Chemistry 3202
Grading Standards
June 2005

Pre-Marking Appraisal

The June 2005 chemistry exam was considered a fair exam, well designed, and of reasonable length and difficulty. There were no problems highlighted with any of the questions.

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.

Summary

The provincial average of the Chemistry 3202 exam decreased marginally in June 2005 from 2004. This decrease was caused mainly by poor performance on Core Lab and Core STSE items. It is essential that teachers emphasize the importance of these components of the course in their daily instruction.

Science communication skills were evaluated for the first time on the Chemistry 3202 provincial examination. Three marks in part II of the exam were given for science communication skills. Students generally performed well on this part of the exam.

The questions that dealt with Core Lab and Core STSE outcomes were done poorly.

PART II
Total Value: 50%

Constructive Response/Common Errors

Value

4% 51.(a) Use the table below to answer the following questions.

Reaction Mechanism	ΔH
$Fe^{3+} + H_2O_2 \rightarrow FeOH^{3+} + HO$	- 286.1 kJ
$HO + H_2O_2 \rightarrow H_2O + HO_2$	+ 270.4 kJ
$FeOH^{3+} + HO_2 \rightarrow Fe^{3+} + H_2O + O_2$	- 556.7 kJ

(i) Write the equation for the overall net reaction. **(1 mark)**

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

(ii) Identify reaction intermediate(s) and/or catalyst(s) present. **(2 marks)**

Reaction Intermediate(s): $FeOH^{3+}$, HO, HO_2

Catalyst(s): Fe^{3+}

(iii) What is the enthalpy for the overall reaction? **(1 mark)**

-572.4 kJ

Commentary on Response:

- This item was done very well.

Common Errors:

- Students did not properly balance the equation because Fe^{3+} was left in the overall net equation.
- Students identified Fe^{3+} as a reaction intermediate.

Value

2% 51.(b) The system below is at equilibrium.

$$H_2CO(g) \rightleftarrows CO(g) + H_2(g) \qquad \Delta H = 5.36 \text{ kJ}$$

What effect would increasing the temperature have on the value of K_{eq} for this reaction? Justify your answer.

Answer

According to Le Châtelier's Principle, increasing the temperature causes the equilibrium to shift right. This increases the concentration of products and decreases the concentration of reactants. Since K_{eq} is calculated by dividing the concentration of products by the concentration of reactants, K_{eq} will increase.

(1 mark)	*K_{eq} increases*
(1 mark)	*equilibrium shifts right, causing the concentration of products to increase and the concentration of reactants to decrease, thereby increasing K_{eq}*

Commentary on Response:

- This item was done well.

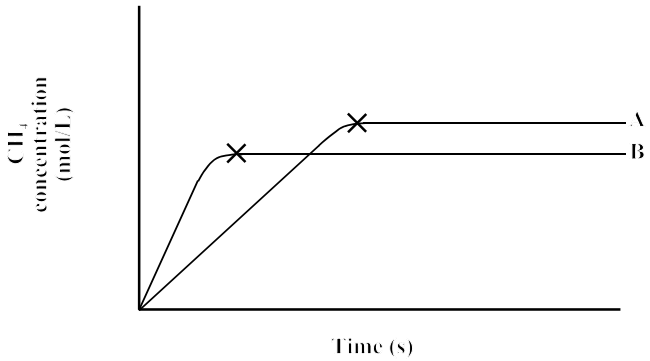
Common Errors:

- Students stated heat as a reactant.

Value

4% 51.(c) Mixtures of hydrogen gas and carbon monoxide are placed in two separate flasks. One flask is at 1000.0 °C and the other is at 1200.0 °C. The graph below shows the change in methane concentration over time for each flask.

$$3\,H_2(g) + CO(g) \rightleftarrows CH_4(g) + H_2O(g) \qquad \Delta H = -206\ kJ$$



(i) Mark an "X" on each line in the graph, where equilibrium is first established. **(½ mark for each X) See diagram.**

(ii) Which temperature condition, 1000.0 °C or 1200.0 °C, is represented by line A in the graph? Provide two reasons for your answer.

Answer

Line A represents the reaction which occurs at 1000.0 °C because this line represents an equilibrium that is reached later than the equilibrium represented by line B. **(1 mark)**

At lower temperatures, reactions proceed slower and therefore an equilibrium takes longer to be established. **(1 mark)**

For line A, the equilibrium concentration of CH_4 is greater than in line B. Given the reaction is exothermic, and according to Le Châtelier's Principle, you would expect a greater concentration of CH_4 at a lower temperature. **(1 mark)**

Commentary on Response:

- This item was done well.

Common Errors:

- Students marked "X" at the intersection of both lines**.**
- Students did not relate concentration of CH_4 to Le Châtelier's Principle**.**
- Students only gave one reason**.**

Value

3% 51.(d) The equilibrium below occurs when nitrogen monoxide is placed in a closed container and decomposes.

$$2\ NO(g) \rightleftarrows N_2(g) + O_2(g)$$

When 0.250 mol of NO(g) is placed in a sealed 1.0 L container at a particular temperature, 40.0% of it decomposes. Calculate the equilibrium constant at this temperature.

(0.250) *x* (0.400) = 0.100 mol of NO react

(2 marks)

	$2\ NO(g) \rightleftarrows N_2(g) + O_2(g)$		
I*nitial*	0.25	0	0
C*hange*	-0.1	0.05	0.05
E*quilibrium*	0.15	0.05	0.05

(1 mark)

$$Keq = \frac{[N_2][O_2]}{[NO]^2}$$

$$= \frac{(0.050)(0.050)}{(.150)^2} = 0.11$$

Commentary on Response:

- This item was done poorly.

Common Errors:

- Students used the ICE table incorrectly, particularly in recognizing the mole ratios.
- Students determined the Keq equation incorrectly.

Value

4% 52.(a) Calculate the pH of a 0.025 mol/L solution of nitrous acid given the K_a for $HNO_2(aq)$ is 7.2×10^{-4}.

	$HNO_2(aq)$	+ $H_2O(\ell)$ $\rightleftarrows$	$H_3O^+(aq)$	+ $NO_2^-(aq)$
I	0.025	-	0	0
C	- x	-	+ x	+ x
E	0.025 - x	-	x	x

(1 mark)

(1 mark) $K_a = \frac{x^2}{0.025 - x} = 7.2 \times 10^{-4}$

$x^2 = 1.8 \times 10^{-5} - 7.2 \times 10^{-4} x$

(½ mark) $x^2 + 7.2 \times 10^{-4} x - 1.8 \times 10^{-5} = 0$

(½ mark) $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{(-7.2 \times 10^{-4}) \pm \sqrt{(7.2 \times 10^{-4})^2 - 4(1)(-1.8 \times 10^{-5})}}{2}$

(½ mark) $x = \frac{-7.2 \times 10^{-4} \pm 8.516 \times 10^{-3}}{2} = 3.897 \times 10^{-3} = [H_3O^+]$

(½ mark) $pH = -\log[3.897 \times 10^{-3} \text{ mol/L}] = 2.41$

Commentary on Response:

- This item was done moderately well. The majority did check to see if solving the quadratic was necessary. Many, however, made the wrong assumption.

Common Errors:

- Students did not use an ICE table.
- Students made sign errors when rearranging the K equation in quadratic form.
- Students made the incorrect assumption that the quadratic was not necessary.

Value

3% 52.(b) The concentration of a solution of arsenic acid, $H_3AsO_4(aq)$ is determined by titrating it with sodium hydroxide, NaOH(aq).

(i) Write the equation for the overall reaction.

students did not have to show the individual steps

$$H_3AsO_4(aq) + OH^-(aq) \rightarrow H_2AsO_4^-(aq) + HOH(\ell)$$

$$H_2AsO_4^-(aq) + OH^-(aq) \rightarrow HAsO_4^{2-}(aq) + HOH(\ell)$$

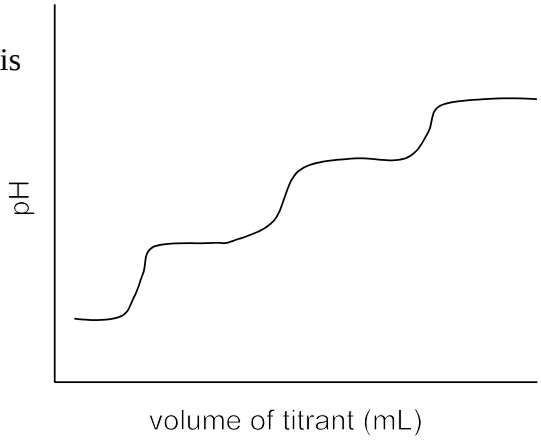
$$HAsO_4^{2-}(aq) + OH^-(aq) \rightarrow AsO_4^{3-}(aq) + HOH(\ell)$$

(1 mark)

$$H_3AsO_4(aq) + 3\,OH^-(aq) \rightarrow AsO_4^{3-}(aq) + 3HOH(\ell)$$

(ii) Draw and label a titration curve for the complete titration.

(1 mark) - labelled axis



(1 mark) - curve

Commentary on Response:

- This item was done poorly.

Common Errors:

- Students did not recognize that the acid was triprotic and did a monotropic transfer.
- Students did not balance the overall reaction.
- Students wrote the wrong formula for $Na_3AsO_4(aq)$**.**
- Students labelled axes incorrectly.
- Students drew the curve for a base being titrated with acid**.**

Value

4% 52.(c) A titration was performed by adding 0.115 mol/L NaOH(aq) to a 25.00 mL sample of H_2SO_4(aq). Using the data below, calculate the concentration of H_2SO_4(aq).

reading (mL)	Trial 1	Trial 2	Trial 3
final reading	17.05	28	39
initial reading	4	17.05	28
volume added	13.05	10.95	11

(1 mark) $H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(\ell)$

25.0 mL 0.115 mol/L

c 10.975 mL (average of two closest readings, trial 2 and 3)

(1 mark) $$n_{NaOH} = c \times V = (0.115\,{}^{mol}\!/_{L}) \times (0.010975\,L) = 0.00126\,mol$$

$$n_{H_2SO_4} = \frac{n_{NaOH}}{2} = \frac{0.00126}{2} = 0.000631\,mol$$

(1 mark) $$c_{H_2SO_4} = \frac{n}{V} = \frac{0.000631}{0.02500} = 0.0252\,{}^{mol}\!/_{L}$$

(1 mark) Science Communication Skills (i.e., proper use of units, formulae and significant figures.)

Commentary on Response:

- This item was done well. Most students received full marks for science communication skills.

Common Errors:

- Students balanced equation incorrectly.
- Students averaged all three trials instead of the two closest.
- Students did not use mole ratio.
- Students reversed the volumes of the acid and the base.

Value

2% 52.(d) The table below shows the results of tests performed on four 0.10 mol/L unknown solutions. Use this data to determine which solution is NaOH(aq) and which is NaCl(aq). Justify your answer.

Solution	Conductivity of Solution	Colour with Bromothymol Blue
A	good	blue
B	good	yellow
C	good	green
D	poor	blue

(1 mark) *NaOH(aq) is a strong base, with 100% dissociation, therefore it is a good conductor and turns blue when bromothymol is added. It is therefore solution A*

(1 mark) *NaCl(aq) is neutral, with 100% dissociation, therefore it is a good conductor and turns green when bromothymol is added. It is therefore, solution C.*

Commentary on Response:

- This item was done poorly. The green color of bromothymol blue was confusing for many students.

Common Errors:

- Students did not recognize that bromothymol blue in a neutral solution would be a shade of color between yellow and blue (e.g., green).
- Students' justifications for their choices were incorrect.

Value

2% 52.(e) A piece of magnesium is placed in both hydrochloric acid, HCl (aq), and acetic acid, CH_3COOH (aq), according to the information below. Compare both reactions in terms of reaction rate and amount of hydrogen gas produced. Justify your answer.

Reaction 1
$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + 2\ H_2(g)$
5.0 g Mg
150 mL of 0.10 mol/L acid

Reaction 2
$Mg(s) + 2\ CH_3COOH(aq) \rightarrow Mg(CH_3COO)_2(aq) + 2\ H_2(g)$
5.0 g Mg
150 mL of 0.10 mol/L acid

Answer

Reaction 1 is faster because it contains HCl(aq), which is a strong acid, and reaction 2 contains $CH_3COOH(aq)$, which is a weak acid. The same amount of $H_2(g)$ is produced in both reactions both reactions ultimately consume the same amount of reactants.

(½ mark)	reaction 1 is faster
(½ mark)	HCl(aq) is a strong acid whereas $CH_3COOH(aq)$ is a weak acid
(½ mark)	same amount produced
(½ mark)	the amount of reactants are the same

Commentary on Response:

- This item was done well.

Common Errors:

- Students did not realize that HCl(aq) is a strong acid and $CH_3COOH(aq)$ is a weak acid.
- Students did not compare the amounts H_2 gas produced.

Value

2% 53.(a) A butane torch can be used to determine the heat capacity of antifreeze. Butane, C_4H_{10}, has a molar heat of combustion of 802.3 kJ/mol. List the laboratory equipment and the data needed to determine the specific heat capacity of antifreeze solution.

(1 mark) *Lab Equipment:* *any two of the following: tin can, antifreeze, balance, butane torch, ...*

(1 mark) *Data needed:* *any two of the following: initial and final temperature of antifreeze, specific heat capacity of antifreeze, mass of torch before and after, molar mass C_4H_{10}, mass of antifreeze*

Commentary on Response:

- This item was done very well.

Common Errors:

- none

4% 53.(b) Calculate the enthalpy change for the following reaction:

$4\ HCl(g) + O_2(g) \rightarrow 2\ Cl_2(g) + 2\ H_2O(g)$

Given the following information:

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$	$\Delta H = -185$ kJ	- 185 kJ
$H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(\ell)$	$\Delta H = -285.8$ kJ	- 285.8 kJ
$H_2O(g) \rightarrow H_2O(\ell)$	$\Delta H = 40.7$ kJ	+ 40.7 kJ

Answer

$4\ HCl(g) \rightarrow 2\ H_2(g) + 2\ Cl_2(g)$	$\Delta H = +340$ kJ	**(1 Mark)**
$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell)$	$\Delta H = -571.6$ kJ	**(1 Mark)**
$2\ H_2O(\ell) \rightarrow 2H_2O(g)$	$\Delta H = -81.4$ kJ	**(1 Mark)**
Enthalpy	$\Delta H = -282$ kJ	**(1 Mark)**

Commentary of Response:

- This item was done very well. Many students received full marks.

Common Errors:

- Students did not account for the last step in the overall equation.

Value

2% 53.(c) A 1.50 g sample of granola bar is placed in a bomb calorimeter with a heat capacity of 10.2 kJ/ºC. When the bar is completely burned the temperature of the calorimeter and its contents increased by 3.10 ºC. What is the fuel value of the bar?

(½ mark) $q = C\Delta t = (10.2\ {}^{kJ}\!/\!_{{}^{o}C})(3.10\ {}^{o}C) = 31.62\ kJ$

(½ mark) $fuel\ value = \frac{energy}{mass} = \frac{31.62\ kJ}{1.50\ g} = 21.1\ {}^{kJ}\!/\!_{g}$

(1 mark) Science Communication Skills (i.e., proper use of units, formulae and significant figures.)

Commentary on Response:

- This item was done poorly. Most students only completed the first calculation required.

Common Errors:

- Students used q = mcΔT instead of q = CΔT.
- Students did not know how to calculate fuel value.

Value

4% 53.(d) The reaction below shows the combustion of ethyne.

$$C_2H_2\,(g) + 2\,O_2(g) \rightarrow 2\,CO_2(g) + H_2O(\ell)$$

(i) Use the bond energies in the table below to calculate the molar heat of reaction for ethyne.

Bond	Energy (kJ)
O – H	460
C – H	338
C ≡ C	891
C = O	745
O = O	498

$$C_2H_2\,(g) + 2\,O_2(g) \rightarrow 2\,CO_2(g) + H_2O(\ell)$$

	H - C ≡ C - H	O = O	O = C = O	H - O - H
	891 kJ +2(338 kJ)	2(498 kJ)	4(745 kJ)	2(460kJ)
(1 Mark)	1567 kJ	996 kJ	2980 kJ	920 kJ

(1 mark)

$$\Delta H_{rxn} = \sum H(bond\ breakage) - \sum H(bond\ formation)$$
$$= BE\ (reactants) - BE\ (products)$$
$$= 3900\ kJ - 2563\ kJ = -1337\ kJ$$

Commentary on Response:

- This item was fairly well done.

Common Errors:

- Students did not take coefficients into account.
- Students did not recognize the triple bond.

Value

(ii) A calorimetry experiment performed by a student determined the molar heat of this reaction to be -1289 kJ/moL. Give two reasons why there is a difference in the ΔH value obtained from calorimetry and the value obtained from bond energies?

Answer

There is a difference in the ΔH value obtained from calorimetry and the value obtained from bond energies because bonding energies are an average bond energy and are not exact (e.g., all C-H bonds in CH_4 are not equal, however only the average bond energy is reported). Also, when performing a calorimetry experiment, experimental error most likely occurs that will produce a different value.

(1 mark)	bond energies are based on averages
(1 mark)	experimental error

Commentary on Response:

- This item was done poorly.

Common Errors:

- Students did not understand that bond energies is an average of a particular bond in many different molecules.

Value

4% 54.(a) What is the mass of magnesium produced by the electrolysis of molten magnesium chloride, $MgCl_2$, if a 250.0 mA current passes for 1.50 hours?

(1 mark) $Q = It = (0.250\ mA)(5400\ s) = 1350$

(1 mark) $1350 \div 96\ 500 = 0.0139896\ mol\ e^-$

(1 mark) $0.0139896\ mol\ e^- \div 2 = 6.9948 \times 10^{-3}\ mol\ Mg = 0.170\ g$

(1 mark) Science Communication Skills (i.e., proper use of units, formulae and significant figures.)

Commentary on Response:

- This item was fairly well done.

Common Errors:

- Students did not convert mA to A.
- Students did not use a mole ratio to find the moles of Mg, instead stated that moles of electrons equals moles of Mg.
- Students calculated mass using the molar mass of $MgCl_2$ instead of Mg.

Value

4% 54.(b) Balance the redox reaction below for basic conditions.

$$MnO_4^-(aq) + CN^-(aq) \rightarrow MnO_2(s) + OCN^-(aq)$$

(1 mark) $MnO_4^-(aq) + 4\ H^+(aq) + 3\ e^- \rightarrow MnO_2(s) + 2\ H_2O(\ell)$

(1 mark) $CN^-(aq) + H_2O(\ell) \rightarrow OCN^-(aq) + 2\ H^+(aq) + 2\ e^-$

(½ mark) $2\ MnO_4^-(aq) + 8\ H^+(aq) + 6\ e^- \rightarrow 2MnO_2(s) + 4\ H_2O(\ell)$

(½ mark) $3\ CN^-(aq) + 3\ H_2O(\ell) \rightarrow 3\ OCN^-(aq) + 6\ H^+(aq) + 6\ e^-$

(½ mark) $2\ MnO_4^-(aq) + 3\ CN^-(aq) + 2\ H^+(aq) \rightarrow 2MnO_2(s) + 3\ OCN^-(aq) + H_2O(\ell)$

$2\ MnO_4^-(aq) + 3\ CN^-(aq) +$ (2 $H^+(aq)$ + 2 $OH^-(aq)$) $\rightarrow 2MnO_2(s) + 3\ OCN^-(aq) + H_2O(\ell) + 2\ OH^-$

(2 $H^+(aq)$ + 2 $OH^-(aq)$) $\rightarrow$ 2 $H_2O(\ell)$

(½ mark) $2\ MnO_4^-(aq) + 3\ CN^-(aq) + H_2O(\ell) \rightarrow 2MnO_2(s) + 3\ OCN^-(aq) + 2\ OH^-(aq)$

Commentary on Response:

- This item was done fairly well**.**

Common Errors:

- Students did not separate the two half reactions.
- Students balanced electrons incorrectly.
- Students balanced for acidic solution and not basic solution (i.e., omitted the last step).
- Students did not simplify the final answer (i.e., left H_2O as a reactant and product).

Value

2% 54.(c) Pyrometallurgy and hydrometallurgy are methods of isolating metals from its ore. Which of these processes would you propose for a new nickel smelter being built in Newfoundland and Labrador? Justify your answer.

Answer

Pyrometallurgy - any two of the following: efficient, inexpensive, proven technology readily available

Hydrometallurgy - any two of the following: fewer impurities in solution, no $SO_2(g)$ produced thereby limiting the amount of acid rain, byproduct (sulfuric acid) is marketable

(1 mark for each justification)

Commentary on Response:

- This item was done poorly. Most students attempted this question but answered incorrectly. It was obvious from responses that students were "guessing". Many students stated on the exam that they were not taught this concept.

Common Errors:

- Students did not understand the difference between the two or the environmental concerns of each.
- Students indicated a process without justifying it.

CHEMISTRY 3202 ITEM ANALYSIS
SELECTED - RESPONSE (PART I)

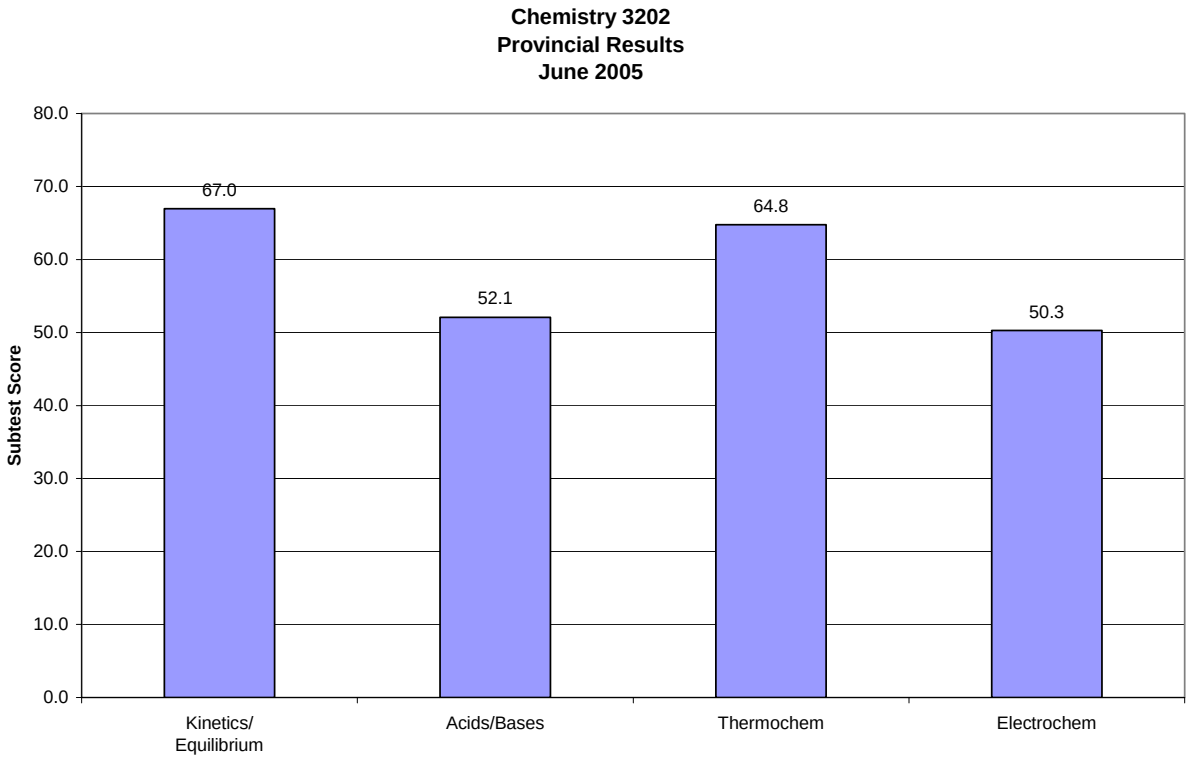
Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
1	B	5.4	84.4	4.3	5.7
2	C	0.8	1.5	90.1	7.6
3	A	48.8	32.3	1.6	17
4	A	68.9	14.1	2.3	14.6
5	B	1.7	59.1	29.7	9.5
6	B	6.2	63.8	18.6	11.3
7	C	3.9	3.8	61.4	30.7
8	A	72.3	15.2	4.6	7.9
9	A	19.4	45.4	22.4	12.5
10	B	2.5	65.1	21.4	10.9
11	B	12.2	83.3	3.4	1.2
12	C	8.5	4	76.8	10.7
13	D	5.5	1.2	6.2	87.1
14	B	3	76.9	13.5	6.6
15	B	8.3	82.8	2.4	6.4
16	D	10.2	4.9	57.5	27.3
17	C	3.3	4	49.2	43.3
18	D	17.1	4.8	11	67
19	C	5.9	12.8	72.4	8.8
20	D	2.5	1.5	0.6	95.4
21	C	18	20.1	31.5	30.4
22	D	3.9	22.5	44.6	28.7
23	A	84.2	5.8	4.8	5
24	A	13.6	37.5	31.6	17.1
25	D	8.3	30.5	6.9	54.3

Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
26	B	18.8	56.5	15.6	8.8
27	A	80.4	12.4	4.6	2.6
28	B	1.4	72.2	2.1	24.2
29	B	6	76.5	12.5	5.1
30	C	9.6	30.2	57.2	2.9
31	B	18.6	54.6	16	10.7
32	D	12.2	3.7	35.3	48.8
33	D	7.6	24.1	7.7	60.2
34	B	4.5	83.1	8.6	3.2
35	C	1.6	1.3	95.7	1.3
36	B	13	79.7	7.2	0.1
37	C	10.4	19.7	53.8	16
38	A	80.2	3	11.2	5.5
39	A	45.2	20.2	14.2	20.3
40	B	53.9	19.2	13.8	13
41	C	35.3	18.1	32.9	13.6
42	B	3	57.5	37	2.4
43	D	27.7	3.6	18.4	50.3
44	A	46.6	32	15.9	5.3
45	A	51.8	12.4	16.3	19.3
46	C	8.9	11	71.4	8.6
47	C	13.4	25.3	48.9	12.1
48	B	10.7	43.7	11.7	33.2
49	A	84.1	13.4	1.5	0.9
50	B	6.4	55.3	18.4	19.4

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

CHEMISTRY 3202 ITEM ANALYSIS
CONSTRUCTED - RESPONSE (PART II)

Item	Students Completing Item	Value	Average
51.(a)	2095	4	3.4
51.(b)	2095	2	1.3
51.(c)	2095	4	2.5
51.(d)	2095	3	1.6
52.(a)	2095	4	2.3
52.(b)	2095	3	0.6
52.(c)	2095	4	2
52.(d)	2095	2	0.7
52.(e)	2095	2	1
53.(a)	2095	2	1.5
53.(b)	2095	4	3.1
53.(c)	2095	2	1
53.(d)	2095	4	2.4
54.(a)	2095	4	2.1
54.(b)	2095	4	2.3
54.(c)	2095	2	0.2


Chemistry 3202
Provincial Results
June 2005
Subtest Score
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
67.0
52.1
64.8
50.3
Kinetics/ Equilibrium
Acids/Bases
Thermochem
Electrochem