

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!

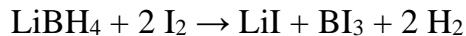
Part I - Multiple choice questions (20 marks in total for Part 1: Bubble in the answers for this part on the provided scantron sheet – *DO NOT* answer these questions in your exam booklet!)

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 correct 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 $\text{pK}_{\text{a}2}$ 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 H₂CO₃
 - c. a major greenhouse gas
 - d. acid-base neutral oxide
 - e. very unstable
9. Find incorrect chemical formula:
 - a. Boron nitride, B₃N₂
 - b. Phosphorus pentoxide, P₄O₁₀
 - c. Silicic acid, Si(OH)₄
 - d. Sulfur, S₈
 - e. Aluminum tetrahydroborate, Al(BH₄)₃
10. Find a typical acidic oxide:
 - a. BeO
 - b. SO₂
 - c. Tl₂O
 - d. Al₂O₃
 - 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 BF₃ are +0.63 and -0.21 respectively. Partial charges on B and Cl in BCl₃ are +0.78 and -0.26. Would you expect the B atom to be less positive in BF₃ than in BCl₃? Explain your reasoning.
 - b. Boron triiodide cannot be obtained directly from the elements. The large scale production of this chemical follows the equation:



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

- c. Calculate ΔH for the previous reaction if $\Delta H_f(\text{LiBH}_4) = -190.8 \text{ kJ mol}^{-1}$, $\Delta H_f(\text{LiI}) = -270.4 \text{ kJ mol}^{-1}$, $\Delta H_f(\text{BI}_3) = +71.1 \text{ kJ mol}^{-1}$, and comment on the thermodynamic spontaneity of the reaction.
- d. Why are B–F bonds in BF_3 shorter than in $[\text{BF}_4]^-$?

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 $[\text{Cs}(2,2,2\text{-crypt})]^+$ nor $[\text{Li}(2,2,2\text{-crypt})]^+$ is stable.

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

- a. $\text{B(OH)}_3 + \text{Sr(OH)}_2 \rightarrow$
- b. $\text{AlCl}_3 + \text{H}_2\text{O} \rightarrow$
- c. $\text{NO}_2 + \text{H}_2\text{O} \rightarrow$
- d. $\text{Na}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow$
- e. $\text{F}_2 + \text{I}_2 \rightarrow$
- f. $\text{SiCl}_4 + \text{H}_2\text{O} \rightarrow$
- g. $\text{As}_2\text{O}_5 + \text{H}_2\text{O} \rightarrow$
- h. $\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow$
- i. $\text{CaO} + \text{H}_2\text{O} \rightarrow$
- j. $\text{KH} + \text{B}_2\text{H}_6 \rightarrow$

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:

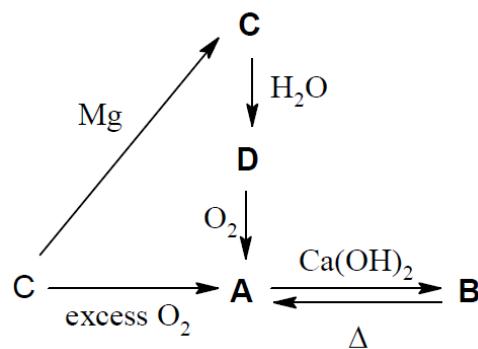
- First ionization potential
- Lattice enthalpy
- Unit cell of a crystal

20. (10 marks) The following questions apply to BrF_3 .

- 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 .
- Using VSEPR theory suggest the most likely structure of this compound.
- 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, $(\text{HBNH})_3$, 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 $(\text{SO}_3)_3$ but solid SeO_3 forms a tetramer $(\text{SeO}_3)_4$.
- 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

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

Approximating pKa: $\text{pKa}_1 = 8 - 5p$, $\text{pKa}_2 = \text{pKa}_1 + 5$, $\text{pKa}_3 = \text{pKa}_2 + 5$,

1	H	1	1
1,00797		2	
3	Li	4	Be
6,989		9,0122	
11	Na	12	Mg
22,9898		24,312	
19	K	20	Ca
39,102		40,08	
37	Rb	38	Sr
85,47		87,62	
55	Cs	56	Ba
132,905		137,34	
87	Fr	88	Ra
(223)		(226)	
3		4	
21	Sc	22	Ti
39,102		40,08	
37	Y	40	Zr
85,47		88,905	
55	La	57	Hf
132,905		138,91	
87	Ac	89	Rf
(227)		(260)	
4		5	
23	V	24	Cr
40		41	
42	Nb	43	Mo
91,22		92,906	
74	Ta	75	W
178,49		180,948	
105	Re	106	Db
183,85		186,2	
107	Os	108	Sg
190,2		192,2	
109	Ir	110	Bh
195,09		196,987	
110	Pt	111	Hs
200,59		200,59	
111	Au	112	Mt
196,987		200,59	
112	Hg	113	Ds
200,59		204,37	
113	Tl	114	Rg
204,37		207,19	
114	Pb	115	Cn
207,19		208,98	
115	Bi	116	Ts
208,98		(210)	
116	Po	117	Og
(210)		(210)	
117	At	118	Rn
(222)		(222)	
118	Rn	119	
(222)		(227)	
5		6	
13	B	14	C
10,811		12,01115	
13	Al	14	Si
26,9815		28,086	
31	Ga	32	Ge
69,72		72,59	
49	In	50	As
69,72		74,922	
49	Sn	51	Se
74,922		78,96	
50	Sb	52	Br
78,96		79,909	
51	Te	53	Kr
79,909		83,8	
52	I	53	Xe
83,8		83,8	
53	Xe	54	
131,3		131,3	
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58	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
60	140,12	140,907	144,24	(147)	150,35	151,96	157,25	158,924	162,5	164,93	167,26	168,934	173,04	174,97
61	90	91	92	93	94	95	96	97	98	99	100	101	102	103
62	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
63	232,038	(231)	238,03	(237)	(244)	(243)	(247)	(247)	(249)	(254)	(253)	(256)	(254)	(257)