

# Markscheme

**May 2023**

**Chemistry**

**Standard level**

**Paper 3**

23 pages

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## Subject details: Chemistry standard level Paper 3 Markscheme

Candidates are required to answer ALL questions in Section A [15 marks] and all questions from ONE option in Section B [20 marks].

Maximum total = [35 marks].

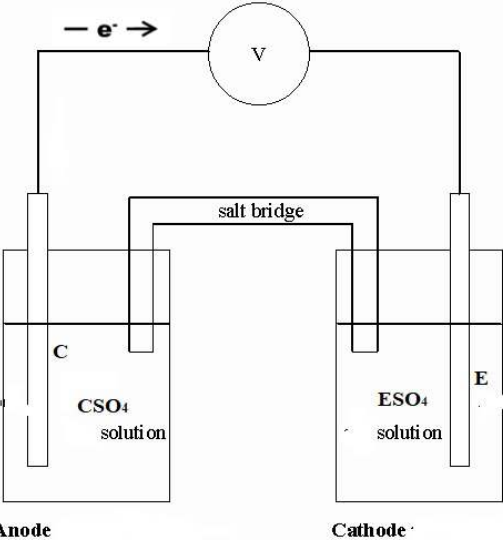
1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “max” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “OR”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading ALTERNATIVE 1 *etc.* Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by *OWTTE* (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then follow through marks should be awarded. When marking, indicate this by adding ECF (error carried forward) on the script.
14. Do not penalize candidates for errors in units or significant figures, unless it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Section A

Question		Answers	Notes	Total
1.	(a)	ionization energy breaks bond/attractive force between nucleus and electron <b>AND</b> electron affinity forms bond/attractive force between nucleus and electron ✓	<i>Accept for ionization energy “energy needed/endergonic to remove an electron”. <b>AND</b> for electron affinity “energy released/exothermic adding an electron”.</i>	1
1.	(b)	electron «removed» from 2p in B <b>AND</b> 2s in Be ✓  shielding effect of 2s «reduces energy needed to remove 2p» <b>OR</b> 2p at higher energy level/further from nucleus <b>OR</b> full 2s more stable «than single electron in p» ✓	<i>Accept electron configurations of <b>both</b> B and Be for M1.</i>	2
1.	(c)	<p style="text-align: center;"> <span style="margin-right: 20px;"><math>\uparrow\downarrow</math></span> <span style="margin-right: 20px;"><math>\uparrow\downarrow</math></span> <span style="margin-right: 20px;"><math>\uparrow</math></span> <span><math>\uparrow</math></span> </p> <p style="text-align: center;"> <span style="margin-right: 20px;">2s</span> <span style="margin-right: 20px;">2p</span> <span style="margin-right: 20px;">✓</span> </p>	<i>Accept second arrow, representing opposite spin, in any 2p box.  Accept half-arrows.</i>	1

Question		Answers	Notes	Total
1.	(d)	greater repulsion when electrons occupy same orbital ✓	<i>Accept electron added to stable half-filled p sublevel.</i>	1
1.	(e)	<p><i>Largest first ionization energy:</i> highest nuclear charge «for a similar radius/same energy level» <b>OR</b> smallest radius <b>OR</b> stable octet ✓</p> <p><i>Largest positive first electron affinity:</i> adding to new principal energy level <b>OR</b> «much» further from nucleus <b>OR</b> shielded by completed inner shell ✓</p>	<i>Do <b>not</b> accept “complete octet” without reference to stability for M1.</i>	2

Question			Answers	Notes	Total
1.	(f)		<p><b>ALTERNATIVE 1:</b> «Xe» lower/smaller/less positive <b>AND</b> larger radius <b>OR</b> «Xe» lower/smaller/less positive <b>AND</b> smaller energy gap to next «principal» energy level ✓</p> <p><b>ALTERNATIVE 2:</b> «Xe» greater <b>AND</b> very high nuclear charge <b>OR</b> «Xe » greater <b>AND</b> poor shielding by inner «d» orbitals ✓</p>	<p>Accept converse arguments for either alternative only if it is clear that Ne being referred to.</p>	1
2	(a)	(i)	+2/II ✓	Do <b>not</b> accept $A^{2+}$ , $A^{+2}$ , 2 <b>OR</b> 2+.	1
2.	(a)	(ii)	C A B D E ✓	Do <b>not</b> accept reverse order unless the answer makes it clear which is the most reactive.	1

Question	Answers	Notes	Total
<p>2. (b)</p>	 <p>Anode</p> <p>Cathode</p> <p>two half cells with electrodes, solutions, salt bridge and connecting wire ✓</p> <p>C as anode <b>AND</b> E as cathode ✓</p> <p>CSO<sub>4</sub> <b>AND</b> ESO<sub>4</sub> «solutions» labelled ✓</p> <p>electron flow shown «on wire» from more reactive to less reactive metal ✓</p>	<p>Voltmeter not needed.</p> <p>Accept salt bridge even if not labelled.</p> <p>Do <b>not</b> award M1 if a battery is included.</p> <p>Do <b>not</b> award M1 if liquid level not shown in container, or if electrodes and ends of salt bridge are not in solutions.</p> <p>Accept salt of C/C<sup>2+</sup> «(aq)» <b>AND</b> salt of E/E<sup>2+</sup> «(aq)» for M3.</p>	<p>4</p>
<p>2. (c)</p>	<p>Anode: bromine / Br<sub>2</sub></p> <p><b>AND</b></p> <p>Cathode: zinc / Zn ✓</p>	<p>Do <b>not</b> accept bromide.</p> <p>Do <b>not</b> accept Br for Br<sub>2</sub></p>	<p>1</p>

Section B

Option A — Materials

Question			Answers	Notes	Total
3.	(a)	(i)	$2\text{CO(g)} \rightarrow \text{C(s)} + \text{CO}_2\text{(g)}$ ✓	<i>Accept reversible arrows.</i>	1
3.	(a)	(ii)	$\llcorner 100 \times 12.01 / 2 \times (12.01 + 16.00) = \gg 21.44\%$ ✓		1
3.	(a)	(iii)	«gaseous» reactants adsorb onto «metal» surface <b>OR</b> catalyst provides surface for reaction to occur ✓  weakens «reactant» bonds <b>OR</b> products desorb ✓	<i>Accept lowers activation energy for M2.</i>	2
3.	(a)	(iv)	bottom up <b>AND</b> molecular assembly «rather than decomposition» ✓		1

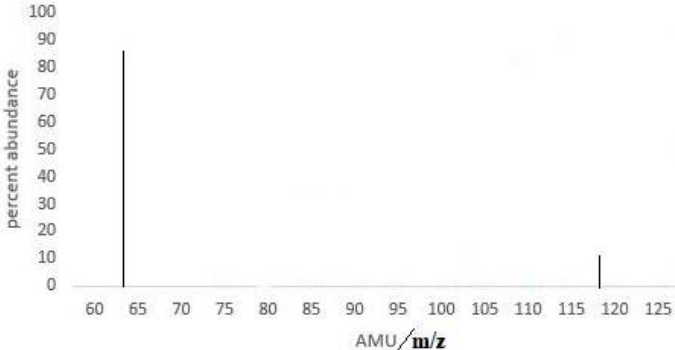


Question			Answers	Notes	Total
3.	(a)	(v)	<p><i>Any one of:</i></p> <p>more easily airborne/inhaled ✓</p> <p>have similar dimensions as biological molecules/interfere with biochemical reactions ✓</p> <p>easily absorbed into body ✓</p> <p>may cross cell membranes ✓</p> <p>large surface area could increase toxicity ✓</p> <p>human defence system not effective with small size ✓</p>	<p><i>Do not accept just large surface area OR toxic/increased toxicity.</i></p>	<p><b>1 max</b></p>

Question			Answers	Notes	Total
3.	(b)	(i)	fluids with «some» properties that are anisotropic/depend on molecular orientation «relative to a fixed axis» ✓	<i>Do not accept general references to a mesophase.</i>	1
3.	(b)	(ii)	polar «molecules» ✓ change orientation upon application of electric field <b>OR</b> «in some orientations» molecules rotate plane of polarization «of polarized light» ✓		2
3.	(b)	(iii)	7 ✓		1
3.	(b)	(iv)	3300 to 3500 ✓	<i>Accept amine/amide/N-H bond.</i>	1

Question			Answers	Notes	Total
3.	(b)	(v)	<p><i>Advantage:</i>                      Any one of:                      long life span/easily reused ✓                      less energy required for manufacturing «due to long life span» ✓                      light weight for construction of vehicles ✓                      less energy required by vehicles «due to high strength to density ratio» ✓                      can be easily moulded into shape ✓                      less material/waste «as high strength to density ratio/easily moulded» ✓</p> <p><i>Disadvantage:</i>                      Any one of:                      non-renewable ✓                      much plastic ends up in ocean ✓                      hazard to wildlife ✓                      takes long time to decompose ✓                      can contain dioxin/health hazard ✓                      toxic fumes when burned ✓</p>	<p><i>Accept do not produce methane in landfills as an advantage.</i>  <i>Do not accept cost arguments for either.</i>  <i>Accept other environmental considerations.</i>  <i>Do not accept converse of the advantage as the disadvantage:</i>  <i>e.g. long life span</i>  <i>and</i>  <i>takes too long to decompose</i></p>	2 max

4.	(a)		metal ions/atoms have different sizes ✓ cations/atoms/layers do not slide over each other as easily ✓ «irregularities» obstruct free movement of electrons ✓	<i>Accept electrons move less easily/less delocalized for M3.</i>	3
4.	(b)		straight line increasing and going through origin/(0,0) ✓		1

Question			Answers	Notes	Total
4.	(c)	(i)	<p>Mass spectrum for elements in shield EHR</p>  <p>89% at 63.5 <b>AND</b> 10% at 118 ✓</p>	<p>Accept range 62.5-64.5 for Cu and 117-119 for Sn. Accept 85-95 % for Cu and 5-15 % for Sn.</p>	1
4.	(c)	(ii)	<p>vapourize «the sample» ✓ ionize «the sample» ✓</p>	<p>Accept relevant equations.</p>	2

Option B — Biochemistry

Question			Answers	Notes	Total
5.	(a)		cannot be synthesized «by the human body» ✓		1
5.	(b)	(i)	hydroxyl <b>OR</b> alkene ✓	Accept –OH/alcohol.  Accept C=C/ <u>carbon-carbon</u> double bond.	1
5.	(b)	(ii)	ester/-CO-O-R ✓	Do <b>not</b> accept carbonyl.	1
5.	(c)	(i)	temperature <b>AND</b> pH ✓		1
5.	(c)	(ii)	«aqueous environment» for chemical reactions <b>OR</b> reactants/products water-soluble ✓	Accept to transport ions/molecules «in/out of cell».	1

Question			Answers	Notes	Total
6.	(a)	(i)	$C_x(H_2O)_y$ ✓		1
6.	(a)	(ii)	« $n=10.5g/180.18g\ mol^{-1}=\Rightarrow 0.0583$ «mol» ✓ « $0.0583\ mol \times 2810\ kJ\ mol^{-1}=\Rightarrow 164$ «kJ» ✓	Award [2] for correct final answer. Award [1 max] for -164 «kJ».	2
6.	(b)	(i)	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ✓  $C_{57}H_{110}O_6 + 81.5O_2 \rightarrow 57CO_2 + 55H_2O$ <b>OR</b> $2C_{57}H_{110}O_6 + 163O_2 \rightarrow 114CO_2 + 110H_2O$ ✓		2
6.	(b)	(ii)	more <b>AND</b> contains less oxygen/contains more carbon/more reduced ✓		1
6.	(c)		<i>Chemical composition:</i> glycerol <b>AND</b> «two» fatty acids <b>AND</b> «one» phosphate ✓  <i>Function:</i> cell/plasma membrane ✓	Accept suitable diagram for M1. Do <b>not</b> accept "hydrophilic head and hydrophobic tail" for M1.  Accept insulation or lipid transport for M2. Do <b>not</b> accept cell wall for cell membrane.	2

Question			Answers	Notes	Total
7.	(a)	(i)	Identity of spot C: leucine ✓		1
7.	(a)	(ii)	serine <b>AND</b> more polar «than phenylalanine» <b>OR</b> serine <b>AND</b> OH group «on side chain» ✓  hydrogen bonding/greater affinity with stationary phase <b>OR</b> less soluble/poor affinity in solvent/mobile phase ✓	<i>M2 may be scored without M1.</i>	2
7.	(b)		bind to substrate at active site ✓ «provide» alternative pathway with lower «activation» energy ✓	<i>Must have idea of binding to substrate <b>AND</b> a specific active site for M1.</i>	2
7.	(c)		additives to detergents/washing powders/liquids <b>OR</b> breakdown oil spills/industrial waste ✓	<i>Accept other industrial use.  Do <b>not</b> accept non-industrial uses, such as pregnancy testing.</i>	1
8.			chemicals found in an organism that are not normally present ✓		1

Option C — Energy

Question			Answers	Notes	Total
9.	(a)	(i)	33% of energy input/released «in fission» is converted to electricity ✓	Do <b>not</b> accept generalizations, such as “Only produces 33% useful energy.”	1
9.	(a)	(ii)	X ${}^3_2\text{He}$ AND Y ${}^3_1\text{H}$ ✓		1
9.	(a)	(iii)	2 <sup>nd</sup> /Y/ ${}^3_1\text{H}$ AND formation ${}^3_1\text{H}$ has greater increase in binding energy «per nucleon than formation ${}^3_2\text{He}$ ✓	Accept 2 <sup>nd</sup> /Y/ ${}^3_1\text{H}$ AND “It is higher on the binding energy curve”.	1



Question			Answers	Notes	Total
9.	(a)	(iv)	deuterium contains more atoms per unit mass «than uranium as it has a lower molar mass» ✓  fusion releases more energy per atom than fission ✓  «solid» uranium «much» more dense «than deuterium» <b>OR</b> uranium contains more atoms per unit volume «than deuterium, as it is a solid» ✓  increase in density has a greater effect than fusion releasing more energy than fission ✓		4
9.	(b)	(i)	$C_7H_{16} \rightarrow C_6H_5CH_3 + 4H_2$ ✓	Accept $C_7H_8$ for $C_6H_5CH_3$ .	1
9.	(b)	(ii)	any alkane <b>AND</b> alkene where total sum of C=7 and H=16; e.g. $C_5H_{12}$ <b>AND</b> $C_2H_4$ ✓		1

Question		Answers	Notes	Total
10.	(a)	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓		1
10.	(b)	<p>ester product ✓</p> <p>glycerol <b>AND</b> correct balancing ✓</p>		2
10.	(c)	conjugated bonds/alternating C=C bonds/delocalized electrons/bonding ✓	<p>Accept 'alternating single and double bonds'.</p> <p>Do <b>not</b> accept 'many double bonds'.</p>	1
11.	(a)	<p>«1000/1367=» 0.7315 «mol ethanol» ✓</p> <p>«<math>C_2H_6O + 3O_2 \rightarrow 2CO_2 + 3H_2O</math> / each ethanol forms two carbon dioxides»</p> <p>«<math>0.7315 \times 2 \times 44.01 \text{ g mol}^{-1} =</math> »64 «g» ✓</p>	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
11.	(b)	(i)	glacier/ice sheets/ retreat/melting <b>OR</b> rising sea levels ✓	Accept other reasonable answers, e.g. ocean acidification, severe weather patterns. Do <b>not</b> accept just 'climate change'.	1
11.	(b)	(ii)	«increase in bond» stretching/vibrating/bending <b>OR</b> bond angles/lengths change ✓	Accept dipole moment changes. Accept light energy is converted into mechanical/potential/internal energy of the molecule.	1
11.	(b)	(iii)	« $M_r \text{ CH}_4: M_r \text{ CO}_2$ / 16.05 ÷ 44.01 =» 0.365 ✓  « $21 \times 0.365 =$ » 7.66 «times» ✓	Award <b>[2]</b> for correct final answer.  Accept 7.64 «times» (integer $M_r$ s).  Award <b>[1 max]</b> for 57.6 «times» if inverted ratio is used.	2
11.	(c)		biofuels <b>AND</b> CO <sub>2</sub> emission involved in mining/refining nuclear fuel <b>OR</b> nuclear <b>AND</b> no CO <sub>2</sub> emitted directly/from fuel. ✓	Accept biofuels <b>AND</b> plants/crops remove CO <sub>2</sub> from atmosphere.  Accept other valid reasoning.	1

Option D — Medicinal chemistry

Question		Answers	Notes	Total
12.	(a)	<p>Any <b>two</b> of:                      oral ✓                      inhalation ✓                      topical/applied to the skin ✓                      parenteral/injection ✓                      suppositories ✓                      eye/ear drops ✓</p>	<p>One mark for any <b>two</b> correct methods.</p> <p>Count multiple methods of injection (intramuscular, subcutaneous, intravenous) as just one method.</p>	1
12.	(b)	<p><b>Similarity:</b>                      both are the ratio between a dose that would cause harm and that required to have an effect  <b>OR</b>                      calculation to divide TD or LD by the effective dose/ED ✓</p> <p><b>Difference:</b>                      toxic dose/TD «for 50%/(TD50)» used for human population <b>AND</b> lethal dose/LD «for 50%/(LD50)» used for animal population ✓</p>	<p>Accept both involve ED/Effective Dose.</p> <p>Accept both compare dose that would cause harm and that required to have an effect for M1.</p>	2
12.	(c)	<p>interferes with pain at source «of injury» ✓                      prevents release of prostaglandins/substances causing swelling/pain ✓</p>		2

Question		Answers	Notes	Total
12.	(d)	<p><b>ALTERNATIVE 1:</b> A: <math>\text{CH}_3\text{COOCOCH}_3</math> ✓ B: <math>\text{CH}_3\text{COOH}</math> ✓</p> <p><b>ALTERNATIVE 2:</b> A: <math>\text{CH}_3\text{COOH}</math> ✓ B: <math>\text{H}_2\text{O}</math> ✓</p> <p><b>ALTERNATIVE 3:</b> A: <math>\text{CH}_3\text{COCl}</math> ✓ B: <math>\text{HCl}</math> ✓</p>	Accept expanded structural formulas.	2
12.	(e)	«opium» poppy ✓		1
12.	(f)	<p><i>Advantage:</i> strong/severe/surgical pain relief <b>OR</b> stops coughing reflex <b>OR</b> fast action ✓</p> <p><i>Disadvantage:</i> addiction <b>OR</b> constipation <b>OR</b> tolerance «leading to overdose» ✓</p>	<p>Accept strong painkillers/analgesics for M1.</p> <p>Accept constipation for M1 if not given as a disadvantage.</p> <p>Accept small therapeutic window for M2. Accept other named specific side effect for M2.</p>	2

Question		Answers	Notes	Total
13.	(a)	$\text{MgCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ <p><b>AND</b></p> $\text{Al}(\text{OH})_3(\text{s}) + 3\text{HCl}(\text{aq}) \rightarrow \text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) \checkmark$	<p><i>Accept appropriate ionic equations.</i></p> <p><i>Do <b>not</b> accept <math>\text{H}_2\text{CO}_3</math> as a product of first reaction.</i></p> <p><i>Ignore equilibrium arrows.</i></p>	1
13.	(b)	<p>«<math>n(\text{MgCO}_3) = 2.00\text{g}/84.32\text{g mol}^{-1} \Rightarrow 0.0237</math>« mol»</p> <p><b>AND</b></p> <p>«<math>n(\text{Al}(\text{OH})_3) = 2.00\text{g}/78.01\text{g mol}^{-1} \Rightarrow 0.0256</math> «mol» ✓</p> <p>«<math>0.0237n(\text{MgCO}_3) \times 2 \Rightarrow 0.0474</math> «n(HCl) neutralised»</p> <p><b>AND</b></p> <p>«<math>0.0256 n(\text{Al}(\text{OH})_3) \times 3 \Rightarrow 0.0768</math> «n(HCl) neutralised» ✓</p>	<p><i>Award [1 max] for any two correct calculations.</i></p>	2
14.	(a)	<p>viruses have no nucleus but bacteria do</p> <p><b>OR</b></p> <p>viruses have no organelles but bacteria do</p> <p><b>OR</b></p> <p>viruses cannot perform biological functions/reproduce without a host but bacteria can</p> <p><b>OR</b></p> <p>viruses are not cells but bacteria are</p> <p><b>OR</b></p> <p>viruses are smaller than bacteria ✓</p>	<p><i>Accept specific structural differences. Such as "bacteria have cytoplasm/ribosomes but viruses do not" or "viruses can have double stranded RNA/single stranded DNA whereas bacteria always have double stranded DNA".</i></p> <p><i>Do <b>not</b> accept "Bacteria are living and viruses are not".</i></p>	1

Question		Answers	Notes	Total
14.	(b)	<p><i>Any two of:</i></p> <p>«bind to receptors to» prevent virus entering cell ✓</p> <p>alter genetic material of cell/cytoplasm «to prevent replication» ✓</p> <p>block enzyme activity in cell «to prevent replication» ✓</p> <p>prevent virus leaving cell «by inhibiting viral enzyme/neuraminidase» ✓</p>		2 max
14.	(c)	<p>side chain modified ✓</p> <p>overcome antibiotic resistance/ penicillinase ineffective ✓</p>	<p><i>Accept R group instead of side chain.</i></p> <p><i>Accept increase the stability of penicillin in GIT/gastrointestinal tract for M2.</i></p>	2
15.		<p><i>Any two of:</i></p> <p>energy efficiency ✓</p> <p>prevention of waste/recycling ✓</p> <p>atom economy/more efficient processes ✓</p> <p>safer/reduced use of solvents ✓</p> <p>design for degradation ✓</p> <p>more sustainable sourcing of reactants/feedstock ✓</p>	<p><i>Accept specific examples.</i></p>	2 max