

Rogers

Chem 206 Fall 2006 section 51

GENERAL CHEMISTRY II
MIDTERM EXAMINATION

INSTRUCTIONS: PLEASE READ THIS PAGE WHILE WAITING TO START YOUR EXAM.

This test paper includes 4 pages (both sides); some potentially useful information is given on back of the periodic table. Check that your paper is complete before starting. You can remove the periodic table if you wish. Answer all questions inside the space provided. Calculators are permitted; cell phones and electronic dictionaries are not allowed. You have 75 min to complete the test. *I suggest you scan the whole test quickly before starting & do the 'easy' stuff first.*

GOOD LUCK! Suggestion: spend 1 min / mark \Rightarrow 25 min left to finish uncertain problems & check.

LAST NAME: marking scheme

FIRST NAME: _____

STUDENT NUMBER: _____

Mark breakdown:

	AVG.	
Page 2.	6.8	/ 10
Page 3.	6.5	/ 10
Page 4.	3.5	/ 10
Page 5.	5.3	/ 10
Page 6.	5.3	/ 11

TOTAL: 27.5 / 50 (max. = 51)

PERCENT: 55 %

EARNED toward
FINAL GRADE: 11 / 20

1. (/ 5 marks) TRUE OR FALSE? Circle T or F to describe each of these statements.

- 5
- (T) / (F) During a chemical reaction that leads to an explosion, the system performs work on the surroundings.
 $\Delta V > 0$ Expansion \rightarrow pushes away surrounding
 $w = -P\Delta V = -P(+)$ = loss of E by system.
yes
- T / (F) Hess's law can be used to calculate changes in thermodynamic functions that vary depending on the mechanism or path of the process.
 = path functions! NO.
 eg. $\Delta H, \Delta S$
STATE functions
- T / (F) When an attractive interaction is broken, energy is released by the system.
 requires E input.
- T / (F) When describing a milky liquid prepared during an experiment, it is best to use the term "solution".
 \rightarrow suspended material! = colloidal suspension, not solution.
- (T) / (F) If a single-cell organism that normally lives in the sea is placed into fresh water, the electrolyte imbalance will cause the organism to swell (expand) and die.
yes
 \therefore isotonic with sea water (high electrolyte)
 cell
 fresh water = low (electrolyte)
 H_2O

2. (/ 5 marks) Hydrogen gas reduces NO to N_2 :

not balanced! $\rightarrow 2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)$
 The initial reaction rates for four mixtures of H_2 and NO were measured at $900^\circ C$ (results shown in the table). Determine the rate law and the rate constant for the reaction at $900^\circ C$. Show your work.
not average (not enough space...)

Expt.	$[H_2]_0$ (M)	$[NO]_0$ (M)	Initial rate (M/s)
1	0.212	0.136	0.0248
2	0.212	0.272	0.0991
3	0.424	0.544	0.793
4	0.848	0.544	1.59

- 1.5 Expt ① vs ②: $[NO]_0 \times 2 \Rightarrow$ initial rate $\frac{0.0991}{0.0248} \approx \times 4$ increase = 2^2
 $[H_2]_0$ constant
work shown
 second order in NO
- 1.5 Expt ③ vs ④: $[H_2]_0 \times 2 \Rightarrow$ initial rate $\frac{1.59}{0.793} \approx \times 2$ increase = 2^1
 $[NO]_0$ constant
work shown
 first order in H_2

5 1 Thus: rate law is $Rate = k [H_2][NO]^2$
no part marks (except if no work shown, then 0.5 each for order & k)

To find rate constant: use any 1 expt's data (best to do average, but not enough space.)
 Using Expt ①:
 $k = \frac{rate}{[H_2]_0 [NO]_0^2} = \frac{0.0248 \text{ M/s}}{(0.212 \text{ M})(0.136 \text{ M})^2}$
lose 0.5 if work not shown

10 $\therefore k \approx \frac{6.32}{0.5 \cdot 0.5} \text{ M}^{-2} \text{ s}^{-1}$ for the reaction at $900^\circ C$.

✓ = 0.5 mark
✓ = 1 mark

-0.25 units/SF

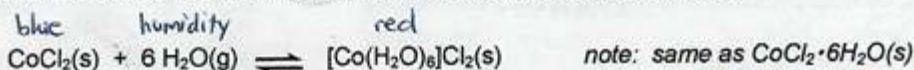
-0.5 for lies...

PAGE 3

CHEM 206 Fall 2006 Section 51 Midterm Exam

ID #: Rogers

3. (/ 10 marks) A simple humidity sensor consists of a cardboard square that is blue in dry weather and red in humid weather. The colour change is due to the formation of a hydrated compound, which forms because water molecules bind to the cobalt ion via coordinate covalent bonds:



AT PARTICULATE LEVEL!

a) (4 marks) Consider the reaction shown above. Briefly explain what causes this reaction to be: if show rxn coord. diagram, worth 0.5

i. Exothermic ($\Delta H^\circ_{\text{rxn}} = -352 \text{ kJ} \cdot \text{mol}^{-1}$ at 25°C) (ie: system loses heat)

2 There is a net formation of bonds during the reaction, so energy is released from the system as heat. Water molecules form 6 new covalent bonds to the cobalt, and two cation-anion interactions may weaken slightly (Cl^- farther from Co centre) but they are not broken, so the net result is bond formation.

ii. Entropically unfavourable ($\Delta S^\circ = -899 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ at 25°C) (ie: system becomes more ordered)

2

①	gas	+	solid	→	solid
	high entropy		low entropy		low entropy
	(disordered)		(ordered)		(ordered)
②	many molecules of reactants			→	fewer molecules

There is a net decrease in the randomness of particles in the system. (entropy goes down.)

TOO HEAVY - EEP!

b) (6 marks) Calculate the standard Gibbs free energy change for this reaction on a hot summer day when the temperature is 35°C . Is the reaction product-favoured at this temperature? (Explain) worth 3

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ using quantities defined at 25°C
 \therefore assuming $\Delta H^\circ + \Delta S^\circ$ are not greatly affected by small changes in temperature

Calc. worth 3

$$= -352 \frac{\text{kJ}}{\text{mol}} - (35 + 273 \text{ K}) (-0.899 \frac{\text{kJ}}{\text{mol} \cdot \text{K}})$$

← must convert to same energy units...

$$= -352 - (-276.9) \text{ kJ/mol}$$

$$= -75.1 \text{ kJ/mol}$$

$\therefore \Delta G^\circ = -75 \text{ kJ/mol}$ of hydrated compound. (2SF: 0 decimal places)

3 explanation Because $\Delta G^\circ < 0$, the entropy of the universe ($\Delta G^\circ = -T\Delta S^\circ_{\text{univ}}$) increases. Thus, the process is spontaneous in the forward direction, according to the second law of thermodynamics.

10 This means the products are more stable than the reactants and the reaction is product-favoured as a result. (Alt) enthalpy sufficient to overcome entropic demand at this temperature.


✓ = 0.5 marks
 ✓ = 1 mark

4. (/ 10 marks) Compare the following three aqueous solutions by completing the table below. Show calculations necessary to support your explanations, but do not calculate the solutions' actual melting point, osmotic pressure and vapour pressure values.

(i)

- 3
- 0.075 M zinc (II) nitrate, $Zn(NO_3)_2$ $Zn^{2+}(aq) + 2NO_3^-(aq) \therefore i=3$ ideally $\therefore [Solute] = 3 \times 0.075M = 0.225M$
 ① HIGHEST [SOLUTE]
 - 0.120 M glycerin, $C_3H_8O_3$ molecular substance $\therefore i=1$ $\therefore [Solute] = 0.120M$
 ② MEDIUM [SOLUTE]
 - 0.050 M lithium bromide, $LiBr$ $Li^+(aq) + Br^-(aq) \therefore i=2$ ideally $\therefore [Solute] = 2 \times 0.050M = 0.100M$
 ③ LOWEST [SOLUTE]

① if calculate with i 's but then don't use them!

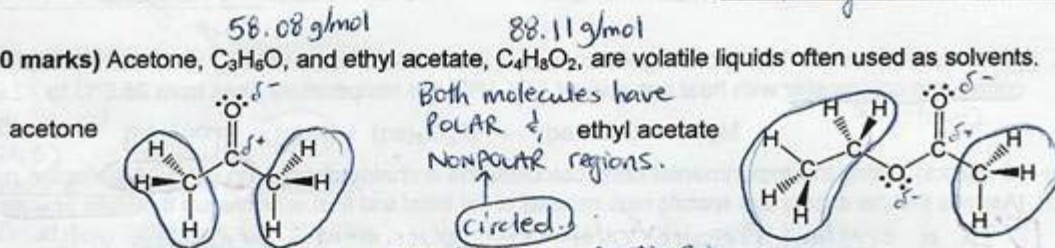
PROPERTY	Highest melting point <small>least depressed</small>	Highest osmotic pressure <small>high solute conc</small>	Highest vapour pressure <small>closest to pure solvent</small>
CHOICE OF SOLUTION	$LiBr(aq)$ ✓	$Zn(NO_3)_2(aq)$ ✓	$LiBr(aq)$ ✓
RELEVANT FORMULA	$\Delta T_f = K_f m$ <small>total solute particles</small> ✓	$\Pi V = n RT$ <small>solute particles</small> ✓	$P_{soln} = \chi_{solvent} P_{solvent}^0$ ✓
BRIEF EXPLANATION	<p>✓ The higher the conc. of dissolved solute particles, the more the freezing point is lowered compared to the pure solvent. The solution with the highest melting point is therefore the one with the lowest concentration of solute. Thus, it is $LiBr(aq)$, with a total conc. of 0.100M.</p>	<p>✓ The higher the conc. of dissolved solute particles, the higher the osmotic pressure generated by the solution. The $Zn(NO_3)_2$ solution has the highest concentration of solute, so would yield the highest osmotic pressure.</p> 	<p>✓ The higher the fraction of volatile molecules in the solution, the higher the vapour pressure. Thus, the $LiBr(aq)$ solution has the highest vapour pressure, because it is the most dilute + therefore has the highest mole fraction of solvent. (The solute is non-volatile.)</p>
Fundamental causes:	<p>✓ Note: solute particles slow down freezing + facilitate melting, which results in the solution having equal rates of melting + freezing at a lower temperature than pure solvent.</p>	<p>Note: Solute particles make the flow of solvent across a semipermeable membrane unequal in rate, if the solvent on one side of the membrane has more "interference" reaching the membrane. Thus, solvent flows into the solution, diluting it + generating osmotic pressure that is proportional to solute concentration.</p>	<p>Note: Solute particles block access to the solution's surface, which decreases the probability that a solvent molecule can reach the surface + evaporate.</p>

1.5
1.5

4.5

10 max 10.5

5. (10 marks) Acetone, C_3H_6O , and ethyl acetate, $C_4H_8O_2$, are volatile liquids often used as solvents.



a) (4 marks) Name and describe two intermolecular forces that would exist between acetone and ethyl acetate molecules in a mixture of the two substances. Clearly indicate which parts of each molecule would be involved for each interaction type.

2
+
2

① Dipole-dipole interactions: ✓
 These are relatively strong forces that exist between partially positive (labelled δ^+) and partially negative (labelled δ^-) regions of the molecules. Thus, a δ^+ carbon would be electrostatically attracted to a δ^- oxygen atom in another molecule. These attractions can be quite strong because the dipole moments are permanent, but still weaker than ion interactions.

OR: dipole-induced dipole...
 ② London dispersion forces: ✓
 These are induced-dipole to induced-dipole forces that occur between nonpolar regions (circled) of the molecules. These forces are quite weak. They result from transient distortions (polarizations) in electron density that occur when the molecules come into contact, which result in very weak dipole moments that permit temporary electrostatic attractions.

b) (6 marks) Imagine you are using a mixture of 25.0 g acetone and 25.0 g ethyl acetate as a cleaning fluid. If this mixture behaves ideally, what would be the vapour pressure above the solution at 30°C? The pure liquids' vapour pressures at 30°C are: $P^{\circ}_{\text{acetone}} = 285 \text{ mm Hg}$; $P^{\circ}_{\text{ethyl acetate}} = 118 \text{ mm Hg}$.

2

✓ $P_{\text{soln}} = P_{\text{acetone}} + P_{\text{ethyl acetate}}$ ✓ since both liquids are volatile.
 ✓ $= X_{\text{acetone}} P^{\circ}_{\text{acetone}} + X_{\text{eth.}} P^{\circ}_{\text{eth.}}$ ⇒ Must find X of each liquid.

2 for mole fractions (must use)

① acetone: $\#n = \frac{25.0 \text{ g}}{58.08 \text{ g}\cdot\text{mol}^{-1}} = 0.4304 \text{ mol}$ (extra SF) $X_{\text{ace}} = \frac{0.4304 \text{ mol}}{(0.4304 + 0.2837) \text{ mol}} = 0.6027$	② ethyl acetate: $\#n = \frac{25.0 \text{ g}}{88.11 \text{ g}\cdot\text{mol}^{-1}} = 0.2837 \text{ mol}$ (extra SF) $X_{\text{eth}} = \frac{0.2837 \text{ mol}}{0.7141 \text{ mol total}} = 0.3973$
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2

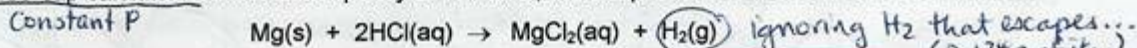
⇒ $P_{\text{soln}} = (0.6027)(285 \text{ mmHg}) + (0.3973)(118 \text{ mmHg})$
 $= 171.8 \text{ mmHg acetone} + 46.88 \text{ mmHg ethyl acetate}$
 $= 218.68 \text{ mmHg}$ ie: $0.2258 \text{ atm} + 0.06168 \text{ atm}$
 $\hat{=} 219 \text{ mmHg}$ ✓ (3 SF) $\hat{=} 0.287 \text{ atm total}$

10

The total pressure above the solution (due to acetone + ethyl acetate vapours) would be 219 mmHg.

✓ = 0.25 marks -0.25 SF
 ✓ = 0.5 marks -0.25 units

6. (/ 11 marks) When 1.50 g of magnesium metal is allowed to react with 200. mL of 1.00 M aq. HCl in a coffee-cup calorimeter with heat capacity of 776 J/°C, the temperature rises from 25.0°C to 42.9°C:



a) (8 marks) Using the experimental data, calculate the enthalpy change (in kJ/mol Mg) for the reaction. [Assume that the density and specific heat capacity of the initial and final solutions are the same as water.]

1 In a constant Pressure calorimeter experiment: heat flow yields ΔH_{rxn}

$$q_{\text{rxn}} = (q_{\text{soln}} + q_{\text{calorimeter}})$$

$$= m C_{\text{soln}} \Delta T_{\text{soln}} + C_{\text{cal}} \Delta T_{\text{cal}}$$

if forget calorimeter -2.5 or the solution -2.5

$$= (1.50\text{g} + 200.\text{mL} \times 1.00\frac{\text{g}}{\text{mL}}) (4.184\frac{\text{J}}{\text{g}^\circ\text{C}}) (42.9 - 25.0) + (776\frac{\text{J}}{^\circ\text{C}}) (17.9)$$

all heat released by reaction is absorbed by the solution and calorimeter
 T_i 25.0°C, T_f 42.9°C for both

$$= 15091.06\text{ J} + 13890.4\text{ J}$$

limited to 3SF each

5 $\therefore q_{\text{rxn}} = -28981.5\text{ J}$ per 1.50g of Mg ← normally ΔH is given per mole...

2 $\# n_{\text{Mg}} = \frac{1.50\text{g}}{24.305\text{g mol}^{-1}} = 0.06172\text{ mol Mg reacted}$

$\therefore \Delta H = \frac{-28981.5\text{ J}}{0.06172\text{ mol}} = -469563.5\frac{\text{J}}{\text{mol}} = -470.\frac{\text{kJ}}{\text{mol Mg}}$ (3SF)
 ✓ answer in kJ

b) (2 marks) Using the thermodynamic data given in the table, calculate the expected value for the standard enthalpy change for the reaction at 298 K.

2 $\Delta H_{\text{rxn}} = \sum n \Delta H_f^{\circ} \text{ products} - \sum n \Delta H_f^{\circ} \text{ reactants}$

$$= [\Delta H_f^{\circ} \text{Mg}^{2+} + 2\Delta H_f^{\circ} \text{Cl}^- + \Delta H_f^{\circ} \text{H}_2] - [\Delta H_f^{\circ} \text{Mg} + 2\Delta H_f^{\circ} \text{HCl}]$$

$$= [-461.96 + 2(-167.46) + 0] - [0 + 2(-167.2)]$$

$$= -796.88 - (-334.4)$$

$$= -462.5\text{ kJ (per mole Mg)}$$

ie: rxn equation as written above

Thermodynamic data for 298 K (data from Silberberg's Chemistry)		
Substance	ΔH_f° (kJ·mol ⁻¹)	S_f° (J·mol ⁻¹ ·K ⁻¹)
Mg(s)	0	32.69
HCl(aq)	-167.2	56.5
Mg ²⁺ (aq)	-461.96	118
Cl ⁻ (aq)	-167.46	55.10
H ₂ (g)	0	130.6

c) (1 mark) Comment on the accuracy of the experimental data (support with a calculation). Suggest one source of error in a calorimetry experiment that might have led to this difference.

1 Accuracy revealed via % error: $\frac{-470. - (-462.5)}{-462.5} \times 100\% = +1.62\%$

The experiment had low % error, so the accuracy is quite high. The experimental data yielded a number that is slightly ABOVE the true value.

11 Possible sources:
 of "too much heat"
 • Some Mg lost (moles Mg "higher" than the really consumed)
 • Calorimeter miscalibrated (actually absorbs less than 776 J/°C)