



2003

Chemistry GA 3: Written examination 2

SPECIFIC INFORMATION

Section A – Multiple choice

This table indicates the approximate percentage of students choosing each distractor. The correct answer is the shaded alternative.

| | A | B | C | D | | A | B | C | D |
|----------|----|----|----|----|----------|----|----|----|----|
| Question | | % | | | Question | | % | | |
| 1 | 4 | 82 | 8 | 6 | 11 | 8 | 7 | 71 | 14 |
| 2 | 4 | 5 | 3 | 88 | 12 | 9 | 6 | 79 | 6 |
| 3 | 73 | 20 | 4 | 3 | 13 | 5 | 8 | 12 | 75 |
| 4 | 16 | 7 | 67 | 10 | 14 | 70 | 7 | 12 | 11 |
| 5 | 49 | 17 | 22 | 12 | 15 | 12 | 58 | 14 | 16 |
| 6 | 26 | 61 | 7 | 6 | 16 | 5 | 6 | 83 | 6 |
| 7 | 9 | 20 | 6 | 65 | 17 | 17 | 50 | 10 | 23 |
| 8 | 8 | 6 | 62 | 24 | 18 | 7 | 33 | 12 | 48 |
| 9 | 12 | 76 | 7 | 5 | 19 | 33 | 56 | 4 | 7 |
| 10 | 15 | 59 | 16 | 10 | 20 | 16 | 12 | 22 | 50 |

Item 4

The most common error (A) was likely caused by misreading the mass of C₈H₁₈ as 45 gram rather than 45 kg suggesting that over 80 per cent of students got the stoichiometry right.

Item 5

The students who chose C were correct in identifying the sign on the electrodes but assumed that Cl₂ was a colourless, odourless gas evolved at the positive electrode. For B, this was choosing the correct gases but incorrect electrode signs.

Items 6–9

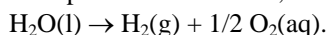
Many students confused the terms cathode and anode (A). Perhaps those who chose B in Item 7 were rushing when they confused an electrolytic cell, i.e. a cell in which electrolysis is occurring, for a galvanic. Then, in Item 8, students confused the electrodes by choosing D rather than C. Even in the apparently straightforward Item 9, there was confusion between the meaning of ‘anode’ and ‘cathode’.

For students the use of the terms ‘positive’, ‘negative’, ‘anode’ and ‘cathode’ in galvanic and electrolytic cells can be confusing since, in the galvanic cell the cathode is positive and the anode is negative, while in the electrolytic cell the cathode is negative and the anode is positive. In both the galvanic and electrolytic cells it is important to remember that the terms anode and cathode refer to the type of half reaction that is occurring, thus:

- cathode = reduction always. Positive in galvanic cell, negative in electrolytic cell
- anode = oxidation always. Negative in galvanic cell, positive in electrolytic cell.

In the galvanic cell, the cathode is the electrode of the positive half cell where reduction occurs. This is a half reaction (e.g. Ag⁺ + e⁻ → Ag) that is spontaneously removing electrons from the electrode and ‘pulling’ electrons from the anode through the external circuit. At the same time, oxidation is occurring at the anode (e.g. Ni(s) → Ni²⁺(aq) + 2e⁻) where electrons are being ‘pushed’ onto this electrode and then around the external circuit to the cathode. Thus, the negatively charged electrons flow from anode to cathode via the external circuit, i.e. from the negative anode to the positive cathode.

In the case of the electrolytic cell, the cathode is the electrode at which reduction occurs. But in this case it does not occur spontaneously. In the electrolytic cell there must always be another source of electric current – perhaps a galvanic cell with a high voltage – that will drive an otherwise unwilling chemical reaction to occur in the electrolytic cell. In the example in Items 5 and 6, the non-spontaneous reaction is the decomposition of water:



At the cathode, the reduction reaction is H₂O(l) + e⁻ → OH⁻(aq) + 1/2 H₂(g), using electrons from the external source of electric current. The external source is driving electrons to the cathode so that the cathode is negative. At the anode, the oxidation reaction is H₂O(l) → 2H⁺(aq) + 1/2 O₂(g) + 2e⁻, releasing electrons to the external current source. The anode is therefore positive, since it must ‘forcibly’ extract electrons from the oxidant in the solution of the electrolytic cell.

Note that, in both galvanic and electrolytic cells, cations go to the cathode and anions go the anode. The difference is that, in galvanic cells, the ions spontaneously go to their respective electrodes because a spontaneously occurring cell reaction is occurring. In the electrolytic cell, the ions must be dragged 'kicking and screaming' to their respective electrodes because the net reaction occurs only because a source of external energy (the external current source) is driving it.

Item 17

When the condensation of three glycine molecules occurs, water is released. There must be two peptide links formed, so the correct molecular mass must be $(75 \times 3) - (18 \times 2) = 189$. A common mistake (D) was to forget to subtract the water molecules.

Item 18

Many chose D and B (thinking presumably of ABC, CAB and BCA with each molecule having its 'turn' in the middle). However, each of the amino acids can be linked in two different ways so that the total number of possible combinations is 6.

Item 19

Each mole of glycine could only make half a mole of urea whereas many chose a 1:1 answer (B).

Item 20

D is an obvious response – urea contains both N and C and must necessarily be in both the C and N cycles. However, response B was also correct. Oxidised N, say in the form of NO_3^- can involve itself in the C cycle by oxidising organic matter. Therefore, both responses were accepted as correct.

Section B – Short answer

Question 1

1a

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 37 | 63 | 0.63 |

No C to C double bonds

1b

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 42 | 18 | 40 | 0.97 |

$\text{CH}_3(\text{CH}_2)_{16}\text{COOH} + 26\text{O}_2 \rightarrow 18\text{CO}_2 + 18\text{H}_2\text{O}$; correct reagents and products, correct stoichiometry

There were two common errors. Many students failed to recognise that the products were CO_2 and water and produced creative guesses of breakdown products of stearic acid. Most got the products right but messed up the stoichiometry.

1ci–ii

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 29 | 18 | 53 | 1.23 |

1ci

Antioxidants

1cii

Reacting preferentially with O_2

Question 2

2a

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 32 | 68 | 0.68 |

Carboxy (no other choice acceptable)

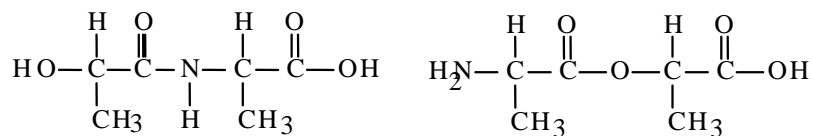
2b

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 33 | 67 | 0.67 |

Lactic acid has no amino group (must mention lactic acid)

2c

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 28 | 30 | 42 | 1.13 |



2di-ii

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 39 | 13 | 48 | 1.09 |

2di

Circle either -CONH- OR -COO-

2dii

Peptide OR ester

The obvious choice was of a peptide and an ester. Many students produced an acid anhydride from the two carboxyl groups. This was accepted although very few correctly named it. However, this was not a disadvantage since such a second choice had to be either the peptide or ester group, so that a fully correct answer to D was still possible.

Question 3

3a

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 12 | 24 | 64 | 1.52 |

$$E = 1.78 \times 5.65 \times 135 = 1358 \text{ J}; \text{ calibration constant} = 1358/1.15 = 1.18 \text{ kJ } ^\circ\text{C}^{-1}$$

3b

| | | | | | |
|-------|----|----|----|----|---------|
| Marks | 0 | 1 | 2 | 3 | Average |
| % | 11 | 21 | 28 | 40 | 1.98 |

$$E = (35.55 - 18.23) \times 1.18 = 20.45 \text{ kJ}; \Delta H = (20.45/(1.324/180)) = 2.78 \times 10^3 \text{ kJ mol}^{-1} \text{ (+ or - one ok)}$$

3c

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 29 | 12 | 59 | 1.29 |

2; sucrose is made of two monosaccharides (2 'glucoses') (or, for example, has double the C atoms)

This question was well done. An error in 3a was not normally fatal to full results in 3b, bearing in mind that students were not further penalised in 3b for an incorrect calibration factor. This was the only question on the paper where students could be penalised for being more than plus or minus one in the correct number of significant figures.

Question 4

4a

| | | | | |
|-------|----|---|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 20 | 8 | 72 | 1.51 |

$$\text{Charge} = 4.00 \times 17.75 \times 60 = 4260 \text{ C}; n(e^-) = 4260/96\,500 = 0.0442 \text{ mol.}$$

4b

| | | | | |
|-------|----|---|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 39 | 9 | 52 | 1.13 |

$$\text{Mass of Au} = 19.3 \times 0.150 = 2.895 \text{ g}; n(\text{Au}) = 2.895/197.0 = 0.0147 \text{ mol.}$$

4ci-ii

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 25 | 18 | 57 | 1.31 |

4ci

$$0.04415/0.01470 = 3.00.$$

4cii

$$= 3 \text{ (or +3)}$$

Question 4a was well done. Question 4b was sometimes answered by using a result from 4a to give an $n(\text{Au})$ value of 1. This was then (correctly) used to give a ratio of unity and then Au^+ as the answer in 4c, thus gaining full marks for 4a. Some students possibly chose Au^+ after noting that it appeared in the electrochemical series in the Data Tables provided.

Question 5

5a

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 45 | 55 | 0.55 |

H₂O is preferentially reduced (OR H₂ is formed – but NOT just ‘Na+ is not reduced’)

5b

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 40 | 60 | 0.60 |

Achieves a lower temperature (‘use of cryolite saves energy’ is ok)

5c

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 24 | 20 | 56 | 1.31 |

Tertiary structure is needed to provide the active site (beware any repeat of the stem)

5d

| | | | | | |
|-------|----|----|----|----|---------|
| Marks | 0 | 1 | 2 | 3 | Average |
| % | 32 | 24 | 17 | 27 | 1.39 |

Tertiary structure held by H-bonds; primary structure held by covalent bonds; covalent bonding stronger than H-bonding (OR H-bonds disrupted at 100°C, but not covalent bonds (note the simple mention of ‘higher temperature disrupts tertiary structure but not primary’ is 1 mark only.)

Question 6

6a

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 18 | 13 | 69 | 1.51 |

Chemical → heat/thermal → mechanical/gas expansion/generator rotation/kinetic → electrical

6bi–ii

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 18 | 38 | 44 | 1.25 |

6bi

More energy lost in greater than one-stage process.

6bii

Higher cost of fuel cells.

Question 7

7ai–iii

| | | | | | | |
|-------|----|----|----|----|----|---------|
| Marks | 0 | 1 | 2 | 3 | 4 | Average |
| % | 41 | 18 | 16 | 14 | 11 | 1.36 |

7ai

Introduction/vaporisation of Sb sample; acceleration of ions

7aii

Electron bombardment

7aiii

Magnetic and/or electric field

7b

| | | | | |
|-------|----|----|----|---------|
| Marks | 0 | 1 | 2 | Average |
| % | 29 | 32 | 39 | 1.10 |

The relative masses and the relative abundance of each isotope; OR number of isotopes and relative atomic mass

7c

| | | | | | |
|-------|----|---|---|----|---------|
| Marks | 0 | 1 | 2 | 3 | Average |
| % | 43 | 6 | 6 | 45 | 1.53 |

$122.9041x + (1 - x)120.9038 = 121.75$; $2.0002x = 0.8462$; $x = 0.423$, $1 - x = 0.577$ thus ($^{123}\text{Sb} = 42.3\%$ and $^{121}\text{Sb} = 57.7\%$)

7d

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 85 | 15 | 0.15 |

$^{121}\text{Sb}^+$ (also accept $^{121}\text{Sb}^{2+}$ and $^{121}\text{Sb}^{3+}$ but NOT negatively charged ions)

7e

| | | | |
|-------|----|----|---------|
| Marks | 0 | 1 | Average |
| % | 23 | 77 | 0.77 |

70

7fi-ii

| | | | | |
|--------------|----------|----------|----------|----------------|
| Marks | 0 | 1 | 2 | Average |
| % | 53 | 15 | 32 | 0.79 |

7fi

Te

7fii

Sn (for interchanging the atoms)

This was a very difficult question for many students. Answers to parts 7ai and 7aii were badly answered. The less successful responses to Question 7d suggested that many students do not know that mass spectrometers normally generate positive ions.

Question 8**8a**

| | | | |
|--------------|----------|----------|----------------|
| Marks | 0 | 1 | Average |
| % | 38 | 62 | 0.62 |

Fe or Ni or (Fe + Ni)

8bi-ii

| | | | | | |
|--------------|----------|----------|----------|----------|----------------|
| Marks | 0 | 1 | 2 | 3 | Average |
| % | 17 | 15 | 21 | 47 | 1.98 |

8bi

The usual structure (3+ must be either on the Co or outside brackets).

8bii

Ion-dipole; covalent

8c

| | | | |
|--------------|----------|----------|----------------|
| Marks | 0 | 1 | Average |
| % | 51 | 49 | 0.49 |

Higher charge on Co^{3+} **8di-ii**

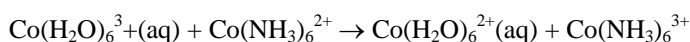
| | | | | |
|--------------|----------|----------|----------|----------------|
| Marks | 0 | 1 | 2 | Average |
| % | 52 | 39 | 9 | 0.56 |

8di

1 and 3 (also accept 2 and 3).

8dii $\text{Co}(\text{H}_2\text{O})_6^{3+}$ will react with water (higher E°).

The intended correct response to 8di was to be 1 and 3. The relative positions of these two half reaction in the electrochemical series gives the spontaneous reaction.



This shows that NH_3 spontaneously transfers from Co(II) to Co(III) in aqueous solution. The half reaction 2 and 3 was accepted since these show that, in aqueous solution in the presence of air (i.e. oxygen) $\text{Co}(\text{NH}_3)_6^{3+}$ is stable and is not converted to $\text{Co}(\text{NH}_3)_6^{2+}$.

Note: No marks to be deducted for omitting states on this paper.

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