*A periodic table will also be provided for the exam

$$\pi = MRT$$

$$\Delta T = k_f m$$

$$\Delta T = k_b m$$

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

$$P = Xsolvent\ P°solvent$$

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

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

$$\ln[A]\,t = -kt + \ln[\mathrm{A}]\,\mathrm{o}$$

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

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

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

$$Sgas = k_H\ Pgas$$

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

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

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

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

$$K = °C + 273$$

1. Rank the following solutions in terms of increasing boiling point (lowest to highest boiling point)

i=3 i=1 i=4 i=1

0.100 m $CaCl_2$, 0.40 m $C_6H_{12}O_6$, 0.125 $AlCl_3$, 0.2 m $C_{12}H_{22}O_{11}$

Order (low to high bp)

0.2 m $C_{12}H_{22}O_{11}$
0.1 m $CaCl_2$
0.4 m $C_6H_{12}O_6$
0.125 m $AlCl_3$

$\Delta T_b = i K_b m$

van Hoff factor

2. Concentrated HCl is 37% by mass HCl with a solution density of 1.2 g/mL.

a. What is the molality of the solution?

mol HCl $37.g \times \frac{1 mol}{36g} = 1.027... mol$

mass of $H_2O = 100.g - 37g = 63g$

$m = \frac{mol\ solute}{Kg\ solvent}$ $m = \frac{1.027 mol}{0.063 kg} =$

16.3m

b. What is the molarity of the solution?

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

$100.g\ solution \times \frac{1mL}{1.2g} =$

83.3mL

2b. $M = \frac{1.027 \text{ mol}}{0.0833 \text{ L}} = 12.3 M$

3. Myoglobin is a protein that uses a heme group to bind oxygen. A sample of myoglobin (a non-electrolyte) with a mass of 1.0 grams is dissolved in water for a final volume of solution of 100.0 mL. The osmotic pressure of the solution is 11.0 torr at 25.0°C. Find the molar mass of myoglobin.

$11.0 \text{ torr} \times \frac{1 \text{ atm}}{760. \text{ torr}} =$

$0.01447... \text{ atm}$

$\pi = MRT$

$M = \frac{\pi}{RT}$

$M = \frac{0.01447 \text{ atm}}{(0.08206 \frac{L \cdot atm}{mol \cdot K})(298 K)}$

$M = 5.92 \times 10^{-4} M$

$5.92 \times 10^{-4} \frac{mol}{L} \times 0.100 L =$

$5.92 \times 10^{-5} \text{ mol}$

$MM = 1.00 g / 5.92 \times 10^{-5} \text{ mol}$

$MM = 1.69 \times 10^{4} \frac{g}{mol}$

4. A certain reaction has a rate constant of 1.75 x 10-1 s-1 at 20.0 °C. What is the value of the rate constant (k) at 40.0 °C if Ea = 55.5 kJ/mol?

→ 293K

→ 313K

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

$$\ln k_2 - \ln(0.175) = \frac{55{,}500\ J/mol}{8.314\ J/mol \cdot K}\left(\frac{1}{293K} - \frac{1}{313K}\right)$$

$$\ln k_2 = 1.74 + 1.95$$

$$k_2 = e^{3.19}$$

$$k_2 = 24.35^{-1}$$

5. A student wants to study the decomposition of a gas "A", and obtained the following data in the lab.

Time (s)	[A], (M)	ln([A])	1/[A]
0	1.00×10^{-2}	−4.61	100
60	6.83×10^{-3}	−4.99	146
120	5.18×10^{-3}		
180	4.18×10^{-3}		
240	3.50×10^{-3}		
300	3.01×10^{-3}	−5.81	333
360	2.64×10^{-3}	−5.94	379

X not zero order, not first order; slopes: -5×10^{-5}, -6×10^{-6}; -6×10^{-3}, 2×10^{-3}; 0.77, 0.77

second order!

a. What is the order of the reaction with respect to A? BRIEFLY explain your reasoning.

calculate slope for each order for two sets of data points, if slope is constant that plot would be linear and thus the order

b. What is the differential rate law including the value of the rate constant with units?

$rate = 0.77\,M^{-1}s^{-1}[A]^2$ (see work above)

c. What is the concentration of [A] after 500 seconds if the initial concentration $[A]_o$ was 0.0100 M?

$$\frac{1}{[A]_{500}} = kt + \frac{1}{[A]_0}$$

$$\frac{1}{[A]_{500}} = (0.77\,M^{-1}s^{-1})(500\,s) + \frac{1}{0.0100\,M}$$

$\frac{1}{[A]_{500}} = 885\ M^{-1}$ $[A]_{500} = \frac{1}{885\ M^{-1}}$

$[A]_{500}$ is 1.1×10^{-3} M

6. Given the following data below for the reaction with the rate defined as Δ[I-]/Δt

$I^- + OCl^- \longrightarrow IO^- + Cl^-$

I⁻ is x2

	1	2	3
[I−]	0.10	0.20	0.30
[OCl−]	0.050	0.050	0.010
Rate (M/ s⁻¹)	3.05 × 10⁻⁴	6.20 ×10⁻⁴	1.83 × 10⁻⁴

rate x2

a. Determine the rate law for the reaction (see work above)

$2^m = 2$ $[I^-]^m$ order is 1

to find $[OCl^-]^n$ using exp 2 & 3

$\frac{1.83 \times 10^{-4}}{6.2 \times 10^{-4}} = \frac{k(0.3)^1(0.01)^n}{k(0.2)^1(0.05)^n}$

rate $= k[I^-]^1[OCl^-]^1$

b. What is the rate constant with units for the reaction?

$0.3 = 1.5(0.2)^n$

rate $= k[I^-][OCl^-]$

using exp #1

$3.05 \times 10^{-4}\ \frac{M}{s} = k(0.10\ M)^1(0.05\ M)^1$

$k = 0.061\ M^{-1}s^{-1}$

$0.2 = 0.2^n$

$n = 1$

1st order for $[OCl^-]$

7. You study the following reaction in the lab: $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$

The experimental rate law is rate = $k[NO2]^2$

Answer the following questions regarding this reaction.

a. Is the following reaction mechanism consistent with the experimentally observed rate law, rate = $k[NO_2]^2$? Explain.

1. $NO_2(g) + NO_2(g) \rightarrow NO_3(g) + NO(g)$ slow
2. $NO_3(g) + CO(g) \rightarrow NO_2(g) + CO_2(g)$ fast

$NO(g) + CO(g) \rightarrow NO(g) + CO_2(g)$

yes b/c Rate determining step slow step rate $= k'[NO_2]^2$ same as exp. sum of steps = overall rxn.

b. Please write a rate law for each elementary step in part a)

#1 rate $= k[NO_2]^2$

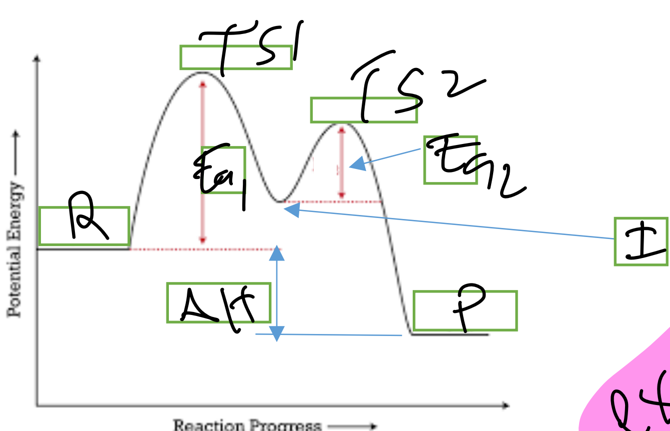
#2 rate $= k[NO_3][CO]$

c. Circle the intermediate in the mechanism in part a

d. Does this reaction mechanism use a catalyst? (Circle one) YES OR NO

8. Please label the following reaction coordinate diagram below

Reactants (R), products (P), transition state 1 (TS1), transition state 2 (TS2), activation energy for step 1(Ea1), activation energy for step 2 (Ea2), intermediate (I), and ΔH (including whether exo- or endothermic)



exothermic, ΔH < 0

9.

For the reaction

$$2C(s)+N_2(g)+5H_2 \rightleftharpoons 2CH_3NH_2(g) \qquad K_c=1.8\times10^{-6}$$

If you begin the reaction with 1.0 mol of N_2, 2.0 mol of H_2, and sufficient C(s) in a 2.00 L container, what are the concentrations of N_2, CH_3NH_2, and H_2 at equilibrium?

$$K_c = \frac{[CH_3NH_2]^2}{[N_2][H_2]^5}$$

* solid not in eq. expression!

$[N_2]_{initial}$ = 1.0 mol / 2.00 L = 0.500 M

$[H_2]$ initial = 2.0 mol / 2.00 L = 1.00 M

	C(s) + N_2(g)	+ $5H_2$(g)	⇌ $2CH_3NH_2$(g)
I	0.500 M	1.00 M	∅
C	−x	−5x	+2x
E	0.500 − x	1.00 − 5x	2x

$$K_c = \frac{(2x)^2}{(0.500)(1.00)^5}$$

−x is negligible small K

$$1.8\times10^{-6} = \frac{4x^2}{0.500}$$

at eq. $x = 4.74\times10^{-4}$

$$x = \sqrt{\frac{1.8\times10^{-6}\times0.500}{4}}$$

$[CH_3NH_2] = 2x = 9.6 \times 10^{-4}\ M$

$[N_2] = 0.500\ M$ $(H_2) = 1.0\ M$

10. For the equilibrium shown below, K_p at 1100°C for this process is 1.13×10^{-5}. If a sample with an initial Cl_2 gas pressure of 0.500 atm was allowed to reach equilibrium. What is the partial pressure of each gas at equilibrium AND the total pressure in the reaction vessel?

$Cl_2(g) \leftrightarrows 2\ Cl(g)$

	Cl_2	Cl
I	0.500	0
C	$-x$	$+2x$
E	$0.500-x$	$2x$

$K_p = 1.13 \times 10^{-5}$

"$-x$" is negligible, small K

$$K_p = \frac{P_{Cl}^2}{P_{Cl_2}}$$

$$K_p = \frac{(2x)^2}{0.500}$$

@ eq

@ eq

$$1.13 \times 10^{-5} = \frac{4x^2}{0.500}$$

$x = 1.19 \times 10^{-3}$ atm

$P_{Cl} = 2x = 2.38 \times 10^{-3}$ atm

$P_{Cl_2} = 0.500$ $P_{total} = 0.502$ atm

$P_{total} = P_{Cl_2} + P_{Cl}$

11. A certain species of fish requires a dissolved oxygen concentration of 7.5 mg O_2 / L of water. Suppose the temperature of a lake in summer is 28.0°C. Would the fish be able to survive in this lake? The Henry's law constant (k_H is 1.2×10^{-3} M/atm) at this temperature. The partial pressure of oxygen gas is 0.17 atm at 28.0 C. Please show all your work.

$S_g = k_H P_{gas}$

convert to M

$\frac{7.5 \text{ mg } O_2}{L} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol}}{32.0 \text{ g}} = 2.3 \times 10^{-4} \text{ M}$

$S_g = \left(1.12 \times 10^{-3} \frac{M}{atm}\right)(0.17 \text{ atm})$

$S_g = 1.9 \times 10^{-4} \text{ M}$

fish can't survive @ 28.0°C

12. What is the vapor pressure if 50.0 grams of calcium chloride is dissolved in 500.0 mL of water (density of water is 1.0 g/mL) at 25.0 °C. The vapor pressure of water at 25.0 C is 23.8 torr.

$$P_{new} = \chi_{solvent} P^{\circ}_{solvent}$$

$$n_{H_2O} = 500.0\,g\,H_2O \times \frac{1\,mol}{18\,g} = 27.8\,mol$$

$$n_{CaCl_2} = 50.0\,g \times \frac{1\,mol}{110.9} = 0.455\,mol\ CaCl_2$$

$i = 3$

Ca^{2+} Cl^- Cl^-

$$\chi_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + i\,n\ CaCl_2}$$

$$\chi_{H_2O} = \frac{27.8\,mol}{27.8\,mol + 3(0.455\,mol)}$$

$\chi = 0.953$

$P_{new} = 23.8 \text{ torr} (0.953)$

$P_{new} = 22.7 \text{ torr}$