

Exam 1



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Exam #1 – CHM1311A

Date: October 10th, 2018

Length: 80min

Last Name: Corrected

Dr. Matthew Lafrenière

First Name: _____

Student #: Updated

READ THESE INSTRUCTIONS:

- Calculator permitted (Faculty approved or any other kind)
- Do not forget to show your units!
- Be sure to show your work!
- **CIRCLE YOUR FINAL ANSWER**

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.

Read carefully:

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

Signature: _____

Generally: - 0.25 pts per missing unit to a max of 2 pts per question and part.

Exam 1

Question	Points Possible	Points Earned	TA initial
1	10		
2	5		
3	15		
4	5		
5	20		
6	5		
7	5		
8	20		
Total	85 96		

→ Bonus question

+ 24 pts

61

Exam 1

Question 1 (10 points). Provide the names for the chemical compounds below. Be sure to provide both the systemic and common (trivial) name for metals.

RbBr

Answer: Rubidium bromide (1)

SiO₂

Answer: Silicon dioxide (1)

Hg(ClO₄)₂

Answer: Mercury (II) perchlorate (0.5) & Mercuric perchlorate (0.5)

KClO₃

Answer: Potassium chlorate (1)

CsClO

Answer: Cesium hypochlorite (1)

KMnO₄

Answer: Potassium permanganate (1)

Ca₃(PO₄)₂

Answer: Calcium phosphate (1)

Pb(IO₃)₂

Answer: Lead (II) iodate (1)

Sn(Cr₂O₇)₂

Answer: Tin (IV) dichromate (0.5) & stannic dichromate (0.5)

Exam 1

Question 2 (5 points). Provide the molecular formulas for the following chemical names.

Mercuric cyanide

Answer: $\text{Hg}(\text{CN})_2$ (1)

Chromic oxide

Answer: Cr_2O_3 (1)

Ferrous sulfate

Answer: FeSO_4 (1)

Lead sulfide

Answer: PbS (1)

Magnesium sulfate heptahydrate

Answer: $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (1)

Exam 1

Question 3 (15 points). Sofosbuvir ($C_{22}H_{29}FN_3O_9P$), a drug sold by Gilead Sciences, is a medication used for the treatment of individuals infected with the hepatitis C virus. Answer the following questions:

- Calculate the molar mass of sofosbuvir. Be sure to show all your work.

$$\begin{aligned}
 22 \times 12.011 \text{ g/mol C} &= 264.242 \text{ g/mol C} \\
 29 \times 1.00794 \text{ g/mol H} &= 29.23026 \text{ g/mol H} \\
 1 \times 18.998 \text{ g/mol F} &= 18.998 \text{ g/mol F} \\
 3 \times 14.0067 \text{ g/mol N} &= 42.0201 \text{ g/mol N} \\
 9 \times 15.9994 \text{ g/mol O} &= 143.9946 \text{ g/mol O} \\
 1 \times 30.974 \text{ g/mol P} &= 30.974 \text{ g/mol P}
 \end{aligned}$$

↳ For final answer:
 - no sig figs! (-0.25)
 - no units? (-0.5)

Answer (a): 529.46 g/mol

- What is the percent by mass of hydrogen in sofosbuvir?

$$\% \text{ mass} = \frac{(\# \text{ atoms of } x) \times (\text{mm } x)}{\text{mm compound}} \times 100\%$$

$$\% \text{ mass Hydrogen} = \frac{29.23026 \text{ g/mol H}}{529.46 \text{ g/mol sofosbuvir}} \times 100\% = 5.52\% \text{ H}$$

Answer (b): 5.52% H

- What is the percent by mass of nitrogen in sofosbuvir?

$$\% \text{ mass nitrogen} = \frac{42.0201 \text{ g/mol N}}{529.46 \text{ g/mol sofosbuvir}} \times 100\% = 7.93\% \text{ N}$$

Answer (c): 7.93% N

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- If a physician is required to provide 400 mg of sofosbuvir daily to her patient, how many atoms of oxygen are contained in this daily treatment?

$$1 \text{ mol } C_{22}H_{29}FN_3O_9P = 9 \text{ moles of oxygen}$$

$$400 \text{ mg } C_{22}H_{29}FN_3O_9P = \frac{0.400 \text{ g } C_{22}H_{29}FN_3O_9P}{529.46 \text{ g/mol } C_{22}H_{29}FN_3O_9P} = 0.0007555 \text{ mol Sofosbuvir}$$

$$0.0007555 \text{ mol Sofosbuvir} \times \frac{9 \text{ moles oxygen}}{1 \text{ mol Sofosbuvir}} = 0.0067994 \text{ mol O}$$

$$0.0067994 \text{ mol O} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 4.09 \times 10^{21} \text{ atoms O}$$

Answer (d): 4×10^{21} atoms O

- ~~If a physician is required to provide 400 mg of sofosbuvir daily to her patient, how many moles of carbon are contained in this daily treatment?~~

$$1 \text{ mol } C_{22}H_{29}FN_3O_9P = 22 \text{ mol Carbon}$$

$$\text{From calculation above: } 0.0007555 \text{ mol } C_{22}H_{29}FN_3O_9P$$

$$0.0007555 \text{ mol Sofosbuvir} \times \frac{22 \text{ mol C}}{1 \text{ mol Sofosbuvir}} = 0.016621 \text{ mol C}$$

Bonus Q

Answer (e): 2.0×10^{-2} mol C

Exam 1

Question 4 (5 points). Dopamine (153.181 g/mol), a neurotransmitter important in neuronal function, contains 62.7% C, 7.21% H, 9.19% N, and 20.9% O. What are the empirical and molecular formula for dopamine?

assume 100g of dopamine:

$$\text{C: } 62.7\% \rightarrow \frac{62.7 \text{ g C}}{12.01 \text{ g/mol C}} = 5.2202 \text{ mol C}$$

$$\text{H: } 7.21\% \rightarrow \frac{7.21 \text{ g H}}{1.00794 \text{ g/mol H}} = 7.1532 \text{ mol H}$$

$$\text{N: } 9.19\% \rightarrow \frac{9.19 \text{ g N}}{14.00674 \text{ g/mol N}} = 0.6561 \text{ mol N}$$

$$\text{O: } 20.9\% \rightarrow \frac{20.9 \text{ g O}}{15.9994 \text{ g/mol O}} = 1.306 \text{ mol O}$$

$$\begin{array}{cccc} \text{C} & \text{H} & \text{O} & \text{N} \\ \frac{5.2202}{0.6561} & \frac{7.1532}{0.6561} & \frac{1.306}{0.6561} & \frac{0.6561}{0.6561} \end{array} = \begin{array}{cccc} \text{C}_{7.96} & \text{H}_{10.90} & \text{O}_{1.99} & \text{N}_1 \end{array}$$

↓ okay to round
 $\text{C}_8\text{H}_{11}\text{O}_2\text{N}_1$

molecular formula:

$$\frac{\text{mm empirical formula}}{\text{mm mol. formula}} = \frac{153.18 \text{ g/mol}}{153.18 \text{ g/mol}} = 1$$

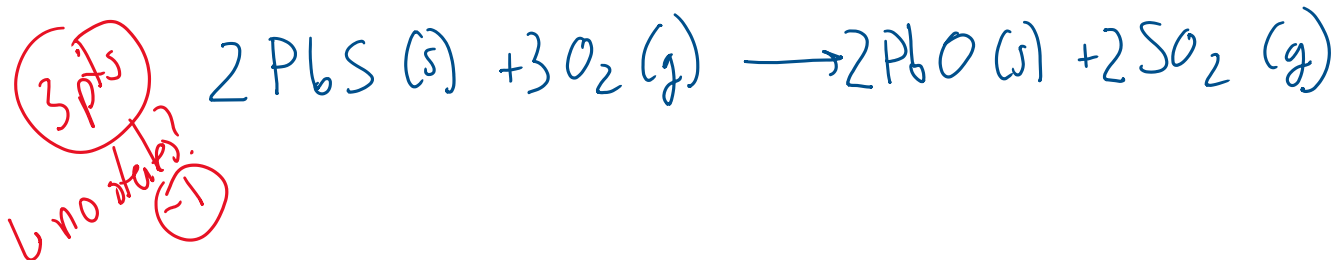
Answer (Empirical formula): $\text{C}_8\text{H}_{11}\text{O}_2\text{N}_1$

Answer (Molecular formula): $\text{C}_8\text{H}_{11}\text{O}_2\text{N}_1$

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Question 5 (20 points). Industrially, solid galena (lead sulfide) reacts with oxygen gas to generate lead oxide and sulfur dioxide. Answer the following questions and be sure to show all your work:

- Write the balanced, chemical equation outlined by the question above. Do not forget to include your states.



- If 5.670 kg of galena reacts with 600.61 L of oxygen gas at 27.6°C and 1.01 bar, how much (mL) sulfur dioxide will we produce? What is the limiting reagent?

Galena (PbS): $5.670 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 5670 \text{ g PbS} = 23.697 \text{ mol PbS}$
 $\frac{5670 \text{ g PbS}}{239.266 \text{ g/mol PbS}}$

Oxygen: 600.61 L O₂ (g)
 T: 27.6°C + 273.15 K = 300.75 K
 P: 1.01 bar
 R: 0.0831451 $\frac{\text{L} \cdot \text{bar}}{\text{mol} \cdot \text{K}}$ (From eq. page)

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n = \frac{(1.01 \text{ bar})(600.61 \text{ L})}{(0.0831451 \frac{\text{L} \cdot \text{bar}}{\text{mol} \cdot \text{K}})(300.75 \text{ K})}$$

$$n = 24.259 \text{ mol O}_2$$



24.259 mol O₂ (g) × $\frac{2 \text{ mol SO}_2}{3 \text{ mol O}_2} = 16.173 \text{ mol SO}_2 \text{(g)}$

23.697 mol PbS (s) × $\frac{2 \text{ mol SO}_2}{2 \text{ mol PbS}} = 23.697 \text{ mol SO}_2 \text{(g)}$

∴ O₂ is the limiting reagent

2) $PV = nRT$

$$V = \frac{nRT}{P}$$

Answer (sulfur dioxide): $\frac{(16.173 \text{ mol SO}_2)(8.314 \times 10^{-2} \frac{\text{L} \cdot \text{bar}}{\text{mol} \cdot \text{K}})(300.75 \text{ K})}{1.01 \text{ bar}} = 4.00 \times 10^5 \text{ mL}$

Answer (Limiting reagent): O₂

V = 400.416 L or 400416.1 mL

1) -0.25 no sig figs
 ↳ -0.5 if no units

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- What amount of excess reagent will be remaining following the complete consumption of the limiting reagent in the previous point? Your answer may need to be in either grams or milliliters.

Total moles PbS: 23.697 moles

① To generate 16.173 mol SO₂(g), we need:

$$16.173 \text{ mol SO}_2(g) \times \frac{2 \text{ mol PbS}}{2 \text{ mol SO}_2} = 16.173 \text{ mol PbS}$$

① Excess reagent: 23.697 moles PbS - 16.173 moles PbS = 7.524 mol PbS

$$7.524 \text{ mol PbS} \times \frac{239.266 \text{ g}}{\text{mol}} \text{ PbS} = 1800.24 \text{ g PbS}$$

-0.25 sig figs
-0.5 units

①

Answer (excess reagent): 1.80 × 10³ g PbS

- If 345 L of SO₂ are obtained, what is the percent yield for this reaction?

$$\% \text{ yield} = \frac{\text{actual}}{\text{theoretical}} \times 100\%$$

$$\% \text{ yield} = \frac{345 \text{ L SO}_2(g)}{400.416 \text{ L SO}_2(g)} \times 100\% = 86.2\%$$

①

Answer (percent yield): 86.2% ①

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Question 6 (5 points). The ratio of effusion rates for two gases was determined to be 2.2. The identity of one of the gases was experimentally determined to molecular oxygen. What is the identity of the other gas?

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

$$\frac{\text{Rate O}_2}{\text{Rate unk}} = 2.2$$

$$2.2 = \frac{\sqrt{MM_{unk}}}{\sqrt{MM_{O_2}}}$$

$$2.2 = \frac{\sqrt{MM_{unk}}}{5.656}$$

$$MM_{unk} = 154.88 \frac{g}{mol} \quad \text{closest gas? Xe}$$

Answer (gas identity): Xenon (2)

Question 7 (5 points). Calculate the root-mean-square speed for krypton at 58.4°C.

$$v_{RMS} = \frac{\sqrt{3RT}}{MM_{gas}}$$

$$\text{Krypton: } 83.80 \frac{g}{mol} \times \frac{1 mol}{1000g} = 0.0838 \frac{kg}{mol}$$

$$v_{RMS} = \frac{(3) \times (8.31451 \frac{J}{mol \cdot K}) \times (58.4^\circ C + 273.15 K)}{0.0838 \frac{kg}{mol} \text{ krypton}}$$

$$v_{RMS} = 314.146 \frac{m}{s}$$

Answer (root-mean-square speed): 314 m/s

-0.25 sig fig
-0.5 units

Bonus question

Exam 1

Question 8 (20 points). The decomposition of dinitrogen pentoxide to nitrogen dioxide and oxygen gas was examined and the following kinetic data was determined:

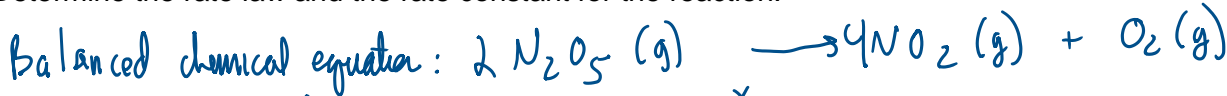
decomposition ↑

[N ₂ O ₅] M	Initial rate (M/s) (x10 ⁻⁵)
0.92	0.95
1.23	1.20
1.79	1.93
2.00	2.10
2.21	2.26

← starting concentration

No states? -2

Determine the rate law and the rate constant for the reaction.



The generic rate law: $\text{rate} = k [\text{N}_2\text{O}_5]^x$

[N ₂ O ₅] M	Initial rate (x10 ⁻⁵) $\frac{\text{M}}{\text{s}}$	$\ln \frac{A_0}{A_T}$	$\frac{1}{A_T} - \frac{1}{A_0}$
2.21	2.26	0.0000	0
2.00	2.10	0.0998	0.0475
1.79	1.93	0.2107	0.1062
1.23	1.20	0.5859	0.3605
0.92	0.95	0.8764	0.6345

→ Data fits 1st kinetics better than first, so reaction is 1st order. (2)

→ to calculate rate constant, use the rate law:

$$\text{Rate} = k [\text{N}_2\text{O}_5]^1$$

$$2.26 \times 10^{-5} \frac{\text{M}}{\text{s}} = k$$

$$2.21 \text{ M}$$

$$k = 1.02 \times 10^{-5} \text{ s}^{-1}$$

No units? -1 pt

Answer (rate law): $\text{Rate} = k [\text{N}_2\text{O}_5]^1$

Answer (rate constant): $\pm 1.02 \times 10^{-5} \text{ s}^{-1}$

(2)

Exam 1

Gas Laws

$$PV = nRT$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

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

$$P_A = \chi_A P_T$$

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

$$E_K = \frac{1}{2} m u^2$$

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

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

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

Equilibrium

$$K_P = K_C (RT)^{\Delta n}$$

$$\ln \left(\frac{K_2}{K_1} \right) = -\frac{\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Acid/Base

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

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

$$pH + pOH = 14$$

$$K_a \times K_b = K_w$$

Thermochemistry

$$\Delta U = q + W$$

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

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

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

$$q = mc\Delta T$$

$$q = n\Delta H$$

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

The atom

$$E = h\nu$$

$$c = \nu\lambda$$

$$\Delta E = -R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

Kinetics

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

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

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

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

$$\ln \left(\frac{k_2}{k_1} \right) = -\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Other

$$n = m/MM$$

$$C = n/V$$

Exam 1

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\text{pH} = \frac{\text{pK}_{a1} + \text{pK}_{a2}}{2}$$

$$\% \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \cdot 100\%$$

$$C_A = \frac{n_A}{n_T}$$

Data For Water

$$c = 2.13 \text{ J g}^{-1} \text{ K}^{-1} \text{ (solid)}$$

$$\text{Density} = 1.00 \text{ g/mL (at } 25^\circ\text{C)}$$

$$K_w = 1.0 \times 10^{-14}$$

$$c = 4.184 \text{ J g}^{-1} \text{ K}^{-1} \text{ (liquid)}$$

$$\Delta H^\circ_{\text{fus}} = 6.02 \text{ kJ mol}^{-1}$$

$$c = 2.01 \text{ J g}^{-1} \text{ K}^{-1} \text{ (gas)}$$

$$\Delta H^\circ_{\text{vap}} = 40.7 \text{ kJ mol}^{-1}$$

Constants and Conversion Factors

1 mmHg = 1 torr	1 atm = 101.325 kPa	1 cm ³ = 1 mL	1000 L = 1 m ³
760 mmHg = 1 atm	1 atm = 1.013125 bar	1000 mL = 1 L	1 mol = 22.7 L at STP

Avogadro's Number	N_A	6.022×10^{23}	mol^{-1}
Rydberg constant	R_H	2.179×10^{-19}	J
Boltzmann's constant	k_B	1.38065×10^{-23}	$\text{J} \cdot \text{K}^{-1}$
Gas constant	R	8.31451	$\text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
	R	0.08206	$\text{L} \cdot \text{atm} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
	R	8.31451	$\text{m}^3 \cdot \text{Pa} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
	R	8.31451	$\text{L} \cdot \text{kPa} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
	R	0.0831451	$\text{bar} \cdot \text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$
Planck's constant	h	6.62608×10^{-34}	$\text{J} \cdot \text{s}$
Speed of Light	c	2.99792458×10^8	$\text{m} \cdot \text{s}^{-1}$

Exam 1

Table of Ionization Constants at 25.0°C

Acid		$K_a =$
Iodic acid	$\text{HIO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{IO}_3^-$	1.6×10^{-1}
Chlorous acid	$\text{HClO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{ClO}_2^-$	1.1×10^{-2}
Chloroacetic acid	$\text{HC}_2\text{H}_2\text{ClO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_2\text{H}_2\text{ClO}_2^-$	1.4×10^{-3}
Nitrous acid	$\text{HNO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NO}_2^-$	7.2×10^{-4}
Hydrofluoric acid	$\text{HF} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{F}^-$	6.6×10^{-4}
Formic acid	$\text{HCHO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CHO}_2^-$	1.8×10^{-4}
Benzoic acid	$\text{HC}_7\text{H}_5\text{O}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_7\text{H}_5\text{O}_2^-$	6.3×10^{-5}
Hydrazoic acid	$\text{HN}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{N}_3^-$	1.9×10^{-5}
Acetic acid	$\text{HC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_2\text{H}_3\text{O}_2^-$	1.8×10^{-5}
Hypochlorous acid	$\text{HOCl} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OCl}^-$	2.9×10^{-8}
Hydrocyanic acid	$\text{HCN} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CN}^-$	6.2×10^{-10}
Phenol	$\text{HOC}_6\text{H}_5 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{C}_6\text{H}_5\text{O}^-$	1.0×10^{-10}
Hydrogen peroxide	$\text{H}_2\text{O}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HO}_2^-$	1.8×10^{-12}

Table of Solubility Product Constants

Compound	K_{sp}	Compound	K_{sp}	Compound	K_{sp}
$\text{Cd}(\text{OH})_2$	2.5×10^{-14}	Ag_2CrO_4	1.9×10^{-12}	AgI	1.5×10^{-16}
CdS	8.0×10^{-28}	PbI_2	8.7×10^{-9}	PbCrO_4	1.8×10^{-14}
$\text{Ca}(\text{SO}_4)$	9.1×10^{-6}	PbCl_2	1.9×10^{-5}	$\text{Ba}(\text{OH})_2$	5.0×10^{-3}

Exam 1

Scrap paper

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Scrap paper

