

Chemistry 3202 Grading Standards June 2004

Pre-Marking Appraisal

The June 2004 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 was statistical analysis run on item data to enhance reliability and consistency of marking.

Summary

This was the first provincial examination for the new program in Chemistry 3202. The unit distribution and format of the exam was a good representation of the course and should be continued in future years.

PART II
Total Value: 50%

Value

2% 51(a) For faster relief, why should antacid medication be chewed rather than swallowed whole? Explain.

- chewing increases surface area more collisions between antacid and acid
- collision frequency ↑, successful collisions ↑ (faster relief)

Commentary on Response:

This question was generally well done.

Common Errors:

Those who scored 1 out of 2 did mention surface area increased but did not mention frequency of collisions.

2% 51(b) Initially 4.00 mol of HCl(g) and 4.00 mol of $\text{O}_2\text{(g)}$ were placed in a 2.00 L vessel and allowed to establish equilibrium. If at equilibrium, the vessel contained 0.500 mol of $\text{Cl}_2\text{(g)}$, what is the value of K_{eq} ?

$$C_{\text{O}_2} = C_{\text{HCl}} = \frac{n}{v} = \frac{4.00\text{mol}}{2.00\text{L}} = 2.00\text{M} \qquad C_{\text{Cl}_2} = \frac{n}{v} = \frac{0.500\text{mol}}{2.00\text{L}} = 0.250\text{M}$$

	$2 \text{HCl(g)} + \text{O}_2\text{(g)} \rightleftharpoons \text{H}_2\text{O}_2\text{(g)} + \text{Cl}_2\text{(g)}$			
I	2.00	2.00	0	0
C	-0.500	-0.250	+0.250	+0.250
E	1.50	1.75	+0.250	+0.250

$$\begin{aligned}
 K_{\text{eq}} &= \frac{[\text{H}_2\text{O}_2][\text{Cl}_2]}{[\text{HCl}]^2[\text{O}_2]} \\
 &= \frac{(0.250)(0.250)}{(1.50)^2(1.75)} = 0.0159 \text{ or } 1.59 \times 10^{-2}
 \end{aligned}$$

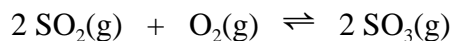
Commentary on Response:

This question was done well.

Common Errors:

- Students improperly set up the ICE table.
- Students did not properly convert values to concentrations.
- Students did not correctly write the K_{eq} expression.

51(c) 1 mol each of $\text{SO}_2(\text{g})$ and $\text{O}_2(\text{g})$ are placed in a 1.0L reaction vessel and allowed to reach equilibrium. The concentrations of the reactants and products after various time periods are shown in the data table below.



Reaction Time (min.)	$[\text{SO}_2]$ mol/L	$[\text{O}_2]$ mol/L	$[\text{SO}_3]$ mol/L
0.0	1.00	1.00	0.00
1.0	0.86	0.93	0.14
2.0	0.76	0.88	0.24
3.0	0.68	0.84	0.32
4.0	0.64	0.82	0.36
5.0	0.64	0.82	0.36
6.0	0.64	0.82	0.36

2% 51(c)(i) When was equilibrium established? Justify your answer.

at $t = 4.0$ min conc. stopped changing

Commentary on Response:

The question was done very well.

Common Errors:

None

Value

3% 51(c)(ii) Compare the forward and reverse reaction rates at 2.0 minutes? Explain.

At 2.0 min. the system still hasn't reached equilibrium. Initially there are only reactants in the reaction flask so the forward reaction is faster than the non-existent reverse reaction (there are more collisions between reactants). The forward reaction slows down as the reactants are consumed and the reverse reaction speeds up as products are produced. In this case (starting with only reactants) the forward reaction will always be faster than the reverse until equilibrium is reached.

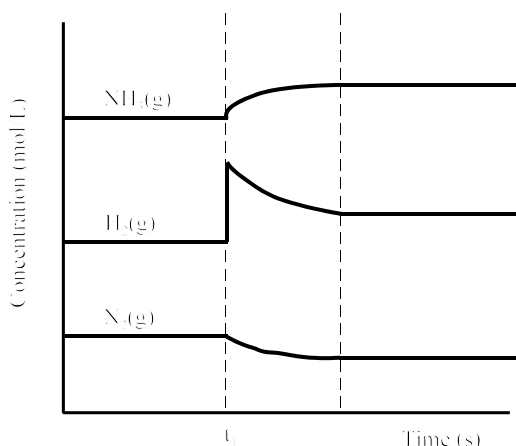
Commentary on Response:

This question was done poorly.

Common Errors:

- Students recognized that the forward reaction rate was faster but struggled in justifying their answer.

3% 51(d) The equilibrium concentrations for $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ are graphed below. More $\text{H}_2(\text{g})$ is added to the system at time t_1 . Extend the graph to show how the concentrations of $\text{N}_2(\text{g})$, $\text{H}_2(\text{g})$ and $\text{NH}_3(\text{g})$ will change until a new equilibrium is established.



Students had to show:

- increase in H_2 and then a decrease in H_2 with a final H_2 concentration higher than original
- increase in NH_3
- decrease in N_2
- all concentrations leveling off at the same time

Note: Ensuring concentration changes were in the correct stoichiometric proportions was not considered in the marking

Commentary on Response:

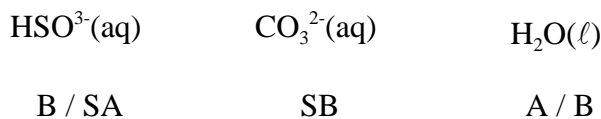
Most students received partial marks because they extended the graph properly for NH_3 and N_2 .

Common Errors:

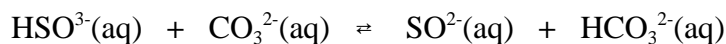
- Students did not properly show the change which occurred in the H_2

- 3% 52(a) Aqueous solutions of lithium hydrogen sulfite (LiHSO_3) and sodium carbonate (Na_2CO_3) are mixed. Write the balanced acid-base reaction indicating which is favoured, products or reactants.

1 mark – listing acids, bases, strong acid, strong base



1 mark - balanced reaction



1 mark - indicating that products are favoured

Commentary on Response:

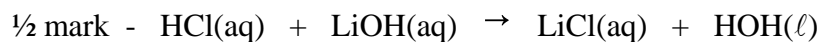
This question was not well done. Students who listed ions and identified the strongest acid and base before writing the equation did well

Common Errors:

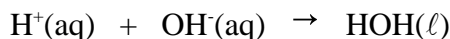
- Students treated the reaction as a double replacement reaction and failed to identify B-L reaction.
- Students often lost half mark for not using equilibrium arrows.

Value

3% 52(b) What is the resulting pH when 20.0 mL of 0.33 mol/L HCl(aq) are mixed with 30.0 mL of 0.15 mol/L LiOH (aq)?



OR



$$\frac{1}{2} \text{ mark} \quad n\text{HCl} = n\text{H}_3\text{O}^+ = c \cdot v = (0.33 \text{ mol/L})(0.0200 \text{ L}) = 0.0066 \text{ mol}$$

$$\frac{1}{2} \text{ mark} \quad n\text{LiOH} = n\text{OH}^- = c \cdot v = (0.15 \text{ mol/L})(0.0300 \text{ L}) = 0.0045 \text{ mol}$$

$\frac{1}{2}$ mark - 0.0045 moles OH^- neutralizes 0.0045 moles H_3O^+ leaving excess 0.0021 moles H_3O^+

$$\begin{array}{r} \text{OR} \quad 0.0066 \text{ mol H}_3\text{O}^+ \\ - \quad 0.0045 \text{ mol OH}^- \\ \hline 0.0021 \text{ mol H}_3\text{O}^+ \text{ in excess} \end{array}$$

$$1 \text{ mark} - c = \frac{n}{v_{\text{total}}} = \frac{0.0021 \text{ mol H}_3\text{O}^+}{0.0500 \text{ L}} = 0.042 \text{ mol/L H}_3\text{O}^+$$

$$\frac{1}{2} \text{ mark} - \text{pH} = -\log[\text{H}_3\text{O}^+] = 1.38$$

Commentary on Response:

This question was done well.

Common Errors:

- Students did not write the balanced chemical equation.
- Students who calculated moles in excess used them to calculate pH, omitting the calculation of concentration.
- Students used the excess moles of HCl and the volume of HCl to calculate the new concentration not the new volume.
- Students missed the point of the question and used the [HCl] (0.33 mol/L) to calculate pH.
- Students calculated moles improperly.

Value

4% 52(c) What is the pH of a 0.159 mol/L solution of a weak acid, HA(aq), given the K_a for the acid of 6.9×10^{-9} ?

	HA(aq) + HOH(ℓ) \rightleftharpoons H ₃ O ⁺ (aq) + A ⁻ (aq)			
I	0.159	-	0	0
C	- x	-	+ x	+ x
E	0.159 - x	-	x	x

½ mark - equation

1 mark - ICE table properly completed

½ mark for justification in not using quadratic equation.

Because $\frac{[HA]}{K_a} = 2.3 \times 10^7$ then we can assume $x \ll 0.159$ and

$$0.159 - x = 0.159.$$

1½ marks

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = 6.9 \times 10^{-9} = \frac{(x)(x)}{0.159}$$

$$x^2 = 1.097 \times 10^{-9}$$

$$x = 3.31 \times 10^{-5} = [H_3O^+]$$

½ mark

$$\text{pH} = -\log[H_3O^+] = 4.48$$

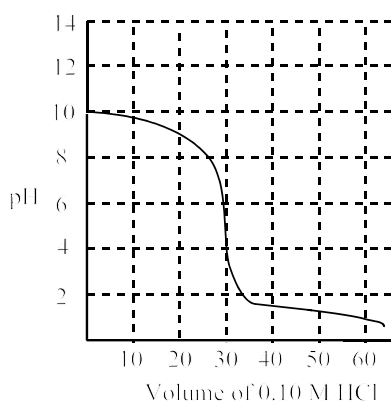
Commentary on Response:

This question was done poorly.

Common Errors:

- Students did not write the acid dissociation equation.
- Students did not do a check to see if they could forgo solving the quadratic.
- Students did not write the K_a expression using the reaction terms; they used x (never showing what x was equal to).

52(d)(i) The graph below shows the titration of a 0.10 M unknown base with 0.10 M HCl.



2%

What is a suitable indicator for this titration? Justify your choice.

Either of the following indicators were acceptable:

Bromocresol green (3.8 - 5.4)

Methyl red (4.8 - 6.0)

Methyl orange (3.2 - 4.4)

Chlorophenyl red (5.2 - 6.8)

Justification: endpoint range ~3 - 7 (or endpoint is ~5)
∴ colour change must occur within these limits

Commentary on Response:

This question was well done.

Common Errors:

- Students did not justify answers properly

2% 52(d)(ii) Is the unknown base weak or strong? Explain.

Weak base

WB + SA - pH of end pt < 7

Commentary on Response:

This question was well done.

Common Errors:

- Students were confused with the difference between a strong and weak base

Value

3% 53(a) A 0.910g sample of sucrose, $C_{12}H_{22}O_{11}$, (Molar Mass = 342.34 g/mol) is burned in a bomb calorimeter and the temperature of the calorimeter and contents increased from 22.5 °C to 27.5 °C. If the heat capacity of the calorimeter and contents was 4.50 kJ/°C, calculate the molar heat of combustion of sucrose.

½ mark -

$$nC_{12}H_{22}O_{11} = \frac{0.910 \text{ g}}{342.34 \text{ g/mol}} = 2.66 \times 10^{-3} \text{ mol}$$

½ mark - $\Delta T = T_f - T_i = 27.5 \text{ °C} - 22.5 \text{ °C} = 5.0 \text{ °C}$

2 marks -

$$q_{\text{rxn}} = -q_{\text{cal}}$$

$$n\Delta H = -C\Delta T$$

$$\Delta H = \frac{-C\Delta T}{n} = \frac{-(4.50 \text{ kJ/°C})(5.0\text{°C})}{2.66 \times 10^{-3} \text{ mol}} = -8500 \text{ kJ/mol}$$

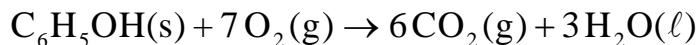
Commentary on Response:

This question was well done.

Common Errors:

- Students did not use negative sign.

- 53(b) When a 2.00 g sample of pure phenol, $\text{C}_6\text{H}_5\text{OH(s)}$, is burned according to the equation below, 65.0 kJ of heat is released.



2%

- (i) Calculate the molar heat of combustion for phenol.

½ mark -

$$n\text{C}_6\text{H}_5\text{OH} = \frac{2.00 \text{ g}}{94.12 \text{ g/mol}} = 2.12 \times 10^{-2} \text{ mol}$$

1 ½ marks -

$$\Delta H = \frac{q}{n} = \frac{-65.0 \text{ kJ}}{2.12 \times 10^{-2} \text{ mol}} = -3070 \text{ kJ/mol}$$

Commentary of Response:

This question was well done.

Common Errors:

- Students did not use negative sign

- 3% (ii) Using the data below, calculate the standard heat of formation, ΔH_f° , of phenol.

Substance	Standard heat of Formation $\Delta H_f^\circ, (\text{kJ} / \text{mol})$
$\text{C}_6\text{H}_5\text{OH(s)}$?
$\text{CO}_2(\text{g})$	-394
$\text{H}_2\text{O}(\ell)$	-286

½ mark $\Delta H_f^\circ \text{O}_2 = 0$

1½ marks

$$\begin{aligned} \Delta H_{\text{comb}}^\circ &= \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants} \\ \Delta H_{\text{comb}}^\circ &= (n\Delta H \text{CO}_2 + n\Delta H \text{H}_2\text{O}) - (n\Delta H \text{C}_6\text{H}_5\text{OH} + n\Delta H \text{O}_2) \\ -n\Delta H \text{C}_6\text{H}_5\text{OH} &= \Delta H_{\text{comb}}^\circ - (n\Delta H \text{CO}_2 + n\Delta H \text{H}_2\text{O}) \\ &= -3070 \text{ kJ} - (6 \cdot -394 \text{ kJ} + 3 \cdot -286 \text{ kJ}) \\ &= -3070 \text{ kJ} + 3222 \text{ kJ} \end{aligned}$$

Commentary on Response:

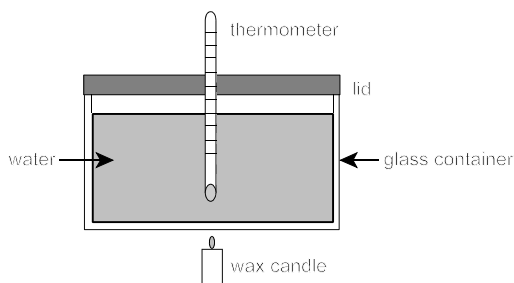
This question was poorly done. Many students did not recognize that this required the answer to (i) above. If students got the wrong answer in (i) and used it or another incorrect value for the ΔH_f° phenol, in (ii) they were not penalized twice (i.e., students could get full marks on (ii) if they used the incorrect value for ΔH_f° phenol).

Common Errors:

- Students took the value of -65.0 kJ from the stem instead of their answer to (i).
- Students thought that the answer to (i) was the $\sum \Delta H$ (reactants) instead of ΔH_{rxn} .
- Students had problems with rearranging the equation.

Value

- 2% 53(c) The molar enthalpy of combustion of candle wax, $\text{C}_{25}\text{H}_{52}(\text{s})$, was determined in an experiment using the apparatus shown in the diagram below.



The following two quantities were measured:

- mass of water in glass container = 200g
- initial temperature of water = 25.4°C

- (i) State two other quantities that would also have to be measured in order to determine the molar enthalpy of combustion of the candle wax.
- final T of H_2O
 - mass of candle wax burned

Commentary on Response:

This question was poorly done.

Common Errors:

- Students did not state mass of candle burned.
- Students indicated that moles of candle wax could be measured.

2% 53(b)(ii) Suggest one improvement that could be made to the experimental apparatus, and briefly state how this would help to increase the accuracy of the result.

- stirrer in water - even the heat distribution - better measure
- thermometer too close to heat source - higher value
- insulate whole apparatus - heat not lost to surroundings
- device to channel heat into water - less error of heat lost

1 mark for improvement

1 mark for reason

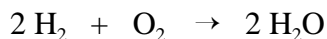
Commentary on Response:

This question was well done.

Common Errors:

- Students stated that the lid should be removed.
- Students stated that the glass could be put in styrofoam, not realizing that a burning candle is below it.
- Students suggested using a bunsen burner as heat source.

2% 53(d) Using the bond energies given, determine the enthalpy of reaction for:



Bond	Average Bond Energy (kJ)
H - H	436
O = O	498
H - O	464

$$\begin{aligned}
 \Delta H_{\text{rxn}} &= \sum \text{BE}_{\text{reactants}} - \sum \text{BE}_{\text{products}} \\
 &= (2 \times \text{H-H} + 1 \times \text{O=O}) - (4 \times \text{H-O}) \\
 &= (2 \times 436 \text{ kJ} + 1 \times 498 \text{ kJ}) - (4 \times 464 \text{ kJ}) \\
 &= (872 \text{ kJ} + 498 \text{ kJ}) - (1856 \text{ kJ}) \\
 &= -486 \text{ kJ}
 \end{aligned}$$

Commentary on Response:

This question fairly well done.

Common Errors:

- Students never applied the formula, even though the formula was given in the data table.
- Students did not recognize the number of bonds nor the correct coefficients.

Value

3% 54(a) A stainless steel spoon is put into an electrolytic cell that has 3.10 A of electricity passing through it for 2.50 h. What mass of silver will be produced?

$$\frac{1}{2} \text{ mark - } t = 2.50 \text{ h} = 9.00 \times 10^3 \text{ s}$$



1 mark -

$$n_{\text{e}^-} = \frac{It}{F} = \frac{(3.10 \text{ A})(9.00 \times 10^3 \text{ s})}{96500 \text{ C/mol}} = 0.289 \text{ mol e}^-$$

$\frac{1}{2}$ mark - 1 mol e^- for each mol Ag^+ ,

$$\therefore 0.289 \text{ mol e}^- = 0.289 \text{ mol Ag}^+ = 0.289 \text{ mol Ag(s)}$$

$$\frac{1}{2} \text{ mark - } m_{\text{Ag}} = n \times M = 0.289 \text{ mol} \times 107.89 \text{ g/mol} = 31.2 \text{ g}$$

Commentary on Response:

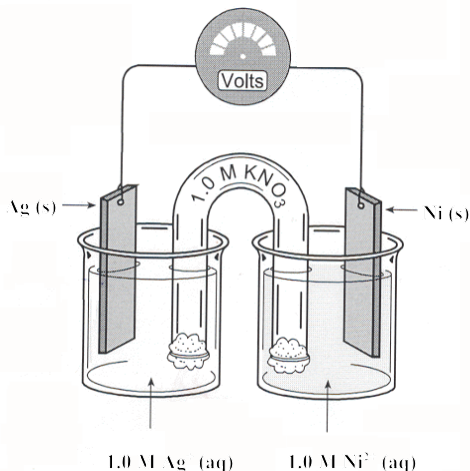
This question was poorly done.

Common Errors:

- Students did not include $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$.
- Students did not stating mole ratio $\text{Ag}^+ : \text{e}^-$.
- Students used $m = \frac{n}{M}$ to calculate mass.
- Students did not convert time from h to s.

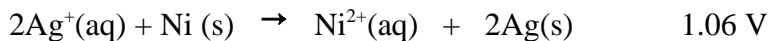
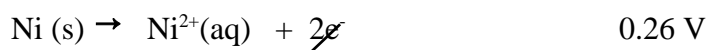
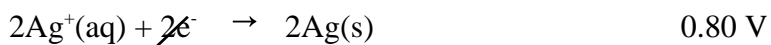
Value

54(b) Refer to the diagram below to answer questions (i) and (ii).



2%

- (i) What is the balanced equation for the overall reaction and the maximum possible voltage for the cell?



Commentary on Response:

This question was poorly done.

Common Errors:

- Students reversed the oxidation-reduction half reactions.
- Students doubled the voltage of the half reaction for Ag^+ .

1%

- (ii) Explain what would happen to the voltage if the salt bridge was removed.

There would be no voltage as the circuit would now be broken

Commentary on Response:

This question was poorly done.

Common Errors:

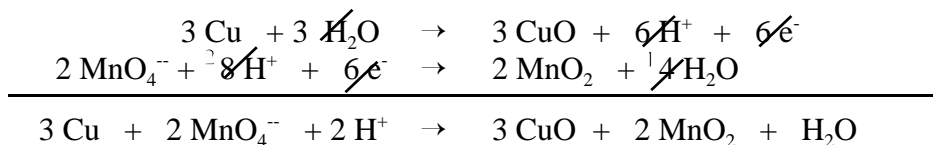
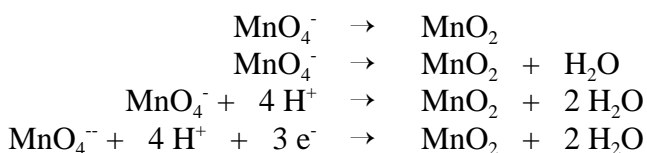
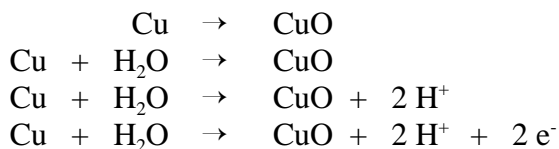
- Students indicated that the voltage would either increase or decrease.
- In answering the question students stated that salt bridge was for e^- transfer.

Value

54(c) Copper metal will undergo a redox reaction with permanganate ions.

3%

(i) Balance the redox reaction below under acidic conditions.



½ mark - balance oxygen
½ mark - balance hydrogen
½ mark - balance electrons
½ mark - electron ratio

Commentary on Response:

Students had the most difficulty in balancing electrons.

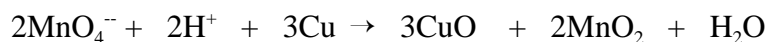
Common Errors:

- Students used oxidation number method.
- Students separated half reactions and balanced with H₂O and H with H⁺.

Value

1% 54(c)(ii)

What mass of copper is required to completely react with 1.0 mol of permanganate ions?



$$1\text{ mol MnO}_4^- = \frac{3\text{ mol Cu}}{2\text{ mol MnO}_4^-} = 1.5\text{ mol Cu}$$

$$\text{mass} = n \times M = 1.5\text{ mol} \times 63.55\text{ g/mol} = 95\text{ g Cu}$$

Commentary on Response:

Some students did not make the connection that they needed the balanced equation from (i).

Common Errors:

- Students just calculated mass using 1.0 mol
(i.e., $m = n \cdot M = 1.0\text{ mol} \cdot 63.55\text{ g/mol} = 63.55\text{ g}$)
- Students attempted to calculate mass of MnO_4^- .

CHEMISTRY 3202 ITEM ANALYSIS
SELECTED - RESPONSE (PART I)

Item	Answer	Cognitive Level	Responses				
			Multiple Answers or No Response	A	B	C	D
			%	%	%	%	%
1	C	1	0.1	10	3	75.6	11.3
2	C	1	0.4	10.8	13.7	61.2	14
3	C	2	0.1	2.8	5.1	86.2	5.8
4	A	1	0	74.7	4.5	16.1	4.8
5	D	1	0	1.4	10.2	3.7	84.7
6	B	3	0.3	4.4	70.6	15.3	9.3
7	B	2	0.1	5.5	76.7	9.4	8.3
8	B	1	0.1	11.4	60.1	11.5	16.9
9	A	2	0.2	48.2	32.3	10.6	8.7
10	A	2	0.1	72.4	7.4	10.7	9.4
11	B	2	0	10.5	77.7	1.4	10.4
12	A	2	0.3	75.4	12.9	5.7	5.6
13	D	1	0	26.8	1.3	8.4	63.5
14	D	1	0	2.4	7.3	1.9	88.4
15	B	1	0.1	6.5	80.2	10.1	3.1
16	A	1	0.1	94.2	0.7	2.8	2.3
17	B	2	0.1	7.3	84.4	5.5	2.8
18	B	2	0.1	3.7	92.5	1.4	2.4
19	C	2	0.1	1.6	20.6	73.5	4.3
20	B	1	0.1	1.6	86.3	11	1
21	B	2	0.1	6.4	84.9	3.3	5.3
22	D	2	0.1	8.8	1.3	2.9	86.8
23	C	3	0.1	14.5	4.6	72.9	7.9
24	B	2	0.4	24.5	50.5	14.1	10.5
25	B	2	0.4	4.5	58.3	28.8	8

Item	Answer	Cognitive Level	Responses				
			Multiple Answers or No Response	A	B	C	D
			%	%	%	%	%
26	A	1	0.1	25.7	37.3	25.4	11.5
27	B	2	0.1	16.9	77.9	3	2.1
28	C	3	0.3	8.2	19.8	64.7	7
29	D	1	0.3	5.1	17.6	20.5	56.5
30	C	3	0	4.4	16.5	70.4	8.7
31	D	1	0.1	10.5	2.5	2.8	84.1
32	C	2	0	7	3.9	81.3	7.8
33	B	2	0.1	9.6	81.6	6.7	2
34	B	1	0.1	4.9	88.1	4.3	2.5
35	C	2	0.2	30.3	9.2	50.2	10
36	B	1	0.2	10.2	65.5	20.5	3.5
37	B	2	0.1	11.4	64.6	17.3	6.8
38	B	2	0.1	6.3	81.2	2.5	9.9
39	D	1	0.1	26.6	0.7	0.8	71.9
40	A	2	0.1	54.1	22.1	13.4	10.3
41	C	1	0.1	5.3	17.5	69.1	8
42	D	2	0.5	23.2	29.2	6.6	40.5
43	C	2	0.1	6.1	15.7	77.6	0.6
44	B	2	0.2	10.4	58.4	16.1	15
45	A	1	0.3	56.5	14	13.8	15.3
46	D	3	0.2	8.8	11.5	14.9	64.7
47	A	2	0.2	60.6	11.3	15.5	12.5
48	B	2	0.7	12.9	63	12.9	10.5
49	B	1	0.1	8.5	76.7	9.8	4.8
50	D	1	0.5	25.5	6.6	28.7	38.7

CHEMISTRY 3202 ITEM ANALYSIS
CONSTRUCTED - RESPONSE (PART II)

Item	Cognitive Level	Students Completing Item	Value	Average	Average % Per Item
51(a)	2	1817	2	1.4	72.4
51(b)	2	1817	3	1.9	61.9
51(c)(i)	3	1817	2	1.9	94.9
51(c)(ii)	2	1817	3	1	34.3
51(d)	3	1817	3	1.6	52.1
52(a)	2	1817	3	1.3	43.3
52(b)	2	1817	3	1.7	55.3
52(c)	3	1817	4	2	48.8
52(d)(i)	2	1817	2	1.3	65.6
52(d)(ii)	2	1817	2	1.5	75.8
53(a)	2	1817	3	2.2	72.8
53(b)(i)	2	1817	2	1.3	62.8
53 (b)(ii)	2	1817	2	0.6	31.9
53(c)(i)	3	1817	2	1.1	56.9
53(c)(ii)	3	1817	2	1.2	58.5
53(d)	2	1817	2	1.3	64.1
54(a)	2	1817	3	1.6	53.4
54(b)	2	1817	3	1.1	36.8
54(c)	2	1817	4	2	50.7

**Chemistry 3202
June 2004**

