

LAST NAME:

Rogers

FIRST NAME:

answer key

STUDENT ID:

W09

NIGHT

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:

Average grades

Page 2. 6.7 / 11 = 61%

Page 3. 4.2 / 8 = 53%

Page 4. 4.0 / 8 = 50%

Page 5. 2.4 / 5 = 48%

Page 6. 6.6 / 9 = 73%

} Review these topics!

TOTAL: 24 / 40 (max. = 41)

PERCENT: 60 %

EARNED toward

FINAL GRADE: / 20

✓ = 1 ✓ = 0,5 ✗ = 0.25 points

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

T / F If a solution of a gas-phase solute is suddenly exposed to a lower partial pressure of the gas, the concentration of dissolved gas will begin to decrease.
bubbles out... $C_{gas} = k P_{gas}$

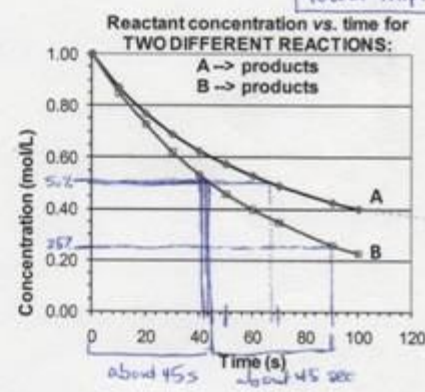
T / F This reaction likely proceeds via a multi-step mechanism: $C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O$.
6 molecules!

T / F The last elementary step in any multi-step reaction limits the rate of the overall reaction.
slowest

5 T / F The melting point of clean snow is lower than the melting point of dirty snow.
relatively pure water contains solutes

$\Delta T_f = K_f m$ solutes
 more solutes, lower mp.

T / F From the graph, curve B corresponds to a first-order reaction whereas curve A does not.
 $t_{1/2}$ constant true.

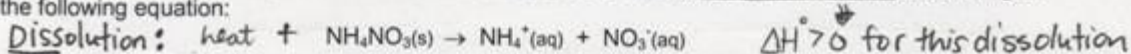


2. (6 marks) In the table, circle the substance with the desired property and provide a brief explanation.

Desired property	Choices (= pure substances!) <i>NOT SOLUTIONS!</i>	Brief explanation (in point form - key words only)
2 Higher boiling point	$Na^+ Cl^-$ vs. $H-Cl$ <u>NaCl</u> vs. HCl ionic solid vs. molecular, gas at RT	<ul style="list-style-type: none"> higher bp means higher forces between particles. ionic solid: strong interionic forces (ion-ion) small polar molecule: dipole-dipole forces weaker forces, requires lower T to boil
2 Higher vapour pressure	CH_3OH vs. CH_3SH polar vs. polar	<ul style="list-style-type: none"> higher P_{vap} means more volatile (weaker forces) both polar BUT CH_3OH has hydrogen bonding CH_3SH has dipole-dipole forces weaker forces more volatile
2 Higher solubility in water	Br_2 vs. ICl nonpolar molecules vs. polar molecules	<ul style="list-style-type: none"> solubility in water (polar) higher if have stronger interactions with water (like dissolves like) $Br-Br$ has induced dipole-dipole forces w/ H_2O $I-Cl$ has dipole-dipole forces with H_2O stronger ∴ more soluble

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- # 3. (8 marks) Instant cold packs contain ammonium nitrate and water separated by a thin plastic divider. When the divider is broken, the ammonium nitrate dissolves via an endothermic process according to the following equation:



- a) (7 marks) To study this process, 1.25 g of NH_4NO_3 was dissolved in enough water to make 25.0 mL of solution in a perfectly insulated coffee-cup calorimeter. The solution's temperature decreased from 25.8 °C to 21.9 °C. Use these data to find the enthalpy change for this process (per mole of NH_4NO_3).
[Note: assume the solution is dilute enough to be treated as "pure water" in your calculations.]

Calorimetry at constant pressure (coffee-cup calorimeter) $\Delta P = 0$

thus: $q_p = \Delta H_{\text{diss}}$ will need to scale heat flow per mole NH_4NO_3 .

$q_{\text{diss}} = -(q_{\text{calorimeter}} + q_{\text{solution}})$ From 1st law of thermo.

not given C
∴ ignore this!

use $MC_s \Delta T$ 25.8 °C down to 21.9 °C.
Solution treated as pure water
∴ can ignore the mass of solute too
without large error. (or, can include)

if include solute mass too,
 $m_{\text{soln}} = 26.25 \text{ g}$
∴ $q_{\text{diss}} = +428.34 \text{ J}$
∴ $\Delta H_{\text{diss}} = +27.4 \text{ kJ/mol}$

$= -((25.0 \text{ mL})(1.00 \frac{\text{g}}{\text{mL}}))(4.184 \frac{\text{J}}{\text{g} \cdot \text{K}})(21.9 - 25.8 \text{ }^\circ\text{C})$
difference $-3.9 \text{ }^\circ\text{C} = -3.9 \text{ K}$ (decrease)

∴ $q_{\text{diss}} = +407.94 \text{ J}$ endothermic (good...)

So, how many moles of NH_4NO_3 produced this heat absorption?

$m = 1.25 \text{ g}$
 $MM = 80.044 \text{ g} \cdot \text{mol}^{-1}$ } $n = \frac{1.25 \text{ g}}{80.044 \text{ g} \cdot \text{mol}^{-1}} \approx 0.01562 \text{ mol}$

Thus: $\Delta H_{\text{diss}} = \frac{q_{\text{diss}}}{n} = \frac{+407.94 \text{ J}}{0.01562 \text{ mol}} \approx 26116.5 \frac{\text{J}}{\text{mol}} \Rightarrow \Delta H_{\text{diss}} \approx 26 \frac{\text{kJ}}{\text{mol}}$

- b) (1 mark) Is work done on/by the system during this process? Explain with a few key words.

No, work is not done, because there is no significant volume change during this dissolving process (perhaps tiny change, but not much).

note: $w = -P\Delta V$ but solid + water \rightarrow aqueous solution with nearly identical volume ($\Delta V \approx 0$)
constant (not zero)
∴ work POSSIBLE...

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See Kotz Ch. 14 Example 14.9

- # 4. (8 marks) Imagine you are studying a complex metal-containing compound with formula: $\text{Fe}(\text{NH}_3)_6\text{Cl}_2$. You wish to learn if this compound is covalent (i.e., nonelectrolyte) or if it contains ions (i.e., electrolyte), so you perform the following experiment:

- You prepare an aqueous solution of well-defined concentration: 0.0207 m ← molality = $\frac{\text{mol solute}}{\text{kg solvent}}$
- You very carefully measure the solution's melting point: -0.116°C

Use this data and relevant reference data from the information page to:

- determine the melting point expected if the compound is a nonelectrolyte
- determine the observed van't Hoff factor, i , of this compound using the data above
- conclude whether the compound is covalent or if it contains ions.

Show all calculations and include brief explanatory comments.

- (1) IF non-electrolyte, $i = 1$ (each solute molecule remains intact)
 ↗ does not yield ions (✓)
- $$\Delta T_f = i K_f m$$
- where $K_f = \text{H}_2\text{O}'\text{s freezing point depression constant}$
- $$= (1)(1.86^\circ\text{C}\cdot\text{kg}\cdot\text{mol}^{-1})(0.0207\text{ mol}\cdot\text{kg}^{-1})$$
- $$= 0.038502^\circ\text{C}$$
- Compound's conc. (since applying i separately here)
- i.e. if the solute does not dissociate, the melting point of solution should be -0.0385°C .

- (2) We observed m.p. = -0.116°C , so $i > 1$... but what is its numerical value?
 ↗ there are MANY
- $$\frac{\Delta T_f}{\Delta T_f} = \frac{i K_f m}{(1) K_f m}$$
- observed m.p. depression / expected m.p. depression } compare
- $$\frac{0.116^\circ\text{C}}{0.0385^\circ\text{C}} = \frac{i}{1}$$
- Thus: $i = 3.013$ ✓
 $\therefore i \doteq 3$
- Alternate approach

$$\Delta T_f = i K_f m$$

$$0.116 = i (1.86)(0.0207)$$

$$i = 3.013$$

Simplest approach!
- Alternate approach:

Calculate observed [solute]

$$m_{\text{obs}} = \Delta T_f / K_f$$

$$= 0.116^\circ\text{C} / 1.86^\circ\text{C}\cdot\text{m}^{-1}$$

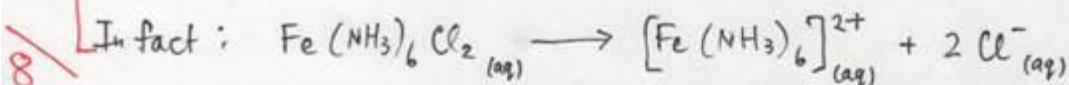
$$= 0.06237\text{ molal}$$

and that's more than [compd]

$$\frac{m_{\text{obs}}(\text{total})}{m_{\text{compound}}} = 3.01 = i$$

↑ ions per compd

- (3) Because the observed van't Hoff factor is > 1 , the compound MUST contain ions. The i value of 3 suggests that each $\text{Fe}(\text{NH}_3)_6\text{Cl}_2$ dissociates into 3 ions when it dissolves.



5. (5 marks) Anthropologists can estimate the age of a bone or other organic matter by its carbon-14 content (radioactive isotope, ^{14}C , half-life 5730 years). The ^{14}C in a living organism is constant until the organism dies, after which time the ^{14}C decays with first-order kinetics.

Suppose a bone from an ancient human contains 19.5% of the ^{14}C found in living organisms. How old is the bone? Your answer must include calculations (not only approximations) and brief explanatory comments.

• Radioactive isotope ^{14}C , $t_{1/2} = 5730 \text{ y}$

• 1st order decay: use 1st-order integrated rate law

$$\ln [^{14}\text{C}]_t = \ln [^{14}\text{C}]_0 - kt$$

\swarrow 19.5% of originally present \swarrow 100% of originally present

← how long it's been decaying (ie. dead...)
 where $k = \frac{\ln 2}{t_{1/2}}$ because 1st order.
 $\therefore k = 1.2097 \times 10^{-4} \text{ y}^{-1}$

Thus: $\ln [^{14}\text{C}]_t - \ln [^{14}\text{C}]_0 = -kt$

$$\ln \frac{[^{14}\text{C}]_t}{[^{14}\text{C}]_0} = -kt$$

$$\therefore t = \frac{\ln \left(\frac{[^{14}\text{C}]_t}{[^{14}\text{C}]_0} \right)}{-k}$$

$$= \frac{\ln \left(\frac{19.5}{100} \right)}{-1.2097 \times 10^{-4} \text{ y}^{-1}}$$

$$= \frac{-1.635}{-1.2097 \times 10^{-4} \text{ y}^{-1}}$$

$$= 13513.7 \text{ y} \quad \text{math. but data has } \underline{3\text{SF}} \dots$$

$\therefore t \approx 13500$ years of radioactive decay has occurred... thus this is the bone's approximate age.

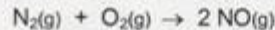
1.50

3.5

5

$\checkmark = 1$, $\checkmark = 0.5$, $\checkmark = 0.25$ points...

- # 6. (9 marks) Our atmosphere is composed primarily of nitrogen and oxygen, which coexist at 25°C without reacting to any significant extent. However, the two gases can react to form nitrogen monoxide, an atmospheric pollutant, according to the following equation:



- a) (7 marks) Determine whether or not this reaction is spontaneous at 298 K. Show full calculations and explanatory comments. **WORTH**

Thermodynamic data at 298 K		
Substance	ΔH_f° (kJ/mol)	S_f° (J/mol·K)
$\text{N}_2(\text{g})$	0	191.56
$\text{O}_2(\text{g})$	0	205.07
$\text{NO}(\text{g})$	91.3	210.76

For rxn to be spontaneous: $\Delta G_{\text{rxn}}^\circ < 0$

where $\Delta G_{\text{rxn}}^\circ = \Delta H_{\text{rxn}}^\circ - T\Delta S_{\text{rxn}}^\circ$

$$\Delta H_{\text{rxn}}^\circ = \sum n \Delta H_f^\circ \text{ products} - \sum n \Delta H_f^\circ \text{ reactants} \quad \text{Hess's law (same for } \Delta S_{\text{rxn}}^\circ \text{)}$$

$$= [2 \text{ mol} (91.3 \frac{\text{kJ}}{\text{mol}})] - [1 \text{ mol} (0 \frac{\text{kJ}}{\text{mol}}) + 1 \text{ mol} (0 \frac{\text{kJ}}{\text{mol}})]$$

$$= +182.6 \text{ kJ} - 0 \text{ kJ} \quad \text{SF: keep 1 decimal place (0 is reference value...)} \quad \text{subtraction rules}$$

$= +182.6 \text{ kJ}$ \Leftarrow endothermic reaction, absorbs heat from surroundings
enthalpically UNFAVOURABLE

$$\Delta S_{\text{rxn}}^\circ = [2 \text{ mol} (210.76 \frac{\text{J}}{\text{mol}\cdot\text{K}})] - [1 \text{ mol} (191.56 \frac{\text{J}}{\text{mol}\cdot\text{K}}) + 1 \text{ mol} (205.07 \frac{\text{J}}{\text{mol}\cdot\text{K}})]$$

$$= 421.52 \text{ J/K} - 396.63 \text{ J/K} \quad \text{SF: keep both decimal places...}$$

$= +24.89 \text{ J/K}$ \Leftarrow entropically FAVOURABLE, disorder of system \uparrow
not per mol (cancels)

Thus: $\Delta G_{\text{rxn}}^\circ = (182.6 \text{ kJ}) - (298\text{K})(0.02489 \text{ kJ/K})$

$$= 182.6 \text{ kJ} - 7.417 \text{ kJ} \quad \text{SF: keep 1 decimal place ... (addition rules)}$$

$= +175.2 \text{ kJ}$ \Leftarrow thermodynamically UNFAVOURABLE
not per mol
i.e. NOT spontaneous.

- b) (1 mark) Does your conclusion from part (a) agree with the fact that N_2 and O_2 do not react significantly in the atmosphere? If so, explain how (key words only). If not, explain what this discrepancy might tell you about the reaction (key words only).

Yes \checkmark non-spontaneous means not product-favoured, so the reaction will "stop" (reach equilibrium, actually) after only a small amount of forward reaction has occurred. In other words, the reaction is reactant-favoured.

- c) (1 mark) Automotive exhaust systems are a significant source of atmospheric NO pollution. Can you think of any reason why? Explain with a few key words. **Best: NO could form as combustion product from fuel!**

Exhaust systems are Hot. For this reaction, $\Delta S_{\text{rxn}}^\circ > 0$, so at elevated temperatures, the entropy term $-T\Delta S_{\text{rxn}}^\circ$ will become larger. This means the $\Delta G_{\text{rxn}}^\circ$ value will become more "negative" i.e. more product will form. (which it will, unless $T > 7336 \text{ K}!!$)

*NOTE: even if $\Delta G_{\text{rxn}}^\circ$ stays > 0 , some product will form... hotter than SUN.