

CHM 1311 - F

First Midterm

Oct 17 – 2017

(Prof. S. Gambarotta)

Your Name: _____

Student #: _____

1. The solution key will be posted today on the web. Solutions will be worked out in the next DGD.
2. You must respond to all exercises.
3. Periodic Table and relevant values are at the end.
4. A few scratch sheets are at the very end. Report in the booklet the minimum amount of calculations to show your reasoning.

Read carefully:

Cellular phones, unauthorized electronic devices or course notes (unless an open-book exam) are not allowed during this exam. Phones and devices must be turned off and put away in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, the following may occur: academic fraud allegations will be filed which may result in your obtaining a **0** (zero) for the exam.

By signing below, you acknowledge that you have read and ensured that you are complying with the above statement.

Signature: _____

1. (1 point) A normal breath takes in about 1.0 L of air. Assuming that air has an average molar mass of 28.8 g (molar mass_{air} = 28.8), and that its density is 0.97 g/L, how many molecules of air do you take in with each breath?

1L of air corresponds to 0.97 g.

The “moles” of air are : $0.97/28.8$ and which once multiplied by N gives:

Answ. 2.0×10^{22}

2. (2 points) Terephthalic acid, used in the production of polyester fibers and films, is composed of carbon, hydrogen, and oxygen. When 0.6943 g of terephthalic acid was subjected to combustion analysis it produced 1.471 g CO₂ and 0.226 g H₂O. What is its empirical formula?

Grams of C in the sample: $1.471/44 \times 12 = 0.40$

Grams of H in the sample: $0.226/18 \times 2 = 0.025$

Grams of O in the sample = $0.6943 - 0.40 - 0.025 = 0.269$

Moles of C = $0.40/12 = 0.033$

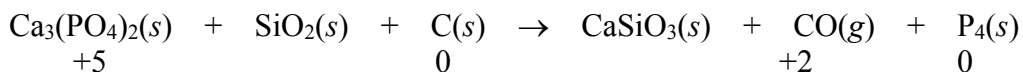
Moles of H = $0.025/1 = 0.025$

Moles of O = $0.269/16 = 0.0168$

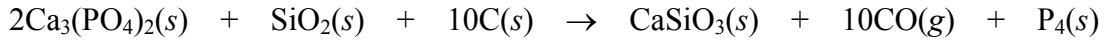
The ratio would give C₂H_{1.5}O₁ and which should be multiplied by 2 yielding:

Anw. C₄H₃O₂

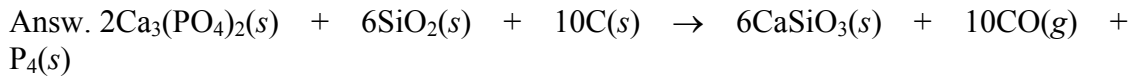
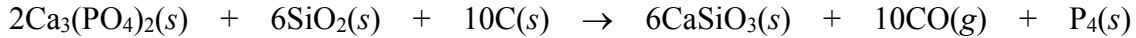
3. (3 points) Balance the following equation:



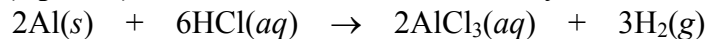
P exchanges 10 electrons to get into P₄ and C exchanges 2 and the electron balance yields:



the subsequent mass balance yields:

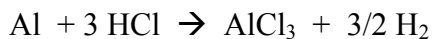


4. (2 points) Aluminum metal dissolved in hydrochloric acid as follows:



- What is the minimum volume of 6.0 M HCl(aq) needed to completely dissolve 3.20 g of aluminum in this reaction?
- What mass of AlCl₃ would be produced by complete reaction of 3.20 g of aluminum?

$$\text{Moles of Al} = 3.2/26.98 = 0.118$$



Thus moles HCl needed: $0.118 \times 3 = 0.356$ which, divided by the molarity, corresponds to 59.3 mL

The mass of AlCl₃ = 0.118 moles x molar mass AlCl₃ = 15.8 g

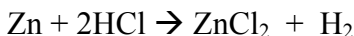
- Answ. a) 59.3 mL
b) 15.8 g

5. (1 point) A flask containing neon gas is connected to an open-ended mercury manometer. The open end is exposed to the atmosphere, where the prevailing pressure is 745 torr. The mercury level in the open arm is 50 mm/Hg below that in the arm connected to the flask of neon. What is the neon pressure, in torr?

$$P_{\text{int}} = P_{\text{ext}} = P_{\text{atm}} = P_{\text{ne}} + P_{\text{Hg}}$$

$$P_{\text{atm}} - P_{\text{Hg}} = P_{\text{Ne}} \quad 745 - 50 = 695 \text{ torr}$$

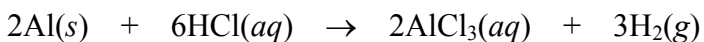
6. (1 point) Small quantities of hydrogen can be prepared by the addition of hydrochloric acid to zinc. A sample of 195 mL of hydrogen was collected over water at 25°C and 1.00 bar. What mass of hydrogen was collected? ($P_{\text{H}_2\text{O}} = 0.0320 \text{ bar}$ at 25°C).



$$\text{Moles of H}_2 = V (P - P_{\text{H}_2\text{O}}) / RT = 0.195 \times 0.968 / 298 \times 0.0831$$

$$\text{gr H}_2 = 2 \times \text{moles H}_2 = 0.0154 \text{ g}$$

7. (2 points) Aluminum metal shavings (10.0 g) are placed in 100 mL of 6.00 M hydrochloric acid. What is the maximum volume of hydrogen, measured at STP (273K, 101.325 kPa), which can be produced?



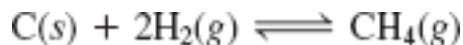
Find the limiting reagent:

$$\text{Based on Al: } 10.0 / 26.98 \times 3/2 = 0.557 \text{ moles of H}_2$$

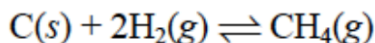
$$\text{Based on HCl: } 0.1 \times 6.00 \times 3/6 = 0.3 \text{ moles of H}_2$$

Maximum moles of H₂ are 0.3 which at STP converts to 6.81 L

8. (1 point) For the following reaction, $K = 0.262$ at 1000°C :



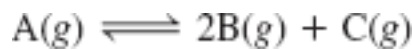
At equilibrium, P_{H_2} is 1.22 bar. What is the equilibrium partial pressure of $\text{CH}_4(g)$?



$$K = \frac{P_{\text{CH}_4}}{P_{\text{H}_2}^2} = 0.262$$

$$P_{\text{CH}_4} = K \cdot P_{\text{H}_2}^2 = (0.262)(1.22)^2 = 0.38996 \text{ bar} = \mathbf{0.390 \text{ bar}}$$

9. (2 points) Compound A decomposes according to the following equation:



A sealed 1.00-L container initially contains 1.75×10^{-3} mol of $\text{A}(g)$, 1.25×10^{-3} mol of $\text{B}(g)$, and 6.50×10^{-4} mol of $\text{C}(g)$ at 100°C . At equilibrium, $[\text{A}]$ is 2.15×10^{-3} mol/L. Find $[\text{B}]$ and $[\text{C}]$.

Initial concentrations:

$$[\text{A}] = (1.75 \times 10^{-3} \text{ mol}) / (1.00 \text{ L}) = 1.75 \times 10^{-3} \text{ mol/L}$$

$$[\text{B}] = (1.25 \times 10^{-3} \text{ mol}) / (1.00 \text{ L}) = 1.25 \times 10^{-3} \text{ mol/L}$$

$$[\text{C}] = (6.50 \times 10^{-4} \text{ mol}) / (1.00 \text{ L}) = 6.50 \times 10^{-4} \text{ mol/L}$$



Initial	1.75×10^{-3}	1.25×10^{-3}	6.50×10^{-4}
Change	$-x$	$+2x$	$+x$
Equilibrium	$1.75 \times 10^{-3} - x$	$1.25 \times 10^{-3} + 2x$	$6.50 \times 10^{-4} + x$

$$[\text{A}]_{\text{eq}} = 2.15 \times 10^{-3} = 1.75 \times 10^{-3} - x$$

$$x = -0.00040$$

$$[\text{B}]_{\text{eq}} = 1.25 \times 10^{-3} + 2x = \mathbf{4.5 \times 10^{-4} \text{ mol/L}}$$

$$[\text{C}]_{\text{eq}} = 6.50 \times 10^{-4} + x = \mathbf{2.5 \times 10^{-4} \text{ mol/L}}$$

Bonus question (4 points)

The following reaction takes place at 80.1°C:



The following time and concentration data are collected:

t (s)	[Ru(NH ₃) ₅ Cl ²⁺]	ln (Ru(NH ₃) ₅ Cl ²⁺)	1/(Ru(NH ₃) ₅ Cl ²⁺)
0	1.50 x 10 ⁻²	-4.20	66.7
1.00 x 10 ⁻³	1.08 x 10 ⁻²	-4.53	92.6
2.00.x 10 ⁻³	7.78 x 10 ⁻³	-4.86	128.5
3.00.x 10 ⁻³	5.61 x 10 ⁻³	-5.18	178.2
5.40.x 10 ⁻³	2.55 x 10 ⁻³	-5.97	392
1.01.x 10 ⁻²	5.46 x 10 ⁻⁴	-7.51	1830
4.00.x 10 ⁻²	3.01 x 10 ⁻⁸	-17.3	3.32 x10 ⁷

Which of the following is the correct value of the rate constant?

Answer: 328 1/s

Data For Water

Density = 1.00 g/mL (at 25°C)

 $s = 2.13 \text{ J g}^{-1} \text{ K}^{-1}$ (solid) $s = 4.184 \text{ J g}^{-1} \text{ K}^{-1}$ (liquid) $s = 2.01 \text{ J g}^{-1} \text{ K}^{-1}$ (gas) $\Delta H^{\circ}_{\text{fus}} = 6.02 \text{ kJ mol}^{-1}$ $\Delta H^{\circ}_{\text{vap}} = 40.7 \text{ kJ mol}^{-1}$ **Constants and Conversion Factors**

1 mmHg = 1 torr 760 mmHg = 1 atm 1 atm = 101.325 kPa 1 atm = 1.013125 bar
 1 cm³ = 1 mL 1000 mL = 1 L 1000 L = 1 m³

Avogadro's Number	N	$6.022 \times 10^{23} \text{ mol}^{-1}$
Boltzmann's constant	k	$1.30866 \times 10^{-23} \text{ J} \cdot \text{K}^{-1}$
Faraday's constant	F	$96,485 \text{ C} \cdot \text{mol}^{-1}$
Gas constant	R	$8.31451 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$0.08206 \text{ atm} \cdot \text{L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$8.31451 \text{ m}^3 \text{ Pa} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	R	$0.0831451 \text{ bar} \cdot \text{L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
Planck's constant	h	$6.62608 \times 10^{-34} \text{ J} \cdot \text{s}$
Speed of Light	c	$2.99792458 \times 10^8 \text{ m} \cdot \text{s}^{-1}$

Gas Laws

$$PV = nRT$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_T = P_1 + P_2 + P_3 + \dots$$

$$d = \frac{m}{V} = \frac{P \cdot MM}{RT}$$

$$E_k = \frac{1}{2}mv^2$$

$$u_{rms} = \sqrt{\frac{3RT}{MM}}$$

$$\frac{\text{Rate A}}{\text{Rate B}} = \sqrt{\frac{MM_B}{MM_A}}$$

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

Equilibrium

$$K_p = K_c(RT)^{\Delta n}$$

Acid/Base

$$pOH = -\log[OH^-]$$

$$pH = -\log[H^+]$$

$$pH + pOH = 14$$

$$K_a \times K_b = K_w$$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$$pH = \frac{pK_{a1} + pK_{a2}}{2}$$

Thermochemistry

$$\Delta U = q + W$$

$$W_{\text{system}} = -P\Delta V = -\Delta nRT$$

$$\Delta H = \Delta U + P\Delta V$$

$$q_p = \Delta U + P\Delta V$$

$$q = ms\Delta T$$

$$\Delta H_{\text{rxn}}^\circ = \sum n\Delta H_f^\circ(\text{pds}) - \sum n\Delta H_f^\circ(\text{rxts})$$

The atom

$$E = hv$$

$$c = v\lambda$$

$$E = -B/n^2$$

Kinetics

$$[A]_t = [A]_o - kt$$

$$\ln[A]_t = \ln[A]_o - kt$$

$$1/[A]_t = 1/[A]_o + kt$$

$$k = Ae^{(-E_a/RT)}$$

$$\ln(k_2/k_1) = (-E_a/R)(1/T_2 - 1/T_1)$$

