Department of Chemistry
Memorial University
Chemistry 1050

Fall 2013 Deferred Examination

Time 3 hours

NAME:_____ MUN Student Number:_____

Circle your professor's name:

Dr. R. Davis Dr. T. Fridgen Dr. C. Kozak

Read the Following Carefully

1. This exam has 11 pages. Question are on pages 2 through 10 and a periodic table is on page 11. Ensure that all pages for the examination paper are present.

2. A sheet containing the periodic table, physical constants and some equations which may be useful to you are provided. The periodic table sheet is the last page of the exam paper and should be detached for easier use.

3. Read each question carefully and answer each question in the space provided.

4. Show all relevant calculations.

5. Numerical answers should be reported to the appropriate number of significant digits and MUST include the correct units.

Questions	Points	Grade
1-4	10	
5-7	9	
8-10	8	
11-16	14	
17-19	11	
20-21	12	
22-25	10	
26-29	13	
30-31	6	
total	93	

1. The pressure in a certain airplane nose tire is 165 psi (pounds per square inch). Given that 1 bar = 14.5 psi which of the following are equivalent pressures to 165 psi? Circle all that are equivalent and do your calculations in the space below. **(2 marks)**

   i) 11.4 bar

   ii) 0.114 kPa

   iii) 8530 torr

   iv) 11.6 atm

2. Hydrogen peroxide (H_2O_2, molar mass=34.014 g mol^{-1}) decomposes to water and oxygen according to the following chemical reaction:

$$2\,H_2O_2(l) \rightarrow 2\,H_2O(l) + O_2(g)$$

   What volume of oxygen (molar mass=31.999 g mol^{-1}) will be produced at 25.0 ^oC and at 1.01 bar when 30.0 g of hydrogen peroxide decomposes entirely? **(4 marks)**

3. Deviations from the ideal gas law are often observed at high pressure and low temperature. Explain why. **(2 marks)**

4. On a cold spring morning, a camper's air mattress is flatter than when it was blown up the previous warm afternoon. Assuming no leaks, use kinetic molecular theory to explain this observation. **(2 marks)**

5. A 2.0 L helium balloon, initially at 25 °C and 102 kPa and with no leaks, is released and makes it to 10 km above the earth to the Tropopause where the pressure is 21 kPa. At this point the volume of the balloon is 7.3 L. What is the temperature at this altitude? **(3 marks)**

6. In 90 days, the pressure of a bicycle tire filled with N_2 drops to 80% of its initial value due to effusion. If the tire was filled with CO_2, how long (in days) will it take for the pressure to drop by the same amount? **(2 marks)**

7. Magnesium metal reacts with acid in solution according to the following balanced equation:

$$\mathrm{Mg}(s) + 2\,\mathrm{H}^{+}(aq) \rightarrow \mathrm{Mg}^{2+}(aq) + \mathrm{H}_2(g)$$

When 0.1021 g of Mg(s) is combined with enough acid solution to make 150.0 g of solution in a coffee cup calorimeter, all of the magnesium reacts, raising the temperature from 21.8 to 24.9 °C. Determine the enthalpy of reaction, $\Delta_r H$, for that shown above. Assume the solution to be made up of water so that the specific heat capacity is 4.184 J g^{-1} °C^{-1}. **(4 marks)**

8. Mined iron oxide (Fe_2O_3) can be reduced to iron (Fe) by reacting it with carbon monoxide according to the following reaction.

$$Fe_2O_3(s) + 3\,CO(g) \rightarrow 2\,Fe(s) + 3\,CO_2(g)$$

Use the following set of thermochemical reactions to determine the enthalpy change for the above reaction. **(3 marks)**

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta_r H^o = -393.5\ \text{kJ mol}^{-1}$$

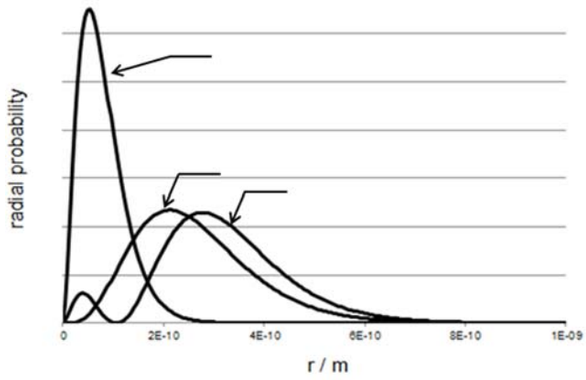
$$C(s) + CO_2(g) \rightarrow 2CO(g) \qquad \Delta_r H^o = 172.5\ \text{kJ mol}^{-1}$$

$$Fe_2O_3(s) \rightarrow 2\,Fe(s) + \frac{3}{2}\,O_2(g) \qquad \Delta_r H^o = 824.2\ \text{kJ mol}^{-1}$$

9. From a molecular point of view, describe where the energy absorbed in an endothermic reaction goes. **(1 mark)**

10. A 1.0 kg block of aluminum (specific heat = 0.897 J g^{-1} $^oC^{-1}$) at 925 ^{o}C is dropped into 2.0 kg of water at 25 ^{o}C. The water is heated to its boiling point and some of the water boils away. How much water boils away? Use data from the Periodic Table and Data page. **(4 marks)**

11. The plot to the right contains the radial probability diagrams for the 1s, 2s, and 2p orbitals. Label them in the spaces on the diagram and briefly explain your choices. **(2 marks)**



13. Write the ground state condensed electron configurations for the following. **(6 marks)**
Note: Do not forget that H and He comprise the first period in the periodic table.

P :

Cr :

Mn^{2+} :

Po (element 84):

Se :

Sn^{2+} :

14. Explain, in terms of quantum numbers, why there are only two s-block elements per period. **(1 mark)**

15. A hydrogen atom undergoes a transition from the ground state to the n=4 state.

a) Will this process involve emission or absorption of a photon? Explain. **(1 mark)**

b) Is the n=2 to n=3 transition a higher or lower energy transition? Explain. **(1 mark)**

c) Will the transition from the ground state to the n=4 state of Li^{2+} be a higher or lower energy transition than the same transition for the hydrogen atom. Explain. **(1 mark)**

16. a) Briefly explain why the melting point of MgO (2852 ^{o}C) is higher than that that of CaO (2613 ^{o}C). **(1 mark)**

b) Briefly explain why the melting point of CaS (2525 ^{o}C) is significantly greater than that of $CaCl_2$ (772 ^{o}C). **(1 mark)**

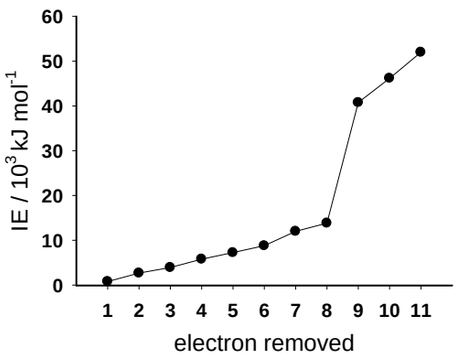
17. a) Arrange the following elements in order of increasing first ionization energy: Si, F, In, N. **(1 mark)**

b) Arrange the following elements in order of increasing atomic radius: Ca, Rb, S, Si, Ge, F. **(1 mark)**

c) Arrange the following isoelectronic species in order if increasing size: Ar, Cl^-, S^{2-}, K^+, Ca^{2+}. **(1 mark)**

d) Which pair of the following four elements would provide the <u>most</u> vigorous chemical reaction and what would the product be: Rb(s), Na(s), $Cl_2(g)$, $F_2(g)$? **(1 mark)**

18. To the right is a plot of successive ionization energies for argon (Ar). There is a smooth increase in the energy required to remove the first through the 8th electrons. Explain why the energy to remove the 9th electron does not follow this smooth trend and is so much larger than the energy required to remove the 8th electron. **(2 marks)**



19. a) Draw the Lewis structure for SF_4. **(2 marks)**

b) What is the electron group geometry and molecular shape? **(1 mark)**

electron group geometry_____

molecular shape _____

c) Sketch the shape of SF_4 and include the bond angles. **(1 marks)**

d) Is SF_4 polar or non-polar? **(1 mark)**

20. a) Draw a Lewis structure of the phosphate ion (PO_4^{3-}) that obeys the octet rule and assign formal charges. **(2 marks)**

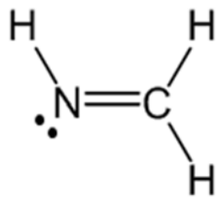
b) Draw a Lewis structure of PO_4^{3-} where the formal charges are reduced as much as possible and assign formal charges. **(2 marks)**

c) How many resonance structures can be drawn for part b? **(1 mark)**

d) Calculate the P-O bond order for PO_4^{3-}. **(1 mark)**

e) What is the shape of PO_4^{3-}? **(1 mark)**

21. The presence of methyleneimine, H_2CNH, in the atmosphere of Titan is important because through gas phase reactions, the nitrogen can be incorporated into biological molecules such as amino acids and nucleic acid bases. Use Valence Bond and Orbital Hybridization Theories to describe the bonding in methyleneimine. Your answer should show the following steps. **(5 marks)**



i) Using the Lewis structure of H_2CNH to the right, use VSEPR to predict the shapes around C and N.

ii) Provide a description of the orbital hybridization at C and N.

iii) Provide a sketch, illustrating the type of **all** the bonds in the molecule, sigma (σ) or pi (π), and the atomic and/or hybrid orbitals that overlap to form these bonds.

iv) In what type of orbital is the lone pair of electrons on the nitrogen?

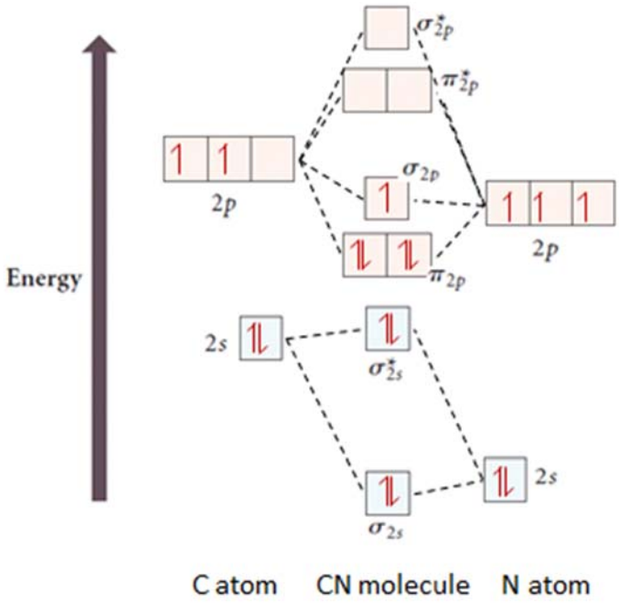
22. Explain why the use of atomic orbitals alone to describe the bonding and geometry of methane, CH_4, gives an inaccurate prediction compared to the observed geometry and bonding. **(2 marks)**

23. The MO diagram for CN is given to the right. **(3 marks)**

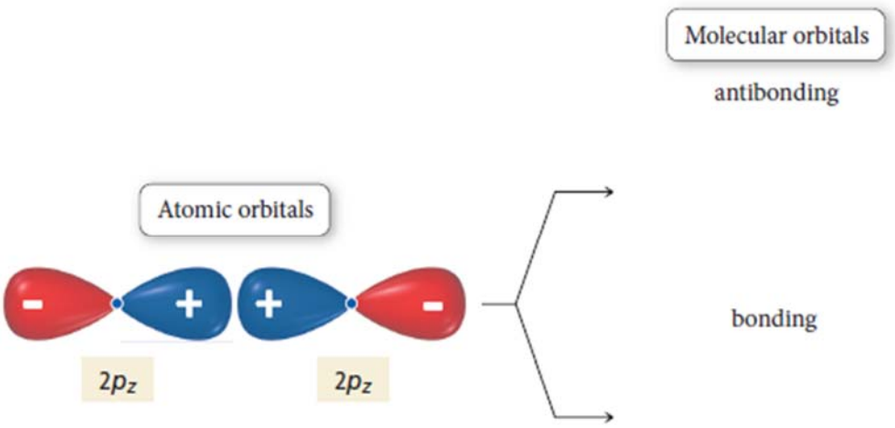
a) What is the bond order for CN?

b) What is the bond order for CN^-?

c) What is the bond order for CN^+?

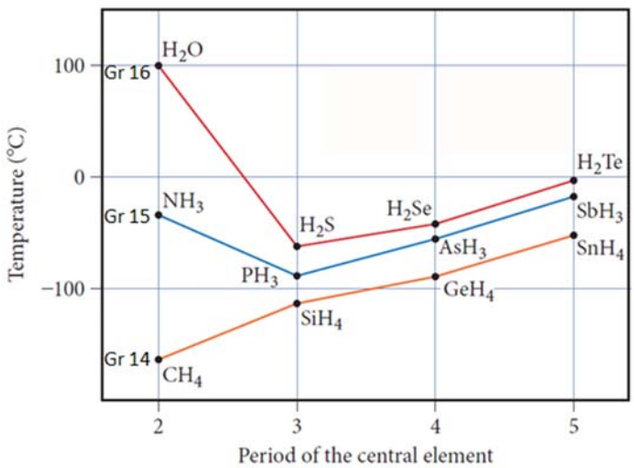


24. Sketch the bonding and antibonding orbitals that result from the linear combinations of two p orbitals as shown in the diagram below. Don't forget to show the phases of the bonding and antibonding orbitals. **(3 marks)**



25. a) Explain why the boiling points decrease over the series SnH_4, GeH_4, SiH_4, CH_4. **(1 mark)**

b) Explain why the trend is significantly different for the group 15 and 16 hydrides in that NH_3 and H_2O have very high boiling points. **(1 mark)**

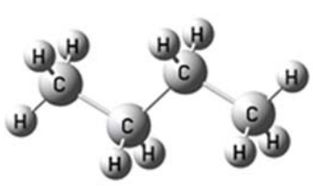


Boiling points of group 14, 15, and 16 hydrides.

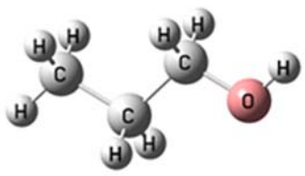
26. Atmospheric pressure on Mount Caubvick, the highest peak in the Torngat Mountain range, is about 87.4 kPa, compared to 101.3 kPa at sea level. At what temperature will water boil on Mount Caubvick? Use data from the Periodic Table and Data page. **(4 marks)**

27. The heats of vaporization and fusion for water are 40.7 and 6.02 kJ mol^{-1}. Briefly explain why the heat of vaporization is so much higher than the heat of fusion of a substance. **(2 marks)**

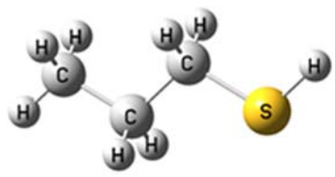
28. Rank the following three liquids in order of highest to lowest boiling point? Briefly justify your answer. **(3 marks)**



butane



1-propanol



1-propanethiol

29. a) Ethylene glycol (molar mass=62.07 g mol^{-1}) is a non-volatile solute that is added to water in a car's cooling system to increase the temperature range of over which the coolant mixture is liquid. What is the freezing point of a solution formed by adding 715 g of ethylene glycol to 4.10 kg of water? K_f of water is 1.86 ^oC kg mol^{-1}. **(3 marks)**

b) How would the boiling point change if, instead of ethylene glycol, the same number of ***moles*** of $CaCl_2$ were added to the same amount of water in part a)? Be specific and provide a brief explanation of your answer. **(1 mark)**

30. a) The lattice enthalpy for $AgNO_3$ is -820 kJ mol^{-1} and the enthalpies of hydration for Ag^+ and NO_3^- are -471 and -314 kJ mol^{-1}, respectively. Calculate the enthalpy associated with the following reaction, dissolution of $AgNO_3$. Show your work. **(3 marks)**

$$AgNO_3(s) \rightarrow Ag^+(aq) + NO_3^-(aq)$$

b) The reaction above is endothermic. Despite this, silver nitrate is very soluble in water. What is the thermodynamic driving force behind the dissolution of silver nitrate? **(1 mark)**

31. Which of the following solutes, CCl_4 or CH_2Cl_2, would you expect to be more soluble in water? Explain your answer in terms of the shapes of the solutes and intermolecular forces between the solutes and water. **(2 marks)**