

## 2012 SPRING Semester Midterm Examination For General Chemistry I

**Date:** March 28 (Wed), **Time Limit:** 7:00 ~ 9:00 p.m.

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
<b>1</b>	/10	<b>6</b>	/20	<b>/150</b>
<b>2</b>	/8	<b>7</b>	/15	
<b>3</b>	/12	<b>8</b>	/25	
<b>4</b>	/8	<b>9</b>	/20	
<b>5</b>	/12	<b>10</b>	/20	

\*\* This paper consists of 10 sheets with 10 problems (page 9: claim form, page 10: periodic table). 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.

(채점답안지 분배 및 이의신청 일정)

### 1. Period, and Procedure

1) Return and Claim Period: **April 2 (Mon), Quiz Session; 7: 00 ~ 7:30**

2) Procedure: During the quiz hour, you can take your mid-term paper scored. If you have any claims on it, you can submit a claim paper with your opinion. After writing your opinions on any paper you can get easily, attach it with a stapler to your mid-term paper scored (Please, write your name, professor, and class.). Submit them to your TA. The papers with the claims will be re-examined by TA.

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

***(A solution file with answers for the examination will be uploaded on 3/31 at the web.)***

### 2. Final Confirmation

1) Period: April 9 (Mon)-10 (Tue)

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

\*\* For further information, please visit a *General Chemistry website* at [www.gencheminkaist.pe.kr](http://www.gencheminkaist.pe.kr).

1. (a) Calculate the maximum wavelength of electromagnetic radiation needed to eject electrons from the surface of tungsten, which has a work function of  $7.29 \times 10^{-19}$  J.

**(Answer)**

(b) If the maximum speed of electrons emitted from the tungsten surface is  $2.00 \times 10^6$  m s<sup>-1</sup>, calculate the wavelength of the incident radiation.

Planck's constant  $h = 6.626 \times 10^{-34}$  J·s; speed of light  $c = 2.998 \times 10^8$  m·s<sup>-1</sup>;

electron mass  $m_e = 9.109 \times 10^{-31}$  kg

**(Answer)**

2. In many-electron atoms,

(a) Which of the quantum numbers govern the energy of an orbital?

**(Answer)**

(b) Which of the quantum numbers govern the shape and spatial orientation of an orbital?

*Write the full name of each quantum number for (a) and (b).*

**(Answer)**

3. Which of the following statements are true for many-electron atoms? If false, explain why.

(a) The effective nuclear charge  $Z_{\text{eff}}$  is independent of the number of electrons present in an atom.

**(Answer)**

(b) Electrons in an s-orbital are more effective than those in other orbitals at shielding other electrons from the nuclear charge because an electron in an s-orbital can penetrate to the nucleus of the atom.

**(Answer)**

(c) Electrons having  $l = 2$  are better at shielding than electrons having  $l = 1$ .

**(Answer)**

(d)  $Z_{\text{eff}}$  for an electron in a p-orbital is lower than for an electron in an s-orbital in the same shell.

**(Answer)**

4. (a) Which has the larger second ionization energy, B or C, and why?

**(Answer)**

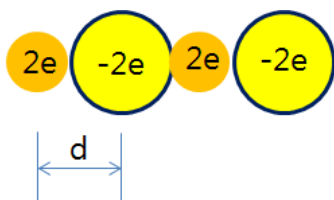
(b) Which is the largest and which is the smallest among  $K^+$ ,  $Cl^-$ , and  $Ca^{2+}$ , and why?

**(Answer)**

5. (a) We learned that the Coulomb potential energy of the interaction of two individual ions is

$\frac{z_1 z_2 e^2}{4\pi\epsilon_0 r_{12}}$ , where  $z_1 e$  and  $z_2 e$  are the charges of the two ions and  $r_{12}$  is the distance between

two ions. Consider the following one-dimensional nanorod made of only four ions. The distance between two adjacent ions is  $d$ . The charge of each ion is indicated ( $2e$  or  $-2e$ ). Calculate the total Coulomb potential energy of this system.



**(Answer)**

(b) In which of the nanorods  $Mg^{2+}Se^{2-}Mg^{2+}Se^{2-}$  and  $Ca^{2+}Se^{2-}Ca^{2+}Se^{2-}$  are the interactions between the ions stronger? Why?

**(Answer)**

6. (a) Write the Lewis structures of  $\text{SO}_2$  and  $\text{N}_2\text{O}$ . Indicate the most stable structure for each molecule and explain the reason.

**(Answer)**

(b) Write the most probable Lewis structures of  $\text{HNO}$  and  $\text{HON}$  molecules. Which one would be energetically favored? Why?

**(Answer)**

7. Place the following molecules or ions in order of decreasing bond length, and explain the reason.

(a) the CO bond in  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{CO}_3^{2-}$

**(Answer)**

(b) the SO bond in  $\text{SO}_2$ ,  $\text{SO}_3$ ,  $\text{SO}_3^{2-}$

**(Answer)**

(c) the CN bond in  $\text{HCN}$ ,  $\text{CH}_2\text{NH}$ ,  $\text{CH}_3\text{NH}_2$

**(Answer)**

8. (a) Use the VSEPR theory to sketch and name the molecular geometries of the molecules,  $\text{SCl}_2$ ,  $\text{SCl}_4$ , and  $\text{SCl}_6$ , and state whether each is polar or nonpolar.

**(Answer)**

(b) Bromine can form compounds or ions with any number of fluorine atoms from one to five ( $\text{BrF}$ ,  $\text{BrF}_2^-$ ,  $\text{BrF}_3$ ,  $\text{BrF}_4^-$ ,  $\text{BrF}_5$ ). Describe their geometries based on the VSEPR theory.

**(Answer)**

9. Use valence (VB) theory to predict the hybridization in formaldehyde and allene. Sketch the hybrid atomic orbitals depicting their overlap and  $\sigma$  and  $\pi$ -bonding.

(a) formaldehyde  $\text{H}_2\text{C}=\text{O}$

**(Answer)**

(b) allene  $\text{H}_2\text{C}=\text{C}=\text{CH}_2$

**(Answer)**

10. (a) Draw the molecular orbital energy-level diagram for  $N_2$  and label the energy levels according to the type of orbitals from which they are made, whether they are  $\sigma$  or  $\pi$ -orbitals, and whether they are bonding or antibonding.

**(Answer)**

(b) The orbital structure of the heteronuclear diatomic ion  $NO^+$  is similar to that of  $N_2$ . How will the fact that the electronegativity of N differs from that of O affect the molecular orbital energy-level diagram of  $NO^+$  compared with that of  $N_2$ ? Use this information to draw the energy-level diagram for  $NO^+$ .

**(Answer)**

(c) In the molecular orbitals, will the electrons have a higher probability of being at N or at O? Why?

**(Answer)**



<The Answers>

Problem	points	Problem	points	TOTAL pts
<b>1</b>	5+5 /10	<b>6</b>	14+6 /20	<b>/150</b>
<b>2</b>	4+4 /8	<b>7</b>	5+5+5 /15	
<b>3</b>	3+3+3+3 /12	<b>8</b>	10+15 /25	
<b>4</b>	4+4 /8	<b>9</b>	10+10 /20	
<b>5</b>	8+4 /12	<b>10</b>	10+5+5 /20	

1. (a) This involves the photoelectric equation,  $E_{\max} = \frac{1}{2}m_e v_e^2 = h\nu - \Phi$ , where  $\Phi$  is the work function ( $7.29 \times 10^{-19}$  J) representing the minimum energy (and hence maximum wavelength) of photons required for photoelectric effect.

$$E_{\min} = 7.29 \times 10^{-19} \text{ J} = hc/\lambda_{\max}$$

$$\lambda_{\max} = (6.626 \times 10^{-34} \text{ J}\cdot\text{s}) (2.988 \times 10^8 \text{ m}\cdot\text{s}^{-1}) / (7.29 \times 10^{-19} \text{ J}) = 2.72 \times 10^{-7} \text{ m or } 272 \text{ nm}$$

(b) Maximum energy of electrons ejected by impact of photons of wavelength  $\lambda$  is given by,

$$E_{\max} = \frac{1}{2}m_e v_e^2 = \frac{1}{2} (9.109 \times 10^{-31} \text{ kg}) (2.00 \times 10^6 \text{ m}\cdot\text{s}^{-1})^2 = 18.2 \times 10^{-19} \text{ J} = hc/\lambda - \Phi$$

$$\text{Hence, } hc/\lambda = 25.5 \times 10^{-19} \text{ J}$$

$$\lambda = (6.626 \times 10^{-34} \text{ J}\cdot\text{s}) (2.988 \times 10^8 \text{ m}\cdot\text{s}^{-1}) / 25.5 \times 10^{-19} \text{ J} = 0.779 \times 10^{-7} \text{ m or } 77.9 \text{ nm}$$

2. (a) principal quantum number and orbital angular momentum quantum number

(b) orbital angular momentum quantum number and magnetic quantum number

3. (a) false.  $Z_{\text{eff}}$  is considerably affected by the total number of electrons present in the atom because the electrons in the lower energy orbitals will "shield" the electrons in the higher energy orbitals from the nucleus. This effect arises because the e-e repulsions tend to offset the attraction of the electron to the nucleus.

(b) true.

(c) false. The electrons are increasingly less able to penetrate to the nucleus as  $l$  increases.

(d) true.

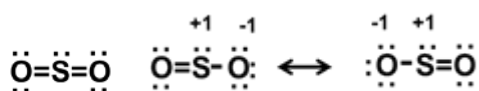
4. (a) The *first* ionization of each removes a 2p electron, but the *second* removes a 2s electron from B, but only another 2p electron from C. The change in subshell with B means it has the higher second ionization energy.

(b) All three have the same number of electrons, but  $\text{Cl}^-$  has the fewest number of protons in its nucleus to hold these electrons in place (making it the *largest*) while  $\text{Ca}^{2+}$  has the largest number of protons (making it the *smallest*).  $\text{K}^+$  is in between.

5. (a)  $\frac{e^2}{4\pi\epsilon_0 d}(-4 + 4/2 - 4/3 - 4 + 4/2 - 4) = \frac{-17e^2}{6\pi\epsilon_0 d}$  **[correct answer =  $(-7e^2)/(3\pi\epsilon_0 d)$ ]**

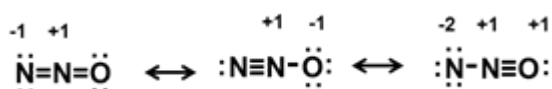
(b)  $\text{Mg}^{2+}\text{Se}^{2-}\text{Mg}^{2+}\text{Se}^{2-}$ , the same charge, smaller distance, smaller positive ions

6. (a)  $\text{SO}_2$



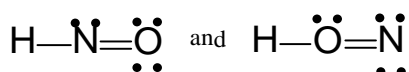
stable          resonance structure

$\text{N}_2\text{O}$



stable          most stable          least stable  
 $\therefore$  Negative charge  
 on more negative atom

(b)



$\text{HNO}$  is energetically favored because of the neutral formal charge.

7. (a)  $\text{CO}_3^{2-} > \text{CO}_2 > \text{CO}$

$\text{CO}_3^{2-}$  : resonance between two single bonds and one double bond

$\text{CO}_2$  : two double bonds;  $\text{CO}$  : triple bond

(b)  $\text{SO}_3^{2-} > \text{SO}_2 \sim \text{SO}_3$

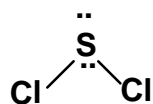
$\text{SO}_3^{2-}$  : resonance between two single bonds and one double bond

$\text{SO}_2$  : double bonds;  $\text{SO}_3$  : double bonds

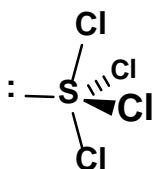
(c)  $\text{CH}_3\text{NH}_2 > \text{CH}_2\text{NH} > \text{HCN}$

$\text{CH}_3\text{NH}_2$  : single bond;  $\text{CH}_2\text{NH}$  : double bond;  $\text{HCN}$  : triple bond

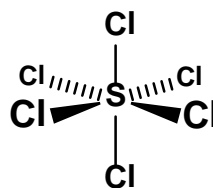
8. (a)



**Angular or bent**  
**Polar**



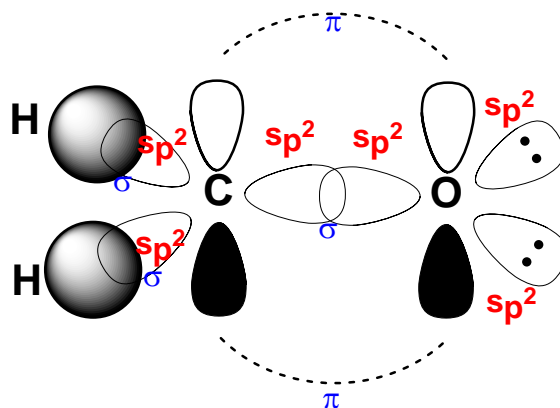
**Seesaw**  
**Polar**



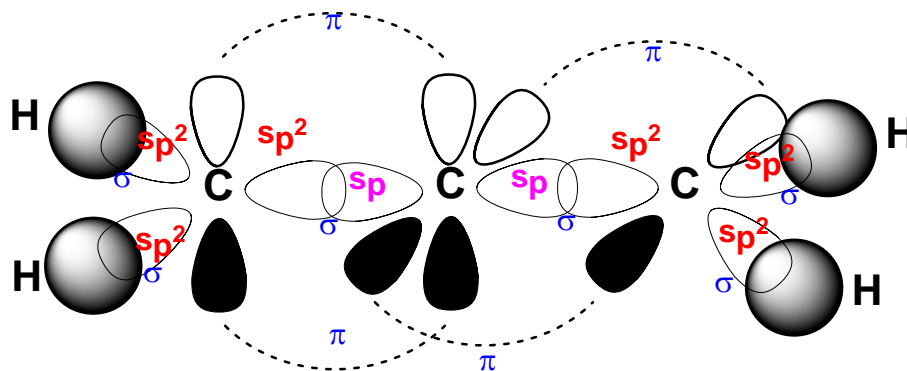
**Octahedral**  
**Nonpolar**

(b)  $\text{BrF}$ (linear),  $\text{BrF}_2^-$ (linear),  $\text{BrF}_3$  (T-shaped),  $\text{BrF}_4^-$ (square planar),  $\text{BrF}_5$  (square pyramidal)

9. (a) C atom is  $sp^2$ -hybridized, as is the O atom. These trigonal planar  $sp^2$  orbitals  $\sigma$ -bonded with 1s orbital of H atom and 2p orbital of O atom. Unhybridized 2p orbital of C atom and O atom form a  $\pi$ -bond which is orthogonal to the  $\sigma$ -bond.

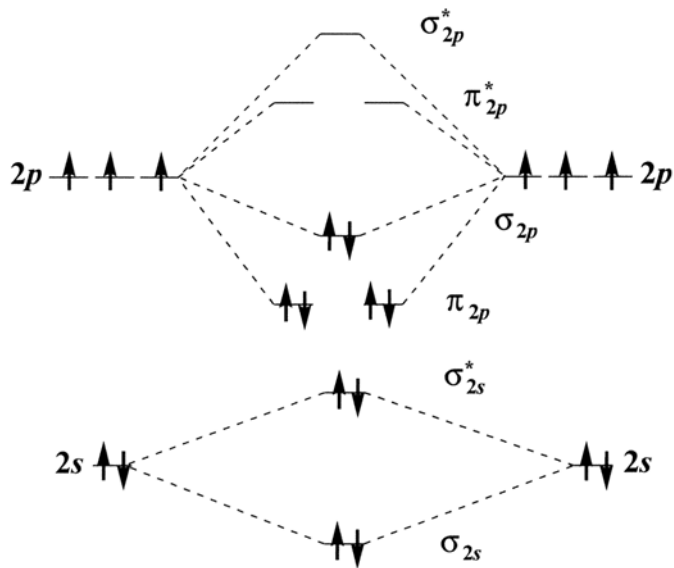


(b) The central C atom forms one  $\pi$ -bond on each side. These  $\pi$ -bonds are orthogonal to  $\sigma$ -bond. The central C atom must be  $sp$ -hybridized. The terminal C atoms are  $sp^2$  hybridized. These  $sp^2$  orbitals are  $\sigma$ -bonded with 1s orbitals of H atoms and the  $sp$  hybrid orbital of the central C atom.



10.

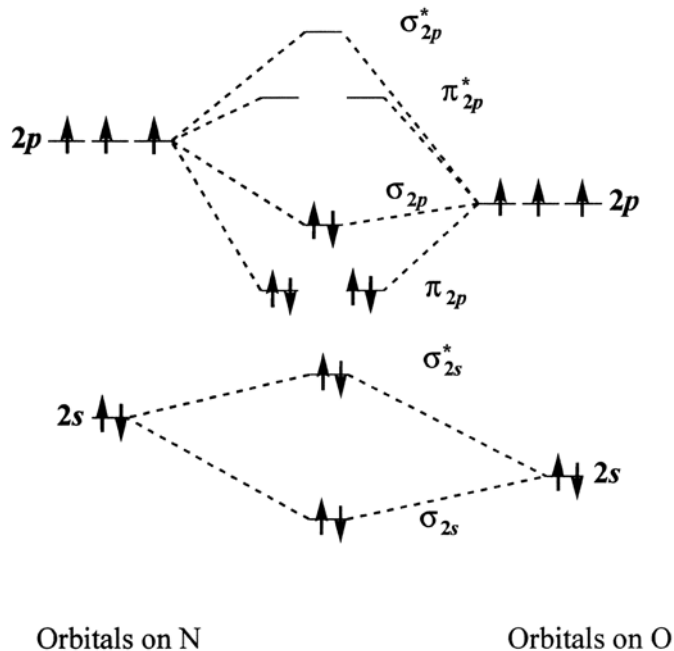
(a) The energy level diagram for N<sub>2</sub> is as follows:



(b) The oxygen atom is more electronegative, which will make its orbitals lower in energy than those of N. The revised energy-level diagram is shown below. This

will make all of the bonding orbitals closer to O than to N in energy and will make all the antibonding orbitals closer to N than to O in energy.

Energy level diagram for NO<sup>+</sup>



(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.

## 2012 SPRING Semester Final Examination For General Chemistry I

**Date:** May 23 (Wed), **Time Limit:** 7:00 ~ 9:00 p.m.

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
<b>1</b>	/12	<b>6</b>	/24	<b>/150</b>
<b>2</b>	/15	<b>7</b>	/12	
<b>3</b>	/20	<b>8</b>	/15	
<b>4</b>	/16	<b>9</b>	/20	
<b>5</b>	/16			

\*\* This paper consists of 10 sheets with 9 problems (page 8,9: constants & periodic table, page10: 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.

### 1. Period, Location and Procedure

- 1) Return and Claim Period: **May 25 (Friday, 11: 00 a.m. ~ 13: 00 p.m., 2 hours)**
- 2) **Location: Creative Learning Bldg.(E11)**

Class	Room	Class	Room
<b>A</b>	<b>301</b>	<b>G</b>	<b>403</b>
<b>B</b>	<b>302</b>	<b>H</b>	<b>406</b>
<b>C</b>	<b>310</b>	<b>I</b>	<b>408</b>
<b>D</b>	<b>401</b>	<b>J</b>	<b>411</b>
<b>F</b>	<b>402</b>		

- 3) Claim Procedure:  
(During the period, you can take the marked exam paper from your TA and should hand in the paper with a FORM for claims if you have any claims on it.)  
To get more information, visit the website at [www.gencheminkaist.pe.kr](http://www.gencheminkaist.pe.kr).

### 2. Final Confirmation

- 1) Period: **May 29 (Tue, 09:00 a.m.) - 30(Wed, 09:00 a.m.) [24 hours]**
- 2) Procedure: During this period, you can check final score of the examination *on the website* again.

1. A mixture of  $\text{CH}_4(\text{g})$  and  $\text{C}_2\text{H}_6(\text{g})$  has a total pressure of 0.50 atm. Just enough  $\text{O}_2(\text{g})$  is added to the mixture to bring about its complete combustion to  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{g})$ . The total pressure of the two product gases is found to be 2.1 atm.

(a) Assuming constant volume and temperature, find the balanced equation of the combustion of  $\text{CH}_4(\text{g})$  with  $\text{O}_2(\text{g})$ .

**(Answer)**

(b) Assuming constant volume and temperature, find the balanced equation of the combustion of  $\text{C}_2\text{H}_6(\text{g})$  with  $\text{O}_2(\text{g})$ .

**(Answer)**

(c) What is the mole fraction of  $\text{CH}_4$  in the original mixture?

**(Answer)**

2. Below are the van der Waals constants (a and b) for three gases: A, B and C.

Gas	a / atm L <sup>2</sup> mol <sup>-2</sup>	b / L mol <sup>-1</sup>
A	3.592	0.04267
B	6.714	0.05636
C	5.284	0.04424

Identify the gases CO<sub>2</sub>, NO<sub>2</sub> and SO<sub>2</sub> as A, B or C, giving brief reasons.

**(Answer)**

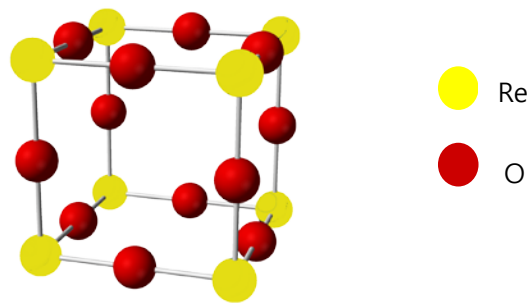
3. (a) State which attractive intermolecular forces are likely to predominate in associations amongst particles in the following substances: HF (liquid), SO<sub>2</sub> (liquid), CuSO<sub>4</sub>.5H<sub>2</sub>O (solid), and SO<sub>3</sub> (solid).

**(Answer)**

(b) Write the right order in decrease of surface tension: CH<sub>3</sub>OH, H<sub>2</sub>O, CH<sub>3</sub>COCH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>OH

**(Answer)**

4. Rhenium oxide crystallizes with a structure that has a primitive cubic lattice, as shown here.



(a) What is the formula of rhenium oxide?

**(Answer)**

(b) Calculate the length of the edge of the unit cell by using the ionic radii of rhenium ( $0.70 \text{ \AA}$ ) and oxygen ( $1.26 \text{ \AA}$ ).

**(Answer)**

(c) Calculate the density ( $\text{g/cm}^3$ ) of this compound ( $M_{\text{Re}} = 186.21 \text{ g/mol}$ ,  $M_{\text{O}} = 16 \text{ g/mol}$ ).

**(Answer)**



5. Calculate the work for each of the following processes beginning with a gas sample in a piston assembly with  $T = 305 \text{ K}$ ,  $P = 1.79 \text{ atm}$ , and  $V = 4.29 \text{ L}$ : (a) irreversible expansion against a constant external pressure of  $1.00 \text{ atm}$  to a final volume of  $6.52 \text{ L}$ .

**(Answer)**

(b) isothermal, reversible expansion to a final volume of  $6.52 \text{ L}$ .

**(Answer)**

6. For the following process, state whether  $q$ ,  $w$ ,  $\Delta U$ , and  $\Delta H$  are positive (+), negative (-), or zero (0).

Process	$q$	$w$	$\Delta U$	$\Delta H$
Reversible, isothermal expansion of an ideal gas				
Reversible, constant-pressure heating of an ideal gas				
Boiling of water at $100 \text{ }^\circ\text{C}$ and $1 \text{ atm}$ external pressure				
Reversible, adiabatic compression of an ideal gas				

7. Complete the following table (all values are in kilojoules per mole).

Compound MX	$\Delta H_f^\circ$ M(g)	Ionization energy M	$\Delta H_f^\circ$ X(g)	Electron affinity X	$\Delta H_L$ MX	$\Delta H_f^\circ$ MX(s)
(a) NaCl	108	494	122	+349	787	?
(b) KBr	89	418	97	+325	?	-394
(c) RbF	?	402	79	+328	774	-558

**(Answer)**

8. The atmosphere above the surface of the earth behaves as isentropic, i.e, the molar entropy of the air has the same value up to 10 km. When the temperature and pressure at the surface of the earth is 25 °C, and 760 torr, respectively, calculate the temperature of the air at 10 km, where pressure is 210 torr. Assume that air is ideal gas and specific heat at constant pressure is  $C_{p,m} = 7/2 R$  (R: gas constant).

**(Answer)**

9. Two containers of the same size are separated by a stopcock. Each container has one mole of oxygen gas at 1 bar and 300 K. The containers are made of high quality insulator. By turning the stopcock, the oxygen gas in each container is allowed to mix with that in the other container.

(a) What kind of system is this? Open, closed or isolated?

**(Answer)**

(b) What is the change in internal energy?

**(Answer)**

(c) What is the change in enthalpy?

**(Answer)**

(d) What is the change in entropy?

**(Answer)**

(e) What is the change in Gibbs free energy?

**(Answer)**

## FUNDAMENTAL CONSTANTS

Name	Symbol	Value
Atomic mass constant	$m_u$	$1.660\ 54 \times 10^{-27}$ kg
Avogadro's constant	$N_A$	$6.022\ 14 \times 10^{23}$ mol <sup>-1</sup>
Boltzmann's constant	$k$	$1.380\ 65 \times 10^{-23}$ J·K <sup>-1</sup>
Fundamental charge	$e$	$1.602\ 18 \times 10^{-19}$ C
Faraday's constant	$F = N_A e$	$9.648\ 53 \times 10^4$ C·mol <sup>-1</sup>
Gas constant	$R = N_A k$	$8.314\ 47$ J·K <sup>-1</sup> ·mol <sup>-1</sup> $8.314\ 47$ L·kPa·K <sup>-1</sup> ·mol <sup>-1</sup> $8.205\ 74 \times 10^{-2}$ L·atm·K <sup>-1</sup> ·mol <sup>-1</sup> $62.36\ 37$ L·Torr·K <sup>-1</sup> ·mol <sup>-1</sup> $8.314\ 47 \times 10^{-2}$ L·bar·K <sup>-1</sup> ·mol <sup>-1</sup>
Mass of electron	$m_e$	$9.109\ 38 \times 10^{-31}$ kg
Mass of neutron	$m_n$	$1.674\ 93 \times 10^{-27}$ kg
Mass of proton	$m_p$	$1.672\ 62 \times 10^{-27}$ kg
Planck's constant	$h$	$6.626\ 08 \times 10^{-34}$ J·s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J·s
Rydberg constant	$\mathcal{R}$	$3.289\ 84 \times 10^{15}$ Hz
Speed of light	$c$	$2.997\ 92 \times 10^8$ m·s <sup>-1</sup>
Standard acceleration of free fall	$g$	$9.806\ 65$ m·s <sup>-2</sup>
Vacuum permittivity	$\epsilon_0$	$8.854\ 19 \times 10^{-12}$ J <sup>-1</sup> ·C <sup>2</sup> ·m <sup>-1</sup>

## RELATIONS BETWEEN UNITS\*

Property	Common unit	SI unit
Mass	2.205 lb (lb = pound)	1.000 kg
	1.000 lb	453.6 g
	1.000 oz (oz = ounce)	28.35 g
	1.000 ton (= 2000 lb)	907.2 kg
	1 t (t = tonne, metric ton)	10 <sup>3</sup> kg
Length	1.094 yd (yd = yard)	1.000 m
	0.3937 in. (in. = inch)	1.000 cm
	0.6214 mi (mi = mile)	1.000 km
	1 in.	2.54 cm
	1 ft (ft = foot)	30.48 cm
	1.000 yd	0.9144 m
	1 Å (Å = ångström)	10 <sup>-10</sup> m
Volume	1 L (L = liter)	10 <sup>3</sup> cm <sup>3</sup> , 1 dm <sup>3</sup>
	1.000 gal (gal = gallon) <sup>†</sup>	3.785 dm <sup>3</sup> (3.785 L)
	1.00 ft <sup>3</sup> (ft <sup>3</sup> = cubic foot)	$2.83 \times 10^{-2}$ m <sup>3</sup> (28.3 L)
	1.00 qt (qt = quart) <sup>†</sup>	$9.46 \times 10^{-2}$ m <sup>3</sup> (0.946 L)
Time	1 min (min = minute)	60 s
	1 h (h = hour)	3600 s
	1 day	86 400 s
Pressure	1 atm (atm = atmosphere)	$1.013\ 25 \times 10^5$ Pa
	1.000 Torr or 1.000 mmHg	133.3 Pa
	1.000 psi (psi = pounds per square inch)	6.895 kPa
	1 bar	10 <sup>5</sup> Pa
Energy	1 cal	4.184 J
	1 eV	$1.60218 \times 10^{-19}$ J; 96.485 kJ·mol <sup>-1</sup>
	1 C·V	1 J
	1 kWh (kWh = kilowatt hour)	$3.600 \times 10^3$ kJ
	1 L·atm	101.325 J
Temperature conversions	(Fahrenheit temperature)/°F = $\frac{5}{9} \times$ (Celsius temperature)/°C + 32 (Celsius temperature)/°C = $\frac{5}{9} + \{$ (Fahrenheit temperature)/°F - 32} (Kelvin temperature)/K = (Celsius temperature)/°C + 273.15	

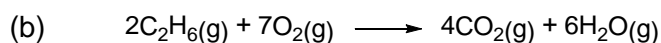
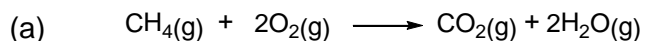
\*Entries in boldface type are exact.

<sup>†</sup>The European and Canadian Imperial quart and gallon are 1.201 times as large.

## <The Answers>

Problem	points	Problem	points	TOTAL pts
<b>1</b>	3+3+6 /12	<b>6</b>	6*4 /24	<b>/150</b>
<b>2</b>	5+5+5 /15	<b>7</b>	4+4+4 /12	
<b>3</b>	3+3+6+3+5/20	<b>8</b>	15 /15	
<b>4</b>	5+3+8 /16	<b>9</b>	3+3+3+6+5/20	
<b>5</b>	8+8 /16			

1.



(c) Partial pressures of  $\text{CH}_4$  and  $\text{C}_2\text{H}_6$  are  $x$  and  $y$ , respectively.

$$x + y = 0.50$$

$$3x + 5y = 2.1$$

The solution is  $x = 0.20$  atm, and  $y = 0.30$  atm, thus, the mole fraction of  $\text{CH}_4$  is  $x/(x+y) = 0.4$

2.

$\text{CO}_2$  A - smallest value of constant  $a$  (nonpolar molecule)

$\text{NO}_2$  C - high value of constant  $a$  (polar molecule);  
similar value of constant  $b$  to  $\text{CO}_2$  (similar size)

$\text{SO}_2$  B - high value of constant  $a$  (polar molecule);  
highest value of constant  $b$  (biggest molecule)

3.

(a) HF (liquid) – hydrogen bonding

$\text{SO}_2$  (liquid) – dipole-dipole forces

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  (solid) – ionic, ion-dipole and hydrogen bonding

$\text{SO}_3$  (solid) – London (dispersion) force

(b)  $\text{H}_2\text{O} > \text{CH}_3\text{OH} \sim \text{C}_2\text{H}_5\text{OH} > \text{CH}_3\text{COCH}_3$

4.

(a)  $\text{ReO}_3$

(b)  $a = 2r_{\text{Re}} + 2r_{\text{O}} = 3.92 \text{ \AA}$

(c)  $d = m/a^3 = \frac{[M(\text{Re}) + 3M(\text{O})]/N_A}{a^3} = \frac{(186.21 + 3 \times 16) \text{ g/mol}}{6.022 \times 10^{23} \text{ mol}^{-1} \times (3.92 \times 10^{-8} \text{ cm})^3} = 6.46 \text{ g/cm}^3$

5.

(a) The irreversible work of expansion against a constant opposing pressure is given by

$$w = -P_{\text{ex}} \Delta V$$

$$w = -(1.00 \text{ atm})(6.52 \text{ L} - 4.29 \text{ L})$$

$$= -2.23 \text{ L} \cdot \text{atm}$$

$$= -2.23 \text{ L} \cdot \text{atm} \times 101.325 \text{ J} \cdot \text{L}^{-1} \cdot \text{atm}^{-1} = -226 \text{ J}$$

(b) An isothermal expansion will be given by

$$w = -nRT \ln (V_2/V_1)$$

$n$  is calculated from the ideal gas law:

$$n = \frac{PV}{RT} = \frac{(1.79 \text{ atm})(4.29 \text{ L})}{(0.08206 \text{ L} \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1})(305 \text{ K})} = 0.307 \text{ mol}$$

$$w = -(0.307 \text{ mol})(8.314 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1})(305 \text{ K}) \ln \frac{6.52}{4.29}$$

$$= -326 \text{ J}$$

Note that the work done is greater when the process is carried out reversibly.

6.

Process	q	w	$\Delta U$	$\Delta H$
Reversible, isothermal expansion of an ideal gas	+	-	0	0
Reversible, constant-pressure heating of an ideal gas	+	-	+	+
Boiling of water at 100°C and 1 atm external pressure	+	-	+	+
Reversible, adiabatic compression of an ideal gas	0	+	+	+

7.

$$(a) \quad \Delta H_L = \Delta H_f^\circ(\text{Na, g}) + \Delta H_f^\circ(\text{Cl, g}) + I_1(\text{Na}) \\ - E_{\text{ea}} \text{ of Cl} - \Delta H_f(\text{NaCl(s)})$$

$$787 \text{ kJ} \cdot \text{mol}^{-1} = 108 \text{ kJ} \cdot \text{mol}^{-1} + 122 \text{ kJ} \cdot \text{mol}^{-1} + 494 \text{ kJ} \cdot \text{mol}^{-1} \\ - 349 \text{ kJ} \cdot \text{mol}^{-1} - \Delta H_f(\text{NaCl(s)})$$

$$\Delta H_f(\text{NaCl(s)}) = -412 \text{ kJ} \cdot \text{mol}^{-1}$$

$$(b) \quad \Delta H_L = \Delta H_f^\circ(\text{K, g}) + \Delta H_f^\circ(\text{Br, g}) + I_1(\text{K}) \\ - E_{\text{ea}}(\text{Br}) - \Delta H_f(\text{KBr(s)})$$

$$\Delta H_L = 89 \text{ kJ} \cdot \text{mol}^{-1} + 97 \text{ kJ} \cdot \text{mol}^{-1} + 418 \text{ kJ} \cdot \text{mol}^{-1} \\ - 325 \text{ kJ} \cdot \text{mol}^{-1} + 394 \text{ kJ} \cdot \text{mol}^{-1} \\ = 673 \text{ kJ} \cdot \text{mol}^{-1}$$

$$(c) \quad \Delta H_L = \Delta H_f^\circ(\text{Rb, g}) + \Delta H_f^\circ(\text{F, g}) + I_1(\text{Rb}) - E_{\text{ea}}(\text{F}) - \Delta H_f(\text{RbF(s)})$$

$$774 \text{ kJ} \cdot \text{mol}^{-1} = \Delta H_f^\circ(\text{Rb, g}) + 79 \text{ kJ} \cdot \text{mol}^{-1} \\ + 402 \text{ kJ} \cdot \text{mol}^{-1} - 328 \text{ kJ} \cdot \text{mol}^{-1} + 558 \text{ kJ} \cdot \text{mol}^{-1}$$

$$\Delta H_f^\circ(\text{Rb, g}) = 63 \text{ kJ} \cdot \text{mol}^{-1}$$

8.

If  $S_1$  is the entropy on earth and  $S_2$  is the entropy at 10 Km above the surface of the earth, the condition is isentropic, and thus  $S_2 - S_1 = \Delta S = 0$ .

At the pathway with changing T and P,

$$\Delta S = -nR \ln(P_2/P_1) + nC_{p,m} \ln(T_2/T_1) = 0$$

$$\ln(T_2/T_1) = R/C_{p,m} \ln(P_2/P_1)$$

$$\ln T_2 = \ln(298) + 2/7 \ln(210/760) = 5.330$$

$$\therefore T_2 = 206 \text{ K} = -67 \text{ }^\circ\text{C}$$

9.

(a) The containers are well insulated and the oxygen gas cannot escape the containers. Thus this system is isolated system.

(b) No work or heat is done. Thus the change in internal energy is zero.

(c) No work or heat is done. Thus the change in enthalpy is zero.

(d) If the volume of one container is V, then after mixing, the gas in each container can have access to 2V. So the entropy change of the gas is  $2 \cdot n \cdot R \cdot \ln(2V/V) = (2)(1 \text{ mol})(1.9872 \text{ cal/mol/K})\ln(2) = 2.75 \text{ cal/K} = 11.5 \text{ J/K}$

$$(e) \quad \Delta G_{\text{sys}} = -T\Delta S_{\text{tot}} = -(300\text{K})(11.5\text{J/K}) = -3.4 \text{ kJ}$$

Please note that in this "isolated" system, the system itself is the universe.