AQA Qualifications

A-LEVEL
CHEMISTRY

CHEM5 Energetics, Redox and Inorganic Chemistry
Mark scheme

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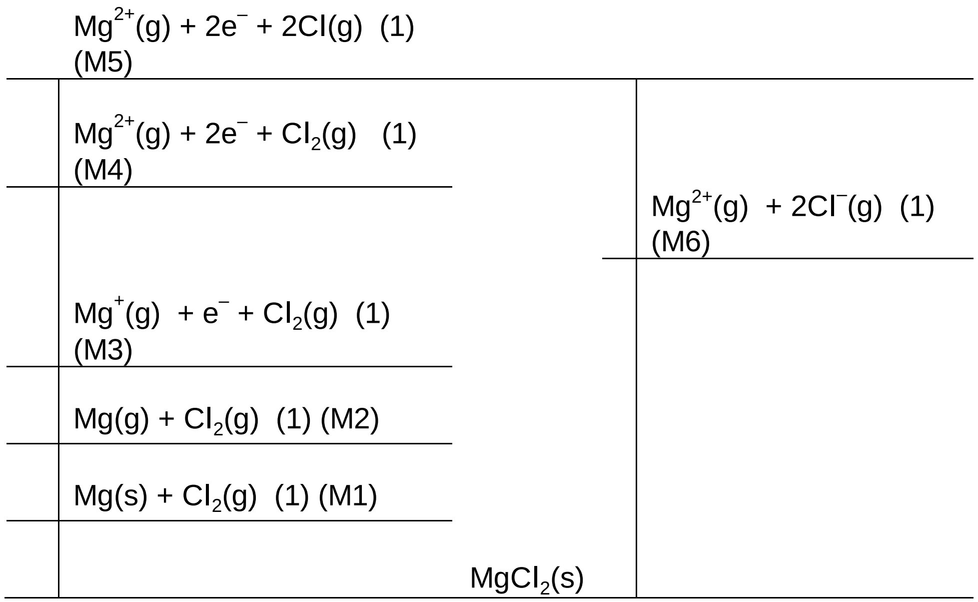
Version 1: Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from aqa.org.uk

Question	Marking Guidance	Marks	Comments
1(a)	The enthalpy change / heat energy change/ ΔH for the formation of one mole of (chloride) ions from (chlorine) atoms	1	Allow enthalpy change for $Cl + e^- \rightarrow Cl^-$ Do not allow energy change ionisation energy description is CE=0 Allow enthalpy change for the addition of 1 mol of electrons to Chlorine atoms penalise Cl_2 and chlorine molecules CE=0 allow chlorine ions
	Atoms and ions in the gaseous state	1	Or state symbols in equation Cannot score M2 unless M1 scored except allow M2 if energy change rather than enthalpy change ignore standard conditions

1 (b)	 $Mg^{2+}(g) + 2e^{-} + 2Cl(g)$ (1) (M5) $Mg^{2+}(g) + 2e^{-} + Cl_2(g)$ (1) (M4) $Mg^{2+}(g) + 2Cl^{-}(g)$ (1) (M6) $Mg^{+}(g) + e^{-} + Cl_2(g)$ (1) (M3) $Mg(g) + Cl_2(g)$ (1) (M2) $Mg(s) + Cl_2(g)$ (1) (M1) $MgCl_2(s)$	6	Allow e for electrons (i.e no charge) State symbols essential If no electrons allow M5 but not M3,M4 If incorrect 1/2 Cl_2 used allow M3 and M4 for correct electrons (scores 2/6)

1(c)	$-\Delta H_f(MgCl_2) + \Delta H_a(Mg) + 1^{st}\ IE(Mg) + 2^{nd}\ IE(Mg) + 2\Delta H_a(Cl)$ $= -2EA(Cl) - LE(MgCl_2)$ $-2EA(Cl) = 642 + 150 + 736 + 1450 + 242 - 2493 = 727$ $EA(Cl) = -364$ (kJ mol^{-1})	1 1 1	Allow Enthalpy of Formation = sum of other enthalpy changes (incl lattice formation) Allow –363 to –364 Allow M1 and M2 for -727 Allow 1 (1 out of 3) for +364 or +363 but award 2 if due to arithmetic error after correct M2 Also allow 1 for –303 Units not essential but penalise incorrect units Look for a transcription error and mark as AE-1
1(d)(i)	Magnesium (ion) is smaller **and** more charged (than the sodium ion) OR magnesium (ion) has higher charge to size ratio / charge density (magnesium ion) attracts water more strongly	1 1	Do not allow wrong charge on ion if given Do not allow similar size for M1 Do not allow mass/charge ratio Mark independently Mention of intermolecular forces, (magnesium) atoms or atomic radius CE=0
1(d)(ii)	Enthalpy change = $-LE(MgCl_2) + \Sigma(\Delta H_{hyd}ions)$ $= 2493 + (-1920 + 2 \times -364)$ $= -155$ (kJ mol^{-1})	1 1	Units not essential but penalise incorrect units

Question	Marking Guidance	Mark	Comments
2(a)	The enthalpy (change) to break 1 mol of H—O / bonds Averaged over a range of compounds / molecules	1 1	Allow heat energy Penalise energy but mark on ignore states CE=0 for ionic bonds
2(b)	$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ ΔH = (H–H) + $\frac{1}{2}$(O=O) – 2(H–O) / sum of(bonds broken) - sum of (bonds formed) = 436 + 496/2 – 2 × 464 = –244 (kJ mol^{-1})	 1 1 1	 Allow 1 mark only for +244 and –488 Units not essential but penalise incorrect units
2(c)(i)	same reaction / same equation / same number / same reactants and same products / same number and type of bonds broken and formed	1	Do not allow similar

2(c)(ii)	There must be a slight difference between the actual bond enthalpy (in water) and mean bond enthalpies for the O–H bond (in other molecules)	1	Allow bond enthalpy value for enthalpy of formation may not be under standard conditions. Allow reference to bond energy rather than bond enthalpy Do not allow heat loss or experimental error Do not allow mean bond enthalpies are not accurate

Question	Marking Guidance	Mark	Comments
3(a)(i)	$\Delta H = \Sigma$(enthalpies formation products) – Σ(enthalpies formation reactants)	1	Or correct cycle with enthalpy changes labelled
	= –111 –(–75 – 242)	1	
	= (+)206 (kJ mol^{-1})	1	–206 scores 1 only Units not essential if ans in kJ mol^{-1} but penalise incorrect units
3(a)(ii)	$\Delta S = \Sigma$(entropies of products) – Σ(entropies reactants)		
	= 198 + 3 × 131 – (186 + 189)	1	
	= (+) 216 (J K^{-1} mol^{-1}) OR 0.216 <u>kJ K^{-1} mol^{-1}</u>	1	Units not essential but penalise incorrect units

3(b)	When $\Delta G = 0$ OR $\Delta H = T\Delta S$	1	
	$T = \Delta H/\Delta S$	1	M2 also scores M1
	$= 206 \times 1000/216$	1	Allow error carried forward from (a)(i) and (a)(ii) Ignore unexplained change of sign from – to +
	= 954 K	1	Allow 953 – 955, Units of K essential, must be +ve If values from (a)(i) and (a)(ii) lead to negative value in M3 allow M1 to M3 but do not allow negative temperature for M4 If negative value changed to positive for M4, allow M4
3(c)	To speed up the rate of reaction OR wtte	1	Allow so that more molecules have energy greater than the activation energy IF T in 3(b) > 1300 allow answers such as; to reduce energy cost to slow down reaction do NOT allow to increase rate

3(d)(i)	**Method 1** $\Delta G = \Delta H - T\Delta S$		
	$\Delta G = -41 - (1300 \times -42/1000)$ (M1)	1	If 42 and not 42/1000 used can score M3 only but allow $\Delta G = -41 \times 1000 - (1300 \times -42)$ (M1)
	= +13.6 <u>kJ mol^{-1}</u>	1	=13600 <u>J mol^{-1}</u> (M2) Units essential
	ΔG must be negative for the reaction to be feasible. OR ΔG is positive so reaction is not feasible	1	
	Method 2		
	For reaction to be feasible ΔG must be negative or zero	1	
	T when $\Delta G = 0 = \Delta H / \Delta S = 976K$	1	
	ΔS is -ve so ΔG must be +ve at temperatures above 976K / at 1300 K	1	

3(d)(ii)	If the temperature is lowered (Ignore reference to catalyst and/or pressure)	1	Alternative mark scheme (if T is calculated) Allow T reduced to 976 K or lower M1
	ΔG will become (more) <u>negative</u> because <u>the $-T\Delta S$ term will be less positive</u>/ <u>$T\Delta S > \Delta H$</u>	1	At this temperature (the reaction becomes feasible because) ΔG <= 0 M2

Question	Marking Guidance	Mark	Comments
4(a)	$Mg + H_2O \rightarrow MgO + H_2$	1	ignore state symbols
	White solid/powder/ash/smoke	1	ignore precipitate ignore fumes
	(Bright) <u>white</u> light/flame	1	allow glow penalise effervescence under list principle
4(b)	$2Na + \frac{1}{2}O_2 \rightarrow Na_2O$ / $4Na + O_2 \rightarrow 2Na_2O$	1	Allow multiples, ignore state symbols Allow $2Na + O_2 \rightarrow Na_2O_2$
	white / yellow solid/ash/smoke	1	ignore precipitate ignore fumes
	orange / yellow flame	1	

Question	Marking Guidance	Mark	Comments
5(a)(i)	1500	1	
5(a)(ii)	Ionic lattice / giant ionic	1	Mention of vdW / covalent bonding / molecules / atoms / metal etc CE=0
	Strong <u>attraction</u> between <u>oppositely charged ions</u> / Na^+ and O^{2-} OR lots of energy required to separate/ overcome attraction between oppositely charged ions / Na^+ and O^{2-}	1	Do not allow incorrect formulae for ions.
5(a)(iii)	200 (K)	1	Allow range 10–273 (K) CE = 0 if temperature >573 K, otherwise mark on Allow correct answers in ^{o}C but units must be given.
	SO_2 smaller (molecule) (than P_4O_{10}) (or converse)	1	also SO_2 has lower M_r / less surface area/less polarisable / fewer electrons penalise SO_3 and P_2O_5 for M2 only
	vdW forces <u>between molecules</u> are weaker / require less energy to separate molecules	1	ignore dipole-dipole If covalent bonds broken lose M2 and M3 but can gain M1

5(b)	$SO_2 + H_2O \rightarrow H_2SO_3$ / $H^+ + HSO_3^-$ / $2H^+ + SO_3^{2-}$	1	can be equilibrium sign instead of arrow
	1	1	Allow values between 1–3 mark independently

5(c)	Reacts with / neutralises bases / alkalis	1	Allow any given base or alkali including OH^-
	$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$	1	Allow $CaO + SiO_2 \rightarrow CaSiO_3$ or equation with any suitable base M2 can score M1 even if equation unbalanced or incorrect

Question	Marking Guidance	Mark	Comments
6(a)	Electron acceptor / gains electrons	1	do not allow electron pair acceptor
6(b)	Fe^{2+} ions	1	
	Fe^{2+}/Fe or Fe^{2+} or it has smallest / most negative electrode potential / $\underline{E^o}$	1	Do not allow Fe/Fe^{2+} Cannot score M2 if M1 incorrect
6(c)	$Pt\|H_2\|H^+\|\|Ag^+\|Ag$ allow dashed phase boundaries $2H^+$ loses one mark (M2)	1 1	M1 for H_2 H^+ Ag^+ Ag in correct order M2 for Pt correct and correct phase boundaries Ignore state symbols. M1 must be correct to score M2 If answer correct but all in reverse order allow 1 mark out of two
	Any **two** correct conditions • 298 K /25 °C • 100 kPa • both solutions of unit concentration • zero current	2	Allow 1 bar Do not apply list principle, mark correct answers.

6(d)	E Au^+(/Au) > E O_2 (/ H_2O) OR e.m.f. / *E*cell = 0.45 V	1	If both species in electrode given, must be in correct order i.e. Au^+/Au
	Au^+ (ions) oxidise water OR water reduces Au^+ (ions)	1	Allow water donates electrons to Au+
	Gold metal/solid/precipitate **OR** bubbles / effervescence of (oxygen gas) / gas produced	1	Penalise incorrect observations
	$2Au^+ + H_2O \rightarrow 2Au + 2H^+ + \frac{1}{2}O_2$ OR $4Au^+ + 2H_2O \rightarrow 4Au + 4H^+ + O_2$	1	Allow multiples

6(e)(i)	1.24 (V)	1	Do not allow -1.24

6(e)(ii)	Chloride ions / Cl^- react with / form a precipitate with silver ions/ Ag+ / form AgCl	1	Penalise reaction of chloride ions with iron ions or iron

6(f)	E O_2 (/H_2O) > E Fe^{3+} (/Fe^{2+}) (or e.m.f / *E*cell = 0.46 V)	1	Species in electrode if all given must be in correct order
	Therefore the iron(II) ions are oxidised (or converted) into iron(III) ions (by oxygen)	1	If chloride ions oxidised to chlorine, lose M2 M2 can be obtained or lost from equation. Ignore observations.

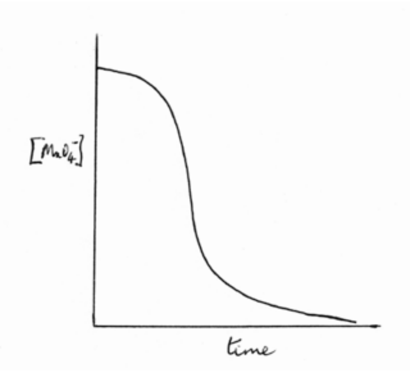
M

Question	Marking Guidance	Mark	Comments
7(a)	$Cr(OH)_3 + 3H_2O + 3H^+ \rightarrow [Cr(H_2O)_6]^{3+}$	1	Can start with $Cr(H_2O)_3(OH)_3$ for each equation Ignore any unnecessary preliminary preparation of $Cr(OH)_3$
	Green / grey-green solid	1	Mark colours independently from equations Allow green ppt.
	Forms green / purple / ruby / violet solution	1	ignore shades of colours
	$Cr(OH)_3 + 2H_2O + OH^- \rightarrow [Cr(H_2O)_2(OH)_4]^-$	1	Allow with 5 or 6 OH^- provided complex has co-ordination number of 6 Penalise complex ions with incorrect charges overall or or if shown on ligand.
	Forms green solution	1	Note that for each equation final complex must be 6 co-ordinate

7(b)	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$	1	Allow two correct equations via intermediate hydroxide in both cases even if first equation uses OH^- instead of NH_3
	Blue (solution)	1	Mark colours independently from equations
	Dark/deep/royal blue <u>solution</u>	1	
	$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$	1	
	pink/red (solution)	1	
	Brown / straw / yellow <u>solution</u>	1	ignore darkens in air/with time

Question	Marking Guidance	Mark	Comments
8(a)	$[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(H_2O)_4(OH)_2 + 2NH_4^+$	1	Allow equation with OH^- provided equation showing formation of OH^- from NH_3 given
	Green precipitate	1	
	$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$	1	
	Green precipitate	1	effervescence incorrect so loses M4
8(b)(i)	Colourless/(pale) green changes to pink/purple (solution)	1	Do not allow pale pink to purple
	Just after the end-point MnO_4^- is in excess/present	1	
8(b)(ii)	$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$	1	
	Moles $KMnO_4 = 18.7 \times 0.0205/1000 = (3.8335 \times 10^{-4})$	1	Process mark
	Moles $Fe^{2+} = 5 \times 3.8335 \times 10^{-4} = 1.91675 \times 10^{-3}$	1	Mark for M2 x 5
	Moles Fe^{2+} in 250 $cm^3 = 10 \times 1.91675 \times 10^{-3} =$ 0.0191675 moles in 50 cm^3	1	Process mark for moles of iron in titration (M3) x10
	Original conc $Fe^{2+} = 0.0191675 \times 1000/50 = 0.383$ $\underline{\text{mol dm}^{-3}}$	1	Answer for moles of iron (M4) x 1000/50 Answer must be to at least 2 sig. figs. (0.38)

Question	Marking Guidance	Mark	Comments
9(a)	$2MnO_4^{-} + 16H^{+} + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$	1	
	Mn^{2+} OR Mn^{3+}	1	If catalyst incorrect can only score M1 and M3
	(Possible because) Mn can exist in variable oxidation states	1	
	E_a lowered because oppositely charged ions attract	1	These marks can be gained in any order
	Mn^{3+} (reduced) to Mn^{2+} by $C_2O_4^{2-}$ / equation	1	M5 may appear before M2
	Mn^{2+} (oxidised (back)) to Mn^{3+} by MnO_4^{-} / equation	1	M5 and M6 can be scored in unbalanced equations or in words showing: $Mn^{3+} + C_2O_4^{2-} \rightarrow Mn^{2+}$ $Mn^{2+} + MnO_4^{-} \rightarrow Mn^{3+}$

9(b)	**Graph marks**  		Cannot score graph marks (M1 and M2) if no axes and/or no labels
	S-shaped curve must not rise significantly and must not fall rapidly initially.	1	
	Starts on concentration axis **and** is levelling out (can level out on time axis or above but parallel to time axis)	1	
	Explanation marks Slope / rate increases as catalyst (concentration) forms	1	Explanation marks can be awarded independent of graph.
	Slope / rate decreases as (concentration) of MnO_4^- ions /reactant(s) decreases (OR reactants are being used up)	1	

CHEM5 Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available ‘any **two** from’ is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.

2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.

2.3 Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that ‘right + wrong = wrong’.

Each error / contradiction negates each correct response. So, if the number of error / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by ‘Ignore’ in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can be given for a correct numerical answer, without any working shown unless the question states ‘Show your working’.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the ‘extra information’ column or by each stage of a longer calculation.

3.3 Interpretation of ‘it’

Answers using the word ‘it’ should be given credit only if it is clear that the ‘it’ refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are most likely to be restricted to calculation questions and should be shown by the abbreviation e.c.f. or conseq in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited **unless** there is a possible confusion with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do not allow

Ignore or insufficient is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

Do **not** allow means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.