



# CHMB31H3

## Introduction to Inorganic Chemistry

### Term test 1

October 15, 2018

### Candidate Form

Before you begin your examination, please fill out this form and leave it at the side of your desk along with your student I.D. Please sign at time of collection.

Room # \_\_\_\_\_

Seat # (if assigned) \_\_\_\_\_

Name (please print): \_\_\_\_\_

Surname

Given Names

Student Number:

Course: \_\_CHMB31H3\_\_ Instructor's Name: \_\_Alen Hadzovic\_\_\_\_

Signature: \_\_\_\_\_

(sign only at time form is collected)

**CHMB31H3 – Introduction to Inorganic Chemistry**  
**Term test 1**

**October 15, 2018**

**Answer all questions in full.**

***Value of each question is indicated. Total is 85 marks.***

**Aids Allowed:** Appendix and Periodic Table of Elements (both provided at the back)

Non-programmable calculator

Please, read each question carefully and make sure you have indeed answered every part of each question!!!

**Duration: 90 min (1.5 h)**

**GOOD LUCK!!**

Student Name: \_\_\_\_\_

Student Number: \_\_\_\_\_

1. (15 marks) Fill in the blanks to complete the definitions or statements:

- a. All atoms with the same number of protons (1 word) in their nucleus (1 word) constitute a chemical element.
- b. During the alpha (1 word) decay a radioactive element emits nucleus of  ${}^4\text{He}$ , while during the beta minus decay an electron (1 word) is emitted.
- c. The heaviest element produced in stellar nucleosynthesis is iron. (1 word)
- d. The valence shell electronic configuration  $\text{ns}^2\text{np}^3$  is typical for the elements of Group 15 (1 number) found in p (1 letter) block of the periodic table.
- e. Every wavefunction has a angular (1 word) component and radial (1 word) component.
- f. Atomic radii decrease (1 word) from left to right in the periodic table.
- g. Lewis acids are electron pair donors. (3 words)
- h. Reducing reagent is electron donor. (1 word)
- i. Hybridization of the central atom is determined based on electron (1 word) geometry.

2. (4 marks) Find the missing nuclides/particles (marked with X):

- a.  $\text{X} + {}^{1}\text{n} \rightarrow {}^{239}\text{U} + \gamma$
- b.  ${}^{58}\text{Fe} + 2 {}^{1}\text{n} \rightarrow \text{X} + \beta^-$
- c.  ${}^{56}\text{Fe} + \gamma \rightarrow \text{X} + 2\alpha + 4 {}^{1}\text{n}$
- d.  $\text{X} + {}^{21}\text{Ne} \rightarrow {}^{22}\text{Na} + {}^{11}\text{B}$

Answer:

a.  ${}^{238}\text{U}$

b.  ${}^{60}\text{Co}$

c.  ${}^{44}\text{Ti}$

d.  ${}^{12}\text{C}$

3. (4 marks) The next subshell after f is g subshell.

- What would be the value of the quantum number  $\ell$  for the g subshell?
- How many orbitals would the g subshell have?
- What would be the first shell (defined with the principal quantum number) that would have a g subshell?
- How many nodes a g orbital has?

Answer:

- |               |         |
|---------------|---------|
| a. $\ell = 4$ | b. nine |
| c. $n = 5$    | d. four |

4. (10 marks) The following questions relate to aluminium (Al) and chlorine (Cl).

- Based only on their relative position in the periodic table, decide which one has higher first ionization energy (potential). Explain.
- Calculate  $Z_{\text{eff}}$  for a 3p electron for both Al and Cl (show full calculation not only the final result!!)
- Using your results from b), calculate  $I_1$  for both Al and Cl. Does your prediction from a) match the calculated results?

Answer:

a. Since  $I_1$  increases left-to-right in PTE, Cl should have higher  $I_1$

b. For Al

$$(1s^2)(2s^22p^6)(3s^23p^1)$$

$$\sigma = 2 \times 0.35 + 8 \times 0.85 + 2 \times 1.00 = 9.50$$

$$Z_{\text{eff}} = 13 - 9.50 = 3.50$$

c. For Al

$$I_1(\text{Al}) = \frac{1212.1 \frac{\text{kJ}}{\text{mol}} \times Z_{\text{eff}}^2}{n^2} = \frac{1312.1 \frac{\text{kJ}}{\text{mol}} \times 3.50^2}{3^2}$$

$$= 1785.9 \frac{\text{kJ}}{\text{mol}}$$

The prediction from a) is matching the calc.

For Cl

$$(1s^2)(2s^22p^6)(3s^23p^5)$$

$$\sigma = 6 \times 0.35 + 8 \times 0.85 + 2 \times 1.00 = 10.9$$

$$Z_{\text{eff}} = 17 - 10.9 = 6.10$$

For Cl

$$I_1(\text{Cl}) = \frac{1212.1 \frac{\text{kJ}}{\text{mol}} \times Z_{\text{eff}}^2}{n^2} = \frac{1312.1 \frac{\text{kJ}}{\text{mol}} \times 6.10^2}{3^2}$$

$$= 5424.8 \frac{\text{kJ}}{\text{mol}}$$

5. (7 marks) The following are questions about iodine pentafluoride,  $\text{IF}_5$ .

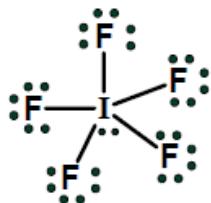
- Based on the position of elements, in the periodic table, decide if I–F bond is nonpolar covalent, polar covalent or ionic.
- Draw a Lewis structure for  $\text{IF}_5$
- Suggest the most plausible electron and molecular geometry for  $\text{IF}_5$ . Comment on any possible deviation from ideal molecular geometry.
- Suggest hybridization scheme for your central atom in this molecule.

Answer:

a.

It is polar covalent

b.



c.

Electron geometry is: octahedral \_\_\_\_\_

Molecular geometry is: square pyramidal \_\_\_\_\_

Comments?

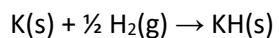
The I – F bond angles are less than  $90^\circ$

d.

$\text{sp}^3\text{d}^2$

6. (10 marks) Consider potassium hydride, KH.

- a. What type of hydride is KH?
- b. If  $r(K^+) = 138 \text{ pm}$  and  $r(H^-) = 145 \text{ pm}$ , suggest a plausible structure for KH.
- c. Potassium hydride can be prepared from K(s) and H<sub>2</sub>(g):



What type of reaction is this?

- d. Draw a Hess cycle for this reaction and show how you would determine  $\Delta H_{\text{latt}}$  from the cycle.

Answer:

a.

saline-like / saline / ionic

b.

138 pm / 145 pm = 0.952 ; CsCl-type structure

c.

redox reaction

d.

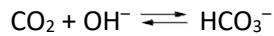
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7. (8 marks) Draw a clear molecular orbital diagram for HCl molecule.

Answer:

8. (5 marks) Identify Lewis acid and Lewis base in the following equilibrium reaction:



- Write the equation for the equilibrium constant for this reaction.
- To which direction (left or right) would equilibrium shift if NaHCO<sub>3</sub> is added? Explain.

Answer:

CO<sub>2</sub> is Lewis acid; OH<sup>-</sup> is Lewis base

$$K = \frac{[\text{HCO}_3^-]}{p_{\text{CO}_2} \times [\text{OH}^-]} \text{ or } K = \frac{[\text{HCO}_3^-]}{[\text{CO}_2] \times [\text{OH}^-]}$$

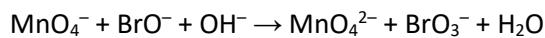
It would shift to the left

9. (2 marks) Estimate pKa<sub>4</sub> for H<sub>5</sub>IO<sub>6</sub>.

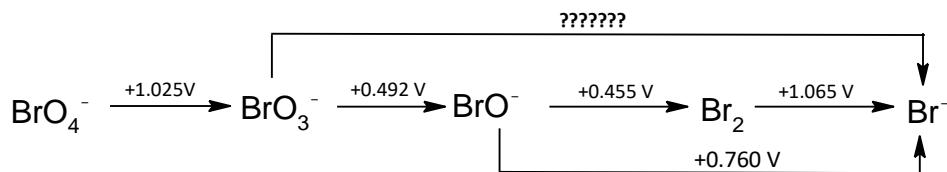
Answer:

pKa<sub>1</sub> = 8 - 5 × 1 = 3 ; pKa<sub>2</sub> = 3 + 5 = 8; pKa<sub>3</sub> = 8 + 5 = 13, pKa<sub>4</sub> = 13 + 5 = 18

10. (12 marks) Consider the following redox reaction that takes place in a basic aqueous solution:



- Write balanced half reactions (e.i. reduction half-reaction and oxidation half-reaction)
- Balance the whole redox reaction
- Determine if the reaction is spontaneous as written above, if the reduction potentials under basic conditions are  $E_{\text{BrO}_3^-, \text{BrO}^-} = +0.492 \text{ V}$  and  $E_{\text{MnO}_4^-, \text{MnO}_4^{2-}} = +0.56 \text{ V}$ .
- Find the missing potential in the Latimer diagram for bromine under basic conditions:



*Answer:*

a.



b.



c.

$$E_{\text{cell}} = E_{\text{red}} - E_{\text{ox}} = +0.56 \text{ V} - (+0.492 \text{ V}) = 0.068 \text{ V}$$

Since  $E_{\text{cell}} > 0$ ,  $\Delta G < 0$  and the reaction is spontaneous.

d.

$$E_{\text{BrO}_3^-, \text{Br}^-} = \frac{4 \times (+0.492 \text{ V}) + 1 \times (+0.455 \text{ V}) + 1 \times (+1.065 \text{ V})}{4 + 1 + 1} = 0.581 \text{ V}$$

Name: \_\_\_\_\_

Student No.: \_\_\_\_\_

11. (6 marks) Calculate partial charge ( $\delta$ ) on Si in  $\text{SiCl}_4$  and on Br in  $\text{BrF}_3$  if  $\chi(\text{Si}) = 1.90$ ,  $\chi(\text{Cl}) = 3.15$ ,  $\chi(\text{Br}) = 2.95$  and  $\chi(\text{F}) = 4.00$ .

Answer:

$$\delta(\text{Si}) = 4 - 0 - 2 \times 4 \left( \frac{1.90}{1.90 + 3.15} \right) = 0.99$$

$$\delta(\text{Br}) = 7 - 4 - 2 \times 3 \left( \frac{2.95}{2.95 + 4.00} \right) = 0.45$$

12. (2 marks) Give one example for:

- Industrial production of  $\text{H}_2$  gas
- Laboratory production of  $\text{H}_2$  gas.

Answer:

a.

steam-hydrocarbon reforming ( $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 3\text{H}_2$ ); or water-gas shift reaction ( $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$ ) or carbon-steam reaction ( $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$ )

b.

a metal (such as Na, K or Li) with  $\text{H}_2\text{O}$  or a metal (Al, Zn, etc.) with acid

- END OF TEST -

**APENDIX: Formulae, tables and plots**

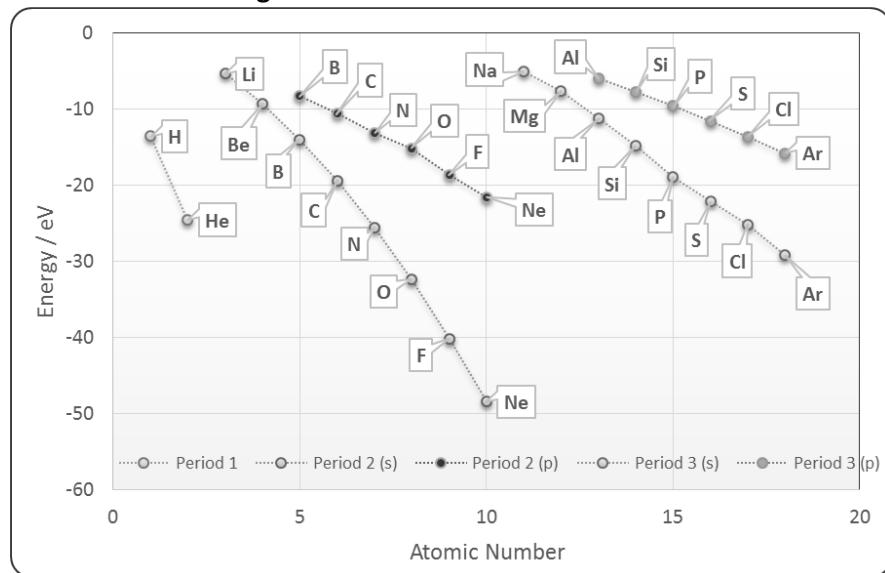
$$I_1 = \frac{1312.1 \frac{kJ}{mol} \times Z_{eff}^2}{n^2}$$

$$\Delta H_{latt} = - \frac{1.07 \times 10^5 \times v \times |z_+||z_-|}{r_+ + r_-} \frac{kJ \times pm}{mol}$$

$$E^0 = \frac{n_A E_A^0 + n_B E_B^0 + \dots}{n_A + n_B + \dots}$$

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

**Approximating pKa:**  $pK_a = 8 - 5p$ ,  $pK_a = pK_a + 5$ ,  $pK_a = pK_a + 5$ , .....

**Valence orbital energies****Hybridization schemes for electron geometries**

Steric Number	Electron geometry	Hybridization Scheme(s)
2	Linear	sp, pd, sd
3	Trigonal planar	sp <sup>2</sup> , p <sup>2</sup> d
4	Tetrahedral	sp <sup>3</sup> , sd <sup>3</sup>
5	Trigonal bipyramidal	sp <sup>3</sup> d
6	Octahedral	sp <sup>3</sup> d <sup>2</sup>

**Ratios for structure types:**

Ratio range	AB type	AB <sub>2</sub> type
0.732 – 1	CsCl	CaF <sub>2</sub>
0.414 – 0.732	NaCl	TiO <sub>2</sub>
0.225 – 0.414	ZnS	-

Name:

Student No.:

1	H	1	1
1,00797		2	
3	Li	4	Be
6,989		9,0122	
11	Na	12	Mg
22,9898		24,3112	
19	K	20	Ca
39,102		40,08	
37	Rb	38	Sr
85,47		87,82	
55	Cs	56	Ba
132,905		137,34	
87	Fr	88	Ra
(223)		(226)	
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