)(i)	**M1** white ppt. **M2** structure 	**2**
8(b)(ii)	**M1** lone pair / p-orbital / electrons on the nitrogen / NH_2 **AND** overlap / delocalised / incorporated **AND** with the (π–electrons) ring / π system **M2** increasing its electron density (of the ring) **OR** it can polarise the electrophile / Br_2 better	**2**
8(c)	lone pair / p-orbital on N is delocalised **AND** into C=O group / across the two electronegative O and N	**1**

Question	Answer	Marks
8(d)	 **M1 / M2** *any two for one mark, all four for two marks:* • lone pair on N • correct arrow from lone pair N to C (of C=O) • correct dipole on C=O • correct arrow from the C=O bond to O atom **M3** correct intermediate **M4** arrow from $O^{(-)}$ to C–O bond **AND** arrow from C–C*l* bond to C*l* **ALLOW** arrow from anywhere on O^- to C–O bond	**4**
8(e)(i)	pH at which a molecule has no overall charge / is neutral / exist as a zwitterion	**1**
8(e)(ii)	$C_6H_5CH_2CH(NH_2)COO^-$	**1**
8(f)	 **M1** correct peptide bond displayed (there must be a saturated carbon attached to either side of the peptide group) **M2** rest of the dipeptide correct	**2**

Question	Answer	Marks
9(a)	due to the electron-withdrawing effect/electronegative / –I effect of chlorine **AND** stabilising the anion / carboxylate ion **OR** weakening the O-H bond	**1**
9(b)(i)	$(COOH)_2 + 2SOCl_2 \rightarrow (COCl)_2 + 2HCl + 2SO_2$	**1**
9(b)(ii)	CO_2 [1]  [1]	**2**
9(b)(iii)	 **M1** one correct repeat unit (within their structure) **M2** the rest of the structure correct ecf on one incorrect monomer used [If structure partly or fully skeletal: continuation bonds must be dashed / wavy / different or have through brackets]	**2**
9(c)(i)	CHI_3 / triiodomethane	**1**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>9(c)(ii)</td><td>
<table>
<tr><th>chemical shift (δ)</th><th>splitting pattern</th><th>number of ^{1}H atoms responsible for the peak</th><th>number of protons on adjacent carbon atoms</th></tr>
<tr><td>1.15</td><td>triplet</td><td>3</td><td>2</td></tr>
<tr><td>2.25</td><td>singlet</td><td>3</td><td>0</td></tr>
<tr><td>3.60</td><td>singlet</td><td>2</td><td>0</td></tr>
<tr><td>3.95</td><td>quartet / quad ruplet</td><td>2</td><td>3</td></tr>
</table>
mark as any three [1] any six [2] any nine [3] all twelve [4]
</td><td>4</td></tr>
<tr><td>9(c)(iii)</td><td>  OR  </td><td>1</td></tr>
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