CHEM 14A
Instructor: Dr. Laurence Lavelle

YOUR NAME (last name, first name) Kilkeary, Christina

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FALL 2019
MIDTERM

(Total number of pages = 14)

(Total points = 120)

(Total time = 120 minutes)

<u>Carefully</u> remove the last two pages: Constants and Formulas, and Periodic Table.**

YOUR DISCUSSION SECTION 1H

YOUR TA's NAME Jose Moreno

WRITE IN PEN

Do not use white-out.

Show all your work to receive full credit. Check units and significant figures.

Box your final answer.

This is a closed book exam: Only a pen and simple scientific calculator are allowed.

No other material allowed.

Good Luck

Do not write on this page.

QUESTION	SCORE
1	16
2	14
3	13
4	7
5	12
6	7
7	16
8	14.
TOTAL (max 120)	99

Q1. Riboflavin (Vitamin B2) is an essential vitamin found in milk, cheese, and eggs, and plays a critical role in cellular respiration. When 0.7360 g of Riboflavin are burned in the presence of molecular oxygen, 1.463 g of CO_2, 0.3524 g of H_2O, and 0.1096 g of N_2 are produced according to the balanced combustion reaction shown below. (16pt)

17C's 4N's 6 O's in Riboflavin
20H's

$$\text{Riboflavin} + 19\,O_2(g) \rightarrow 17\,CO_2(g) + 10\,H_2O(g) + 2\,N_2(g)$$

0.7360 g; 1.463 g (0.03324 mol); 0.3524 g (0.01956 mol); 0.1096 g (0.003912 mol)

Determine the Empirical Formula for Riboflavin.

convert to mols:

$$1.463\,g \cdot \frac{1\,mol}{44.0095\,g\,CO_2} = 0.03324\,mol\,CO_2$$

$$0.3524\,g \cdot \frac{1\,mol}{18.01528\,g} = 0.01956\,mol\,H_2O$$

$$0.1096\,g \cdot \frac{1\,mol}{28.0134\,g} = 0.003912\,mol\,N_2$$

0.03324 mol C ; 0.03912 mol H ; 0.007824 Mol N

empirical formula

Riboflavin: $C_{17}H_{20}O_6N_4$

$$0.0334\,mol\,C \cdot \frac{12.0107\,g}{1\,mol} = .4016\,g\,C$$

$$0.03912\,mol\,H \cdot \frac{1.00794\,g}{1\,mol} = .03943\,g\,H$$

$$0.007824\,mol\,N \cdot \frac{14.0067\,g}{1\,mol} = 0.104588\,g\,N$$

$$0.7360\,g - gC - gH - gN = 0.1858\,g\ \text{Oxygen}$$

$$0.1858\,g\,O \cdot \frac{1\,mol}{15.9994\,g} = 0.0116144\,mol\,O$$

$$\frac{0.03324\,mol\,C}{0.007824\,mol\,N} = 4.25$$

$$\frac{0.03912\,mol\,H}{0.007824\,mol\,N} = 5$$

$$\frac{0.0116144\,mol\,O}{0.007824\,mol\,N} = 1.5$$

× 4 = 17 C's, 20 H's, 6 O's, 4 N's

+16

You later learn that the molar mass of Riboflavin is 376.3 $g.mol^{-1}$. Determine the molecular formula for Riboflavin.

emp form: $C_{17}H_{20}O_6N_4$

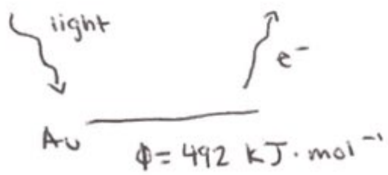
↳ this mass is 376.36

$C_{17}H_{20}O_6N_4$ is also the molecular formula

Q2A. Gold is a valuable element not only for its monetary value but also for its use in biological applications. For example, gold nanoparticles are used in medical diagnostics as tracers. The work function of Au(s) is 492 $kJ.mol^{-1}$.
What is the longest wavelength light (in nm) that can remove an electron from gold? (6pt)

14

6



$492\ kJ \cdot mol^{-1} \cdot \frac{1000 J}{1 kJ} = 4.92 \times 10^5\ J \cdot mol^{-1} \cdot \frac{1 mol}{6.02214 \times 10^{23}}$

$= 8.1699 \times 10^{-19}$ J / Au atom

$E_p - \phi = E_k$

$E_p > \phi$

$\frac{hc}{\lambda} =$

$\lambda = .000000243$ m

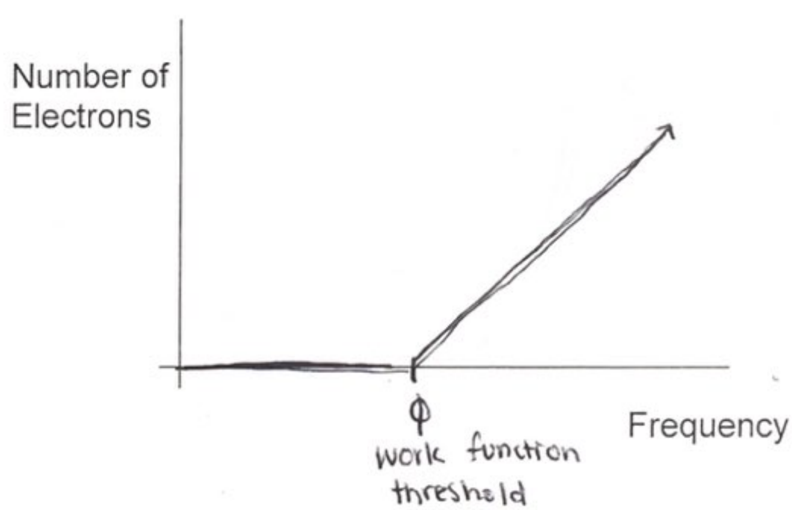
$E_p = h\nu \quad \nu = \frac{c}{\lambda} \quad E_p = \frac{hc}{\lambda}$

$\lambda = 243$ nm

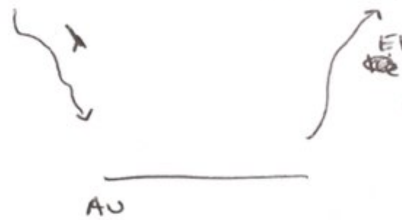
(Concept question)

Q2B. A beam of light at constant intensity and increasing frequency is shone on a metal surface. A detector reads the number of electrons ejected from the sheet of metal. The graph below has the frequency of the incoming light on the x-axis and the number of the ejected electrons on the y-axis. Draw the excepted plot for the number of the electrons as a function of frequency. Write on the x-axis the frequency at which electrons will start to be ejected. (6pt)

0



Q2C. In another photoelectric experiment, light at a fixed frequency is shone on a gold surface and the measured kinetic energy of an electron released from the gold metal is 5.02 eV, what is the wavelength (in nm) of the incoming light? (8pt) 8



$E_K = 5.02\ eV$

$= 8.042 \times 10^{-19}\ J$

$5.02\ eV \cdot \frac{1.602 \times 10^{-19}\ J}{1\ eV}$

$E_p - \Phi = E_K$

$E_p = \frac{hc}{\lambda}$

$\frac{hc}{\lambda} = E_K + \Phi$

from a)

$\frac{hc}{\lambda} = 8.042 \times 10^{-19}\ J + 8.1699 \times 10^{-19}$

$\frac{hc}{\lambda} = 1.621194 \times 10^{-18}$

$h = 6.62608 \times 10^{-34}\ J \cdot s$

$c = 2.99792 \times 10^{8}\ m \cdot s^{-1}$

$\lambda = 123\ nm$

Q3A. Electron diffraction is used to determine the structure of biological molecules. Calculate the wavelength of an electron traveling at 1.0×10^5 m.s^{-1}. (6pt)

λ v

$\lambda = \frac{h}{p}$ $p = mv$

$\lambda = \frac{h}{mv}$

$m_e = 9.109383 \times 10^{-31}$ kg 6

+5

$h = 6.62608 \times 10^{-34}$ J.s

$v = 1.0 \times 10^5$ m.s^{-1}

-1 7.3 nm

$\lambda = 7$ nm

(Concept questions)

Q3B. What is the name of the equation used in Q3A? (2pt)

De Broglie's equation

+2

Q3C. Eosinophils, a type of white blood cell in your body, can use bromine to produce anti parasitic compounds, such as hypobromite, to fight off parasitic infections.

A bromine atom contains one unpaired electron in the $4p_z$ state. If we assume this unpaired electron is spin up, what are its quantum numbers? (4pt)

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

4p ↿⇂ ↿⇂ ↿
-1 0 1

+4

How many electrons in bromine possess identical values for the first two quantum numbers, n and l, as the unpaired electron? Include the unpaired electron in your answer. (2pt)

how many have n=4 l=1 (4p)

+2

5 electrons

+13

(Concept and calculation questions)

Balmer series n=2

Q4 Light with a wavelength of 102.557 nm excites a hydrogen-atom gas sample. Is the change in energy of a hydrogen atom positive or negative when it absorbs a photon? What is the principal quantum number of the state that the electron was excited to? Make sure to show all your calculations. (12pt)

The change in energy of a hydrogen atom is positive when it absorbs a photon. +2

$\lambda = \frac{h}{p}$ $c = \lambda\nu$

$E = h\nu$

+1

$\nu = \frac{c}{\lambda}$

$\lambda = 102.557$ nm

$= 1.02557 \times 10^{-7}$ m

$E_n = -\frac{hR}{n^2}$

$\Delta E =$

+1

$\Delta E = \left(-\frac{hR}{n^2}\right) - \left(-\frac{hR}{n^2}\right)$

+2 $1.9369 \times 10^{-18} = \left(-\frac{hR}{4}\right) - \left(-\frac{hR}{n^2}\right)$

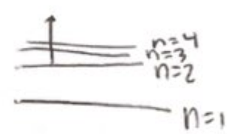
$1.9369 \times 10^{-18} = -5.449 \times 10^{-19} + \left(-\frac{hR}{n^2}\right)$

$E = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ +1

$n^2 = 0.878344$

$n = 1$ 3

$\frac{hc}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$



$1.9369 \times 10^{-18} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$

$5.8875774 \times 10^{-34} = \left(\frac{1}{4} - \frac{1}{n^2}\right)$

If 100 kJ of energy was absorbed by the gas sample, how many photons in total caused electronic excitations? How many moles of hydrogen were excited assuming one photon interacted with one unique hydrogen atom? (4pt)

$100 \text{ kJ} \cdot \frac{1000 \text{ J}}{1 \text{ kJ}} = 100\,000 \text{ J}$

+1

+7

(Concept questions)

Q5A. Write the full electron configuration. (4pt)

F $1s^2 2s^2 2p^5$

As $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$

Q5B. Which neutral element has the following electron configuration? (4pt)

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ Cu

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$ Co

Q5C. Calcium ions are important in the process of neurotransmitter release at the neuromuscular junction. Write the full electron-configuration for the ground-state of a calcium ion. not neutral (4pt)

Ca: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Ca^+: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Ca^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6$

+12

(Concept questions)

Q6A. Magnesium ions are a known cofactor in over 300 enzymatic reactions. What are the possible angular momentum quantum numbers of the highest energy electrons in these magnesium ions? Indicate the corresponding subshell of each angular momentum quantum number. (4pt)

7

0

Mg : [Ne] $3s^2$

$n = 3$

angular momentum quantum number → $l = 0$

adding electrons to make Mg ions could have possible l's being 0, ..., n-1

So 0, 1, 2 possible angular momentum quantum numbers

3s 3p 3d

Q6B. Arrange the following elements in order of **increasing** atomic radii (e.g. X < Y < Z).

Rb, Sr, Sn, Te, I (2pt)

Sr < Rb

Sn < Sr

Sn < Te

I < Te < Sn < Sr < Rb

2

Q6C. Arrange the following elements in order of **increasing** ionization energy. (2pt)

N, As, Sb, P, Bi

ionization: losing an electron

Bi < Sb < As < P < N

Bi < Sb < As < P < N

2

Q6D. Briefly explain why the first ionization energy of oxygen is lower than the first ionization energy for nitrogen. (2pt)

1

The first ionization energy is lower for Oxygen than nitrogen because a half filled shell that oxygen would have if an e⁻ was removed is more stable than a partially filled shell like Nitrogen would have had if an e⁻ is removed. e⁻-e⁻ repulsion

Q6E. Arrange the following elements in order of **increasing** electronegativity. (2pt)

F, Cl, Br, I

I < Br < Cl < F

2

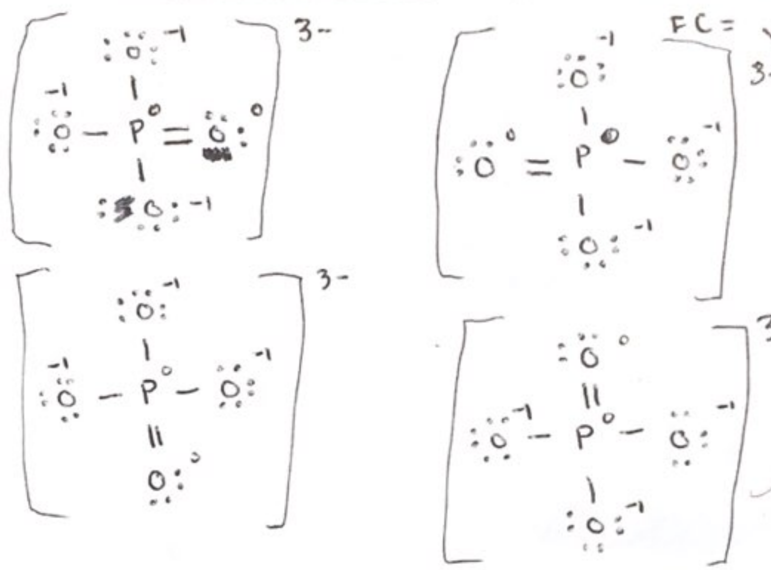
In class there have been many excellent student questions.

(Concept questions)

Q7A. Protein phosphorylation is an important regulatory process for cell cycling and enzyme activity. In protein phosphorylation an amino acid residue is phosphorylated by a protein kinase by the addition of a covalently bound phosphate (PO_4^{3-}). Draw four PO_4^{3-} resonance structures and assign formal charges to all atoms. (8pt)

P: 5 ve⁻
4×O: 24 ve⁻
+ 3 ve⁻
32 ve⁻ total

FC = ve⁻ − (lone e⁻'s + paired e's / 2)



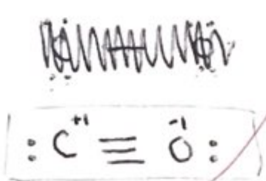
Are the phosphorus-oxygen bond lengths the same or different? Why? (2pt)

All the P–O bond lengths are the same because in the actual structure of PO_4^{3-} the electrons are all delocalized and it is a hybrid of all 4 resonance structures.

Q7B. In low doses, small molecules such as carbon monoxide (CO) and hydrogen sulfide (H_2S) are cell-signaling agents. However, in high doses they are lethal. Draw the most stable Lewis structures for each compound. (6pt)

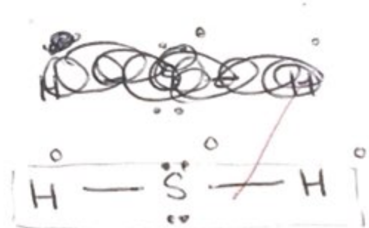
carbon monoxide

C: 4 ve⁻
O: 6 ve⁻
10 ve⁻ total



hydrogen sulfide

2x H: 2 ve⁻
S: 6 ve⁻
8 ve⁻ total



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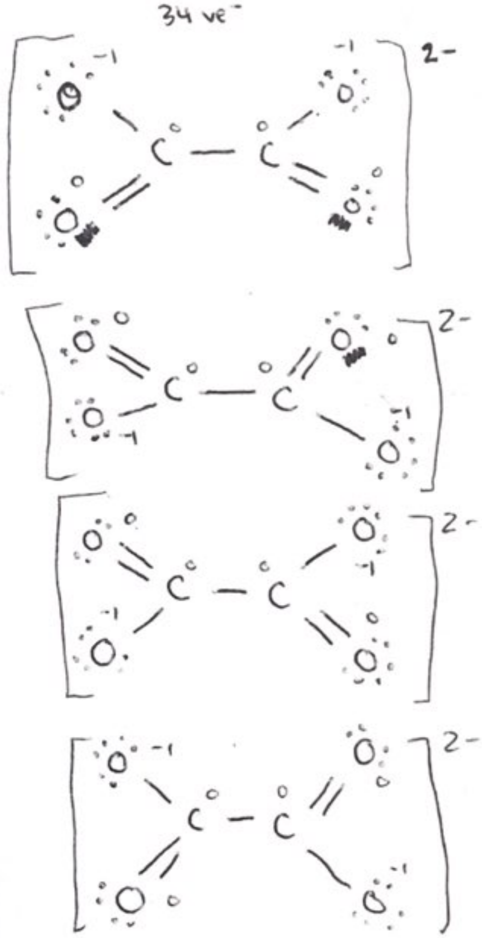
Chemistry Community surpassed 9 million page views this quarter.
Many student questions and student-student discussion involved the assigned homework and often centered on figuring out the structures and bonding in molecules as this is a major topic in Chem 14A.

(Concept questions)

Q8. Draw the Lewis structure, including resonance structures where appropriate, for (a) the oxalate ion, $C_2O_4^{2-}$ (there is a C–C bond with two oxygen atoms attached to each carbon atom); (b) BrO^+; (c) the acetylide ion, C_2^{2-}.
Assign formal charges to each atom. (14pt)

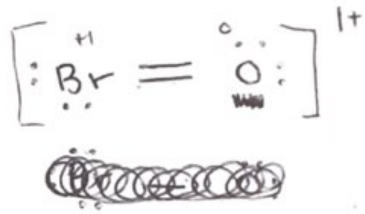
a) $C_2O_4^{2-}$

2 x C: 8 ve⁻
4 x O: 24 ve⁻
+2 ve⁻
34 ve⁻



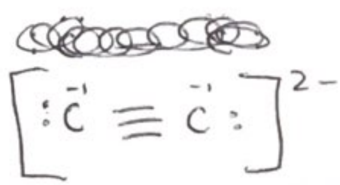
b) BrO^+

Br: 7 ve⁻
O: 6 ve⁻
−1 ve⁻
12 ve⁻



c) C_2^{2-}

2 x C: 8 ve⁻
+2 ve⁻
10 ve⁻



+14