

Rogers

Chem 206 Fall 2007 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 (look at it!) 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 in 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:

	<u>Average</u>	<u>%</u>
Page 2.	9.6 / 15	64
Page 3.	5.8 / 10	58
Page 4.	7.4 / 10	74
Page 5.	5.0 / 8	63
Page 6.	4.0 / 8	50

TOTAL: 31.8 / 50 (max. = 51)

PERCENT: 63.6 %

EARNED toward
FINAL GRADE: 12.7 / 20

Much higher than usual -
Good work.

1. (10 marks) ^{2 each} TRUE OR FALSE? Circle T or F to describe each of these statements.

(T) / F A liquid's normal boiling point is the temperature at which the liquid has a vapour pressure of 1 atmosphere.

T / (F) A short-lived species formed during one step of a process and consumed in a subsequent step is known as a transition state.
= intermediate.

10 (T) / F Molarity and molality are equivalent for very dilute solutions. yes, because then $d_{\text{soln}} = d_{\text{H}_2\text{O}}$...

(T) / F A solution in contact with air at atmospheric pressure will contain a lower concentration of dissolved O_2 than a solution in contact with 1 atm of pure $\text{O}_2(\text{g})$.

$P_{\text{O}_2 \text{ air}} \ll 1 \text{ atm} \quad \therefore C = kP$ will be lower

T / (F) This process is more product-favoured at higher temperatures: $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{SO}_3(\text{g})$.

$$\Delta G = \Delta H - T\Delta S$$

$\Delta S_{\text{rxn}}^\circ < 0$ (entropically unfavourable according to system)

2. (5 marks) SHOW YOUR WORK. A biochemist studying the breakdown of the insecticide DDT finds that it decomposes by a first-order reaction with a half-life of 12 years. How long does it take DDT in a soil sample to decompose from 275 ppb to 15 ppb? Recall: ppb = parts per billion, by mass.

DDT \rightarrow products (1st order in DDT)

$$\ln [\text{DDT}]_t = \ln [\text{DDT}]_0 - kt \quad \checkmark \text{ where } t_{1/2} = \frac{\ln 2}{k} \quad \text{because 1st order}$$

$$t = \frac{\ln \left(\frac{[\text{DDT}]_t}{[\text{DDT}]_0} \right)}{-k}$$

$\checkmark \therefore k = 0.05776 \text{ year}^{-1}$
(molecules breaking down per year...)

5

$$= \frac{\ln \left(\frac{15 \text{ ppb}}{275 \text{ ppb}} \right) \checkmark}{-0.05776 \text{ year}^{-1}}$$

\rightarrow max 3 if only analyze # of $t_{1/2}$'s (NOT EXACT)

$$= 50.358 \text{ years}$$

$$\therefore t \approx 50. \checkmark \text{ or } 5.0 \times 10^1 \text{ years (2SF)}$$

15

-0.25 for incorrect S.F.s

3. (10 marks) MULTIPLE CHOICE – Circle your answer. You do not need to show your work.

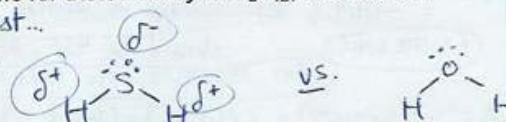
$$\Delta E_{\text{sys}} = q + w \text{ and } \Delta E_{\text{univ}} = 0 \dots$$

a) (1 mark – choose ONE) One statement of the first law of thermodynamics is that...

1. the amount of work done on a system is dependent on the pathway. *true but not 1st law*
2. ~~x~~ the total work done on a system must equal the heat absorbed by the system. *not true*
3. ~~x~~ the heat flow in or out of a system is independent of the pathway. *not true*
4. the total energy flow in or out of a system is equal to the sum of the heat transferred to or from the system and the work done by or on the system.
5. in any chemical process the heat flow must equal the change in enthalpy. *true at constant P, but not 1st law.*

b) (2 marks – choose ONE) The force primarily responsible for the solubility of $\text{H}_2\text{S}(\text{g})$ in water is...

1. ~~x~~ hydrogen bonding. *strongest...*
2. induced-dipole – induced-dipole interactions.
3. dipole – dipole interactions.
4. ~~x~~ ion – dipole interactions. *not an ion!*
5. ~~x~~ covalent bonding.



- polar but does not hydrogen bond! Not H-O, N, F...

c) (3 marks – choose ONE) If cost per gram were not a concern, which of the following substances would be the most efficient per unit mass for melting ice from sidewalks and roads?

- | | | | |
|--|------------------|---------|--|
| 1. x Glucose, $\text{C}_6\text{H}_{12}\text{O}_6$ | MM = 180.2 g/mol | $i = 1$ | 5.5×10^{-3} particles/gram of substance |
| 2. LiCl | MM = 42.44 | $i = 2$ | 4.7×10^{-2} ← HIGHEST |
| 3. NaCl | MM = 58.44 | $i = 2$ | 3.4×10^{-2} |
| 4. CaCl_2 <i>judged i only</i> | MM = 110.99 | $i = 3$ | 2.7×10^{-2} |

Calculate $1\text{g} \times \left(\frac{1\text{mol}}{\text{MM}}\right) \times \left(\frac{\text{particles released}}{1\text{mol}}\right) = \boxed{}$ solute particles per gram
 Needs to be high to cause largest $\Delta T_f = K_m \text{ solutes}$

d) Phosgene is a toxic gas prepared by reacting carbon monoxide with chlorine: $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{COCl}_2(\text{g})$. The data in the table were obtained in a kinetics study of this reaction.

Answer the following two questions about this reaction.

(2 marks – choose ONE) The rate law is...

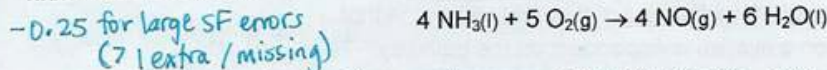
1. rate = $k[\text{CO}][\text{Cl}_2]$
2. rate = $k[\text{CO}]^2[\text{Cl}_2]$
3. rate = $k[\text{CO}][\text{Cl}_2]^2$
4. rate = $k[\text{CO}]^2[\text{Cl}_2]^2$
5. none of the above

Run	Initial [CO] (mol/L)	Initial [Cl ₂] (mol/L)	Initial rate (mol/L·s)
1	1.00	0.100	1.29×10^{-29}
2	0.100	0.100	1.33×10^{-30}
3	0.100	1.00	1.30×10^{-29}
4	0.100	0.0100	1.32×10^{-31}

(2 marks – choose as many as apply) The reason for choosing the rate law above was...

1. ~~x~~ Wild guess – this type of data doesn't help us determine the rate law. *It absolutely does.*
2. ~~x~~ It matches the reaction's balanced equation. *Yes, but since mechanism not given, not relevant!*
3. When $[\text{CO}]_0$ was changed by a factor of 10, the initial rate changed by a factor of 10. *Run 1 vs 2*
4. When $[\text{Cl}_2]_0$ was changed by a factor of 10, the initial rate changed by a factor of 10. *Run 2 vs 3*
5. ~~x~~ When $[\text{CO}]_0$ was decreased by a factor of 10, the initial rate decreased by a factor of 100. *– but only when $[\text{Cl}_2]_0$ was also decreased by $\times 10$ (Run 1 vs. 4)*

4. (10 marks) Ammonia is an important chemical feedstock. Consider the oxidation of ammonia to yield nitric oxide and water.



a) (6 marks) Is the reaction spontaneous at 25°C? Explain, and show all calculations. \rightarrow show $\Delta G^\circ < 0$ or $\Delta S_{\text{univ}}^\circ > 0$

Thermodynamic data at 298 K		
Substance	ΔH_f° (kJ/mol)	S_f° (J/mol·K)
$\text{NH}_3(\text{g}) \times 4 \text{ mol}$	-46.1	192.3
$\text{O}_2(\text{g}) \times 5 \text{ mol}$	0	205.1
$\text{NO}(\text{g}) \times 4 \text{ mol}$	90.2	210.7
$\text{H}_2\text{O}(\text{l}) \times 6 \text{ mol}$	-285.8	69.9

-0.5 unit problems

-1 for backwards Hess's law (each time)

$$\Delta H^\circ = [4(90.2) + 6(-285.8)] - [4(-46.1) + 5(0)] \text{ kJ (mole units cancel out)}$$

$$= -1354 - (-184.4) \text{ kJ}$$

$$= -1169.6 \text{ kJ for rxn as written (NOT "per mole")}$$

EXOTHERMIC HEAT RELEASED INTO SURROUNDINGS CAUSES INCREASED DISORDER IN SURROUNDINGS

-1 for forgetting to scale by moles (each time)

$$\Delta S^\circ = [4(210.7) + 6(69.9)] - [4(192.3) + 5(205.1)] \text{ J/K (moles cancel)}$$

$$= 1262.2 - (1994.7) \text{ J/K}$$

$$= -532.5 \text{ J/K for rxn as written}$$

ENTROPICALLY UNFAVOURABLE (9 mol gas \rightarrow 4 mol gas + 6 mol liquid - seems reasonable decreased disorder)

0.5 for math errors.

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -1169.6 \text{ kJ} - (298 \text{ K})(-0.5325 \text{ kJ/K})$$

$$= -1010.9 \text{ kJ}$$

$$= -1011 \text{ kJ}$$

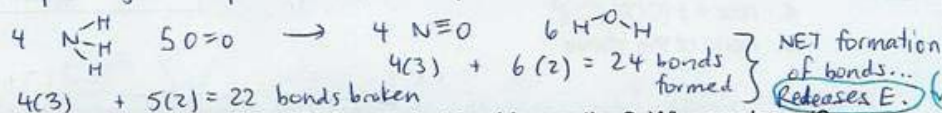
units MUST match

6 $\Delta G^\circ < 0 \therefore$ SPONTANEOUS \leftarrow energy released overall into universe as randomness (in surroundings: $\Delta H^\circ < 0$)

b) (2 marks) Would this reaction evolve heat or require an input of heat? Explain briefly.

2 $\Delta H^\circ < 0$ means heat is released into the surroundings (exothermic). i.e. system loses E as heat

Simple logical explanation (too simple, since don't have bond strengths):



c) (2 marks) Do you think it would be worth trying to find a catalyst for this reaction? Why or why not?

flexible: some points if mention effect of a catalyst on Ea or rate...

2 The reaction is spontaneous, therefore product-favoured, BUT we have NO IDEA if it is fast or slow at this temperature. (we DON'T KNOW Ea)

A catalyst would increase the reaction rate, so we would reach our maximum yield of products faster. ~~It would at least be~~ It would at least be worth looking into finding a catalyst, particularly if the rxn is slow.

10 However, if it is already fast, we should be careful - it is very exothermic...

5. (8 marks) Biochemists have discovered more than 400 mutant varieties of hemoglobin, the blood protein that carries oxygen throughout the body. A few of the mutants function normally, but many result in disease. Imagine you are a scientist studying a mutant hemoglobin associated with a fatal disease. You perform the following experiment to determine its molar mass:

- Dissolve 21.5 mg of the protein in water at 5.0°C to make 1.50 mL solution
- Measure this solution's osmotic pressure: 3.61 torr

According to this data, what is the molar mass of this mutant hemoglobin protein?

Must assume it acts as a molecule with $i=1$ since no other info. given.

Use osmotic pressure to find # moles of solute particles:

$$\Pi V = nRT$$

$$\therefore n = \frac{\Pi V}{RT} = \left(\frac{3.61 \text{ torr}}{760 \frac{\text{torr}}{\text{atm}}} \right) (0.00150 \text{ L})$$

$$\frac{(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}) (5 + 273 \text{ K})}{278 \text{ K}}$$

* Remember to include units, so it becomes obvious that you need to do some unit conversions.

$$\therefore n = 3.123 \times 10^{-7} \text{ mol of protein particles}$$

And $n = \frac{\text{mass}}{\text{MM}}$ by definition

$$\therefore \text{MM} = \frac{\text{mass}}{n} = \frac{0.0215 \text{ g}}{3.123 \times 10^{-7} \text{ mol}}$$

$$= 68838 \text{ g/mol}$$

$$\therefore \text{MM} = 68800 \text{ g/mol} \quad (3 \text{ SF from temperature})$$

2SF also accepted, but not correct in Kelvins...

↑
large, but proteins are extremely large molecules...

ID #: Rogers-
making scheme

6. (8 marks) A manufacturer claims that its new "diet" dessert has "fewer than 10 Calories per serving". To test the claim, a chemist at the Department of Consumer Affairs places one serving in a bomb calorimeter (heat capacity 8.151 kJ/K) and burns it in oxygen. The temperature increases by 4.937°C. Is the manufacturer's claim correct? Include calculations to support your answer, and a brief explanation.

Most people did not explain at all.



analogous to digestion! (x)

definitely not constant p
 likely only CO₂ + H₂O is gases

measured at constant volume, q_v

$$\Delta E = q + w$$

$$= q_v + P\Delta V$$

$$\therefore \Delta E = q_v = \text{energy content of the food}$$

released via combustion / digestion

Assuming no heat is lost: (x)

$$-q_v = (q_{cal} + q_{sample/products})$$

heat released from food

all heat absorbed by apparatus + contents

$$= mC\Delta T + mC\Delta T$$

8.151 $\frac{kJ}{K}$ heat capacity of calorimeter (no mass needed)

not given \therefore must ignore here.

But, sample much smaller than bomb calorimeter, so perhaps is negligible...

No explanations

-2

$$= \left(8.151 \frac{kJ}{K}\right) \left(4.937^\circ C \times \frac{1K}{1^\circ C}\right) + 0$$

-2 if convert ΔT of 4.937 into 277.9K
 ΔT is SAME value in $^\circ C$ & kelvins!
 The degree + the Kelvin are the same size.

$$-q_v = 40.24 \text{ kJ}$$

$$q_v = -40.24 \text{ kJ}$$

(i.e., released during combustion rxn)

This is high school chem 205 knowledge + EMPHASIZED in class.

Convert to dietary Calories (Cal):

$$|q| = 40.24 \text{ kJ} \times \frac{1 \text{ Cal}}{4.184 \text{ kJ}} = 9.618 \text{ Cal (kcal)}$$

Because less than 10 Cal was released by burning the sample, it seems that the manufacturer's claim is valid. However, we had ignored the quantity of heat absorbed by the sample itself... so maybe it is very close...
 (Either answer, yes or no, valid if supported)

8