NAME Key Section (circle one): A/King or B/Madison

Chemistry 141
Final Exam
Fall 2018

This exam has 200 points in total.
Part I. Short Answer. Answer 12 of the next 13 questions. You MUST cross out the one you wish not to be graded. 5 points each.

You must do both parts a and b of each problem.			
	Name	Chemical Formula	
1a.	Nitrogen trifluoride	NF_3	3
1b.	Calcium carbonate	$CaCO_3$	2
2a.	Ammonium Bromide	NH_4Br	3
2b.	Magnesium sulfate heptahydrate	$MgSO_4 \cdot 7H_2O$	2

3. Magnesium has 3 stable isotopes. What is the isotopic abundance of ^{24}Mg?

Isotope	Mass	Isotopic Abundance
^{24}Mg	23.98504 amu	?
^{25}Mg	24.98583 amu	10.00%
^{26}Mg	25.98259 amu	11.01%

(23.98504 · .7899 + 24.98583 · .1 + ... 25.98259 · .1101) = ~~24.~~ 24.305049255

4 sig figs → 24.31

2 78.99 %

What is the atomic weight of Magnesium (show your work)?

3 24.31 g/mol

↳ Any indication that they multiplied the % by the masses is fine

4. How many moles of PbO are produced from the reaction of 5.0 mol of PbS and 6.0 mol of O_2?

$$2\ PbS\ (s) + 3\ O_2\ (g) \rightarrow 2\ PbO\ (s) + 2\ SO_2$$

5 4.0 moles PbO

1 pt.

$$5.0\ mol\ PbS \cdot \frac{2\ PbO}{2\ PbS} = 5.0\ mol\ PbO$$

$$6.0\ mol\ O_2 \cdot \frac{2\ PbO}{3\ O_2} = 4.0\ mol\ O_2 \leftarrow \text{Limiting Reagent}$$

2 pts for right track but ~~wrong~~ incorrect

5. What is the oxidation number of each element in $NaBiO_3$?

Na: +1 (1 pt) Bi: +5 (3 pt) O: -2 (2 pt)

6. True or False:

1 F A. When chemical bonds are broken, energy is released.

1 T B. The phase change of liquid to solid, commonly called freezing, is exothermic.

1 T C. The electrons in a molecule can be in an excited state if it absorbs a photon.

1 F D. If a substance absorbs red photons, it will appear red.

1 F E. Heat (q) and work (w) are two examples of state functions.

7. Rank the following atoms or ions:

A. Increasing ATOMIC radius: O, F, Ga, Br

1 F < O < Br < Ga

B. Increasing IONIC radius : Ti^{4+}, V^{5+}, Cl^-

2 V^{5+} < Ti^{4+} < Cl^-

C. Increasing Second Ionization Energy: K, Ca, Sc

2 Ca < Sc < K

8. Which of the following molecules would exhibit dipole-dipole interactions as an intermolecular force? Circle *all* correct answers.

1 A) ICl_4^-

1 B) PCl_5

1 (C) ClF_3

1 (D) SO_2

1 E) None of the above

9. Which of the following molecules would have the molecular geometry known as T-Shaped? Circle *all* correct answers.

1 A) ClO_3^-

1 (B) ClF_3

1 C) NF_3

1 (D) IF_3

1 E) None of the above

10. How many total, angular, and radial nodes does a 4d orbital have?

Total Nodes: 3 (2 pt) Angular nodes: 2 (2 pt) Radial Nodes: 1 (1 pt)

11. Which atom or ion has exactly 3 **unpaired** electrons? Circle *all* correct answers.

1 (A) Cr^{3+}

1 B) P^+

1 C) Sc

1 (D) V^{2+}

12. Adding the following compounds to water will increase the boiling point and decrease the freezing point. Assuming one mole of each is added to water. Rank the compounds in terms of boiling point elevation (1 = highest to 3 = lowest)

5 2 NaCl, 1 $MgCl_2$, 3 CH_3CH_2OH

2 out of 5 wrong -3

13. Indicate if the following combinations will form a stable solution. Fill in the blank with the appropriate key term: soluble, insoluble, miscible, or immiscible.

1 Soluble $Pb(NO_3)_2$ (s) in H_2O (l)

2 Miscible CH_3OH (l) in NH_3 (l)

2 insoluble NaCl (s) in CO_2 (l)

Part II. Problems. Answer 6 of the next 7 questions. You MUST cross out the one you wish not to be graded. 12 points each.

14. What is the **wavelength** of a photon that can excite an electron in a hydrogen atom from the 1s orbital to a 3d orbital? Report your answer in nanometers and with three significant digits.

$\Delta E_n = -2.178 \times 10^{-18}\ J \left(\frac{1}{3^2} - \frac{1}{1^2}\right) = 1.936 \times 10^{-18}\ J$

$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\ J \cdot s \cdot 2.998 \times 10^{8}\ \frac{m}{s}}{\lambda} = 1.936 \times 10^{-18}\ J$

$\lambda = 1.0261 \times 10^{-7}\ m = \boxed{103\ nm}$

15. A. What are the partial pressures of all gases when a 1.7 L ridged container of N_2O_5 at 0°C and 1.00 atm pressure decomposes completely into NO_2 (g) and O_2 (g)?

Unbalanced Reaction: $N_2O_5\ (g) \rightarrow 2NO_2\ (g) + \frac{1}{2}O_2(g)$

$n_{NO_2} = n_{N_2O_5} \cdot \frac{2\ NO_2}{1\ N_2O_5}$ $P_{NO_2} = \frac{n_{NO_2} RT}{V} = \frac{n_{N_2O_5} RT}{V} \cdot \frac{2\ NO_2}{1\ N_2O_5} = P_{N_2O_5} \cdot 2$

$= 1.0 \times 2$

$P_{N_2O_5}$ 0 atm

P_{NO_2} 2.00 atm

P_{O_2} 0.50 atm

$n_{O_2} = n_{N_2O_5} \cdot \frac{\frac{1}{2}\ O_2}{1\ N_2O_5}$ $P_{O_2} = \frac{n_{O_2} RT}{V} = \frac{n_{N_2O_5} RT}{V} \cdot \frac{\frac{1}{2}\ O_2}{1\ N_2O_5}$

$= P_{N_2O_5} \cdot \frac{1}{2} = 1.0 \times \frac{1}{2}$

16. In each list:

A. Circle which molecule will have **the highest boiling point**. Why?

F_2 (**Br_2**) Cl_2

Why? Br_2 has the highest Molecular weight and is the most polarizable. London Dispersion will be strongest.

B. Circle which molecule that will have **the highest vapor pressure**.

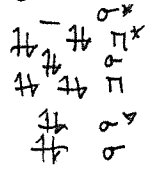
CH_3CH_2OH CH_3COCH_3 (**$CH_3CH_2CH_3$**)

Why? Propane has only L.D. and therefore the weakest IMF's.

C. Circle which atom or molecule will be **diamagnetic**.

(**N_2**) O_2 Al

Why? In the class demo, it did not stick to the magnet.
Also the MO diagram has no unpaired electrons



17. An unknown compound contains *only* carbon, nitrogen, and hydrogen (and no oxygen). When the unknown is combusted completely with excess oxygen it produces 55.0 g of CO_2, 15.8 g of H_2O, and 23.0 g of NO_2. What is the empirical formula of the compound?

C: $55.0\text{ g } CO_2 \cdot \frac{1\text{ mol } CO_2}{44\text{ g}} \cdot \frac{1\text{ mol C}}{1\text{ mol } CO_2} = 1.25$ $\quad \frac{1.25}{.5} = 2.5 \times 2 = 5$

H: $15.8\text{ g } H_2O \cdot \frac{1\text{ mol } H_2O}{18.02\text{ g}} \cdot \frac{2\text{ mol H}}{1\text{ mol } H_2O} = 1.75$ $\quad \frac{1.75}{.5} = 3.5 \times 2 = 7$

N: $23.0\text{ g } NO_2 \cdot \frac{1\text{ mol } NO_2}{46.01\text{ g}} \cdot \frac{1\text{ mol N}}{1\text{ mol } NO_2} = 0.50$ $\quad \frac{.5}{.5} = 1 \times 2 = 2$

$C_5H_7N_2$

18. When the following solutions are mixed together, what precipitate (if any) will form? If no precipitate forms, indicate that fact.

A. $Al(NO_3)_3$ (aq) + $Ba(OH)_2$ (aq) → $Al(OH)_3$ (s) precipitates

Balanced: $2Al(OH)_3\text{ (aq)} + 3Ba(OH)_2\text{ (aq)} \rightarrow 2Al(OH)_3\text{ (s)} + 3Ba(NO_3)_2\text{ (aq)}$

B. Na_2SO_4 (aq) + $Pb(NO_3)_2$ (aq) → $PbSO_4$ (s) precipitates

$Na_2SO_4\text{ (aq)} + Pb(NO_3)_2\text{ (aq)} \rightarrow PbSO_4\text{ (s)} + 2NaNO_3\text{ (aq)}$

C. KCl (aq) + NH_4Br (aq) → No Precipitate.

$KCl\text{ (aq)} + NH_4Br\text{ (aq)} \rightarrow KBr\text{ (aq)} + NH_4Cl\text{ (aq)}$

19. What is the mass of $Ca(OH)_2$ (s) required to neutralize 12.0 ml of 3.50 M $HClO_4$ (aq)?

Balanced Reaction: $Ca(OH)_2 + 2HClO_4 \rightarrow 2H_2O\text{ (l)} + Ca(ClO_4)_2\text{ (aq)}$

moles $HClO_4$: $.012\text{ L} \cdot 3.5\text{ M} = .042\text{ moles } HClO_4$

moles $Ca(OH)_2$: $.042\text{ moles } HClO_4 \cdot \frac{1\text{ Ca(OH)}_2}{2\text{ HClO}_4} = .021\text{ moles } Ca(OH)_2$

mass $Ca(OH)_2$: $.021\text{ moles } Ca(OH)_2 \cdot \frac{74.098\text{ g}}{1\text{ mol } Ca(OH)_2} = 1.56\text{ g } Ca(OH)_2$

20. Given the following reactions,

$Fe_2O_3\text{ (s)} + 3CO\text{ (s)} \rightarrow 2Fe\text{ (s)} + 3CO_2\text{ (g)} \quad \Delta H = -28.0\text{ kJ}$

$3Fe\text{ (s)} + 4CO_2\text{ (s)} \rightarrow 4CO\text{ (g)} + Fe_3O_4\text{ (s)} \quad \Delta H = +12.5\text{ kJ}$

What is the enthalpy of the reaction of Fe_2O_3 with CO?

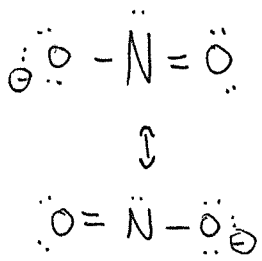
$3\,Fe_2O_3\text{ (s)} + CO\text{ (g)} \rightarrow CO_2\text{ (g)} + 2\,Fe_3O_4\text{ (s)}$

$3 \cdot (-28.0\text{ kJ}) + 2(12.5\text{ kJ}) = -59.0\text{ kJ}$

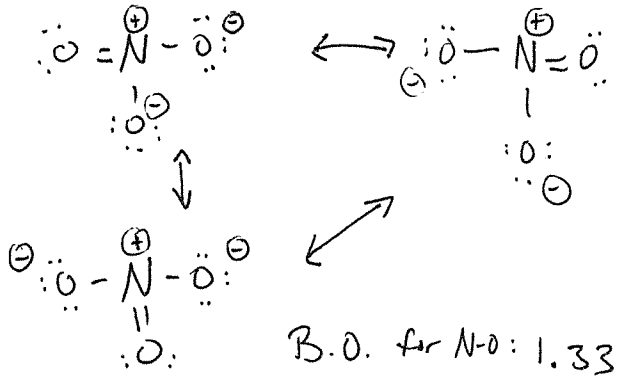
Part III. Problems. Answer 4 of the next 5 questions. You MUST cross out the one you wish not to be graded. 17 points each.

22. A. Using Lewis structures and resonance structures, which molecule has a higher bond order, NO_2^- or NO_3^-?

NO_2^- has a higher Bond order



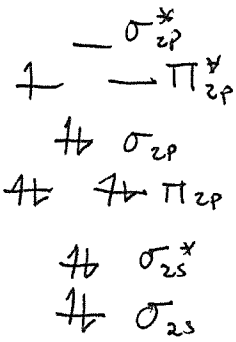
B.O. for N-O = 1.5



B.O. for N-O: 1.33

B. Using a molecular orbital diagram, which molecule has a higher bond order, NO or NO^-? Draw the molecular orbital diagrams and indicate the electron filling. Hint: NO has a molecular orbital diagram similar to N_2.

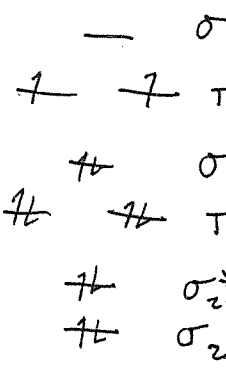
NO:



B.O. = 2.5

NO has a higher Bond order.

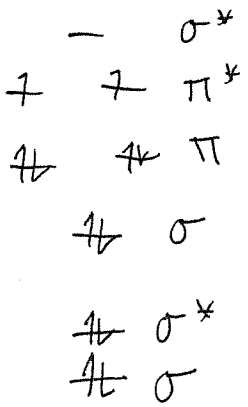
NO^-



B.O. = 2

C. Using molecular orbital theory, decide if OF is more likely to form an OF^+ ion or an OF^- ion Draw the molecular orbital diagram and indicate the electron filling. Hint: OF has a molecular orbital diagram similar to O_2.

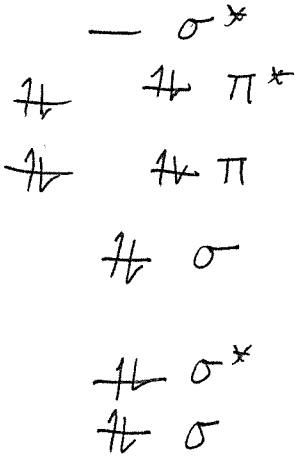
OF^+



B.O. = 2

OF^+ is more likely to form. It has a larger bond order and is more stable

OF^-



B.O. = 1

21. A. How much heat (in kJ) is required to convert a 100. cm^3 block of **ice** that has an initial temperature of -40.°C into liquid water at 0.0 °C? (Data: ΔH_{fus} = 6.01 kJ/mole, density (ice)=0.9340 g/cm^3, C_p (ice)= 2.1 J/g °C, C_p (water)= 4.2 J/g °C)

Warming ice: $q = mC\Delta T = 100.\ cm^3 \cdot \frac{0.9340\ g}{cm^3} \cdot \frac{2.1\ J}{g\ °C} \cdot 40.\ °C = 7,845.6\ J$

melting ice: $q = n \cdot \Delta H = 100.\ cm^3 \cdot \frac{.9340\ g}{cm^3} \cdot \frac{1\ mol}{18.02\ g} \cdot 6.01\ kJ/mol = 31.185\ kJ$

$q_{Total} = 31.185\ kJ + 7.8456\ kJ = \boxed{39.\ kJ}$

B. Using enthalpies of formation, would the combustion of 1.07 L of methane (g) at 1.00 atm of pressure and 25 °C provide enough heat to melt the 100. cm^3 block of **ice**? Show all work.

Substance	$\Delta H_f°$ (kJ/mol)
CH_4 (g)	-75.0
H_2O (g)	-242
CO_2 (g)	-393.5

$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$

$\Delta H_{rxn} = -393.5 + 2 \cdot -242. - (-75.0)$

$\Delta H_{rxn} = -802.5\ kJ$

$q = n\Delta H_{rxn} = \frac{PV}{RT} \cdot \Delta H = \frac{1.0\ atm \cdot 1.07\ L}{.08206\ \frac{L\,atm}{mol\,K} \cdot 298.15\ K} \cdot -802.5\ kJ = -35.1\ kJ$

No there is not enough energy to warm the ice and melt the ice.
35.1 kJ < 39 kJ

C. Using bond enthalpies, would the combustion of 1.0 g of acetylene (HCCH) provide enough heat to melt the 100. cm^3 block of **ice**? Show your work.

Hint: Acetylene is a linear molecule with one hydrogen attached to each carbon.

Bond Type	C-H	C-C	O-H	C=O	C=C Double bond	C≡C Triple bond	O=O
Bond Enthalpy (kJ/mol)	413	348	463	799	614	839	495

$H-C\equiv C-H + \frac{5}{2}\ O=O \longrightarrow 2\ O=C=O + H-O-H$

$\Delta H_{rxn} = 2(C-H) + (C\equiv C) + \frac{5}{2}(O=O) - (4(C=O) + 2(O-H))$

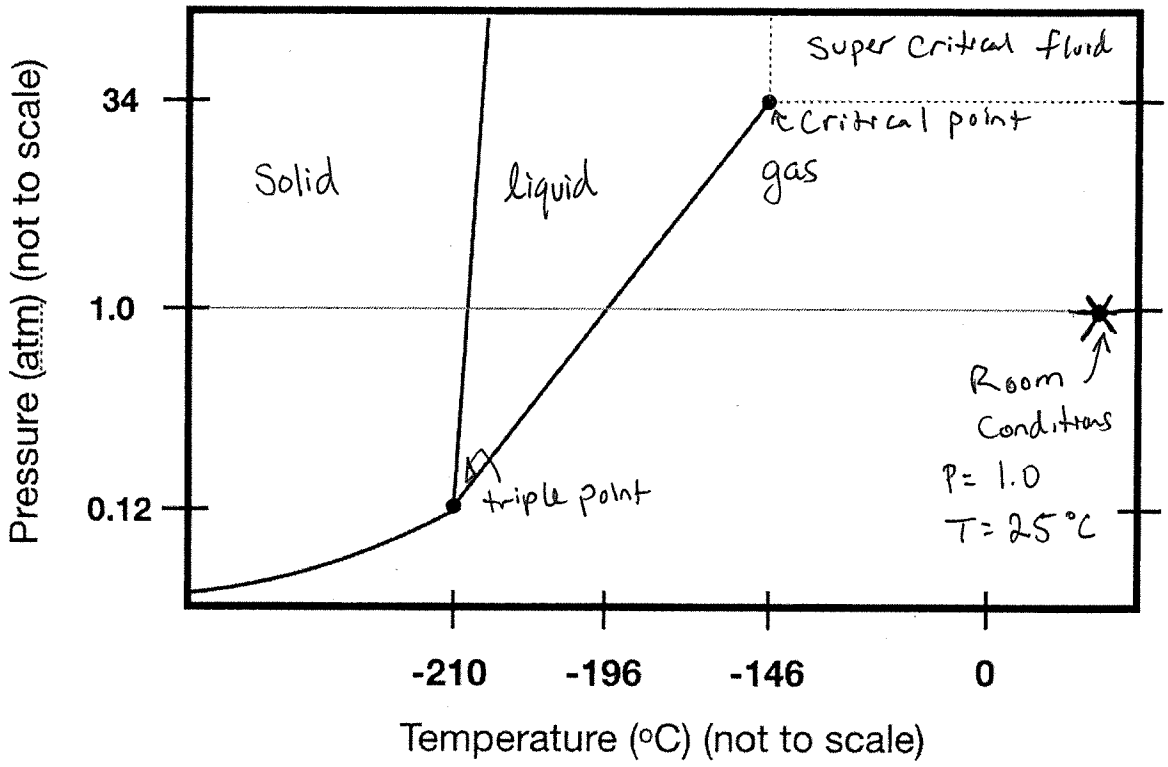
$\Delta H_{rxn} = 2(413) + 839 + \frac{5}{2} \cdot 495 - (4(799) + 2(463))$

$\Delta H_{rxn} = -1219.5\ kJ$

$q = n\Delta H = 1.0\ g\ C_2H_2 \cdot \frac{1\ mol}{26.04\ g\ C_2H_2} \cdot -1219.5\ kJ = -46.8\ kJ$

yes there is enough energy to warm the ice and melt the ice. 46.8 kJ > 39 kJ

23. Below is the phase diagram for N_2. The gray solid line at 1.0 atm is given to help guide your eye.



A. Label the following 6 points on the graph. Label each region as either solid, liquid, gas, or super critical fluid. Label the triple point and the critical point.

B. What is the phase transition that happens at 1 atm of pressure as the temperature increases from -200 °C to 25 °C? Evaporation

C. What is the minimum pressure necessary to create liquid N_2? 0.12 atm

D. At 2 atm of pressure, which value is closest to the freezing temperature of N_2? Circle the best answer:

a) -211 °C (b) -209 °C c) -192 °C d) -200 °C e) -140 °C

E. Label the phase diagram with at star (*) at the pressure and temperature conditions of this room. Define the P and T at this point.

P = 1.00 atm
T = 25°C

24. Balance the following redox reaction using the methods of half reactions. Show your work.

A. $NH_3(g) + O_2(g) \rightarrow NO(g) + H_2O(g)$

$NH_3 + H_2O \longrightarrow NO + 5H^+ + 5e^-$

$4e^- + 4H^+ + O_2 \longrightarrow 2H_2O$

$4NH_3 + 4H_2O \rightarrow 4NO + 20H^+ + 20e^-$

$+$

$20e^- + 20H^+ + 5O_2 \rightarrow 10H_2O$

$\boxed{4NH_3 + 5O_2 \rightarrow 6H_2O + 4NO}$

B. Which reactant has been oxidized?

NH_3

C. Which reactant has been reduced?

O_2

D.(b) If 3.49 g of ammonia and 2.16 g oxygen are allowed to react, what volume of nitric oxide is evolved at 273.2K and 1.00 atm?

NH_3 $n = 3.49\ g\ NH_3 \cdot \frac{1\ mol}{17.03\ g} = 0.205\ mol$ $\quad 0.205\ mol\ NH_3 \cdot \frac{4\ NO}{4\ NH_3} = 0.205\ mol\ NO$

O_2 $n = 2.16\ g\ O_2 \cdot \frac{1\ mol}{32\ g} = 0.0675\ mol$ $\quad 0.0675\ mol\ O_2 \frac{4\ NO}{5\ O_2} = .054\ mol\ NO$

O_2 is the limiting reagent.

$n_{NO} = 0.054$ $\quad V = \frac{nRT}{P} = \frac{0.054\ mol \cdot 0.08206 \frac{L\,atm}{mol\,K} \cdot 273.2\ K}{1.00\ atm} = \boxed{1.21\ L}$

25. A solution of 5.00 g of lauryl alcohol in 0.100 kg of benzene freezes at 4.1°C. Calculate the molar mass of lauryl alcohol. K_f for benzene is 5.12 °C kg/mol and the normal freezing point of benzene is 5.5°C. Show all work.

$\Delta T_f = -K_f \cdot m = -K_f \cdot \frac{\text{mass(g)} \frac{1\ mol}{MW(g)}}{\text{mass of solvent (kg)}}$

~~5.12 5.5 °C =~~

$4.1°C - 5.5°C = -5.12 \frac{°C\,kg}{mol} \cdot \frac{5.00\ g \cdot \frac{1\ mol}{MW(g)\ lauryl\ alcohol}}{0.100\ kg\ benzene}$

$\frac{-1.4 \cdot 0.100\ kg}{-5.12 \cdot 5.00\ g} = \frac{1\ mol}{MW(g)\ Lauryl\ alcohol}$ or $MW = \frac{-5.12 \frac{°C\,kg}{mol} \cdot 5.00\ g}{-1.4 \cdot 0.100\ kg}$

$MW = 183\ g/mol \rightarrow \boxed{180\ g/mol}$ (2 sig figs)

Part I: 60 pts Part II: ~~68 pts~~ 72 pts Part III: 68 pts