Directions: You have two hours to complete this exam. This exam is closed book and electronic device. The only allowed device for this exam is a calculator. You may remove this equation sheet/periodic table. Make sure to write your name on the first page of the exam.

$$\pi = MRT$$

$$\Delta T = k_f m$$

$$\Delta T = k_b m$$

$$R = 0.08206\ \frac{L.atm}{mol\ K}$$

$$P = Xsolvent\ P°solvent$$

$$[A]t = -kt + [A]o$$

$$t\frac{1}{2} = \frac{[A]o}{2k}$$

$$\ln[A]\ t = -kt + \ln[A]\ o$$

$$t\frac{1}{2} = \frac{0.693}{k}$$

$$\frac{1}{[A]t} = kt + \frac{1}{[A]o}$$

$$t\frac{1}{2} = \frac{1}{k[A]o}$$

$$Sgas = k_H\ Pgas$$

$$1\ atm = 760\ mm\ Hg = 760\ torr$$

$$k = Ae^{-Ea/RT}$$

$$ln\frac{k2}{k1} = \frac{Ea}{R}\left(\frac{1}{T1} - \frac{1}{T2}\right)$$

$$R = 8.314\frac{J}{mol\ K}$$

$$K = °C + 273$$

Periodic Table of the Elements

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Ch 104
Summer 2024
Exam 1 Friday July 19th
Watkins

Name: ANSWER KEY

1. When 14.7 grams of a compound (a non-electrolyte) is dissolved in 941.4 grams of benzene (C_6H_6) the new freezing point is 4.90 °C. The freezing point of pure benzene is 5.50 °C and the k_f of benzene is 5.12 °C. What is the molar mass of the organic compound? (**10 pts**)

$$\Delta T_f = k_f m$$

$$-(4.90\,°C - 5.50\,°C) = 5.12 \frac{m}{°C} (m)$$

$$0.60\,°C = 5.12 \frac{m}{°C} (m)$$

$$m = \frac{0.60\,°C}{5.12\,°C/m} = 0.11718\ldots m$$

Kg of solvent = 0.9414 Kg

$$\frac{0.11718 \text{ mol}}{\text{kg}} \times 0.9414 \text{ kg} = 0.1103 \text{ mol}$$

molar mass = $\frac{14.7 \text{ g}}{0.1103 \text{ mol}}$ = 133 g/mol

$i = 2$

2. Sea water has a sodium chloride concentration of 3.5 grams of NaCl/100.0 mL of solution. The osmotic pressure of blood is 7.1 atm at 37.0°C. Does sea water have the same osmotic pressure as blood if it is at 37.0 °C? **Yes or no? AND show all calculations used to determine your answer. (8 pts)**

$\Pi = iMRT$

[NaCl]

$3.5 g\ NaCl \times \frac{1 mol}{58 g} \times \frac{1}{0.100 L} =$

$0.603 \frac{mol}{L}$

$\Pi = (2)(0.603 M)(0.08206 \frac{L \cdot atm}{mol \cdot K})(310 K)$

31 atm

NO, Π of 31 atm is >> 7.1 atm for blood

3. Concentrated nitric acid has a concentration of 67% by mass (67 grams of HNO_3/100.0 g of solution). The density of this solution is 1.40 g/mL . Answer the following questions **(8 pts)**

a. What is the mole fraction of water?

$n_{H_2O}: 33g \times \frac{1 mol}{18g} = 1.83$ mol

$n_{HNO_3}: 67g \times \frac{1 mol}{63g} = 1.06$ mol

$\chi_{H_2O}: \frac{1.83}{1.83+1.06}$ = 0.630

also accepted $\frac{1.83}{1.83+2(1.06)}$ = 0.46

b. What is the molarity?

$M = \frac{mol\ solute}{L\ solution}$

$100.g \times \frac{1 mL}{1.40g} = 71.4 mL$

$M = \frac{1.06 mol}{0.0714 L} = 15 M$

c. What is the molality?

$m = \frac{mol\ solute}{Kg\ solvent}$

mass of solvent = 100.g − 67.0g = 33.0g

$m = \frac{1.06 mol}{0.033 Kg} = 32 m$

4. A student obtained the following data for decomposition of hydrogen peroxide,
$2H_2O_2$ (l) → $2H_2O$ (l)+ O_2 (g)
Answer the following questions. Graphs ARE NOT required but graph paper is provided on the next page if you want to make plots. The student wants to determine the rate law, rate = $k[H_2O_2]^m$. **(10 pts)**

Time (s)	**$[H_2O_2]$ mol/L**
0	1.0
120	0.91
300	0.78
600	0.59
1200	0.37
1800	0.22
2400	0.13
3000	0.082
3600	0.050

a. Is the reaction zero, first or second order with respect to hydrogen peroxide?

1st order has constant slope

b. What is the rate law and rate constant with units?

rate = $7.9\times10^{-4}\ s^{-1}[H_2O_2]^1$

c. What is the concentration of hydrogen peroxide after 5000.0 seconds?

$\ln[H_2O_2]_{5000s} = -kt + \ln(1.0)$

$\ln[H_2O_2] = -7.9\times10^{-4}\ s^{-1} \cdot 5000s + 0$

$[H_2O_2] = e^{-3.95} = 0.019M$

d. Describe two ways to increase the rate of the reaction for decomposition of hydrogen peroxide.

↑ $[H_2O_2]$ concentration

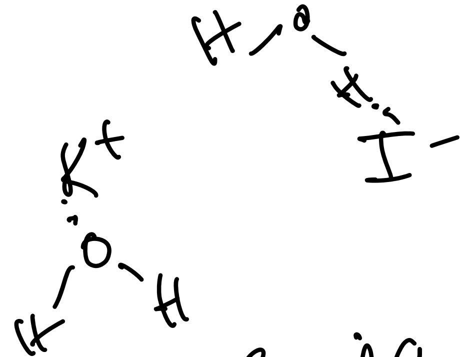
↑ temperature

other answers possible

5. Determine whether each of the following solutes are miscible in water or hexane (C_6H_{14}) and explain your choice. **(6 pts)**

a. Potassium iodide

water

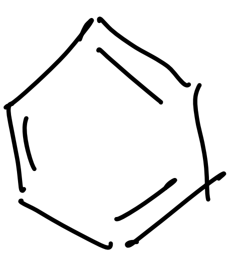


interacts via ion-dipole IMFs

b. Acetic Acid (CH_3COOH)

polar miscible w/ polar H_2O via dipole-dipole & H bonds

c. Benzene (C_6H_6)



non-polar miscible w/ hexane via LDF IMF

6. Given the proposed mechanism for the reaction below answer the following questions. **(10 pts)**

$H_2(g)+2ICl(g) \longrightarrow I_2(g)+2HCl(g)\ \Delta H<0$

Experimental rate law: rate= $k[H_2][ICl]$

Step 1 (slow) $H_2(g) + ICl(g) \longrightarrow HI(g) + HCl(g)$

Step 2 (fast) $HI(g) + ICl(g) \longrightarrow I_2(g) + HCl(g)$

a. Write a rate law for each elementary step

Step 1 : rate= $k[H_2]^1[ICl]^1$

Step 2: rate= $k[HI]^1[ICl]^1$

b. Is the proposed mechanism is valid for the reaction studied in the lab and experimentally determined rate law? Yes or No and explain your answer.

Yes b/c sum of steps = overall rxn

1) $H_2 + ICl \rightarrow HI + HCl$

$+\ HI + ICl \rightarrow I_2 + HCl$

$H_2 + 2ICl \rightarrow I_2 + 2HCl$

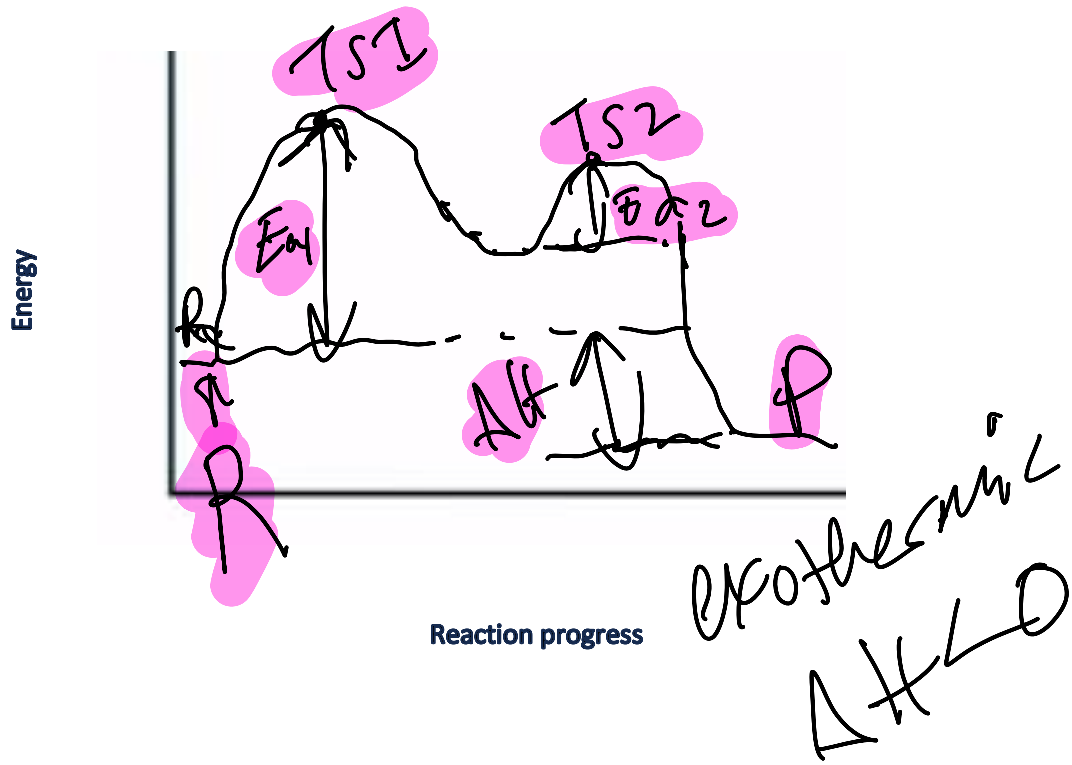
2) The RDS, slow step, rate law is the same as exp. rate law

c. What molecule is the intermediate for this reaction mechanism?

HI (g)

6 continued

d. Draw and label a reaction coordinate diagram for the reaction mechanism from #6. **You can use the following abbreviations (P for products, R for reactants, TS1 and TS2 for transition state for step 1 and step 2 Ea1 and Ea2 for activation energy for step 1 and step 2, and ΔH).**



7. Given the data below please answer the following questions, make sure to include the rate constant with units. The reaction is: NH_4^+ (aq) + NO_2^- (aq) → N_2(g) + $2H_2O$ (l) and the reaction rate is defined at rate = $-\Delta[NH_4^+]/\Delta t$. **(10 pts)**

Experiment	$[NH_4^+]$	$[NO_2^-]$	Initial rate (mol/L-s)
1	0.100 M	0.0050 M	1.35×10^{-7}
2	0.100 M	0.010 M	2.70×10^{-7}
3	0.200 M	0.010 M	5.40×10^{-7}

a. What is the rate law for this reaction?

rate = $k[NH_4^+]^1[NO_2^-]^1$

b. What is the rate constant (k)?

using exp #1

$1.35 \times 10^{-7} \frac{M}{s} = k(0.100M)(0.00500M)$

$k = 2.7 \times 10^{-4} M^{-1}s^{-1}$

c. What is the rate of the reaction if the concentration of ammonium ion and nitrite ion are 0.100 M?

rate = $2.7 \times 10^{-4} M^{-1}s^{-1}(0.100M)(0.100M)$

$= 2.7 \times 10^{-6} \frac{M}{s}$

8. The reaction, $C_4H_8(g) \longrightarrow 2C_2H_4(g)$, has an activation energy of 262 kJ/mol. At 327.0 °C, the rate constant, k, is 6.1×10^{-8} s−1. What is the value of the rate constant at 300.0°C? **(8 pts)**

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

$$\ln k_2 - \ln(6.1 \times 10^{-8}) = \frac{262{,}000\text{ J/mol}}{8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}} \cdot \left(\frac{1}{573} - \frac{1}{600}\right)$$

$+16.6$

$$k_2 = e^{-19.2}$$

$4.5 \times 10^{-9}\ s^{-1}$

9. The equilibrium constant (Kp) for the reaction $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ at 100 °C is **2.2 x 10 $^{--10}$**. Answer the following questions **(10 pts).**

a. If the initial pressure is 0.100 atm for $COCl_2$ what is the partial pressure of each gas at equilibrium?

$K_p = 2.2 \times 10^{-10}$

$COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$

I 0.100 M   ∅   ∅

C −x   +x   +x

E 0.100   x   x

$2.2 \times 10^{-10} = \frac{x^2}{0.100}$

$x = 4.6 \times 10^{-10}$

$P_{COCl_2} = 0.100 atm$

$P_{CO} = P_{Cl_2} = 4.6 \times 10^{-6}$

b. Is this equilibrium reactant or product favored? Briefly explain your answer.

K <<< 1 reactant favored and as can be seen from part a the P_{CO} & P_{Cl_2} products is very, very small ⓐ ⇌

c. If the volume of the reaction vessel is decreased which direction will the reaction shift (reactants or products) to offset the stress and re-establish equilibrium?

reactants ↓V, ↑P shifts to side w/ least moles of gas to re-establish equilibrium compared to P_{COCl_2}

10. When 0.0322 moles of NO gas and 1.70 grams of bromine gas are placed in a 2.00 L reaction vessel at 25.0°C, the equilibrium pressure of NOBr was 0.438 atm. What is the equilibrium constant, Kp, at 25.0°C? **PV=nRT (8 pts)**

$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$

	$2NO$	Br_2	$2NOBr$
I	0.394 atm	0.130 atm	∅
C	−2x	−x	+x
E	0.394 − 2x	0.130 − x	+x

☆ Typo for initial amounts so graded work for calculating P_{NO} & P_{Br_2} initially and setting up ICE chart w/ correct change x values

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

$P_{NO} = \frac{(0.0322\ mol)(0.08206\ \frac{L \cdot atm}{mol \cdot K})(298K)}{2\ L}$

$P_{NO} = 0.394\ atm$

P_{Br_2} $n_{Br_2} = 1.70g \times \frac{1\ mol}{159\ g} =$

$P_{Br_2} = \frac{(0.0106\ mol)(0.08206\ \frac{L \cdot atm}{mol \cdot K})(298K)}{2\ L}$

$P_{Br_2} = 0.130\ atm$

11. For the following reaction: $H_{2\,(g)} + I_2\,(g) \rightleftharpoons 2HI\,(g)$, **$\Delta H<0$ determine whether the reaction will shift towards the reactants, products or neither. (6 pts)**

a. Increase in pressure

nothing! moles of gaseous reactants = moles of products

b. Increase in temperature

↑ temp shift left (reactant)
Keq ↓

c. Addition of hydrogen gas

shift right (products)

d. Removal of iodine gas

shift left (reactants

12. At 0.0°C the solubility of oxygen gas is 0.0221 M at a pressure of 1.0 atm. At the same temperature, 0.0°C if the pressure is increased to 5.0 atm what mass of oxygen gas can be dissolved in two liters of water? **(6 pts)**

$S_g = k_H P_{gas}$

Find k_H first @ 0°C

$0.0221\ M = k_H\ (1\ atm)$

$k_H = 0.0221\ \frac{M}{atm}$

$P_{O_2} \uparrow 5.0\ atm$

$S_g = 0.0221\ \frac{M}{atm} \times 5\ atm = 0.111\ M$

in 2L of H_2O $\quad 0.111\ \frac{mol\ O_2}{L} \times 2\ L \times \frac{32\ g}{1\ mol}$

$= 7.1\ g\ O_2$

BONUS (2 pts)

If you had to name a cat what periodic element name would you give the cat and why? For example, my cat's Argon because he is just like a noble gas content and doesn't want to interact (aka react) with any other cats.

Xenon & Argon

My cats