Rogers.

GENERAL CHEMISTRY II
MIDTERM TEST

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 1ˢᵗ.*
GOOD LUCK! *Suggestion: spend 1 min / mark ⇨ 25 min left to finish uncertain problems & check.*

LAST NAME: marking scheme.   FIRST NAME: _____

STUDENT NUMBER: _____

<u>Mark breakdown:</u>

	Averages		%
Page 2.	7.8	/ 11	70.6
Page 3.	8.3	/ 11	75.5
Page 4.	3.9	/ 8	48.5
Page 5.	6.3	/ 10	63.4
Page 6.	6.5	/ 11	59.4

TOTAL: 32.8 / 50 (max. = 51)

PERCENT: 65.7 % AVERAGE.

EARNED toward
FINAL GRADE: 13.1 / 20

CHEM 206 Winter 2006 Section 01   MIDTERM TEST   ID #: *marking scheme*

 # 1. (__ / 11 marks) *True or False?* Circle T or F to correctly describe each statement; you do not need explain your answers.

T / **(F)** According to the first law of thermodynamics, any <u>system's</u> internal energy is constant.
✗ universe's!

(T) / F A solution containing an <u>ionic compound</u> will have a <u>lower vapour pressure</u> than a solution containing the same concentration of a <u>molecular compound</u>. $i > 1$ $i = 1$ → higher [solute particles] $P_{vap} = \chi P°_{solvent}$

(T) / F A sample of iron <u>powder</u> will oxidize more quickly in air than a <u>single block</u> of iron of the <u>same</u> mass. → a reaction at surface between Fe and O_2

T / **(F)** Colloidal dispersions <u>appear cloudy</u> because of <u>light scattering</u> off of the <u>solvent</u> molecules. ✗

T / **(F)** Hydrophobic substances are <u>not very soluble in water</u> because the <u>London dispersion forces</u> NO! between the hydrophobic molecules are <u>much stronger than</u> the dipole–induced-dipole ✓ interactions between the water and the hydrophobic molecules.

T / **(F)** When a gas-forming reaction occurs in a system, the surroundings <u>perform work</u> on the system. ✗
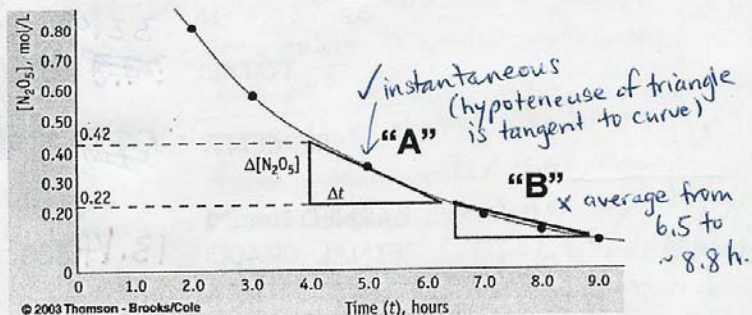$\Delta V_{sys} > 0$, expansion. $W = -P\Delta V$ = – system does work

T / **(F)** For the reaction below, <u>gold ions will form 4x more quickly</u> than H^+ ions are <u>consumed</u>. ✗
$Au(s) + NO_3^-(aq) + 4H^+(aq) \rightarrow Au^{3+}(aq) + NO(g) + 2H_2O(l)$
(4H^+ for 1Au^{3+}) Au^{3+} forms more SLOWLY (4x..) than H^+ used.

(T) / F If the dissolution of a particular salt releases heat but requires a net increase in organization, the salt will have a <u>lower solubility at higher temperatures</u> than at lower temperatures. $\Delta G = \Delta H - T\Delta S$
✓ heat released $\Delta H < 0$ solubility? ΔG for dissolving...   – |— —|
more order $\Delta S < 0$ lower sol'y means smaller ΔG +

T / **(F)** The vapour pressure above a mixture of two volatile liquids depends <u>only</u> on the vapour pressure of the liquid that is more volatile. $P_{total\ vap} = \chi_1 P_1° + \chi_2 P_2°$ depends on BOTH

(T) / F Gibbs free energy is an example of a state function.

T / **(F)** On the graph, triangles "A" & "B" represent ways to calculate <u>instantaneous</u> reaction rates for different moments during the reaction.


✓ instantaneous (hypoteneuse of triangle "A" is tangent to curve)
"B" ✗ average from 6.5 to ~8.8h.

11

W = 0.25   −0.25 SF } total on page.   −0.25 per math error
X = 0.5   −0.25 units
✓ = 1.0

CHEM 206 Winter 2006 Section 01   MIDTERM TEST   ID #: marking scheme

 # 2. (__ / 11 marks) Scientists investigating the origins of life have spent considerable efforts attempting to synthesize amino acids such as glycine directly from the simple compounds ammonia, methane and oxygen:

$$NH_3(g) + 2\,CH_4(g) + \tfrac{5}{2}\,O_2(g) \rightarrow NH_2CH_2COOH(s) + 3\,H_2O(l)$$
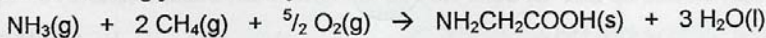
a) **(2 marks)** Using <u>logic only</u>, explain how the system's entropy would change <u>if this reaction occurred</u>.

Substance	ΔH°_f (kJ/mol)	S°_f (J/mol·K)
$NH_3(g)$	−46.11	192.34
$CH_4(g)$	−74.81	186.15
$O_2(g)$	0	205.03
$NH_2CH_2COOH(s)$	−528.1	103.51
$H_2O(l)$	−285.83	69.91

reactants
5.5 mol of GAS (high entropy)

products
1 mol solid (low entropy)
3 mol liquid (moderate entropy)

There would be a very ✓ dramatic DECREASE in entropy (MORE ORDER).

b) **(2 marks)** Calculate ΔS°_{rxn} for this reaction at 298 K; does this value agree with your prediction in (a)?

$$\Delta S^\circ_{rxn} = \checkmark \Delta S_f \text{ products} - \Delta S_f \text{ reactants}$$

−0.5 → if include T   −0.5 wrong order

$$= [(1\,mol)(103.51\ J/mol·K) + (3\,mol)(69.91\ J/mol·K)] - [(1\,mol)(192.34\ J/mol·K) + (2\,mol)(186.15\ J/mol·K) + (2.5\,mol)(205.03\ J/mol·K)]$$

$$= (313.24\ J/K) - (1077.215\ J/K) \quad \text{...note moles cancel...}$$

$$\therefore \Delta S^\circ = -763.98\ J/K \checkmark < 0 \text{ means } \checkmark \text{ increase in order (agrees with (a))}$$

Prof: Subtraction -0.2 decimal places

c) **(4 marks)** Thermodynamically speaking, should this reaction proceed spontaneously at 298 K if all substances are in their standard states? Include calculations to support your answer.

0.5 Need to show $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ < 0$ to be spontaneous. ✓

$$\Delta H^\circ_{rxn} = [1(-528.1\ kJ) + 3(-285.83\ kJ)] - [1(-46.11\ kJ) + 2(-74.81\ kJ) + 2.5(0)] \text{ in } kJ$$
...moles cancel...

$$= (-1385.59) - (-195.73)$$

$$= -1189.86\ kJ \checkmark \text{ (although really has only 1 decimal place for correct SF)}$$

$$\Delta G^\circ_{rxn} = -1189.86\ kJ - (298\ K)(-0.76398\ kJ/K) \quad \text{note units now match!}$$

$$= -1189.86 - (-227.66\ kJ)$$

$$\Rightarrow \Delta G^\circ_{rxn} = -962.2 \checkmark\ kJ$$

0.5 □   Yes ✓ the reaction is thermodynamically favourable.

d) **(3 marks)** If this reaction were indeed practically feasible, would it give a higher yield of products at higher temperatures or at lower temperatures? Explain.

1.0 { "Higher yield" means more product, ie. is the reaction more favourable at higher or lower temperatures?

interpretation

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \quad \text{where } \Delta H < 0, \Delta S < 0 \text{ for this reaction.}$$

the larger the negative value, the more products we will obtain

2.0 { explain.   If T is larger, the −TΔS term in this case will become a larger, positive number. The effect is that more of the enthalpic favourability due to $\Delta H < 0$ is cancelled out at higher temperatures, and the ΔG becomes ✓ smaller, or even positive.

Thus: a higher yield would result at lower temperatures.

CHEM 206 Winter 2006 Section 01   MIDTERM TEST   ID #: _Marking scheme_

 # 3. (__/ 8 marks) Methanol (CH_3OH; bp 65°C) boils nearly 230°C higher than methane (CH_4; bp -164°C), but decanol (shown on left; bp 229°C) boils only 55°C higher than decane (shown on right; bp 174°C).
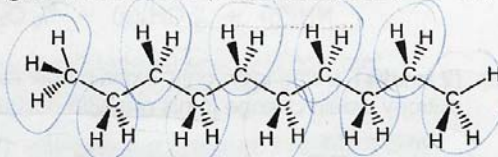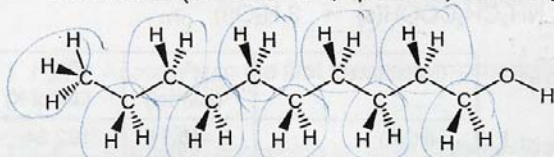
a) **(4 marks)** Briefly explain (in point form) what causes methanol and methane to have such different boiling points.

$H-\overset{H}{\underset{H}{C}}-\overset{\delta^-}{O}:\cdots H\delta^+$ bp 65°C

each molecule: "donate" 1 H ↗ "accept" 2 H

$H-\overset{H}{\underset{H}{C}}-H$ bp -164°C
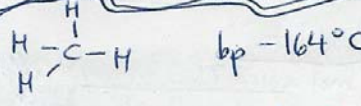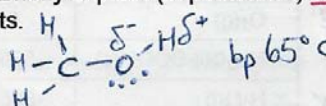
describe forces 2.0

• polar molecule ✗
• O-H permits H-bonding
  (strongest intermolecular force)

• also has London dispersion forces
  (~1 contact point/molecule)
  estimate only...
⇓
• strong intermolecular forces 75%
• must be overcome for molecules ✗ to leave bulk liquid + enter vapour phase (evaporate)

• nonpolar molecule ✗
• only London dispersion forces ✗
  (weakest force)

• small molecule ∴ not very polarizable (~1 point of contact with other molecules...)
  100% very weak forces

describe bp 2.0

• must build up vapour until vapour ✗ pressure reaches Pext ⇒ T = bp.
• requires much more kinetic ✗ energy (thermal E ∝ temperature)
  ∴ much higher temperature ✗ if intermolecular forces are strong
  ∴ methanol requires high T to boil than methane does.

b) **(4 marks)** Why is the bp difference is so much smaller for decanol and decane? Explain briefly (point form is ok).

decanol bp 229°C

| ~10 L.D.F. = 77% approx. |
| ~10 + 3 London |
| L.D.F. H-bonds dispersion |

decane bp 174°C   100% London dispersion forces

2.0 max.

Similarities: • most of molecule is nonpolar ✗ (-CH_2- × 10) due to long chain
⇒ majority of contacts between molecules will involve London ✗ dispersion forces, for both substances.

• each interaction is weak, but ~~≈~~ many points ✗ of contact, ⇒ add up to overall ✗ strong intermolecular forces
∴ both substances have high bp (high T to reach Pvap = Pext)
✗ (correlates with high Mw causing ↑ polarizability ✗ since molecules can touch at many points, + get tangled....)

Difference: decanol has OH group ∴ can Hydrogen bond ✗
2.0 max.   BUT... 3 possible H-bonds (2 accepted, 1 donated)/molecule is small contribution to ✗ overall intermolecular forces (since so many nonpolar points of contact!)
⇒ decanol does have a higher bp, but the difference is not very great ✗

4

4

8

−0.25 SF   −0.25/math error
−0.25 units

CHEM 206 Winter 2006 Section 01   MIDTERM TEST   ID #: _marking scheme_

 # 4. (__/ 10 marks) Imagine you are sitting in a hot sauna. The stove (heater) in the sauna has a layer of rocks on top, so that you can pour water onto them to create steam, which makes the sauna feel hotter.

a) **(6 marks)** Imagine you poured 225 mL of 45°C water onto the hot rocks, and it all evaporated to form steam. How much heat was absorbed from the hot rocks?   — must heat it first to 100°C

Note: $\Delta H°_{vap}$ of $H_2O(l)$ at 100°C = 40.68 kJ/mol; other data is given on the information sheet.

Important: a 2-stage process, 1st heat to 100°C, then evaporate.

$$q_{heating} + q_{evap} = q_{absorbed} \text{ from rocks}$$

① $q_{heating} = mC\Delta T$

$= (225 mL \times 1.00 \, g/mL)(4.184 \, J/g°C)(100 - 45 °C)$

$= (225 g)(4.184 \, J/g°C)(55°C)$

$= 51777 \, J$ where should have only 2SF to match ΔT

② $q_{evap} = \Delta H°_{vap} \cdot \#n_{H_2O}$

$= (40.68 \, kJ/mol)(225 g / 18.02 \, g/mol)$ $(= 12.49 \, mol \, H_2O)$

$= 507.9 \, kJ$ where should have only 3SF to match mass.

⇒ $q_{absorbed \, from \, rocks} = q_{heating} + q_{evap} = \overset{2SF}{51.777 \, kJ} + \overset{no \, decimals, \, 3SF}{507.9 \, kJ}$

$= 559.68 \, kJ$

$\boxed{q_{absorbed} = 560 \, kJ}$ no decimal places, 2 SF.

b) **(4 marks)** If 15% of the steam from part (a) condensed onto 12500 cm² of your skin (about half your body's surface area), by how many degrees would the temperature of your skin rise?   note: ignored heat released by cooling the water

Assume that: (1) the heat is transferred quantitatively into the outer 0.10 cm of skin.
(2) the density and heat capacity of skin are the same as water.
[If you could not do part (a), use 15% of 750 kJ...which is not correct...]

① steam condenses + releases heat: opposite to evaporation $(q_{evap})!$

$∴ q_{condense} = -q_{evap} = -507.9 \, kJ$

② only 15% of steam condenses onto skin: $q_{skin} = 0.15 (-q_{condense})$

$= 0.15 (+507.9 \, kJ)$

$= 76.19 \, kJ$ (really only 3SF)

③ heat absorbed + warms up "watery skin" (I assumed liquid H_2O's data; solid ok)

$q_{skin} = mC\Delta T$ where $m = [(12500 cm²)(0.10 cm)] \times (1.00 \, g/mL)$

$⇒ \Delta T = \dfrac{q_{skin}}{mC}$ $m = 1250 g$

& $1 cm³ = 1 mL$ fundamental metric system relationship

$= \dfrac{76.19 \, kJ \times 1000 \, J/kJ}{(1250 g)(4.184 \, J/g°C)}$

$\boxed{∴ \Delta T = 14.5°C}$
$= 15°C \, (2SF)$ Wow! This is huge — I made a rather large overestimation of the % of steam that condenses on you!!

√ = 1 mark
✗ = 0.5 mark

−0.25 SF

CHEM 206 Winter 2006 Section 01   **MIDTERM TEST**   ID #: _marking scheme_

 # 5. (___/ 11 marks) A 0.6 mL teardrop has a density of 1.0 g/mL and contains 0.67% NaCl by mass.

λ = 2

a) (7 marks) If NaCl is the only solute present in the teardrop, what is the osmotic pressure exerted by the solution at 37°C?

① Osmotic pressure:
$$\Pi V = nRT$$
$$\Pi = \frac{nRT}{V} \quad \therefore \text{ need moles of solute particles! per given volume}$$

So ③ Using total # dissolved particles:
$$\Pi = \frac{(1.376 \times 10^{-4} \text{ mol})(0.08206 \frac{L\cdot atm}{mol\cdot K})(37 + 273 \text{ K})}{0.6 \text{ mL} \times \left(\frac{1L}{1000 \text{ mL}}\right)}$$

$$= \frac{0.00350 \text{ L·atm}}{0.0006 \text{ L}}$$

$$= 5.83 \text{ atm}$$

∴ Π ≐ 6 atm   1SF due to volume data.

② Moles of NaCl as dissolved particles in 0.6mL:
$$\left(0.6 \text{ mL} \times \frac{1.0 \text{ g}}{1 \text{ mL}}\right) \times 0.0067 = 0.00402 \text{ g NaCl}$$
mass of teardrop   % NaCl

$$n_{NaCl} = \frac{0.00402 \text{ g}}{58.443 \text{ g/mol}} = 6.879 \times 10^{-5} \text{ mol}$$

But, when dissolved, NaCl yields Na⁺, Cl⁻
so λ = 2
∴ n_{ions} = 2 × 6.879×10⁻⁵ mol NaCl
= 1.376 × 10⁻⁴ mol dissolved ions
= solute particles that contribute to colligative properties

⊗ IF ignore van't Hoff ?λ, ⟹ lose total of ✗.   1.5

b) (4 marks) If we assume that teardrops are isotonic with the liquid inside your eyes, what would happen if you applied a solution with a lower concentration of solutes to your eyes? That is, can you explain using basic molecular-level arguments and appropriate diagrams what might cause the pain you feel when you get clean water in your eyes in the shower?   worth

↳ EYE

inside eye, have high solute, like in tears

NOTE: I am not suggesting that our eyes could explode in the shower... ... but if our eyes did not have ways to pump extra H₂O out, they could!

EXPAND
permeable to H₂O, not solutes
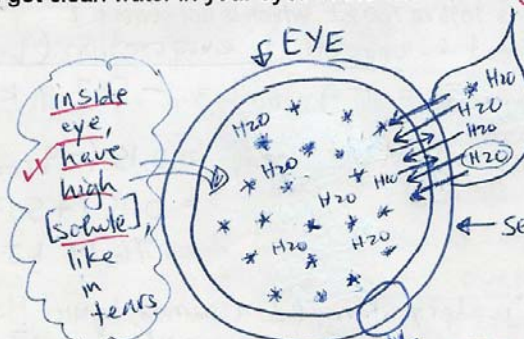
CLEAN H₂O contains very little solute (*)
∴ relatively high concentration of water compared to inside eye

← semipermeable membrane (eyeball)
• permeable to water molecules, but not solute

• more H₂O strikes membrane from clean-water side than from inside-eye side
⟹ net flow of water into eye (OSMOSIS)
⟹ pressure builds up in eye
⟹ causes discomfort / pain.

max worth 1.

11