Name

1. (5 points) One of the most important molecules in biochemical systems is adenosine triphosphate, ATP. ATP has a molecular formula of $C_{10}H_{12}N_5O_{13}P_{3(s)}$. Write the equation for the standard enthalpy of formation for 1 mole of adenosine triphosphate.
(elemental P is $P_{4(s,\ wwhite)}$)

$$\tfrac{3}{4}\ P_{4(s,\ wwhite)} + 10C_{(s)} + 6H_{2(g)} + 5/2\ N_{2(g)} + 13/2\ O_{2(g)} \rightarrow C_{10}H_{12}N_5O_{13}P_{3(s)}.$$

2. (5 points) The optic nerve needs a minimum of 2.00×10^{-17} J of energy to trigger a series of impulses that eventually reach the brain for the eye to detect visible light.
How many photons of yellow-orange light with a $\lambda = 589$ nm are emitted from a low-pressure sodium lamp in a parking lot?

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

$$\Delta E = \frac{hc}{589x10^{-9}} = 3.372\ 6x10^{-19}J$$

$$number\ of\ photons = \frac{2.00x10^{-17}J}{3.372\ 6x10^{-19}J} = 59.3\ photons$$

3. Styrene is an organic liquid that easily combusts in the presence of oxygen. The $\Delta H°_{rxn}$ for the following reaction is —4395.0kJ. Using the standard heats of formation listed on the formula page, calculate the heat of formation ($\Delta H°_f$) for styrene,$C_8H_{8(l)}$?

$$C_8H_{8(l)} + 10\ O_{2(g)} \rightarrow 8CO_{2(g)} + 4\ H_2O_{(l)}$$

$$\Delta H_{rxn} = \Delta H\ products - \Delta H\ reactants$$

$$\Delta H_{rxn} = 4\Delta H_{H2O} + 8\Delta H_{CO2} - \Delta H_{styrene}$$

$$\Delta H_{rxn} - 4\Delta H_{H2O} - 8\Delta H_{CO2} = \Delta H_{styrene}$$

$$-4395.0kJ - 4\ mol\ (-285.83\ kJ/mol) - 8\ mol\ (-393.5\ kJ/mol) = 1\ mole\ x\ -\Delta H°\ styrene$$

$$\Delta H°_{(styrene)} = -103.7\ kJ/mol$$

4. (10 points) Given below are several electron configurations that might be correct for the nitrogen atom. Indicate whether each of these representations are the ground state, the excited state, or un-allowed (forbidden) state. Using Hund's rule, the Pauli principle, and aufbau (building up), BRIEFLY explain your choices. [Some might violate more than one rule.]

	1s	2s	2p	3s			
a)	↑↓	↑↓	↑ ↑ ↓	__	**ES**	GS	FS
b)	↑↓	↑↓	↑ ↑ ↑	__	ES	**GS**	FS
c)	↑↓	↑↑	↑ ↑ ↑	__	ES	GS	**FS**
d)	↑↓	↑	↑ ↑ ↑	↑	**ES**	GS	FS
e)	↑↓	↑↓	↑↓ ↑ __	__	**ES**	GS	FS

Write your explanations here.

a) Violates Hund's rule: When filling a subshell with degenerate orbitals, the electron diagram with the lowest energy has the electrons in the same spin in separate orbitals until the subshell is ½ filled. This minimizes repulsions and maximizes spin: the third electron is spin down. Spin is not maximized. This is a higher energy state than ground state.
b) This is an example of the ground state for nitrogen. Pauli, Hund, and Aufbau are obeyed.
c) This violates Pauli Exclusion Principle: no two electrons can have the same 4 quantum numbers. The 2s subshell has two electrons with the same [n, l, m_l, m_s].
d) This violates Aufbau: From handouts on the website and lecture, the most stable (lowest energy) occurs when the electrons are in the lowest possible n, l. This order follows Madelung's rules (mentioned briefly, but illustrated with "Craig's fill chart", that lower n, l values fill first before higher n, l values. (I pointed out in class that it is a diagonal fill. *Some atoms violate Madelung's rule; this is generally seen in the transition metals, and the inner transition.* ***This is not part of the answer, but interesting.***
e) This violates Hund: spin is not maximized and repulsions are not minimized.

5. (8 points total) The combustion of 0.1584 g benzoic acid increases the temperature of a bomb calorimeter by 2.54°C.
   a. (4 points) Calculate the heat capacity of the calorimeter. The energy released by the combustion of benzoic acid is —26.42 kJ per gram.
   b. (4 points) A 0.2130 g sample of the vanillin is burned in the same calorimeter, and the temperature increases by 3.25°C. What is the energy of combustion of vanillin in kJ/g? Show positive and negative signs clearly in answers for clarity.

– q(process) = q calorimeter, HBz stands for benzoic acid

$$C_V\Delta T = -\Delta H \text{ x mass}$$

$$C_V \text{ x } 2.54°C = -(-26.42 \text{ kJ/g HBz x } 0.1584 \text{ g HBz})$$

$$C_V = 4.185\text{kJ}/2.54°C = 1.65 \text{ kJ/°C}$$

– q(process) = q calorimeter, Van stands for vanillin

$$C_V\Delta T = -\Delta H \text{ x mass}$$

$$1.65\text{kJ/°C x } 3.25°C = -\Delta H \text{ x } 0.2130\text{g Van}$$

$$\Delta H = -25.2 \text{ kJ/g}$$

6. (10 points) A sample of gold metal must absorb radiation with a minimum frequency of $1.2619 \text{ x } 10^{15} \text{ s}^{-1}$ before it can emit an electron from its surface via the photoelectric effect.
   a. (2 points) What is the minimum energy required to produce this effect? (ϕ, PE)
   b. (8 points) If the surface of the gold sample is irradiated with light of wavelength 106 nm, what is the maximum possible velocity of the emitted electrons? Mass of an electron is $9.10938\text{x}10^{-31}$kg

Minimum energy (φ) $\Delta E = H\nu = 6.626\text{x}10^{-34}\text{Js x } 1.2619\text{x}10^{15}\text{s}^{-1}$= $\mathbf{8.361x10^{-19}J}$

$$\Delta E_{photon} = \frac{6.626\text{x}10^{-34}\text{Js x } 2.998 \text{ x } 10^{8} \text{ m/s}}{106 \text{ x } 10^{-19} \text{ m}} = 1.874\ 03 \text{ x } 10^{-18} \text{ J}$$

$\Delta E = \varphi$ **+ KE so KE =** $\Delta E - \varphi$ **(you solved for this in part a.)**

$KE = 1.874\ 03 \text{ x } 10^{-18} \text{ J} - 8.361\text{x}10^{-19}\text{J} = 1.037\ 897\ 03 \text{ x } 10^{-18}\text{J}$

$KE = ½\ m_e v^2$, $v = (2 \text{ x } 1.037\ 897\ 03 \text{ x } 10^{-18}\text{J}/9.109\ 4 \text{ x } 10^{-31}\text{kg})^{1/2}$

$1.51 \text{ x } 10^{7}$m/s (hope this is right, my calculator is broken.)

7. **(5points)** What is the ΔH_{RXN} at constant pressure for the reaction of interest?

   Reaction of interest: $ClF_{(g)}$ + $F_{2(g)} \rightarrow ClF_{3(g)}$
   Pathway reactions:
   Equation 1: $2ClF_{3(g)} + 2\ O_{2(g)} \rightarrow Cl_2O_{(g)} + 3F_2O_{(g)}$ ΔHrxn = 341.4 kJ/mol
   Equation 2: $F_{2(g)} + 1/2\ O_{2(g)} \rightarrow F_2O_{(g)}$ ΔHrxn = –21.8 kJ/mol
   Equation 3: 2 $ClF_{(g)} + O_{2(g)} \rightarrow Cl_2O(g + F_2O_{(g)}$ ΔHrxn = + 167.4 kJ/mol

   ~~½ $Cl_2O_{(g)}$~~ + ~~½ •3$F_2O_{(g)}$~~ → ½ •2$ClF_{3(g)}$ + ~~½ •2 $O_{2(g)}$~~ –341.4/2
   $F_{2(g)}$ + ~~½ $O_{2(g)}$~~ → ~~$F_2O_{(g)}$~~ –21.8kJ
   ½ •2 $ClF_{(g)}$ + ~~½$O_{2(g)}$~~ → ~~½$Cl_2O_{(g)}$~~ + ~~½$F_2O_{(g)}$~~- 167.4/2

ΔH for the process is –108.8 kJ

8. [4 points] An electron in the hydrogen atom can undergo only set transitions. Calculate the wavelength for an electron transitioning from n =10 to n =2. Based on n_f, is this visible, infrared, or ultraviolet light? Explain your choice.

$$\frac{1}{\lambda} = \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = 1.0968x10^7 m^{-1} x \left(\frac{1}{2_f^2} - \frac{1}{10_i^2}\right)$$

$$\frac{1}{\lambda} = 1.0968x10^7 m^{-1} x\ 0.24$$

$$\frac{1}{\lambda} = 2632320\ m^{-1}$$

λ=3.799x10^{-7}m, 379.9nm

Based on n_f, this would be visible light, since the Balmer series ends with n = 2. However, the value is shorter by a smidge, so near Ultraviolet was also ok

9. **(4 points**) Suppose you were marooned on a tropical island and had to make a primitive barometer using sea water (density = 1.10 g/mL). What height would the water reach in your barometer when a mercury barometer would reach 77.5 cm? d (Hg) = 13.6g/mL

$$\frac{\textbf{13.6 g Hg/mL x77.5 cm high}}{\textbf{1.10 g sea water/mL}} = 958\ cm\ high$$

10. (6 points) A 50.0-g sample of water at 100.00°C was placed in an insulated cup. Then 25.3-g of zinc at 25.00°C was added to the water. The temperature of the water dropped to 96.68°C. What is the specific heat of the zinc?

q(Cal) = –q(metal)

Cp water x mass water x ΔT water =– Cp metal x mass metal x ΔT metal

$$\text{Cp metal} = \frac{\text{Cp water x mass water x } \Delta T \text{ water}}{-\text{ mass metal x } \Delta T \text{ metal}}$$

$$\text{Cp metal} = \frac{4.184 \text{J/g°C x } 50.0 \text{ g water x } (96.68°\text{C}-100.00°\text{C})}{-(25.3 \text{ g metal x } (96.68°\text{C}-25.00°\text{C}))} = 0.383 \text{ J/g°C}$$

11. (4 points) An incandescent light bulb is filled with 6.00 x 10^{-5} mol of argon. The bulb has a volume of 800.0 mL. What is the pressure of the argon in the light bulb at 75°C?

$$P\ Ar = \frac{6.00 \bullet 10^{-5}\ mol\ Ar \bullet\ 0.08206 \bullet\ (75 + 273.15)\ K}{0.8000\ L} = \boldsymbol{ANS:\ \ 0.00214\ atm}$$

12. (10 points) A quantity of Neon gas originally at 5.25 atm in a 2.00-L container at 26.0°C is transferred to a 12.5 L container at 20°C. A quantity of He originally at 5.25 atm and 26.0°C in a 5.00-L container is transferred to the same container (12.5L) containing the neon.

    a. (3 points) What is the pressure of the neon in the new container?
    b. (3 points) What new pressure of the He gas?
    c. (2 points) What is the total pressure of the new container?
    d. (2points) What are the mole fractions of He and Ne in the new container?

P_{Ne}	5.25 atm	2.00L / 299.15K	293.15K / 12.5 L	0.8232 atm, to 3 SF, 0.823 atm
P_{He}	5.25 atm	5.00L / 299.15K	293.15K / 12.5 L	2.058 atm, to 3 SF, 2.06 atm

P_{total}= 2.058 +0.8232= 2.881atm. 2.88 atm

$$\frac{P_{Ar}}{P_{total}} \Big| \frac{N_{Ar}}{N_{total}} \qquad \frac{P_{Ne}}{P_{total}} \Big| \frac{n_{Ne}}{N_{total}}$$

Mole fraction of each gas

X_{Ne}	$\frac{0.8232\ atm}{2.881\ atm}$	0.2858, **0.286**	X_{He}	$\frac{2.058\ atm}{2.881\ atm}$	= 0.7144, **0.714**

13. (6 points) At a given temperature and pressure, it takes 4.85 minutes for a 1.5 L sample of helium effuse through a membrane. How long does it take for 1.5 L of fluorine effuse under the same conditions? Rate = distance/time. Assume that the membranes are 3.0 nm long

$$\frac{rate\ F_2}{rate\ He} = \sqrt{\frac{He}{F_2}}; \quad \frac{rate\ F_2}{} = rate\ He\ x\ \sqrt{\frac{He}{F_2}}$$

$$\frac{rate\ F_2}{} = \frac{3.00nm}{4.85\ min} x \sqrt{\frac{4.002amu}{37.996\ amu}} = 0.207\ nm/min$$

$$\frac{time\ to\ effuse\ F_2}{} = \frac{3.00\ nm}{0.207\ nm/min} = 14.9\ min$$

14. (5 points) State which of the following sets of quantum numbers would be possible and which would not. Using one or two sentences (not <,>, =,≥, or any with slashes-use your words) explain what is wrong with the quantum numbers that are not possible. Note: missing the spin quantum number is not an error.

   a. n =5, l = 9, ml = –1 **since l is restricted to values of n–1 to 0, l cannot be greater than n. the maximum value of l is 4.**

   b. n = 18, l =0, ml = 0 **It is an 18 s orbital.**

   c. n =9, l = 2, ml = –3 **n and l values are possible here, but ml is restricted to values that range from –2 to +2.**

   d. [–5, 0, 1] **n cannot be negative or fractions. Also if l= 0, ml cannot be 1. It would be 0 as well.**

   e. [2, –1, 0] **because l is directly linked to n, l cannot be a negative value**

15. (6points) Fill in the blanks with the correct response:

   a. The number of orbitals with the quantum numbers [3,1,1] is **1, this is a 3p orbital.**
   b. When n = 5, the angular momentum quantum number***, l***, can be what value(s) **there are 5 values of l, 0, 1, 2, 3, or 4.**
   a) Of, the 3s, the $5fy^3$, and the $9d_{xy}$ orbitals, the orbital with the smallest number of radial nodes. **Not surprisingly it is the $5fy^3$ orbital. It has the most angular nodes (3), but the least (1) radial nodes. The first appearance of the f orbitals is n=4. The 4f orbitals have no radial nodes. The first appearance of a radial node is n=5, while the 9d orbital has (9-2-1) or 4 radial nodes.**
   c. Which color of visible light has the lowest energy? **Red light is the lowest visible light**
   d. The sub shell with the quantum numbers [7,3] is **7f orbital**
   e. Which value of n has the first appearance of the d orbitals? **The first appearance of the d orbitals is n = 3.**

16. **(6 points)** A 23.5-mL volume of hydrochloric acid reacts completely with a solid sample of $MgCO_3$. The volume of CO_2 formed is 154 mL at 25.98°C and 731.6 mmHg. What is the molarity of the acid solution?

$2HCl_{(aq)} + MgCO_{3(s)} \rightarrow CO_{2(g)} + H_2O_{(l)} + MgCl_{2(aq)}$

$$P = 731.6\ mmHgX \frac{1atm}{760\ mmHg} = 0.9626atm$$

$$V(gas) = 154\ mLx \frac{10^{-3}L}{1mL} = 0.154\ L$$

$$V(acid) = 23.5mLx \frac{10^{-3}L}{1mL} = 0.0235\ L$$

$25.98°Cx \frac{1K}{1°C} + 273.15K = 299.13K;\ PV = nRT$, solving for moles of gas,

$$\frac{PV}{RT} = \frac{0.96263\ atmx0.154L}{\frac{0.08206Latm}{Kmol} x\ 299.13K} = 0.0060393\ mol\ CO_2$$

$$0.0060393\ mol\ CO_2 x \frac{2HCl}{1CO_2} x \frac{1}{0.0235L} = 0.514\mathcal{M}\ HCl$$

17. **(8 points)** A sample of nitrogen gas is at STP. The volume of the container is decreased while keeping the temperature constant. Use kinetic-molecular theory to explain whether each of the following would increase, decrease, or remain constant and WHY.

a) the average KE: **The temperature is constant so the average KE is also constant. Changing the temperature would change the average KE.**

b) the average speed: **The average speed is dependent on KE = ½ mv^2. The average KE depends on the temperature. If the temperature increases, the molecules have more KE, and should move faster with greater force for collisions; since the temperature is constant, the KE is constant, and the speed is also constant.**

c) the frequency of the collisions: **The frequency of the collisions is inversely proportional to the volume; volume is indicative of the surface area inside the ballon. There will be more collisions with the walls of the container, because the path that the molecules travel is shorter to have a successful collision with the container walls even though the KE is constant.**

d) the frequency of collisions per unit area: **The frequency of the collisions per unit area must go if the frequency of the collisions increases. The area is decreasing because volume is decreasing.**

e) The pressure of the gas: **Pressure is a measure of the number of collisions/unit area and the force/unit area. If the force stays the same (KE does not change) but the number of collisions increases, the pressure must also increase. This is the basis of Boyle's Law.**

18. (6 points) Give the electron configuration for the following elements or ions. [You can give noble gas core]:

a. Sb: [Kr] $5s^2 4d^{10} 5p^3$

b. Polonium [Xe] $6s^2 4f^{14} 5d^{10} 6p^4$

c. Nickel (III) ion : atom [Ar]$4s^2 3d^8$, energy order [Ar] $3d^8 4s^2$, ion [Ar] $3d^7$

d. Cr^{2+} atom [Ar]$4s^1 3d^5$, energy order [Ar] $3d^5 4s^1$, ion [Ar] $3d^4$

e. Se [Ar]$4s^2 3d^{10} 4p^4$,

f. Iron(II) atom [Ar]$4s^2 3d^6$, energy order [Ar] $3d^6 4s^2$, ion [Ar] $3d^6$

g. Atom: [Ar]$4s^1 3d^{10}$ this atom has 18 + 11 electrons = 29 electrons, it is Cu

h. Cl [Ne] $3s^2 3p^7$

i. Co^{2+} atom [Ar]$4s^2 3d^7$, energy order [Ar] $3d^7 4s^2$, ion [Ar] $3d^7$

19. **Extra credit (8 points)** Calculate the amount of heat needed to convert 10.00 g of ice at –24.05 ºC to water at 28.22 ºC. (figure out how many steps first and be sure to use correct specific heats) $C_{(ice)}$ = 2.06 J/g°C, $\Delta H_{(fus)}$ for H_2O is 334.J/g, $C_{(H2O)}$ = 4.184 J/g°C,

    ice J(–10·°C) to ice (0°C) to water (0°C) to water (50°C)

    2.06J/gK(10.00g)((0.00 –(–24.05))°C + 334J/g (10.00g) + 4.184J/gK(10.00g)(28.22•C–0.00°C)
    =495.4J +3,340J+1,181J=5016 J

20. **Extra credit (5 points)** Goldie Locks was visiting her old friends, The Bears. She decided to take a bath in their tub. Tub. The tub holds 80.95 gallons of water. The water is 110.5°F. This water is too hot! How many gallons of cold water (40.0°F) does she need to add to cool the tub water to a nice toasty 102.1°F, which is just right? (All you need to solve this problem is here!)

$$-\,C_P m\Delta T_{(\text{cold water added})} = C_P m\Delta T_{(\text{tub water}}$$

simplifying the problem:

1. **the conversion from gallon to liter and liter to mass is the same for both sides**

    gallon x 3.7854 L/1 gallon x 1000 mL/L x 1 g/mL,

    so we can keep the gallons the conversion factors will cancel
2. **the specific heats will also cancel so we can cross those out. Now we are left with**

80.95 gallons tub water x $(\Delta T)_{tub}$ = ??? gallons water added x $(\Delta T)_{cold\ water}$

If we convert °F to °C, we have this formula: $(T_{\circ F} - 32°F)/1.8 = (T_{\circ C})$, but since this is a temperature change, we can just take the difference between the two temperatures in °F!/1.8! WTW!!
But it simplifies even more because 1.8 is a divisor on both sides of the equation
–80.95 gallons $_{tub\ water}$ x(102.1°F–110.5°F)$_{tub}$ = ? gallons water addedx(102.1°F–40.0°F)$_{cold\ water}$
10.9 gallons of 40.0°F water needed to be added.