Day 20 Question 6: Space for Work and Answers

Day 20: Practice Exam
Section II: Scoring Guidelines

1. **(10 points)**

The equation below shows a reaction between ethylamine and water.

$C_2H_5NH_2(aq) + H_2O(l) \text{ ------ > } C_2H_5NH_3^+(aq) + OH^-(aq)$

The base-dissociation constant, K_b, for the ethylamine ion is 5.6×10^{-4}.

(a) Given a 80.4 mL sample of a 0.500 M solution of ethylamine.

(i) Write the equilibrium expression for the reaction and calculate the OH- ion concentration.

$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$	**1 point** is earned for writing the correct equilibrium expression
Concentration at equilibrium $[C_2H_5NH_3^+] = X$ $[OH^-] = X$ $[C_2H_5NH_2] \approx 0.500$ M *(low dissociation)*	
$5.6 \times 10^{-4} = \frac{x^2}{0.500}$ **X = [OH-] = 0.017 M**	**1 point** is earned for the correct calculation of the [OH-]

(ii) Calculate the pOH of the solution.

pOH = -log [OH-] pOH = -log (0.017 M) = **1.78**	**1 point** is earned for the correct calculation of the pOH

(b) Calculate the % ionization of the ethylamine in the solution in part (a).

$\%\text{ dissociation} = \frac{[C_2H_5NH_3^+]}{[C_2H_5NH_2]} \times 100$ $\textbf{\% dissociation} = \frac{\textbf{0.017 M}}{\textbf{0.500 M}} \textbf{ x 100}$ **% dissociation = 3.4 %**	**1 point** is earned for correctly calculating the % dissociation

(c) What would be the pH of a solution made by adding 11.4 grams of ethylammonium bromide ($C_2H_5NH_3Br$) to 150. ml of a 0.200-molar solution of ethylamine?

Write equilibrium equation

$C_2H_5NH_3^+$ <=====> $H^+ + C_2H_5NH_2$

Calculate K_a

$$K_a = \frac{[H^+][C_2H_5NH_3^+]}{[C_2H_5NH_2]} = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-4}}$$

$K_a = 1.8 \times 10^{-11}$

Determine initial [ ] of the solutions

$[H+] = 0$

$[C_2H_5NH_2] = 0.200\ M$

$$[C_2H_5NH_3^+] = 11.4\ g\ C_2H_5NH_3^+ \times \frac{1\ mol}{126\ g} \times \frac{1}{.150\ L}$$

$[C_2H_5NH_3^+] = 0.603$ M

1 point is earned for calculating initial $[C_2H_5NH_3^+]$

Determine final [ ] of the solutions

$[H+] = X$

$[C_2H_5NH_2] = 0.200\ M + X \approx 0.200\ M$

$[C_2H_5NH_3^+] = 0.603\ M - X \approx 0.603\ M$

X will be very small due to low dissociation

Determine [H+] and pH

$$1.8 \times 10^{-11} = \frac{(X)(.200\ M)}{0.603\ M}$$

$X = [H+] = 5.4 \times 10^{-11}$

1 point is earned for calculating [H+]

$pH = -\log [5.4 \times 10^{-11}]$

pH = 10.3

1 point is earned for correctly calculating the pH

d) A student adds 0.140 grams of solid silver nitrate to the solution in part (a)

(i) Calculate the concentration of the silver ion in the solution.

$AgNO_3(s)$ <=====> $Ag+(aq) + NO_3^-(aq)$

$$[Ag+] = \frac{0.140\ g\ AgNO_3}{0.0804\ L} \times \frac{1\ mol\ AgNO_3}{169.9\ g\ AgNO_3} \times \frac{1\ mol\ Ag+}{1\ mole\ AgNO_3}$$

[Ag+] = 0.010 M

1 point earned for correcting calculating [Ag+]

(ii) Will silver hydroxide form as a precipitate? Justify your answer with a calculation. (The value of K_{sp} for silver hydroxide is 1.52×10^{-8})

Precipitate of AgOH will form.

1 point earned for stating that precipitate will form

$[OH-] = 0.017$ M (calculation a(i))

$Q = Ag+][OH-] = (0.010\ M)(0.017\ M)$

$Q = 1.74 \times 10^{-4}$

$K_{sp} = 1.52 \times 10^{-8}$

1 point earned for showing that Q is greater than K_{sp}

$Q > K_{sp}$

2. **(10 points)**

In two separate experiments, a sample of an unknown hydrocarbon was burned in air, and a sample of the same hydrocarbon was placed into an organic solvent.

(a) When the hydrocarbon sample was burned in a reaction that went to completion, 2.2 grams of water and 3.6 liters of carbon dioxide were produced under standard conditions. What is the empirical formula of the hydrocarbon?

$2.2\ g\ H_2O \times \frac{1\ mol\ H_2O}{18\ g\ H_2O} \times \frac{2\ mol\ H}{1\ mol\ H_2O} =$ **0.24 mol H**	**1 point** is earned for calculating moles of H and C.
$3.6\ L\ CO_2 \times \frac{1\ mol\ CO_2}{22.4\ L\ CO_2} \times \frac{1\ mol\ C}{1\ mol\ CO_2} =$ **0.16 mol C**	
Mole Ratio = $\frac{0.24}{0.16} = \frac{1.5}{1} = \frac{3H}{2C}$	**1 point** is earned for correctly calculating the empirical formula.
Empirical Formula = C_2H_3	

b) When 4.05 grams of the unknown hydrocarbon was placed in 100.0 grams of benzene, C_6H_6, the freezing point of the solution was measured to be 1.66°C. The normal freezing point of benzene is 5.50°C and the freezing-point depression constant for benzene is 5.12°C/m. What is the molecular weight of the unknown hydrocarbon?

$T = i \times Kf \times m \quad (i = 1)$ $m = \frac{\Delta T}{kf} = \frac{3.84\ °C}{5.12\ °C/m} = 0.750\ m$	**1 point** is earned for calculating moles of the solute.
moles = molality x kg solvent moles = 0.750 mol/Kg x 0.100 Kg = **0.0750 moles**	
Molecular Weight = $\frac{mass}{moles} = \frac{4.05\ g}{0.0750\ mol}$	**1 point** is earned for correctly calculating the molecular mass.
Molecular Weight = 54.0 g/mol	

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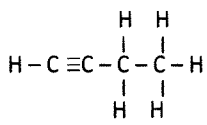
(c) What is the molecular formula and the name of the hydrocarbon?

$\frac{\text{Molecular Weight } 54\ g}{\text{Empirical Mass } 27\ g} = 2$ Molecular formula = $2(C_2H_3)$ Molecular formula = **C_4H_6** Molecular name = **butyne**	**1 point** is earned for a correct formula **1 point** is earned for a name that is consistent with the formula.

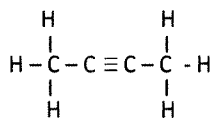
(d) Write the balanced equation for the combustion reaction that took place in (a)

$2C_4H_6$ + **$11O_2$** ------> **$8CO_2$** + **$6H_2O$**	**1 point** is earned for correct reactants and products **1 point** earned for correctly balancing the equation

(e) Draw two isomers for the hydrocarbon.



1-butyne



2-butyne

1 point is earned for each correctly drawn structure of butyne isomers..

(2 points total)

3. **(10 points)**

(a) Determine the order of the reaction with respect to each of the reactants, and write the rate law for the reaction.

m = Order with respect to A $\frac{\text{Rate 4}}{\text{Rate 3}} = \frac{2.4 \times 10^{-2}}{1.2 \times 10^{-2}} = \frac{k[0.20]^m[0.10]^n}{k[0.10]^m[0.10]^n}$ $2 = 2^m$ **m = 1** *n = Order with respect to B* $\frac{\text{Rate 2}}{\text{Rate 1}} = \frac{6.0 \times 10^{-3}}{3.0 \times 10^{-3}} = \frac{k[0.05]^m[0.10]^n}{k[0.05]^m[0.05]^n}$ $2 = 2^n$ **n = 1** **Rate = *k* [A] [B]**	**1 point** is earned for calculating order with respect to A (m) and order with respect to B (n). **1 point** is earned for the correct rate law.

(b) Calculate the value of the rate constant, *k*, for the reaction. Include the units.

$k = \frac{\text{Rate}}{[A][B]} = \frac{(3.0 \times 10^{-3}\ M.sec^{-1})}{(0.05\ M)(0.05\ M)}$ **$k = 1.2\ M^{-1}.sec^{-1} = 1.2\ L/(mol \cdot sec)$**	**1 point** is earned for correctly calculating the rate constant. **1 point** for the correct unit.

(c) If another experiment is attempted with [A] and [B], both at 0.02 molar, what would be the rate initial rate of disappearance of A?

Rate = k[A] [B] **$\text{Rate} = \frac{1.2\ L}{mol.sec} \times \frac{0.02\ mol}{L} \times \frac{0.02\ mol}{L}$** Rate = 4.8×10^{-4} mol /L.sec^{-1} **Rate = 4.8×10^{-4} M/sec^{-1}**	**1 point** is earned for setup **1 point** is earned for correctly calculating the rate of disappearance of A **1 point** is earned for the correct unit

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(d) The following reaction mechanisms was proposed for the reaction above:

Rxn 1: A + B -----> C + D
Rxn 2: D + B -----> C

(i) Show that the mechanism is consistent with the balanced reaction.

Rxn 1: A + B -----> C + ~~D~~ Rxn 2: ~~D~~ + B -----> C **A + 2B -----> 2C**	**1 point** earned for a correctly shown mechanism

(ii) Show that the step is the rate determining step, and explain your choice.

Rxn 1: **A + B -----> C + D (slow)** Rxn 2: D + B -----> C (fast) **Rxn 1 is the rate determining step because its rate law, rate = k [A] [B], is the same as the experimentally determined rate law.**	**1 point** is earned for stating that Rxn 1 is the rate determining step. **I point** is earned for correctly justifying the answer

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4. **(15 points)**

(a) Boron triiodide is reacted with ammonia.

(i) Balanced equation $BI_3 + NH_3 \text{ ------ > } I_3BNH_3$	**1 point** is earned for correct reactants **2 points are** earned for correct products **1 point** is earned for correctly balancing the equation

(ii) Which species in the reaction is the Lewis acid? Explain.

BI_3 is the Lewis acid because The compound has and incomplete octet and **can accept a pair of electrons** from NH_3	**1 point** is earned for the correct choice with explanation.

b) A piece of calcium carbonate is placed in excess nitric acid.

(i) Balanced equation $2\,H^+ + CaCO_3 \text{ -----> } Ca^{2+} + H_2O + CO_2$	**1 point** is earned for correct reactants **2 points** are earned for correct products **1 point** is earned for balancing mass and charge

(ii) What will be the sign for ΔS° for the reaction? Explain.

ΔS° will be positive because **a gaseous product (high entropy) is formed from a solid product (low entropy).**	**1 point** is earned for the correct sign of ΔS° with correct explanation.

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(c) Fluorine gas is bubbled through a solution of lithium chloride.

(i) Balanced equation $F_2 + 2\,Cl^- \text{ ----> } Cl_2 + 2\,F^-$	**1 point** is earned for correct reactants **2 points** are earned for correct products **1 point** is earned for balancing mass and charge

(ii) Which species will be the reducing agent in the reaction? Explain your answer.

Chlorine is the reducing agent (oxidized substance) because **its oxidation number in the reaction increases from -1 to 0**	**1 point** is earned for the correct answer with an appropriate explanation.

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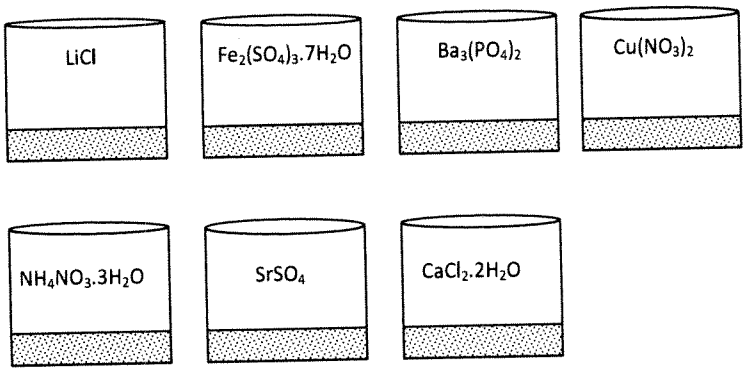
5. **(9 points)**

Seven solid compounds were placed in beakers as shown below.



An unknown compound is to be identified by students through observations and results of laboratory tests. The observations and test results obtained by one student are listed in order from (a) through (e). Write the formula(s) of compound(s) that the student should eliminate in the box following each result.

(a) The unknown compound is white.

Recall: Compounds of **transition metals** are generally colored.
Note: Compounds containing a **transition metal** should be eliminated

$Fe_2(SO_4)_3.7H_2O$ **$Cu(NO_3)_2$**	**1 point** is earned for each correct formula **(2 points total)**

(b) The unknown compound dissolves readily in water.

Note: Any Compound containing an insoluble ion should be eliminated

$Ba_3(PO_4)_2$ **$SrSO_4$**	**1 point** is earned for each correct formula **(2 points total)**

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(c) Forms a white precipitate when added to aqueous $AgNO_3$ solution.

Recall: Ag+ + Cl- ------> AgCl(s) (a white precipitate)
Note: Eliminate any remaining compound that does not contain Cl- ion.

$NH_4NO_3.3H_2O$	**1 point** for eliminating $NH_4NO_3.3H_2O$ or **1 point** for eliminating $Fe_2(SO_4)_3.7H_2O$ if it hasn't been previously eliminated.

(d) When heated, the mass of the compound after heating was less than the mass of the compound before heating.

Recall: Hydrates contains water in their crystalline structures. When heated, the water evaporates, leaving behind anhydrous compound that weighs less than the hydrate

Note: Eliminate any remaining compounds that is not a hydrate.

LiCl	**1 point** for eliminating LiCl or **1 point** for eliminating either $Ba_3(PO_4)_2$, $SrSO_4$, or $CuNO_3$ if they have not been previously eliminated

(e) Below:

(i) Write the formula(s) of the compound(s) that has yet to be eliminated. This is your unknown compound.

$CaCl_2.2H_2O$	**1 point** is earned for identifying $CaCl_2.2H_2O$ as the unknown

(ii) Describe any other test that could be done using only the substances in the beaker to further confirm the identity of the unknown.
Indicate the result of the test as well as formula of any products that are formed from your testing.

Dissolve $CaCl_2.2H_2O$ and $Fe_2(SO_4)_3.7H_2O$ in separate test tubes, and then **mix the two solutions.**	**1 point** for describing mixing the unknown with a compound that will form a precipitate.
A white **precipitate of $CaSO_4$** should form.	**1 point** is earned for correctly identifying the formula of the precipitate

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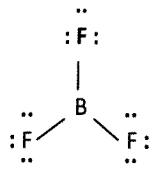
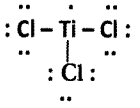
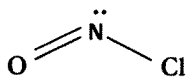
6. **(7 points)**

Answer the following questions about Lewis structures and shapes of compounds.

a) Draw Lewis structures for BF_3 and $TiCl_3$.

(i) BF_3 	**1 point** is earned for correctly drawing the structure for BF_3
(ii) $TiCl_3$ 	**1 point** is earned for correctly drawing the structure for $TiCl_3$

b) Determine the molecular geometries including all idealized bond angles for ClNO where the N atom is in the center of the molecule.

	**1 point** is earned for correctly stating the geometry and bond angle.
Molecular Geometry = **V-shape bent angular**	Allow point if molecule is correctly drawn without stating the shape.
Idealize bond angles: **113° – 120°**	

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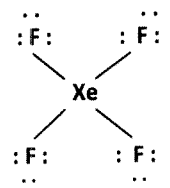
(c) Classify XeF_4 as polar or nonpolar and explain why.



Nonpolar

XeF_4 (Xenon tetrafluoride) has a square planer geometry that allows the **four Xe-F polar bonds (dipole moments) to cancel out.**

1 point is earned for stating that the molecule is nonpolar.

1 point is earned for explanation that is consistent with the type of molecule stated .

(d) Describe the orbital hybridization scheme used by the central atom in its sigma bonding for the following molecules. How many pi bonds are contained in each molecule?

(i) XeF_4 - d^2sp^3 hybridization

no (zero) pi bonds

1 point is earned for correctly identifying hybridization and number of pi bonds in XeF_4

(ii) XeF_2 - dsp^3 hybridization

no (zero) pi bonds

1 point is earned for correctly identifying the hybridization and number of pi bonds in XeF_2

Reference Materials

PERIODIC TABLE OF THE ELEMENTS

												5	6	7	8	9		2
												B	C	N	O	F		He
												10.81	12.01	14.01	16.00	19.00		4.00
												13	14	15	16	17		10
												Al	Si	P	S	Cl		Ne
												26.98	28.09	30.97	32.06	35.45		20.18
												31	32	33	34	35		18
												Ga	Ge	As	Se	Br		Ar
												69.72	72.59	74.92	78.96	79.90		39.95
												49	50	51	52	53		36
												In	Sn	Sb	Te	I		Kr
												114.82	118.71	121.75	127.60	126.91		83.80
												81	82	83	84	85		54
												Tl	Pb	Bi	Po	At		Xe
												204.38	207.2	208.98	(209)	(210)		131.29
												80	81	82	83	84		86
												Hg	Tl	Pb	Bi	Po		Rn
												200.59	204.38	207.2	208.98	(209)		(222)
1																		
H																		
1.008																		
3	4																	
Li	Be																	
6.94	9.01																	
11	12																	
Na	Mg																	
22.99	24.30																	
19	20	21	22	23	24	25	26	27	28	29	30							
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn							
39.10	40.08	44.96	47.90	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39							
37	38	39	40	41	42	43	44	45	46	47	48							
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd							
85.47	87.62	88.91	91.22	92.91	95.94	(98)	101.1	102.91	106.42	107.87	112.41							
55	56	57	72	73	74	75	76	77	78	79	80							
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg							
132.91	137.33	138.91	178.49	180.95	183.85	186.21	190.2	192.2	195.08	196.97	200.59							
87	88	89	104	105	106	107	108	109	110	111								
Fr	Ra	†Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg								
(223)	226.02	227.03	(261)	(262)	(266)	(264)	(277)	(268)	(271)	(272)								

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
140.12	140.91	144.24	(145)	150.4	151.97	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
232.04	231.04	238.03	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)

*Lanthanide Series

†Actinide Series