Chemistry 14-A
Mid term exam
Sunday, May 2nd, 2021

PROBLEM	Points available	Points scored
1	12	
2	13	
3	14	
4	16	
5	14	
6	15	
total	84	

Name Cantley Alexis
Last First

Signature [signature]

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Alexis Cantley

Instructions: **This exam has 6 questions plus a periodic table at end of exam. Different questions have different numbers of points. Verify you have the right number of pages before you begin. Write your name on each page.** Raise your hand if you don't understand a question. **SHOW YOUR WORK!** No credit will be given for an unsubstantiated or illegible answer. Write legibly, use proper units throughout and use significant figures in all answers. Good luck!

Possibly useful information:

12 inches = 1 foot, 2.54 cm = 1 inch.

$h = 6.63 \times 10^{-34}$ J sec $N_o = 6.02 \times 10^{23}$ mol^{-1} $c = 3.00 \times 10^{8}$ m sec^{-1}

$m_e = 9.11 \times 10^{-31}$ kg 1 a.m.u. = 1.661×10^{-27} kg 1 Å = 10^{-10} m

mass (proton) = $1.672\ 62 \times 10^{-27}$kg mass (neutron) = $1.674\ 93 \times 10^{-27}$ kg

1 eV = 1.602×10^{-19} J K.E. $=1/2mv^2 = p^2/2m$

$F = -\Delta V/\Delta r$ $\lambda\nu = c$ $\Delta E = E_f - E_i = e_{photon} = h\nu$ $h\nu = h\nu_o + K.E.(electron)$

$\lambda = \frac{h}{mv} = \frac{h}{p}$ $\Delta mv\, \Delta x = \Delta p\, \Delta x \geq \frac{h}{4\pi}$

$E_n = -(2.18 \times 10^{-18}\text{ J})\, Z^2/n^2$

$n - \ell - 1$ spherical (radial) nodes; ℓ angular nodes; $n - 1$ total nodes

$n = 1, 2, ... \infty$ $\ell = n - 1, ... 0$ $m_\ell = -\ell .... 0 .... \ell$

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1a. Quinone, which is used in the dye industry and in photography, is an organic compound containing only C, H, and O. What is the empirical formula of the compound if you find that 0.105 g of the compound gives 0.257 g of CO_2 and 0.0350 g of H_2O when burned completely in excess oxygen? (8)

C: $0.257g\ CO_2 \times \frac{12.01g\ C}{44.01g\ CO_2} = 0.0701g\ C \times \frac{1\ mol\ C}{12.01g\ C} = \frac{0.00584}{.00194} = 3C$

H: $0.0350g\ H_2O \times \frac{2.02g\ H}{18.02g\ H_2O} = 0.00392g\ H \times \frac{1\ mol\ H}{1.008g\ H} = \frac{0.00388}{.00194} = 2H$ 3

$0.105g - 0.0701g - 0.00392g = 0.03098g\ O \times \frac{1mol\ O}{16g\ O} = \frac{.00194}{.00194} = 1\ O$

3

empirical formula : C_3H_2O

1b. Given a formula mass of approximately 108 g/mol, what is its molecular formula? (2)

$\frac{108g/mol}{54.05g/mol} \approx 2$

$C_3H_2O \times 2$

$(12.01 \times 3) + (1.008 \times 2) + 16 = 54.05$

molecular formula : $C_6H_4O_2$

1c. One a.m.u. is exactly 1/12th of the mass of a ^{12}C isotope which contains 6 protons, 6 neutrons and 6 electrons. Why then is the a.m.u. lighter than the mass of a proton or a neutron? (2)

The a.m.u is lighter because part of Carbon 12's mass is converted into energy to stabilize the nucleus. This phenomenon is binding energy which causes the a.m.u to be lighter than a proton or neutron, as protons and neutrons don't have their own binding energy by themselves. This is why hydrogen was not used as the standard for calculating a.m.u.

tot 12

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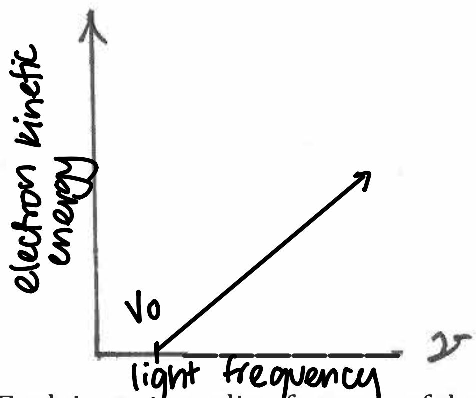
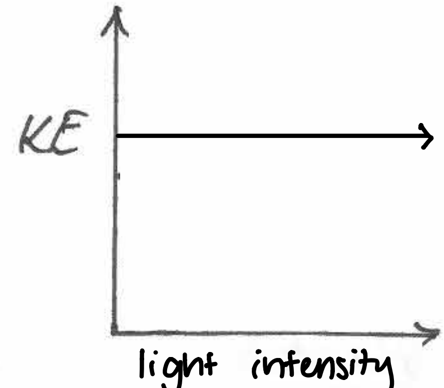
2a. Sketch two graphs to show how the kinetic energy of ejected electrons varies with (a) frequency, (b) intensity of light striking a metal surface. (3)





2b. Explain any puzzling features of these graphs from the point of view of the classical theory that existed before Einstein's introduced his approach to the photo-electric effect. (3)

With the classical theory it would be more logical that if you increased the light intensity more energy would be inputted into the system. With this emitted electrons would increase in kinetic energy as light intensity also increases. From the perspective of the classical view it doesn't make sense why light intensity doesn't affect KE, when light frequency is proportional to KE. In reality, this makes sense since light is a wave and has particle duality

c. Light with a wavelength of 400. nm (nanometers) strikes the surface of cesium metal resulting in the ejection of electrons with a kinetic energy of 1.54 x 10^{-19} J. Calculate the work function of this metal. (4)

$h\nu = \Phi + KE$

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

$\Phi = h\nu - KE$

$4\times10^{-7}\,m = \frac{3\times10^{8}\,m\cdot s^{-1}}{\nu}$

$\Phi = (6.63\times10^{-34}\,J\cdot s)(7.5\times10^{14}\,s^{-1}) - (1.54\times10^{-19}\,J)$

$\nu = 7.5\times10^{14}\,s^{-1}$

$\boxed{\Phi = 3.43\times10^{-19}\,J}$

d. Now calculate the threshold frequency for cesium. (2)

$\Phi = h\nu_0$

$\nu_0 = \frac{\Phi}{h} = \frac{4.82\times10^{-18}\,J}{6.63\times10^{-34}\,J\cdot sec} = \boxed{7.27\times10^{15}\,s^{-1}}$

total 13

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3a. Briefly explain what characterizes the scientific method according to Popper's approach. (3)

According to Popper's approach, one of the requirements for a theory is that it has the ability to be refuted. Therefore a theory can only be conclusive through being refuted. All theories will be accepted provisionally but eventually can be refuted as it is easier to prove something wrong.

3b. Explain any advantages and disadvantages of a long-form periodic table compared with an 18-column periodic table. (3)

An advantage of the long form table is that the f-block is in the right spot in regards to atomic number and not on its own under the table. One disadvantage is that the long form table is extremely big and long and can be hard to display while an 18 column table is easier to display.

3c. What if anything was problematical about the placement of tellurium and iodine in early periodic tables? (3)

The placement of tellurium and iodine was problematic in early tables because these tables were arranged by atomic mass which caused tellurium and iodine to have a pair reversal. Tellurium was placed after iodine even though it had a smaller atomic number because it had a heavier atomic mass. This order didn't make sense considering that I is a halogen and Te is group 6.

3d. How is this issue connected with the occurrence of isotopes of many elements? (3)

The atomic mass of an element consists of the average mass of the element's isotopes, so despite an atom possibly having less protons and a smaller atomic number, an element may be heavier because of heavier isotopes. This may lead to the element consisting of fewer protons that what is signified by its atomic mass.

Tot 12

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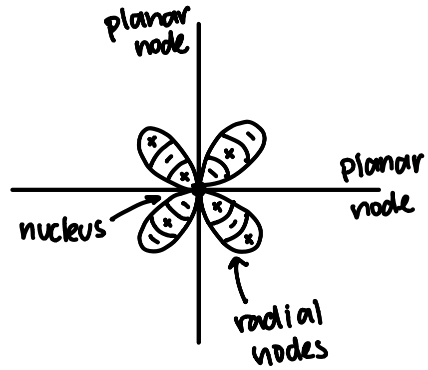
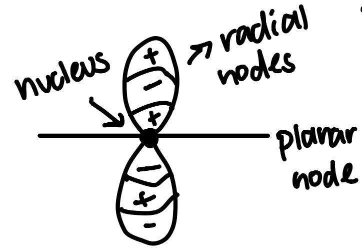
4a. Draw the following orbitals and show all nodes and phases that are present in each one. (6)

(i) 5d

planar: 2
$l = 2$
radial: 2
$n-1-l = 2$

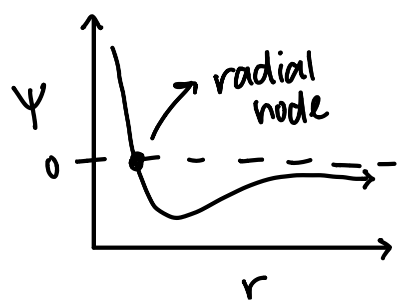


(ii) 4p



planar: 1
$l = 1$
radial: 2
$n-l-1 = 2$

4b. Sketch a graph of Ψ against the distance from the nucleus for a 2s orbital. (2)



$n-l-1 = 1$ radial node

4c. What two features of this graph are not easily interpreted physically although strictly correct? (2)

One feature is that the wave function (Ψ) turns negative after the radial node which tells us that the probability of determing the electron is negative after a certain point.
A second feature is that the probability of finding the electron at the nucleus is infinite since as r approaches 0, the wave function approaches infinity.

4d. Write a balanced equation for the reaction between NaOH and H_3PO_4 to form water and Na_3PO_4 (2)

$$3NaOH + H_3PO_4 \rightarrow 3H_2O + Na_3PO_4$$

4(e) Calculate the mass of water that should form when 10.0 g of each reactant produce the given products. (4)

$$10g\ NaOH \times \frac{1 mol\ NaOH}{39.998g\ NaOH} \times \frac{1 mol\ H_3PO_4}{3mol\ NaOH} \times \frac{97.998g\ H_3PO_4}{1mol\ H_3PO_4} = 8.167g\ H_3PO_4$$

NaOH limiting reagent

$$10g\ NaOH \times \frac{1\ mol\ NaOH}{39.998g\ NaOH} \times \frac{3\ mol\ H_2O}{3mol\ NaOH} \times \frac{18.016g\ H_2O}{1mol\ H_2O} = \boxed{4.50g\ H_2O}$$

total 16

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5a. Briefly state the Pauli Principle and give an example of an orbital/box diagram to illustrate it. (2)

The Pauli Exclusion Principle says that no two electrons can share the same four quantum numbers. This means that only two electrons are allowed per orbital and each electron has opposite spin.
Example: Be: $1s^2$ [↑↓] $2s^1$ [↑↓] → electrons have opposite spins so quantum numbers are $n=2$ $l=0$ $m_l=0$ $m_s=+1/2$ or $-\frac{1}{2}$

5b. Briefly state the Hund Principle and give an example of a configuration to illustrate it. (2)

The Hund principle says that electrons are filled by themselves in orbitals before being paired up to minimize electron repulsion and maximize spin.

example: nitrogen: $1s^2$ [↑↓] $2s^2$ [↑↓] $2p^3$ [↑ | ↑ | ↑]
↳ filled singularly

5c. Give the electronic configurations for, (4)

(i) The Sc^{+2} ion $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$

(ii) The Cu^+ ion $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

(You can use abbreviations such as [Ne] etc.)

5d. Explain the order of electron filling in atoms of K, Ca and Sc. (4)

In both Ca and K, 3d has a higher energy than 4s so you would fill the electrons in the 4s orbital first. However at Sc, 4s has a greater energy than 3d so 3d fills first. Also to limit electron repulsion the last 2 electrons enter 4s since 4s is larger than 3d.

Total 12

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No. 6. Circle one correct answer.

a. The orbital diagram for a ground-state nitrogen atom is

	1s	2s	2p		
A.	↑↓	↑↓	↑	↑	↑
B.	↑↓	↑↓	↑↓	↑	
C.	↑↓	↑	↑	↑	↑
D.	↑↓	↑↓	↑↓	↑	↑

b. Which ground-state atom has an electron configuration described by the following *orbital diagram*?

	3s	3p		
[Ne]	↑↓	↑	↑	↑

A) phosphorus B) nitrogen C) arsenic D) vanadium E) none of these

c. Which of the following electron configurations is impossible, according to the Pauli exclusion principle?

A) $1s^2 2s^2 2p^6$

B) $1s^2 2s^2 2p^3$

C) $1s^2 2s^5$

D) $1s^2 2s^2 2p^6 3s^1$

E) $1s^2 2s^2 2p^1$

d. Which of the following electron configurations represents an excited state of the indicated atom?

A) Ne: $1s^2\ 2s^2\ 2p^6$

B) N: $1s^2\ 2s^2\ 2p^3$

C) P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2\ 4s^1$

D) Na: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2\ 3s^1$

E) He: $1s^2$

e. Which of the following sets of four quantum numbers (n, l, m_l, m_s) correctly describes an electron occupying a d orbital of an element in the third row of the transition metals?

A) $4\ \ 2\ \ 2\ \ +\frac{1}{2}$

B) $5\ \ 2\ \ 1\ \ -\frac{1}{2}$

C) $5\ \ 3\ \ -1\ \ -\frac{1}{2}$

D) $4\ \ 1\ \ 0\ \ -\frac{1}{2}$

E) $5\ \ 0\ \ 0\ \ -\frac{1}{2}$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 30.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (97.91)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (208.98)	85 At (209.99)	86 Rn (222.02)
87 Fr (223.02)	88 Ra (226.03)	89 Ac (227.03)	104 Rf (261.11)	105 Ha (262.11)	106 Sg (263.12)												
				58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (144.91)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
				90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237.05)	94 Pu (244.06)	95 Am (243.06)	96 Cm (247.07)	97 Bk (247.07)	98 Cf (251.08)	99 Es (252.08)	100 Fm (257.10)	101 Md (258.10)	102 No (259.10)	103 Lr (262.11)