Chemistry CAT 3: Written examination

GENERAL INFORMATION

Areas of study

1. Supplying and using energy
2. Food chemistry
3. The Periodic Table: an overview of chemistry

Criteria

1. Knowledge of the key areas
2. Understanding of the key issues and chemical principles
3. Application of chemical concepts to explain observations
4. Interpretation of experimental data
5. Knowledge of experimental procedures and techniques
6. Understanding of experimental procedures and techniques
7. Competency in performing calculations

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Area of Study
Q1 (12 marks)	*	*	*					3
Q2 (5 marks)	*	*	*	*		*		3
Q3 (7 marks)	*		*					2
Q4 (6 marks)	*	*	*					2
Q5 (10 marks)	*	*	*	*	*		*	1,2
Q6 (6 marks)	*	*	*	*	*	*	*	1
Q7 (7 marks)	*	*			*	*		1
Q8 (6 marks)	*	*	*	*				1,3
Q9 (7 marks)	*	*	*					1,3

Total = 66 marks
Note the balance of the paper:

1. Supplying and using energy 38%
2. Food chemistry 27%
3. The Periodic Table: an overview of chemistry 35%

SPECIFIC INFORMATION

Question-by-question details

Question 1

a. (3) (i) Chlorine* (Cl, Cl_2 both acceptable)
(ii) The response should make the following two points: core charge increases across the period* the greater the core charge, the more strongly the outer electron clouds are attracted*

b. (2) (i) Any *three* * of silicon, phosphorus, sulfur and chlorine (must be completely correct to obtain the mark – two only, or the inclusion of an inappropriate element, score zero)
(ii) Silicon *(Si) (This is the only correct answer)

c. (3) (i) strongest oxidant – chlorine* (Cl, Cl_2 both acceptable) strongest reductant – sodium* (Na is acceptable)
(ii) $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$* (must be balanced to obtain the mark)

d. (4) (i) Any one of the following:
SiO_2*(s) + H_2O(l) ® H_2SiO_3(aq) *(for whole equation; or + $2H_2O \rightarrow H_4SiO_4$)
$P_2O_3(s) + 3H_2O(l) \rightarrow 2H_3PO_3(s)$ or (aq)
$P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(l)$ or (aq)
$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
$SO_3(l) + H_2O(l) \rightarrow H_2SO_4(l)$
$Cl_2O(g) + H_2O(l) \rightarrow 2HOCl(aq)$
$Cl_2O_7(l) + H_2O(l) \rightarrow 2HClO_4(aq)$
(Accept also if the acid is shown in dissociated form, e.g. $\rightarrow H^+(aq) + ClO_4^-(aq)$)
(ii) Any one of the following:
Na_2O*(s) + $H_2O(l) \rightarrow 2NaOH(aq)$ *(for whole equation)
$Na_2O_2(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2O_2(aq)$
$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$
(Accept also if base is shown in dissociated form, e.g. $\rightarrow Mg^{2+}(aq) + 2OH^-(aq)$)

Si was accepted as both a non-metal and a 'metalloid'. Either SO_2 and SO_3 was the almost universal choice of an acidic oxide, with Na_2O as the (almost) sole basic oxide. A small oportion of students interchanged 'oxidant' and 'reductant' and no mark was awarded when this occurred.

Question 2

a. (3) The response should make at least three of the following points:
*result shows that atoms are mostly 'free space'
*result shows that there must be a small concentrated mass of positive charge causing the occasional µ-particle to bounce back
free space must contain the electrons (possibly orbiting the nucleus)
these observations were contrary to the then current 'plum pudding' model of the atom

b. (2) Any two of:
*protons and neutrons in nucleus
*electrons are in constant motion around nucleus
*electrons arranged in shells around nucleus
*electrons arranged in shells and subshells
*electron spin

Reasonably well done. Some tolerance was shown for certain obvious English language difficulties. However, to achieve full marks, the required points had to be unambiguously made.

Question 3

a. (3) The following letters are the circled answers

Protein	**B, C, J**
Carbohydrate	**B, C**
Fat	**B, C**

b. (4) The following letters are the circled answers

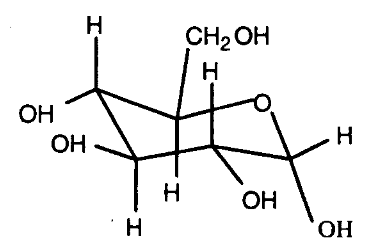
Carbon*	**B**
Hydrogen*	**C, (G)**
Oxygen*	**B, (C), (H)**
Nitrogen*	**G, H**

CO_2(B) is the source of all the oxygen absorbed by a plant during photosynthesis. However, H_2O(C) should also be accepted as a correct response if it is given as well as B, as also should NO_3^-(H). Thus the correct response for oxygen is either B alone; or B and C; or B, C and H. For hydrogen, NH_4^+ should also be accepted in addition to H_2O.

A question that should have been simple enough, but was surprisingly badly done.

Question 4

a. (3) (i) Carbohydrate*
(ii) During digestion, the above compound is hydrolysed. Sketch the products of this hydrolysis.



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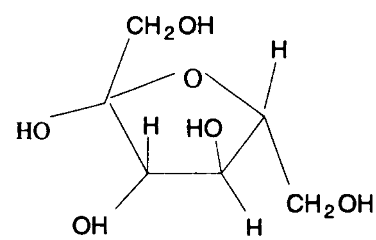

*

Note that the important point is to show that the –O– is converted to –OH HO– by hydrolysis. If this was correctly shown diagrammatically, we gave one mark. Two marks were given for a reasonable go at copying the correct structures – as well as anything that was obviously a simple mis-transcription.

b. (3) (i) To stabilise a food (e.g butter) in a colloidal form that allows water and oil components to mix.*
(ii) The lecithin molecule has both hydrophilic* ($-O^-$, $-N^+(CH_3)_3+$ – one of these must be included or explicitly referred to in the example given) and hydrophobic* ($-(CH_2)_{16}CH_3$) parts. One mark for simply referring to the terms 'hydrophobix' and 'hydrophilic' – the other mark for identifying both these parts of the molecule.

Although markers were to be 'tolerant' of mis-transcriptions of the structures in the regions away from the reaction centre, this did not extend to tolerating a six-membered ring where a five-membered ring was wanted!

The reasons for adding emulsifiers to food were limited in most cases to the standard 'stops oil and water components unmixing'.

Question 5

a. (3) Calibration factor

$$= \frac{\text{electrical energy deposited *}}{\text{temperature rise}}$$
$$= \frac{7.50 \times 1.35 \times 5.00 \times 60}{25.90 - 24.63}$$
$$= \frac{3037.5}{1.27}$$
$$= 2392 JK^{-1} *$$

(One mark for calculating the correct temperature rise, one for the correct general formula, –1 for >4 sig figs!)

b. (2) Energy content of biscuit

$$= \frac{\text{Energy released *}}{2.63}$$
$$= \frac{(24.63 - 23.76) \times 2.392}{2.63}$$
$$= \frac{0.87 \times 2.392}{2.63}$$
$$= 0.791 kJg^{-1}$$

c. (1) Incomplete digestion*

d. (1) Cannot define number of mole of biscuit because it's a mixture of many substances*

e. (3) Temperature rise

$$= \frac{\text{energy released *}}{\text{calibration factor}}$$
$$= \frac{0.055 \times 890\,000}{16 * \times 3550}$$
$$= 0.862 K *$$

(One mark for correct general formula, one for calculating no. of mole of methane)

The error first noted a couple of years ago where students confused the temperature rise of the calibration step with the overall temperature rise when the reaction step and calibration steps are carried out in a non-traditional order (i.e. reaction first, calibration second) is still prevalent.

Question 6

a. (3) Charge on copper ion

$$= \frac{\text{mole of electrons passed *}}{\text{mole;of copper deposited}}$$
$$= \frac{3.00 \times 2200 \times 63.5}{96\,500 * \times 4.40}$$
$$= \frac{0.068}{0.069}$$

= 1.0; i.e. the copper (I) ion has a charge of +1*

b. (3) Ag deposition C*
Pb deposition D*
Cr deposition E*

A few ingenious students assumed the ion was Cu^{2+}, and then calculated an expected value of the Faraday constant, observed that it was out by a factor of 2 and concluded (correctly) that the ion was really Cu^{+}....

Question 7

a. (3) (i) Show Zn in $Zn(NO_3)_2$ and Ag in $AgNO_3$ * (all or nothing)
(ii) Zn → Ag*
(iii) any strong electrolyte not containing a halide or hydroxide ion* (be tolerant of SO_4^{2-})

b. (3)

	Equation for half reaction	Electrode (cathode or anode?)
Oxidation	$Zn(s)$ ® $Zn^{2+}(aq) + 2e^{-}$*	anode*
Reduction	$Ag^{+}(aq) + e^{-}$ ® $Ag(s)$*	cathode

One mark only for the anode-cathode pair – both must be correct to gain the mark.

c. (1) $2Ag^{+}(aq) + Zn(s) \rightarrow 2Ag(s) + Zn^{2+}(aq)$*

A predictable range of responses.

Question 8

a. (5) (i) $4Cr^{2+}(aq) + O_2(g) + 4H^{+}(aq) \rightarrow 4Cr^{3+}(aq) + 2H_2O(l)$** (one for getting the identity of the products and reactants correct – two if correctly balanced)
(ii) $Cr^{3+}(aq) + 3OH^{-}(aq) \rightarrow Cr(OH)_3(s)$*
(iii) $2Cr^{2+}(aq) + 2H^{+}(aq) \rightarrow 2Cr^{3+}(aq) + H_2(g)$*
credit should also be given for:
$2Cr^{2+}(aq) + 2H_2O(l) \rightarrow 2Cr^{3+}(aq) + H_2(g) + 2OH^{-}(aq)$*
(iv) ligand substitution* (no equation required, but one may be used to correctly answer this part)

b. (1) $1s^22s^2p^63s^2p^6d^54s^1$* OR $1s^22s^2p^63s^2p^6d^44s^2$* (the first is correct, but is not required by the study structure, so the second version will be accepted)

The real discriminator. Some students who incorrectly dealt with this question had near-perfect well-drilled responses to the rest of the paper; a small minority had quite ordinary responses on the rest of the paper and simply sailed through this potentially simple question. And there was a smaller group of students who were both well-drilled AND able to deal with a non-standard question.

Question 9

a. (3) The response should make at least three of the following points:
*Excitation involves an electron going to a higher energy level
*Emission spectra result from the electron dropping from a high to a low energy state
*Many different energy levels are available to the electron in the H atom
*Each energy level may be associated with a different line in a complex spectrum
*Energy difference is related to wavelength of emitted radiation (e.g. $E = h\nu$)

b. (1) Nuclear binding energy* OR nuclear fusion* OR conversion of mass into energy*

c. (1) $4\,^{1}H_{1}$ ® $^{4}He_{2}$ + 2e* (don't insist on a clear indication that the electron is a positive electron or positron)

d. (2) The following points should be made in the answer – full marks for any two:

*Heavy elements are synthesised deep inside large stars

*Heavy elements are made from lighter elements by nuclear fusion

*Large stars explode distributing the heavy elements widely

*planets like Earth condense from material containing some of the residue of an exploded star

A predictable range of responses.

Note that 'Food chemistry' occupied a little less than one-third of the paper. The examination setting panel justifies this on the grounds that the content of this section is significantly less than the content in the other two sections. A similar judgment has been made over several years now regarding the 'Surface chemistry' section in Unit 3.