THERMOCHEMISTRY

1. (3 points) Liquid ethanol, C_2H_5OH, has a standard molar enthalpy of formation of $\Delta H^\circ_f = 277.69$ kJ/mol of ethanol. Which of the following chemical equations has an enthalpy change of -277.69 kJ?

   (a) $4\ C(s) + 6\ H_2(g) + O_2(g) \rightarrow 2\ C_2H_5OH(\ell)$

   (b) $2\ CO(s) + 3\ H_2(g) \rightarrow C_2H_5OH(\ell) + 1/2\ O_2(g)$

   (c) $2\ C(s) + 3\ H_2(g) + 1/2\ O_2(g) \rightarrow C_2H_5OH(\ell)$

   (d) $2\ C(s) + H_2O(g) + 2\ H_2(g) \rightarrow C_2H_5OH(\ell)$

2. (4 points) Which of the following enthalpy changes can be designated as a standard molar enthalpy of formation? *(There may be more than one answer.)*

   (a) $4\ Al(s) + 3\ O_2(g) \rightarrow 2\ Al_2O_3(g)$ $\Delta H^\circ = -1675.7$ kJ

   (b) $CaCl_2(s) \rightarrow Ca(s) + Cl_2(g)$ $\Delta H^\circ = +795.8$ kJ

   (c) $CaCO_3(s) \rightarrow Ca(s) + C(s) + 3/2\ O_2(g)$ $\Delta H^\circ = +1206.9$ kJ

   (d) $S(s) + Cl_2(g) + 1/2\ O_2(g) \rightarrow SOCl_2(g)$ $\Delta H^\circ = -212.5$ kJ

3. (3 points) One of the most important reactions in our economy is the first step in the production of nitric acid from ammonia.

   $$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$$

   What is the enthalpy change for this reaction as it is written here? *(All possible answers are rounded to one decimal place.)*

   (a) -1627.6 kJ

   (b) -1043.5 kJ

   (c) -905.2 kJ

   (d) -105.4 kJ

   (e) +105.4 kJ

   (f) +905.2 kJ

   (g) None of the above

4. (3 points) Titanium(IV) chloride is prepared from titanium(IV) oxide by the following reaction with an enthalpy change of 504.7 kJ.

   $TiO_2(s) + 4\ HCl(g) \rightarrow TiCl_4(\ell) + 2\ H_2O(g)$ $\Delta H^\circ_{rxn} = +504.7$ kJ

   Use the data in your textbook (Appendix L) and the enthalpy change for the reaction of TiO_2 with HCl (see above) to calculate the standard molar enthalpy of formation of $TiCl_4(\ell)$.

   (a) $\Delta H^\circ_f = -435.0$ kJ

   (b) $\Delta H^\circ_f = -527.3$ kJ

   (c) $\Delta H^\circ_f = -804.2$ kJ

   (d) $\Delta H^\circ_f = +804.2$ kJ

   (e) none of the above

5. (3 points) Suppose you treat 1.0 g of magnesium or 1.0 g of calcium with the same volume of HCl(aq) in separate calorimeters. In which calorimeter would the temperature rise be greater?

   $Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ $\Delta H^\circ_{rxn} = -466.8$ kJ

   $Ca(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ $\Delta H^\circ_{rxn} = -542.8$ kJ

   (a) Calorimeter containing magnesium

   (b) Calorimeter containing calcium

Atomic Structure

1. (4 points) Indicate which of the statements below is true and which is false.

   _____The higher the frequency of light, the greater the energy of the light.

   _____The higher the frequency of light, the greater the velocity of light.

   _____A shell of electrons with $n = 3$ has three subshells with a total of nine orbitals.

   _____An atom of nickel has 10 electrons assigned to the 3*d* subshell.

2. (3 points) Radiation in the ultraviolet region causes dyes to fade and skin to tan. If you are bombarded with ***1 mole of photons*** with a wavelength of 300 nm, what amount of energy are you being subjected to?

   (a) 6.63×10^{-19} J

   (b) 4.00×10^{-10} kJ

   (c) 4.00×10^{5} kJ

   (d) 400 kJ

   (e) A whole bunch!

3. (8 points) Using the ***spectroscopic notation*** [e.g., $1s^2 2s^2$], write electron configurations for the following atoms or ions:

   (a) P ***(please do not use the noble gas notation for this element)***

   (b) Mn

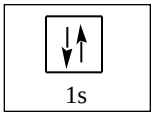
   (c) Ir (iridium)

   (d) Cr^{2+}

4. (9 points) Using the ***orbital box notation***, write electron configurations for the following atoms or ions. ***Please use the noble gas notation for all the answers!***

   (a) Al

   (b) Co^{3+}



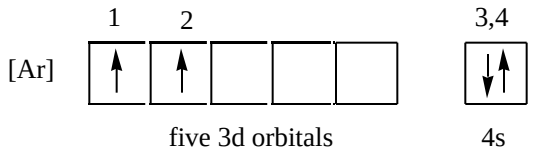
Orbital box notation

   Is the cobalt(III) ion diamagnetic or paramagnetic? _____

   (c) U

   (d) Cl^- (chloride ion)

5. (5 points) The configuration for an element is given below.



(a) What is the identity of the element with this configuration? _____

(b) Are atoms of the element paramagnetic or diamagnetic? _____

(c) Write a complete set of quantum numbers for each of the electrons numbered in the configuration above.

Electron	***n***	ℓ	$\mathbf{m}_\ell$	$\mathbf{m}_s$
1	_____	_____	_____	_____
2	_____	_____	_____	_____
3	4	0	0	+1/2
4	_____	_____	_____	_____

6. (5 points) It has been predicted that elements near the end of the seventh row of the periodic table will be stable enough to be isolated. Suppose you have just found element 117, and, in honor of your great college, you have named it Oneontium (On).

(a) Using the spectroscopic notation — and the rare gas notation — write the electron configuration for Oneontium.

(b) Name another element in the same group as Oneontium. _____

(c) Would you expect Oneontium to be a solid, liquid, or gas? _____

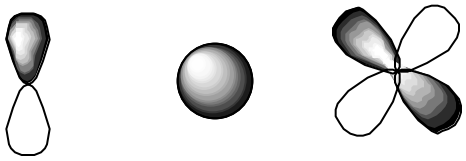
(d) Oneontium will react with H_2 to give a simple compound. What is the formula of this compound?

_____

7. (20 points) **Atomic structure and quantum numbers**

(a) For a 5f orbital, the value of n is _____, the value of ℓ is _____, and a possible value of m_ℓ is _____.

(b) Each drawing below represents a type of atomic orbital. Give the letter designation for the orbital and its value of ℓ.



letter	_____	_____	_____
ℓ value	_____	_____	_____

(c) An atomic orbital with 2 nodal planes is _____

(d) How many electrons can be associated with the following sets of quantum numbers?

	Number of Electrons
n = 3, and ℓ = 1	_____
n = 2, ℓ = 1, and m_ℓ = +1	_____
n = 5 and ℓ = 2	_____
n = 2, ℓ = 1, m_ℓ = -1, and m_s = +1/2	_____

(e) What element has the electron configuration [Ar]$3d^{10}4s^{1}$? _____

(f) What element has a 2+ ion with the configuration [Ar]$3d^{7}$? _____

(g) What anion has the electron configuration of a krypton atom? _____

(h) Which ion (or ions) is (are) NOT likely to be found in a chemical compound? Cs^{+}, Ti^{5+}, Cl^{2-}, and Al^{3+}? _____

(i) Which element has the *largest difference* between the 1st and 2nd ionization energies: K or Ti? _____

Periodic Trends

1. (11 points) Indicate the answer with the appropriate symbol or name.

   (a) Of the elements O, S, and F, which has the largest atomic radius? _____

   (b) Which is larger, a Cl atom or a Cl^- anion? _____

   (c) What element in the 3rd period has the largest electron affinity?_____

   (d) Which has the largest ionization energy: O, S, or Se? _____

   (e) Which of the following has the largest radius: O^{2-}, N^{3-}, or F^-? _____

   (f) Place the following elements in order of increasing ionization energy: P, Cl, and F

   _____ _____ _____
   smallest IE *largest IE*

   (g) Which of the following groups of elements is arranged correctly in order of increasing ionization energy?

   (i) C < Si < Li < Ne (iii) Li < Si < C < Ne

   (ii) Ne < Si < C < Li (iv) Ne < C < Si < Li

   (h) What element in Group 5A has the largest ionization energy? _____

   (i) What element in the alkaline earth group has the largest atomic radius? _____

   (j) Which element in the 5th period has the largest atomic radius? _____

2. (6 points) Answer the questions below about the elements A and B, which have the electron configurations shown.

   A = $[Kr]5s^1$ B = $[Ar]3d^{10}4s^24p^4$

   (a) Is element A a metal, nonmetal, or metalloid? _____

   (b) Which element would have the greater ionization energy? _____

   (c) Which element should have the greater affinity for an electron? _____

   (d) Which element has larger atoms? _____

   (e) Which is more likely to form an anion? _____

   (f) If A and B were to combine to form a compound, what is the likely formula of that compound?

   _____

Electron Configurations & Trends—Explaining Experimental Observations

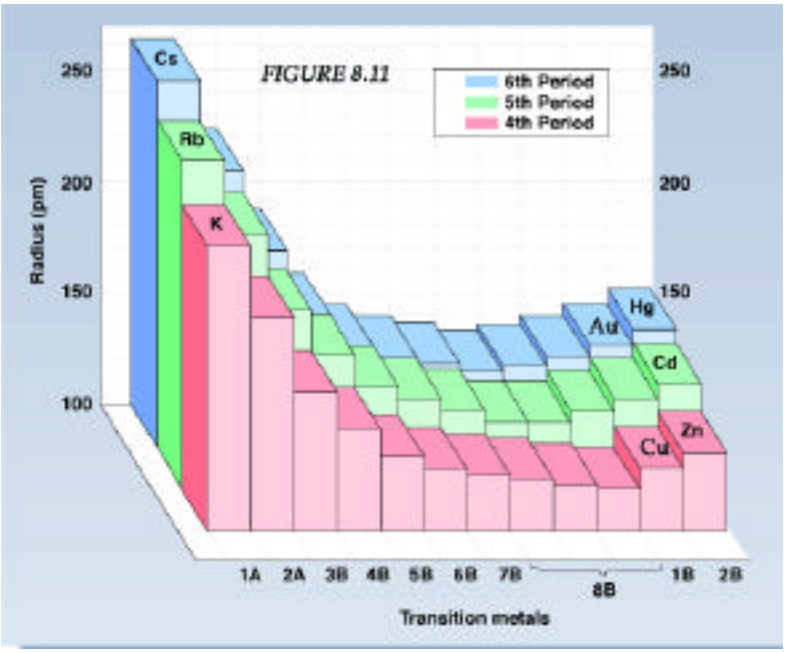
1. (3 points) Explain why the reaction of calcium metal and fluorine gas does NOT have the following balanced equation:

$$2\ Ca(s) + 3\ F_2(g) \rightarrow 2\ CaF_3(s).$$

This equation implies that the product of the reaction contains a Ca^{3+} ion (and F^- ion). To create a +3 calcium ion would require an enormous amount of energy because the last electron removed to make the ion comes from an inner electron shell. (The first two electrons removed come from the 4s and the third must come from the 3p orbitals.) (See pages 363-364 of Chemistry & Chemical Reactivity.) For this reason we have the general principle that the charges on metal ions are the same as their group number in the periodic table.

2. (2 points) Which element has the larger *density*, Cu or Au? Explain your choice briefly.

The answer to this question — gold — arises from Figure 8.11, trends in transition metal atom sizes. Notice that the size of a gold atom is not that much greater than the size of than a copper atom. Density is the ration of mass to volume. Because a gold atom is much heavier than a copper atom (197 g/mol for gold versus 63.5 g/mol for copper), and is only slightly larger, this means that the density of gold is much greater than that of copper.



Group Questions (8 points)

1. How could you determine the enthalpy change for the conversion of graphite to diamond, a reaction that cannot be done easily in the laboratory?

   C(graphite) → C(diamond) ΔH°_{rxn} = ? kJ

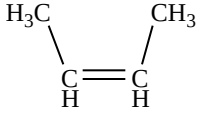
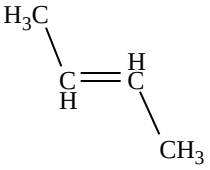
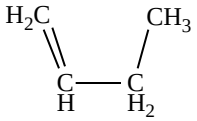
   Among the experimental information you have is the enthalpy change for the combustion of diamond.

   C(diamond) + O_2(g) → CO_2(g) ΔH°_{rxn} = -395.4 kJ

   Use this and any other information you have available in your book to answer this question.

2. Isomers are molecules with the same elemental composition but a different atomic arrangement. There are, for example, three ways of arranging the atoms in a compound with the formula C_4H_8. (See structures at the right.) The enthalpy of combustion of each isomer (i.e., the ΔH°_{rxn} when the isomer burns in O_2 to give CO_2 and H_2O) can be determined using a calorimeter (and is given in the table).

   Knowing that the enthalpy of formation of 1-butene is -20.5 kJ/mol, calculate the enthalpy of formation value for *cis*-2-butene.

	Name	Enthalpy of Combustion
	cis-2-butene	-2687.5 kJ/mol
	trans-2-butene	-2684.2 kJ/mol
	1-butene	-2696.7 kJ/mol