Chem 10113, Exam 2 **Answer Key**

October 30, 2019

1. (4 points) The niobium(IV) ion, Nb^{4+}, has one unpaired electron. List all *possible* quantum numbers for this unpaired electron.

   l = 2 m_s = +1/2, -1/2 m_l = -2, -1, 0, +1, +2 n = 4

2. (1 point) Which ***one*** of the following subshells is impossible? 7s 4p 5g 3f 6d

3. Contrary to what we've learned in Gen Chem, metals and nonmetals sometimes do combine to form molecular compounds. One such compound, tungsten hexafluoride, WF_6 (molar mass = 297.8), is actually a gas at room temperature.
   (***Note***: The following three questions, all pertaining to WF_6, can be answered independently!)

   (a) (7 points) **SHOW ALL WORK.** Determine the density of $WF_{6(g)}$ in g/L at STP.

   @ STP, the Standard Molar Volume of a gas = 22.4 L/mole

   (1 mole / 22.4 L) (297.8 g/mole) = 13.3 g/L

   (b) (9 points) **SHOW ALL WORK.** In a commercial process, WF_6 is prepared from the mineral wolframite, $FeMnW_2O_8$ (molar mass = 606.5), by treatment with hydrogen fluoride (HF). Determine the mass (in kg) of wolframite that is required to prepare 500 L of WF_6 if the gas is collected at 28 °C with a pressure of 1450 mmHg.

   moles WF_6 = n = PV/RT = (1450/760)atm (500 L) / (0.0821 L·atm/mole·K) (301 K)

   n = 38.60 moles WF_6

   (38.60 moles WF_6) (1 mole $FeMnW_2O_8$ / 2 mole WF_6) (606.5 g/mole) (1 kg / 10^3 g)

   = 11.7 kg

   (c) (8 points) **SHOW ALL WORK.** In its commercial production process, WF_6 is purified using a gas-separation membrane system. If helium passes through one such membrane at a rate of 7.50 L/min, determine the time (in hours) required for 500 L of WF_6 to pass through the same membrane.

   Graham's Law of Effusion!

   7.50 L/min / ER_{WF_6} = $\{ (297.8 \text{ g/mole}) / (4.00 \text{ g/mole}) \}^{1/2}$

   ER_{WF_6} = 0.869 L/min

   (500 L) (1 min / 0.869 L) (1 hr / 60 min) = 9.59 hr

4. (8 points) **SHOW ALL WORK.** A gas mixture is 55.2 % N_2, 18.6 % CH_4, and 26.2 % CO by mass. Determine the partial pressure of CO (in torr) if the total pressure is 1.25 atm.

in 100 g of the gas mixture:

(55.2 g N_2) (1 mole / 28.02 g) = 1.970 mole N_2

(18.6 g CH_4) (1 mole / 16.04 g) = 1.160 mole CH_4

(26.2 g CO) (1 mole / 28.01 g) = 0.935 mole CO

total moles = 4.065 moles

X_{CO} = 0.935 mole / 4.065 moles = 0.230

$P_{CO} = X_{CO} P_{total}$ = 0.230 (1.25 atm) (760 torr / atm) = 219 torr

5. (3 points) The values listed below are the atomic radii (in *pico*meters) for the following atoms: S, Na, P, Mg, Al, O, K. Match each radius with the corresponding element.

73 O 103 S 110 P 143 Al 160 Mg 186 Na 227 K

6. (1 point) Which element in question 5 above has the highest electron affinity? O

7. (1 point) Which element in question 5 above has the lowest second ionization energy? Mg

8. (1 point) Which has the longest wavelength? (circle one)

ultraviolet radiation radio waves X-rays green light infrared radiation

9. (9 points) **SHOW ALL WORK.** Ultraviolet radiation is often used to initiate reactions by breaking specific chemical bonds. Determine which type of chemical bond in the ***table*** below is most likely to be broken by UV radiation with a wavelength of 258 nm (*nano*meters). Show an appropriate, logical calculation to support your answer. (***Note***: h = 6.626×10^{-34} J·sec)

Bond	Energy (kJ/mole)
C–H	414
O–H	464
H–H	436
C–C	347
C=C	611
C≡C	837
C–O	361
C=O	736
C≡O	1072

$E = hc/\lambda = (6.626 \times 10^{-34}$ J·sec) $(3.00 \times 10^{8}$ m/sec) / $(258 \times 10^{-9}$ m)

$E = 7.70 \times 10^{-19}$ J = 7.70×10^{-22} kJ

= energy of one photon (one bond)

$(7.70 \times 10^{-22}$ kJ/photon) $(6.022 \times 10^{23}$ photons/mole)

= 464 kJ/mole (~ O-H bond)

10. (4 points) Give the ***orbital diagram*** for the ***valence shell*** configuration of each of the following.

(a) Pd

↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑

5s 4d

(b) Ir^{3+}

↑↓ ↑ ↑ ↑ ↑

5d

11. (3 points) Circle any of the following that have the ***exact*** ***same valence shell electron configuration*** as argon (Ar).

Mg P^{3-} K Ca^{2+} Al Ti^{4+} Cr^{4+} Al^{3+} Kr

12. (10 points) **SHOW ALL WORK.** A sample of $N_2O_{3(g)}$ has a pressure of 0.17 atm. The temperature (in K) is doubled and some of the N_2O_3 decomposes to form $N_2(g)$ and $O_2(g)$. At that point the total gas pressure in the container is 0.55 atm. Determine the mole percent of N_2O_3 that decomposes.

Doubling T causes P to double, so initial $P_{N_2O_3}$ = 0.34 atm

$2\ N_2O_3$	$\longrightarrow$	$2\ N_2$	+	$3\ O_2$
0.34 atm		0		0
- 2x		+ 2x		+ 3x
0.34 - 2x		2x		3x

P_{total} = 0.55 = (0.34 - 2x) + 2x + 3x ∴ x = 0.070

N_2O_3 decomposed = 2x = 2(0.070) = 0.14 atm

% decomposed = 0.14 / 0.34 x 100% = 41 %

13. (10 points) **SHOW ALL WORK.** When 5.00 g of white phosphorus, $P_{4(s)}$, is burned in $O_{2(g)}$ to form $P_4PO_{10(s)}$, enough heat is generated to raise the temperature of 2.50 kg of water from 20.0 °C to 31.8 °C. Determine the enthalpy of formation ($\Delta H°_f$) of $P_4O_{10(s)}$ under these conditions. Include any appropriate ***balanced chemical equation(s)*** for the process.

q = heat produced by combustion of P_4 = heat required to warm up the water

q = (2500 g) (4.184 J/g·°C) (31.8 °C - 20.0 °C) = 123,428 J = 123.4 kJ

$P_{4(s)} + 5\ O_{2(g)} \longrightarrow P_4O_{10(s)}$ $\Delta H°_f\ (P_4O_{10})$ = - q / mole P_4

(5.00 g) (1 mole P_4 / 123.9 g) = 0.04036 mole

$\Delta H°_f\ (P_4O_{10})$ = - 123.4 kJ / 0.04036 mole = - 3,058 kJ/mole

14. (10 points) **SHOW ALL WORK.** An ice cube (at 0.0 °C) weighing 12.0 g is added to a mug containing 160 g of hot coffee, the temperature of which is 90.0 °C. Determine the final temperature of the coffee after the system has come to thermal equilibrium. (Assume no heat loss to the surroundings and assume that the specific heat of the coffee is the same as that of water. ***Note***: The heat of fusion of H_2O is 6.00 kJ/mole.)

heat to melt ice = (12.0 g) (1 mole / 18.0 g) (6,000 J/mole) = 4,000 J

heat lost by coffee = heat required to melt the ice + heat gained by H_2O

(160 g) (4.184 J/g·°C) (90.0 °C - T_f) = 4,000 J + (12.0 g) (4.184 J/g·°C) (T_f - 0 °C)

T_f = 78.2 °C

15. (4 points) Write the ***short-hand*** electron configuration for bismuth (Bi).

$[Xe]^{54}\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^3$

16. (7 points) **SHOW ALL WORK.** Given the thermochemical equation,

$$N_2H_{4(l)} + N_2O_{4(g)} \longrightarrow 2\ N_2O_{(g)} + 2\ H_2O_{(g)} \qquad \Delta H° = -382.1 \text{ kJ}$$

and the following standard heats of formation ($\Delta H°_f$):

compound	$H_2O_{(g)}$	$N_2H_{4(l)}$	$N_2O_{4(g)}$
$\Delta H°_f$ (kJ/mole)	- 241.8	50.6	11.1

Determine the standard heat of formation ($\Delta H°_f$) of $N_2O_{(g)}$ in kJ/mole.

$\Delta H°_{rxn} = \sum \Delta H°_f \text{ (products)} - \sum \Delta H°_f \text{ (reactants)}$

$- 382.1 = \{ 2(\Delta H°_f(N_2O) + 2(-241.8) \} - \{ 50.6 + (11.1) \}$

$\Delta H°_f(N_2O) = 81.6$ kJ/mole