JAC NYA Final Exam W09 --- Condensed Version (working spaces removed)

1. (4 marks) John Dalton's 1808 atomic theory had four important concepts. While they were largely correct, we know today that some of the aspects of his theory were slightly off. Point out *one* inaccuracy in Dalton's atomic theory and correct it based on current knowledge.

2. (10 marks) An electron in an excited hydrogen atom emits light with a frequency of 1.141×10^{14} Hz (s^{-1}) to reach the energy level for which at $n = 4$.
   a) From which energy level did the electron come? n = _____
   b) If this hydrogen atom (at $n = 4$) were to then to absorb a photon, what would be the longest possible wavelength of this photon? λ = _____

3. (4 marks) Which is the more stable electron: that in a ground-state H atom or that in a ground-state He^+ ion? Explain your choice.

4. (4 marks) When compounds of barium are heated in a flame, green light (λ = 554nm) is emitted. How much energy does **one mole** of these photons carry?

5. (5 marks) We know light has a dual nature: depending on the phenomenon, it may behave either as a wave or as particles. Give an example of a phenomenon where light clearly has particle-like properties, and explain how the properties are particle-like.

6. (3 marks) Identify groups of isoelectronic species from the following list:

   C Mn^{2+} B^- Zn Fe^{3+} Ge^{2+}

7. (8 marks) State the following:
   a) The orbital designation (e.g., 1*s*) associated with the quantum numbers $n = 4$, $l = 2$ _____
   b) The m_l values allowed for a *d* orbital _____
   c) The allowed values of l when $n = 4$ _____
   d) The number of orbitals with $n = 3$ and $l = 1$ _____
   e) The number of *p*-orbital electrons in the valence shell of a sulphur atom _____
   f) The quantum number that characterises the shape of an atomic orbital _____
   g) The lowest value of *n* for which a *d* subshell can occur _____
   h) The physical meaning of m_l _____

8. (12 marks) Fill in the following table. Check the appropriate boxes to indicate the species' magnetic properties.

Species	Electron Configurations (Noble gas notation acceptable)
Potassium □ paramagnetic □ diamagnetic	
Copper □ paramagnetic □ diamagnetic	
Oxide ion □ paramagnetic □ diamagnetic	
Manganese(II) ion □ paramagnetic □ diamagnetic	

9. (5 marks) An ion having a 4+ charge and a mass number of 50 has 2 electrons with principal quantum number n = 1, 8 electrons with principal quantum number n = 2, and 10 electrons with principal quantum number n = 3.

   Identify this ion and give its electron configuration.

10. (6 marks)

    a) Rank the following three ions in order of increasing ionic radius: Sc^{3+}, Cl^{-}, Ca^{2+}. Explain your answer.

    b) Rank the following three atoms in order of increasing first ionization energy: Mg, Ar, Sr. Explain your answer.

11. (8 marks)

    a) List and explain the factors that affect lattice energy.
    b) Place the following in order of increasing melting point. Explain your ranking:

    LiI CaO RbI

12. (18 marks)

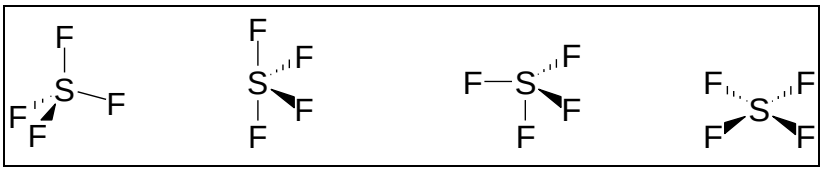
    a) Construct a Born-Haber cycle for the formation of aluminum iodide from its constituent elements. The cycle must clearly indicate which steps are expected to be exo- or endothermic. Pay attention to physical states.

b) Calculate the energy required to separate the ionic lattice into gas-phase ions.

	(**Absolute values**) kJ/mol
Sublimation energy for solid iodine	62.3
Bond energy of iodine	151
First electron affinity of iodine	295.2
Sublimation energy of aluminum	557
First ionization energy for aluminum	578
Second ionization energy for aluminum	1,820
Third ionization energy for aluminum	2,748
Fourth ionization energy for aluminum	11,578
Heat of formation of aluminum iodide	395

13. Aluminum(IV) iodide (AlI_4) cannot be formed. Explain why this is the case by making reference to the energies involved in formation of this compound.

14. (5 marks) Consider the four possible shapes of the SF_4 molecule below:



Choose the preferred molecular structure and explain your choice.

15. (6 marks) Identify whether or not the following molecules are polar or non-polar. Justify your answers in each case:
    a) SO_2
    b) CO_2

16. (6 marks) Using the following data:

heat of reaction of magnesium in hydrochloric acid	-464 kJ/mol
heat of formation of MgO	-602 kJ/mol
heat of formation of water	-285 kJ/mol

Calculate the heat of reaction between magnesium oxide and hydrochloric acid.

17. (3 marks) Draw the best Lewis structure for diazomethane (CH_2N_2). Include all non-zero formal charges. The arrangement of the atoms is shown below:

H
C N N
H

18. (6 marks) Draw an orbital overlap diagram for CH_2=CH-OH. Label the orbitals (e.g., sp^3, $2p$) and bond types, and show the valence electrons present (mark as · or ↑, ↓).

19. (15 marks) Using VSEPR theory, complete the following table;

Species	Lewis Structure	3D representation (Include bond angles)	Name of molecular geometry
HArF			
ONF			
ICl_4^-			

20. (9 marks) Consider the formula C_3H_7ON.
    a) Draw a pair of diastereomers having this formula.
    b) Draw a pair of enantiomers having this formula.
    c) Draw a pair of structural isomers, without repeating any of the structures used in parts a and b.
21. (4 marks) Which of the following ions has the longest N-O bond: NO_2^- or NO^-? Explain in detail, using any relevant structures to support your answer.

22. (9 marks) Consider the reaction between gaseous hydrogen cyanide (HCN) and hydrogen gas to form gaseous methylamine (CH_3NH_2). ΔH for this reaction is -158 kJ/mol of methylamine formed. Calculate the bond energy between C and N in HCN using the following data:

Bond	Bond energy (kJ/mol)
H–H	432
C–H	413
C–N	305
C=N	615
N–H	391

23. (8 marks) Arrange the following pure substances in order of increasing boiling point:

CH_3CH_2OH CH_3OCH_3 $C_2H_5OC_2H_5$ $CH_3CH_2CH_3$

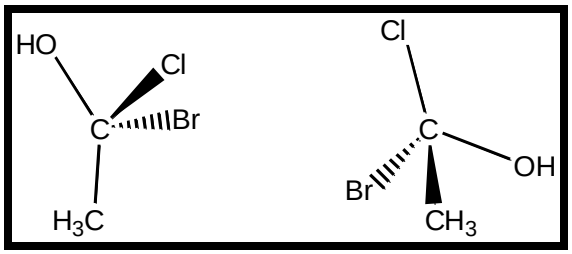
Boiling point	Molecule	Justification of ranking based on IMF

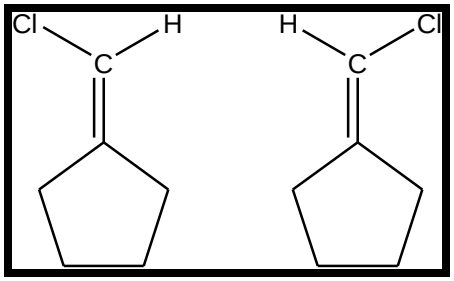
24. (6 marks)

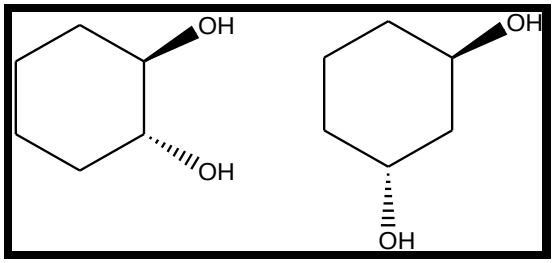
a) Match the following relationships to the correct set of molecules by inserting the correct letter in the boxes.

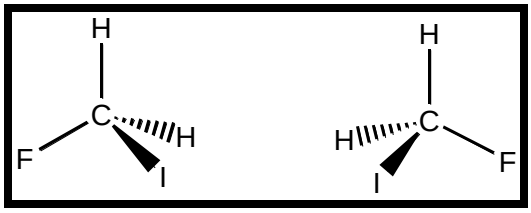
A = enantiomers B = identical

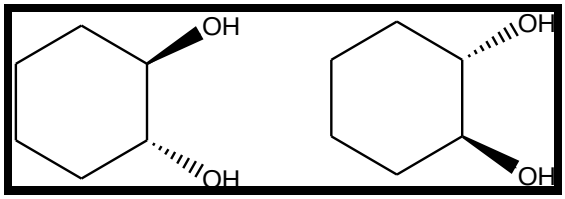
C = diastereomers D = structural isomers

i. 

ii. 

iii. 

iv. 

v. 

b) Which set(s) of molecules listed above would have different boiling points?

25. (4 marks) Depict and name the strongest intermolecular force between a water molecule and an ammonia molecule.

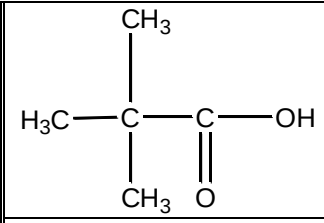
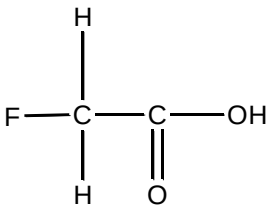
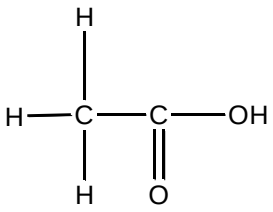
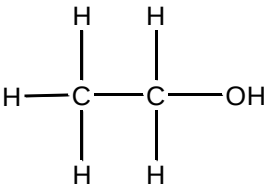
26. (4 marks) Which is the stronger base: CH_3^- or OH^-? Explain your answer.

27. (6 marks) Based on the information in the table, identify each substance as either an ionic compound, a network covalent compound, a metal, or a molecular (covalent) compound. Briefly explain your reasoning.

Sample	Soluble in water	Soluble in hexane or alcohol	Melting range	Conducts electricity	Identity	Reasoning
A	No	No	Greater than 500^{o}C	Yes		
B	No	Yes	Less than 100^{o}C	No		
C	Yes	No	Greater than 500^{o}C	No		

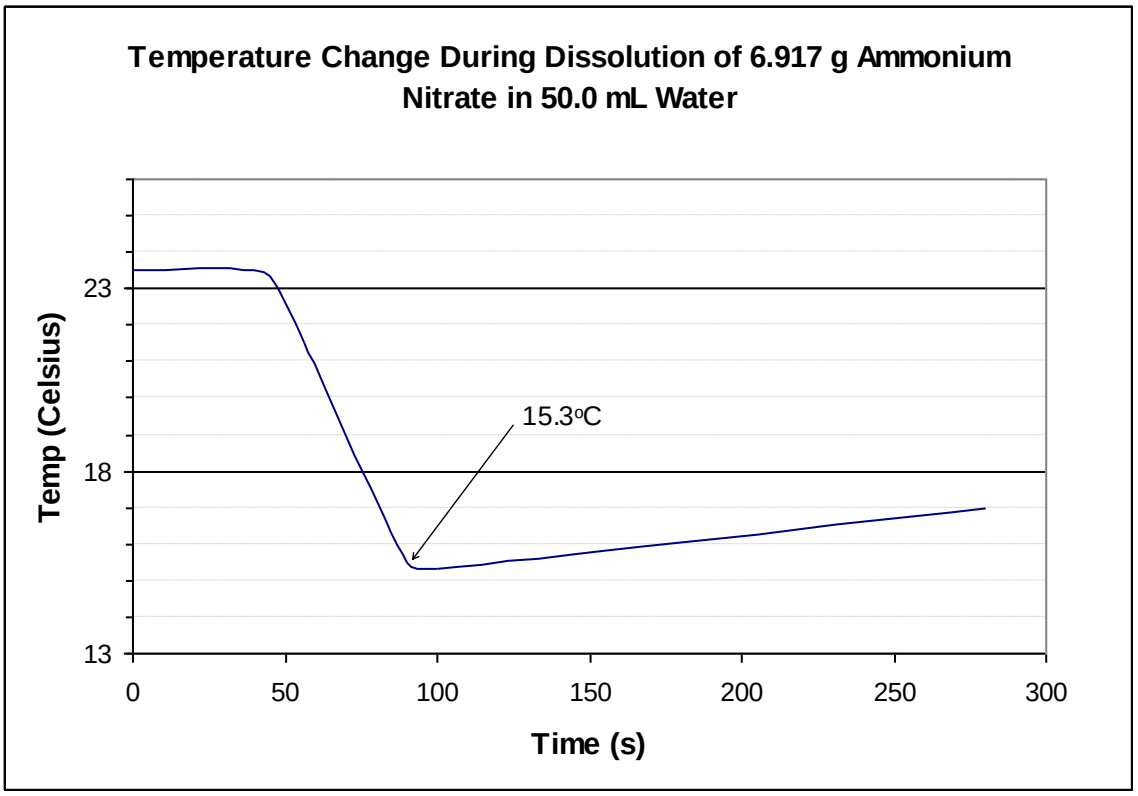
28. (10 marks)

a) Rank the following compounds according to increasing pK_a. (1 = lowest pK_a, 4 = highest pK_a). Lone pairs have been omitted from these structures for clarity.

Structure				
Ranking				

b) Give an explanation of your ranking.

29. (12 marks) An experiment is conducted in a coffee cup calorimeter by dissolving solid ammonium nitrate into water and monitoring the change in temperature of the solution over time. The following graph is produced:



a) The lowest recorded temperature of the solution during the experiment is 15.3°C. Explain why this is not the most accurate final temperature (T_f) of the solution.

b) Use graphical analysis to obtain a more accurate theoretical final temperature. Show your work directly on the graph.

Theoretical T_f = _____ °C

c) Use the following data taken from the experiment to calculate the enthalpy of solution for ammonium nitrate.

Mass of empty calorimeter system	7.390 g
Volume of water added to calorimeter	50.0 mL
Mass of ammonium nitrate added	6.917 g
Mass of calorimeter system containing final solution	64.707 g
Specific heat capacity of solution	4.18 J/(g K)
Heat capacity of coffee cup	25.0 J/K
Molar mass of ammonium nitrate	80.04 g/mol