



Concordia
UNIVERSITY

Rogers F05

COURSE	GENERAL CHEMISTRY II	NUMBER	CHEM 206	SECTION	12 51
EXAMINATION	Final Examination	DATE	December 19, 2005	TIME	1900-2200
INSTRUCTOR	Dr. Carrie ROGERS				

MATERIALS ALLOWED: NO YES (PLEASE SPECIFY)

CALCULATORS ALLOWED: NO YES programmable calculators must be reset

Chem 206 --- GENERAL CHEMISTRY II

LAST NAME: Marking scheme FIRST NAME: _____
STUDENT NUMBER: _____ SIGNATURE: _____

Instructions: PLEASE READ THIS PAGE WHILE WAITING TO START.

- Make sure your exam has 13 pages, including this page, information sheet & periodic table.
- Write your student ID number on all pages.
- Write all answers legibly in the space provided (use the backs of pages for rough work).
- Non-programmable calculators are allowed; cell phones & electronic dictionaries are not.
- You are allowed to remove the periodic table and information sheet.
- Read ALL questions quickly BEFORE starting the exam; do the "easy" questions first.
- Suggestion: spend <15 minutes per page to have 30 minutes left to check your work.

Mark breakdown:	Page 2.	/ 17
	Page 3.	/ 8
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	Page 5.	/ 9
	Page 6.	/ 12
	Page 7.	/ 10
	Page 8.	/ 10
	Page 9.	/ 13
	Page 10.	/ 7
	Page 11.	/ 10
	TOTAL:	/ 100 (MAXIMUM MARK = 104)

1. (17 marks) TRUE OR FALSE? Circle T or F to describe each of these statements.

1 mark each:

- T / F According to the first law of thermodynamics, a system's internal energy cannot change.
- T / F When a system is at equilibrium, there is no reaction occurring in either direction at the molecular level.
- T / F If a mixture is cloudy, it is more correct to describe it as a colloidal dispersion than as a solution.
- T / F If three reactions occur in sequence, the equilibrium constant for the overall reaction will be the same as the smallest of the three equilibrium constants.
- T / F Oil and water are immiscible because the hydrogen bonds between water molecules are much stronger than the dipole-induced-dipole interactions between water and oil molecules.
- T / F A catalyst increases the rate constant for a reaction by increasing the pre-exponential (also known as the frequency factor, A) for the reaction.
- T / F Half-life is useful for understanding radioactive substances, because the half-life of any first-order process (such as radioactive decay) depends on the initial concentration of decaying substance.

2 marks each:

- T / F A solution containing an ionic compound will have a lower vapour pressure than a solution containing the same concentration of a molecular compound.
 $i \neq 1$ α [solute particles]
 higher C] \Rightarrow lower P_{vap} $\therefore \downarrow \chi_{\text{sol}}$
 $i = 1$
 $P_{\text{vap}} = \chi_{\text{sol}} P_{\text{solvent}}^{\circ}$
- T / F The activation energy for the reaction $A \rightarrow B$ is the same as the activation energy for the reaction $B \rightarrow A$, regardless of the difference in thermodynamic stability of the two substances A and B.
- T / F If a compound with a pK_a of 9.0 is placed into a solution with a pH of 7.4, the majority of the compound's molecules will be present in their conjugate base form.
 $\text{more acidic than } \text{SO}_2/\text{SO}_3 \text{ H}_2\text{A}/\text{A}^-$
 no.
- T / F For a proposed mechanism to be described as "consistent with experiment", the experimentally observed rate law for the reaction must be the same as the expected rate law for the first step in the proposed mechanism.
- T / F A reaction mixture whose reaction quotient is less than the value of the reaction's equilibrium constant will be faster in the direction that leads to reactants, until equilibrium is reached.
 $Q < K$ $A \rightarrow B$
 $Q = \frac{[B]}{[A]}$ where B is too small
 \therefore proceeds fwrd.

2. (/ 4 marks) People often describe the reaction of an acid with a base as "neutralization". In what ways is this accurate, and in what situations might this description be misleading?

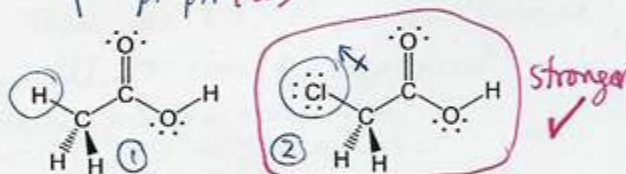
accurate...

- ① harsh properties of acid + base are reduced (x)
- ② acids have low pH, bases have high pH, + react to yield less extreme pH (x)
- ③ strong acid + strong base yields salt + water, where the salt is comprised of species that have essentially no acidic/basic properties → solution is neutral (pH 7) in pH after rxn. (x)
- ie: conjugate base of strong acid & conjugate acid of strong base are each extremely weak + do not deprotonate or protonate water significantly.

misleading...

- weak acid or weak base yields a conjugate base/acid that is also "weak" ∴ has significant basic/acidic properties
 - solution will not be neutral pH after a neutralization rxn.
- OR
- if do not consume all of each substance... (w)
 - weak-weak rxns must know relative strengths to predict equiv. pt pH (w)

3. (/ 12 marks) Consider these two carboxylic acids:



a) (4 marks) Based on the structures of the two acids, which do you expect to be stronger? Explain.

Only difference: 1 H replaced by Cl, and Cl has larger χ than H.

Acids are stronger if the bond to the δ^+ H being attacked by an incoming base is more polar (not necessarily weaker!). or, weaker conjugate base

The Cl in acid 2 has a larger electronegativity than carbon, so the Cl acts as an electron-withdrawing group (inductive effect). This means the Cl "pulls" on the electron density in the Cl-C bond; this effect carries through the molecule's bonds + makes the O pull more strongly on the O-H bond's electron pair, which makes the H look more electron-poor (Lewis acidic). This enhances the δ^+ character of the H and makes it more attractive to the incoming base (Lewis base), compared to in acid 1 that lacks this electron-withdrawing Cl.

Similar arguments:

more stable conj. base correlates to stronger acid
 conj. base of 2 is more stable than 1's due to inductive stabilization by EW-Cl pulling O's lone pair closer. More stable lone pair, less basic.

4

4

choice 1.0

general statement 0.5

explain X-C bond effect 1.5

conclusion of explanation 1.0

8

3. continued... units

SF for (b) only

-0.25

0.25



Thermodynamic data for the reaction of the acids with water, in aqueous solution at 25°C

Acid	ΔH°_{rxn} (kJ/mol)	ΔS°_{rxn} (J/mol·K)
CH ₃ COOH	-0.57	-92.6
ClCH ₂ COOH	-4.70	-70.8

- b) (4 marks) Using the thermodynamic data in the table, calculate ΔG°_{rxn} for the reaction of each of these acids with water at 25°C. Would these reactions become more or less product-favoured at higher temperatures? Why? Calc ΔH_{rxn} , ΔS_{rxn} - lose 1.

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

For CH₃COOH:

$$\Delta G^\circ_{rxn} = -0.57 \frac{\text{kJ}}{\text{mol}} - (298\text{K})(-0.0926 \frac{\text{kJ}}{\text{mol}\cdot\text{K}}) = 27.02 \text{ kJ/mol} \quad \text{reactant-favoured}$$

For ClCH₂COOH:

$$\Delta G^\circ_{rxn} = -4.70 \frac{\text{kJ}}{\text{mol}} - (298\text{K})(-0.0708 \frac{\text{kJ}}{\text{mol}\cdot\text{K}}) = 16.40 \text{ kJ/mol} \quad \text{slightly less reactant-favoured.}$$

Each reaction is entropically unfavourable ($\Delta S^\circ_{rxn} < 0$), which means that at higher temperatures, the T ΔS term will become a larger positive number. Thus, as $T \uparrow$, ΔG°_{rxn} will become more positive, and the reactions will be even less product-favoured.

also accept Le Chatelier's principle explanation but need to specify $\Delta H < 0$ to get full marks.

- c) (4 marks) Using the thermodynamic data provided, calculate the acid dissociation constant, K_a , for each of the acids at 25°C. Which acid is stronger according to these K_a 's? Explain briefly.

$$\Delta G^\circ_{rxn} = -RT \ln K \Rightarrow K = e^{-\Delta G^\circ_{rxn}/RT}$$

For CH₃COOH:

$$K = e^{-(27.02 \text{ kJ/mol}) \cdot (1000 \text{ J/kJ}) / ((8.314 \text{ J/mol}\cdot\text{K})(298\text{K}))} = e^{-10.91} = 1.835 \times 10^{-5}$$

For ClCH₂COOH:

$$K = e^{-(16.40 \text{ kJ/mol}) \cdot (1000 \text{ J/kJ}) / ((8.314 \text{ J/mol}\cdot\text{K})(298\text{K}))} = e^{-6.617} = 1.335 \times 10^{-3}$$

These equilibrium constants are K_a 's because they are derived from the reaction of each acid with water: $HA + H_2O \rightleftharpoons A^- + H_3O^+$

ClCH₂COOH has a larger K_a and therefore its reaction with water is more product-favoured than that of CH₃COOH (although neither rxn is actually product-favoured, and both acids are therefore "weak"). Thus, ClCH₂COOH is a stronger acid than CH₃COOH.

4. (1/9 marks) A forensic chemist is given a white solid that is suspected of being pure cocaine ($C_{17}H_{21}NO_4$, molar mass 303.35 g/mol). She dissolves 1.22 ± 0.01 g of the solid in 15.60 ± 0.01 g of benzene, and finds that the freezing point is lowered by 1.32 ± 0.04 °C. [The K_f of benzene is 5.12 °C·kg/mol.]

a) (5 marks) Use the experimental data to calculate the molar mass of the white solid.

5

2.5 $\Delta T_f = K_f \cdot m$ (where $m = \text{moles solute} / \text{kg solvent}$ \checkmark definition of molality)

$\Rightarrow m = \frac{\Delta T_f}{K_f}$ \checkmark (rearranged only)

$= \frac{1.32^\circ\text{C}}{5.12^\circ\text{C}\cdot\text{kg}\cdot\text{mol}^{-1}}$ \checkmark

$\therefore m = 0.2578 \text{ mol} / \text{kg solvent}$ \checkmark (3SF allowed)

1.5 Since 15.60g benzene used as solvent: moles solute = $\frac{0.2578 \text{ mol} \times 0.01560 \text{ kg benzene}}{1 \text{ kg benzene}}$ \checkmark

$= 4.022 \times 10^{-3} \text{ mol}$ \checkmark (3SF allowed)

1.0 $\text{MM} = \frac{\text{mass}}{\text{mole}} = \frac{1.22 \text{ g solute}}{4.022 \times 10^{-3} \text{ mol}} = 303.3 \text{ g/mol} \hat{=} \boxed{303 \text{ g/mol}}$ (3SF)

close to expected MM 303.35 g/mol!

if calculate expected molality + use that to conclude MM same as cocaine, max 3.75

b) (4 marks) Assuming that the percent uncertainty in the calculated molar mass is the same as the percent uncertainty in the temperature change, calculate the uncertainty in the molar mass. Could the chemist accurately state that the substance is cocaine? For example, is the uncertainty small enough to distinguish cocaine from codeine ($C_{18}H_{21}NO_3$, molar mass 299.36 g/mol)?

4

1.0 % uncertainty in $\Delta T = \frac{0.04^\circ\text{C}}{1.32^\circ\text{C}} \times 100\% = 3.03\%$ \checkmark uncertainty (2SF...)

no marks for % difference

1.5 Thus: uncertainty in MM = $0.0303 \times 303.3 = 9.2$ \checkmark g/mol (2SF...)

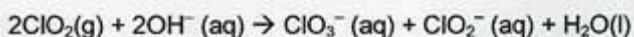
Thus: experimental MM = 303.3 ± 9.2 \checkmark g/mol OR 303 ± 9 \checkmark g/mol (better)

(lose this if use real formula)

1.0 The MM of codeine is 299.36 g/mol, which lies within the range of $294 - 312$ \checkmark g/mol determined via experiment for the white solid.

0.5 Therefore: NO, \checkmark the chemist cannot be certain that the white solid is cocaine.

5. (1/12 marks) Chlorine dioxide (ClO_2) is a gas used as a disinfectant in municipal water-treatment plants. It dissolves in basic solution to produce the strong oxidizing agents ClO_3^- and ClO_2^- .



- a) (5 marks) Using the kinetic data given in the table, determine the rate law for this reaction and the average value of its rate constant at 298 K.

Kinetic data for reaction at 298 K			
Run #	$[\text{ClO}_2]_0$ (mol/L)	$[\text{OH}^-]_0$ (mol/L)	Initial rate (mol/L·s)
1	0.060	0.030	0.0248
2	0.020 $\div 3$	0.030	0.00827 $\div 3$
3	0.020	0.090 $\times 3$	0.0247 $\times 3$

3 The rxn is first order wrt each reactant:

$$\text{rate} = k [\text{ClO}_2]^1 [\text{OH}^-]^1 \quad \checkmark \quad (-0.5 \text{ if omit } k)$$

2 run ①: $k = \frac{\text{rate}}{[\text{ClO}_2]_0 [\text{OH}^-]_0} = \frac{0.0248 \text{ mol/L}\cdot\text{s}}{(0.060 \text{ mol/L})(0.030 \text{ mol/L})} = 13.8 (\text{mol/L})^{-1} \text{s}^{-1} \quad \checkmark$

Same for run ② }
13.72 for run ③ } \checkmark

$$\text{average} = \frac{(13.8 + 13.8 + 13.7)}{3} \quad \checkmark$$

$$= 13.8 \text{ M}^{-1} \text{s}^{-1}$$

$$k \approx 14 \text{ M}^{-1} \text{s}^{-1}$$

- b) (2 marks) Does the balanced chemical equation correctly represent the mechanism of this reaction? Did you need to analyze kinetic data to make this conclusion? Why or why not?

2 No, the equation cannot represent the mechanism, because it suggests that the reaction would be quatermolecular. Four species colliding simultaneously is highly improbable. We can deduce this without doing any experiments - just common sense. \checkmark

- c) (2 marks) What can you deduce about the nature of the rate-limiting step of this reaction?

2 The experimental rate law is second order overall, which suggests that the rate-limiting step involves one molecule of ClO_2 and one molecule of OH^- in a single-collision reaction (elementary RLS). \checkmark

• misunderstood: RLS highest E_a 0.5
or slowest step 0.25

- d) (3 marks) If this reaction was performed at 298 K using an initial ClO_2 concentration of 0.015 M in a solution with pH 11.75, what would be the initial reaction rate?

$$\text{rate} = k [\text{ClO}_2]_0 [\text{OH}^-]_0$$

$$= (13.8 \text{ M}^{-1} \text{s}^{-1})(0.015 \text{ M})(5.62 \times 10^{-3} \text{ M})$$

$$= 1.16 \times 10^{-3} \text{ M s}^{-1}$$

$$\therefore \text{rate} \approx 1.2 \times 10^{-3} \text{ M s}^{-1} \quad \checkmark$$

$$\text{If } \text{pH} = 11.75, \text{ pOH} = 14 - 11.75 = 2.25 \quad \checkmark$$

$$\therefore [\text{OH}^-] = 10^{-2.25} = 5.62 \times 10^{-3} \text{ M} \quad \checkmark$$

(really 2SF)

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \quad 0.25$$

6. (1/10 marks) Imagine you are sitting in a hot sauna. The stove (heater) in the sauna has a layer of rocks on top of it, so that you can pour water onto them to create steam, which makes the sauna feel hotter.

- a) (5 marks) Imagine you poured 225 mL of 45°C water onto the hot rocks, and it all evaporated to form steam. How much heat needed to be absorbed from the hot rocks?
 [$\Delta H_{\text{vap}}^{\circ}$ of $\text{H}_2\text{O}(\text{l})$ at 100°C = 40.68 kJ/mol; other data on information sheet.]

5

First: heat H_2O from 45° → 100°C (endothermic) \checkmark 2 steps...
 $q = m C \Delta T$
 $2.25 = (225 \text{ mL} \times \frac{1.00 \text{ g}}{1 \text{ mL}}) (4.184 \frac{\text{J}}{\text{g} \cdot ^\circ\text{C}}) (55^\circ\text{C})$
 $= 51777 \text{ J}$
 $q_{\text{warming}} = 51.8 \text{ kJ}$ (only 2 SF...)
 (∴ no decimal places)

Second: \checkmark evaporate at 100°C → steam (endothermic)
 $q = \Delta H_{\text{vap}}^{\circ} \times n$
 $= (40.68 \frac{\text{kJ}}{\text{mol}}) (\frac{225 \text{ g}}{18.02 \text{ g} \cdot \text{mol}^{-1}})$
 1.75
 $q_{\text{evaporating}} = 507.9 \text{ kJ}$ (only 3 SF)
 (∴ no decimal places)

1

Total heat required = $q_{\text{warming}} + q_{\text{evaporating}}$ \checkmark
 $= 51.8 + 507.9 \text{ kJ}$
 $= 559.6$
 $\therefore q = 560. \text{ kJ}$ (no decimal places)
 absorbed from rocks.

- b) (5 marks) If 2.5% of the steam from part (a) condensed onto 1.25 m² of your skin (about half your body's surface area), by how many degrees would the temperature of your skin rise?
 Assume that:

- the heat was transferred quantitatively into the outer 1.0 mm of skin. Find ΔT .
- the density and heat capacity of skin are the same as water, since human cells are ~90% water.

Find mass of skin + use $m C \Delta T = q$ to find ΔT , where q is heat released by condensing

5

2.5

Volume of skin warmed up = $1.25 \text{ m}^2 \times (\frac{1.00 \text{ mm}}{1000 \text{ mm/m}}) = 1.25 \times 10^{-3} \text{ m}^3$

Treating skin as if it were like water: convert m³ to mL to relate to mass
 $V = 1.25 \times 10^{-3} \text{ m}^3 \times (\frac{100 \text{ cm}}{1 \text{ m}})^3 = 1.25 \times 10^{-3} \text{ m}^3 \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3}$

$= 1250 \text{ cm}^3$

and by definition, for H_2O , $1 \text{ cm}^3 = 1 \text{ mL}$ (given)

$\therefore V = 1250 \text{ mL}$ \checkmark

$m = 1250 \text{ mL} \times \frac{1 \text{ g}}{1 \text{ mL}} \therefore m = 1250 \text{ g of "H}_2\text{O"}$ \checkmark

2.5

$q_{\text{skin}} = m C \Delta T \Rightarrow \Delta T = \frac{q}{m C} = \frac{507900 \text{ J} \times 0.025}{(1250 \text{ g})(4.184 \text{ J/g} \cdot ^\circ\text{C})} = 2.43^\circ\text{C} \approx 2.4^\circ\text{C}$ (2 SF)

10

note: $q_{\text{skin}} = -q_{\text{condensing}} = q_{\text{evaporating}}$ i.e. heat comes from condensation process releasing energy
 (common sense for crazy answers ± 0.25)

7. (/ 10 Marks) An artificial fruit beverage contains 11.0 g of tartaric acid, $\text{H}_2\text{C}_4\text{H}_4\text{O}_6$, and 20.0 g of its salt, potassium hydrogen tartrate ($\text{KHC}_4\text{H}_4\text{O}_6$), per liter. Tartaric acid is a diprotic acid, but in this situation only the first ionization step is important ($K_{a1} = 1.0 \times 10^{-3}$).

a) (4 marks) Would this beverage behave as a buffer? Why or why not?

① Tartaric acid is a weak acid since $K_a \ll 1$
+ $\text{KHC}_4\text{H}_4\text{O}_6$ is its conjugate base ✓

② Initial concentrations: in one liter of solution

$\text{H}_2\text{C}_4\text{H}_4\text{O}_6$: MM = 150.089 g/mol ✓
n = 11.0 g / MM
= 0.07329 mol ✓
conc. = 0.07329 mol/L

$\text{KHC}_4\text{H}_4\text{O}_6$: MM = 188.179 g/mol ✓
n = 20.0 g / MM
= 0.1063 mol ✓
conc. = 0.1063 mol/L

Ratio of $\frac{\text{HA}}{\text{A}^-} = \frac{0.07329}{0.1063} = \frac{0.069}{1}$ ✓ very close to 1:1 ratio ✓ ∴ can buffer.

⇒ conclusion: Yes it can act as a buffer, but its capacity might not be very high since $\sim 0.1 \text{ M}$ conc. is not very high.

b) (6 marks) A person's stomach usually contains about 75 mL of stomach acid, which is essentially hydrochloric acid with a pH of approximately 2.00. If you drink a glass (250 mL) of the beverage described above, what will be the pH of the final mixture in your stomach?

Treat the juice as a buffer + calculate pH after adding stomach's acid.

In 250 mL of juice:

$n_{\text{H}_2\text{A}} = (0.250 \text{ L})(0.07329 \text{ mol/L})$
= 0.01832 mol

$n_{\text{HA}^-} = (0.250 \text{ L})(0.1063 \text{ mol/L})$
= 0.02658 mol

↓ marks for this down here.

$n_{\text{HCl}} = 0.075 \text{ L} \times \text{conc. HCl}$

conc. HCl = conc. H_3O^+ ✓ since 100% dissociates (strong acid)

= $10^{-\text{pH}}$

$[\text{HCl}] = 10^{-2.00} = 1.0 \times 10^{-2} \text{ M}$

Thus: # $n_{\text{HCl}} = (0.075 \text{ L})(1.0 \times 10^{-2} \text{ M})$ ✓
= $7.5 \times 10^{-4} \text{ mol} = \# n_{\text{H}_3\text{O}^+}$

Our buffer:

$\text{H}_2\text{A} + \text{H}_2\text{O} \rightleftharpoons \text{HA}^- + \text{H}_3\text{O}^+$ ✓ equation

Initial 0.01832 mol ✓

rxn + 0.00075

final 0.01907 mol ✓

0.02658 mol ✓

- 0.00075

0.02583 mol ✓

0 mol

Still in buffering ratio

0.00075 mol ✓

- 0.00075 ✓

0 mol

0 mol

Use Henderson-Hasselbalch equation to calculate pH of buffer now:

$$\text{pH} = \text{p}K_a + \log \frac{[\text{HA}^-]}{[\text{H}_2\text{A}]}$$

$$= -\log(1.0 \times 10^{-3}) + \log \left(\frac{0.02583}{0.01907} \right)$$

$$= 3.00 + 0.132$$

∴ pH = 3.13 ✓ The mixture in the stomach would now be much less acidic.

Criteria: TO ACT AS A BUFFER

- ① weak acid + conj base pair
- ② present in nearly 1:1 ratio
- ③ relatively high concentrations

4 2.5

0.5

1.5

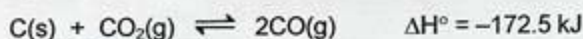
6 2.5

2

or eqn treatment

10

8. (/ 13 marks) At high temperatures, a dynamic equilibrium exists between carbon monoxide, carbon dioxide and solid carbon:



At 850°C, the equilibrium constant K_c is 0.153.

a) (3 marks) What is the value of K_p ? *ok if don't show work here*

$$K_p = \frac{(P_{\text{CO}})^2}{P_{\text{CO}_2}} \quad \checkmark \text{ but } P = \left(\frac{n}{V}\right)RT \quad \checkmark$$

$$\Rightarrow K_p = \frac{\left(\frac{n_{\text{CO}}}{V}\right)^2 (RT)^2}{\left(\frac{n_{\text{CO}_2}}{V}\right) (RT)} = K_c \times RT$$

by any route
 \checkmark TOTAL 1.5

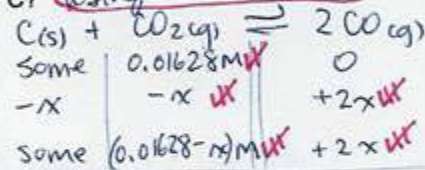
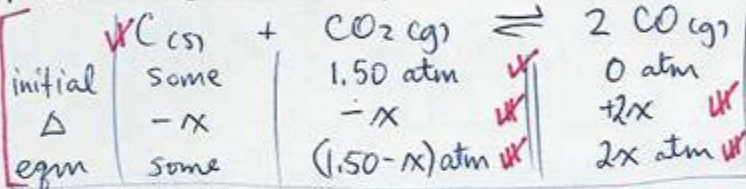
also: $K_p = K_c \times (RT)^{\Delta n_{\text{gases}}}$
where here $\Delta n_{\text{gases}} = 2 - 1 = 1$

$$= (0.153) \left(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right) (850 + 273 \text{ K})$$

$$= 14.099$$

$$\therefore K_p = 14.1 \quad \checkmark$$

b) (6 marks) If solid carbon plus 1.50 atm of CO_2 are placed in a 1.00 L container, what would be the pressures of CO_2 and CO when equilibrium has been established at 850°C? *using concentrations*



where $[\text{CO}_2] = P/RT = 0.01628 \text{ M}$

$$K_c = 0.153 = \frac{[\text{CO}]^2}{[\text{CO}_2]} = \frac{(2x)^2}{0.01628 - x}$$

cannot use approximation \checkmark
 $(0.153)(0.01628 - x) = 4x^2$

$$0 = 4x^2 + 0.153x - 0.002490$$

$$x = \frac{-0.153 \pm \sqrt{0.153^2 - 4(4)(-0.002490)}}{2(4)}$$

$$= \frac{-0.153 \pm \sqrt{0.06325}}{8}$$

$$\therefore x = 0.01231 \text{ M} = \Delta \text{ in } [\text{CO}_2]$$

$$\therefore P_{\text{CO}_2} = (0.01628 - 0.01231) \times RT = 0.366 \text{ atm}$$

$$\therefore P_{\text{CO}} = 2(0.01231) \times RT = 2.27 \text{ atm}$$

$$K_p = 14.1 = \frac{(P_{\text{CO}})^2}{P_{\text{CO}_2}} = \frac{(2x)^2}{1.50 - x} \quad \checkmark \quad (-0.5 \text{ if use } K_c \text{ with } P_{\text{CO}_2})$$

cannot use approximation $\therefore K_p \gg \text{initial } P$

$$(14.1)(1.50 - x) = 4x^2$$

$$0 = 4x^2 + 14.1x - 21.15$$

$$x = \frac{-14.1 \pm \sqrt{(14.1)^2 - 4(4)(-21.15)}}{2(4)}$$

$$= \frac{-14.1 \pm \sqrt{537.21}}{8}$$

$$\Rightarrow \Delta \text{ in } P_{\text{CO}_2} = x = 1.13 \text{ atm} \quad \checkmark \text{ (other is negative)}$$

$$P_{\text{CO}_2} = 1.50 - 1.13 = 0.37 \text{ atm} \quad \checkmark$$

$$P_{\text{CO}} = 2(1.13) = 2.26 \text{ atm} \quad \checkmark$$

c) (2 marks) How will the equilibrium pressure of CO change if the temperature is decreased? Why?

The reaction is exothermic in the forward direction \therefore heat can be treated like a product. If thermal energy is decreased by decreasing temperature, the equilibrium will shift right \therefore the CO pressure (product) will INCREASE.

d) (2 marks) How will the equilibrium pressure of CO change if some argon is added? Why?

Argon is an inert gas that is not involved in the reaction. Adding Ar does not affect the partial pressures (concentrations) of the reactants/products, so the reaction is unaffected. The P_{CO} will not change.

full marks if specify that Ar does not react with CO or CO_2 . *only if supported!!*

10. (/ 10 marks) A saturated solution of an unidentified ionic salt with the formula MX_2 exhibits an osmotic pressure of 74.4 mm Hg at 25°C .

a) (3 marks) What is the total concentration of dissolved ions in this solution?

3

$$\Pi V = nRT \quad \text{where osmotic pressure results from total solute particles}$$

ie: all dissolved ions

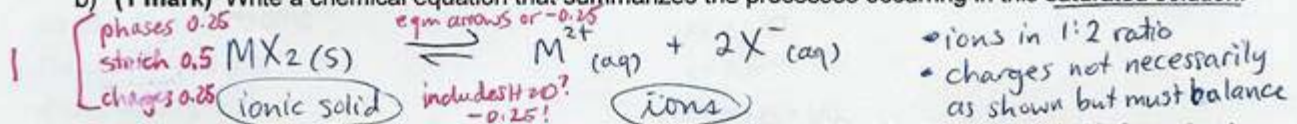
$$\frac{n}{V} = \frac{\Pi}{RT} = \frac{(74.4 \text{ mm Hg}) \times \left(\frac{1 \text{ atm}}{760 \text{ mm Hg}}\right)}{(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(25 + 273 \text{ K})} \rightarrow \Pi = 0.09789 \text{ atm}$$

in atm

$$\therefore \left(\frac{n}{V}\right) = 4.00 \times 10^{-3} \text{ M} \quad (3 \text{ SF... extra digits: } 4.003 \times 10^{-3} \text{ M})$$

total ions.

b) (1 mark) Write a chemical equation that summarizes the processes occurring in this saturated solution.



c) (6 marks) Assuming that MX_2 is fully dissociated (i.e., no ion-pairing) in this saturated solution, what is the value of its K_{sp} ?

$$K_{sp} = [\text{M}^{2+}][\text{X}^{-}]^2$$

van't Hoff factor $i = \text{maximum}$
(\checkmark) $\Rightarrow i = 3$ for MX_2
can use $[\]$ directly.

① Use total ion concentration of saturated solution to determine individual ion concentrations:

4

$$\text{Total [ion]} = 4.003 \times 10^{-3} \text{ M} = [\text{M}^{2+}] + [\text{X}^{-}]$$

and, ions formed in a $1 \text{ M}^{2+} : 2 \text{ X}^{-}$ ratio, so $[\text{X}^{-}] = 2[\text{M}^{2+}]$

$$\text{Thus: } 4.003 \times 10^{-3} \text{ M} = [\text{M}^{2+}] + 2[\text{M}^{2+}]$$

$$4.003 \times 10^{-3} \text{ M} = 3[\text{M}^{2+}]$$

$$[\text{M}^{2+}] = 1.334 \times 10^{-3} \text{ M}$$

$$\text{So } [\text{X}^{-}] = 2[\text{M}^{2+}] = 2.669 \times 10^{-3} \text{ M}$$

② Sub in to calculate value of K_{sp} :

$$K_{sp} = [1.334 \times 10^{-3} \text{ M}][2.669 \times 10^{-3} \text{ M}]^2$$

$$\therefore K_{sp} = 9.50 \times 10^{-9}$$

sub in whatever $[\]$'s they get...
in molarity

HAPPY HOLIDAYS

10

1-1.5
gift
marks
here

just for
multiplying!