CHMB31H3 – Introduction to Inorganic Chemistry
FINAL EXAM

December 11, 2018

Answer all questions in full.
Value of each question is indicated. Total is 115 marks.
***Aids Allowed*: Periodic Table of Elements provided at the back**
Appendix with formulas
Calculator

Duration: 180 min (3 h)

GOOD LUCK & HAPPY HOLIDAYS!

Part I - Multiple choice questions (20 marks in total for Part 1: Bubble in the answers for this part on the provided scantron sheet – *DO NOT* answer these questions in your exam booklet!)

1. Identify the unknown nuclide formed in the reaction $^{243}\text{Am} + {}^{48}\text{Ca} \rightarrow ? + 3\text{n}$
   a. ^{288}Mc
   b. ^{284}Nh
   c. ^{288}Fl
   d. ^{291}Og
   e. ^{290}Mc
2. How many nodes does a 4f orbital have?
   a. Four nodes in total – three radial and one angular
   b. Four nodes in total – one radial and three angular
   c. Three nodes in total – one radial and three angular
   d. Three nodes in total – zero radial and three angular
   e. Three nodes in total – three radial and one angular
3. Find the <u>*correct*</u> statement:
   a. The first ionization potentials decrease from left to right in the Periodic Table.
   b. S is a non-metallic element in s-block.
   c. The reactivity of Group 1 metals increases down the group.
   d. Oxygen has no allotropes.
   e. Alpha particle has two protons and two electrons.
4. For the anion $BeCl_4^{2-}$, the VESPER theory would predict:
   a. A bent molecular geometry
   b. An octahedral molecular geometry
   c. A T-shaped molecular geometry
   d. A trigonal planar molecular geometry
   e. A tetrahedral molecular geometry.
5. Using Pauling rules predict the pK_{a2} value for H_3PO_4
   a. 3
   b. 5
   c. 8
   d. 9
   e. 13
6. The elements of Group 17 are also known as:
   a. Chalcogens
   b. Noble gases
   c. Tetrels
   d. Halogens
   e. Transition elements.

7. What do $Be(OH)_2$ and $Al(OH)_3$ have in common?
    a. They are both strong bases
    b. They have high solubility in water
    c. They are both amphoteric
    d. Neither can be isolated.
    e. They are both used as raw materials for the isolation of elements.
8. Carbon monoxide (CO) is:
    a. a good oxidizing agent
    b. a source of H_2CO_3
    c. a major greenhouse gas
    d. acid-base neutral oxide
    e. very unstable
9. Find *incorrect* chemical formula:
    a. Boron nitride, B_3N_2
    b. Phosphorus pentoxide, P_4O_{10}
    c. Silicic acid, $Si(OH)_4$
    d. Sulfur, S_8
    e. Aluminum tetrahydroborate, $Al(BH_4)_3$
10. Find a typical acidic oxide:
    a. BeO
    b. SO_2
    c. Tl_2O
    d. Al_2O_3
    e. PbO

Part II – Short answer questions (95 marks in total: Answer the questions for this part in your exam booklet on the RULED (right) SIDE ONLY! Only material on ruled side will be marked! Use the unruled (left) side for your drafts and calculations – these drafts will not be marked!)

11. (*10 marks*) The following questions cover boron halides.

    a. The calculated partial charges on B and F in BF_3 are +0.63 and –0.21 respectively. Partial charges on B and Cl in BCl_3 are +0.78 and –0.26. Would you expect the B atom to be less positive in BF_3 than in BCl_3? Explain your reasoning.

    b. Boron triiodide cannot be obtained directly from the elements. The large scale production of this chemical follows the equation:

$$LiBH_4 + 2\ I_2 \rightarrow LiI + BI_3 + 2\ H_2$$

    What is **reducing** and what is **oxidizing** reagent in this reaction?

c. Calculate ΔH for the previous reaction if $\Delta H_f(LiBH_4) = -190.8$ kJ mol^{-1}, $\Delta H_f(LiI) = -270.4$ kJ mol^{-1}, $\Delta H_f(BI_3) = +71.1$ kJ mol^{-1}, and comment on the thermodynamic spontaneity of the reaction.
d. Why are B–F bonds in BF_3 shorter than in $[BF_4]^-$?

12. (*5 marks*) Predict the chemical formulas for nihonium (Nh) oxides. Which one is more stable? Explain.

13. (*5 marks*)

a. A very common Sn(II) salt is $SnCl_2$. This chloride is a Lewis acid and can react with one equivalent of a Lewis base, such as a halide anion, X^-. What would be the structure of the product?

b. Would you expect a reaction between an acidic aqueous solution of Sn^{2+} and PbO_2? Explain your reasoning.

14. (*10 marks*) What are five structural types of borohydrides? Using Wade's rules predict the structure type for B_5H_{11} cluster.

15. (*2 marks*) Suggest why neither $[Cs(2,2,2\text{-crypt})]^+$ nor $[Li(2,2,2\text{-crypt})]^+$ is stable.

16. (*10 marks*) Finish and balance the following reactions!

a. $B(OH)_3 + Sr(OH)_2 \rightarrow$
b. $AlCl_3 + H_2O \rightarrow$
c. $NO_2 + H_2O \rightarrow$
d. $Na_2O_2 + H_2O \rightarrow$
e. $F_2 + I_2 \rightarrow$
f. $SiCl_4 + H_2O \rightarrow$
g. $As_2O_5 + H_2O \rightarrow$
h. $SO_3 + H_2SO_4 \rightarrow$
i. $CaO + H_2O \rightarrow$
j. $KH + B_2H_6 \rightarrow$

17. (*4 marks*) Write the reaction showing autoprotolysis taking place in liquid ammonia. Using this reaction, provide the definition of acids and bases in liquid ammonia.

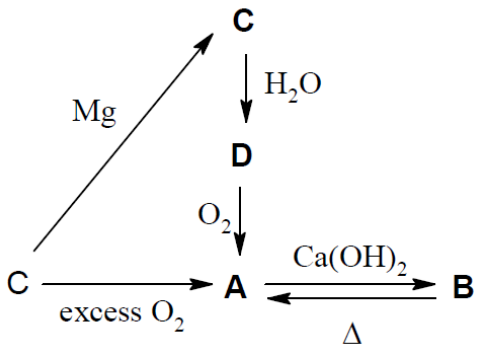
18. (*5 marks*) Describe the contact process for the synthesis of sulfuric acid (either in words or through chemical equations). Make sure to mention the raw materials and the reason for the catalyst use.

19. (*6 marks*) Define the following:
    a. First ionization potential
    b. Lattice enthalpy
    c. Unit cell of a crystal

20. (*10 marks*) The following questions apply to BrF_3.
    a. Pauling electronegativity values for F and Br are 4.0 and 3.0 respectively. Calculate the partial charges on F and Br in BrF_3.
    b. Using VSEPR theory suggest the most likely structure of this compound.
    c. Using the structure predict if the BrF_3 molecule is polar or not. Explain.

21. (*4 marks*) Single element–element bonds for the first members of the p block (N, O, F) are significantly weaker than the element–element bonds for the elements below them (P, S and Cl). Explain this trend.

22. (10 marks) In the following scheme identify carbon-containing products A – D and write balanced chemical equation for each reaction:



23. (8 marks) Describe differences and similarities in bonding, structure and reactivity (using HCl as an example) between borazene, $(HBNH)_3$, and benzene, C_6H_6.

24. (6 marks) Briefly explain (in one or two sentences) the following observations:
    a. Unlike NH_3, BiH_3 is very unstable compound.

    b. Solid SO_3 forms a trimer $(SO_3)_3$ but solid SeO_3 forms a tetramer $(SeO_3)_4$.

    c. NH_3 can be obtained from N_2 and H_2, but PH_3 has to be prepared from PCl_3 and $LiAlH_4$.

- END OF TEST -

Appendix

$$\delta = \textit{Number of valence electrons on } X - \textit{Number of lone electrons on } X - 2 \times \sum_{bonds} \left(\frac{\chi_x}{\chi_x + \chi_y} \right)$$

Approximating pKa: $pKa_1 = 8 - 5p$, $pKa_2 = pKa_1 + 5$, $pKa_3 = pKa_2 + 5$, ……

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	s		d										p					
1	1 H 1,00797																	2 He 4,0026
2	3 Li 6,939	4 Be 9,0122											5 B 10,811	6 C 12,01115	7 N 14,0067	8 O 15,9994	9 F 18,9984	10 Ne 20,183
3	11 Na 22,9898	12 Mg 24,312											13 Al 26,9815	14 Si 28,086	15 P 30,9738	16 S 32,064	17 Cl 35,453	18 Ar 39,948
4	19 K 39,102	20 Ca 40,08	21 Sc 44,956	22 Ti 47,90	23 V 50,942	24 Cr 51,996	25 Mn 54,938	26 Fe 55,847	27 Co 58,9332	28 Ni 58,71	29 Cu 63,546	30 Zn 65,37	31 Ga 69,72	32 Ge 72,59	33 As 74,922	34 Se 78,96	35 Br 79,909	36 Kr 83,8
5	37 Rb 85,47	38 Sr 87,62	39 Y 88,905	40 Zr 91,22	41 Nb 92,906	42 Mo 95,94	43 Tc (98)	44 Ru 101,07	45 Rh 102,905	46 Pd 106,4	47 Ag 107,87	48 Cd 112,40	49 In 114,82	50 Sn 118,69	51 Sb 121,75	52 Te 127,60	53 I 126,9044	54 Xe 131,3
6	55 Cs 132,905	56 Ba 137,34	57 La 138,91	72 Hf 178,49	73 Ta 180,948	74 W 183,85	75 Re 186,2	76 Os 190,2	77 Ir 192,2	78 Pt 195,09	79 Au 196,967	80 Hg 200,59	81 Tl 204,37	82 Pb 207,19	83 Bi 208,98	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (260)	105 Db (260)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Nh (282)	114 Fl (285)	115 Mc (289)	116 Lv (289)	117 Ts (294)	118 Og (294)

f

6	58 Ce 140,12	59 Pr 140,907	60 Nd 144,24	61 Pm (147)	62 Sm 150,35	63 Eu 151,96	64 Gd 157,25	65 Tb 158,924	66 Dy 162,5	67 Ho 164,93	68 Er 167,26	69 Tm 168,934	70 Yb 173,04	71 Lu 174,97
7	90 Th 232,038	91 Pa (231)	92 U 238,03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)