GCE 2005
January Series

ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark Scheme

Chemistry

CHM5 - Thermodynamics and Further Inorganic Chemistry

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

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' 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.

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Guidance on the award of the mark for Quality of Written Communication

Quality of Written Communication assessment requires candidates to:

- select and use a form and style of writing appropriate to purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate; and
- ensure text is legible, and spelling, grammar and punctuation are accurate, so that meaning is clear.

For a candidate to be awarded 1 mark for quality of written communication on the question identified as assessing QWC in a unit test, the minimum acceptable standard of performance should be:

- the longer parts (worth 4 marks or more) should be structured in a reasonably logical way, appropriate and relevant to the question asked;
- ideas and concepts should be explained sufficiently clearly to be readily understood. Continuous prose should be used and sentences should be generally be complete and constructed grammatically. However, minor errors of punctuation or style should not disqualify;
- appropriate AS/A level terminology should be used. Candidates should not use such phrases as 'fighting disease', 'messages passing along nerves', 'enzymes being killed' etc, but a single lapse would not necessarily disqualify. Technical terms should be spelled correctly, especially where confusion might occur, e.g. mitosis/meiosis, glycogen/glucagon.

The Quality of Written Communication mark is intended as a recognition of competence in written English. Award of the mark should be based on overall impression of performance on the question identified on the paper as assessing QWC. Perfection is not required, and typical slips resulting from exam pressure such as 'of' for 'off' should not be penalised. Good performance in one area may outweigh poorer performance in another. Care should be taken not to disqualify candidates whose lack of knowledge relating to certain parts of a question hampers their ability to write a clear and coherent answer; in such cases positive achievement on other questions might still be creditworthy. No allowance should be made in the award of this mark for candidates who appear to suffer from dyslexia or for whom English is a second language. Other procedures will be used by the Board for such candidates.

Examiners should record 1 or 0 at the end of the paper in the Quality of Written Communication lozenge. This mark should then be transferred to the designated box on the cover of the script.

CHM5 Thermodynamics and Further Inorganic Chemistry

Question 1

(a) (i) Mass/M_r = 4.22/133.5 1
= 0.316 1

(ii) pH = –log[H^+] 1
[H^+] = 5.62×10^{-4} 1
Penalise answers to two significant figures once in (i) and (ii)

(iii) $[Al(H_2O)_6]^{3+}$ 1

(iv) $[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H_3O^+(aq)$ 1
or $[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+(aq)$

(v) $5.62 \times 10^{-4} \times 100/0.0316$ 1
= 1.78 to 1.80% 1
Allow consequential to answers in (a)(i) and (ii)

(b) White precipitate formed 1
Colourless gas, or CO_2, evolved 1

(c) (i) White precipitate formed 1
$3AgNO_3 + AlCl_3 \rightarrow 3AgCl + Al(NO_3)_3$ 1
or $Ag^+ + Cl^- \rightarrow AgCl$

(ii) $Al^{3+}(aq)$ reacts with $NH_3(aq)$ forming a white precipitate 1
cannot see if AgCl precipitate has dissolved 1

(d) (i) White or steamy fumes evolved 1

(ii) $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$ 1
or $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

A proton donor or an acid 1

Total 17

Question 2

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ 1

(b) $S^-(g)$ 1

(c) The negative S^- ion 1
repels the electron being added 1

(d) (i) Enthalpy of atomisation of sulphur 1

(ii) Second ionisation enthalpy of calcium 1

(iii) Second electron affinity of sulphur 1

(e) Electron more strongly attracted 1
nearer to the nucleus or attracted by Ca^+ ion 1

(f) Correct cycle

e.g. + 178 + 279 + 590 +1145 – 200 + E –3013 + 482 = 0 1

= 539 1

Allow one mark for – 539

Total 11

Question 3

(a) (i) 0.60 V 1

(ii) $H_2O + H_2SO_3 \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ 1

(b) (i) $2IO_3^- + 2H^+ + 5H_2O_2 \rightarrow 5O_2 + I_2 + 6H_2O$ Species 1
Balanced 1

(ii) The concentration of the ions change or are no longer standard or
the e.m.f is determined when no current flows 1

(iii) Unchanged 1

(iv) Increased 1
Equilibrium IO_3^-/I_2 displaced to the right
1
Electrons more readily accepted or more reduction occurs
or electrode becomes more positive (Q o L) 1

(c) VO_2^+ 1
5 or V 1
$V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 3e^-$ 1

Total 12

Question 4

(a) (i) SO_2 1
+4 1

(ii) $4P + 5O_2 \rightarrow 2P_2O_5$ 1
or $P_4 + 5O_2 \rightarrow P_4O_{10}$

(b) (i) B 1
E 1
They have low melting points
or there are weak van der Waals forces between molecules 1

(ii) Add water or heat in a flame 1
Test pH check flame colour 1
13/14 yellow 1

(c) (i) $NaHSO_3$ 1
(ii) $NaHSO_3 + NaOH \rightarrow Na_2SO_3 + H_2O$ 1
or $HSO_3^- + OH^- \rightarrow SO_3^{2-} + H_2O$

(iii) Phenolphthalein or alizarin yellow or thymol blue 1

Total 12

Question 5

(a) $3d^7$ 1

(b) $[Co(H_2O)_6]^{2+}$ 1
Pink 1

(c) (i) $[Co(NH_3)_6]^{2+}$ 1
Pale brown or straw 1

(ii) $[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$ 1

(d) $[Co(NH_3)_6]^{3+}$ 1
An oxidising agent 1

Total 8

SECTION B

Question 6

(a) Ligand:-
atom, ion or molecules which can donate a pair of electrons to a metal ion. 1

co-ordinate bond:-
a covalent bond 1
in which both electrons are donate by one atom 1

(b) (i) Two correct complex ions 1
Balanced equation 1
Two correct colours 2

(ii) Complex with a bidentate ligand 1
Balanced equation 1
NB en *not allowed as a ligand unless structure also given*

More molecules/ions formed 1
Increase in entropy 1
more stable complex formed 1
Max 2

(c) ΔE; energy absorbed by electron, ground to excited state (Q o L) 1
h; Planck's constant or a constant 1
Change in
Oxidation state 1
Ligand 1
Co-ordination number 1

Apply list principle to incorrect additional answers
Total 16

Question 7

(a) Iron has low reactivity 1
Hence carbon reduction can be used 1
Iron can be purified readily or used impure 1

Titanium is reactive and forms an oxide /nitride 1
Impurity makes titanium brittle/useless 1
Pure titanium produced/needed 1
Na more reactive than Ti 1
TiO_2 reacts with C to form TiC 1

Need/ Cost of making $TiCl_4$ 1
Sodium/magnesium and/or inert gas are very expensive 1
Titanium is extracted in a batch process. 1
Iron is extracted by a continuous process 1
Max 6

(b) (i) Moles MnO_4^- = MV/1000 = $19.6 \times 0.022 \times 10^{-3}$ = 4.312×10^{-4} 1

Equation or ratio $5Fe^{2+} : MnO_4^-$ 1

Moles Fe^{2+} in 25 cm^3 = $5 \times 4.312 \times 10^{-4}$ = 2.156×10^{-3} 1

Moles Fe^{2+} in 250 cm^3 = $2.156 \times 10^{-3} \times 10$ 1

= 2.156×10^{-2}

Mass Fe^{2+} = moles $Fe^{2+} \times M_r$ = $2.156 \times 10^{-2} \times 55.8$ = 1.203 g 1

Percentage, by mass, of iron in sample = $1.203 \times 100/1.27$

= 94.7 to 95.3% 1

NB If M_r of $FeSO_4$ used then last two marks lost

(ii) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$ 1

(iii) $PV = nRT$ 1

$V = nRT/P = 2.156 \times 10^{-2} \times 8.31 \times 295/ 98000$ 1

= 5.393×10^{-4} m^3 or 5.393×10^{-1} dm^3 1

= 539 to 540 cm^3 1

NB Answers to (b)(iii) not dependent on correct answer to (b)(ii) but allow if answer correctly linked to an incorrect answer (b)(ii)
Allow conversion to cm^3 even if m^3 incorrect
Allow answers based on an incorrect equation in (b)(ii)

NB Answers using 1.82×10^{-2}

$PV = nRT$ (1)

$V = nRT/P = 1.82 \times 10^{-2} \times 8.31 \times 295/ 98000$ (1)

= 4.55×10^{-4} m^3 (1)

= 455 to 456 cm^3 (1)

Max 4

Total 17

Question 8

(a) (i) An appropriate alkene; $CH_3CH_2CHCH_2$ or $(CH_3)_2CCH_2$ 1

Isomer 1 1

Isomer 2 1

Position isomerism 1

Mechanism

electrophilic attack and electron shift to Br (Unless H^+ used) 1

carbocation 1

reaction with carbocation 1

[Allow mechanism marks for the alkene $CH_3CHCHCH_3$]
[Allow one mark if mechanism for minor product given]

(ii) An appropriate carbonyl; CH_3CH_2CHO 1
Mechanism nucleophilic attack and electron shift to O 1
anion intermediate 1
reaction with anion 1

[Allow mechanism marks for the carbonyl $(CH_3)_2CO$]
Isomer 1 1
Isomer 2 1
Optical isomerism 1

NB Isomer structures must be tetrahedral

NB Penalise "stick" structures once in part (a)

(b) QoL Large charge on carbonyl carbon atom due to bonding to O and Cl 1
Nucleophiles have electron pairs which can be donated 1
Equation Species 1
Balanced 1

Total 18

Question 9

(a) Iron 1
Heterogeneous; catalyst in a different phase from that of the reactants 1

Poison; a sulphur compound (allow sulphur) 1
Poison strongly adsorbed onto active sites/ blocked 1
Poison not desorbed or reactants not adsorbed or
catalyst surface area reduced 1

(b) Pale green solution 1
Green precipitate formed 1
Insoluble in excess ammonia 1
Equation:-
e.g. $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ Species 1
Balance 1
Max 4

NB Allow equations with H_2O and OH^- if reaction of H_2O with NH_3 also given

Total 9