Chm 451 Exam 2 30 October 2013 Name:

This test has 100 points available. You may skip up to 10 points worth. Your score will be determined as 110 minus the sum of the number wrong + number skipped. Scores over 100 will stand as is. You can use your data sheets for the last 30 minutes 10:15 – 10:45. Plan your time! Exam ends promptly at 10:45.

1. Which ONE of the following salts would form acidic solutions in water?

A. $NaC_2H_3O_2$ B. NH_4Cl C. KBr

E. LiOH F. Na_2CO_3

2 – 3. In class I reacted gaseous boron trifluoride and ammonia.

2. What sort of bond was formed between boron BF_3 and NH_3?

A. ionic B. hydrogen bonding

C. coordinate covalent D. covalent

3. The product obtained was a:

Circle one: solid, liquid, OR gas

4. The best hard acid among these listed:

Mg^{+2} K^+ Ag^+ F^- Cl^- S^{-2}

5. The best soft acid among these listed:

Mg^{+2} K^+ Ag^+ F^- Cl^- S^{-2}

6. The best hard base among these listed:

Mg^{+2} K^+ Ag^+ F^- Cl^- S^{-2}

7. The best soft base among these listed:

Mg^{+2} K^+ Ag^+ F^- Cl^- S^{-2}

8. BrF_3 is an aprotic solvent that autodissociates slightly, like water does. Which of these represents the autodissociation of BrF_3?

A. $BrF_3 \rightleftharpoons BrF_2^+ + F^-$

B. $2\ BrF_3 \rightleftharpoons BrF_2^+ + BrF_4^-$

C. $BrF_3 \rightleftharpoons Br^{+3} + 3\ F^-$

D. $BrF_3 + H_2O \rightleftharpoons BrF_2OH + HF$

9. Which oxyacid has the largest K_a?

A. H_3AsO_2 B. H_3AsO_3 C. H_3AsO_4

10. What equilibrium explains how glacial acetic acid allows us to differentiate between the acid strengths of HCl and HBr (collectively represented as HX)?

A. $HX + HC_2H_3O_2 \rightleftharpoons H_2C_2H_3O_2^+ + X^-$

B. $HX + HC_2H_3O_2 \rightleftharpoons H_2X^+ + C_2H_3O_2^-$

C. $H_2C_2H_3O_2^+ + C_2H_3O_2^- \rightleftharpoons 2\ HC_2H_3O_2$

D. $HX + HC_2H_3O_2 \rightleftharpoons C_2H_3O_2^- + X^- + H_2$

11. Which two lattices types have the same packing efficiency?

A. bcc and fcc B. bcc and hcp

C. fcc and hcp D. simple and hcp

E. simple anc fcc

12 – 15. What are characteristics of lattices with low packing efficiency? Circle your choice for each.

12. low melting point or high melting point

13. generally soft or generally hard

14. low density or high density

15. large ionization energy or low ionization energy

16. In close-packed unit cells, the radius of the tetrahedral holes, $r_{tet} = 0.225 r_{sphere}$, and the radius of octahedral holes, $r_{oct} = 0.414\ r_{sphere}$. The ionic radius of Na^+ is 95 pm and that of Br^- is 185 pm. The ratio of these radii, $r_{cation} / r_{anion} = 0.514$. The Na^+ ions occupy

A. all of the tetrahedral holes

B. half of the tetrahedral holes

C. all of the octahedral holes

D. half of the octahedral holes

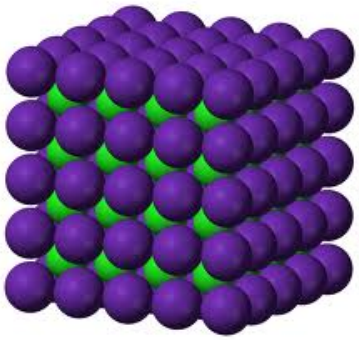
E. all of the cubic holes

F. half of the cubic holes

17. Using the same answers as in the previous problem, what do you predict for MgS, for which the radius ratio is 0.35?

A B C D E F

18 – 19. Use this figure to answer the next two questions:



18. If the green and purple spheres represent the same atom, this lattice is:

A. hcp B. ccp C. bcc

D. simple cubic E. other

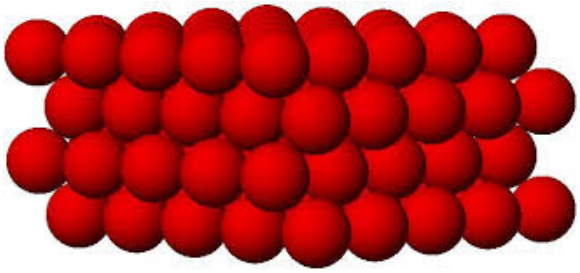
19. If the green and purple spheres represent different ions, this lattice is:

A. NaCl lattice B. CsCl lattice

C. rutile lattice D. wurtzite lattice

E. other

20. The lattice shown here is:



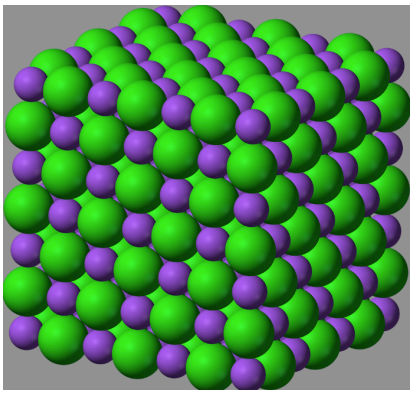
A. hcp B. ccp C. bcc

D. simple cubic E. other

21. What is the coordination number for the cations and anions in NaCl?

A. 4 B. 6 C. 8 D. 12 E. other

22. Which equation is true regarding e, the length of the cell edge for NaCl, shown here. Note r_- = radius of Cl^- and r_+ = radius of Na^+.



A. $e = r_+ + r_-$ B. $e = 2r_-$

C. $e = 2r_+ + 2r_-$ D. $e = 4r / \sqrt{2}$

23. How many Na^+ and Cl^- occupy each unit cell?

A. two of each B. four Na^+ and two Cl^-

C. four of each D. two Na^+ and four Cl^-

24. Suppose NaCl formed using the hcp unit cell rather than the fcc unit cell. How many Na^+ and Cl^- would occupy each unit cell?

A. two of each B. four Na^+ and two Cl^-

C. four of each D. two Na^+ and four Cl^-

25. When would one predict an ionic substance uses the CsCl lattice?

A. when the cations are larger than the anions

B. when the cations are smaller than the anions

C. when the ions are similar in size

D. when there is only one cation per anion

26. What is the ratio of space-filling spheres to octahedral holes to tetrahedral holes in the hcp lattice?

A. 1 : 1 : 2 B. 1 : 2 : 4

C. 2: 1 : 2 D. 1 : 1 : 4

E. other

27 – 32. Predict the sign for each step in the formation of LiF via the Born-Haber cycle.

27. $Li(s) \longrightarrow Li(g)$ ΔH = + or -

28. $Li(g) \longrightarrow Li^+(g) + e^-$ ΔH = + or -

29. $1/2\ F_2(g) \longrightarrow F(g)$ ΔH = + or -

30. $F(g) + e^- \longrightarrow F^-(g)$ ΔH = + or -

31. $Li^+(g) + F^-(g) \longrightarrow LiF(s)$ ΔH = + or -

32. $Li(s) + 1/2\ F_2(g) \longrightarrow LiF(s)$ ΔH_f = + or -

33. Which equation above corresponds to the lattice energy?

27 28 29 30 31 32

34. Ag_2HgI_4 is a yellow solid featuring iodide ions in a cubic close packed array. The Ag^+ and Hg^{+2} ions occupy only tetrahedral holes. What fraction of the tetrahedral holes are occupied?

A. 1/2 B. 1/4 C. 1/8

D. 3/8 E. all F. other

35 – 38. True/False for the Bravis lattice types:

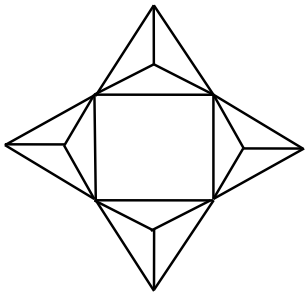
35. T F The tetragonal unit cell has all angles equal to 90^o.

36. T F The monoclinic unit cell has three unique angles, none of which equals 90^o.

37. T F The triclinic unit cell requires the edge lengths to be equal, a = b = c.

38. T F The rhomohedral unit cell requires the edge lengths to be equal, a = b = c.

39. What is the charge on this silicate anion?



A. +2 B. -2 C. +4 D. -4

E. +6 F. -6 G. other

40 – 43. Answer these questions about an n-type semiconductor.

40. An n-type semiconductor could be made by doping silicon with traces of Ga or As. Circle one.

41. An n-type semiconductor has

A. some electrons in antibonding orbitals

B. some empty bonding orbitals

42. When an n-type semiconductor is joined to a p-type semiconductor, the n-type is slightly higher or lower in energy than the p-type. Circle one.

43. In a diode, electrons can flow from n-type to p-type or from p-type to n-type. Circle one.

44. Sodium peroxide reacts with water forming:

A. $Na_2O(aq) + H_2(g)$ B. $NaOH(aq) + O_2(g)$

C. $NaOH(aq) + H_2O_2(aq)$ D. $NaOH(aq) + H_2(g)$

45. Three of the alkali metals form a superoxide salt when burned in oxygen. Which are they?

A. Li, Na, K B. Na, K, Rb C. K, Rb, Cs

46. The alkaline metal oxides all form extremely stable lattices. What lattice type do they utilize?

A. NaCl lattice B. CsCl lattice C. fluorite lattice

D. rutile lattice E. wurtzite lattice

47. Which ONE statement about saline hydrides is not true?

A. Calcium hydride reacts with water to produce $H_2(g)$

B. Saline hydrides are solids.

C. Saline hydrides are air and moisture sensitive.

D. Sodium hydride dissolves in acid.

48. Which statement about the alkali metals is NOT true?

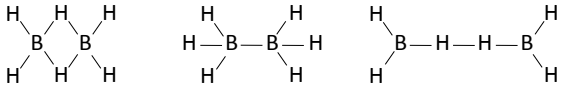
A. Several have densities less than that of water.

B. Several have melting points less than 100 ^{o}C.

C. Several exhibit the fcc lattice in the solid phase.

D. All have electron configurations ending in ns^1.

49. Circle the correct structure of diborane:



50. What is the formula for boric acid?

A. $B(OH)_3$ B. H_2BO_4

C. HBO_4 D. $HB(OH)_3$

51. What accounts for the acidic nature of boric acid?

A. All compounds with a hydrogen in their formula are acidic.

B. The OH group from one boric acid molecule deprotonates another boric acid

C. Boric acid autodissociates.

D. The boron atom is a Lewis acid

52. Aluminum metal reacts with both acids and bases to produce hydrogen gas:

$2\ Al(s) + 6\ H_3O^+(aq) + 6\ H_2O \rightarrow 2\ [Al(OH_2)_6]^{3+}(aq) + 3\ H_2(g)$

$2\ Al(s) + 2\ OH^-(aq) + 6\ H_2O \rightarrow 2\ [Al(OH)_4]^-(aq) + 3\ H_2(g)$

Which ONE statement is true?

A. $[Al(OH)_4]^-(aq)$ is an acidic ion.

B. $[Al(OH)_4]^-(aq) + [Al(OH_2)_6]^{3+}(aq)$ would react to form Al.

C. $[Al(OH_2)_6]^{3+}(aq)$ is a Lewis acid

D. Both reactions (from above) are reversible.

53. The graphite allotropic form of carbon exhibits sp^2 hybridized carbons and the diamond form exhibits sp^3 carbons. What hybridization is exhibited by carbons in buckminsterfullerene?

A. sp B. sp^2 C. sp^3

D. Half sp^2 and half sp^3

54. Allotropes are known for all of these elements except

A. P B. S C. Sn D. Mg

55. What accounts for the "inert" chemical reactivity of $N_2(g)$?

A. Nitrogen does not have available d-orbitals.

B. Nitrogen's triple bond is thermodynamically stable.

C. Nitrogen has a stable half-filled electron configuration $2p^3$.

D. Nitrogen's extremely short bond makes the molecule virtually spherical.

56. $PCl_5(s)$ is actually an ionic substance, consisting of

A. PCl_4^+ and Cl^- B. PCl_4^- and PCl_6^+

C. P^{+5} and five Cl^- D. PCl_4^+ and PCl_6^-

57. The ions/compounds O_2^+, O_2, O_2^-, and O_2^{-2} are respectively

A. paramagnetic, paramagnetic, paramagnetic, and paramagnetic.

B. paramagnetic, diamagnetic, paramagnetic, and diamagnetic.

C. diamagnetic, paramagnetic, diamagnetic, and diamagnetic.

D. paramagnetic, paramagnetic, paramagnetic, and diamagnetic.

58. Fluorine forms some of the strongest bonds in chemistry, often with bond strengths greater than 500 kJ/mol. Which one of these bonds is NOT strong?

A. F-F B. C-F C. Si-F

D. H-F E. B-F F. P-F

59. Diborane bursts into flames upon exposure to air. The reaction (all unbalanced) is:

A. $B_2H_6 + O_2 \rightarrow B_2O_3 + H_2$

B. $B_2H_6 + O_2 \rightarrow B(OH)_3 + H_2$

C. $B_2H_6 + O_2 \rightarrow B + H_2O$

D. $B_2H_6 + O_2 \rightarrow B_2O_3 + H_2O$

60. In the Ostwald process for producing nitric acid, ammonia is burned in air producing $NO_2(g)$. This gas is then reacted with water to produce nitric acid according to:

A. $2\ NO_2(g) + 2\ H_2O(g) \rightarrow 2\ HNO_3(aq) + H_2(g)$

B. $2\ NO_2(g) + 2\ H_2O(g) \rightarrow 2\ HNO_3(aq) + N_2H_4(g)$

C. $3\ NO_2(g) + H_2O(g) \rightarrow 2\ HNO_3(aq) + NO(g)$

D. $2\ NO_2(g) + H_2O(g) \rightarrow 2\ HNO_3(aq) + H_2O_2(g)$

61. Which of these substances has the most covalent character?

A. LiF B. LiI C. $LiCH_3$ D. CaC_2

62. What other gas, besides O_2, supports combustion?

A. NO_2 B. N_2O C. N_2 D. NH_3

63. Which of these is NOT a potential ligand?

A. NH_4^+ B. NH_3 C. NH_2^- D. N_2

64 – 65. The lanthanide contraction accounts for why third row metals have a

64. larger/smaller radius than expected based on the trend for first and second row metals. Circle one.

65. larger/smaller first ionization energy than expected based on the trend for first and second row metals. Circle your choice.

66. How many diastereomers are possible for tetrahedral $ZnCl_2(NH_3)_2$?

A. one B. two C. three D. other

67. How many diastereomers are possible for square planar $PdCl_2(NH_3)_2$?

A. one B. two C. three D. other

68 – 70. The next three questions pertain to the compound $[Cr(OH_2)_3(NH_3)_3](NO_3)_3$.

68. What is the coordination number for chromium?

A. two B. four C. six D. nine

69. What is the oxidation state of chromium?

A. +2 B. +3 C. +6 D. other

70. How many diastereomers are possible?

A. one B. two C. three D. four

71 – 74. The next three questions pertain to the compound $[Rh(en)_2Cl_2](NO_3)$. The "en" is ethylenediamine, $NH_2CH_2CH_2NH_2$.

71. What is the coordination number for rhodium?

A. two B. four C. six D. seven

72. What is the oxidation state of rhodium?

A. +2 B. +3 C. +6 D. other

73. How many diastereomers are possible?

A. one B. two C. three D. four

74. Is the complex chiral? Circle Yes or No

75 – 77. Circle the member of each pair most likely to be low spin.

75. $MnCl_6^{-4}$ or $Mn(CN)_6^{-4}$

76. $Fe(OH_2)_6^{+2}$ or $Ru(OH_2)_6^{+2}$

77. $Fe(NH_3)_6^{+2}$ or $Fe(NH_3)_6^{+3}$

78. For octahedral complexes, what d-electron configurations are either high-spin or low spin?

A. $d^4 – d^7$ B. $d^4 – d^8$ C. $d^0 – d^{10}$ D. $d^4 – d^{10}$

79. Are tetrahedral complexes high or low spin?

A. always high spin B. always low spin

C. both possible D. low spin possible for $d^3 – d^7$

80. Which of these is often associated with square planar complexes

A. high-spin d^8 B. diamagnetic d^8

C. low-spin d^6 D. early transition metals

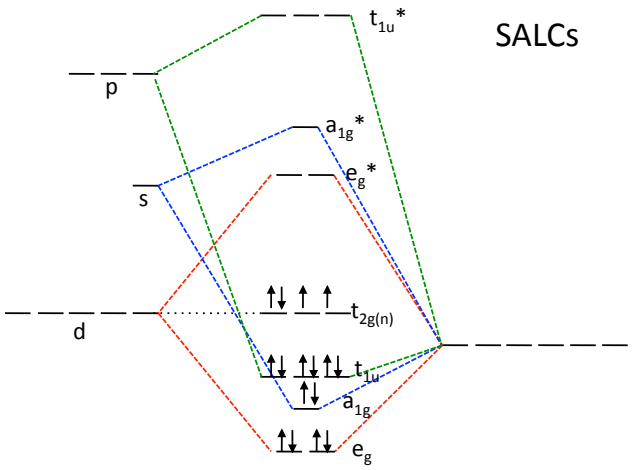
81. Which d-orbital would be highest in energy in a square planar environment according to crystal field energy?

A. d_{xy} B. d_{xz} C. d_{yz} D. $d_{x^2-y^2}$ E. d_{z^2}

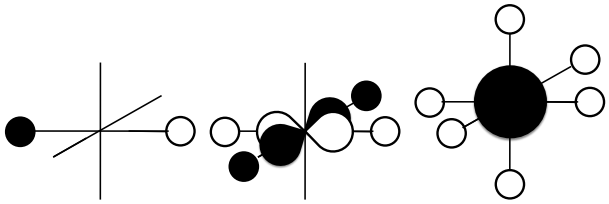
82. Which two d-orbitals would be lowest in energy in a square planar environment according to crystal field energy?

A. d_{xy} & $d_{x^2-y^2}$ B. d_{xz} & d_{yz} C. $d_{x^2-y^2}$ & d_{z^2}

83 – 100. Refer to this MO diagram to answer most of the remaining questions.



83 – 85. Consider these diagrams:



83. What does the first (left) diagram represent?

A. a t_{1u} SALC B. an e_g SALC

C. an a_{1g} SALC D. a t_{1u} MO

E. an e_g MO F. an a_{1g} MO

84. What does the middle diagram represent?

A. a t_{1u} SALC B. an e_g SALC

C. an a_{1g} SALC D. a t_{1u} MO

E. an e_g MO F. an a_{1g} MO

85. What does the third (right) diagram represent?

A. an a_{1g} bonding MO B. an a_{1g} antibonding MO

C. an e_g bonding MO D. an e_g antibonding MO

E. a t_{1u} bonding MO F. a t_{1u} antibonding MO

86 - 87. A coordination chemist would call this complex

86. Circle one: low or high spin

87. Circle one: d 0 1 2 3 4 5 6 7 8 9 10

88. The value referred to as Δ_o is the difference in energy between the MOs labeled:

A. t_{1u} and e_g B. t_{2g} and e_g*

C. t_{1u} and e_g* D. a_{1g} and t_{1u}*

89. Does this diagram represent a system with π-back bonding? Circle: Yes or No

90. Is the complex paramagnetic? Circle: Yes or No

91 – 95. What orbitals constitute the $t_{2g}(n)$? More than one!

A. d_{xy} B. d_{xz} C. d_{yz} D. $d_{x^2-y^2}$ E. d_{z^2}

96 – 99. Octahedral transition metal complexes can have 12 – 22 electrons, depending on factors.

96. Why is 12 the minimum number of electrons?

A. each ligand contributes 2 electrons

B. there are always 12 core electrons

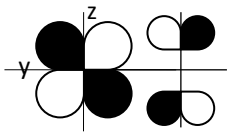
C. the transition metals lose their s-electrons first

D. π-back bonding requires a minimum of 12 electrons.

97. Which member is most likely to allow over 18 electrons (Scenario 1)?

MF_6^{-4} or $M(CN)_6^{-4}$

98. This figure shows the interactions involved in π-back bonding. What is a possible identity of the ligand?



A. PF_3 B. CN^- C. C_2F_4 D. C_2H_6

99. Which complex is most likely to participate in π-back bonding (Scenario 3)?

$Fe(NH_3)_6^{+2}$ or $Fe(CN)_6^{-4}$

100. Referring back to the MO diagram, what molecular orbital changes in energy the most when π-back bonding occurs?

A. a_{1g} B. e_g C. t_{1u} D. t_{2g}

E. a_{1g}* F. e_g* G. t_{1u}*

Answers:

1. B
2. C
3. solid
4. Mg^{+2}
5. Ag^{+}
6. F^{-}
7. S^{-2}
8. B
9. C
10. A
11. C
12. low
13. soft
14. low
15. low
16. C
17. B
18. C
19. B
20. A
21. B
22. C
23. C
24. A
25. C
26. A
27. +
28. +
29. +
30. -
31. -
32. -
33. 31
34. D
35. T
36. F
37. F
38. T
39. G
40. As
41. A
42. lower
43. n-type
44. C (or B)
45. C
46. A
47. D
48. C
49. left figure
50. A
51. D
52. C
53. B
54. Mg
55. B
56. D
57. D
58. A
59. D
60. C
61. C
62. B
63. A
64. smaller
65. larger
66. A
67. B
68. C
69. B
70. B
71. C
72. B
73. B
74. Yes
75. $Mn(CN)_6^{-4}$
76. $Ru(OH_2)_6^{+2}$
77. $Fe(NH_3)_6^{+3}$
78. A
79. A
80. B
81. D
82. B
83. A
84. E
85. B
86. low
87. 4
88. B
89. No
90. Yes

91-95. A, B, C circled

96. A
97. MF_6^{-4}
98. C
99. $Fe(CN)_6^{-4}$
100. D