Grading Standards
Chemistry 3202
June 2007

Pre-Marking Appraisal

The examination was considered fair and had sufficient coverage of each unit of study and each level of cognitive learning.

Post Marking Report

Marking Standard and Consistency

Marker reliability was checked by obtaining a random sample of 50 papers that went through the marker panel and marks were assigned to each question on a separate sheet of paper. The 50 exams were put back into the original stack of exams and corrected again when they appeared. The two values were compared and if there were discrepancies, the chief marker would review the scoring with the individual marker.

Throughout the marking process there were statistical analysis ran on item data to enhance reliability and consistency of marking.

Each marker also made on-going notes regarding partial marks and scoring for their particular question. Whenever a non-common error occurred, it was scored by consensus of the board and made note of, for scoring consistency.

Summary

Overall performance in the Chemistry 3202 examination improved in June 2007 compared to that of June 2006. As in past years performance was lower for items that assessed outcomes at higher cognitive levels. It is important that students be exposed to higher order questioning throughout the year.

Very often it appeared students did not read questions carefully and critically.

Commentary on Responses

Part I - Selected Response - Total Value: 50%

Item #39: Students did not perform well on this item. Students may have interpreted pathway to mean type of reaction or confused the terms dependent and independent.

Item #23: Students did not perform well on this item. Students may have missed the term “final” or the term “pipette”.

Item #50: Students did not perform well on this item. Most students calculated the oxidation value, but did not recognize they were asked for the reduction value.

Part II - Constructed Response - Total Value: 50%

Value
6% 51.(a) Use the table below to answer the following questions.

Reaction Mechanism	Rate	ΔH (kJ)
$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$	very fast	−116
$2\ NO_2(g) \rightarrow 2\ NO(g) + 2\ O(g)$	very slow	−175
$2\ O(g) + 2\ O_2(g) \rightarrow 2\ O_3(g)$	slow	88

(i) What is the enthalpy for the overall reaction?

Answer:
ΔH = (- 116 kJ) + (- 175 kJ) + (88 kJ) = - 203 kJ **1 mark**

Common Errors
Students:
- made addition mistakes.
- transposed numbers from the table into the calculation.

(ii) Identify the reaction intermediate(s) and/or catalyst(s) present.

Reaction Intermediate(s):

Answer: NO_2 & O **1 mark**

Catalyst(s):

Answer: NO **1 mark**

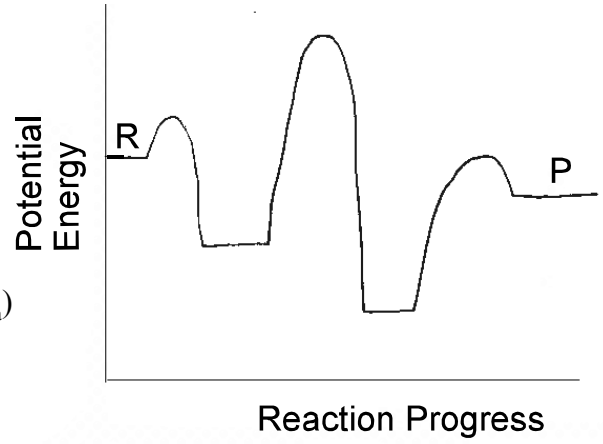
Common Error
Students gave NO_2 and O as the catalysts and NO as the reaction intermediate.

(iii) Sketch a clearly labelled potential energy diagram for this reaction mechanism.

Answer:

3.0 marks:

(0.5 marks) label axes
(0.5 marks) overall exo
(0.5 marks) step 1 & 2 exo;
(0.5 marks) step 3 endo
(0.5 marks) step 2 slow (high E_a)
(0.5 marks) 3 humps



Common Errors

Students:

- missed the endothermic 3rd step.
- identified 2nd step as RDS.
- failed to draw diagram identifying each step as exothermic and endothermic.

Value

3% 51.(b) All Canadian automobiles are equipped with catalytic convertors to improve air quality.

(i) Using the mechanism below for ozone production, describe how catalytic convertors decrease ground level ozone concentrations.

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$

$$2\ NO_2(g) \rightarrow 2\ NO(g) + 2\ O(g)$$

$$2\ O(g) + 2\ O_2(g) \rightarrow 2\ O_3(g)$$

Answer: Catalytic convertors remove NO. **1 mark**

Looking at mechanism, removal of NO decreases the amount of

NO_2 produced (Step 1). Less NO_2 means less atomic O (step 2).

There is less atomic O to react with O_2 to form O_3 (ozone). **1 mark**

Common Errors

Students:

- thought that the three steps were taking place in the convertor.
- explained the three steps and ended up saying that O_3 is formed.
- linked the word catalytic convertor to catalyst and said that NO was the convertor.

(ii) Describe one way to improve the design of a catalytic convertor that will increase its ability to reduce air pollution.

Possible Answers: - even larger surface area

- new catalyst developed to adsorb pollutants

1 mark - for any one improvement

Common Errors

Students:

- suggested using a honeycomb shape which is already in the convertor.
- suggested making it bigger with no reference to surface area.

Value

4% 51. (c) The system below is at equilibrium.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) + \text{energy}$$

(i) If the gases are in a sealed container, explain the effect increasing the volume would have on the equilibrium position.

Answer: Increasing volume means decreasing pressure. **0.5 mark**s

Le Chatelier predicts the system will try to increase pressure by shifting

to produce more gas molecules. **0.5 marks**

Shift left (favors reverse rxn) **1 mark**

Reactants increase; products decrease.

Common Errors

Students:

- omitted stating the shift or stating a decrease in pressure explanation.
- stated that there is an increase in pressure (not a decrease).

(ii) Explain what effect increasing the temperature of the reaction vessel would have on the value of K_{eq} for this reaction.

Answer: Forward reaction is exothermic.

Increase in temperature, LCP predicts the system will try to decrease temp

by shifting to use up energy.

Shift left (favors reverse rxn) **1 mark explanation**

The value of K will decrease. **1 mark**

Common Errors

Students:

- did not state or give an explanation of the equilibrium being exothermic.
- predicted the incorrect direction of shift.
- did not state the change in "K" or stated the incorrect change in "K".

Value

4% 52.(a) A primary standard of $Na_2CO_3(s)$ is used to determine the concentration of a hydrochloric acid solution. In the first trial a solution containing 0.5012 g of $Na_2CO_3(s)$ required 21.35 mL of HCl(aq) to reach the equivalence point.

$2\ HCl(aq) + Na_2CO_3(s) \rightarrow H_2O(\ell) + CO_2(g) + 2\ NaCl(aq)$

(i) Based on this trial, what is the concentration of HCl(aq)?

Answer:

n (Na_2CO_3) = m/M = 0.5012 g / 105.99 g/mol = 0.004728(7) mol **1 mark**

$$n(HCl) = 0.004728(7)\ mol \times \frac{2\ mol\ HCl}{1\ mol\ Na_2CO_3} = 0.009457(5)\ mol$$ **0.5 marks**

c (HCl) = n/v = 0.009457(5) mol/ 0.02135 L = 0.4430 mol/L **0.5 marks**

Science communication skills **1 mark**

Common Errors

Students:

- calculated molar mass incorrectly.
- calculated the moles of HCl instead of moles of Na_2CO_3.
- omitted the mole ratio step.

(ii) Why is it important to perform more than one trial?

Possible Answers: - consistency of results

1 mark - for any one reason

Value

2% 52. (b) What is happening at a molecular level, to explain why the pH of 1.0 mol/L $CH_3COOH(aq)$ is greater than the pH of 1.0 mol/L $H_2COOH(aq)$?

Answer:

At equal concentrations, CH_3COOH having the higher pH means it is the weaker acid. **1 mark**

At the molecular level, weaker means that it is less ionized, thus less H_3O^+ and higher pH. **1 mark**

Commentary on Response

The chemical formula "$H_2COOH(aq)$"contained a typo and should have been "HCOOH(aq)". This typo had no impact on student answers.

Common Errors

Students:

- confused low vs high pH vs $[H_3O^+]$.
- considered CH_3COOH / H_2COOH to be a conjugate acid/base pair.
- considered triprotic/diprotic nature of acids.
- considered bond type and bond numbers.
- considered collision theory, bond theories, intermolecular forces (LDF, D-D, H-bonding).
- considered number of H with more H being the stronger acid.

Value

4% 52.(c) Ethylamine is a weak base that ionizes according to the reaction below. Calculate the percent ionization of a 0.500 mol/L solution of ethylamine if its K_b is 4.27×10^{-4}.

$$C_2H_5NH_2(aq) + H_2O(\ell) \rightleftharpoons C_2H_5NH_3^+(aq) + OH^-(aq)$$

Answer:

	$C_2H_5NH_2$	$\rightleftharpoons$	$C_2H_5NH_3^+$	OH^-
I	0.5		0	0
C	$-x$		$+x$	$+x$
E	$0.500 - x$		$+x$	$+x$

(1 mark)

Assume $0.500 - x \sim 0.500$ **(0.5 marks)**

check $\dfrac{[C_2H_5NH_{2i}]}{K_b} = \dfrac{0.500}{4.27\times10^{-4}} = 1171 > 500$ assume good **(0.5 marks)**

$$K = \frac{[C_2H_5NH_2][OH^-]}{[C_2H_5NH_2]} = \frac{x^2}{0.500} = 4.27\times10^{-4}$$ **(0.5 marks)**

$$x = \sqrt{(4.27\times10^{-4})(0.500)} = 1.46\times10^{-2}$$ **(0.5 marks)**

$$\%\,ionization = \frac{[\ ]_{change}}{[\ ]_{initial}}\times100\% = \frac{x}{0.500}\times100\% = \frac{0.0146}{0.500}\times100\% = 2.91\%$$ **(1 mark)**

Common Errors

Students:

- omitted ICE table of reasoning the relationship of species.
- omitted qualifying assumption and/or check.
- calculated % ionization improperly; used [change] / [equilibrium] or [equilibrium] / [initial].
- solved the quadratic incorrectly if they chose to use it.

Value

4% 52. (d) The table below shows the results of tests performed on four 0.10 mol/L unknown solutions at 25 °C. Explain how this data can be used to identify which solution is $NH_3(aq)$, and which solution is NaOH(aq).

Solution	Conductivity of Solution	Color with Thymolphthalein
A	good	blue
B	good	colourless
C	poor	colourless
D	poor	blue

Answer:

NH_3 is a weak base; **(0.5 marks)**

weak indicates poor conductivity **(0.5 marks)**

base indicates thymolphthalein will be blue **(0.5 marks)**

answer is solution D **(0.5 marks)**

NaOH is a strong base; **(0.5 marks)**

strong indicates good conductivity **(0.5 marks)**

base indicates thymolphthalein will be blue **(0.5 marks)**

answer is solution A **(0.5 marks)**

Common Error

Students:

- assumed that if one is a base the other must be an acid (especially NH_3).
- described one species and not the other.
- commented on the information in the table but did not link it to one species or the other.

Value

3% 53.(a) 5.50 g of NaOH(s) is dissolved in 175 mL of water in a coffee cup calorimeter. If the temperature of the water increased by 2.1 °C, calculate the molar heat of solution for NaOH(s).

Answer:

D (H_2O) = 1.00 g/mL thus m (H_2O) = 175 g

c (H_2O) = $c_{aq\ soln}$

$q_{system} = - q_{surroundings}$

$q_{NaOH} = - q_{aq\ soln}$

$= - mc\Delta T$

$= - (5.50\ g + 175\ g)\ (4.184\ J/g°C)\ (2.1°C)$

$= - (180.(5)\ g)\ (4.184\ J/g°C)\ (2.1°C)$

$= - 15(86)\ J$ **(2 marks)**

$$n = \frac{m}{M} = \frac{5.50g}{40.00\text{g/mol}} = 0.137(5)\ \text{mol}$$ **(0.5 marks)**

$$\Delta H = \frac{q}{n} = \frac{-1586}{0.137(5)\ \text{mol}} = -12000\text{J or } -12\text{kJ}$$ **(0.5 marks)**

Note:

Students who did not find the mass of the aqueous solution by adding the mass of NaOH and the mass of water were not penalized. Using the mass of water alone for the surroundings was also accepted for full marks.

Common Errors

Students:

- calculated the concentration from the mass of NaOH and volume of water, then they used that value in the equation $q = mc\Delta T$.
- did not make q_{system} value negative.

Value

3% 53. (b) Calculate the total energy required to heat 225 g of H_2O from −25.0 °C to 80.0 °C. (c_{ice} = 2.01 J/g·°C)

Answer:

$q_1 = mc_s\Delta T$ = (225 g) (2.01 J/g·°C) (0.0°C - (-25.0°C)) = 113(06) J **(0.5 marks)**

$q_2 = n\,\Delta H_{fus} = \frac{225\text{ g}}{18.02\text{ g/mol}} \times 6.02\text{ kJ/mol} = 75.1(7)\text{ kJ}$ **(1 mark)**

$q_3 = mc_\ell\Delta T$ = (225 g) (4.184 J/g·°C) (80.0°C - 0.0°C)) = 753(12) J **(0.5 marks)**

ΔE_{total} = 11.3(1) kJ + 75.1(7) kJ + 75.3(1) kJ = 161.8 kJ **(1 mark)**

Common Errors

Students:

- did not recognize this as a heating curve question and did only one calculation; $q = mc\Delta T$.
- used the wrong ΔH value.
- used the wrong ΔT or calculated as $T_{initial} - T_{final}$.
- tried to do it as a calorimetry question using negatives ($q_{system} = - q_{surr}$).

Value

3% 53. (c) Using the data below, calculate ΔH for

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

Bond	Average Bond Energy (kJ)
H–H	436
N≡N	945
N–H	360

Answer:

$$N \equiv N + 3\ H\text{-}H \rightarrow 2\ \begin{array}{c} H\text{-}N\text{-}H \\ | \\ H \end{array}$$

$$1 \times N \equiv N + 3 \times H\text{-}H \rightarrow 6 \times N\text{-}H$$

$\Delta H = \Sigma BE_{reactants} - \Sigma BE_{products}$

$= [(1 \times 945) + (3 \times 436)] - [(6 \times 360)]$ **1.5 marks**

$= [945 + 1308] - [2160]$

$= 2253 - 2160$

$= 93$ kJ **0.5 marks**

Science communication skills **1 mark**

Common Errors

Students:

- used incorrect structure for NH_3; often tried to put the 2 NH_3's together with a triple bond.
- subtracted the sum of reactants from the sum of the products.
- added all bond energies together.
- tried to do using heats of formation as zero for N_2 and H_2.

Value

4% 53.(d) Using the data below, calculate the enthalpy change for the following reaction.

$$2\ N_2(g) + 5\ O_2(g) \rightarrow 2\ N_2O_5(g) \qquad \Delta H = ?$$

Answer:

x 2	$N_2(g) + 3\ O_2(g) + H_2(g) \rightarrow 2\ HNO_3(\ell)$		$\Delta H = -87.1$ kJ
x -2	$N_2O_5(g) + H_2O(\ell) \rightarrow 2\ HNO_3(\ell)$		$\Delta H = -76.6$ kJ
x -2	$\frac{1}{2}\ O_2(g) + H_2(g) \rightarrow H_2O(\ell)$		$\Delta H = -285.8$ kJ
	$2\ N_2(g) + 6\ O_2(g) + 2\ H_2(g) \rightarrow 4\ HNO_3(\ell)$		$\Delta H = -174.2$ kJ **(1 mark)**
	$4\ HNO_3(\ell) \rightarrow 2\ N_2O_5(g) + 2\ H_2O(\ell)$		$\Delta H = +153.2$ kJ **(1 mark)**
	$2\ H_2O(\ell) \rightarrow O_2(g) + 2\ H_2(g)$		$\Delta H = +571.6$ kJ **(1 mark)**

$$2\ N_2(g) + 5\ O_2(g) \rightarrow 2\ N_2O_5(g) \qquad \Delta H = 550.6 \text{ kJ}$$

(1 mark)

Common Errors

Students:

- manipulated the equations, but did not include enthalpy values.
- multiplied 3rd equation by 10.
- did not include equation manipulations.
- failed to change signs of the enthalpy values.
- tried to use the heat of formation equation to solve for ΔH.

Value

3% 54.(a) Under acidic conditions, balance the redox reaction below.

$$Ag_2O + Si \rightarrow Ag + SiO_3^{2-}$$

Answer:

$2\ e^- + 2\ H^+ + Ag_2O \rightarrow 2\ Ag + H_2O$] x 2 **(1 mark)**

$3\ H_2O + Si \rightarrow SiO_3^{2-} + 6\ H^+ + 4\ e^-$ **(1 mark)**

$4\ e^- + 4\ H^+ + 2\ Ag_2O \rightarrow 4\ Ag + 2\ H_2O$ **(0.5 marks)**

$3\ H_2O + Si \rightarrow SiO_3^{2-} + 6\ H^+ + 4\ e^-$

$2\ Ag_2O + H_2O + Si \rightarrow 4\ Ag + SiO_3^{2-} + 2\ H^+$ **(0.5 marks)**

Common Errors

Students:

- did not balance silver atoms.
- did not multiply by LCM.
- placed electrons on the wrong sides of the half reactions.
- tried to balance as if it was not redox.
- tried to balance without breaking it into half reactions.
- tried to balance using basic conditions (OH^-).
- did not use the correct number of electrons to balance charge.
- dissociated Ag_2O and/or SiO_3^{2-}.

Value

4% 54.(b) An electrolytic cell has a zinc strip anode and a zinc strip cathode placed in a solution of zinc sulfate. A current of 0.500 A is supplied for 900.0 seconds.

(i) What mass of zinc is electroplated?

Answer:

Zn plates at the cathode: $Zn^{2+} + 2\ e^- \rightarrow Zn$

$Q = I\ t = (0.500\ A)\ (900.0\ s) = 450\ C$ **(0.5 marks)**

$$n(e^-) = \frac{Q}{F} = \frac{450C}{96500C/mol\ e^-} = 0.00466(3)\ mol\ e^-$$ **(0.5 marks)**

$$n(Zn) = 0.00466(3)\ mol\ e^- \times \frac{1\ mol\ Zn}{2\ mol\ e^-} = 0.00233(2)\ mol$$ **(0.5 marks)**

$m\ (Zn) = n \times M = (0.00233(2)\ mol)\ (65.38\ g/mol) = 0.152\ g$ **(0.5 marks)**

Science communication skills **(1 mark)**

Common Errors

Students:

- did not find moles of Zn from moles of electrons using the mole ratio.
- multiplied by the inverse ratio.

(ii) Explain one reason why the actual observation could be less than the predicted value.

Possible Answers: - current does not remain constant

- wire resistance

- some plated zinc lost in transfer

1 mark - for any one explanation

Common Error

Students gave too general an answer (e.g., human error).

Value

3% 54. (c) Three different elements were combined with solutions of their anions. The results are shown in the table below.

Element	Anion		
	$A^-(aq)$	$B^-(aq)$	$C^-(aq)$
A	-	no reaction	no reaction
B	reaction	-	reaction
C	reaction	no reaction	-

Which is the correct order of anions from strongest to weakest reducing agent? Explain.

Answer:

$\longrightarrow$

strongest *weakest*

$A^- \rightarrow C^- \rightarrow B^-$ **(1 mark)**

A^- is oxidized (loss e^-; reducing agent) twice - both B and C

C^- is oxidized once - only B

B^- is not oxidized at all - neither A or C **(2 marks)**

Common Errors

Students:

- answered from the point of view of elements not anions.
- assumed elements are oxidizing, thus reducing agents (e.g., thinking they are metals).
- omitted the negative sign on the anion when listing the strongest to weakest.

TABLE 1
CHEMISTRY 3202 ITEM ANALYSIS
SELECTED RESPONSE (PART I)

Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
1	D	8.1	2.0	4.2	85.6
2	C	19.0	3.2	74.4	3.3
3	A	37.9	4.6	28.3	28.9
4	D	1.9	14.7	1.0	82.4
5	C	0.1	2.1	97.1	0.8
6	B	4.1	85.1	10.0	0.9
7	B	14.3	66.7	12.0	7.0
8	B	27.9	66.9	3.4	1.6
9	C	0.1	20.8	69.4	9.6
10	C	25.1	4.6	60.2	9.8
11	C	13.0	13.6	58.3	15.0
12	C	11.0	26.3	52.8	9.3
13	C	8.5	13.9	67.5	10.0
14	C	30.2	3.1	64.1	2.6
15	D	3.8	16.2	9.3	70.6
16	B	6.2	67.6	4.4	21.8
17	D	12.4	17.7	15.9	53.7
18	A	66.4	2.7	21.5	9.2
19	B	10.6	63.9	14.6	10.8
20	D	20.7	9.9	9.6	59.6
21	B	11.0	58.5	11.7	18.9
22	C	1.7	1.0	96.3	0.9
23	A	16.3	22.5	59.5	1.7
24	A	42.6	13.1	26.1	17.9
25	A	57.0	26.8	5.7	10.4

Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
26	B	9.9	76.8	3.0	10.3
27	B	31.2	58.7	6.8	3.2
28	C	11.9	0.8	75.1	12.1
29	B	3.2	70.3	25.0	1.5
30	B	1.7	80.6	14.7	3.0
31	D	28.7	30.5	5.9	34.7
32	C	14.8	17.5	56.6	11.1
33	D	30.0	7.4	6.7	55.9
34	A	94.8	2.0	2.5	0.7
35	C	10.3	18.6	38.5	32.3
36	A	91.8	5.5	1.1	1.7
37	C	2.5	12.3	75.9	9.2
38	B	8.4	63.6	4.6	23.0
39	D	3.1	4.8	64.9	27.1
40	A	63.0	13.6	10.4	12.7
41	D	2.3	2.0	30.7	64.9
42	A	54.4	13.4	13.9	18.1
43	B	9.5	64.3	21.5	4.5
44	B	9.2	68.1	8.0	14.6
45	C	13.8	23.6	55.3	7.1
46	A	64.8	29.9	2.8	2.3
47	C	16.9	6.2	69.8	6.9
48	D	25.1	10.7	24.0	40.1
49	D	15.9	18.7	12.5	52.8
50	B	5.3	36.5	49.4	8.5

NOTE: Percentages may not add to 100% due to multiple responses or missing values.

TABLE 2
CHEMISTRY 3202 ITEM ANALYSIS
CONSTRUCTED RESPONSE (PART II)

Item	Students Completing Item	Value	Average
51.(a)	2079	6	4.4
51.(b)	2079	3	0.6
51.(c)	2079	4	2.0
52.(a)	2079	4	3.1
52.(b)	2079	2	0.6
52.(c)	2079	4	2.4
52.(d)	2079	4	1.9
53.(a)	2079	3	1.6
53.(b)	2079	3	1.7
53.(c)	2079	3	2.4
53.(d)	2079	4	3.2
54.(a)	2079	3	1.8
54.(b)	2079	4	2.3
54.(c)	2079	3	1.7