Name

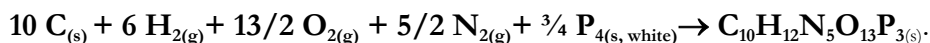1. (5 points) One of the most important molecules in biochemical systems is adenosine triphosphate, ATP. ATP has a molecular formula of $C_{10}H_{12}N_5O_{13}P_{3(s)}$. Write the equation for the standard enthalpy of formation for 1 mole of adenosine triphosphate. (elemental P is $P_{4(s,\ white)}$)

$$10\ C_{(s)} + 6\ H_{2(g)} + 13/2\ O_{2(g)} + 5/2\ N_{2(g)} + ¾\ P_{4(s,\ white)} \rightarrow C_{10}H_{12}N_5O_{13}P_{3(s)}.$$

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?

$$\Delta E = \frac{hc}{589\ x\ 10^{-9}m} = 3.337x10^{-19}J$$

$$\#\ of\ photons = \frac{2.00\ x10^{-17}J}{3.337x10^{-19}J} = 59.3\ photons$$

   59 or 60 are acceptable, since you can't have fractions of photons.

3. (5 point) Calculate the standard enthalpy of reaction, using enthalpies of formation for the reaction below. Show your work for full credit; Show positive and negative signs clearly in answers for clarity.

$$O_{2(g)} + 4NH_{3(g)} \rightarrow 2\ N_2H_{4(g)} + 2\ H_2O_{(g)}$$
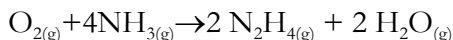
$\Delta H°f\ (NH_{3(g)}) = –46.19$ kJ/mol; $\Delta H°f\ (H_2O_{(g)}) = –241.82$kJ/mol;
$\Delta H°f(N_2H_{4(g)}) = 95.40$ kJ/mol; $\Delta H°f\ (H_2O_{(l)}) = –285.83$kJ/mol

$\Delta H°_{rxn} = 2$ moles $\Delta H°f\ (H_2O_{(g)}) + 2$ moles $\Delta H°f(N_2H_{4(g)}) — (4$ moles $\Delta H°f\ (NH_{3(g)})$
$\Delta H°_{rxn} = 2$ moles $(–241.82$kJ/mol$) + 2$ moles$(95.40$ kJ/mol$) — [4$ moles $(–46.19$kJ/mol$)]$
$= –483.64$kJ$+190.80$kJ$+184.76$kJ

$$–108.08kJ$$

NOTE: When multiplying by a whole number, all the significant figures of the number are maintain. Why? The operation is the same as adding those numbers. Oxygen is an element. No heat of formation for elements.

4. (10 points) Given below are several electron configurations that might be correct for the oxygen 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.]

a)   ↑↓   ↑↓   ↓↑ ↑ ↓   __   ES   GS   FS
     1s   2s   2p   3s

Obeys auf bau [building from the lowest n, l to highest n, l without skipping energy levels]; obeys Pauli [no two electrons in the same orbital can have the same 4 quantum numbers], but the spins are not parallel. This means the spin is not maximized. Hund's rule maximizes spin and minimizes repulsions. 1 s and 2 s follow Hund's Rule and Pauli

b) ↑↓   ↑↓   ↑ ↑ ↑↓   __   ES   GS   FS
   1s   2s   2p   3s

This looks good! Obeys Pauli, Hund's Rule, Aufbau.

c) ↑↓   ↑↓   ↑↑ ↑ ↑   __   ES   GS   FS
   1s   2s   2p   3s

2 p follows Hund's rule BUT 2p is forbidden b/c it does not follow Pauli. Pauli Exclusion principle: 2 electrons in the same orbital can't have same 4 quantum numbers. Aufbau is followed

d) ↑↓   ↑↓   ↑ ↑ ↑   ↑   ES   GS   FS
   1s   2s   2p   3s

This violates Aufbau. It takes energy to move electrons into a higher energy state. Both electrons in the 3s orbitals are in an excited state. All electrons satisfy Pauli and Hund's Rule.

e) ↑↓   ↑↓   ↑↓ ↑↓ __ __   ES   GS   FS
   1s   2s   2p   3s
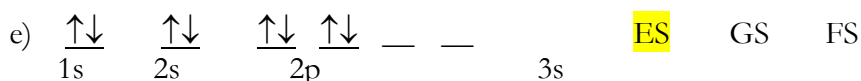
This violates Hunds' rule. This means the spin is not maximized. Hund's rule maximizes spin and minimizes. This configuration has maximized repulsions

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.

$-q_{(rxn)}=Cv\Delta T_{(calorimeter)}$

$-(-26.42kJ/g\ HBz)/(0.1584g\ HBz) = C_v(2.54°C)$

$C_v= 1.648\ kJ/°C$

$C_v= 1.65kJ/°C$

$-(\Delta H_{(comb)})(0.2130\ vanillin) = 1.658\ kJ/°C(3.25°C)$

$\Delta H_{(comb)} = -25.1kJ/g$ vanillin

6. (6 points) A sample of platinum metal must absorb radiation with a minimum energy (Work function, ϕ)of 6.35 eV 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 in Joules? [$1.6022\ x10^{-19}J = 1\ eV$]
    b. (2 points) What wavelength radiation will provide a photon of this energy?
    c. (2 points) If the surface of the platinum sample is radiated with light of wavelength 55.4 nm, what is the maximum possible kinetic energy of the emitted electrons?

$$\frac{6.35\ eV}{} \; x \; \frac{1.6022x10^{-19}J}{1eV} = 1.02\ x10^{-18}J$$

$$\lambda = \frac{hc}{1.017\ x10^{-18}J} = 195\ nm$$

$$\Delta E = \frac{hc}{55.4\ x\ 10^{-9}m} = 3.586x10^{-18}J$$

this part was not an answer for the exam. sorry

$-\Delta E$ **photon** $= \Delta E$ **electron absorbed**

ΔE **electron = minimum energy + KE**

$3.586\ x\ 10^{-18}J - 1.017\ x\ 10^{-18}J = KE = 2.569x10^{-18}J$

$$\sqrt{\frac{2x2.569x10^{-18}\ kgx\ m^2/s^2}{9.109\ 382\ x\ 10^{-31}kg}} = 2.37\ x10^6\ m/s$$

7. **SORRY this was on chapter 8. IT WILL BE EXTRA CREDIT.**
    (6 points) The bromine monochloride molecule, has a bond length of 213.8 pm and a dipole moment of 0.518D.
    a. Which atom in the molecule is expected to have a negative charge. Briefly explain your choice. Cl
    b. Calculate the effective charges on the Br and Cl atoms in the molecule in units of the electron charge e. (constants and formula on front page).
    c. Draw the molecule showing the direction of the dipole and the charge in e^- (i.e., the fraction of the charge of an electron) units on each atom in the molecule

$$\mu = Qr$$

$$\frac{0.518\ D}{213.8\ pm}\ x\ \frac{3.335\ 64x10^{-30}\ Cm}{1D}\ x\ \frac{1pm}{1x10^{-12}m}\ x\ \frac{1e}{1.602\ 177\ x\ 10^{-19}C} = 0.0504e$$

Br→Cl⊖

8. (6 points) Ammonia will burn in the presence of a platinum catalyst to produce nitric oxide, NO. Determine the heat of reaction at constant pressure? Show your work for full credit; Show positive and negative signs clearly in answers for clarity.

PATHWAY OF INTEREST 4 $NH_{3(g)}$+5 $O_{2(g)}$→4 $NO_{(g)}$ + 6 $H_2O_{(g)}$

PATHWAY 1:	$N_{2(g)}$ + $O_{2(g)}$→ 2 $NO_{(g)}$	ΔH = +180.6 kJ
PATHWAY 2:	$N_{2(g)}$ + 3 $H_{2(g)}$→ 2 $NH_{3(g)}$	ΔH = –91.8 kJ
PATHWAY 3:	2 $H_{2(g)}$ + $O_{2(g)}$→ 2 $H_2O_{(g)}$	ΔH = –483.7 kJ

PATHWAY OF INTEREST   4 $NH_{3(g}$+5 $O_{2(g)}$→4 $NO_{(g)}$ + 6 $H_2O_{(g)}$

PATHWAY 1:	$N_{2(g)}$ + $O_{2(g)}$ → 2 $NO_{(g)}$	ΔH = 180.6 kJ
PATHWAY 2:	$N_{2(g)}$ + 3 $H_{2(g)}$→ 2 $NH_{3(g)}$	ΔH = –91.8 kJ
PATHWAY 3:	2 $H_{2(g)}$ + $O_{2(g)}$ → 2 $H_2O_{(g)}$	ΔH = –483.7 kJ

$2N_{2(g)}$ + 2 $O_{2(g)}$ → 4 $NO_{(g)}$	ΔH = 180.6 kJ x 2
$4NH_{3(g)}$ → $2N_{2(g)}$ + $6H_{2(g)}$	ΔH = + 91.8 kJ x 2
6 $H_{2(g)}$ + $3O_{2(g)}$ → 6 $H_2O_{(g)}$	ΔH = -483.7 kJ x3
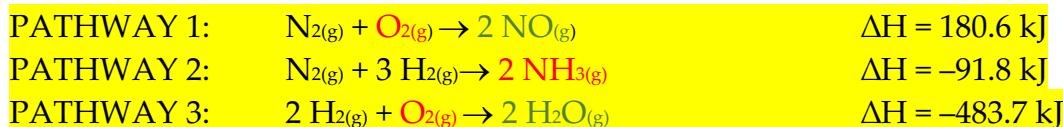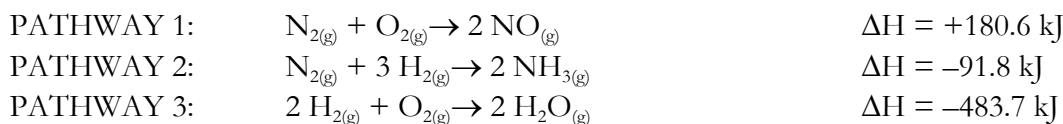
As you can see the hydrogens cancel, as do the nitrogens. –906.3 kJ

9. [4 points] An electron in the hydrogen atom can undergo only set transitions. Calculate the wavelength for an electron transitioning from n =12 to n =3. Based on n_f, is this visible, infrared, or ultraviolet light? Explain your choice.

$$\frac{1}{\lambda} = 1.0968x10^7 m^{-1}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = 1.096\ 8x10^7 m^{-1}\left(\frac{1}{3^2} - \frac{1}{12^2}\right)$$

$$\frac{1}{\lambda} = 1.142\ 5x10^6 m^{-1}$$

λ= 875.27 nm

Since n_f is 3, the light must be in the infrared region of the spectrum.

10. (8 points) A 28.2 g sample of nickel is heated to 99.8 °C and placed in a coffee cup calorimeter containing 150.0 g of water at 23.5°C. After the metal cools (and the water warms!) the final temperature of the metal and the water is 25.0°C. Calculate the specific heat capacity of nickel, if no heat escapes to the environment. Show positive and negative signs clearly in answers for clarity.

$$-q_{(metal)}=C_Pm\Delta T_{(calorimeter)}$$
$$-q_{(metal)} = 4.184J/g°C \times 150.0 \text{ g} \times (25.0°C -23.5°C)$$
$$-q_{(metal)} =941.4 \text{ J}$$

$$C_P= -941.4J/(28.2g \times(25.0°C-99.8°C)$$
$$=0.446J/g°C$$
$$\boxed{0.45J/g°C}$$

11. (6 points) Give the electron configuration for the following elements or ions.   [You can give noble gas core]:

    a.   Sb [Kr] $5s^24d^{10}5p^3$ OR Sb [Kr] $4d^{10}5s^25p^3$
    b.   Polonium Po [Xe] $6s^24f^{14}5d^{10}6p^3$ OR Po [Xe] $4f^{14}5d^{10}6s^26p^3$
    c.   Nickel (III) ion start with the atom in energy order **[Ar] $3d^84s^2$**
                 Remove 3 electrons Ni^{3+} **[Ar]$3d^7$**
    d.   Cu   [Ar]$4s^13d^{10}$
    e. Cr^{2+} **the atom is [Ar] $3d^54s^1$ the ion is [Ar]$3d^4$**
    f. Co^{2+} start with the atom in energy order **[Ar] $3d^74s^2$**
                 Remove 3 electrons Co^{2+} **[Ar]$3d^7$**

12. 6 points) Fill in the blanks with the correct response:
    a.   The number of orbitals with the quantum numbers [3,1,1] is

1

    b.   The number of un-paired electrons in a Co^{2+} ion is

4

    c.   When n = 5, the angular momentum quantum number*, l,* can be what value(s)

0, 1, 2, 3, 4

    a)   Of, the 3s, the $5fy^3$, and the $9d_{xy}$ orbitals, the orbital with the smallest number of radial nodes.

$5fy^3$ it has 1 radial node, the 3s has 2, and 9d has 6

    d.   The sub shell with the quantum numbers [7,3] is

e. Which color of visible light has the lowest energy?

7f

red

f. Light with a short wavelength has a (high/low) energy.

High energy

13. **Part 1** (0.25 points) Assuming constant pressure, **determine the sign of the energies** based on the following descriptions:

a. Surroundings get hotter and the volume of the system increases.
b. Surroundings get hotter and the volume of the system decreases
c. Surroundings get colder and the system expands in volume.
d. Surroundings get hotter and the volume of the system does not change.

system	The q of the system is +/—?	The value of w is +/—?	ΔE is +/— or undetermined
A	—, lost enerty	—, lost energy, did work	—
B	—, lost enerty	+, gained energy, work done on it	Undetermined
C	+, gained enerty	—, lost energy, did work	Undetermined
D	—, lost enerty		—

Part 2: (3 points) Fluorine and chlorine gas react to make chlorine trichloride. Before the reaction, the volume of the gaseous mixture was 10.00 L. After the reaction, the volume was 3.00 L. Calculate the value of the total energy change for the creation of one mole of chlorine trichloride, ΔE, in kilojoules. [HINT: w =-PΔV] (This will come in handy: 101.33 J = 1L•atm)

Show positive and negative signs clearly in answers for clarity.

$$\frac{3}{2} F_{2(g)} + \frac{1}{2} Cl_{2(g)} \rightarrow ClF_{3(g)} \qquad \Delta H°_f = —158.87 \text{ kJ/mol}$$
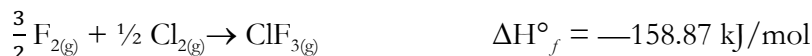
Express your answer with the appropriate units.

$$\Delta E = q + w$$

$$X =— 158.87kJ+—\frac{95.0 \text{ atm } x \text{ } 101.33J}{1L \bullet atm} x \frac{1kJ}{1000J} x(— 7.00L)$$

—158.87kJ+67.38 kJ = —91.5kJ

14. (10 points) Circle the best choice in the list and explain your choice based on shielding effects, quantum shielding, and/or Z_{eff}. Writing true or false = zero points. (use the back of the page for more space-number your answers)

    a.   Smallest radius: Ca^{2+}, Sr^{2+}, Ra^{2+}

       Size of atoms and ions increases down a family with increasing n value. These elements are in the 2A family. The smallest ion will be the smallest atom since they all have the same charge. The outermost electron for the calcium ion is closest to the nucleus.

    b.   Lowest ionization energy: K, Ca, Sc

Ionization energy is the energy to remove an electron from an atom in the gas phase. Ionization energies tend to increase across the periodic table and decrease down. This is due to shielding in the blocks coupled with an increasing Z as one moves from left to right in the periodic table. The lowest ionization energy should be the atom that is furthest to the right, with the lowest Z (and therefore the lowest Z_{eff}. Ca and K are in the same row and block, Ca has a larger Z_{eff} so it will have a larger ionization energy than K. Sc is the first electron in the 3d shell. These electrons are lower in energy, and closer to the nucleus, so Sc has a higher Zeff than either of the two.

    c.   Smallest atom: As, I, Br

Size of atoms and ions increases down a family with increasing n value. These elements are in the 7A family. The smallest atom will have the smallest radius The outermost electron for the bromine atom is closest to the nucleus. It has the highest attraction, the smallest radius, the smallest atom.

    d.   Largest negative electron affinity: O, B, Na

The trend for electron affinity is to increase across the periodic table. Non metals tend to have the largest affinity because the addition of an electron allows for more filled sub-levels, approaching a noble gas core.

    e.   The largest ion (or atom-see addendum sheet) Al^{3+}, Al, Al^{2+}

The lower the shielding for the same Z, the higher the Z_{eff}. This means the outermost electrons is more strongly attracted to the nucleus, and the radius of the atom or ion decreases. The aluminum atom has the most shielding for the three species, the outermost electron is the least attracted and therefore the atom should be the largest of the three.

15. (12 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. (4 points) What are the mole fractions of He and Ne in the new container?

a) **Find new pressures**
b) **Find moles of each gas:**
c) **Find mole fraction**

5.25 atm	2.00L	293.15K	=0.823 atm
12.5 L		299.15K	

5.25 atm	5.00 L	293.15K	= 2.06 atm
12.5L		299.13K	

The P total =0.823 atm + 2.06 atm = 2.88 atm

5.25 atm	2.00L	=0.4277 mol Ne
299.15K	$R_{L \cdot atm}$	

5.25 atm	5.00 L	= 1.069 mol He
299.15K	$R_{L \cdot atm}$	

$$X_{Ne} = \frac{0.4277}{0.4277 + 1.609} = 0.256$$

$$X_{He} = \frac{1.609}{0.4277 + 1.609} = 0.790$$

OR $\quad \frac{n_{Ne}}{n_{total}} = \frac{P_{Ne}}{P_{total}} = \frac{0.823}{2.88} = 0.256 \quad \frac{n_{He}}{n_{total}} = \frac{P_{He}}{P_{total}} = \frac{2.06}{2.88} = 0.790$
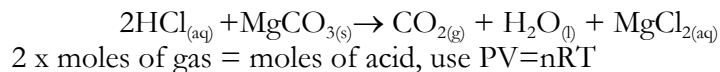
16. (6 points) The titanium (II) ion is iso-electronic with the calcium atom. Briefly explain your answers for each part.
   (a) Are there any differences in the electron configurations of titanium (II) and calcium?
   (b) Will the 2s orbital in calcium be more stable than the 2s orbital in titanium?
   (c) Will calcium and titanium (II) have the same number of unpaired electrons?

(a)**The titanium (II) ion has 0 electrons in the 4s subshell and 2 electrons in the 3d subshell. The calcium atom has no electrons in the 3d subshell and 2 electrons in the 3d subshell**
(b) the electron configuration for Ca : $1s^2 2s^2 3s^2 3p^6 4s^2$, titanium (II) $1s^2 2s^2 3s^2 3p^6 3d^2$. Titanium has a larger Z for the same number of electrons. The attraction of the 2s electrons to the titanium nucleus is stronger. The energy of the orbital is lower and more stable than that of calcium which has a smaller Z.
c) The number of unpaired electrons for the two species is not the same. The calcium atom has no unpaired electrons, while the titanium(II) ion has 2 unpaired electrons.

17. **(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?

$$2HCl_{(aq)} + MgCO_{3(s)} \rightarrow CO_{2(g)} + H_2O_{(l)} + MgCl_{2(aq)}$$
2 x moles of gas = moles of acid, use PV=nRT

$$\frac{PV}{RT} = moles\ CO_2$$

$$\frac{731.6\ mmHg}{760\ mmHg/atm} x \frac{154\ mL}{1000\ ml/L} \div \left(R_{L,atm}\ x299.13K\right) = 0.006039\ moles\ CO_2$$

0.006039 mol CO_2	2 mol HCl	= 0.012079 mol HCl
	1 mol CO_2	

0.012079 mol HCl	= 0.5139 M HCl	0.514 M HCl
0.0235 mL solution		

18. (5 points) Using your knowledge of the everyday and super hero world, place the following sources of light in order of increasing energy: [This means: start with the smallest (lowest) energy and end at the highest energy. Do not put numbers next to the letters; you need to write out the correct order of letters. You will receive no credit if you are not clear about your answer.]:

   a. Gamma rays that turned Bruce Banner into the Hulk
   b. The red color in red dye no. 28; a component of an insecticide used to kill Mediterranean fruit flies
   c. Infrared heat from the wires in your toaster used to burn toast
   d. Superman's x-ray vision used to see through walls and watch nefarious evil deed doers.
   e. The green color of the Green Lantern's lamp

   C, B, E, D, A

19. (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.

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

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

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