2004 Chemistry GA 3: Written examination

GENERAL COMMENTS

The examination was clearly accessible to the majority of students, and it was pleasing to note that eleven students scored full marks. There were many good responses, although there continue to be areas of concern.

Many students had difficulty providing short, written explanations of chemical concepts. Markers sometimes found themselves in the position of trying to read the mind of a student who had written a confused and sometimes contradictory account of a question. It is often hard to know if this was primarily a problem with English expression or a lack of chemical understanding. Although markers are given clear guidelines during training, the difficulty of making fair and just judgments still remains, particularly for NESB students. Advice to such students could perhaps concentrate on the advantage of answering questions demanding written responses in point form.

Discussions that involve atomic and molecular properties must often include mention of energy considerations, as, for example, when discussing the relation of ionisation energy to core charge. Students must have at least a qualitative grasp of electrical attraction and repulsion; however, too many students did not seem to have this skill. Given that many chemistry students do not simultaneously take physics, teachers should ensure that this qualitative understanding is included, where needed, in classroom discussions.

SPECIFIC INFORMATION

Section A – Multiple-choice questions

This table indicates the number of students who chose each option. The correct answer is indicated by shading.

	A	B	C	D	Comments
Question	%	%	%	%	
1	8	80	12	0	Mass number (131) - Atomic number (53) = 78.
2	5	5	25	65	Nuclear fusion reactors are yet to be developed, so they could not, even in principle, replace existing fission reactors.
3	3	10	80	6	Combining the half reactions to eliminate the electrons gives $4Al^{3+} + 6O^{2-} + 3C \rightarrow 4Al + 3CO_2$ The only response that this can correspond to is $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$
4	24	17	13	45	One mol of CH_4 produces 900 kJ of heat. This will vaporise (900/44) = 20.5 mol of H_2O. The mass of H_2O vaporised equals 20.5 mol x 18 g mol^{-1} = 368 g. Twenty-five per cent of students gave response A, which was the mole of water vaporised.
5	10	5	8	77	The cell reaction for the fuel cell is given as $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ Subtracting the given anode half reaction from this and simplifying gives $4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$
6	11	10	72	7	One mol of CH_4 uses eight mol of electrons. This generates 8 x 96 500 C of electric charge = 7.7 x 10^5 C. This is nearest to 8 x 10^5 C.
7	52	20	15	13	Even if a student was unsure about the nature of the reaction of Ca with water, they should have known that A was correct because: • (B) – the Pt|Sn^{4+}, Sn^{2+} half cell does not require Sn • (C) – there are many soluble compounds of calcium • (D) – the half cell containing the Sn^{4+} is separated from the proposed half cell containing Ca with a salt bridge.
8	15	53	23	8	From the electrochemical series, F_2 (+2.87) and Au^+ (+1.68) will **oxidise** water to O_2 (+1.23) while the reducing agent Mg (-2.36) will **reduce** water (-0.83) to H_2 and OH^-.
9	9	14	20	57	The same mole of electricity is used to deposit silver from Ag^+ and copper from Cu^{2+}. It will therefore take two electrons to deposit one copper atom and one electron to deposit one silver atom. Hence, half a mole of copper for every mole of electrons and one mole of silver for

					each mole of electrons. Twenty per cent of students inverted the result by choosing response (C).
10	58	8	16	17	The first electron removed needs only about one tenth of that needed to remove the second electron; the ratios for first, second, third, etc. go 1 : 9.2 : 13.9 : 19.3 : 27.1. It is reasonable to conclude that the first electron is alone in an outer shell and the atom must be from Group I (or 1).
11	18	36	6	40	Since an electron is emitted by the nucleus, the mass number must remain unchanged. Because a negative charge is removed from the nucleus, the nuclear charge must increase by one unit and hence the atomic number must increase by one unit. Thirty-six per cent of students chose response (B), correctly identifying that the mass number must remain unchanged but becoming confused about the need for both the atomic number and the nuclear charge to increase.
12	18	58	19	5	An increasing atomic size will lead to a decreasing first ionisation energy and hence an increasing metallic character. Note that the core charge must remain constant within a group (A). Outer shell ionisation energies will **decrease** down a group (C) and the number of outer shell electrons remains constant within a group (D).
13	15	58	11	16	The -s^2p^5 outer shell configuration indicated an atom in group VII. It will therefore be a strong oxidant (it was chlorine). (A) is a group III atom (Al) or transition metal (Fe and Zn); these are all metals and will have reducing rather than oxidising properties.
14	15	7	51	28	The oxidation numbers of manganese in the possible responses are (A): +2, (B): +4, (C): +7 and (D): +6. The question asked for the compound with the highest oxidation number of Mn.
15	7	82	6	4	This was straight recall.
16	6	13	14	67	Many students probably solved this by inspection. The atomic mass is closer to 63 than to 65 so there must be more of ^{63}Cu than of ^{65}Cu. More precisely, 63.6 = 63x + 65(1 - *x*). Solving this equation leads to *x* = 0.7 and a ^{63}Cu : ^{65}Cu ratio of 2.3 : 1. Clearly that response 3 : 1 is the closest correct response.
17	83	4	9	4	This was another straight recall item.
18	11	10	67	12	The molar mass of glucose is 180. The condensation of glucose to form a disaccharide will lead to the loss of one water molecule (molar mass = 18) so that the molar mass of maltose is: (2 x 180) - 18 = 342.
19	2	21	73	5	Both fat and glycogen are stored in the human body, but glucose is for current use. This was a recall question.
20	78	3	1	18	This was a recall question.

Section B – Short answer questions

Question 1

Marks	**0**	**1**	**2**	**3**	**4**	**5**	**Average**
%	7	11	16	19	23	24	**3.2**

i

H_2NCONH_2 or $CO(NH_2)_2$, etc.

ii.

COOH

iii.

any one of SiO_2, P_2O_3, P_2O_5, SO_2, SO_3, Cl_2O, Cl_2O_7

iv

H_2O

v.

Fe

Formulas were required; no marks were given for names.

Many of the markers commented that this question was a very good early predictor of a student's performance on the rest of the paper.

Question 2a

Marks	0	1	Average
%	17	83	0.9

F or fluorine (the common spelling error, 'flourine', was also accepted).

2b

Marks	0	1	2	Average
%	18	16	66	1.6

Exothermic. e^- moves from higher (or 4s level/subshell) to lower (or 3s level/subshell) E level.

2c

Marks	0	1	Average
%	31	69	0.7

$1s^2 2s^2 2p^5$

Question 3a

i.

Marks	0	1	2	3	Average
%	16	12	15	57	2.2

7.43

RMM benzoic acid = 122
amount of benzoic acid = 2.50/122
= 0.0205 mol.
energy released = 0.0205 x 3227
= 66.13 kJ
calibration factor = 66.13/8.90
= 7.43 (only allow this mark if within ±1 of the correct significant figure)

ii.

Marks	0	1	2	3	Average
%	31	33	27	9	1.2

$\mathbf{2}C_7H_6O_2(\mathbf{s}) + \mathbf{15}O_2(g) \rightarrow \mathbf{14}CO_2(g) + \mathbf{6}H_2O(l); \Delta H = -6454 \text{ kJ mol}^{-1}$

One mark was given for the correct reactants, products and states (liquid or gas was ok for water); one mark was given for the correct stoichiometry of a chemically correct reaction, and the third mark for the correct magnitude and sign of a heat of reaction that is consistent with the number of mole of benzoic acid (for example, -3227 kJ mol^{-1} is ok for one mole of benzoic acid).

The most common error was forgetting to double the heat of combustion when using a balanced equation, such as the one given above. Another common error was omitting the negative sign.

3b

i.

Marks	0	1	2	Average
%	23	14	63	1.5

3.84 kJ g^{-1}

energy released = 2.21 x 5.56
= 12.29 kJ
heat of combustion of lignite = 12.29/3.20
= 3.84

ii.

Marks	0	1	Average
%	76	24	**0.3**

The first sample contains water so that some of the energy released is used to heat this extra water.

The extra water in sample 1 would absorb more heat, so the temperature would not rise quite as high as sample 2. Few students were able to produce an adequate explanation like this.

Question 4a

Marks	0	1	Average
%	68	32	**0.4**

$PbO_2 + H_2SO_4 + 2H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$

Students were not penalised for omitting 'states' when writing this equation. The most common errors were in the stoichiometry.

4b

i.

Marks	0	1	Average
%	30	70	**0.7**

2.5 x 3600 x 1.0 = 9000 kJ

ii.

Marks	0	1	Average
%	20	80	**0.9**

$2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2H_2SO_4$

iii.

Marks	0	1	Average
%	54	46	**0.5**

Greater than 12 volts (any voltage **greater** than 12 V was accepted).

Many students did not recognise that the recharging voltage must be higher that 12 volts.

Question 5a

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

$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Too many students chose to discharge sodium via $Na^+(aq) + e^- \rightarrow Na(s)$.

5b

i.

Marks	0	1	Average
%	33	67	**0.7**

$2Cl^- \rightarrow Cl_2 + 2e^-$

ii.

Marks	0	1	Average
%	40	60	**0.7**

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

5c

i.

Marks	0	1	Average
%	67	33	**0.4**

No change

Often this part of Question 5 was not attempted. Alternatively, having got Question 5a correct, some students then proposed to discharge sodium.

ii.

Marks	0	1	Average
%	55	45	**0.5**

A greater proportion of chlorine evolved (or only chlorine evolved).

This part of the question was also often not answered. Students obviously found electrolysis difficult.

Question 6a

Marks	0	1	2	Average
%	48	27	25	**0.8**

For transition metals, energies of 3d and 4s subshells are close, so electrons can be more readily lost from both/either 4s and/or 3d subshells. For Group II metals, the d (or equivalent) subshell is not close so only two outer electrons can be lost.

To get two marks both transition metals and Group II metals had to be mentioned.

While many students scored one mark in this part of Question 6, very few scored the second mark. Many students struggled to relate the many oxidation states in transition metals to the closeness of the energies of the 4s and 3d subshells and the subsequent possibility of their having many different oxidation states. One frequent error was to state that electrons were able to oscillate between the 4s and 3d subshells. After responding correctly up to this point, some students then omitted to mention the Group II metals and to identify the difference between them and the transition metals. These students received just the one mark.

6b

Marks	0	1	2	3	4	Average
%	11	9	19	27	33	**2.7**

Property	**Increases or decreases?**	**Explanation for predicted trend**
Atomic size	decreases	Increasing the core charge (nuclear charge), outer electrons are pulled closer to nucleus (emphasis on the effect of the core charge on size).
Electronegativity	increases	Increasing the core charge (nuclear charge), greater pull/attraction on outer shell electrons (emphasis on core charge on electron attracting power).

6c

i.

Marks	0	1	Average
%	38	62	**0.7**

The energy required to remove an electron (not electrons).

ii.

Marks	0	1	Average
%	46	54	**0.6**

The outermost electron in potassium is further from the nucleus than the outer shell electron in sodium and so weaker attraction (the electron is more easily removed).

Questions 6b and 6c were fairly well answered, although Question 6cii. provided some difficulty. Too many students tried to answer the question by rearranging the stem rather than moving from the increasing size to the greater distance of the outer electron from the core. Too few students seemed to have a clear enough qualitative understanding of the laws of electrostatics. Another common error was the assertion that the core charge of Na was greater than the core charge of K.

Question 7a

Marks	0	1	2	Average
%	57	29	15	**0.6**

An emission line indicates the existence of a specific energy level difference (between two electron levels); many lines allow us to deduce the existence of a range of energy levels/shells/subshells in the atom.

Question 7a was the least well answered question on the paper. A common error was to identify emission lines as energy levels rather than as an indication of a difference between two energy levels. To score a second mark in this question it was necessary to as least imply that a large number of the energy level differences were used to build up a picture of a range or set of energy levels, but few students got to that point. Only the very best students scored two marks here.

7b

Marks	0	1	2	Average
%	36	11	53	**1.2**

The same (or ‘nearly the same’). They have the same nuclear charge (or the same number of electrons).

There were some excellent answers here from students who were obviously not producing pre-learned answers.

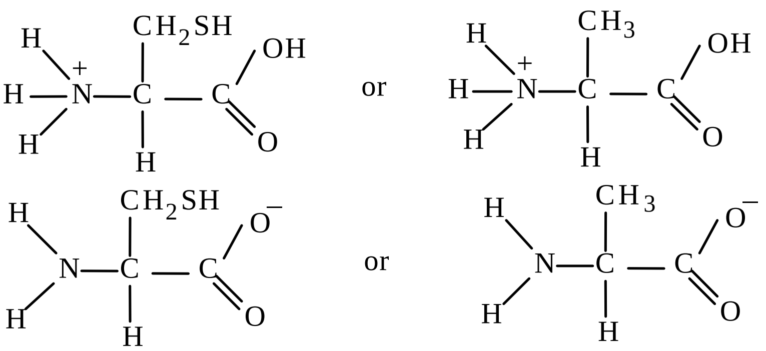
Question 8a

Marks	0	1	Average
%	23	77	**0.8**

CONH (the whole group must have been circled).

8b

Marks	0	1	2	3	Average
%	33	17	22	27	**1.5**



One mark was awarded for giving the correct structures for both amino acids, another mark for giving the correct structure at pH 2 and a third mark for giving the correct ion at pH 12. The + and - signs must have been attached to the appropriate N and O atoms respectively to gain the ‘pH’ marks.

8c

Marks	0	1	2	Average
%	31	32	37	**1.1**

- NH_4^+ (or NH_3 or NO_2^- or NO_3^-)
- bacterial fixing of nitrogen (or NH_3/Haber process, or NO/lightning flashes as appropriate).

If HNO_3 was given, no mark was awarded for the substance itself, but a ‘consequential mark’ was available for a correct description of its formation.

In general this was a well answered question, with 8c being the worst-done part. Students commonly scored only one mark here, and many had trouble describing how their chosen molecule or ion was actually made from nitrogen.

Question 9a

i.

Marks	0	1	2	Average
%	30	24	45	1.2

Energy per 35 g of biscuit = 3.7x16 + 0.9x37 + 26x17
= 543.7 kJ
Energy per gram = 534.7/35
= 15kJ

Note: 594/17 was the result if cellulose was included.

ii.

Marks	0	1	Average
%	67	33	0.4

Cellulose provides extra energy in the calorimeter.

Surprisingly, many students who had carefully omitted using the mass of cellulose fibre from the calculation of the energy in Question 9ai., thereby obtaining the correct answer, then seemed unable to put that choice into words in 9aii.

9b

i.

Marks	0	1	2	Average
%	33	4	63	1.4

Hydrophilic (or polar) and hydrophobic (or non-polar) groupings.

ii.

Marks	0	1	2	Average
%	49	22	28	0.9

$C_3H_8O_3 + 3CH_3(CH_2)_{16}COOH \rightarrow C_{57}H_{110}O_6 + 3H_2O$

One mark was given for showing 3x water, and another for the correct formula or structure of triglyceride.

iii.

Marks	0	1	2	Average
%	33	12	55	1.3

- Saturated
- There are no carbon-carbon double bonds.

$CH_2—O—CO—(CH_2)_{16}CH_3$
|
$CH—O—CO—(CH_2)_{16}CH_3$
|
$CH_2—O—CO—(CH_2)_{16}CH_3$

Questions 9bi. and 9biii. were quite well done. However, in Question 9bii., too many students forgot about the water altogether or were unable to construct the triglyceride molecule.