Chem 1A, Fall 2018
Midterm Exam#3 Review Exercises

1. (*i*) Write the electron configuration and the orbital "box" diagram for the valence-shell electrons of each of the following ions. (*ii*) Which ions achieve the noble gas configuration? Name the noble gas.

(a) Mg^{2+}

(b) Cr^{3+}

(c) Fe^{3+}

(d) S^{2-}

(e) Br^{-}

2. The formation of lithium fluoride, LiCl, involves the following reaction:

$$Li(s) + ½ Cl_2(g) \rightarrow LiCl(s); \quad \Delta H^o_f = -408 \text{ kJ/mol}$$

Draw the Born-Haber Cycle for the formation of lithium fluoride from lithium and fluorine gas that includes the steps below, and calculate the lattice energy (U_L) for LiF.

Steps:	ΔH in kJ/mol
1) $Li(s) \rightarrow Li(g)$;	$\Delta H_s = 161$;
2) $Li(g) \rightarrow Li^+(g) + e^-$;	IE = 520;
3) $Cl_2(g) \rightarrow 2Cl(g)$;	BE = 243;
4) $Cl(g) + e^- \rightarrow Cl^-(g)$;	EA = –349;
5) $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$;	U_L = ? (lattice energy)

3. Rank the following ionic compounds in increasing lattice energy.

(a) LiF, LiCl, NaCl, KCl, KBr;

(b) Li_2O, MgO, LiF, LiCl, NaCl;

4. For each of the following molecules or polyatomic ions, determine the total number of valence electrons.

(a) BF_3

(b) ClF_3

(c) CO_3^{2-}

(d) SF_4

(e) PCl_5

(f) $POCl_3$

(g) SO_4^{2-}

(h) XeF_4

5. (a) Draw all resonance Lewis structures for N_2O molecule. (b) Calculate the formal charge of each atom in each Lewis structure. (c) Propose the most and least favored Lewis structures, and explain your reasoning.

6. For each of the following molecules: (*i*) determine the total number of valence electrons; (*ii*) draw the Lewis structure; (*iii*) indicate the *hybridization* on the central atom; (*iv*) predict the molecular geometry and indicate whether it is polar or nonpolar. (Atoms in bold are central atoms.)

(a) **B**F_3 (b) **Cl**F_3 (c) **P**Cl_3 (d) **S**F_4 (e) **Xe**F_4

7. Given the following values of bond energy (BE, in kJ/mol):

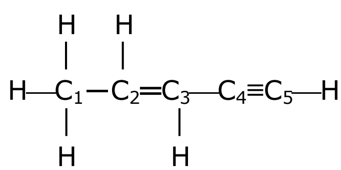
Bonds:	H—H	C—C	C—H	C—F	H—O	H—F	F—F	C≡O
BE:	436	345	415	439	467	569	160	1080

Calculate the enthalpy change for the following reactions and indicate whether each reaction is exothermic or endothermic.

(a) $CH_4(g) + 4F_2(g) \rightarrow CF_4(g) + 4HF(g)$

(b) $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$

8. Refer to the following structure and answer questions (a) - (e):



(a) The total number of σ-bonds = ______; the number of π-bonds = _____.

(b) Which C—C bond has the highest bond energy? ___________

(c) What type of *hybridization* is found at: C_1: ______; C_2:_____; C_4: _____?

(d) What is the geometrical orientation of bonds (or bonded atoms) around the following center?

(*i*) C_1: _______________; (*ii*) C_2 :________________; (*iii*) C_4 : ___________;

(e) Give the predicted bond angles at: C_1: ____; C_3: ____; and C_5: ____.

9. (a) Write a complete electron configuration for the following diatomic molecules and molecular ions using the molecular orbital notation, such as, $(\sigma_{1s})^2 (\sigma_{1s}^*)^2 (\sigma_{2s})^2 (\sigma_{2s}^*)^2$… etc.

C_2^{2-} NO O_2 O_2^{2-}

(b) Draw the molecular orbital energy diagrams for the valence-shell electrons of each of the above molecules and molecular ions, determine the bond order in each molecule or ion, and indicate whether it is diamagnetic or paramagnetic.

10. A rigid cylinder is fixed with movable piston that can moves freely within the cylinder. The cylinder initially contains 67.4 mL of N_2O gas at 1.05 atm and 20.5^oC. (a) What is the gas pressure if the temperature is increased to 83.0^oC at constant volume? (b) What is the gas pressure if the volume is increased to 100.0 mL and the temperature to 83.0^oC? (c) What is the gas volume if the pressure and temperature are increased to 1.55 atm and 83.0^oC, respectively?

11. A gaseous compound has a density of 3.66 g/L at 25.0^oC and 755 torr. (a) Determine the molar mass of the compound. (b) If the compound is composed of 53.3% carbon, 11.2% hydrogen, and 35.5% oxygen, by mass, what is the molecular formula?

12. A weather balloon is filled with 1.25 kg of helium gas at 21.0^oC and 1.00 atm pressure. (a) What is the volume of balloon in liters of the balloon under this condition? (b) If the balloon rises to an altitude where the atmospheric pressure and air temperature are 463 torr and –30^oC, respectively, what is the volume of the balloon? (Assume that the balloon is completely elastic)

13. Potassium chlorate, $KClO_3$, decomposes when heated to produce O_2 gas according to the following equation:

$$2KClO_{3(s)} \rightarrow 2KCl(s) + 3\ O_2(g)$$

A 1.05-g mixture of $KClO_3$ and KCl is placed in a test-tube fitted with stopper that has rubber tubing that would allow the O_2 gas produced by $KClO_3$ to be collected over water in a graduated gas cylinder. When all of $KClO_3$ in the mixture is completely decomposed, 182 mL of O_2 was collected at 22^oC.
(a) If the total gas pressure ($P_{O2} + P_{H2O}$) is 755.0 torr, what is the partial pressure of O_2 gas?
(b) How many moles of O_2 gas was produced? (c) How many grams of $KClO_3$ were decomposed?
(d) Assuming that all of $KClO_3$ in the mixture was decomposed, calculate the percentage (by mass) of $KClO_3$ in the mixture. (R = 0.08206 $^{L.atm}/_{mol.K}$'; vapor pressure of water at 22 ^oC = 19.8 torr)

14. Magnesium reacts with hydrochloric acid producing hydrogen gas according to the following equations:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

A student obtained 0.0800 g of magnesium strip and reacted it with excess dilute HCl solution in a eudiometer. When the reaction was completed, 79.0 mL of H_2 gas was collected over water at 25^oC and the total gas pressure ($P_{H2} + P_{H2O}$) was 745.8 torr. Calculate: (a) the partial pressure of H_2 gas; (b) the mole of H_2 gas produced; (c) the mass of Mg reacted, and (d) the mass percent of pure magnesium in the strip. (The vapor pressure of water at 25^oC is 23.8 torr.)

15. Sodium azide, NaN_3, decomposes when heated according to the following equation:

$$2NaN_{3(s)} \rightarrow 2Na(s) + 3N_2(g)$$

How many grams of NaN_3 are needed to produce enough N_2 gas to inflate a 45.0-L airbag at 30.0^oC and 806 torr, if: (a) the NaN_3 sample decomposes 100%? (b) only 92.0% of NaN_3 decomposes?

16. A gaseous compound is composed of 67.6% uranium and the rest is fluorine. Under a certain condition of temperature, pressure and centrifuge speed, this compound diffuses through membrane separators at a rate of 64.0 mL/minute. Under the same condition, N_2 gas diffuses through the same membrane at a rate of 227 mL/minute. (a) Calculate the molar mass of the uranium compound. (b) Determine its molecular formula of the compound.

17. Calculate the root-mean-square speed (u_{rms}) of H_2 and N_2 at 25°C.
(Molar mass: H_2 = 2.02 x 10^{-3} kg/mol; N_2 = 2.80 x 10^{-2} kg/mol; R = 8.314 J/(mol.K); 1 J = 1 kg.m^2/s^2)

18. Write the sequence of reactions that lead to: (a) the formation of HNO_3 from the reaction of N_2 with O_2; (b) the formation of H_2SO_4 from burning sulfur.

19. Write a balance equation of the reaction of: (a) $CaCO_3$ with HNO_3, and (b) $CaCO_3$ with H_2SO_4.

20. (a) Name three most abundant element in the atmosphere. (b) In which region of the atmosphere do you find the ozone layer?

Answers:

1. (a) Mg^{2+} : $1s^2\ 2s^2\ 2p^6$; ↑↓ (1s) ↓↑ (2s) ↑↓ ↓↑ ↑↓ (2p);

   (b) Cr^{3+} : [Ar] $3d^3$; [Ar] ___ (4s) ↑ ↑ ↑ ___ ___ (3d)

   (c) Fe^{3+} : [Ar] $3d^5$; [Ar] ___ (4s) ↑ ↑ ↑ ↑ ↑ (3d);

   (d) S^{2-}: [Ne] $3s^2\ 3p^6$; [Ne] ↓↑ (3s) ↑↓ ↓↑ ↑↓ (3p);

   (e) Br^- : [Ar] $4s^2\ 3d^{10}\ 4p^6$; [Ar] ↑↓ (4s) ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ (3d) ↑↓ ↑↓ ↑↓ (4p);

   (*ii*) (a) Mg^{2+} = Ne; (d) S^{2-} = Ar; (c) Br^- = Kr

2. Lattice energy (U_L) for LiCl = -861.5 kJ/mol

3. (a) KBr < KCl < NaCl < LiCl < LiF;

   (b) NaCl < LiCl < LiF < Li_2O < MgO

4. (*i*) Number of valence electrons:

   (a) 24 (b) 28 (c) 24 (d) 34 (e) 40 (f) 32 (g) 32 (h) 36

7. $\Delta H_{rxn} = \Sigma(BE_{reactants}) - \Sigma(BE_{products})$

   (a) ΔH_{rxn} = -1732 kJ (exothermic reaction)

   (b) ΔH_{rxn} = 206 kJ (endothermic reaction)

8. (a) 10 σ-bonds and 3 π-bonds;
   (b) bond with highest energy is C_4—C_5 (a triple bond)
   (c) Hybridization at: $C_1 = sp^3$; $C_2 = sp^2$; $C_4 = sp$;
   (d) Geometrical orientation at: C_1 = tetrahedral; C_2 = trigonal planar; C_4 = linear;
   (e) Bond angles at: $C_1 = 109.5^o$; $C_3 = 120^o$; $C_5 = 180^o$;

9. (a) C_2^{2-} : $(\sigma_{1s})^2 (\sigma_{1s}^*)^2 (\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^2$

   NO : $(\sigma_{1s})^2 (\sigma_{1s}^*)^2 (\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^2 (\pi_{2p}^*)^1$

   O_2 : $(\sigma_{1s})^2 (\sigma_{1s}^*)^2 (\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^2 (\pi_{2p}^*)^2$

   O_2^{2-} : $(\sigma_{1s})^2 (\sigma_{1s}^*)^2 (\sigma_{2s})^2 (\sigma_{2s}^*)^2 (\pi_{2p})^4 (\sigma_{2p})^2 (\pi_{2p}^*)^4$

   (b)

C_2^{2-}	NO	O_2	O_2^{2-}
___ σ_{2p}^*	___ σ_{2p}^*	___ σ_{2p}^*	___ σ_{2p}^*
___ ___ π_{2p}^*	↑ ___ π_{2p}^*	↑ ↑ π_{2p}^*	↑↓ ↑↓ π_{2p}^*
↑↓ σ_{2p}	↑↓ σ_{2p}	↑↓ ↑↓ π_{2p}^*	↑↓ ↑↓ π_{2p}^*
↑↓ ↑↓ π_{2p}	↑↓ ↑↓ π_{2p}	↑↓ σ_{2p}	↑↓ σ_{2p}

	$\uparrow\downarrow$ σ_{2s}^*	$\uparrow\downarrow$ σ_{2s}^*	$\uparrow\downarrow$ σ_{2s}^*	$\uparrow\downarrow$ σ_{2s}^*
	$\uparrow\downarrow$ σ_{2s}	$\uparrow\downarrow$ σ_{2s}	$\uparrow\downarrow$ σ_{2s}	$\uparrow\downarrow$ σ_{2s}
	KK	KK	KK	KK
BO:	3	2.5	2	1
	diamagnetic	paramagnetic	paramagnetic	diamagnetic

10. (a) 1.27 atm; (b) 0.858 atm; (c) 55.4 mL
11. (a) 90.1 g/mol; (b) $C_4H_{10}O$
12. (a) 7.54 x 10^3 L; (b) 1.02 x 10^4 L
13. (a) 735.2 torr; (b) 7.27 x 10^{-3} mol; (c) 0.594 g; (d) 55.6%
14. (a) 722.0 torr; (b) 3.07 x 10^{-3} mol; (c) 0.0746 g; (d) 93.3%
15. (a) 83.2 g; (b) 90.4 g
16. (a) 352 g/mol; (b) UF_6
17. $u_{rms}(H_2)$ = 1920 m/s; $u_{rms}(N_2)$ = 515 m/s