Chemistry 3202 Grading Standards
June 2006

Pre-Marking Appraisal

The examination was considered fair and had sufficient coverage of each unit of study and each level of cognitive learning. The following decisions were made by the marking board:

Item # 8 - Both A and D were accepted as plausible answers for this item.

Item #43 - This item was dropped due to a typing error.

Post Marking Report

a) Marking Standard and Consistency

Marker reliability was checked by obtaining a random sample of 50 papers. On the first marking day, these 50 papers were marked and the value for each question was recorded on a separate sheet of paper. The 50 papers were put back into the original stack of papers to be corrected over the next week. Throughout the marking period, these reliability papers were corrected by the markers, the two values were compared and if there were discrepancies in the marks, the chief marker would discuss and review the scoring with the individual marker.

b) Summary

Overall performance in the Chemistry 3202 examination improved from June 2005 to June 2006. As in past years, however, performance was lower for items that assessed outcomes from core Labs and STSE units. Core Labs and STSE units enrich and enhance material in each unit of the course. It is essential that teachers complete all core labs and STSE units to ensure that students are prepared for the examination. On provincial examinations, Core Lab and STSE outcomes are often assessed at higher levels of learning. Teachers, therefore, should assess these areas of the course throughout the school year in a similar manner.

Teachers should also encourage students to read questions carefully and critically. Very often on the provincial examination, errors occur because students fail to read the whole question. If they read the complete question or read it several times, they are less likely to misinterpret the item and are more likely to perform better.

c) Commentary on Responses

Part I - Selected Response - Total Value: 50%

Item #3 - Students did not perform well on this item. The item required students to make a connection between the kinetic molecular theory and collision theory.

Items #9 and #22 - Students did not perform well on these items. The items required students to make a connection between the concept of K constant and temperature.

Part II - Constructed Response - Total Value: 50%

3% 51.(a) Explain two ways that the rate of $CO_2(g)$ production can be increased in the reaction below.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(\ell)$$

Answer: Any two of the following:

1. Increase [HCl] - Increases the number of particles; increases the number of collisions; thus there are more successful collisions
2. Increase temperature - Increases the speed of particles; increases the number of collisions and their intensity; thus more successful collisions
3. Increase surface area of $CaCO_3$ - Increases the number of exposed particles; increases the number of collisions; thus more successful collisions
4. Add a catalyst - Lowers the activation energy (E_a); more collisions now have the energy needed for the reaction

1 mark - ½ mark each for any two ways above
2 marks - 1 mark for each explanation

Common Errors
Students:
- used Le Chatelier's Principle and shifts in equilibrium to answer the item.
- suggested increasing the concentration of a solid, $CaCO_3(s)$.

2% 51.(b) What is the equation for step 3 in the reaction mechanism below? Show workings.

Step 1:	$2\ NO \rightarrow N_2O_2$
Step 2:	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3:	?
Overall reaction:	$2\ NO + 2\ H_2 \rightarrow N_2 + 2\ H_2O$

Answer:
$H_2 + N_2O \rightarrow N_2 + H_2O$

2 marks - ½ mark for each reactant and product

2% 51.(c) At 1000 K, sulfur dioxide is converted into sulfur trioxide, as shown below.

$$2\ SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \qquad K = 284$$

If $[SO_2] = 0.0150$ mol/L, $[O_2] = 0.0250$ mol/L, and $[SO_3] = 0.0400$ mol/L, is the mixture at equilibrium? Justify your answer.

Answer:

$$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.0400)^2}{(0.0150)^2(0.0250)} = 284$$

The mixture is at equilibrium because the calculated value of K is equal to the value given in the question.

1 mark - correct expression and answer
1 mark - justification

Common Errors
Students:
- calculated the value of K but did not justify whether the system was at equilibrium.
- set up the ratio correctly, but could not complete the calculation to get the value 284.
- stated the system was at equilibrium because the concentration of the products was equal to the concentration of the reactants.

4% 51.(d) The equilibrium below was established under constant temperature conditions.

$$Co(H_2O)^{2+}(aq) + 4\ Cl^-(aq) \rightleftarrows CoCl_4^{2-}(aq) + 6\ H_2O(\ell)$$

pale pink *deep blue*

(i) Explain what colour change would occur if $AgNO_3$ was added to the system, producing a precipitate.

Answer:
The addition of $AgNO_3$ causes a precipitate of AgCl to form, which causes a decrease in $[Cl^-]$. The system opposes the change by shifting left and the colour of the system will become more pink

decrease in $[Cl^-]$	**0.5 marks**
the systems shifts left	**0.5 marks**
the colour changes more pink	**1 mark**

Common Errors
Students:
- treated the item as an indicator problem (i.e. used the indicator table to answer the question).
- identified NO_3^- as a strong base; when base was added, the solution turned blue.
- did not identify AgCl as the precipitate.

(ii) When the equilibrium is placed in an ice bath it turns pale pink. Is ΔH for the forward reaction positive or negative? Justify your answer.

Answer:
A shift towards pale pink indicates that the reverse reaction is favored. The energy term must be on the reactant side if there is a decrease in energy (decrease in temperature by being placed in an ice bath). Therefore the reaction is endothermic so ΔH for the forward reaction is positive.

0.5 marks - the reverse reaction is favored
0.5 marks - energy term must be on the reactant side (endothermic)
1 mark - ΔH for the forward reaction is positive

Common Errors
Students:
- misinterpreted ΔH and temperature.
- stated that the energy was absorbed by the ice bath so ΔH was positive.
- did not state if ΔH was positive or negative.

2% 51.(e) Explain what happens to the value of K in the equilibrium below when the temperature of the system is increased.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) + \text{heat}$$

Answer:

The reaction is exothermic. Therefore, an increase in temperature causes the system to shift left (reverse) to counter the change, thus forming more reactants. Since these species are in the denominator of the K expression, the overall value of K will decrease.

K will decrease	**1 mark**
Explanation	**1 mark**

Common Error

Students stated that as temperature increases the reaction rate increases, so K increases.

4% 52.(a) Calculate the pH of a 0.15 mol/L solution of HCN(aq) if K_a is 6.2×10^{-10}.

Answer:

	$HCN_{(aq)}$	+ $H_2O_{(l)} \rightleftharpoons$	$H_3O^+_{(aq)}$	+	$CN^-_{(aq)}$
I (mol/L)	0.15		~ 0		0
C (mol/L)	- x		+ x		+ x
E (mol/L)	0.15 - x		x		x

Assume: 0.15 - x ~ 0.15 Check: $\frac{[HCN]_i}{K_a} = 0.15 = 2.4 \times 10^8 > 500$

∴ Assumption is good

$$Ka = \frac{[H_3O^+]\,[CN^-]}{[HCN]}$$ **0.5 marks**

$$6.2 \times 10^{-10} = \frac{x^2}{0.15}$$ **0.5 marks**

$x = 9.6 \times 10^{-6}$ mol/L $= [H_3O^+]$ **0.5 marks**

pH $= -\log [H_3O^+]$

$= -\log\ 9.6 \times 10^{-6} = 5.02$ **0.5 marks**

ICE table	**1 mark**
assumption and check	**1 mark**

Common Errors

Students:

- omitted the ICE table.
- omitted the K expression.
- if the quadratic formula wasn't used, they did not state the assumption.

2% 52.(b) Determine the Brønsted-Lowry acid-base neutralization reaction that occurs when $CH_3COOH(aq)$ is added to $Na_2SO_3(aq)$. Indicate which side of the reaction is favoured.

Answer:

Species present: CH_3COOH- acid, Na^+ - neutral, SO_3^{2-} - base, H_2O - acid or base

Equation: $CH_3COOH + SO_3^{2-} \rightleftarrows CH_3COO^- + HSO_3^-$

Therefore, products are favoured.

Identifying properties of species present	**0.5 marks**
Equation	**1 mark**
Products are favoured.	**0.5 marks**

Common Errors

Students:

- did not list species present in solution.
- did not dissociate the ionic compound.
- showed the complete neutralization of SO_3^{2-} to produce H_2SO_3.
- did not include charges on the ions.

2% 52.(c) A cup of herbal tea turns from red to pink when a slice of lemon is added to it. Drops of tea remaining in the cup turn purple as the cup is being washed with soapy water. What causes the colour changes observed?

Answer:

Herbal tea acts as an indicator. Soap is basic giving it a purple color, while lemons are acidic giving it a pink color.

Makes reference to herbal tea being an indicator and adding an acid such as lemons turns it pink. **1 mark**

Makes reference to herbal tea being an indicator and adding a base such as soap turns it purple. **1 mark**

Common Error

Students did not make reference to herbal tea acting as an indicator**.**

4% 52.(d) What is the pH of a solution formed by mixing 30.0 mL of 0.100 mol/L KOH with 70.0 mL of 0.200 mol/L HCl(aq)?

Answer:

$KOH + HCl \rightarrow KCl + H_2O$ Ratio is 1:1 **0.5 marks**

n (HCl / H_3O^+) = c x v = (0.200 mol/L) (0.0700 L) = 0.0140 mol
n (KOH / OH^-) = c x v = (0.100 mol/L) (0.0300 L) = 0.00300 mol **0.5 marks**

n $(HCl / H_3O^+)_{excess}$ = 0.0140 mol - 0.00300 mol = 0.0110 mol **0.5 marks**

$$c(HCl / H_3O^+) = \frac{n\ excess}{v_{total}} = \frac{0.110\ mol}{0.100\ L} = 0.110\ mol/L$$ **1 mark**

$pH = -\log [H_3O^+] = -\log 0.110 = 0.959$ **0.5 marks**

1 mark - science communication skills

Common Errors

Students:

- did not write a balanced chemical equation or show that the ratio was 1:1.
- did not calculate the excess amount.
- did not calculate the total volume.
- used incorrect significant figures for pH.
- assumed 0.00300 mol > 0.0140 mol, thereby miscalculating the limiting reagent.

2% 52.(e) Samples of hydrochloric acid, of unknown concentration, were titrated with a solution of sodium carbonate. The flasks were rinsed with a sodium carbonate stock solution before the samples of hydrochloric acid were added. Explain what effect this would have on the calculated concentration of acid.

Answer:

The calculated concentration of hydrochloric acid would be lower because rinsing with sodium carbonate, a base, would neutralize some of the acid. It would take less sodium carbonate to neutralize the HCl during the titration.

Rinsing with sodium carbonate, a base, would neutralize HCl. **1 mark**
It would take less sodium carbonate to neutralize the HCl. **1 mark**

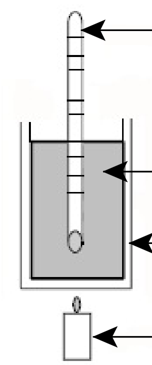
Common Errors

Students:

- did not indicate that the concentration of the acid would decrease.
- did not explain that HCl was neutralized by a base.
- stated that the acid is weaker instead of saying the concentration decreased.

5% 53.(a) In order to determine the molar heat of combustion of candle wax, $C_{25}H_{52}(s)$, water is heated in an aluminum can by a candle. The following results were recorded.

Mass of water	100.0 g
Mass of aluminum can	15.0 g
Specific heat capacity of $H_2O(\ell)$	4.184 J/g°C
Specific heat capacity of Al(s)	0.900 J/g°C
Initial temperature of $H_2O(\ell)$ and Al(s)	22.0 °C
Final temperature of $H_2O(\ell)$ and Al(s)	26.5 °C
Original mass of candle ($C_{25}H_{52}$)	10.62 g
Final mass of candle ($C_{25}H_{52}$)	10.32 g



Answer:

$\Delta T = 4.5^\circ C$ $\quad\quad$ Δcandle mass = 0.30 g

$q_{comb} = -\, q_{surr}$

$= -\,[\,(mc\Delta T)_{H2O} + (mc\Delta T)_{Al}]$

$= -\,[\,(100.0\text{ g} \times 4.184\text{ J/g}^\circ\text{C} \times 4.5^\circ\text{C}) + (15.0\text{ g} \times 0.900\text{ J/g}^\circ\text{C} \times 4.5^\circ\text{C})]$

$= -\,[\,1882.8\text{ J} + 60.75\text{ J}]$ **1 mark for q_{water}**

= - 1943 J **1 mark for q_{Al}**

0.5 mark for sign

M ($C_{25}H_{52}$) = 352.77 g/mol

$n(C_{25}H_{52}) = \frac{m}{M} = \frac{0.30\text{ g}}{352.77\text{ g/mol}} = 0.00085\text{ mol}$ **0.5 marks**

$\Delta H = \frac{q}{n} = \frac{-1943\text{ J}}{0.00085\text{ mol}} = -2300000\text{ J/mol}$ or -2300 kJ/mol **1 mark**

1 mark - science communication skills

Common Errors
Students:

- omitted the negative sign.
- omitted units and formulae.
- used the incorrect mass for wax and therefore calculated the incorrect number of moles.
- used incorrect formula ($q = C\Delta T$) to calculate q.
- incorrectly rearranged formula; used $\Delta H = n / q$.

2% 53.(b) How many moles of methanol must burn to raise the temperature of 100.0 g of aluminum by 80.0 ºC? Assume all heat is absorbed by the aluminum, $c_{Al} = 0.900$ J/g · ºC, and the molar heat of combustion of methanol, $CH_3OH(\ell)$, is -239 kJ/mol.

Answer:

$q\ (CH_3OH) = -\ q_{surr}$
$= -\ [100.0\ g \times 0.900\ J/g^\circ C \times 80.0^\circ C]$
$= -\ 7200\ J$
$= -\ 7.20\ kJ$ **1 mark**

$n\ (CH_3OH) = \dfrac{q}{\Delta H} = \dfrac{-\ 7.20\ kJ}{-\ 239\ kJ/mol} = 0.0301\ mol$ **1 mark**

Common Errors
Students:

- omitted the negative sign.
- did not convert to same units for energy or did not convert properly.
- used incorrect formula; $q = C\Delta T$.
- incorrectly rearranged formula; used $\Delta H = n / q$.

3% (c) A 20.0 g sample of NaCl(s), at 801.0 ºC, is heated to 1000.0 ºC. Given the information below, calculate the total energy required to heat the sample.

Specific heat capacity of NaCl(s)	1.23 J/gºC
Specific heat capacity of NaCl(ℓ)	1.10 J/gºC
ΔH_{fus} of NaCl(s)	28.0 kJ/mol
melting point of NaCl(s)	801.0 ºC

Answer:

$q_1 = mc\Delta T = (20.0\text{ g})(1.10\text{ J/g°C})(1000.0\text{°C} - 801.0\text{°C})$

$= 4378\text{ J}$ **1 mark**

$q_2 = n\Delta H = \dfrac{20.0\text{ g}}{58.44\text{ g/mol}}(28.0\text{ kJ/mol})$

$= (0.3422\text{ mol})(28.0\text{ kJ/mol})$

$= 9.582\text{ kJ}$ **1 mark**

$\Delta E = q_1 + q_2 = 4378\text{ J} + 9.582\text{ kJ}$

$= 4.378\text{ kJ} + 9.582\text{ kJ}$

$= 13.96\text{ kJ}$ **1 mark**

Common Errors

Students:

- did two $q = mc\Delta T$ equations in addition to the $q = n\Delta H$ before calculating ΔE.
- did not calculate ΔT.
- did not convert to same units for energy or did not convert properly.

3% 53.(d) Given the data below, calculate the energy required to break the C-H bond.

$$CH_4(g) + 2O_2(g) \rightarrow 2H_2O(g) + CO_2(g) + 965\text{ kJ}$$

Bond	Bond Energy (kJ/mol)
H - O	460
C=O	745
O=O	498

Answer:
$4\,(C - H) + 2\,(O = O) \rightarrow 4\,(O - H) + 2\,(C = O)$

$\Delta H_{rxn} = \Sigma$ BR (reactants) - Σ BE (products)

- 965 kJ = [4 (C – H) + 2 (498 kJ/mol)] - [4 (460 kJ/mol) + 2 (745 kJ/mol)]

- 965 kJ = [4 (C – H) + 996 kJ] - [1840 kJ + 1490 kJ] **0.5 marks**

- 965 kJ = [4 (C – H) + 996 kJ] - [3330 kJ] **1.5 marks**

-965 kJ - 996 kJ + 3330 kJ = 4 (C - H)

(C - H) = 1369 kJ / 4 mol **0.5 mark**

(C - H) = 342 kJ/mol **0.5 mark**

Common Errors
Students:
- did not recognize that there are four O-H bonds in 2 H_2O.
- did not recognize that there are two C=O bonds in CO_2.
- did not recognize that the sign on ΔH would be negative.
- did not divide by 4 to calculate the energy required to break a C-H bond.

3% 54.(a) Balance the redox reaction below under acidic conditions.

$$Cr^{2+}(aq) + IO_3^-(aq) \rightarrow Cr^{3+}(aq) + I_2(s)$$

Answer:

$[Cr^{2+} \rightarrow Cr^{3+} + e^-] \times 10$ **1 mark**

$10\,e^- + 12\,H^+ + 2\,IO_3^- \rightarrow I_2 + 6\,H_2O$ **1 mark**

$10\,Cr^{2+} + 12\,H^+ + 2\,IO_3^- \rightarrow 10\,Cr^{3+} + I_2 + 6\,H_2O$ **1 mark**

Common Errors
Students:
- did not add 1 e^- to the $Cr^{2+} \rightarrow Cr^{3+}$ half reaction
- incorrectly balanced IO_3^- with H_2O and H^+.

3% 54.(b) Refer to the galvanic cell below to answer the following questions.

$Al(s)|Al^{3+}(aq)||Ni^{2+}(aq)|Ni(s)$

(i) What is the overall cell reaction and cell voltage? Show workings.

Answer:

$2 \times [Al \rightarrow Al^{3+} + 3e^-]$	$E^\circ = 1.66$ V	**0.5 marks**
$3 \times [Ni^{2+} + 2e^- \rightarrow Ni]$	$E^\circ = -0.26$ V	**0.5 marks**
$2Al + 3Ni^{2+} \rightarrow 2Al^{3+} + 3Ni$	$E^\circ_{cell} = 1.40$ V	**1 mark**

Common Errors

Students:

- had difficulty with math when they used $E^\circ = E^\circ_{cathode} - E^\circ_{anode}$.
- did not multiply half reactions by the appropriate values to balance electrons before adding to get the overall equation.
- multiplied the E° values by the coefficients used to balance electrons.

(ii) Give two reasons why the cell voltage determined experimentally was less than the calculated value in (i).

Answer: Any two of the following:

1. concentration may not be 1.0 mol/L
2. temperature may not be 25˚C
3. voltmeter may not be accurate
4. surface of metal not clean

1 mark - 0.5 marks each for any two of the above

4% 54.(c) The titanium cathode in an electrolytic cell increases in mass by 2.35 g in 36.5 min at a current of 6.50 A. What is the charge on the titanium ion? Show workings.

Answer:

$t = (36.5 \text{ min}) (60 \text{ s/min}) = 2190 \text{ s}$ **0.5 marks**

$Q = I t = (6.50 \text{ A}) (2190 \text{ s}) = 14235 \text{ C}$ **0.5 marks**

$n(e^-) = \frac{Q}{F} = \frac{14235 \text{ C}}{96500 \text{ C/mol } e^-} = 0.1475 \text{ mol } e^-$ **0.5 marks**

$n(Ti) = \frac{m}{M} = \frac{2.35 \text{ g}}{47.90 \text{ g/mol}} = 0.04906 \text{ mol}$ **0.5 marks**

Reduction: $Ti^{?+} + ?\, e^- \rightarrow Ti$

$? = \frac{0.1475 \text{ mol } e^-}{0.04906 \text{ mol}} = 3$ **0.5 marks**

Ti^{3+} **0.5 marks**

1 mark - science communication skills

Common Errors

Students:

- did not calculate the moles of Ti.
- used moles of Ti instead of moles of electrons in $Q = n_e F$.
- did not convert the time or multiplied by 3600 s for converting minutes to seconds.

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

Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
1	A	70.9	1.2	7.1	20.8
2	B	7.4	74.9	6	11.7
3	C	3.7	14.2	27.2	54.7
4	C	9.6	10.5	75.6	4.1
5	B	27.7	24.7	12.6	34.9
6	B	9	83.3	2.6	5.2
7	C	3.3	3	92	1.7
8	A & D	4.5	6.3	1.6	87.7
9	C	5.3	6.4	36.9	51.5
10	A	79.8	6.8	12.2	1.2
11	B	1.4	78.3	1.2	19.1
12	D	13.3	1.6	4.3	80.8
13	D	5.5	8.9	8.6	77
14	C	13.4	2.6	75	9
15	B	4.5	82.9	0.7	12
16	C	6.8	29.9	56.3	7
17	B	15.9	54.7	23.5	5.4
18	C	7.7	27.9	56.8	7.5
19	A	59.6	5	22	13.2
20	B	2.3	81.6	13.8	2.4
21	B	2.2	82.1	14.4	1.3
22	B	9.8	40.5	36	13.6
23	C	12.2	26.2	48.5	12.9
24	D	3.4	40.8	2.5	53.2
25	B	8.5	24	56	11.5

Item	Answer	Responses			
		A	B	C	D
		%	%	%	%
26	C	13.5	31.9	53.8	0.7
27	D	8.6	13.4	29.5	48.5
28	B	34.6	48.7	6.1	10.5
29	A	75.5	6.3	13.8	4.4
30	A	82.1	2.5	8.6	6.8
31	C	14.1	10.9	34	40.9
32	C	4.9	5.4	77.7	11.8
33	B	28	44.4	17.4	10.1
34	B	6.5	77.8	11.8	3.9
35	B	15.7	53.9	25.3	5
36	C	2.4	5.5	83.5	8.5
37	B	7.1	86.9	1.2	4.8
38	B	4.1	86.8	7.6	1.5
39	B	13.4	77.8	5.6	3.1
40	B	23.5	33.4	24.5	18.5
41	B	14.3	69.5	12.6	3.6
42	B	10.6	59.8	21.8	7.7
43	DROPPED				
44	A	68.3	13.6	5	12.7
45	D	21.9	20.2	12.7	44.9
46	D	13.8	9.1	12	64.9
47	B	27.1	45.3	20.6	6.9
48	D	16.6	17.5	14.3	51.1
49	D	11.1	45.4	17.2	25.8
50	D	33.8	17.4	11.4	37.1

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

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

Item	Students Completing Item	Value	Average
51.(a)	1986	3	1.3
51.(b)	1986	2	1.7
51.(c)	1986	2	1.4
51.(d)	1986	4	1.6
51.(e)	1986	2	1.2
52.(a)	1986	4	2.4
52.(b)	1986	2	1
52.(c)	1986	2	1.2
52.(d)	1986	4	2.5
52.(e)	1986	2	0.9
53.(a)	1986	5	3
53.(b)	1986	2	1.2
53.(c)	1986	3	2.4
53.(d)	1986	3	1.9
54.(a)	1986	3	1.7
54.(b)	1986	3	1.9
54.(c)	1986	4	1.5