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: __________________

Name: ______________________________ Student No.:_________________________

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}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 ns^2np^3 is typical for the elements of Group _15_ (1 number) fond 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. $\mathbf{X} + {}^{1}n \rightarrow {}^{239}U + \gamma$

   b. ${}^{58}Fe + 2\,{}^{1}n \rightarrow \mathbf{X} + \beta^{-}$

   c. ${}^{56}Fe + \gamma \rightarrow \mathbf{X} + 2\alpha + 4\,{}^{1}n$

   d. $\mathbf{X} + {}^{21}Ne \rightarrow {}^{22}Na + {}^{11}B$

Answer:

a. ^{238}U

b. ^{60}Co

c. ^{44}Ti

d. ^{12}C

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3. (*4 marks*) The next subshell after f is g subshell.
   a. What would be the value of the quantum number ℓ for the g subshell?
   b. How many orbitals would the g subshell have?
   c. What would be the first shell (defined with the principal quantum number) that would have a g subshell?
   d. 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).
   a. Based only on their relative position in the periodic table, decide which one has higher first ionization energy (potential). Explain.
   b. Calculate Z_{eff} for a 3p electron for both Al and Cl (show full calculation not only the final result!!)
   c. 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

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

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

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

For Cl

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

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

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

c. For Al

$$I_1(Al) = \frac{1212.1\frac{kJ}{mol} \times Z_{eff}^2}{n^2} = \frac{\frac{1312.1kJ}{mol} \times 3.50^2}{3^2} = 1785.9\frac{kJ}{mol}$$

The prediction from a) is matching the calc.

For Cl

$$I_1(Cl) = \frac{1212.1\frac{kJ}{mol} \times Z_{eff}^2}{n^2} = \frac{\frac{1312.1kJ}{mol} \times 6.10^2}{3^2} = 5424.8\frac{kJ}{mol}$$

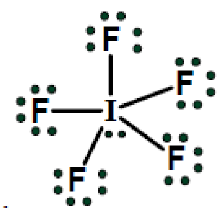
5. (7 *marks*) The following are questions about iodine pentafuloride, IF_5.
    a. Based on the position of elements, in the periodic table, decide if I–F bond is nonpolar covalent, polar covalent or ionic.
    b. Draw a Lewis structure for IF_5
    c. Suggest the most plausible electron and molecular geometry for IF_5. Comment on any possible deviation form ideal molecular geometry.
    d. 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°

d.

sp^3d^2

6. (10 *marks*) Consider potassium hydride, KH.
   a. What type of hydride is KH?
   b. If $r(K^+)$ = 138 pm and $r(H^-)$ = 145 pm, suggest a plausible structure for KH.
   c. Potassium hydride can be prepared from K(s) and H_2(g):

$$K(s) + \tfrac{1}{2} H_2(g) \longrightarrow KH(s)$$

   What type of reaction is this?

   d. Draw a Hess cycle for this reaction and show how you would determine ΔH_{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:

$$CO_2 + OH^- \rightleftharpoons HCO_3^-$$

- Write the equation for the equilibrium constant for this reaction.
- To which direction (left or right) would equilibrium shift if $NaHCO_3$ is added? Explain.

Answer:

CO_2 is Lewis acid; OH^- is Lewis base

$K = \frac{[HCO_3^-]}{p_{CO_2} \times [OH^-]}$ or $K = \frac{[HCO_3^-]}{[CO_2] \times [OH^-]}$

It would shift to the left

9. (*2 marks*) Estimate pKa_4 for H_5IO_6.

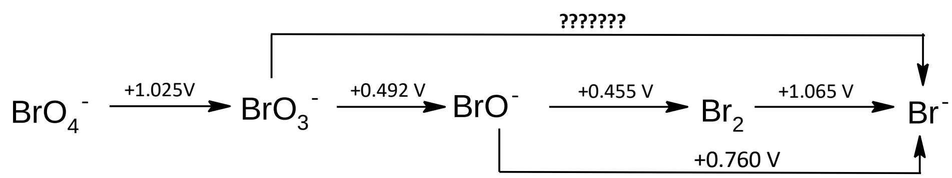
Answer:

$pKa_1 = 8 - 5 \times 1 = 3$; $pKa_2 = 3 + 5 = 8$; $pKa_3 = 8 + 5 = 13$, **$pKa_4 = 13 + 5 = 18$**

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

$$MnO_4^- + BrO^- + OH^- \longrightarrow MnO_4^{2-} + BrO_3^- + H_2O$$

a. Write balanced half reactions (e.i. reduction half-reaction and oxidation half-reaction)
b. Balance the whole redox reaction
c. Determine if the reaction is spontaneous as written above, if the reduction potentials under basic conditions are $E_{BrO_3^-,BrO^-}$ = + 0.492 V and $E_{MnO_4^-,MnO_4^{2-}}$ = +0.56 V.
d. Find the missing potential in the Latimer diagram for bromine under basic conditions:



Answer:

a.

reduction half reaction: $MnO_4^- + e^- \rightarrow MnO_4^{2-}$

oxidation half reaction: $BrO^- + 4\ OH^- \rightarrow BrO_3^- + 4e^- + 2\ H_2O$

b.

$4\ MnO_4^- + BrO^- + 4\ OH^- \rightarrow 4\ MnO_4^{2-} + BrO_3^- + 2\ H_2O$

c.

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

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

d.

$$E_{BrO_3^-,Br^-} = \frac{4 \times (+0.492V) + 1 \times (+0.455V) + 1 \times (+1.065\ V)}{4+1+1} = 0.581\ V$$

11. (6 *marks*) Calculate partial charge (δ) on Si in $SiCl_4$ and on Br in BrF_3 if $\chi(Si) = 1.90$, $\chi(Cl) = 3.15$, $\chi(Br) = 2.95$ and $\chi(F) = 4.00$.

Answer:

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

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

12. (2 *marks*) Give one example for:
    a. Industrial production of H_2 gas
    b. Laboratory production of H_2 gas.

Answer:

a.

steam-hydrocarbon reforming ($CH_4 + H_2O \rightarrow CO_2 + 3H_2$); or water-gas shift reaction ($CO + H_2O \rightarrow CO_2 + H_2$) or carbon-steam reaction ($C + H_2O \rightarrow CO + H_2$)

b.

a metal (such as Na, K or Li) with H_2O or a metal (Al, Zn, etc.) with acid

- END OF TEST –

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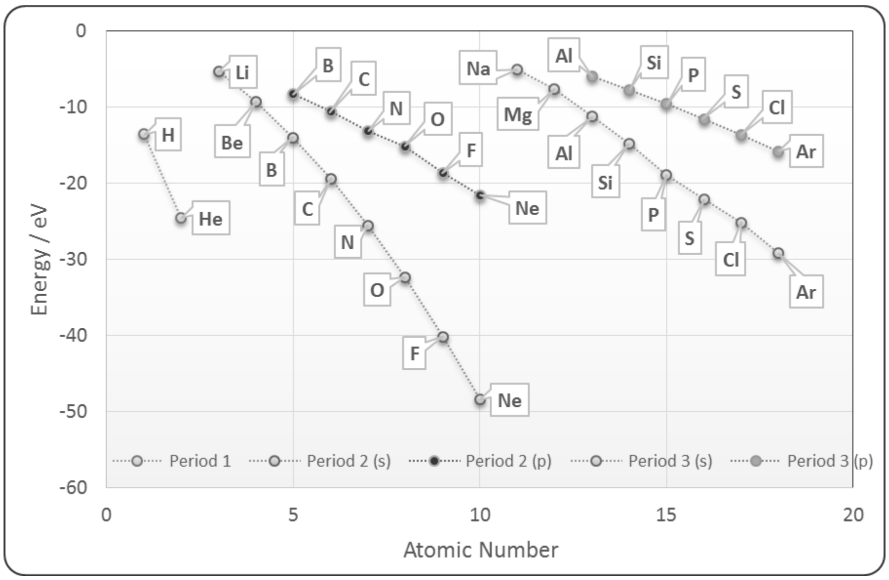
APENDIX: Formulae, tables and plots

$$I_1 = \frac{1312.1\frac{kJ}{mol}\times Z_{eff}^2}{n^2} \qquad \Delta H_{latt} = -\frac{1.07\times10^5\times\nu\times|z_+||z_-|}{r_+ + r_-}\frac{kJ\times pm}{mol} \qquad E^0 = \frac{n_A E_A^0 + n_B E_B^0 + \cdots}{n_A + n_B + \cdots}$$

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

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

Valence orbital energies



Hybridization schemes for electron geometries

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

Ratios for structure types:

Ratio range	**AB type**	**AB_2 type**
0.732 – 1	CsCl	CaF_2
0.414 – 0.732	NaCl	TiO_2
0.225 – 0.414	ZnS	-

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1,00797																	2 He 4,0026
2	3 Li 6,989	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)		114 Fl (285)		116 Lv (289)		118 Uuo ? (293)
	s		d										p					

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)
	f													