2006 **Chemistry GA 3: Written examination 2**

GENERAL COMMENTS

Students in 2006 showed evidence of good understanding of chemical concepts. Some of the results from the very best students were worthy of what is normally expected from high-level tertiary student responses.

Many students experienced difficulties in writing concise and accurate explanations of chemical concepts. This is an important skill for students to develop, since often written language is the only way to communicate more sophisticated chemical concepts to those who do not have access to the 'technical language' of the professional chemist. As has been noted in previous reports, assessors are given clear guidelines about the need to make fair and just judgments that take note of the fact that many students are from non-English speaking backgrounds. However, assessors cannot accept responses that do not answer the question asked, even if they believe the student may have misread the question.

Questions on stoichiometry continued to be well answered. The area of specific chemical difficulty seemed to be the ability to draw extended chemical structures, particularly to the structures requested in Questions 8bi., 8bii. and 9ai. In addition, there were clear difficulties with simple half and full equations such as Questions 5cii., 6ci., 6cii. and 9c. In Question 9c., too many students did not seem to think clearly about the nature of the 'states' that it was appropriate to use. Regular practice would address these difficulties.

SPECIFIC INFORMATION

Section A – Multiple-choice questions

Question	% A	% B	% C	% D	Comments
1	1	3	93	2	
2	1	95	1	3	
3	67	15	10	8	The reaction has a positive Δ*H* and must therefore absorb energy from the surroundings. The decomposition of 2 mole of HI is the reverse of the reaction provided, so that its Δ*H* must be negative and energy will be released. The most common error was to choose the incorrect sign (option B).
4	13	14	13	60	The galvanic cell described has the cell reaction $2Ag^{+} + Cu \rightarrow Cu^{2+} + 2Ag$ so that the intensity of the blue colour of Cu^{2+} will increase.
5	5	7	75	12	In the cell described, the positive electrode is the cathode and the negative electrode is the anode (where oxidation is occurring). Thus, at the negative electrode the reaction occurring is $Cu \rightarrow Cu^{2+} + 2e^{-}$ so that the anions must be moving towards this electrode in the same direction as the electrons in the external circuit and, at the same time, maintaining electrical neutrality around the anode where Cu^{2+} ions are collecting.
6	16	67	5	11	83% of students correctly decided that a fuel cell had a higher efficiency than a 'thermal' power station (options A and B). However only 67% also knew that the fuel cell was more expensive and chose option A.
7	7	53	29	11	Nearly 30% decided that the concentration of Sn^{2+} in the solution would decrease during the electroplating (option C). However, given that there was a tin anode, for every tin ion deposited, another tin ion would be released into solution from the tin anode. Tin ions must move continuously from the anode to the cathode, so option B must be correct.
8	57	21	14	8	0.019 Faraday equals 0.019 mol of electrons. 0.50 g of Cr equals 0.50/52 = 0.0096 mol. Thus each mole of Cr must have provided 2 mol of electrons so that the oxidation number was +2 (option A). Over 20% chose +3 (option B), possibly knowing that +3 is a common oxidation state of Cr.

Question	% A	% B	% C	% D	Comments
9	12	21	56	11	The oxidation of natural gas (methane) in process T and glucose in process Q both involved a change in the oxidation state of carbon. Yet over 30% of students chose option A or B, which did not include process T.
10	15	21	8	57	Students who chose options A or B failed to notice the relevance of process T in which, this time, water is a product. 57% of students correctly recalled that the oxidation of methane and glucose both produce water, as does the condensation of glucose to make starch.
11	9	21	48	22	Option C was the only amino acid given that was not an α-amino acid. Over 40% chose either B or D, perhaps because neither was a 'simple' α-amino acid, with B including an –SH and D an additional –COOH group.
12	3	20	66	12	66% correctly chose option C, in which the sample is placed in the calorimeter, allowed to come to temperature, calibrated by adding energy and measuring the rise in temperature and finally triggering the combustion of the sample and measuring a final temperature rise. Option B would have made sense if '1' and '5' had been reversed.
13	13	85	1	1	A significant percentage of students chose option A; however, glucose is not 'stored' in the body.
14	66	15	9	10	A significant percentage of students chose option B, perhaps because glycogen looked a little more familiar than maltose. However, glycogen and cellulose should have been recognised as being polymers and glycerol is familiar as a component of lipids.
15	2	3	17	78	The only choice should have been between options C and D, since it should be known that III (temperature) causes denaturation. It should also be known that proteins can be hydrolysed by strong acids, so option D is left as the only possible choice. Alternatively, it could be argued that strong acidic or basic media will affect the degree of protonation of such groupings as $–NH_2$ and –COOH and their acid-base conjugates and thereby disrupt the hydrogen bonding that maintains the three dimensional structure of a natural protein.
16	8	84	7	1	
17	8	16	2	73	Atomic radius increases initially down the halide group and then continues to increase from right to left across the third period from Cl to Mg and then to finally increase further as we go from group 2 to group 1, period four.
18	80	13	3	4	The first ionisation energy increases from left to right across the third period and then increases further as we go up the inert gas group from period 3 to period 2.
19	7	2	73	18	Some students were distracted by the mention of atomic numbers and mass numbers and chose option D, failing to remember that the concepts of atomic number and mass number were unknown at the time of Mendeleev.
20	45	9	10	36	Many students chose option D, which, at first glance, may have looked correct since HCl and O_2 can be formed from a balanced reaction between Cl_2O_7 and H_2O. However, the item specifically provides the information that the reaction is **not** a redox reaction, and $HClO_4$ is the only product suggested in which neither Cl not O suffer a change of oxidation state.

Section B – Short answer questions

Asterisks (*) are used in some questions to indicate where marks were awarded.

Question 1a.

Marks	0	1	2	Average
%	11	22	67	**1.6**

1ai.
Atoms are not indivisible **or** contain nucleus and electrons **or** undergo fission or radioactive decay.

1aii.
Atoms of the same element may have different masses **or** isotopes exist **or** they can have different numbers of neutrons.

These two parts were very well done. A small proportion of students misread 'indivisible' as 'invisible'. No credit was given for this misreading.

Question 1b.

Marks	0	1	2	3	Average
%	32	26	24	18	**1.4**

1bi.
Emission lines represent the energy difference between two different electron energy levels as an electron moves between two orbits;* emission results when an electron drops from a high energy level (orbit) to a lower energy level.*

In general, this part was not well answered. The two key points were that a line (or 'colour') indicated an energy **difference** between two energy levels **and** that emission occurs when the electron drops from high to low (or to ground state). Students were able to gain one mark if their answer was partially correct; for example, if there was confusion between the absorption spectrum and emission spectrum. Another common error was mistaking an emission (or absorption) line for an energy level rather than as the difference between two energy levels.

1bii.
Existence of subshell **or** orbitals occupying a 'region of space'.

Part ii. was better answered although a surprising number of students incorrectly stated that shells closer to the nucleus have a higher energy than shells further away from the nucleus.

Question 2a.

Marks	0	1	Average
%	17	83	**0.9**

143

Question 2b.

Marks	0	1	Average
%	52	48	**0.5**

actinides **or** f-block **or** f-subshell

Question 2c.

Marks	0	1	2	Average
%	16	37	47	**1.4**

2ci.
Te

2cii.
137

Question 2d.

Marks	0	1	2	Average
%	14	19	67	**1.6**

Any two of:

- metallic
- good conductor
- dense
- high melting temperature
- variable oxidation state
- coloured salts
- forms complex ions.

Question 2 was generally well done. These were all essentially straight recall questions and no serious misunderstandings were shown.

Question 3a.

Marks	0	1	2	Average
%	40	7	53	**1.2**

let x = abundance of ^{63}Cu

Then for $\frac{62.93x + 64.93(100 - x)}{100}$ * = 63.54; x = 69.5*

Question 3b.

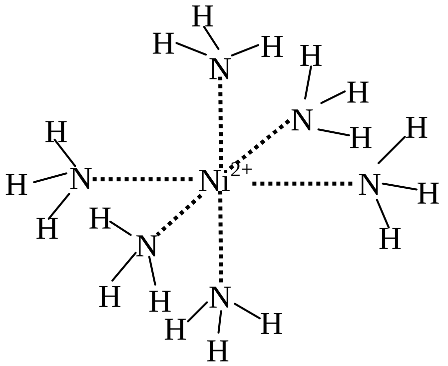
Marks	0	1	2	3	Average
%	17	18	26	39	**2.0**

3bi.
$1s^2 2s^2 p^6 3s^2 p^6 4s^2 3d^8$ **or** $1s^2 2s^2 p^6 3s^2 p^6 d^8 4s^2$

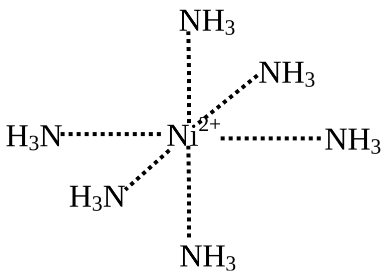
3bii.
$1s^2 2s^2 p^6 3s^2 p^6 d^8$

Part ii. proved to be more difficult that part i. although, in general, they were both well answered.

3biii.
The sketch needed to have correct orientation of ligands. The ammonias should have been more or less symmetrically around the Ni and the N atoms of the ammonia molecules, in structural form, pointing towards the Ni*; the 2+ may have been either directly on the Ni or shown as applying to the whole complex ion or in both such places. For example:



or



Many students did not indicate that the N atom of each ammonia molecule must be nearest to the Ni ion and therefore did not receive the mark. A full structure of the NH_3 molecule was not required to get the mark here.

Question 3c.

Marks	0	1	Average
%	31	69	0.7

Due to systematic filling of a d-subshell.

Many students referred only to the first transition series in answering a question that specifically asked for a more generic explanation. However, correct use of only the first transition series in the explanation was accepted for the mark.

Question 4a.

Marks	0	1	Average
%	20	80	0.8

0.0500 × 0.400 = 0.0200 mol

Question 4b.

Marks	0	1	Average
%	23	77	0.8

0.0500 × 0.760 = 0.0380 mol

Question 4c.

Marks	0	1	2	Average
%	42	27	31	0.9

$$\text{Energy} = \frac{0.038^{*}}{2} \times 49000 = 931 \text{ J*}$$

Students who incorrectly used 0.020 x 49 000, giving 980 J, received one mark. Only 31 per cent of students recognised that KI was the limiting reagent.

Question 4d.

Marks	0	1	2	Average
%	26	33	42	1.2

$$\frac{931}{20.5 - 18.42}^{*} = 448^{*}$$

The second mark was awarded for the correct calculation **and** three significant figures. Students who used an incorrect number of significant figures could not gain full marks, as the question specifically asked for the correct number of significant figures.

Question 4e.

Marks	0	1	2	3	Average
%	29	20	22	29	1.6

Error	Calculated calibration factor too low	No effect on calculated calibration factor	Calculated calibration factor too high
i. The concentration of the lead nitrate solution has been incorrectly recorded and was actually 0.410 M		✓	
ii. The calorimeter was not placed in its polystyrene jacket			✓

4eiii.
A lower temperature change leads to a high calibration factor.

Question 4e. was only moderately well done. An incorrect 'tick' for part ii. made it difficult to gain a mark in part iii.

Question 5a.

Marks	0	1	Average
%	53	47	0.5

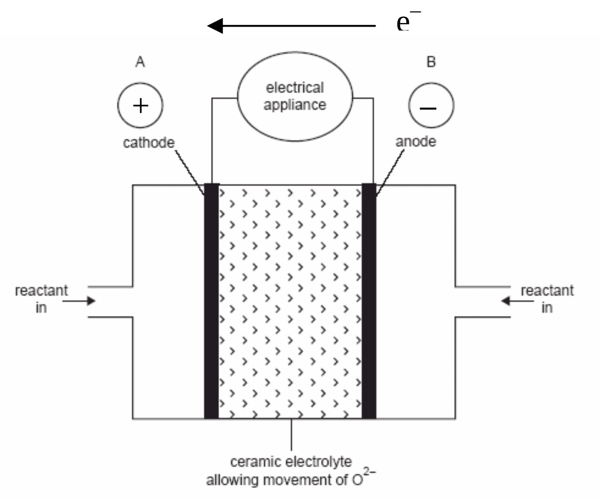
Reactants are delivered continuously.

This should have been a simple recall question.

Question 5b.

Marks	0	1	2	Average
%	16	30	55	1.4

5bi.



bii.
Electrons travel from right to left in an external circuit (see above). This is a galvanic cell operating as a fuel cell and electrons will flow from the anode to the cathode in the external circuit.

Question 5c.

Marks	0	1	2	Average
%	64	26	10	0.5

5ci.
$2H_2 + O_2 \rightarrow 2H_2O(l)$

5cii.
$O_2 + 4e^- \rightarrow 2O^{2-}$

Part c. was poorly answered. About 35 per cent of students answered part i. correctly, and only about 10 per cent could answer part ii. correctly.

Question 5d.

Marks	0	1	2	3	4	5	Average
%	14	20	17	13	27	9	2.6

5di.
Energy = 0.500 × 10 × 60 × 0.600 = 180

5dii.
Q = 0.500 × 10 × 60 = 300

5diii.

300C uses $\frac{300}{96500}^*$

$= 3.108 \times 10^{-3}$ mol of electrons

$= \frac{3.108^*}{2} \times 10^{-3}$ mol of H_2

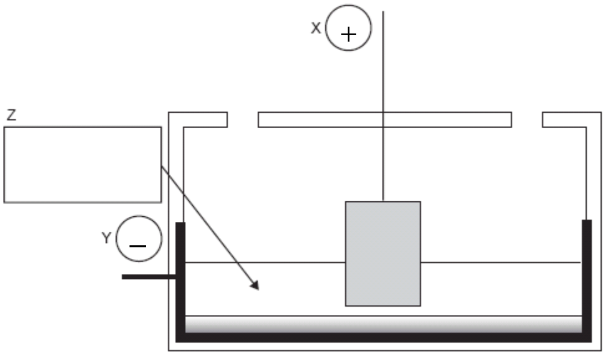
At efficiency of 60% we then have $\frac{3.108}{2} \times 10^{-3} \times \frac{100^*}{60} = 2.59 \times 10^{-3}$

One mark was awarded for calculating the mole of electrons, another for converting to mole of hydrogen and a third for **dividing** by 0.6.

Parts i. and ii. were reasonably well done but many of those who answered part iii. multiplied by 0.6 rather than dividing by 0.6. If the cell is working with 60 per cent efficiency it follows that only 60 per cent of the hydrogen consumed is converted to electricity, hence more hydrogen is needed – not less.

Question 6a.

Marks	0	1	Average
%	37	63	**0.7**



Question 6b.

Marks	0	1	Average
%	53	47	**0.5**

cryolite **or** cryolyte **or** Na_3AlF_6

Question 6c.

Marks	0	1	2	Average
%	46	36	18	**0.8**

6ci.

$C + 2O^{2-} \rightarrow CO_2 + 4e^-$ OR $2O^{2-} \rightarrow O_2 + 4e^-$

6cii.

$Al^{3+} + 3e^- \rightarrow Al$

Question 6d.

Marks	0	1	Average
%	61	39	**0.4**

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ **or** $2H^+ + 2e \rightarrow H_2$

Apart from part a., Question 6 was not well done. Part ci. was frequently 'approximately' correct but many students failed to provide a **balanced** equation. Students are reminded that the medium for Al^{3+} is non-aqueous.

Question 7a.

Marks	0	1	Average
%	73	27	0.3

Ca^{2+}(aq) ions are harder to reduce than Na^{+}(aq) ions (lower reduction potential) **or** Na^{+} is a better oxidant **or** Na is a weaker reductant.

Many students used the terms 'sodium' and 'calcium' when they should have written 'sodium ion' or 'calcium ion'; for example, 'sodium is easier to reduce than calcium…' No marks for given for this type of statement.

Question 7b.

Marks	0	1	Average
%	25	75	0.8

Asbestos is hazardous **or** plastic membrane is more efficient and only allows Na^{+} through **or** higher purity NaOH.

Question 7c.

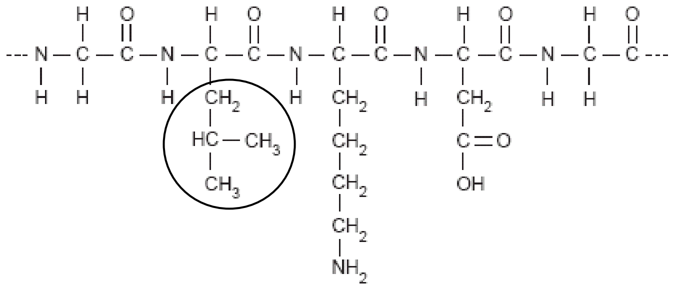
Marks	0	1	Average
%	28	72	0.8

Some plant material (for example, cellulose) is not digestible by humans **or** digestion is not 100 per cent efficient **or** food is not 100 per cent oxidised.

Question 8a.

Marks	0	1	2	Average
%	31	42	27	1.0

8ai.



Students needed to circle the hydrocarbon part only, and it had to be the **whole** group.

8aii.

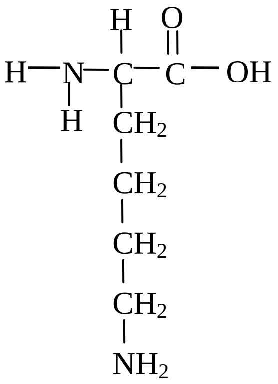
Interior, since the hydrophilic bits interact more strongly with water **or** as this makes the protein more soluble in water.

Most students circled the side chain with the $–NH_2$ group. However, the fact that a hydrophobic side chain should sit in the interior of a protein in water was well recognised.

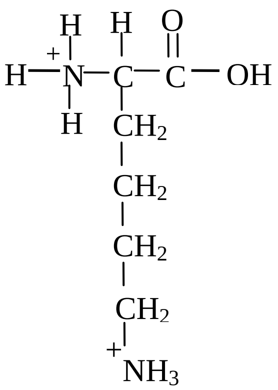
Question 8b.

Marks	0	1	2	Average
%	56	33	10	0.6

8bi.



8bii.



Part b. was not well done. Over half the students scored zero and only 10 per cent were able to correctly identify both structures. Unfortunately, some students had the right idea for part ii. but did not protonate the $–NH_2$ group on the side chain.

Question 8c.

Marks	0	1	Average
%	31	69	**0.7**

The high temperature denatures protein.

Question 8d.

Marks	0	1	Average
%	48	52	**0.6**

NO_3^-

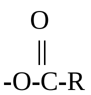
Parts c. and d. were simple recall questions and were fairly well done, although a surprising number of students claimed that HNO_3 is an ion in the soil.

Question 9a.

Marks	0	1	2	3	Average
%	17	28	18	36	**1.8**

9ai.

One mark was awarded for an essentially correct structure of the lipid with the ester structure spelt out; that is, as



The second mark was awarded for having the correct structure of glycerol incorporated into the lipid structure.

9aii.
Oleic acid **or** $C_{18}H_{34}O_2$

Part i. was very poorly answered and the structure of the ester grouping was frequently incorrect. For example, the two oxygen atoms were bonded together or an incorrect number of H atoms were attached to the carbon atoms on the 'glycerol' part of the lipid. Part ii. was generally well done.

Question 9b.

Marks	0	1	2	Average
%	57	7	36	**0.8**

mol of $H_2 = \frac{15}{2} = 7.5$, which gives $\frac{7.5}{2.5}^*$ mol of H_2 per mole of fat, = 3 double bonds per molecule*

Given that this was an unfamiliar type of question, it was very well done. Some students who had not done very well on straight 'recall' questions seemed to do this 'applications' question well.

Question 9c.

Marks	0	1	2	Average
%	24	58	18	**1.0**

$C_{16}H_{32}O_2$(s **or** l) + $23O_2$(g) $\rightarrow$ $16CO_2$(g) + $16H_2O$(g *or* l).

One mark was awarded for correct formulas of reactants and products and the second mark for correct balancing and correct states. Most students had a good idea about the reactants and products of the equation. Marks were generally lost for errors in the states; for example, for writing (aq) for palmitic acid, a reactant that was being burnt in a bomb calorimeter.

Question 9d.

Marks	0	1	Average
%	35	65	**0.7**

Vitamin C preferentially reacts with O_2.