Chem 105 Exam 1

Name ______________________

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This exam is schedule for 75 minutes and I anticipate it to take the full time allotted. You are free to leave if you finish.

In multiple part problems, points awarded will not be penalized for incorrect answer on previous parts, so simply **move on if you get stuck on one part**.

Always neatly show work for partial credit.

Completely stuck on a problem, you can “buy” hints for points.

1. Identify the SI Units for each of the following:

Distance → m

Area → m^2

Density → kg/m^3

Energy → $J = \frac{kg\, m^2}{s^2}$

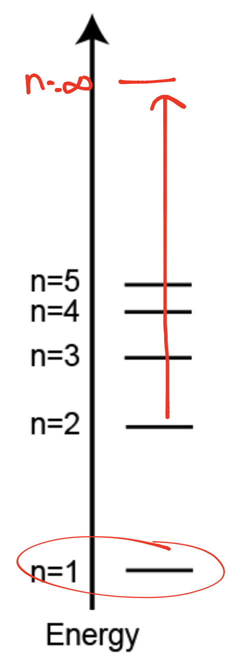
Temperature → K

Velocity → m/s

2. Convert the 100 μg/nm³ to kg/μm³.

$$\frac{100\ \mu g}{nm^3} \left| \frac{10^{-6} g}{1\ \mu g} \right| \frac{1\ kg}{10^3 g} \left| \frac{1\ nm}{10^{-9} m} \right| \frac{1\ nm}{10^{-9} m} \left| \frac{1\ nm}{10^{-9} m} \right| \frac{10^{-6} m}{1\ \mu m} \left| \frac{10^{-6} m}{1\ \mu m} \right| \frac{10^{-6} m}{1\ \mu m} = \frac{100\ kg}{\mu m^3}$$

3. The energy diagram of a single electron atom is shown to the right, please determine:



a. Which transition would **require** the highest energy photon?

$n=1 \rightarrow n=5$

b. **Circle** the energy level of an electron in the ground state.

c. The transition that would produce the longest wavelength photon.

$\uparrow \lambda = \downarrow E$ $\quad n=5 \rightarrow n=4$

d. For an electron in the first excited state, draw the transition that would correspond to the ionization energy. You may add anything to the image that you feel is relevant.

e. Calculate the energy of n = 4 for a hydrogen atom.

$$E_4 = \frac{-2.18\times10^{-18} J}{4^2} = -1.363\times10^{-19} J$$

4. List **two** possible sets of quantum numbers for an electron in a 5p orbital.

5, 1, 0, ½   5, 1, -1, ½   5, 1, 1, ½

5, 1, 0, -½   5, 1, -1, -½   5, 1, 1, -½

5. What is meant by particle-wave duality? Be specific.

When in motion, a particle has the properties of a wave; however, when interacting with matter, the particle interacts as a particle. This is central to understanding how electrons interact with the nucleus of an atom

6. Below are listed the first ionization energy for several atoms in the 3rd shell. Justify the difference seen between the following elements. If the relationship deviates from the expected trend, clearly explain why.

Na vs. Mg Mg vs. Al P vs. S Cl vs. Ar

Atom	Ionization Energy (aJ)
Na	0.823314513
Mg	1.225008303
Al	0.958983726
Si	1.306044503
P	1.6801727
S	1.65991365
Cl	2.077715045
Ar	2.525074726

Mg > Na b/c ↑Z

Mg > Al ... this deviates from the expected trend, It can be explained by considering stable e⁻ config ($3s^2$) and by the extra shielding that the Al e⁻ experiences

P vs. S. this deviates from the expected trend. This can be explained because P has a stable e⁻ config ($3p^3$) and S will create $3p^3$ once ionized

Cl vs Ar Expected based on ↑Z

Which of these elements is most likely to form an ion with a charge of +1? Justify your answer based on the energies listed above **and** electron configurations.

Na. It has the lowest Ionization and it forms the most stable e⁻ config (full shell) upon ionization

7. Determine the **energy and wavelength** of the photon ejected from a hydrogen atom when an electron relaxes from the 7th energy level to the ground state. Report your answer in SI units.

$E_1 = \frac{-2.18 \times 10^{-18} J}{1^2} = -2.18 \times 10^{-18} J$

$E_7 = \frac{-2.18 \times 10^{-18} J}{7^2} = -4.45 \times 10^{-20} J$

Energy 2.14×10^{-18} J

Frequency 3.22×10^{15} Hz

wavelength 9.3×10^{-8} m

$E_{photon} = -4.45 \times 10^{-20} J - -2.18 \times 10^{-18} = 2.14 \times 10^{-18} J$

$\nu = \frac{E}{h} = \frac{2.14 \times 10^{-18}}{6.626 \times 10^{-34}} = 3.22 \times 10^{15}$ Hz $\lambda = \frac{c}{\nu} = 9.3 \times 10^{-8}$ m

8. Order the following elements by INCREASING radius: Na Na^+ Mg^{2+} O^{2-} Ne Mg

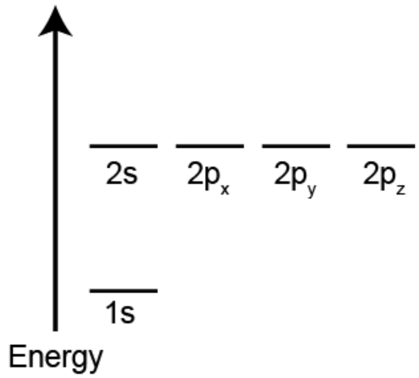
$Mg^{2+} < Na^+ < Ne < Mg < Na < O^{2-}$

Credit also given for O_2^- before Mg or Na

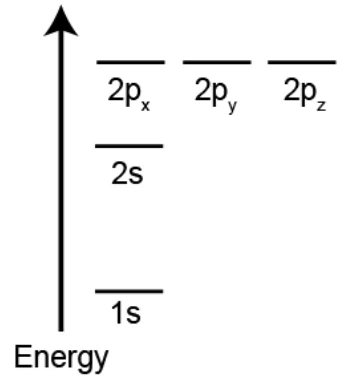
9. Two energy level diagrams are shown. One of these corresponds to Carbon (C^0) and the other the +5 carbon ion (C^{+5}).
   a. Label each graph with C^{5+} and the other with C^0.
   b. Clearly explain why the difference in these diagrams is observed.

C^{+5} is a single e^- atom. All subshells are @ identical energy

C^0 = multi electron. 2S has lower energy than 2P



C^{+5}



C^0

10. Consider the nucleus of an atom. As atoms increase in size, the number of neutrons increases more quickly than the number of protons. Explain why this is necessary.

Neutrons serve as a charge buffer. The more protons that are present, the more neutrons that are needed to separate the charge

11. Complete the table.

Element	Symbol	A	Z	Number of Neutrons	Number of Electrons	Charge
Selenium-79	$^{79}Se^{-2}$	79	34	79-34 = 35	36	-2

because →

12. There are only two stable chlorine isotopes. Chlorine-35, which has an exact mass of 34.96885 amu, composes 75.78% of a sample. Determine the exact mass of the other stable isotope (chlorine-37). Report you answer with 5 sig figs.

$100\% = 75.78 + x$ $\quad x = 24.22\%$

$35.45 = 0.7578(34.96885) + 0.2422y$

$0.2422y = 8.9506$

$y = 36.955$ amu

13. When a photon with an energy of 6.954 x 10^{-19} J strikes the surface of potassium metal, an electron is ejected with no kinetic energy. What is the threshold energy of potassium?

$E_{photon} = \Phi + E_K$

$6.954 \times 10^{-19} J = \Phi + 0$

$\Phi = 6.954 \times 10^{-19} J$

14. Consider Pb (Z = 82).

a. Write the condensed electron configuration. $[Xe]\, 6s^2 4f^{14} 5d^{10} 6p^2$

b. Is this element diamagnetic or paramagnetic? Justify your answer. paramagnetic

6p ↿ ↿ — ← unpaired e^- in 6p

c. Predict two stable ions of Pb. Explain your choice using electron configurations.

Pb^{+2} $[Xe]\, 6s^2 4f^{14} 5d^{10}$

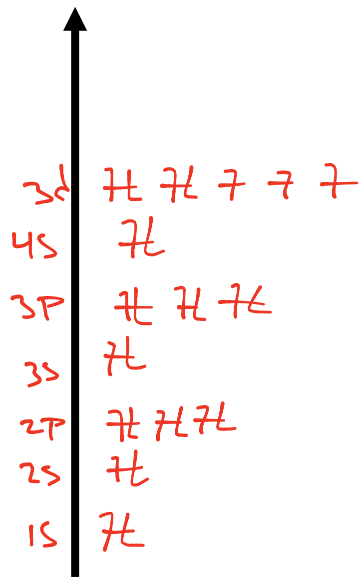
Pb^{+4} $[Xe]\, 4f^{14} 5d^{10}$

OK If show Pb^{-4} w/ correct e^- config

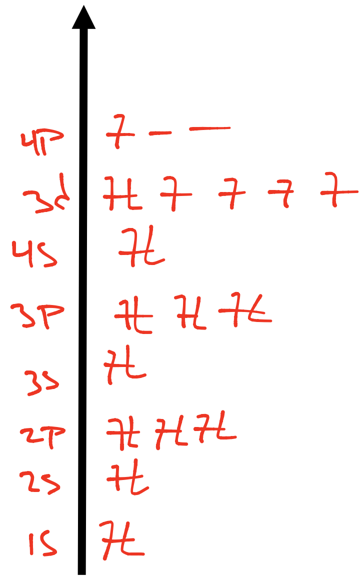
(however, as we learned on Wed, Pb is a metal and will NEVER have a (-) charge

15. **Consider cobalt (Z = 27)**.

a. Show a **complete** orbital energy diagram for the ground state and first excited state. Make sure to label all orbitals and show all electrons.



Ground State



First Excited State

b. Use the above diagram to explain the *quantization of energy*. You can answer this in one sentence.

Electrons are required to exist @ specific energy levels

16. The radius of ^{41}K is 243 pm. Using the information at the back of the exam and assuming the atom is a perfect sphere, calculate the density in SI units.

$^{41}K \rightarrow$ 19 Protons $(1.673 \times 10^{-27}\ kg) = 3.179 \times 10^{-26}\ kg$

22 neutrons $(1.675 \times 10^{-27}\ kg) = 3.685 \times 10^{-26}\ kg$

19 e⁻ $(9.109 \times 10^{-31}\ kg) = 1.731 \times 10^{-29}\ kg$

$243\ pm \cdot \frac{10^{-12}\ m}{1\ pm} = 2.43 \times 10^{-10}\ m$

$V = \frac{4}{3}\pi r^3 = 6.0103 \times 10^{-29}\ m^3$

mass $= 6.865 \times 10^{-26}\ kg$

density $= \frac{6.865 \times 10^{-26}\ kg}{6.0103 \times 10^{-29}\ m^3} = 1142.2\ \frac{kg}{m^3}$

17. Do you expect a neutral potassium atom to be **more or less** dense than a potassium cation? Briefly justify your answer.

less dense. e⁻ have effectively no mass, but removing one e⁻ to make a cation has a big affect on the volume

Answer one of the following:

18. When a 14.86 kg chunk of lead is dropped into a cylinder of water, the height of the column of water increases by 4.17 cm. If the cylinder has a radius of 100 mm, calculate the density of lead. Report your answer in g/mL

$\frac{100\text{ mm}}{} \left| \frac{10^{-3}\text{ m}}{1\text{ mm}} \right| \frac{1\text{ cm}}{10^{-2}\text{ m}} = 10\text{ cm}$

$\frac{14.86\text{ kg}}{} \left| \frac{10^{3}\text{ g}}{1\text{ kg}} \right. = 14860\text{ g}$

$V = \pi r^2 h = \pi (10\text{ cm})^2 (4.17\text{ cm})$

$V = 1309.38\text{ cm}^3 = \text{mL}$

$\text{Density} = \frac{14860\text{ g}}{1309.38\text{ mL}} = 11.35\text{ g/mL}$

19. Calculate the velocity of the ejected electron when a photon (λ = 364 nm) strikes a zinc surface (Φ = 6.8878 x 10^{-13} μJ).

$\frac{364\text{ nm}}{} \left| \frac{10^{-9}\text{ m}}{1\text{ nm}} \right. = 3.64 \times 10^{-7}\text{ m}$

$E_{photon} = \frac{hc}{\lambda} = 5.44 \times 10^{-19}\text{ J}$

$\phi = \frac{6.8878 \times 10^{-13}\ \mu\text{J}}{} \left| \frac{10^{-6}\text{ J}}{1\ \mu\text{J}} \right. = 6.8878 \times 10^{-19}\text{ J}$

$E_{photon} < \phi$, so no particle is ejected

Equations and constants:

$E = h\nu$ $c = \lambda\nu$ $h = 6.626x10^{-34}Js$ $c = 2.998x10^{8}ms^{-1}$

$E_n = \frac{-2.18x10^{-18}J}{n^2}Z^2$ $\Delta E = E_{final} - E_{initial}$ $E_K = \frac{1}{2}mv^2$

$E_{potential} \propto \frac{q_1q_2}{r}$

$m_{electron} = 9.109x10^{-31}kg$ $m_{proton} = 1.673x10^{-27}kg$

$m_{neutron} = 1.675x10^{-27}kg$

$\lambda_{debroglie} = \frac{h}{2v}$

$V_{sphere} = \frac{4}{3}\pi r^3$ $V_{cylinder} = \pi r^2 h$ $A_{circle} = \pi r^2$

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Hydrogen 1 **H** 1.01																		Helium 2 **He** 4.00
Lithium 3 **Li** 6.94	Beryllium 4 **Be** 9.01												Boron 5 **B** 10.81	Carbon 6 **C** 12.01	Nitrogen 7 **N** 14.01	Oxygen 8 **O** 16.00	Fluorine 9 **F** 19.00	Neon 10 **Ne** 20.18
Sodium 11 **Na** 22.99	Magnesium 12 **Mg** 24.31												Aluminum 13 **Al** 26.98	Silicon 14 **Si** 28.09	Phosphorus 15 **P** 30.97	Sulfur 16 **S** 32.07	Chlorine 17 **Cl** 35.45	Argon 18 **Ar** 39.95
Potassium 19 **K** 39.10	Calcium 20 **Ca** 40.08		Scandium 21 **Sc** 44.96	Titanium 22 **Ti** 47.88	Vanadium 23 **V** 50.94	Chromium 24 **Cr** 52.00	Manganese 25 **Mn** 54.94	Iron 26 **Fe** 55.85	Cobalt 27 **Co** 58.93	Nickel 28 **Ni** 58.69	Copper 29 **Cu** 63.55	Zinc 30 **Zn** 65.39	Gallium 31 **Ga** 69.72	Germanium 32 **Ge** 72.61	Arsenic 33 **As** 74.92	Selenium 34 **Se** 78.96	Bromine 35 **Br** 79.90	Krypton 36 **Kr** 83.80
Rubidium 37 **Rb** 85.47	Strontium 38 **Sr** 87.62		Yttrium 39 **Y** 88.91	Zirconium 40 **Zr** 91.22	Niobium 41 **Nb** 92.91	Molybdenum 42 **Mo** 95.94	Technetium 43 **Tc** (98)	Ruthenium 44 **Ru** 101.07	Rhodium 45 **Rh** 102.9	Palladium 46 **Pd** 106.42	Silver 47 **Ag** 107.87	Cadmium 48 **Cd** 112.41	Indium 49 **In** 114.82	Tin 50 **Sn** 118.71	Antimony 51 **Sb** 121.76	Tellurium 52 **Te** 127.60	Iodine 53 **I** 126.90	Xenon 54 **Xe** 131.29
Cesium 55 **Cs** 132.91	Barium 56 **Ba** 137.33	**57-70** *	Lutetium 71 **Lu** 174.97	Hafnium 72 **Hf** 178.49	Tantalum 73 **Ta** 180.95	Tungsten 74 **W** 183.84	Rhenium 75 **Re** 186.21	Osmium 76 **Os** 190.23	Iridium 77 **Ir** 192.22	Platinum 78 **Pt** 195.08	Gold 79 **Au** 196.97	Mercury 80 **Hg** 200.59	Thallium 81 **Tl** 204.38	Lead 82 **Pb** 207.20	Bismuth 83 **Bi** 208.98	Polonium 84 **Po** (209)	Astatine 85 **At** (210)	Radon 86 **Rn** (222)
Francium 87 **Fr** (223)	Radium 88 **Ra** (226)	**89-102** **	Lawrencium 103 **Lr** (262)	Rutherfordium 104 **Rf** (267)	Dubnium 105 **Db** (268)	Seaborgium 106 **Sg** (271)	Bohrium 107 **Bh** (272)	Hassium 108 **Hs** (270)	Meitnerium 109 **Mt** (276)	Darmstadtium 110 **Ds** (281)	Roentgenium 111 **Rg** (280)	Copernicium 112 **Cn** (285)	Ununtrium 113 **Uut** (284)	Ununquadium 114 **Uuq** (289)	Ununpentium 115 **Uup** (288)	Ununhexium 116 **Uuh** (293)	Ununseptium 117 **Uus** (294?)	Ununoctium 118 **Uuo** (294)

*lanthanides	Lanthanum 57 **La** 138.91	Cerium 58 **Ce** 140.12	Praseodymium 59 **Pr** 140.91	Neodymium 60 **Nd** 144.24	Promethium 61 **Pm** (145)	Samarium 62 **Sm** 150.36	Europium 63 **Eu** 151.97	Gadolinium 64 **Gd** 157.25	Terbium 65 **Tb** 158.93	Dysprosium 66 **Dy** 162.50	Holmium 67 **Ho** 164.93	Erbium 68 **Er** 167.26	Thulium 69 **Tm** 168.93	Ytterbium 70 **Yb** 173.04
**actinides	Actinium 89 **Ac** (227)	Thorium 90 **Th** 232.04	Protactinium 91 **Pa** 231.04	Uranium 92 **U** 238.03	Neptunium 93 **Np** (237)	Plutonium 94 **Pu** (244)	Americium 95 **Am** (243)	Curium 96 **Cm** (247)	Berkelium 97 **Bk** (247)	Californium 98 **Cf** (251)	Einsteinium 99 **Es** (252)	Fermium 100 **Fm** (257)	Mendelevium 101 **Md** (258)	Nobelium 102 **No** (259)