PART I *(39 pts.)* **Multiple Choice.** Choose one correct answer for each of the following questions and mark it on both the attached answer sheet and on the exam. Only the answer sheet will be graded. Each multiple question is worth three (3) points.

1. By what coefficient should the frequency of the photon of light associated with the electronic transitions from n = 3 to n = 1 in the hydrogen atom be multiplied to obtain the corresponding frequency associated with the same electronic transition in the $_2He^+$ ion ?

* frequency is directly related to energy $E=h\upsilon$

$\Delta E = -Bz^2\left[\left(\frac{1}{n_f}\right)^2 - \left(\frac{1}{n_i}\right)^2\right]$

for H, z = 1; $1^2 = 1$

He, z = 2; $2^2 = 4$

A. ½
B. 4
C. 2
D. 1/4
E. none of the above

2. Which of the following atoms, designated by their electron configurations, has the highest Ionization energy ?

nitrogen would have the highest 1st I.E. even though oxygen has smaller atomic radius, Nitrogen has a ½-filled p subshell, giving it added stability and making it more difficult to remove an electron

A. [He] $^2 2s^2 2p^2$ C
B. [He] $^2 2s^2 2p^3$ N
C. [He] $^2 2s^2 2p^4$ O
D. [Ne]^{10} $3s^2 3p^3$ P
E. [Ne]^{10} $3s^2 3p^4$ S

3. The equation for the combustion of 2.0 mol of butane gas can be written as

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g) \quad \Delta H < 0$$

Which of the following produces the least heat ?

A. Burning 1.0 mol of $C_4H_{10}(g)$ produces 5 mol H_2O
B. Reacting 1.0 mol of oxygen gas with excess butane gas produces 0.80 mol H_2O
C. Burning enough butane gas to produce 1.0 mol of carbon dioxide gas. and 1.25 mol H_2O
D. Burning enough butane gas to produce 1.0 mol of $H_2O(g)$ 1 mol H_2O
E. All of the above reactions (A, B, C, D) produce the same quantity of heat.

* The one that produces the least am't of product produces least am't of heat

4. Hypothetical elements A_2 and B_2 react to form the compound AB in accordance with the following equations.

$$A_2(aq) + B_2(aq) \rightarrow 2AB(aq) \qquad \Delta H = +271 \text{ kJ}$$

If solutions $A_2(aq)$ and $B_2(aq)$ at the same initial temperature are mixed in a coffee cup calorimeter, the reaction that occurs is.

A. Endothermic, and the temperature of the resulting solution rises.
B. Exothermic ,and the temperature of the resulting solution falls.
C. Endothermic, and the temperature of the resulting solution falls
D. Exothermic, and the temperature of the resulting solution rises.
E. Exothermic or endothermic depending upon the initial and final temperatures.

The fact that ΔH is ⊕ indicates that the reaction requires energy input to occur. The rxn is endothermic, and the energy required to make the rxn occur comes from the surrounding water, thus the water loses energy and its temp goes down

5. Consider the following specific heats of metals

Metal	Specific Heat J / g• °C
$_{29}$Cu (s)	0.385
$_{12}$Mg (s)	1.02
$_{80}$Hg (s)	0.138
$_{47}$Ag (s)	0.237

A 25g sample of each of the above metals at 90 °C is placed in one of four insulated containers possessing identical volumes of liquid water at the same initial room temperature.

Which of the following answers is true?

A. The water with the copper metal will be the hottest.
(B.) The water with the magnesium metal will be the hottest.
C. The water with the mercury metal will be the hottest
D. The water with the silver metal will be hottest.
E. The temperature of the water will be the same in all four containers.

Mg has the highest specific heat capacity, and can thus store more heat energy than the other metals.

6. Which of the following processes is exothermic?

A. First ionization energy of Na(g) atom 1st I.E. always endothermic
B. Sublimation of CO_2(s) , dry ice, to CO_2(g) requires energy
C. Evaporation of H_2O (l) requires energy
D. Electron affinity of S^-(g) ion to form S^{2-}(g) ion E.A. of 2nd electron is endothermic
(E.) none of the above

7. When electrons are removed from neutral $_4$Be, which of the following sets of ionization energy (IE) makes the most sense in going from the first, to the second, to the third ionization energy?

A. First IE, 1750 kJ / mol; second IE 900 kJ / mol; third IE, 2300 kJ / mol.
B. First IE, 900 kJ / mol; second IE, 1750 kJ / mol; third IE, 2300 kJ / mol.
C. First IE, 15,000 kJ / mol; second IE, 1750 kJ / mol; third IE, 900 kJ / mol.
D. First IE, 900 kJ / mol; second IE, 15,000 kJ / mol; third IE, 22,000 kJ / mol.
(E.) First IE, 900 kJ / mol; second IE, 1750 kJ / mol; third IE, 15,000 kJ / mol.

2nd I.E. is always > than 1st I.E. 3rd I.E. should be very high because Be^{2+} is a stable config of He

8. A 5.0 g sample of water initially at 60.0 °C loses 418 J of energy in the form of heat. What is the final temperature of the water after this heat loss. The specific heat of H_20 (l) is 4.18 J /g• °C.

A. 80.0°C
B. 20.0°C
C. 60.0°C
(D.) 40.0°C
E. none of the above

$q = mC\Delta T$

$-418\,J = (5.0\,g)(4.18\,J/g\cdot°C)(T_f - 60.0°C)$

$-418\,J = 20.9\,J/°C\ T_f - 1254\,J$

$836\,J = 20.9\,J/°C\ T_f$

$40.0°C = T_f$

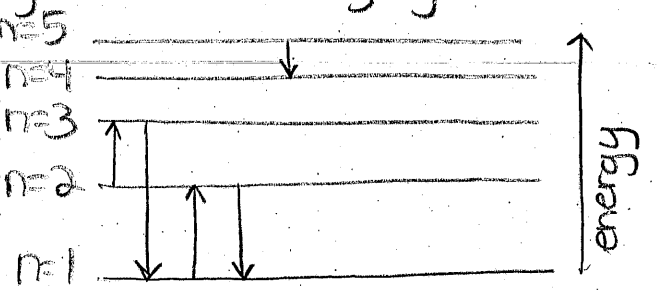
9. If an electron of mass 9.11×10^{-28} g has an associated wavelength of 45 pm, what is its velocity (in m/s)?

$\lambda = \frac{h}{mv}$ OR $v = \frac{h}{\lambda m}$

$v = \frac{6.626 \times 10^{-34}\ \frac{kg \cdot m^2}{s^2} \cdot s \;\left|\; 1000g \;\right|\; 10^{12}\,pm}{(45\,pm)(9.11 \times 10^{-28}\,g) \;\left|\; 1kg \;\right|\; 1m}$

A. 2.72 m/s
B. 1.62×10^{7} m/s
C. 2.72×10^{3} m/s
D. 1.62×10^{4} m/s
E. none of the above

10. Of the following possible transitions of the electron in a hydrogen atom, which absorbs light of the lowest energy? * an absorption of light involves an e⁻ going from lower n to higher n



A. Transition from the n=2 to the n=3 level.
B. Transition from the n=3 to the n=1 level.
C. Transition from the n=1 to the n=2 level.
D. Transition from the n=2 to the n=1 level.
E. Transition from the n=5 to the n=4 level.

11. Nitric acid is produced by the Ostwald process. From the data given, determine the enthalpy change for the reaction

$$12\ NH_3(g) + 21\ O_2(g) + 4\ H_2O(\ell) \Rightarrow 8\ HNO_3(aq) + 4\ NO(g) + 18\ H_2O(g)$$

(1) $4\ NH_3(g) + 5\ O_2(g) \Rightarrow 4\ NO(g) + 6\ H_2O(g)$ $\Delta H_1 = -905.5$ kJ
(2) $2\ NO(g) + O_2(g) \Rightarrow 2\ NO_2(g)$ $\Delta H_2 = -114.1$ kJ
(3) $2\ HNO_3(aq) + NO(g) \Rightarrow 3\ NO_2(g) + H_2O(\ell)$ $\Delta H_3 = +138.2$ kJ

A. - 2584.7 kJ
B. - 1479.1 kJ
C. - 3953.9 kJ
D. - 2848.3 kJ
E. none of the above

1a) $12NH_3(g) + 15O_2(g) \rightarrow 12NO(g) + 18H_2O(g)$ $\Delta H = -2716.5$ kJ

2a) $12NO(g) + 6O_2(g) \rightarrow 12NO_2(g)$ $\Delta H = -684.6$ kJ

3a) $12NO_2(g) + 4H_2O(\ell) \rightarrow 8HNO_3(aq) + 4NO(g)$ $\Delta H = -552.8$ kJ

$\Delta H = -3953.9$ kJ

12. If 1000g of aluminum metal with a heat capacity of 0.902 J/g•°C at -20°C are placed in liquid water at 0.0°C, how many grams of liquid water are frozen by the time that the aluminum metal has warmed to -5.0°C ? The heat of fusion of water is 333 J/g.

A. 40.6 g
B. 54.2 g
C. 13.5 g
D. 0.0542 g
E. none of the above

$q_{metal} = (1000g)(0.902 \frac{J}{g \cdot °C})(-5.0°C + 20°C)$
$= 13530 J$

$q_{metal} + q_{H_2O} = 0$
$13530J + (x)(-333 \frac{J}{g}) = 0$
$x = 40.6g$

13. Ice, $H_2O(s)$, at −7.2°C was added to 296 g of $H_2O(l)$ at 25.3°C in a calorimeter. The ice melted, and the final temperature was 12.2°C. How many grams of ice was added ?

ΔH fusion $[H_2O] = 333$ J/g
sp. heat of $H_2O(s) = 2.06$ J/g•°C
sp. heat of $H_2O(l) = 4.184$ J/g•°C

A. 46.2 g
B. 51.8 g
C. 40.7 g
D. 62.7 g
E. none of the above

① water cools from 25.3°C → 12.2°C $q = mc\Delta T$
② ice warms from −7.2°C → 0°C $q = mc\Delta T$
③ ice melts @ 0°C $q = (\Delta H_{fus\ H_2O})(m)$
④ water that used to be ice warms up from 0°C → 12°C $q = mc\Delta T$

$q_{H_2O} + q_{ice} = 0$
$(296g)(4.184 \frac{J}{g \cdot °C})(25.3°C - 12.2°C) + (x)(2.06 \frac{J}{g \cdot °C})(0 + 7.2°C) + (x)(333 \frac{J}{g})$
$+ (x)(4.184 \frac{J}{g \cdot °C})(12.2°C - 0°C) = 0$

$-16224J + 14.832 \frac{J}{g} x + 333 \frac{J}{g} x + 51.0448 \frac{J}{g} x = 0$
$398.8768 \frac{J}{g} x = 16224 J$
$x = 40.7g$

PART IIA *(42 pts.)*

1. The common name of $_{40}Zr$ is Zirconium.
2. The common name of $_{48}Cd$ is Cadmium.
3. The formula of titanium (IV) phosphide is Ti_3P_4.
4. The name of Sb_2O_3 is diantimony trioxide.
5. The formula of magnesium chlorite is $Mg(ClO_2)_2$.
6. The name of $Co(H_2PO_4)_2$ is cobalt(II) dihydrogen phosphate.
7. The symbol for atomic orbitals with n=5, ℓ=3 is 5f.
8. The experiment that unequivocally demonstrated that an electron has wave-like behavior was electron diffraction.
9. The maximum number of electrons that can be contained in all atomic orbitals with n=3 is 18.
   $\ell = 0, 1, 2$ or $2n^2$
   $m_\ell = 0$ $m_\ell = -1, 0, 1$ $m_\ell = -2, -1, 0, 1, 2$
10. A green laser pointer that emits light at 532 nm has a frequency of 5.64×10^5 Gigahertz (GH_z)
    $c = \lambda\upsilon$ $\upsilon = \frac{c}{\lambda} = \frac{3.00\times10^8 m/s}{532 nm} \left|\frac{10^9 nm}{1 m}\right| \left|\frac{1 GHz}{10^9 Hz}\right|$
11. The number of unpaired electrons in an arsenic $_{33}As^-$ ion is 2.
    4s 3d 4p
12. The corresponding energy of the frequency of 2.45 GHz used in microwave ovens is 1.62×10^{-24} J.
    $E = h\upsilon = (6.626\times10^{-34} J\cdot s)(2.45\times10^9 s^{-1})$
13. The Cl-Cl bond length of 198 pm is equivalent to 0.198 nm. $198 pm \left|\frac{1 m}{10^{12} pm}\right| \left|\frac{10^9 nm}{1 m}\right|$
14. *(4 pts.)* the quantum numbers for the highest energy valence electron(s) in a tin atom, $_{50}Sn$, are n= 5 and l= 1.
15. The unit of joules in mks units (SI system) is $\frac{kg\cdot m^2}{s^2}$.
16. The first ionization energy of 738 kJ / mol of Mg (g) is equivalent to 1.23×10^{-18} J/ Mg (g) atom.
    $\frac{738 KJ}{mol} \left|\frac{1000 J}{1 KJ}\right| \left|\frac{1 mol}{6.022\times10^{23}}\right|$
17. The general rule that electrons in the ground-state electron configuration for a given atom or ion will occupy available equal-energy AO's singly to give a maximum number of unpaired electron is denoted as Hund's rule.
18. The Russian scientist who in 1869 formulated the first periodic table of the elements was Mendeleev.
19. The hydrogen-oxygen fuel cell that provides electricity produces water.
20. Acid rain resulting from the burning of coal is composed of sulfuric acid.

PART IIB *(16 pts.)* **Show your work.**

1. *(8 pts.)*

A. Write out the entire electronic configuration (namely, $1s^2 2s^2 2p^6$ ....) for an isolated neutral tantalum atom, $_{73}Ta$.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14} 5d^3$

Ta^{3+} take the 1st 2 e⁻s from the 6s orbital, the last one from the 5d, leaving 2 e⁻s in the 5d orbital ↑↑ □□□

B. The number of unpaired electrons for an isolated $_{73}Ta^{3+}$ ion is 2.

C. An atomic 2⁻ anion that is **isoelectronic** with a neutral $_{73}Ta$ atom is Lu^{2-}.

isoelectronic means same # of electrons

2. *(8 pts.)*

A. Define in words the standard enthalpy of formation, $\Delta H_f°$, of $Na(HCO_3)(s)$

The enthalpy change that occurs with the formation of 1 mole of a compound from its constituent elements in their most stable states at 1 bar and 25°C.

B. Write an appropriate equation illustrating the standard enthalpy of formation of sodium hydrogen carbonate, $Na(HCO_3)$ (s), for which $\Delta H_f°[Na(HCO_3)(s)] = -951$ kJ.

$$Na_{(s)} + \tfrac{1}{2} H_{2(g)} + C_{(s)} + \tfrac{3}{2} O_{2(g)} \longrightarrow Na(HCO_3)_{(s)} \qquad \Delta H_f = -951\ kJ$$

graphite

C. Rewrite the appropriate balanced equation given in Part B for which $\Delta H° = +5706$ kJ.

$$6\,Na(HCO_3)_{(s)} \longrightarrow 6\,Na_{(s)} + 3H_{2(g)} + 6C_{(s)} + 9O_{2(g)} \qquad \Delta H°_{rxn} = 5706\ kJ$$

PART IIC (6pts.)

1. Determine whether each of the following statements is true or false and briefly explain the reason for your answer.

A. An $_{53}I^-$ anion has a smaller radius than that of a $_{52}Te^{2-}$ anion.

True. The two ions have the same number of electrons (they are isoelectronic). I^- has a greater number of protons, and thus each electron in I^- is subjected to a greater effective nuclear charge, making the radius of I^- smaller than that of Te^{2-}.

B. If an electron and a neutron are moving at the same velocity, the neutron has a larger wavelength than that of the electron. $\lambda = \frac{h}{mv}$

False. Given the de Broglie equation above, with h and v constant, wavelength (λ) is inversely proportional to mass. Thus a neutron, which has much greater mass than an electron, would have a smaller wavelength than an electron moving at the same velocity.