Chemistry I Midterm Exam

15 Nov, 2013

Periodic Table of Elements

1 H 1.0																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 40.0
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)

Constants

$e = 1.60\times10^{-19}$ C

$c = 3.00\times10^{8}$ m·s^{-1}

mass of electron $m_e = 9.11\times10^{-31}$ kg

Avogadro's constant $N_A = 6.02\times10^{23}$ mol^{-1}

Plank's constant $h = 6.626\times10^{-34}$ J·s

Rydberg constant $R = 3.29\times10^{15}$ Hz

1. The kinetic energy of an electron that is emitted from the surface of a potassium sample by a photon is 1.80×10^{-19} J. The work function of potassium is 2.29 eV.
   (a) What is the frequency of the radiation that caused photoejection of the electron? (6%)
   (b) What is the type of this electromagnetic radiation, UV, visible, or IR? (2%)
   (c) The ionization energy of potassium is 418 kJ·mol^{-1}. Is this value equal to the work function of potassium? Why? (4%)

2. (a) List all the valid values of the magnetic quantum number for the 6f-subshell. (2%)

(b) Indicate the mistakes of the quantum number set for an atom: $\{n, l, m_l, m_s\}$ = {3, 0, 1, -1}. (4%)

3. Answer the following questions briefly:
   (a) What is the "inert-pair effect" on heavy atoms? (4%)
   (b) What is a "radical"? (4%)
   (c) What are "parallel spins"? (for electrons) (4%)
   (d) What is the "dissociation energy" of a bond? (4%)
   (e) Is this true that Al^{3+} has greater polarizing power to distort the electron cloud of a neighboring anion than Cs^{+}? Why? (4%)

4. We have an 1-D box of length 300 pm in which there is an electron with quantum number n = 3. What is the probability of finding this electron in a small region at a distance 25 pm from the left wall of the box relative to the probability of finding it in the same small region located at the center of the box? (5%)

5. Write the Lewis structures that obey the octet rule, and determine the formal charge on each atom of the following molecules/ions: (a) P_4 ; (b) HSO_4^- ; (c) N_3^- ; (d) NH_3BF_3 . (5% each)

6. Write the Lewis structure, VSEPR formula, molecular shape, and bond angles for each of the following species: (a) I_3^- ; (b) $POCl_3$; (c) IO_3^- . (5% each)

7. (a) The ground-state electron configuration of the ion H_2^{n-} is $\sigma_{1s}^2\ \sigma_{1s}^{*2}$.What is the charge on the ion? And what is its bond order? (2%)
   (b) The ground-state electron configuration of the ion O_2^{n+} is $\sigma_{2s}^2\ \sigma_{2s}^{*2}\ \sigma_{2p}^2\ \pi_{2p}^4$. What is the value of n? What is its bond order? Is it paramagnetic? (3%)

8. (a) Draw a molecular orbital energy-level diagram for N_2 and label the energy levels according to the type of orbitals from which they are formed , whether they are σ- or π-orbitals, and whether they are bonding or antibonding. (4%)

(b) Draw the energy-level diagram for NO^+. (4%)

(c) In the molecular orbitals of NO^+, will the electrons have a higher probability of being at N or O? Why? (2%)

9. Draw the molecular orbital energy-level diagram for the π-orbitals of benzene and label the HOMO and LUMO. (7%)

Answers

1.(a)

1 eV = 1.60×10^{-19} C × 1 V = 1.60×10^{-19} J ; 2.29 eV = 3.66×10^{-19} J ;

$h\nu = (1.80\times10^{-19} + 3.66\times10^{-19})$; $\nu = 8.24\times10^{14}$ Hz

(b)

$\nu = 8.24\times10^{14}$ Hz ; $\lambda = 3.64\times10^{-7}$ m ; UV

(c)

work function 2.29 eV = 3.66×10^{-19} J ➔ 220 kJ·mol^{-1} ; different to the ionization energy (2%)

In photoelectric process, the electron is ejected from solid metal. But in determining the ionization energy, the electron is from an atom in gas phase. (2%)

2.(a)

3, 2, 1, 0, -1, -2, -3

(b)

when $l = 0$, m_l cant not be 1 (2%)

m_s can not be -1 (2%)

3.(a)

Heavy atoms may form cations two units lower in charge than expected from the group number.

(b)

A species have at least one unpaired electron.

(c)

Electrons with spins aligned in the same direction. (*or* with the same spin quantum number m_s)

(d)

The energy required for breaking a chemical bond homolytically. (文字說明或化學反應式中未表現 homolytically 扣 2%)

(e)

Al^{3+} is more highly charged (2%) , and has smaller ionic radius. (2%)

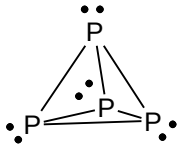
4.

$$\psi(x) = A\sin\left(\frac{n\pi x}{L}\right) = A\sin\left(\frac{3\pi x}{300}\right)$$

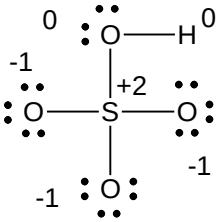
$$\text{ratio of probability} = \frac{\psi^2(25)}{\psi^2(150)} = \frac{A^2\sin^2(\pi/4)}{A^2\sin^2(3\pi/2)} = \frac{\left(\sqrt{2}/2\right)^2}{(-1)^2} = 0.5$$

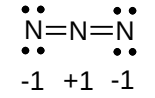
5.

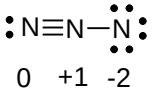
(a) (b) (c) 二者皆可 (d)

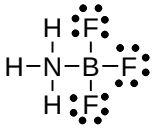


all P atom with formal charge 0





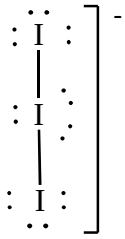


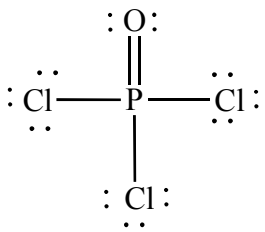


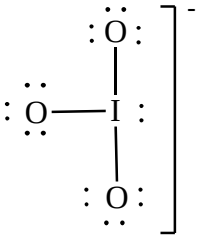
formal charge:
all H & F atoms = 0
N = +1, B = -1

配分：Lewis structure 2%；formal charges 3% 錯一個扣 1%

6.

(a) 

(b) 

(c) 

(resonance forms possible)

(a) The I_3^- molecule is predicted to be linear, so the I—I—I angle should equal 180°. AX_2E_3

(b) The $POCl_3$ molecule is tetrahedral. All bond angles should be 109.5°. AX_4

(c) The shape of IO_3^- will be a trigonal pyramid, so the O—I—O bond angles should be less than 109.5°. AX_3E

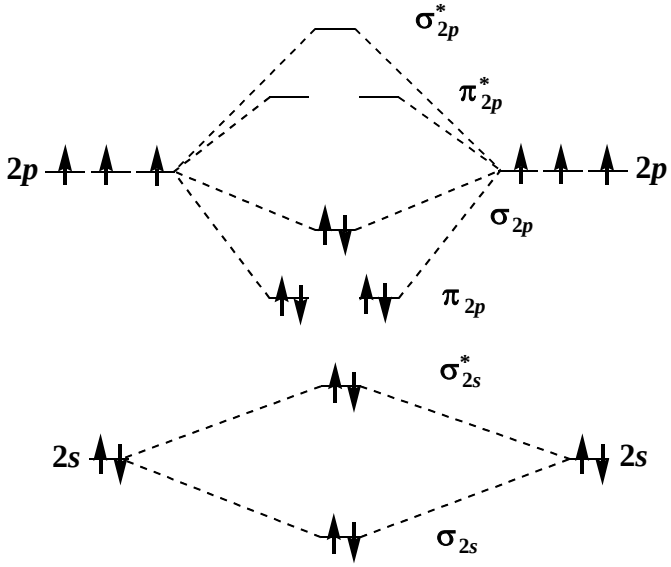
配分：Lewis structure 2%；VSEPR formula、molecular shape、bond angle 各 1%

7.(a) The charge on H_2^{n-} is -2 and the bond order is 0.

(b) n = 2. BO = 3. No.

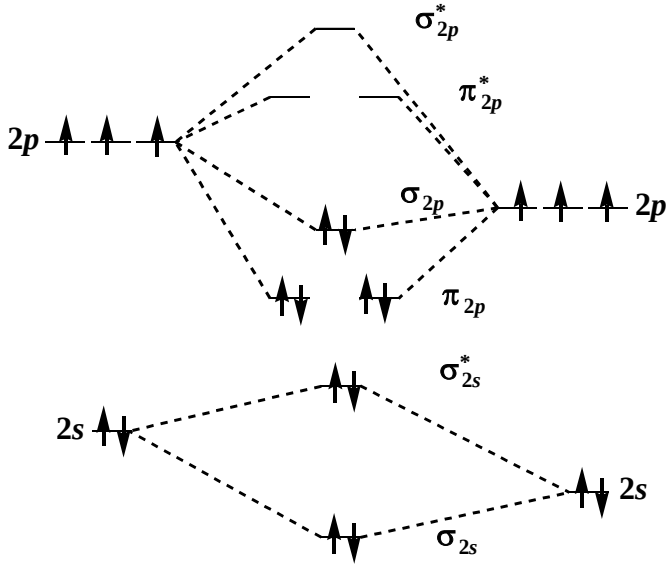
8.

The energy level diagram for N_2 is as follows:



(b)

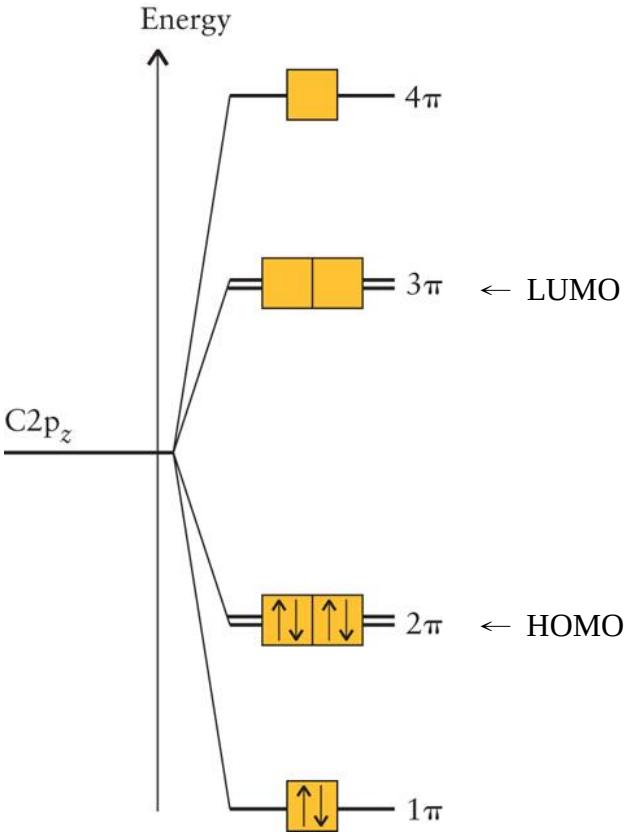
Energy level diagram for NO^+



Orbitals on N Orbitals on O

(c) The electrons in the bonding orbitals will have a higher probability of being at O because O is more electronegative and its orbitals are lower in energy.

9.



配分：energy-level diagram 5%；HOMO、LUMO 標示各 1%