

LAST NAME:

FIRST NAME:

STUDENT ID:

Rogers -

F08

Chem 206 - GENERAL CHEMISTRY II
MIDTERM EXAMINATION

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

- This test includes 4 pages (both sides). Read over the whole test quickly before starting.
 - Calculators are permitted; cell phones and other electronic devices are not allowed.
 - Potentially useful information (look at it...) is given on back of the periodic table.
 - You can remove the periodic table if you wish.
 - Answer all questions in the space provided.
 - You have 70 min to complete the test.
- **GOOD LUCK!**

Mark breakdown:

averages

Page 2. 7.8 / 10 = 78%

Page 3. 5.7 / 8 = 71%

Page 4. 4.8 / 8 = 60%

Page 5. 3.7 / 8 = 46%

Page 6. 7.5 / 10 = 75%

} work on colligative
properties +
kinetics word
PROBLEMS

TOTAL: 29.5 / 43 (max. = 44)

(theory seems ok
+ basic number
crunching)

GOOD WORK!



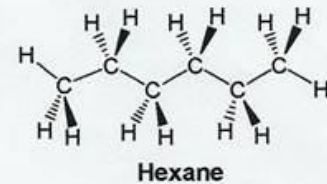
PERCENT: 68.6 %

EARNED toward
FINAL GRADE: / 20

1. (6 marks) TRUE OR FALSE? Circle T or F to describe each of the following statements.

- 1. T / F If the reaction $2 \text{N}_2\text{O}(\text{g}) \rightarrow 2 \text{N}_2(\text{g}) + \text{O}_2(\text{g})$ has a constant half-life throughout an experiment, then the reaction must be first order with respect to $[\text{N}_2\text{O}]$. $t_{1/2} = \frac{\ln 2}{k}$ for 1st order, independent of []
- 1. T / F At higher elevations (where the atmospheric pressure is lower), the boiling point of water is below 100°C and, therefore, cooking foods in boiling water takes less time. more time at lower temperature!
- 1. T / F A catalyst is a substance that lowers raises the activation energy for a reaction's rate-limiting step but is not consumed, in a net sense, by the reaction.
- 1. T / F The freezing point of salt water is lower than the freezing point of fresh water.
 more dissolved ions → yes, f.p. is DEPRESSED by solutes → fewer dissolved ions
- 1. T / F If a reaction occurs by a three-step mechanism in which the slowest step is the second step, then the reaction's overall rate law should be derived from the rate law for the third step.
 rxn can't be faster than its rate-limiting (slowest) step... but anything AFTER that step is so fast it has no effect on rate. second step!
- 1. T / F If a solution of a gas-phase solute is warmed up, some of the gas will come out of solution.
 ↑ T $\Delta S_{\text{sys}} > 0 \therefore$ occurs MORE as T ↑

2. (4 marks) Imagine you wish to dissolve the two vitamins shown below. Based on their structures, determine which solvent (water or hexane) would be better, and for the solvent you choose, identify the strongest solute-solvent interaction. Put your answers in the table.



Solute of interest:	<input checked="" type="radio"/> 1 Vitamin C	<input checked="" type="radio"/> 2 Vitamin A
	<p>hydrogen-bonding groups all over the molecule!</p>	<p>huge nonpolar region</p> <p>tiny hydrogen-bonding region, not worth it for water.</p>
Higher solubility in:	Water or hexane?	Water or hexane?
Name of strongest solute-solvent interaction:	✓ hydrogen bonding	✓ induced-dipole / induced-dipole forces (London dispersion forces)

(no explanation required...)

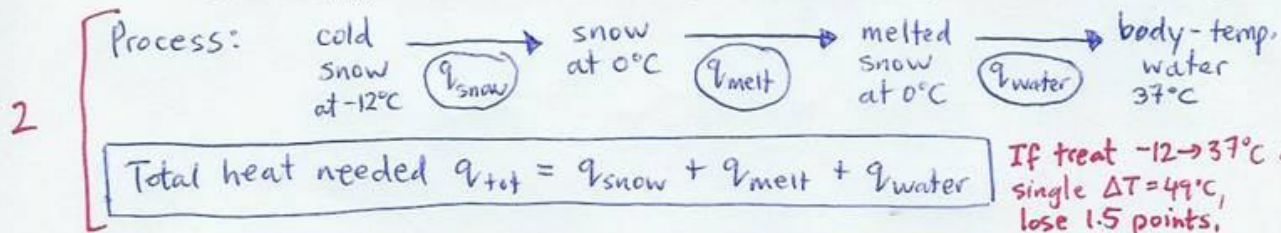
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2

10

ID #: Rogers
marking scheme

3. (8 marks) Imagine you are stranded outside in the winter, and you eat snow to quench your thirst.

a) (6 marks) How much heat (in kJ) would your body need to supply to warm up 8.0×10^2 g of snow from an outside temperature of -12°C to normal body temperature, 37°C ?[note: $\Delta H^\circ_{\text{fusion}}$ for solid water is 6.01 kJ/mol; other useful data is given on the formula sheet.]

1 ① $q_{\text{snow}} = m_{\text{snow}} C_{\text{snow}} \Delta T_{\text{snow}}$ where snow is assumed to be $\text{H}_2\text{O}(s)$
 $= (8.0 \times 10^2 \text{ g})(2.06 \text{ J/g}\cdot\text{K})(12 \text{ K})$ note: $\Delta T = 0 - (-12^\circ\text{C}) = +12^\circ\text{C}$
 $= 19776 \text{ J}$ but degree size same in K.

2 ② $q_{\text{melt}} = (\Delta H^\circ_{\text{fus}})(n)$
 $= (6.01 \text{ kJ/mol})(8.0 \times 10^2 \text{ g} \times 18.02 \text{ g/mol}) (1000 \text{ kJ/J})$
 $= 266814 \text{ J}$

1 ③ $q_{\text{water}} = m_{\text{water}} C_{\text{water}} \Delta T_{\text{water}}$
 $= (8.0 \times 10^2 \text{ g})(4.184 \text{ J/g}\cdot\text{K})(37 \text{ K})$ note: $\Delta T = 37 - (0^\circ\text{C}) = +37^\circ\text{C}$
 $= 123846 \text{ J}$

$$\Rightarrow q_{\text{tot}} = 410436 \text{ J} \approx 410 \text{ kJ} \quad (2 \text{ SF})$$

b) (2 marks) If the energy required in part (a) was provided by burning fat stored in your body, what mass of fat (in pounds, lb) would need to be burned? Assume that 9 Cal of energy is released per gram of fat. [Note: if you could not answer part (a), assume 25000 kJ... which is incorrect...]

- 1 Cal = 4.184 kJ
- 1 lb = 454 g

2 $\frac{1 \text{ g fat}}{9 \text{ Cal}} \times \frac{1 \text{ Cal}}{4.184 \text{ kJ}} \times 410436 \text{ kJ} \times \frac{1 \text{ lb fat}}{454 \text{ g fat}} \approx 0.024 \text{ lb fat} \quad (2 \text{ SF})$

energy unit conversion
 $37.66 \frac{\text{kJ}}{\text{g fat}}$

mass unit conversion
 10.9 g to lbs...

8

4. (8 marks) The osmotic pressure of human blood at body temperature (37°C) is 7.7 atm. If a solution containing equal concentrations of glucose ($C_6H_{12}O_6$) and sodium chloride (NaCl) is to be safely administered to a person intravenously, what must be the concentration (in molarity) of each substance?

$$\begin{aligned} \Pi V &= i n R T \\ \Pi &= i \left(\frac{n}{V} \right) R T \end{aligned} \quad \left. \begin{array}{l} \text{But, we have two types of solute of EQUAL conc.} \\ \text{glucose, } i=1 \checkmark \text{ and } (n_{\text{glu}}/V) = x \checkmark \\ \text{NaCl, } i=2 \checkmark \text{ and } (n_{\text{NaCl}}/V) = x \checkmark \end{array} \right\}$$

$$\begin{aligned} \Pi_{\text{tot}} &= i \left(\frac{n_{\text{glu}}}{V} \right) R T + i \left(\frac{n_{\text{NaCl}}}{V} \right) R T \checkmark \\ &= 1 \times R T + 2 \times R T \\ &= 3 \times R T \checkmark \end{aligned} \quad \left. \begin{array}{l} \text{Remember, osmotic pressure yields} \\ \text{total solute particle concentration,} \\ \text{so we need to split it up into} \\ \text{the contribution from each solute} \\ \text{substance, either now or later...} \end{array} \right\}$$

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$$\therefore x = \frac{\Pi_{\text{tot}}}{3 R T}$$

$$= \frac{7.7 \text{ atm} \checkmark}{(3)(0.08206 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1})(310 \text{ K}) \checkmark}$$

$$\Rightarrow x = 0.10089 \text{ mol/L but 2SF...} \checkmark$$

$$\begin{aligned} \Rightarrow [\text{glucose}] &= 0.10 \text{ M} \checkmark \\ [\text{NaCl}] &= 0.10 \text{ M} \checkmark \end{aligned}$$

↓
see
alternative
approach
below

or Alternative method: first find [total solute], then apply i values & conc. limitations set by the question

$$\Pi V = n R T$$

$$\checkmark \left(\frac{n_{\text{total}}}{V} \right) = \frac{\Pi}{R T} \checkmark \quad \leftarrow \text{sub in values from question, as above}$$

$$\begin{aligned} \Pi &= 7.7 \text{ atm} \checkmark \\ R &= 0.08206 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \checkmark \\ T &= 310 \text{ K} \checkmark \end{aligned}$$

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$$= 0.30269 \text{ mol/L}$$

$$[\text{total solute}] \doteq 0.30 \text{ M} \checkmark \quad \leftarrow \text{these particles came from more than one solute...}$$

$$\hookrightarrow [\text{total solute}] = [\text{glucose}] + [\text{Na}^+] + [\text{Cl}^-]$$

$$0.30 \text{ M} = [\text{glucose}] + 2[\text{NaCl}] \quad \leftarrow \text{and now, note we must have } \checkmark \text{ these substances in equal conc.,}$$

$$0.30 \text{ M} = x + 2x$$

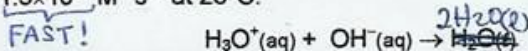
$$0.30 \text{ M} = 3x \checkmark$$

$$x = 0.10 \text{ M}$$

$$\Rightarrow [\text{glucose}] = 0.10 \text{ M} \checkmark \\ [\text{NaCl}] = 0.10 \text{ M} \checkmark$$

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5. (8 marks) Some reactions are so rapid that they are "diffusion-controlled"; that is, the reactants react as quickly as they can collide. An example is the neutralization of H_3O^+ by OH^- , which has a second-order rate constant of $1.3 \times 10^{11} \text{ M}^{-1} \text{ s}^{-1}$ at 25°C .



a) (7 marks) If equal volumes of 2.0 M HCl and 2.0 M NaOH are mixed instantaneously, how much time is required for 99.999% of the acid to be neutralized?

* Gave hints:

① $\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$ is an elementary step.

② $\text{H}_3\text{O}^+(\text{aq})$ is "dissolved H^+ ", $\text{H}^+(\text{aq})$

Should use 0.0020 M HCl instead (see below)
(note: solutions have not been updated yet!)

For those who notice the
(similar to Expt # 4...)

k_{eff}
 $k[\text{OH}^-]$ } bonus point!

But, fault in question: $[\text{OH}^-]$ will NOT be constant throughout rxn (because NOT in excess)! So, poor usage of k_{eff} .
Better if had used 0.0020 M HCl instead, to keep $\gg 10x$ excess OH^- , thus $[\text{OH}^-] \approx \text{constant}$.

• Reaction: 2nd order total, + elementary step

i.e. $\text{rate} = k[\text{H}_3\text{O}^+][\text{OH}^-]$ \therefore 1st order in H_3O^+ (✓)
1st order in OH^- .

• Initially: 2.0 M HCl means 2.0 M H_3O^+ (strong acid) } mixed in equal volumes...
2.0 M NaOH means 2.0 M OH^- } \therefore diluted x 2.
diluted \Rightarrow 1.0 M H_3O^+ and 1.0 M OH^- in mixture initially. (✓)

• Thus: $\text{rate} = k[\text{OH}^-][\text{H}_3\text{O}^+]$ (✓)

$= (1.3 \times 10^{11} \text{ s}^{-1} \text{ M}^{-1})(1.0 \text{ M})[\text{H}_3\text{O}^+]$

what we are "monitoring" in our experiment...

* BONUS ✓

$\Rightarrow k_{\text{eff}}$ to use to monitor $[\text{H}_3\text{O}^+]$; via 1st order rate law

• Thus: disappearance of H_3O^+ is FIRST ORDER with $k_{\text{eff}} = 1.3 \times 10^{11} \text{ s}^{-1}$

b) (1 mark) Under normal laboratory conditions, which do you think the rate of the acid-base neutralization is limited by: (1) the rate of the reaction itself, or (2) the speed of mixing? \Rightarrow HARD TO MIX IN $< 1 \text{ SEC}$

How long for 99.999% of $1 \text{ M } \text{H}_3\text{O}^+$ to be neutralized?

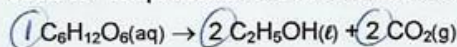
$\ln[\text{H}_3\text{O}^+]_t = \ln[\text{H}_3\text{O}^+]_0 - k_{\text{eff}}t$ ← choice of rate law ✓

$\ln\left\{\frac{[0.00001 \text{ M}]}{[1.0000 \text{ M}]}\right\} = -(1.3 \times 10^{11} \text{ s}^{-1})t$ ← choice of k here ✓

$-11.513 = -1.3 \times 10^{11} \text{ s}^{-1} \times t \Rightarrow t = 8.9 \times 10^{-11} \text{ s}$! well organized algebra 89 ps!

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6. (10 marks) Yeast can produce ethanol (C_2H_5OH) by the fermentation of glucose ($C_6H_{12}O_6$), which is the basis for the production of most alcoholic beverages:



a) (7 marks) Is this reaction product-favoured at $25^\circ C$? Show calculations, and explain your answer briefly.

i.e. is it spontaneous, $\Delta G^\circ_{rxn} < 0$?

Find ΔH°_{rxn} , ΔS°_{rxn} and then ΔG°_{rxn} .

$298 K$

Thermodynamic data at $25^\circ C$		
Substance	ΔH_f° (kJ/mol)	S_f° (J/mol·K)
1 x $C_6H_{12}O_6(aq)$	-1260.0	289
2 x $C_2H_5OH(l)$	-277.0	160.7
2 x $CO_2(g)$	-393.51	213.74

$$\Delta H^\circ_{rxn} = [2 \text{ mol}(-277.0 \frac{\text{kJ}}{\text{mol}}) + 2 \text{ mol}(-393.51 \frac{\text{kJ}}{\text{mol}})] - [1 \text{ mol}(-1260.0 \frac{\text{kJ}}{\text{mol}})]$$

$$= -1341.02 - (-1260.0) \text{ kJ}$$

$$= -81.02 \text{ kJ} \quad \leftarrow \text{but should have 1 decimal place only}$$

$$\Delta S^\circ_{rxn} = [2 \text{ mol}(160.7 \frac{\text{J}}{\text{mol}\cdot\text{K}}) + 2 \text{ mol}(213.74 \frac{\text{J}}{\text{mol}\cdot\text{K}})] - [1 \text{ mol}(289 \frac{\text{J}}{\text{mol}\cdot\text{K}})]$$

$$= 748.88 - 289 \text{ J/K}$$

$$= 459.88 \text{ J/K} \quad \leftarrow \text{should have zero decimal places}$$

$$\Delta G^\circ_{rxn} = \Delta H^\circ_{rxn} - T\Delta S^\circ_{rxn}$$

$$= -81.02 \text{ kJ} - (298 \text{ K})(0.45988 \text{ kJ/K})$$

$$= -81.02 - 137.04 \text{ kJ}$$

$$= -218.06 \text{ kJ}$$

remember SF rules for subtraction... (maintain fewest decimal places...)

$$\Rightarrow \Delta G^\circ_{rxn} = -218 \text{ kJ} \quad \checkmark$$

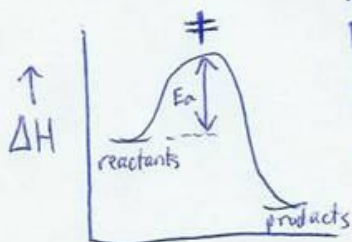
$\Delta G^\circ < 0 \therefore$ spontaneous forward rxn \Rightarrow product-favoured at this temperature \checkmark

b) (3 marks) At higher temperatures, will this reaction reach its ultimate yield of ethanol more quickly or more slowly? Explain (hint: a diagram might help here). Assume the yeast are alive still...

READ THE QUESTION: SPEED/RATE is the realm of KINETICS...

All reactions are faster at higher temperatures.
Because the molecules have greater thermal energy at higher temperatures, more collisions have $E > E_a$ of reaction, so more collisions lead to reaction... and the reaction rate is higher.

The yield itself depends on the magnitude and sign of ΔG°_{rxn} (\neq should be high yield for this reaction at any T), and this yield will always be reached MORE QUICKLY at higher temperatures.



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