

2024 SPRING Semester Mid-term Examination
For General Chemistry I

Date: April 17(Wed), Time Limit: 19:00 ~ 21:00

Write down your information neatly in the space provided below; print your Student ID in the upper right corner of every page.

Professor Name	Class	Student I.D. Number	Name

Problem	points	Problem	points	TOTAL pts
1	/15	6	/8	/100
2	/8	7	/10	
3	/8	8	/16	
4	/10	9	/15	
5	/10			

** This paper consists of 21 sheets with 9 problems (*page 18 - 20*: Equation, constants & periodic table, *page 21*: claim form). Please check all page numbers before taking the exam. Write down your work and answers in the Answer sheet. Please write down the unit of your answer when applicable. You will get 30% deduction for a missing unit.

NOTICE: SCHEDULES on RETURN and CLAIM of the MARKED EXAM PAPER.

(채점 답안지 분배 및 이의신청 일정)

1. Period, Location and Procedure

0 Return and Claim Period: **April 22 (Monday, 19:00 ~ 21:00, 2 hrs)**

The claim is permitted only on this period. Keep that in mind!

0 Location: Each designated room of Creative Learning Bldg. (E11)

Class	Room(E11)
A	301
B	302
C	309
D	303

Procedure

Rule 1: Students cannot bring their writing tools into the rooms (Use a pen only provided by TA)

Rule 2: With or without claim, you must submit the paper back to TA. (Do not go out of the room with it)

If you have any claims on it, write them on the claim form and attach it to the top of the exam paper with a stapler. Give them to your TA.

WARNING!!

If you deliberately alter any original answers or insert something on your marked paper to achieve a better grade, you will get a F grade for this course. Or if you don't keep the rules above, we will regard it as a kind of cheating and give you 0 point. So please don't cheat.

2. Final Confirmation

1) Period: *April 25(Thu.) ~ 26(Fri.)*

2) Procedure: During this period, you can check final score of the examination *on the website* again.

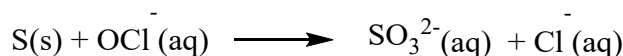
(No additional corrections. If no change in your score after reasoning, the claims were not accepted.)

**** For further information, please visit General Chemistry website at www.gencheminkaist.pe.kr**

1. (15 points)

Answer the following questions:

(a) (3 points) Balance the equation for this reaction in basic solution.



(b) (3 points) Define the term 'polarizability' and explain its significance in the context of atomic and molecular behavior.

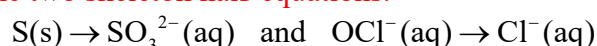
(c) (3 points) Describe what an electrostatic potential map represents and explain the significance of the red and blue color domains in this map.

(d) (3 points) When 70.5 mg of a sample of potassium phosphate (K_3PO_4) was added to 15.0 mL of 0.050 M silver nitrate (AgNO_3) solution, a precipitate formed. How many moles of precipitation are produced?

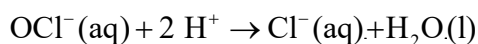
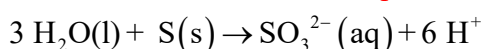
(e) (3 points) Arrange the following compounds in order of higher boiling points, and justify in terms of relevant intermolecular interactions. (a) n-butane; (b) ethene, (c) methane, (d) butanoic acid; (e) 1-propanol.

(a)

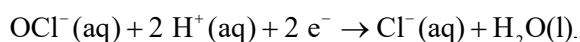
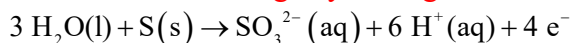
Step 1: Write the two skeleton half-equations.



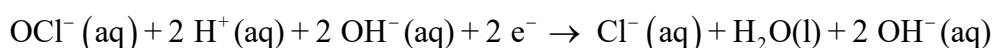
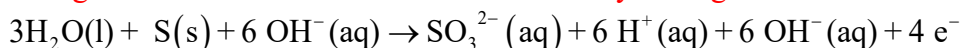
Step 2: Balance each skeleton half-equation for O (with H_2O) and for H atoms (with H^+).



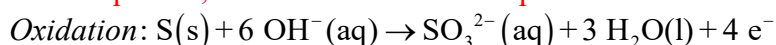
Step 3: Balance electric charge by adding electrons.

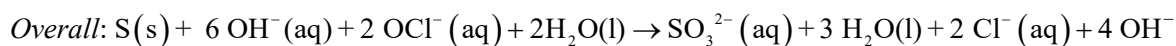
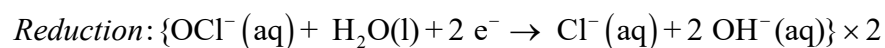


Step 4: Change from an acidic medium to a basic one by adding OH^{-} to eliminate H^+ .

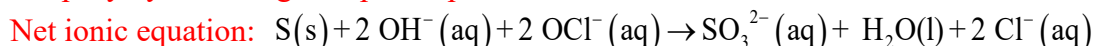


Step 5: Simplify by removing the items present on both sides of each half-equation, and combine the half-equations to obtain the net redox equation.





Simplify by removing the species present on both sides.

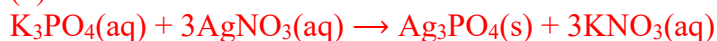


(b) The polarizability provides a measure of the extent to which an electron cloud can be distorted by the application of an electric field or the approach of another molecule.

Polarizability increases with the size of the atom.

(c) The electrostatic potential map is obtained by hypothetically probing an electron density surface with a positive point charge. The positive point charge will be attracted to an electron-rich region—a region of excess negative charge when all the charges of the nuclei and electrons have been taken into account—and the electrostatic potential will be negative.

(d)



$$\text{K}_3\text{PO}_4 \ 70.5 \text{ mg} = 0.0705/212 = 0.333 \text{ mmol.}$$

$$\text{AgNO}_3 = 0.050 \text{ M} \times 15.0 \text{ mL} = 0.75 \text{ mmol.}$$

K_3PO_4 and AgNO_3 react in a 1:3 ratio. Limiting reactant = AgNO_3 .

AgNO_3 and Ag_3PO_4 have a 3:1 relationship.

Precipitated Ag_3PO_4 occurs at 1/3 (mol) of the occurrence of AgNO_3

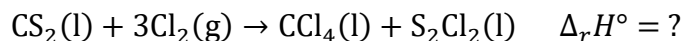
i.e. 0.25 mmol

(e) in order of increasing boiling points: Methane < Ethene < n-Butane < 1-Propanol < Butanoic Acid. The key determining factors are the types and strengths of intermolecular interactions: London dispersion forces, dipole-dipole interactions, and hydrogen bonding.

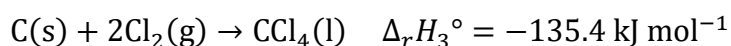
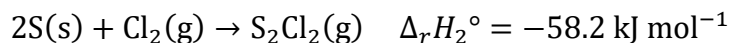
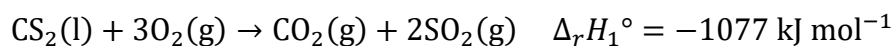
2 (8 points)

CCl_4 , an important commercial solvent, is prepared by the reaction of $\text{Cl}_2(\text{g})$ with a carbon compound.

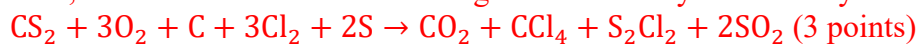
Determine $\Delta_r H^\circ$ for the reaction



Use appropriate data from the following listing.



First, we can see that we are able to get the necessary reactants by combining first three reactions.



However, this reaction has chemical species that need to be eliminated: O_2 , C , 2S , CO_2 , and SO_2 .

Using the last two reactions, all of these chemical species could be eliminated.

Therefore,

$$\begin{aligned} \Delta_r H^\circ &= \Delta_r H_1^\circ + \Delta_r H_2^\circ + \Delta_r H_3^\circ - 2 \times \Delta_r H_4^\circ - \Delta_r H_5^\circ \\ &= -284 \text{ kJ mol}^{-1} \quad (5 \text{ points}) \end{aligned}$$

3. (8 points)

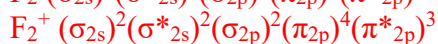
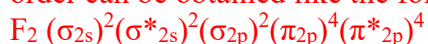
Consider a scenario where an electron is removed from a fluorine molecule, resulting in the formation of an F_2^+ molecular ion.

- (a) (2 points) Provide the molecular electron configurations for both F_2 and F_2^+ .
- (b) (2 points) Determine and state the bond order for each species, F_2 and F_2^+ .
- (c) (2 points) Based on the electron configurations, identify which species (F_2 or F_2^+) is expected to be paramagnetic.
- (d) (2 points) Using your understanding of molecular structure and bonding, predict which species, F_2 or F_2^+ , possesses higher bond dissociation energy.

Answer

(a) (2 pts)

F_2 is a homonuclear diatomic molecule, which has 18 electrons of which 14 are valence electrons. The F_2^+ ion has lost a valence electron and so has 13. Based on the correlation diagram for F_2 , the energetic order can be obtained like the following.



(b) (2 pts) The F_2 molecule has two more bonding than antibonding electrons. Its order is 1; F_2^+ ion has three more bonding than antibonding electrons. Its bonding order is $3/2$.

(c) (2 pts) The F_2 molecule has zero unpaired electrons. Accordingly, F_2 is diamagnetic. The F_2^+ ion has an odd number of electrons. Because at least one electron (a π_{2p}^* electron) is unpaired. So, F_2^+ ion is paramagnetic.

(d) (2 pts) The F_2^+ ion has a larger bond order and therefore requires more energy to dissociate than F_2 ion's case.

4. (10 points)

Maxwell-Boltzmann distribution of speed is given by the following equation

$$f(v) = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} v^2 e^{-mv^2/2k_B T}$$

Where k_B is Boltzmann constant, T is temperature, and v is the speed.

- (a) (4 points) Show that the root-mean-square speed (v_{rms}) is larger than the most probable speed (v_{mp}).
- (b) (3 points) Calculate the ratio of rms speed of H_2 to that of N_2 at room temperature ($v_{rms, H_2}/v_{rms, N_2}$).
- (c) (3 points) Calculate the ratio of rms speed of H_2 at 273 °C to that of H_2 at 0°C (v_{rms} at 273 °C / v_{rms} at 0°C).

Answer: (a)

Most probable speed:

$$v_{mp} = \sqrt{\frac{2k_B T}{m}} = \sqrt{\frac{2RT}{M}} \quad \left[\frac{df(v)}{dv} = 0 \right]_{v=v_{mp}}$$

Mean square speed:

$$\overline{v^2} = \int_0^{\infty} v^2 f(v) dv = \frac{3k_B T}{m} = \frac{3RT}{M}$$

Root-mean-square speed:

$$v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{M}}$$

So root-mean-square speed is larger than the most probable speed

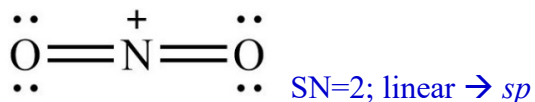
(b) $v_{rms, H_2}/v_{rms, N_2} = (M_{N_2}/M_{H_2})^{1/2} = 14^{1/2}$

(c) v_{rms} at 273 °C / v_{rms} at 0°C = $(273+273 \text{ K} / 273\text{K})^{1/2} = 2^{1/2}$

5. (10 points)

Answer the following questions.

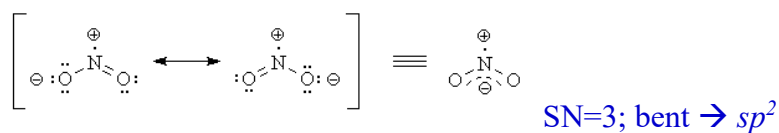
(a) (2 points) Draw the most accepted Lewis (dot) structure for NO_2^+ , predict its molecular shape according to the VSEPR model, and assign the appropriate hybridization for the central N atom.



Structure: +1

Hybridization: +1

(b) (3 points) Draw the most accepted Lewis (dot) structure for NO_2 , predict its molecular shape according to the VSEPR model, and assign the appropriate hybridization for the central N atom.

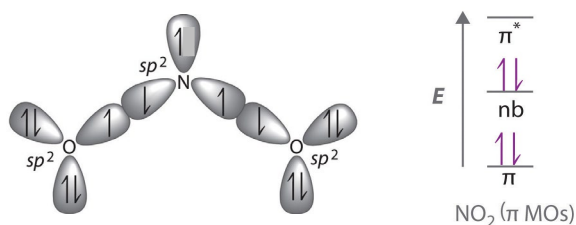


Structure: +1

Hybridization: +1

Resonance: +1

(c) (2 points) You have studied the delocalized π -bonding molecular orbitals for ozone in class. Likewise, draw an energy-level diagram of the π -bonding molecular orbitals, with electrons allocated, based on the Lewis structure for NO_2 proposed in (b).

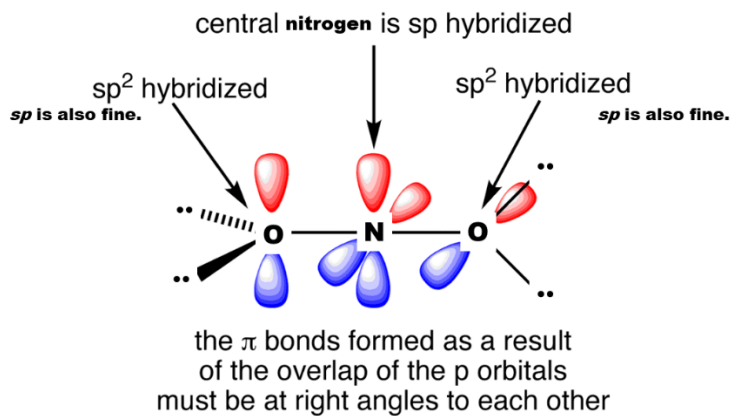


Energy diagram: +1

Electrons: +1

* It is NOT needed to draw something like the left one.

(d) (3 points) Draw an energy-level diagram of the π -bonding molecular orbitals, with electrons allocated, based on the Lewis structure for NO_2^+ given in (a). OR describe the bond (σ and π) characters/geometries with the hybridization concept.



All or nothing!

6. (8 points)

An electron is confined to a 1.2 nm one-dimensional box. Considering that visible light has a wavelength between 400 nm and 700 nm, (a) & (b) determine whether the following transition results in the visible spectrum.

(a) (2 points) $n=2$ to $n=1$

(b) (2 points) $n=3$ to $n=1$

(c) (4 points) Suppose this electron undergoes transitions among all possible states, and several visible spectral lines are observed as a result of these transitions. How many visible spectral lines must be observed?

(a)

$$E_n = \frac{n^2 h^2}{8mL^2}$$

$$E_2 - E_1 = (2^2 - 1^2) \cdot \frac{h^2}{8mL^2} = \frac{3h^2}{8mL^2} = \frac{3 \times (6.626 \times 10^{-34} \text{ J s}^{-1})^2}{8 \times (9.109 \times 10^{-31} \text{ kg}) \times (1.2 \times 10^{-9} \text{ m})^2}$$

$$= 1.3 \times 10^{-19} \text{ J} = h \frac{c}{\lambda} \dots + 1 \text{ pt}$$

$$\therefore \lambda = \frac{hc}{E_2 - E_1} = \frac{(6.626 \times 10^{-34} \text{ J s}^{-1}) \times (2.998 \times 10^8 \text{ m s}^{-1})}{1.3 \times 10^{-19} \text{ J}} = 1520 \text{ nm} \dots + 2 \text{ pt}$$

It is above 700 nm, so it does NOT result in the visible spectrum.

(b)

$$E_3 - E_1 = (3^2 - 1^2) \cdot \frac{h^2}{8mL^2} = \frac{8h^2}{8mL^2} = \frac{8 \times (6.626 \times 10^{-34} \text{ J s}^{-1})^2}{8 \times (9.109 \times 10^{-31} \text{ kg}) \times (1.2 \times 10^{-9} \text{ m})^2}$$

$$= 3.3 \times 10^{-19} \text{ J} = h \frac{c}{\lambda} \dots + 1 \text{ pt}$$

$$\lambda = \frac{hc}{E_3 - E_1} = \frac{(6.626 \times 10^{-34} \text{ J s}^{-1}) \times (2.998 \times 10^8 \text{ m s}^{-1})}{3.3 \times 10^{-19} \text{ J}} = 600 \text{ nm} \dots + 2 \text{ pt}$$

It is within the 400 nm – 700 nm region, so it DOES result in the visible spectrum.

(c)

For any transition from n_i to n_f where $i > f$,

$$\lambda = \frac{hc}{\Delta E} = hc \times \frac{8mL^2}{(n_i^2 - n_f^2)h^2} = \frac{8mcL^2}{(n_i^2 - n_f^2)h}$$

$$= \frac{8 \times (9.109 \times 10^{-31} \text{ kg}) \times (2.998 \times 10^8 \text{ m s}^{-1}) \times (1.2 \times 10^{-9} \text{ m})^2}{(n_i^2 - n_f^2) \times (6.626 \times 10^{-34} \text{ J s}^{-1})} = \frac{475 \text{ nm}}{n_i^2 - n_f^2}$$

In order to fall in the visible region:

$$400 \text{ nm} < \frac{475 \text{ nm}}{n_i^2 - n_f^2} < 700 \text{ nm} \dots + 2 \text{ pt}$$

$$6.78 < n_i^2 - n_f^2 < 11.9$$

There are four transitions satisfying this condition: 3 to 1, 4 to 3, 5 to 4, and 6 to 5. ...+2 pt

Therefore, four visible spectral lines must be observed.

7. (10 points)

Electrons in molecules are described by wavefunctions that extend over more than one atom. Consider an electron that is located in the π -bonding molecular orbital that extends over two adjacent carbon atoms in ethene. The electron can move *freely* between the two C atoms. The internuclear C=C distance is 134 pm.

(1) (2 points) Using the one-dimensional particle-in-the-box model, calculate the wavelength of light that is required to promote an electron from the $n=1$ to the $n=2$ level, assuming that the length of the box is the same as the distance between the two carbon atoms. Express the wavelength in nm.

>>

$$E_n = \frac{n^2 h^2}{8mL^2}$$
$$E_2 - E_1 = h\nu = hc/\lambda$$
$$\frac{6.626 \times 10^{-34} \text{m}^2 \text{kg s}^{-1}}{8(9.109 \times 10^{-31} \text{kg})(1.34 \times 10^{-10} \text{m})^2} (4 - 1) = \frac{2.998 \times 10^8 \text{m/s}}{\lambda}$$
$$\lambda = 1.97 \times 10^{-8} \text{ m} = 19.7 \text{ nm}$$

(2) (3 points) Let's use the same model for 1,3-butadiene ($\text{H}_2\text{C}=\text{CH}-\text{CH}=\text{CH}_2$). Let's assume that we can ignore bond angles and find the size of the box by adding C=C and C-C bond lengths, which is 134 and 148 pm, respectively. Calculate the wavelength of light that can promote an electron from HOMO to LUMO.

>> Since the system has four π electrons, HOMO and LUMO are $n=2$ and 3 levels, respectively.

$$\frac{6.626 \times 10^{-34} \text{m}^2 \text{kg s}^{-1}}{8(9.109 \times 10^{-31} \text{kg})((1.34 \times 2 + 1.48) \times 10^{-10} \text{m})^2} (9 - 4) = \frac{2.998 \times 10^8 \text{m/s}}{\lambda}$$
$$\lambda = 1.14 \times 10^{-7} \text{ m} = 114 \text{ nm}$$

(3) (5 points) To develop molecules that can emit visible light (400-700 nm), what are the minimum and maximum numbers of double bonds that should be included in the molecules? Assume that the molecule is linear and has the conjugated π system such as $\text{C}=\text{C}-\text{C}=\text{C}$, $\text{C}=\text{C}-\text{C}=\text{C}-\text{C}=\text{C}$, $\text{C}=\text{C}-\text{C}=\text{C}-\text{C}=\text{C}-\text{C}=\text{C}$, and so on. Assume that the light emission is associated with the LUMO \rightarrow HOMO transition.

>> As seen above, for the system that has n double bonds and thus $2n$ π electrons, the HOMO-LUMO gap is $E_{n+1}-E_n$.

$$\lambda = \frac{2.998 \times 10^8 \text{m/s}}{\frac{6.626 \times 10^{-34} \text{m}^2 \text{kg s}^{-1}}{8(9.109 \times 10^{-31} \text{kg})((1.34n + 1.48 \times (n - 1)) \times 10^{-10} \text{m})^2} (2n + 1)}$$

For $n = 1$, $\lambda = 19.7 \text{ nm}$

For $n = 2$, $\lambda = 114 \text{ nm}$

For $n = 3$, $\lambda = 229 \text{ nm}$

For $n = 4$, $\lambda = 352 \text{ nm}$

For $n = 5$, $\lambda = 477 \text{ nm}$; the minimum # of C=C bonds

For $n = 6$, $\lambda = 605 \text{ nm}$; the maximum # of C=C bonds

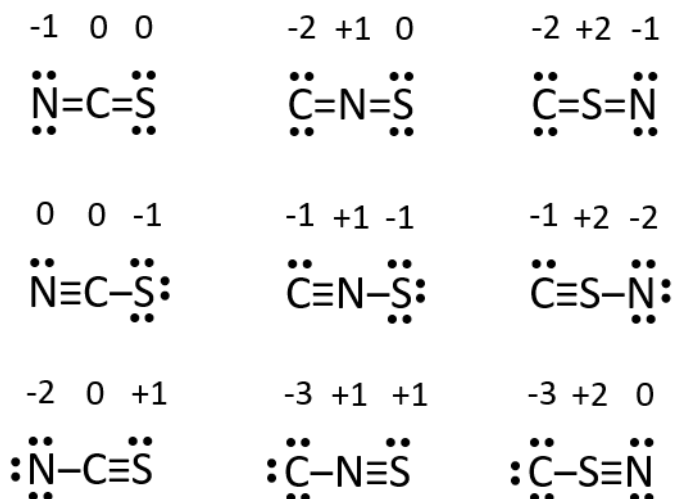
For $n = 7$, $\lambda = 733 \text{ nm}$

8. (16 points)

To detect the presence of Fe(III), the solution of potassium thiocyanate (KSCN) can be used, because Fe-thiocyanate compounds display a blood-red color. There are two binding modes for the Fe-thiocyanate bond formation; N-bonding and S-bonding. To explain this phenomenon, let's consider Lewis structure for thiocyanate anion.

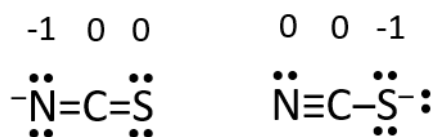
(1) (9 points) Draw all nine possible Lewis structures for a thiocyanate anion and write formal charges for each atom in each Lewis structure.

>>

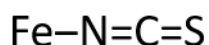


(2) (2 points) What are the two most likely structures considering the formal charge distributions? Draw the structures for the N-bonding and S-bonding modes.

>> Structures with the least charge separation are more likely. Thus, the following two structures are the most likely structures. Considering the electronegativities of N and S, 3.0 and 2.5, respectively, the left structure is more stable, but they are close in energy, resulting in two Fe-binding modes.



N-bonding mode



S-bonding mode



(3) To generate thiocyanate ions, the following reactions can be used.

(3-1) (2 points) $8\text{CN}^- + \text{S}_8 \rightarrow 8\text{SCN}^-$ (S-bonding mode structure)

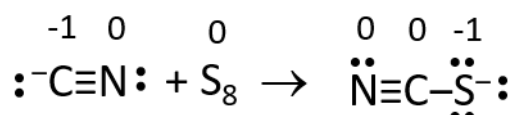
Which atom of the reactants is reduced and which atom is oxidized? Use formal charge changes.

(3-2) (3 points) $\text{CN}^- + \text{S}_2\text{O}_3^{2-} \rightarrow \text{SCN}^- + \text{SO}_3^{2-}$ (N-bonding mode structure)

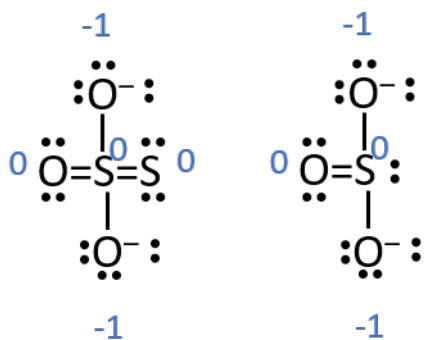
Draw the Lewis structures of $\text{S}_2\text{O}_3^{2-}$ and SO_3^{2-} ions and determine formal charges. Is this reaction a redox reaction or S atom transfer reaction? Rationalize your answer by using formal charges.

>>

(3-1) C is oxidized while S is reduced.



(3-2) As seen below, the formal charge of S does not change over the reaction. (C and N exchange an electron within a molecule; not an inter-molecular exchange). Thus, it is a sulfur atom transfer reaction.



9. (15 points)

The photoelectron spectroscopy (PES) experiment measures the kinetic energies of electrons that are ejected from atoms by the absorption of high-energy photons. The PES studies of sodium atoms excited by X-rays with wavelength 9.890×10^{-10} m show four peaks in which the electrons have speeds 7.992×10^6 m s⁻¹ (peak a), 2.046×10^7 m s⁻¹ (peak b), 2.074×10^7 m s⁻¹ (peak c), and 2.009×10^7 m s⁻¹ (peak d). (

(a) (2 points) Provide the electron configuration of sodium in its ground state.

(b) (2 points) Determine the energy (in electron volts, eV) of the X-rays utilized to irradiate sodium atoms.

(c) (4 points) Compute the kinetic energy (in eV) for electrons corresponding to each peak.

(d) (4 points) Ascertain the ionization energy (in eV) for electrons related to each peak.

(e) (3 points) Correlate each peak to a specific orbital in the sodium atom and illustrate the energy-level diagram of sodium based on photoelectron spectroscopy findings.

(a) The ground-state electron configuration of sodium is $1s^2 2s^2 2p^6 3s^1$.

(b) The energy of the X-rays is

$$E_{X\text{-ray}} = hv = \frac{hc}{\lambda} = \frac{(6.62607 \times 10^{-34} \text{ J s})(2.99792 \times 10^8 \text{ m s}^{-1})}{9.890 \times 10^{-10} \text{ m}} = 2.0085 \times 10^{-16} \text{ J}$$
$$= 2.0085 \times 10^{-16} \text{ J} \left(\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}} \right) = 1253.6 \text{ eV}$$

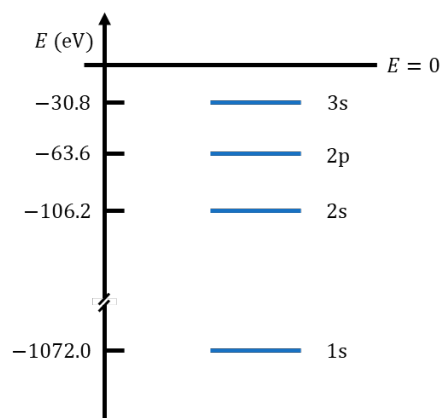
(c)

$$KE = \frac{1}{2} m_e v^2$$
$$KE_a = \frac{(9.10938 \times 10^{-31} \text{ kg})(7.992 \times 10^6 \text{ m s}^{-1})^2}{2} \left(\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}} \right) = 181.6 \text{ eV}$$
$$KE_b = \frac{(9.10938 \times 10^{-31} \text{ kg})(2.046 \times 10^7 \text{ m s}^{-1})^2}{2} \left(\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}} \right) = 1190.0 \text{ eV}$$
$$KE_c = \frac{(9.10938 \times 10^{-31} \text{ kg})(2.074 \times 10^7 \text{ m s}^{-1})^2}{2} \left(\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}} \right) = 1222.8 \text{ eV}$$
$$KE_d = \frac{(9.10938 \times 10^{-31} \text{ kg})(2.009 \times 10^7 \text{ m s}^{-1})^2}{2} \left(\frac{1 \text{ eV}}{1.6022 \times 10^{-19} \text{ J}} \right) = 1147.4 \text{ eV}$$

(d)

$$IE = E_{X\text{-ray}} - E_k$$
$$IE_a = 1253.6 \text{ eV} - 181.6 \text{ eV} = 1072.0 \text{ eV}$$
$$IE_b = 1253.6 \text{ eV} - 1190.0 \text{ eV} = 63.6 \text{ eV}$$
$$IE_c = 1253.6 \text{ eV} - 1222.8 \text{ eV} = 30.8 \text{ eV}$$
$$IE_d = 1253.6 \text{ eV} - 1147.4 \text{ eV} = 106.2 \text{ eV}$$

(e) The Peak a corresponds to removal of a 1s electron. Peaks b, c, and d correspond to removal of a 2p, a 3s, and the 2s electron respectively.



Physical Constants

Avogadro's number	$N_A = 6.02214179 \times 10^{23} \text{ mol}^{-1}$
Bohr radius	$a_0 = 0.52917720859 \text{ \AA} = 5.2917720859 \times 10^{-11} \text{ m}$
Boltzmann's constant	$K_B = 1.3806504 \times 10^{-23} \text{ J K}^{-1}$
Electronic charge	$e = 1.602176487 \times 10^{-19} \text{ C}$
Faraday constant	$F = 96485.3399 \text{ C mol}^{-1}$
Masses of fundamental particles:	
Electron	$m_e = 9.10938215 \times 10^{-31} \text{ kg}$
Proton	$m_P = 1.672621637 \times 10^{-27} \text{ kg}$
Neutron	$m_n = 1.674927211 \times 10^{-27} \text{ kg}$
Permittivity of vacuum	$\epsilon_0 = 8.854187817 \times 10^{-12} \text{ C}^{-2} \text{ J}^{-1} \text{ m}^{-1}$
Planck's constant	$h = 6.62606896 \times 10^{-34} \text{ J s}$
Ratio of proton mass to electron mass	$m_P / m_e = 1836.15267247$
Speed of light in a vacuum	$c = 2.99792458 \times 10^8 \text{ m s}^{-1}$ (exactly)
Standard acceleration of terrestrial gravity	$g = 9.80665 \text{ m s}^{-2}$ (exactly)
Universal gas constant	$R = 8.314472 \text{ J mol}^{-1} \text{ K}^{-1}$ $= 0.0820574 \text{ L atm mol}^{-1} \text{ K}^{-1}$

Values are taken from the 2006 CODATA recommended values,
as listed by the National Institute of Standards and Technology.

Conversion factors

Ångström	$1 \text{ \AA} = 10^{-10} \text{ m}$
Atomic mass unit	$1 \text{ u} = 1.660538782 \times 10^{-27} \text{ kg}$ $1 \text{ u} = 1.492417830 \times 10^{-10} \text{ J} = 931.494028 \text{ MeV}$ (energy equivalent form $E = mc^2$)
Calorie	$1 \text{ cal} = 4.184 \text{ J}$ (exactly)
Electron volt	$1 \text{ eV} = 1.602177 \times 10^{-19} \text{ J} = 96.485335 \text{ kJ mol}^{-1}$
Foot	$1 \text{ ft} = 12 \text{ in} = 0.3048 \text{ m}$ (exactly)
Gallon (U. S.)	$1 \text{ gallon} = 4 \text{ quarts} = 3.785412 \text{ L}$ (exactly)

Liter	$1 \text{ L} = 10^{-3} \text{ m}^3 = 10^3 \text{ cm}^3$ (exactly)
Liter-atmosphere	$1 \text{ L atm} = 101.325 \text{ J}$ (exactly)
Metric ton	$1 \text{ t} = 1000 \text{ kg}$ (exactly)
Pound	$1 \text{ lb} = 16 \text{ oz} = 0.4539237 \text{ kg}$ (exactly)
Rydberg	$1 \text{ Ry} = 2.17987197 \times 10^{-18} \text{ J} = 1312.7136 \text{ kJ mol}^{-1} = 13.60569193 \text{ eV}$
Standard atmosphere	$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 1.01325 \times 10^5 \text{ kg m}^{-1} \text{ s}^{-2}$ (exactly)
Torr	$1 \text{ torr} = 133.3224 \text{ Pa}$

PERIODIC TABLE OF THE ELEMENTS

<http://www.ktf-split.hr/periodni/en/>

GROUP		GROUP NUMBERS										GROUP NUMBERS																																																							
1		IUPAC RECOMMENDATION (1985)										CHEMICAL ABSTRACT SERVICE (1986)																																																							
1A												13 IIIA 14 IVA 15 VA 16 VIA 17 VIIA																																																							
PERIOD	1	2											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA																																																	
	H	He											B	C	N	O	F	Ne																																																	
1	1.0079 HYDROGEN	4.0026 HELIUM											5 10.811 BORON	6 12.011 CARBON	7 14.007 NITROGEN	8 15.999 OXYGEN	9 18.998 FLUORINE	10 20.180 NEON																																																	
2	6.941 Li LITHIUM	9.0122 Be BERYLLIUM											13 28.982 BORON	14 28.086 CARBON	15 30.974 NITROGEN	16 32.065 OXYGEN	17 35.453 FLUORINE	18 39.948 ARGON																																																	
3	22.990 Na SODIUM	24.305 Mg MAGNESIUM	3 44.956 Al ALUMINIUM	4 47.867 Si SILICON	5 50.942 P PHOSPHORUS	6 51.996 S SULFUR	7 54.938 Cl CHLORINE	8 55.845 Ar ARGON	9 58.933 K POTASSIUM	10 58.693 Ca CALCIUM	11 63.546 Sc SCANDIUM	12 65.39 Ti TITANIUM	13 68.923 V VANADIUM	14 72.64 Cr CHROMIUM	15 74.922 Mn MANGANESE	16 78.96 Fe IRON	17 79.904 Co COBALT	18 83.80 Ni NICKEL	19 85.468 Cu COPPER	20 89.904 Zn ZINC	21 91.224 Ga GALLIUM	22 92.906 Ge GERMANIUM	23 95.94 As ARSENIC	24 97.901 Se SELENIUM	25 101.07 Br BROMINE	26 102.905 Kr KRYPTON	27 106.42 Rb RUBIDIUM	28 107.87 Sr STRONTIUM	29 114.82 Y YTTRIUM	30 118.71 Zr ZIRCONIUM	31 121.76 Nb NIObIUM	32 127.60 Mo MOLYBDENUM	33 128.90 Tc TECHNETIUM	34 131.29 Ru RUTHENIUM	35 132.91 Rh RHODIUM	36 137.33 Pd PALLADIUM	37 85.468 Ag SILVER	38 87.62 Cd CADMIUM	39 88.906 In INDIUM	40 91.224 Sn TIN	41 92.906 Sb ANTIMONY	42 95.94 Te TELLURIUM	43 (99) I IODINE	44 101.07 Xe XENON																							
4	39.098 K POTASSIUM	40.078 Ca CALCIUM	39 88.906 Sc SCANDIUM	40 91.224 Ti TITANIUM	41 92.906 V VANADIUM	42 95.94 Cr CHROMIUM	43 (99) Mn MANGANESE	44 101.07 Fe IRON	45 102.91 Co COBALT	46 106.42 Ni NICKEL	47 107.87 Cu COPPER	48 112.41 Zn ZINC	49 114.82 Ga GALLIUM	50 118.71 Ge GERMANIUM	51 121.76 As ARSENIC	52 127.60 Se SELENIUM	53 128.90 Br BROMINE	54 131.29 Kr KRYPTON	55 132.91 Rb RUBIDIUM	56 137.33 Sr STRONTIUM	57 138.91 Y YTTRIUM	58 138.91 Zr ZIRCONIUM	59 140.91 Nb NIObIUM	60 144.24 Mo MOLYBDENUM	61 (145) Tc TECHNETIUM	62 150.36 Ru RUTHENIUM	63 151.96 Rh RHODIUM	64 157.25 Pd PALLADIUM	65 158.93 Ag SILVER	66 162.50 Cd CADMIUM	67 164.93 In INDIUM	68 167.26 Sn TIN	69 168.93 Sb ANTIMONY	70 173.04 Te TELLURIUM	71 174.97 I IODINE	72 178.49 Xe XENON	73 180.95 Ba BARIUM	74 183.84 La LANTHANUM	75 186.21 Ce CERIUM	76 190.23 Pr PRASEODYMIUM	77 192.22 Nd NEODYMIUM	78 195.08 Pm PROMETHIUM	79 196.97 Sm SAMARIUM	80 200.59 Eu EUROPIUM	81 204.38 Gd GADOLINIUM	82 207.2 Tb TERBIUM	83 208.98 Dy DYSPROSIUM	84 (209) Ho HOLMIUM	85 (210) Er ERBIUM	86 (222) Tm THULIUM	87 (223) Yb YtterBIUM	88 (226) Lu LUTETIUM	89 (227) Ac ACTINIDE	90 232.04 Th THORIUM	91 231.04 Pa ProtactINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELEIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MendeLEIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM
5	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YtterBIUM	71 174.97 Lu LUTETIUM	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89 (227) Ac ACTINIDE	90 232.04 Th THORIUM	91 231.04 Pa ProtactINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELEIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MendeLEIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM																		
6	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr ACTINIDE	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRICIUM	108 (277) Hs HASSIUM	109 (286) Mt MEITNERIUM	110 (281) Uu UNUNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUBIUM	114 (289) Uuq UNUNQUADIUM																																																						
7			LANTHANIDE										ACTINIDE																																																						

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(1) Pure Appl. Chem., 73, No. 4, 697-693 (2001)
Relative atomic mass is shown with five significant figures. For elements with no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.
However, these such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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