

Chem 10113, Exam 2

October 30, 2019

Answer Key

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

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

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 $\text{WF}_6(\text{g})$ in g/L at STP.

$$\text{@ STP, the Standard Molar Volume of a gas} = 22.4 \text{ L/mole}$$

$$(1 \text{ mole} / 22.4 \text{ L}) (297.8 \text{ g/mole}) = 13.3 \text{ g/L}$$

- (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.

$$\text{moles } \text{WF}_6 = n = PV/RT = (1450/760)\text{atm} (500 \text{ L}) / (0.0821 \text{ L}\cdot\text{atm}/\text{mole}\cdot\text{K}) (301 \text{ K})$$

$$n = 38.60 \text{ moles } \text{WF}_6$$

$$(38.60 \text{ moles } \text{WF}_6) (1 \text{ mole } \text{FeMnW}_2\text{O}_8 / 2 \text{ mole } \text{WF}_6) (606.5 \text{ g/mole}) (1 \text{ kg} / 10^3 \text{ g})$$

$$= 11.7 \text{ kg}$$

- (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!

$$7.50 \text{ L/min} / ER_{\text{WF}_6} = \{ (297.8 \text{ g/mole}) / (4.00 \text{ g/mole}) \}^{1/2}$$

$$ER_{\text{WF}_6} = 0.869 \text{ L/min}$$

$$(500 \text{ L}) (1 \text{ min} / 0.869 \text{ L}) (1 \text{ hr} / 60 \text{ min}) = 9.59 \text{ hr}$$

4. (8 points) **SHOW ALL WORK.** A gas mixture is 55.2 % N₂, 18.6 % CH₄, 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:

$$(55.2 \text{ g N}_2) (1 \text{ mole} / 28.02 \text{ g}) = 1.970 \text{ mole N}_2$$

$$(18.6 \text{ g CH}_4) (1 \text{ mole} / 16.04 \text{ g}) = 1.160 \text{ mole CH}_4$$

$$(26.2 \text{ g CO}) (1 \text{ mole} / 28.01 \text{ g}) = 0.935 \text{ mole CO}$$

$$\text{total moles} = 4.065 \text{ moles}$$

$$X_{\text{CO}} = 0.935 \text{ mole} / 4.065 \text{ moles} = 0.230$$

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

5. (3 points) The values listed below are the atomic radii (in *picometers*) 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 (*nanometers*). Show an appropriate, logical calculation to support your answer. (*Note:* $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{sec}$)

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

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

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

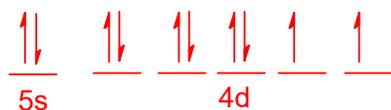
= energy of one photon (one bond)

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

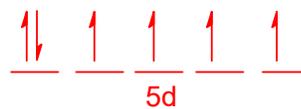
$$= 464 \text{ kJ/mole} \quad (\sim \text{O-H bond})$$

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

(a) Pd



(b) Ir³⁺

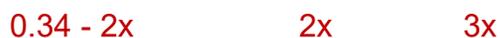
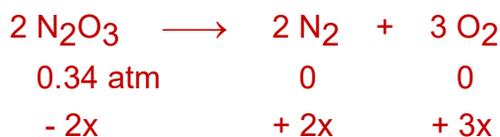


11. (3 points) Circle any of the following that have the exact same valence shell electron configuration as argon (Ar).

Mg P³⁻ K Ca²⁺ Al Ti⁴⁺ Cr⁴⁺ Al³⁺ Kr

12. (10 points) **SHOW ALL WORK.** A sample of N₂O₃(g) has a pressure of 0.17 atm. The temperature (in K) is doubled and some of the N₂O₃ decomposes to form N₂(g) and O₂(g). At that point the total gas pressure in the container is 0.55 atm. Determine the mole percent of N₂O₃ that decomposes.

Doubling T causes P to double, so initial P_{N₂O₃} = 0.34 atm



$$P_{\text{total}} = 0.55 = (0.34 - 2x) + 2x + 3x \quad \therefore x = 0.070$$

$$\text{N}_2\text{O}_3 \text{ decomposed} = 2x = 2(0.070) = 0.14 \text{ atm}$$

$$\% \text{ decomposed} = 0.14 / 0.34 \times 100\% = 41 \%$$

13. (10 points) **SHOW ALL WORK.** When 5.00 g of white phosphorus, P₄(s), is burned in O₂(g) to form P₄PO₁₀(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 (ΔH_f[°]) of P₄O₁₀(s) under these conditions. Include any appropriate *balanced chemical equation(s)* for the process.

q = heat produced by combustion of P₄ = heat required to warm up the water

$$q = (2500 \text{ g}) (4.184 \text{ J/g}\cdot\text{°C}) (31.8 \text{ °C} - 20.0 \text{ °C}) = 123,428 \text{ J} = 123.4 \text{ kJ}$$



$$(5.00 \text{ g}) (1 \text{ mole P}_4 / 123.9 \text{ g}) = 0.04036 \text{ mole}$$

$$\Delta H_f^\circ(\text{P}_4\text{O}_{10}) = -123.4 \text{ kJ} / 0.04036 \text{ mole} = -3,058 \text{ kJ/mole}$$

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 H₂O is 6.00 kJ/mole.)

$$\text{heat to melt ice} = (12.0 \text{ g}) (1 \text{ mole} / 18.0 \text{ g}) (6,000 \text{ J/mole}) = 4,000 \text{ J}$$

$$\text{heat lost by coffee} = \text{heat required to melt the ice} + \text{heat gained by H}_2\text{O}$$

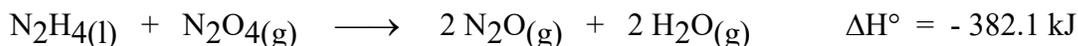
$$(160 \text{ g}) (4.184 \text{ J/g}\cdot\text{°C}) (90.0 \text{ °C} - T_f) = 4,000 \text{ J} + (12.0 \text{ g}) (4.184 \text{ J/g}\cdot\text{°C}) (T_f - 0 \text{ °C})$$

$$T_f = 78.2 \text{ °C}$$

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



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



and the following standard heats of formation (ΔH°_f):

compound	H ₂ O(g)	N ₂ H ₄ (l)	N ₂ O ₄ (g)
ΔH°_f (kJ/mole)	-241.8	50.6	11.1

Determine the standard heat of formation (ΔH°_f) of N₂O(g) in kJ/mole.

$$\Delta H^\circ_{\text{rxn}} = \sum \Delta H^\circ_f (\text{products}) - \sum \Delta H^\circ_f (\text{reactants})$$

$$-382.1 = \{2(\Delta H^\circ_f(\text{N}_2\text{O}) + 2(-241.8))\} - \{50.6 + (11.1)\}$$

$$\Delta H^\circ_f(\text{N}_2\text{O}) = 81.6 \text{ kJ/mole}$$