CHM 1300 and
CHM 1310 B

DATE: December 20, 2004
9:30 am

Dr. Rashmi Venkateswaran

TIME: 3 hours

STUDENT NAME: (Print)____

STUDENT NUMBER:____

COURSE CODE: (Please circle) CHM 1300 CHM 1310B

INSTRUCTIONS:

1. Write your answers on the exam. Please BOLD or HIGHLIGHT your final answer.

2. You are allowed to use electronic calculators during the exam (TI 30X, TI 34, TI 36).

3. Equations and constants are given on pages 18 and 19. A periodic table of the elements is included (page 20).

4. **Use the correct number of significant figures at all times.**

5. Marks allotted to each question are shown in brackets.

7. Use the back of sheets for rough work. Three extra (blank) pages (15, 16 and 17) have also been included.

8. You are advised to read through the exam paper before you begin to write. Answer first those questions that you can do right away, proceeding to more difficult questions thereafter. Allow about ten minutes near the end of the exam period to read quickly through your answers, checking for obvious errors.

Quest.	1	2	3	4	5	6	7	8	9	10	
Marks	/10	/5	/20	/10	/13	/4	/8	/10	/10	/10	/100

(10) 1. (a) The human eye can detect as little as 2.35 x 10^{-18} J of green light of wavelength 510 nm. Calculate the minimum number of photons that can be detected by the human eye.

$$E = h\nu = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ J\,s)(3.00 \times 10^{8}\ \frac{m}{s})}{510 \times 10^{-9}\ m}$$

$$= 3.90 \times 10^{-19}\ J \text{ per photon}$$

$$3.90 \times 10^{-19}\ J \rightarrow 1 \text{ photon}$$

$$2.35 \times 10^{-18}\ J \rightarrow x \text{ photons}$$

$$x = \frac{2.35 \times 10^{-18}\ J}{3.90 \times 10^{-19}\ J/\text{photon}} = \boxed{6.0 \text{ photons}}$$

(b) In a photoelectric effect experiment, light of energy 6.00 x 10^{-19} J is absorbed by a metal, and the ejected electrons have a maximum kinetic energy of 2.70 x 10^{-19} J. Calculate the following:

i) the binding energy of the electrons in the metal

$$E_{kin} = E_{h\nu} - BE$$

$$BE = E_{h\nu} - E_{kin} =$$

$$= 6.00 \times 10^{-19}\ J - 2.70 \times 10^{-19}\ J$$

$$= \boxed{3.30 \times 10^{-19}\ J}$$

ii) the wavelength of the light

$$E = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34}\ J\,s)(3.00 \times 10^{8}\ \frac{m}{s})}{6.00 \times 10^{-19}\ J}$$

$$= 3.31 \times 10^{-7}\ m$$

$$= \boxed{331\ nm}$$

iii) the wavelength of the electrons

$$E = \frac{1}{2}mu^2 \Rightarrow u = \sqrt{\frac{2E}{m}} = \sqrt{2(2.70 \times 10^{-19}\ J)} \qquad = 7.70 \times 10^{5}\ \frac{m}{s}$$

$$\overline{9.10938188 \times 10^{-31}\,Kg}$$

$$\lambda = \frac{h}{mu} = \frac{6.626 \times 10^{-34}\,Js}{(9.10938188 \times 10^{-31}\,Kg)(7.70 \times 10^{5}\,\frac{m}{s})} = 9.45 \times 10^{-10}\,m$$

$$= \underline{\underline{9.45\,\mathring{A}}}$$

(e) What mass of water could have its temperature raised by 5.0 °C by a mole of photons that have a wavelength of 600 nm?

$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,Js)(3.00\times10^{8}\,\frac{m}{s})}{600\times10^{-9}\,m} = 3.31\times10^{-19}\,\frac{J}{photon}$

$\therefore E_{TOT} = \left(\frac{E}{photon}\right)(\#photons) = \left(3.31\times10^{-19}\,\frac{J}{photon}\right)(6.022\times10^{23}\,photon$

$= 2.00\times10^{5}\,J/mol$

$E = mc\Delta T \Rightarrow 2.00\times10^{5}\,\frac{J}{mol} = m\left(4.184\,\frac{J}{g\,°C}\right)(5.0°C)$

$m = 9.54\times10^{3}\,g$

$= \boxed{9.54\,kg}$

(5) 2. What are the quantum numbers of the electrons that are lost by an atom of iron when it forms the ion Fe^{2+}? Why does it lose these particular electrons?

Fe: (atomic # 26)

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ or $[Ar]3d^6 4s^2$

[↑↓] [↑↓] [↑] [↑] [↑] [↑]

when it loses 1 e^-, it is $4s^2 3d^5$

but the second e^- is a 4s electron

⇒ so qn's are $n = 3$ $l = 2$ $m_l = -2$ $m_s = -\frac{1}{2}$

$n = 4$ $l = 0$ $m_l = 0$ $m_s = -\frac{1}{2}$

It loses these particular electrons so it forms a stable half filled orbital for both 4s and 3d.

(20) 3. A certain element X was found to form three compounds with chlorine having the formulae XCl_2, XCl_4, and XCl_6. One of its oxides has the formula XO_3, and X reacts with sodium to form the compound Na_2X.

(a) Is X a metal or a non metal?

non metal

(b) In which group in the periodic table is X located?

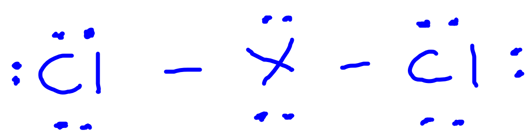
Group 6A or 16

(c) In which rows (periods) in the periodic table could X possibly be located?

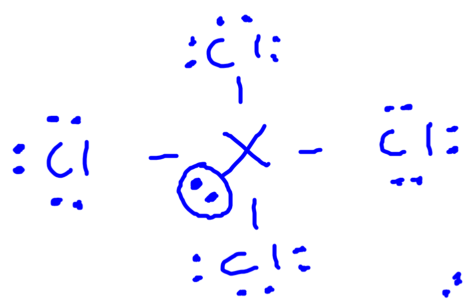
2, 3, 4, 5 or 6

(d) Draw Lewis structures for XCl_2, XCl_4, and XCl_6 and XO_3. Where possible, follow the octet rule. Which of the structures has (have) multiple bonding? Are there any resonance structures to consider?

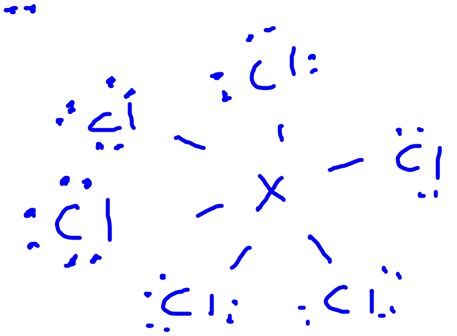
XCl_2: X : $6e^-$
(e) Cl : $2(7e^-)$
$20e^-$
-4
16



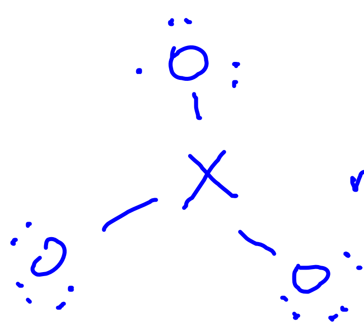
XCl_4: X : $6e^-$
Cl : $4(7e^-)$
$34e^-$



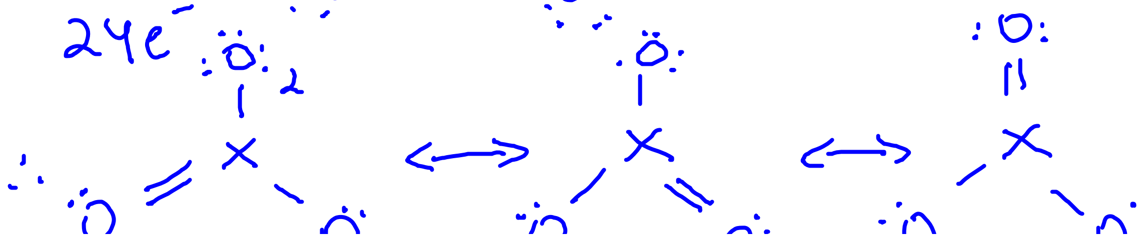
XCl_6: X : $6e^-$
Cl : $6(7e^-)$
$48e^-$



XO_3: X : $6e^-$
O : $3(6e^-)$
$24e^-$



not octet for X!



What do we expect the shapes (electron geometries) of the 4 molecules drawn above to be? Which molecules would be polar? (simply state the names of the shapes…you may draw them only if you wish).

XCl_2: MG: tetrahedral shape: bent

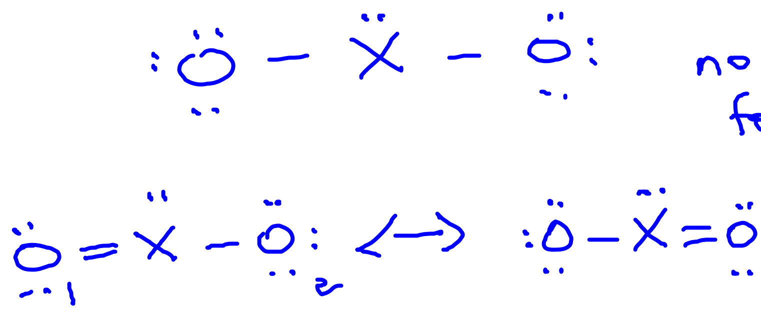
XCl_4: MG: trigonal bipyramidal shape: see saw

XCl_6: MG and shape: octahedral

XO_3: MG and shape: trigonal planar

(f) The element X also forms the oxide XO_2. Draw the Lewis structure for this molecule that obeys the octet rule.

XO_2: X (6e⁻)
O (2×6e⁻)
18e⁻
4e⁻
14e⁻



no octet for X!

(g) Assign formal charges to the atoms in the Lewis structures for XO_2 and XO_3.

XO_2:
$FC_X = 6 - 2 - 3 = 1$
$FC_{O_1} = 6 - 4 - 2 = 0$
$FC_{O_2} = 6 - 6 - 1 = -1$

XO_3
$FC_X = 6 - 0 - 4 = 2$
$FC_{O_1} = 6 - 4 - 2 = 0$
$FC_{O_2} = FC_{O_3} = 6 - 6 - 1 = -1$

(h) If X were to form a compound with Aluminum, what would be its formula?

Al_2X_3

(i) If X were in Period 5, what would be the electron configuration of X expressed using a noble gas core configuration?

$[Kr]\,4d^{10}5s^2 5p^4$

(10) 4. (a) Consider the following galvanic cell:

Ag(s) | Ag^+ (3.0 x 10^{-4} M) | | Fe^{3+} (1.1 x 10^{-3} M), Fe^{2+} (0.040 M) | Pt(s)

i) Write the balanced equation for the spontaneous cell reaction.

$Ag(s) + Fe^{3+} \rightarrow Ag^+ + Fe^{2+}$

ii) Which electrode is the anode and which is the cathode and what are their signs (positive, negative)?

Ag(s) anode (−)

Pt(s) cathode (+)

iii) Calculate the cell potential given the following standard potentials:

$Ag^+ + e^- \rightarrow Ag$	E° = 0.800 V
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	E° = 0.770 V
$Ag(s) \rightarrow Ag^+ + e^-$	E° = −0.800 V
$Fe^{3+} + Ag \rightarrow Fe^{2+} + Ag^+$	E° = −0.030 V

$$E = E° - \frac{RT}{nF}\ln Q = -0.030V - \frac{(8.314)(298)}{(1)(96485)}\ln\frac{(3.0\times10^{-4})(0.040)}{(1.1\times10^{-3})}$$

$$= \boxed{0.086 V}$$

(b) A solution containing vanadium in an unknown oxidation state was electrolyzed with a current of 1.50 A for 30.0 min. It was found that 0.475 g of V was deposited on the cathode. What was the original oxidation state of the vanadium ion?

$$Q = It = (1.50 A)(30.0 min)\left(\frac{60 s}{min}\right) = 2.70\times10^3 C$$

1 mol e^- → 96485 C

x → 2.70×10^3 C

$x = 2.70\times10^3/96485 = 2.80\times10^{-2}$ mol e^-

$$n_V = \frac{m}{MM} = \frac{0.475 g}{50.9415 g/mol} = 9.32\times10^{-3} mol$$

$V^{x+} + xe^- \rightarrow V$

∴ x mol e^- → 1 mol V

2.80×10^{-2} mol e^- → 9.32×10^{-3} mol

$x = \frac{2.80\times10^{-2} mol}{\ldots} = 3$ ∴ oxidation state is (+3)

(13) 5. (a) A reaction that has the stoichiometry below was found to yield the following data:

$$2A + B \rightarrow \text{products}$$

The initial rate of this reaction was determined for several concentrations of $HgCl_2$ and $C_2O_4^{2-}$ and the following rate data were obtained for the rate of disappearance of $C_2O_4^{2-}$:

Experiment	[A](M)	[B](M)	Initial Rate (M/s)
1	0.020	0.030	0.0150
2	0.025	0.030	0.0188
3	0.025	0.040	0.0334

(i) What is the rate law for this reaction?

$$\left(\frac{0.025}{0.020}\right)^x = \left(\frac{0.0188}{0.0150}\right) \qquad \left(\frac{0.040}{0.030}\right)^y = \left(\frac{0.0334}{0.0188}\right)$$

$$1.25^x = 1.25 \qquad 1.33^y = 1.78$$

$$x = 1 \qquad y = 2$$

$$\therefore \text{Rate} = k[A][B]^2$$

(ii) What is the rate constant for this reaction with the correct units?

$$0.0150\,\frac{M}{s} = k\,(0.020\,M)(0.030\,M)^2$$

$$k = 8.33 \times 10^2\ M^{-2}s^{-1}$$

(b) The decomposition of urea, $(NH_2)_2CO$, in 0.10 M HCl follows the equation:

$$(NH_2)_2CO\,(aq) + 2H^+\,(aq) + H_2O \rightarrow 2\,NH_4^+(aq) + CO_2\,(g)$$

At 60.0 °C, $k = 5.84 \times 10^{-6}$ min^{-1} and at 70.0 °C, we find that $k = 2.25 \times 10^{-5}$ min^{-1}. If this reaction is run at 80.0 °C starting with a urea concentration of 0.0020 M, how many minutes will it take for the urea concentration to drop to 0.0012 M?

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

$$\ln\left(\frac{5.84\times10^{-6}}{2.25\times10^{-5}}\right) = \frac{E_a}{8.314}\left(\frac{1}{70.0+273} - \frac{1}{60.0+273}\right)$$

$$\ln\frac{[A_t]}{[A_0]} = -kt$$

$$E_a = 1.28\times10^{5}\ J$$

$$\ln\left(\frac{k_{80}}{2.25\times10^{-5}}\right) = -\frac{1.28\times10^{5}\ J}{8.314}\left(\frac{1}{343} - \frac{1}{353}\right) \qquad k_{80} = 8.03\times10^{-5}$$

$$\ln\left(\frac{0.0812}{0.0820}\right) = -8.03\times10^{-5}\,t$$

$$t = 6.36\times10^{3}\ s = \boxed{106\ min}$$

(c) Suppose a reaction occurs with the mechanism:

Step 1:	$2\,A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} A_2$	(fast)
Step 2:	$A_2 + E \overset{k_2}{\rightarrow} B + C$	(slow)

(i) What is the overall reaction?

$$2A + E \rightarrow B + C$$

(ii) Using the definition of equilibrium, determine the rate expression for the overall reaction in terms of the reactants only.

$$k_1[A]^2 = k_{-1}[A_2]$$

$$\text{Rate} = k_2[A_2][E] = k_2\frac{k_1}{k_{-1}}[A]^2[E]$$

$$= k[A]^2[E]$$

(4) 6. Given that the K_{sp} for $Mg(OH)_2$ is 7.1×10^{-12}, calculate the pH of a saturated solution of this salt.

$$Mg(OH)_2 \rightarrow Mg^{2+} + 2OH^-$$

	$Mg(OH)_2$	Mg^{2+}	$2OH^-$
	—	–	—
	—	$+x$	$2x$
		x	$2x$

$$\therefore K_{sp} = 7.1 \times 10^{-12} = [Mg^{2+}][OH^-]^2 = (x)(2x)^2 = 4x^3$$

$$x = 1.2 \times 10^{-4}\ M$$

$$\therefore [OH^-] = 2x = 2.4 \times 10^{-4}\ M$$

$$\therefore pOH = -\log[OH^-] = -\log(2.4 \times 10^{-4}) = 3.62$$

$$\therefore pH = 14 - pOH = 14 - 3.62 = \boxed{10.38}$$

(8) 7. (a) The pK_a of saccharin, $HC_7H_3SO_3$, a sweetening agent, is 11.68. What is the pH of a 0.010 M solution of sodium saccharinate (a salt of the conjugate base of saccharin) in water?

$$Na\,sacch \rightarrow Na^+ + sacch^-$$

$$sacch^- + H_2O \rightleftharpoons Hsacch + OH^-$$

	$sacch^-$		$Hsacch$	OH^-
I	0.010 M		—	–
C	$-x$		x	x
E	$0.010 - x$		x	x

$$pK_a = -\log K_a = 11.68$$

$$K_a = 10^{-11.68} = 2.09 \times 10^{-12}$$

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{2.09 \times 10^{-12}} = 4.79 \times 10^{-3} = \frac{[Hsacch][OH^-]}{[sacch^-]} = \frac{x^2}{0.010 - x}$$

(b)

$$4.79 \times 10^{-5} - 4.79 \times 10^{-3}x = x^2$$

$$x^2 + 4.79 \times 10^{-3}x - 4.79 \times 10^{-5} = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-4.79 \times 10^{-3} \pm \sqrt{(4.79 \times 10^{-3})^2 + 4(4.79 \times 10^{-5})}}{2}$$

$$= 4.93 \times 10^{-3}\ M$$

[illegible]

If 0.020 mol of NaOH were added to 500.0 mL of a sodium acetate-acetic acid buffer that contains 0.10 M sodium acetate and 0.15 M acetic acid, by how many pH units will the pH of the buffer change? (Assume no volume change on addition of the solid).

$NaOH + HCH_3COO \rightarrow H_2O + CH_3COONa$

	NaOH	HCH_3COO	H_2O	CH_3COONa
I	0.040M	0.15M	/	0.10M
C	-0.040M	-0.040M	/	+0.040M
E	—	0.11 M	/	0.14M

Original $pH = pK + \log \frac{A^-}{HA} = -\log(1.8\times10^{-5}) + \log \frac{0.10}{0.15}$
$= 4.57$

New $pH = pK + \log \frac{A^-}{HA} = -\log(1.8\times10^{-5}) + \log \frac{0.14}{0.11}$
$= 4.85$

$\therefore$ diff in $pH = 4.85 - 4.57 =$ **0.28 pH units**

(c) For the reaction NO_2 (g) + SO_2 (g) $\rightleftharpoons$ NO (g) + SO_3 (g), $K_c = 3.6$ and $\Delta H° = -41.8$ kJ/mol. Answer, in 1-3 words, how the equilibrium concentration of NO will be affected if:

i) More NO_2 is added to the container. increase
ii) Some SO_3 is removed from the container. increase
iii) The temperature of the reaction mixture is raised. decrease
iv) Some SO_2 is removed from the mixture. decrease
v) The pressure of the gas mixture is lowered by expanding the volume to 10.0 L. no change

(10) 8. (a) Barium nitride vaporizes slightly at high temperature by means of the dissociation:

$$Ba_3N_2\,(s) \rightleftharpoons 3\,Ba(g) + N_2\,(g)$$

At 1000. K, the equilibrium constant is 4.5×10^{-19}. At 1200. K, the equilibrium constant is 6.2×10^{-12}.

i) Determine the value of $\Delta H°$ for the reaction.

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

$$\ln\left(\frac{4.5\times10^{-19}}{6.2\times10^{-12}}\right) = \frac{\Delta H°}{8.314}\left(\frac{1}{1200} - \frac{1}{1000}\right)$$

$$\Delta H° = 8.20\times10^{5}\ J/mol$$

ii) What approximation was made in part (i)?

We assume $\Delta H°$ is constant in this temperature range.

(b) Suppose 61.0 g of hot metal that is initially at 120.0 °C is plunged into 100.0 g of water that is initially at 20.00 °C. The final temperature of the mixture is 26.39°C and no heat is lost to the surroundings. Calculate the specific heat capacity of the metal, given that the specific heat capacity of water is 4.184 J $°C^{-1}g^{-1}$.

$$-q_{metal} = q_{water}$$

$$-mc\Delta T_{met} = mc\Delta T_w$$

$$-(61.0\,g)(c)(26.39-120.0)°C = (100.0\,g)\left(4.184\,\frac{J}{g°C}\right)(26.39-20.00)$$

$$c = 0.468\,\frac{J}{g°C}$$ for the unknown metal.

(10) 9. A sample of a new antimalarial drug with a mass of 0.2394 g was made to undergo a series of reactions that changed all of the nitrogen in the drug into N_2. The nitrogen gas had a volume of 18.90 mL when collected over water at 23.80 °C and a pressure of 746.0 Torr. At 23.80 °C, the vapour pressure of water is 22.110 Torr.

(a) Calculate the percentage of nitrogen in the sample.

$P_{N_2} = 746.0 - 22.110 = 723.9$ Torr

$n_{N_2} = \frac{PV}{RT} = \frac{\left(\frac{723.9}{760}\text{atm}\right)(0.01890\text{ L})}{\left(0.08206 \frac{\text{L atm}}{\text{mol K}}\right)(23.80+273\text{ K})} = 7.39 \times 10^{-4}$ mol

mol N = 2 mol N_2 = 1.48×10^{-3} mol

mass N = n MM = $(1.48 \times 10^{-3})(14) = 2.07 \times 10^{-2}$ g

mass % N = $\frac{2.07 \times 10^{-2}\text{ g}}{0.2394\text{ g}}$ = **8.64 %**

mass of N in 6.478 mg sample = 5.60×10^{-4} g

n_N " " " = $\frac{5.60 \times 10^{-4}\text{ g}}{14} = 4 \times 10^{-5}$

(b) When 6.478 mg of the compound was burned in pure oxygen, 17.57 mg of CO_2 and 4.319 mg of H_2O were obtained. What are the percentages of C and H in this compound?

$n_{CO_2} = \frac{17.57 \times 10^{-3}\text{ g}}{44\text{ g/mol}} = 3.99 \times 10^{-4}$ mol

$n_C = n_{CO_2} = 3.99 \times 10^{-4}$ mol $\Rightarrow m_C = n_C MM_C = (3.99 \times 10^{-4}\text{ mol})(12 \frac{\text{g}}{\text{mol}})$
$= 4.79 \times 10^{-3}$ g

mass % C = $\frac{4.79 \times 10^{-3}}{6.478 \times 10^{-3}} \times 100\% = 73.97\%$

$n_{H_2O} = \frac{4.319 \times 10^{-3}\text{ g}}{18\text{ g/mol}} = 2.399 \times 10^{-4}$ mol

$n_H = 2n_{H_2O} = 4.799 \times 10^{-4}$ mol $\Rightarrow m_H = n_H MM_H = 4.799 \times 10^{-4}$ g

mass % H = $\frac{4.799 \times 10^{-4}\text{ g}}{6.478 \times 10^{-3}\text{ g}} \times 100\% = 7.41\%$

(c) Assuming that any undetermined element is oxygen, write an empirical formula for the compound.

mass % O = 100 − 73.97 − 7.41 − 8.64 = 9.98 %

∴ in 6.478 mg sample, m_O = 6.465×10^{-4} g

$$n_O = \frac{6.465 \times 10^{-4}\ g}{16\ g/mol} = 4.04 \times 10^{-5}\ mol$$

$$C_{\frac{3.99 \times 10^{-4}}{4.0 \times 10^{-5}}} H_{\frac{4.799 \times 10^{-4}}{4.0 \times 10^{-5}}} O_{\frac{4.04 \times 10^{-5}}{4.0 \times 10^{-5}}} N_{\frac{4.0 \times 10^{-5}}{4.0 \times 10^{-5}}}$$

C_{10} H_{12} O N

$C_{10}H_{12}ON$

(d) The molecular mass of the compound was found to be 324 g/mol. What is its molecular formula?

$MM_{emp\,form}$ = 10(12) + 12(1) + 1(16) + 1(14)
= 162

$MM_{mol\,form}$ = 324

∴ ratio = 2

∴ Molecular formula = $C_{20}H_{24}O_2N_2$

(10) 10. Choose one of the following topics: quantum chemistry, corrosion, batteries, acids and bases, equilibrium, kinetics, gas laws, or thermodynamics. In a letter of minimum length 1 page and using at least 3 chemical concepts (clearly explained), write to your mother and explain why the particular topic you chose will have an impact on your personal and professional life.

no specific answer

Equations and Constants

Gas Law

$PV = nRT$

$P_{Total} = P_1 + P_2 + P_3 + \ldots$

$d = m/V = P(MM)/RT$

$KE = (1/2)mv_{av}^2$

$$\sqrt{\bar{v}^2} = \sqrt{\frac{3RT}{M}}$$

$$\frac{RateA}{RateB} = \sqrt{\frac{M_b}{M_a}}$$

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

1 atm = 760 Torr = 760 mm Hg = 1.01325×10^5 Pa

Equilibrium

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

$K = [C]^c[D]^d/[A]^a[B]^b$

$K_{sp} = [C]^c[D]^d$

Acid/Base

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

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

$pH + pOH = 14$

$K_a \times K_b = K_w$

$pH = pK_a + \log [A^-?]/[HA]$

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

Concentration (M) = n/V

Electrochemistry

$\Delta G^o = -nFE^o$

$$E = E^o - \frac{RT}{nF}\ln(Q)$$

$$\text{Or } E = E^o - \frac{0.059}{n}\log(Q) \text{ at } 25^oC$$

$Q = I \cdot t$

Quantum Mechanics

$?\cdot ? = c$

$E = h \cdot ?$

$$m = \frac{h}{l c}$$

Energy of state = -2.178×10^{-18} J / n^2

$\Delta x \cdot \Delta p \geq h / 4p$

$E = -C(1/n^2)$

Liquids and Colligative Properties

$\ln(P_1/P_2) = \Delta H^o/R\,(1/T_2 - 1/T_1)$

$P_{solution} = X_{solvent} \bullet P^o_{solvent}$

$\Delta T_{BP} = K_{BP} \bullet m$

$\Delta T_{FP} = K_{FP} \bullet m$

$\Delta T = K \bullet m \bullet i$

$? = cRT$

molality = mol solute/mass solvent (kg)

Data for Question 9	ΔG° (kJ / mol) at 25 °C	
SO_2 (g)	-300.4	
H_2S (g)	-33.01	
H_2O (g)	-228.57	

Thermodynamics

$\Delta U = q$

w_{system} = ?PΔV

$\Delta E = q +\ \ w$

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

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

$\Delta E = nCv\Delta T$

$\Delta H = q_p = m\ Cp\ \Delta T$

$C_p = C_v + R$

$\Delta H_{rxn}°=\Delta n_p \Delta H_f \Delta$(products)?

$\Delta n_r \Delta H_f \Delta$(reactants)

$q_{rev} = -w_{max} = nRT \ln (V_2/V_1)$

$\Delta S = q_{rev} / T$

$\Delta S_{T1-T2} = nC_p \ln(T_2/T_1)$

$\Delta S_{T1-T2} = nC_v \ln(T_2/T_1)$

$$\Delta S^0_{surroundings} = \frac{q_{surroundings}}{T} = \frac{-\Delta H_{sys}}{T}$$

$\Delta G^o = \Delta H^o - T\Delta S^o$

$\Delta G = \Delta G^o + RT \ln(Q)$

$\Delta G^o = - RT \ln(K)$

$\ln(K_1/K_2) = \Delta H^o/R\ (1/T_2 - 1/T_1)$

Kinetics

Rate = k $[A]^x[B]^y[C]^z$

Rate = k

Rate = k[A]

Rate = $k[A]^2$

$[A] = -kt + [A]_0$

$\ln[A] = -kt + \ln[A]_0$

$1/[A] = kt + 1/[A]_0$

$t = [A]_0 / 2k$

ln 2 = kt

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

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

Bonding

$DE = k\ (Q_1Q_2 / r)$

DH_{rxn} = Sn_pD(reactants) -

Sn_rD(products)

Formal Charge = #valence e^- in free atom - #lone pair e^- - 1/2(# bonding e^-)

Data For Water and Other Constants

Density d = 1.00 g/mL (25°C)
$C = 2.13\ J\ g^{-1}\ °C^{-1}$ (solid)
$C = 4.18\ J\ g^{-1}\ °C^{-1}$ (liquid)

$C_p = 2.01\ J\ g^{-}\ °C^{-1}$ (gas)
$\Delta H°_{vap} = 40.7\ kJ\ mol^{-1}$
$\Delta H°_{fus} = 6.02\ kJ\ mol^{-1}$

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

Mokeur's Periodic table of the elements

Key: Symbol, Atomic number (*H 1*); Relative atomic mass (1.00794); Electronegativity (2.1); Most frequent oxidation number (1+); Name (Hydrogen)

	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	*H 1* 1.00794 2.1 1+ Hydrogen																	*He 2* 4.002602 - - Helium
2	**Li 3** 6.941 1.0 1+ Lithium	**Be 4** 9.012182 1.5 2+ Beryllium											**B 5** 10.811 2.0 3+ Boron	**C 6** 12.011 2.5 4+,4- Carbon	*N 7* 14.00674 3.0 3+,3- Nitrogen	*O 8* 15.9994 3.5 2- Oxygen	*F 9* 18.9984032 4.0 1- Fluorine	*Ne 10* 20.1797 - - Neon
3	**Na 11** 22.989768 0.9 1+ Sodium	**Mg 12** 24.3050 1.2 2+ Magnesium											**Al 13** 26.981539 1.5 3+ Aluminum	**Si 14** 28.0855 1.8 4+ Silicon	**P 15** 30.973762 2.1 5+ Phosphorus	**S 16** 32.066 1.8 4+ Sulfur	*Cl 17* 35.4527 3.0 1- Chlorine	*Ar 18* 39.948 - - Argon
4	**K 19** 39.0983 0.8 1+ Potassium	**Ca 20** 40.078 1.0 2+ Calcium	**Sc 21** 44.955910 1.3 3+ Scandium	**Ti 22** 47.88 1.5 4+ Titanium	**V 23** 50.9415 1.6 5+ Vanadium	**Cr 24** 51.9961 1.6 3+ Chromium	**Mn 25** 54.93805 1.5 2+ Manganese	**Fe 26** 55.847 1.8 3+ Iron	**Co 27** 58.9332 1.8 2+ Cobalt	**Ni 28** 58.6934 1.8 2+ Nickel	**Cu 29** 63.546 1.9 2+ Copper	**Zn 30** 65.39 1.6 2+ Zinc	***Ga 31*** 69.723 1.6 3+ Gallium	**Ge 32** 72.61 1.6 4+ Germanium	**As 33** 74.92159 2.0 3+,3- Arsenic	**Se 34** 78.96 2.4 4+ Selenium	***Br 35*** 79.904 2.8 1- Bromine	*Kr 36* 83.80 - - Krypton
5	**Rb 37** 85.4678 0.8 1+ Rubidium	**Sr 38** 87.62 1.0 2+ Strontium	**Y 39** 88.90585 1.3 3+ Yttrium	**Zr 40** 91.224 1.4 4+ Zirconium	**Nb 41** 92.90638 1.6 5+ Niobium	**Mo 42** 95.94 1.8 6+ Molybdenum	Tc 43 98.9063 1.9 7+ Technetium	**Ru 44** 101.57 2.2 3+,4+ Ruthenium	**Rh 45** 102.9055 2.2 3+ Rhodium	**Pd 46** 106.42 2.2 2+ Palladium	**Ag 47** 107.8682 1.9 1+ Silver	**Cd 48** 112.411 1.7 2+ Cadmium	**In 49** 114.82 1.7 3+ Indium	**Sn 50** 118.71 1.8 4+ Tin	**Sb 51** 121.757 1.9 3+,3- Antimony	**Te 52** 127.60 2.1 4+ Tellurium	**I 53** 126.90447 2.5 1- Iodine	*Xe 54* 131.29 - - Xenon
6	***Cs 55*** 132.90543 0.7 1+ Cesium	**Ba 56** 137.327 0.9 2+ Barium	**La 57** 138.9055 1.1 3+ Lanthanum	**Hf 72** 178.49 1.3 4+ Hafnium	**Ta 73** 180.9479 1.5 5+ Tantalum	**W 74** 183.85 1.7 6+ Tungsten	**Re 75** 186.207 1.9 7+ Rhenium	**Os 76** 190.2 2.2 4+ Osmium	**Ir 77** 192.22 2.2 4+ Iridium	**Pt 78** 195.08 2.2 4+ Platinum	**Au 79** 196.96654 2.4 3+ Gold	***Hg 80*** 200.59 1.9 2+ Mercury	**Tl 81** 204.3833 1.8 1+ Thallium	**Pb 82** 207.2 1.8 2+ Lead	**Bi 83** 208.98037 1.9 3+ Bismuth	**Po 84** 208.9824 2.0 2+ Polonium	**At 85** 209.9871 2.2 1- Astatine	*Rn 86* 222.0176 - - Radon
7	***Fr 87*** 223.0197 0.7 1+ Francium	**Ra 88** 226.0254 0.9 2+ Radium	**Ac 89** 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Uun 110 269 - - Ununnilium	Uuu 111 272 - - Unununium	Uu 112 277 - - Ununbium		Uuq 114 289 - - Ununquadium		Uuh 116 289 - - Ununhexium		Uuo 118 293 - - Ununoctium

6	**Ce 58** 140.115 1.1 3+ Cerium	**Pr 59** 140.90765 1.1 3+ Praseodymium	**Nd 60** 144.24 1.1 3+ Neodymium	Pm 61 144.9127 1.1 3+ Promethium	**Sm 62** 150.36 1.2 3+ Samarium	**Eu 63** 151.965 1.2 3+ Europium	**Gd 64** 157.25 1.2 3+ Gadolinium	**Tb 65** 168.92534 1.2 3+ Terbium	**Dy 66** 162.50 1.2 3+ Dysposium	**Ho 67** 164.93032 1.2 3+ Holmium	**Er 68** 167.26 1.2 3+ Erbium	**Tm 69** 168.93421 1.2 3+ Thulium	**Yb 70** 173.04 1.1 3+ Ytterbium	**Lu 71** 174.967 1.2 3+ Lutetium
7	**Th 90** 232.0381 1.3 4+ Thorium	**Pa 91** 231.03588 1.5 5+ Protactinium	**U 92** 238.0289 1.4 6+ Uranium	Np 93 237.082 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

Under normal conditions, bold symbols correspond to solid state, bold italic correspond to liquid state, italic correspond to gaseous state and normal correspond to synthetic elements.