

## 2022 Fall Semester Midterm Examination

### For General Chemistry II

**Date:** October 19 (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
<b>1</b>	/17	<b>6</b>	/12	<b>/100</b>
<b>2</b>	/6	<b>7</b>	/10	
<b>3</b>	/10	<b>8</b>	/10	
<b>4</b>	/8	<b>9</b>	/9	
<b>5</b>	/8	<b>10</b>	/10	

\*\* This paper consists of 20 sheets with 10 problems (*page 18 - 19*: Equation, constants & periodic table, *page 20*: 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: **October 24 (Mon, 20:00 ~ 21:00, 1 hr)**

*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)	Class	Room(E11)
<b>A/B</b>	102	<b>C/D</b>	103

0 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: ***October 27(Thu) ~ 28(Fri)***

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

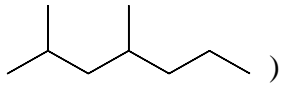
(No additional corrections. If no change in your score after reasoning, the claims were not accepted.)

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

**1. (total 17 pts)**

The alkane of molecular formula  $C_9H_{20}$  (nonane) has 35 structural (constitutional) isomers.

a) Draw the 11 isomers with 7 carbon atoms in a chain.

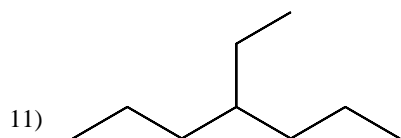
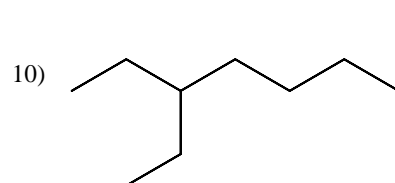
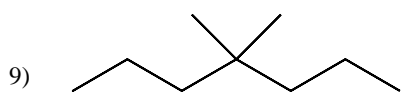
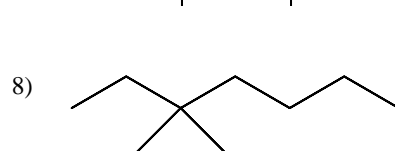
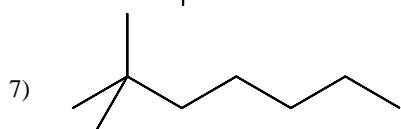
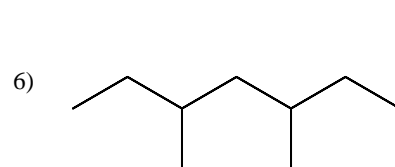
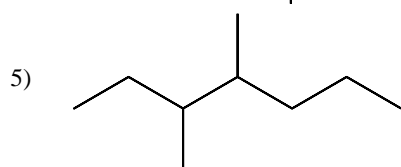
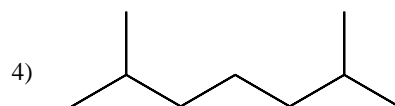
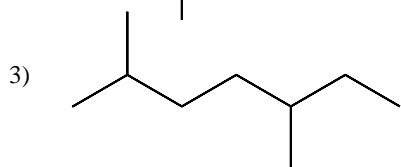
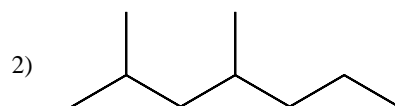
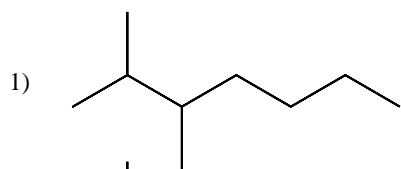
(for example: )

b) Identify the isomers with chiral center(s) among the 11 isomers and mark the chiral carbon(s).

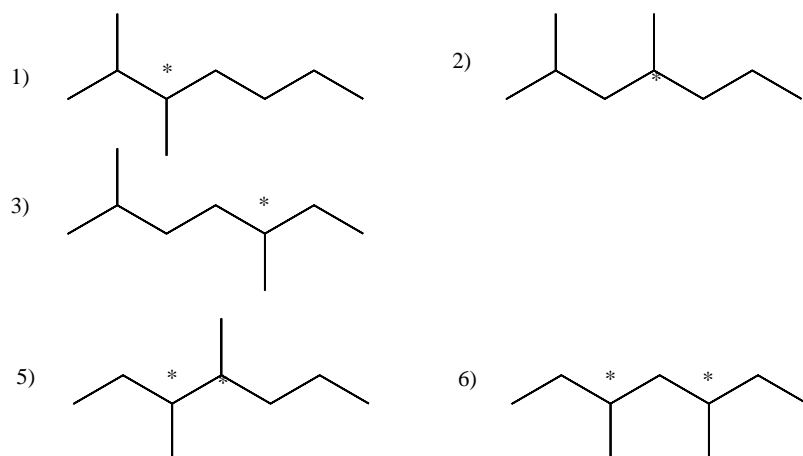
c) Identify the diastereomers.

**Answer**

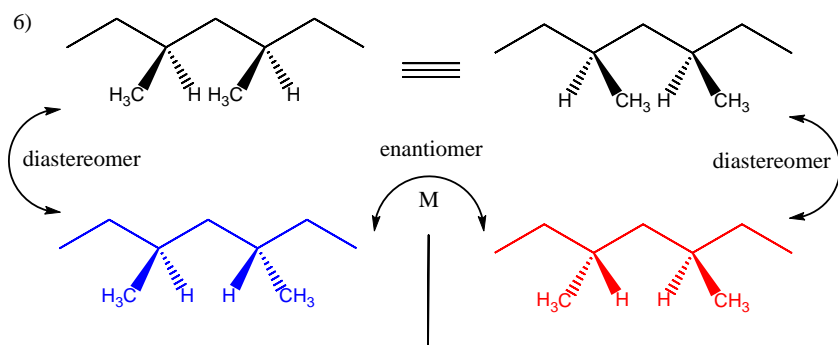
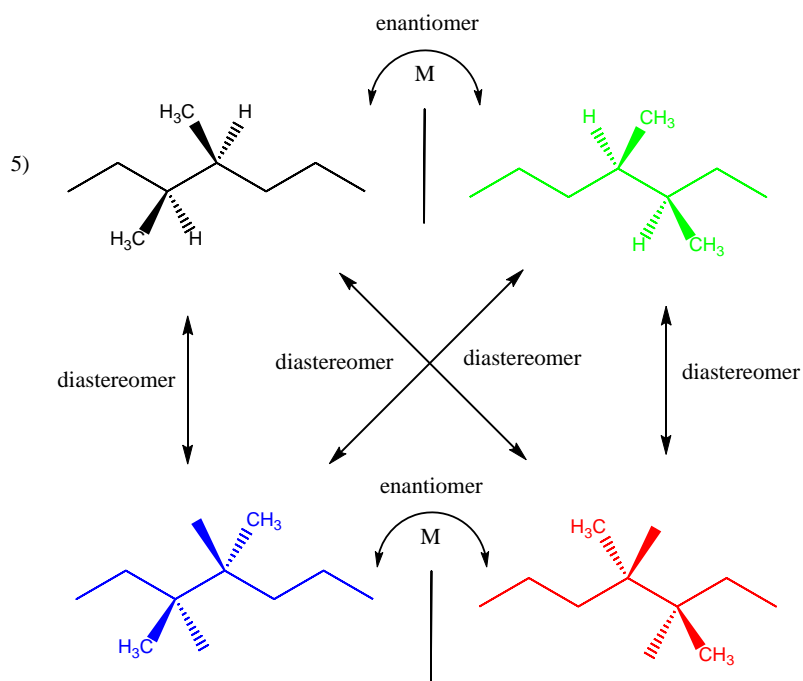
**a) 10 pts (1 pt each, except 2))**



b) 5 pts (1 pt each)



c) 1 pts each (total 2 pts)



2. (total 6 pts)

(a) List three important reactive intermediates in organic reactions.

Answer 3 pts (1 pt each)

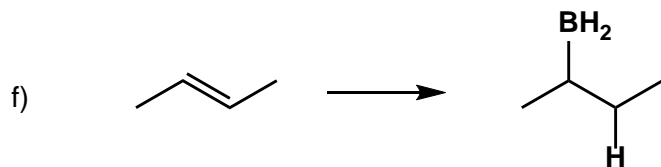
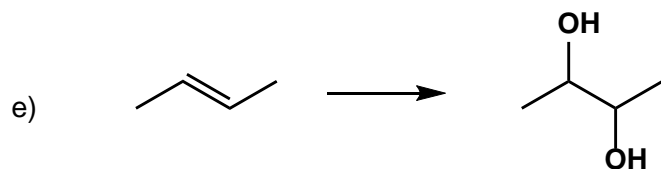
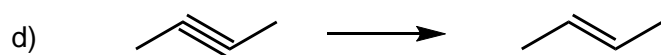
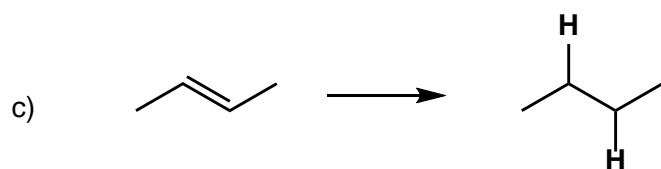
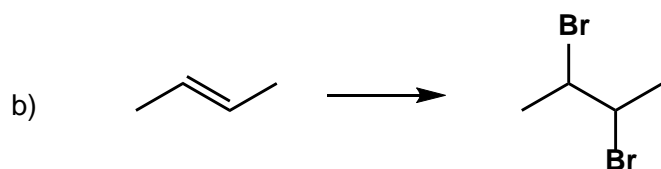
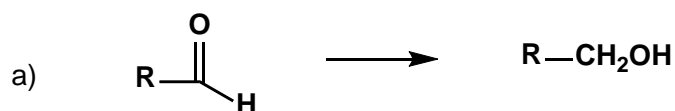
Radical,

Carbanion

Carbocation,



(b) Identify the oxidation reactions among the following reactions.



Answer 3 pts (1.5 pt each)

b), e)

### 3. (total 10 pts)

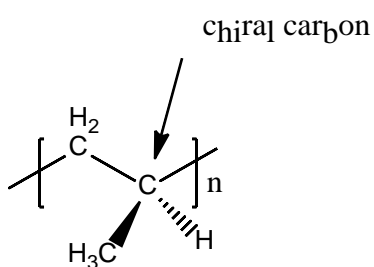
Polymerization of propylene ( $\text{CH}_2=\text{CH}-\text{CH}_3$ ) produces so-called polypropylene with molecular weight of several hundred thousand.

- (a) What kind of polymer it is, condensation or addition?
- (b) Draw the repeating unit of polypropylene and identify the chiral carbon.
- (c) Draw three isomeric structures of polypropylene including their name.

#### Answer

a) Addition (1 pt)

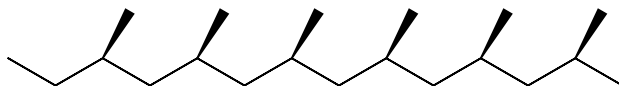
b) (3 pts)



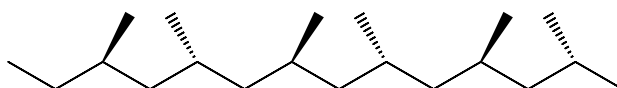
(no reduction for missing n)

c) 6 pts (2 pts each)

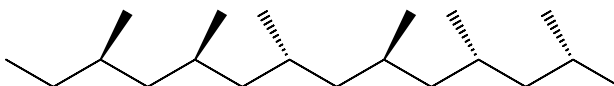
isotactic



syndiotactic



atactic



**4. (total 8 pts)**

(a) Calculate the feed ratio of hexamethylene diamine [ $\text{H}_2\text{N}-(\text{CH}_2)_6-\text{NH}_2$ ] and adipic acid [ $\text{HOOC}-(\text{CH}_2)_4-\text{COOH}$ ] that should be employed to obtain polyamide (Nylon 66) of 11,300 number average molecular weight ( $M_n$ ) at 99% conversion. (molar mass of the repeating unit:  $M_0 = 113$ ).

Answer (6 pts)

Number average of degree of polymerization:  $X_n = M_n / M_0 = 11,300 / 113 = 100$

Extent of reaction:  $p = 0.99$

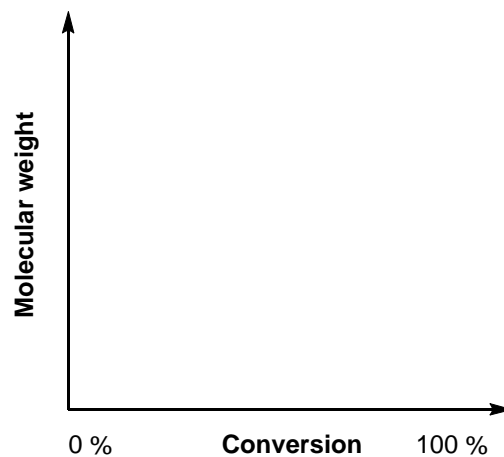
Feed ratio:  $r$

$X_n = (1 + r) / (1 + r - 2rp) = (1 + r) / (1 + r - 2r \times 0.99) = 100$

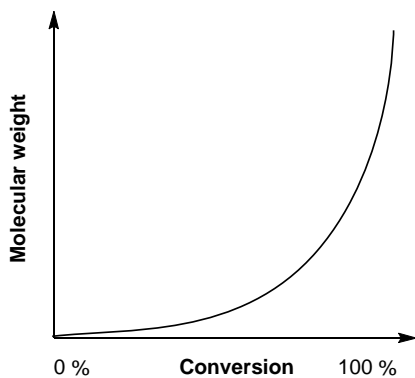
$r = 1$

hexamethylene diamine : adipic acid = 1 : 1 (equal amount of the monomers should be used)

(b) Show the change in molecular weight as a function of conversion for Nylon 66.



Answer (2 pts)



**5. (total 8 pts)**

The following sentences describe the step polymerization reaction. Mark each argument as true (O) or false (X).

- a) any two molecular species in the reaction mixture can react with each other. (   )
- b) monomer concentration decreases steadily throughout the polymerization reaction. (   )
- c) molecular weight of polymers rises steadily throughout the reaction. (   )
- d) long reaction times give high yields but affect molecular weight little. (   )

Answer 2 pts each

a) ( O )

b) ( X )

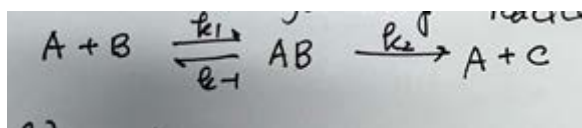
c) ( O )

d) ( X )



**6. (total 12 pts)**

Consider the following reaction



(initial concentration of A is  $[A]_0$ )

(a) Fill in the right-hand side of the following rate expressions.

$$\frac{d[A]}{dt} = ?$$

$$\frac{d[B]}{dt} = ?$$

$$\frac{d[AB]}{dt} = ?$$

$$\frac{d[C]}{dt} = ?$$

(b) If  $[AB]$  rapidly approaches to equilibrium, we can apply steady-state approximation. Express  $[AB]$  in terms of  $[A]_0$  and  $[B]$ .

(c) Derive overall reaction rate. (Be sure to eliminate intermediates from the answer)

$$\frac{d[C]}{dt} = ?$$

**Answer**

1-a) 6 pts (1.5 each)

$$\begin{aligned}\frac{d[A]}{dt} &= -k_1[A][B] + k_{-1}[AB] + k_2[AB] \\ \frac{d[B]}{dt} &= -k_1[A][B] + k_{-1}[AB] \\ \frac{d[AB]}{dt} &= k_1[A][B] - k_{-1}[AB] - k_2[AB] \\ \frac{d[C]}{dt} &= k_2[AB]\end{aligned}$$

1-b) 3 pts

$$\begin{aligned}[A]_0 &= [A] + [AB] \\ \text{SSA: } k_1[A][B] - k_{-1}[AB] - k_2[AB] &= 0 \\ \text{so, } k_1([A]_0 - [AB])[B] - k_{-1}[AB] - k_2[AB] &= 0 \\ [AB] &= \frac{[A]_0[B]}{\frac{k_{-1} + k_2}{k_1} + [B]}\end{aligned}$$

1-c) 3 pts

$$\frac{d[C]}{dt} = v = \frac{k_2[A]_0[B]}{\frac{k_{-1} + k_2}{k_1} + [B]}$$

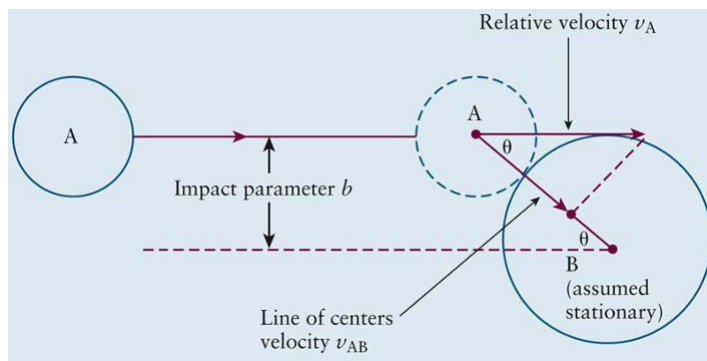
## 7. (total 10 pts)

Total rate of collision between A molecule with B molecule in a gas/unit volume is expressed as follows.

$$Z_{AB} = \sigma_c \sqrt{\frac{8k_B T}{\pi \mu}} \left(\frac{N_A}{V}\right) \left(\frac{N_B}{V}\right)$$

(a) Derive  $\sigma_c$  and  $\mu$ .

(b) Let  $v_A$  be the relative velocity of A with respect to B and the component of the velocity directed along the line of the center be  $v_{AB}$ . Using impact parameter  $b$ , derive  $v_{AB}$  and corresponding energy  $\epsilon_{AB}$ .



Answer

2-a) 4 pts (2 pts each)

$$\sigma_c = \pi d^2$$

$$\mu = \frac{m_A m_B}{m_A + m_B}$$

2-b) 6 pts (3 pts each)

$$v_{AB} = v_A \cos \theta, \quad \sin \theta = \frac{b}{d}$$

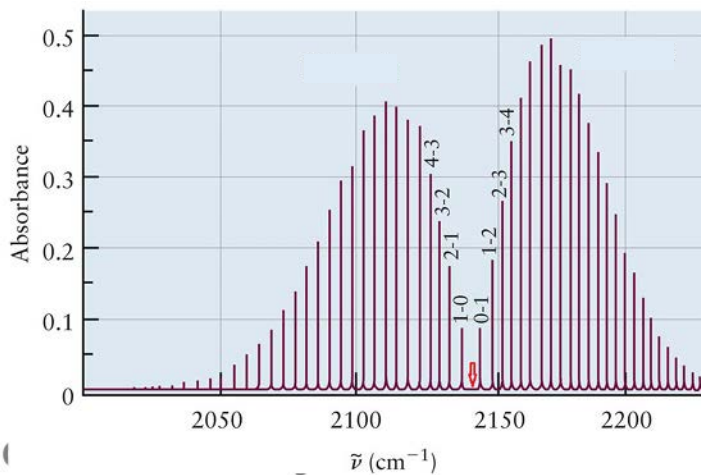
$$\cos \theta = [1 - \sin^2 \theta]^{\frac{1}{2}}$$

$$v_{AB} = v_A \left[ \frac{d^2 - b^2}{d^2} \right]^{\frac{1}{2}}$$

$$\epsilon_A = \frac{1}{2} \mu v_A^2 \rightarrow \epsilon_{AB} = \epsilon_A (d^2 - b^2) / d^2$$

## 8. (10 pts)

(a) In the graph below, indicate P- and R- branches and explain that the peaks are regularly spaced.



Above graph is the vibration-rotation spectrum of CO in the gas phase, measured using IR absorption spectroscopy

(b) Explain the Born-Oppenheimer approximation.

Answer

8-a) 6 pts

Vibrational excitation과 더불어 rotational excitation 및 de-excitation이 수반됨을 언급하고 selection rule  $\Delta v = \pm 1, \Delta J = \pm 1$  이며 P-branch는  $\Delta J = -1$  R-branch는  $\Delta J = +1$ ,  $\Delta E_J \propto (J+1)$  임을 언급하고  $\Delta E_v$  는 Quantum number  $v$ 와 independent 함을 언급하면 만점

8-b) 4 pts

Molecular wave function  $\Psi_{ne}(\{r_e\}, \{R_n\})$ 이  $\phi(\{r_e\}; \{R_n\}) X_n(\{R_n\})$ 으로 decoupling 하는 근사라고 언급하면 만점.

여기서  $\phi(\{r_e\}; \{R_n\})$ 의  $\{R_n\}$ 은 variable이 아니고 parameter라는 것을 언급하여야 함.

(+핵은 전자보다 훨씬 무겁기 때문에 운동 속도가 전자에 비해 훨씬 낮으므로 전자의 파동함수를 도출할 때 핵은 고정되어 있다고 가정하는 것이라고 이야기해도 답으로 인정해 줘야 한다고 생각합니다.)

## 9. (total 9 pts)

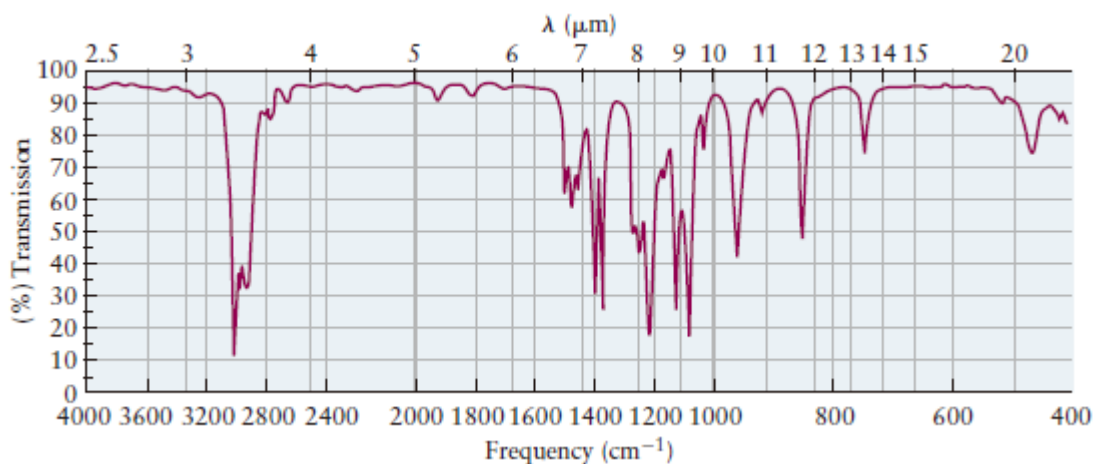
The three IR spectra are from 1-hexanol( $C_6H_{13}OH$ ), nonane( $C_9H_{20}$ ), and tert-butyl methyl ether( $(CH_3)_3OCH_3$ ). Identify which is which, and explain the characteristic bonds with each answer.

**T A B L E 20.4**

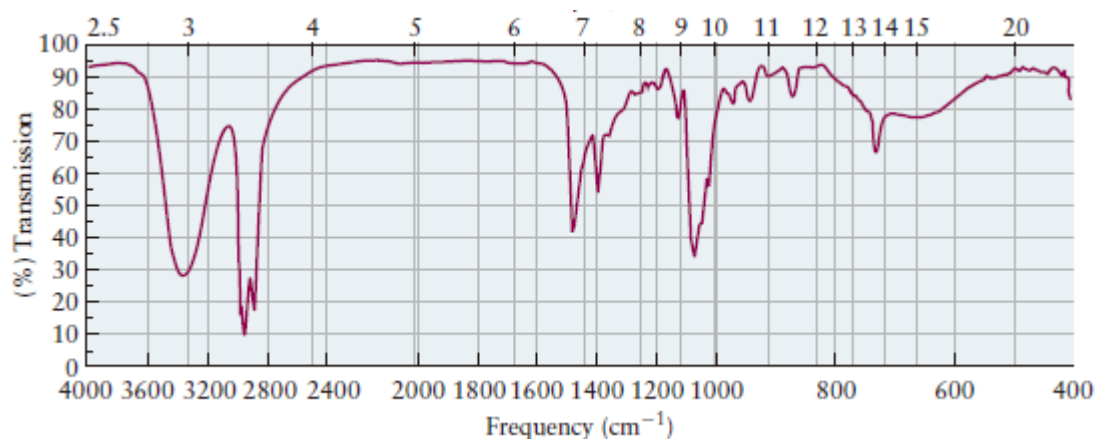
**Characteristic Vibrational Frequencies and Infrared Absorption Intensities of Selected Vibrations and Functional Groups**

Frequency ( $cm^{-1}$ )	Bond or Group	Vibration	Relative Intensity
3650–3200	O–H	Stretching	Weak to strong
3550–3100	N–H	Stretching	Medium
3300–2700	C–H	Stretching	Weak to medium
2250–2100	C $\equiv$ C	Stretching	Weak
1820–1630	C=O	Stretching	Strong
1680–1600	C=C	Stretching	Weak to medium
1430–1390	C–N	Stretching	Strong
1250–1000	C–O	Stretching	Strong

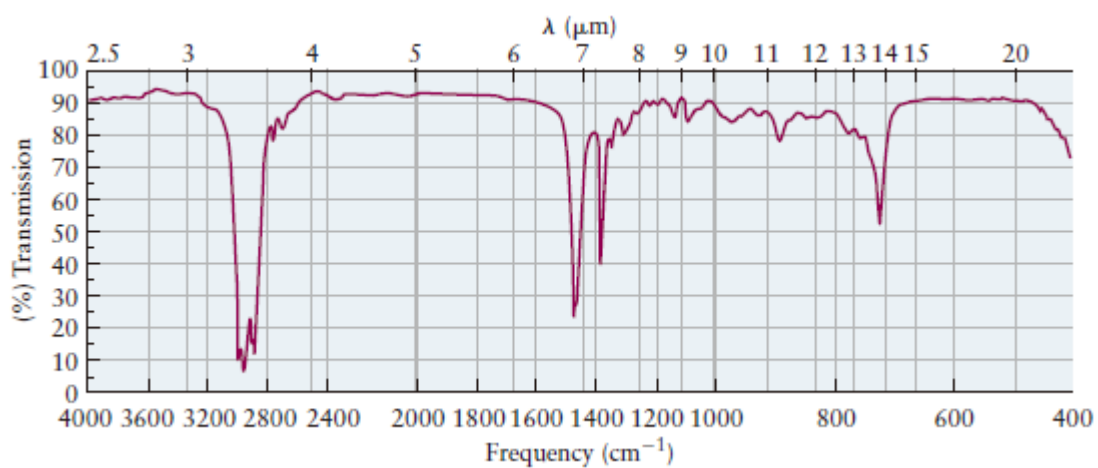
1)



2)



3)



**Answer 3 pts each**

- 1) tert-butyl methyl ether( $(\text{CH}_3)_3\text{OCH}_3$ ) / C–O peaks are observed around  $1200\text{ cm}^{-1}$ .
- 2) 1-hexanol( $\text{C}_6\text{H}_{13}\text{OH}$ ) / O–H peak observed around  $3300\text{ cm}^{-1}$ .
- 3) nonane( $\text{C}_9\text{H}_{20}$ ) / Only C–H peaks observed.

**10. (total 10 pts)**

Consider trans-1,3-butadiene.

(a) What is the total number of valence electrons?

How many valence electrons are involved in  $\sigma$  – and  $\pi$  – bond?

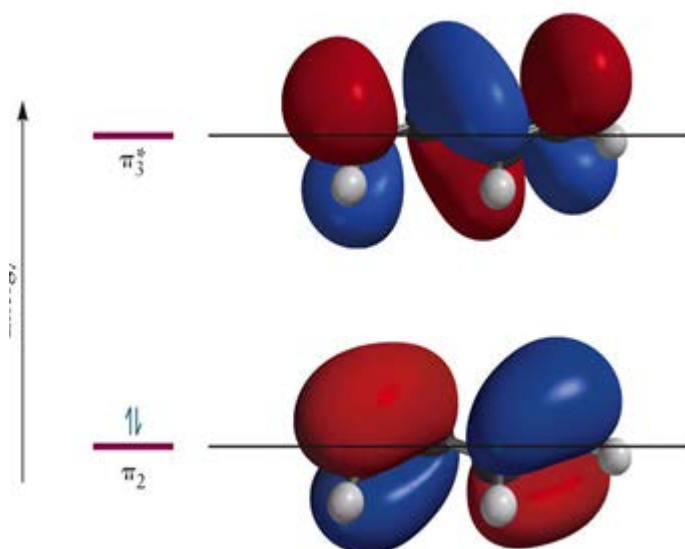
(b) Draw a schematic diagram of HOMO and LUMO.

**Answer**

10-a) 4 pts

22 valence electrons

10-b) 6 pts (3 each)



Node 표시 확실하게 해야 만점.

## 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																	
<div>GROUP</div> <div>1 1A</div> <div>2 IIA</div> <div>3 IIIB</div> <div>4 IVB</div> <div>5 VB</div> <div>6 VIB</div> <div>7 VIIB</div> <div>8</div> <div>9</div> <div>10</div> <div>11 IB</div> <div>12 IIB</div> <div>13 IIIA</div> <div>14 IVA</div> <div>15 VA</div> <div>16 VIA</div> <div>17 VIIA</div> <div>18 VIIIA</div>																	
<div>PERIOD</div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div> <div>9</div> <div>10</div> <div>11</div> <div>12</div> <div>13</div> <div>14</div> <div>15</div> <div>16</div> <div>17</div> <div>18</div>																	
<div>GROUP NUMBERS</div> <div>IUPAC RECOMMENDATION (1985)</div> <div>CHEMICAL ABSTRACT SERVICE (1986)</div> <div>ATOMIC NUMBER</div> <div>SYMBOL</div> <div>RELATIVE ATOMIC MASS (1)</div> <div>ELEMENT NAME</div>																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar
1.0079	4.0026	6.941	9.0122	10.811	12.011	14.007	15.999	18.998	20.180	22.990	24.305	26.982	28.086	30.974	32.065	35.453	39.948
HYDROGEN	HELIUM	LITHIUM	BERYLLIUM	BORON	CARBON	NITROGEN	OXYGEN	FLUORINE	NEON	SODIUM	MAGNESIUM	ALUMINIUM	SILICON	PHOSPHORUS	SULPHUR	CHLORINE	ARGON
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.39	69.723	72.64	74.922	78.96	79.904	83.80
POTASSIUM	CALCIUM	SCANDIUM	TITANIUM	VANADIUM	CHROMIUM	MANGANESE	IRON	COBALT	NICKEL	COPPER	ZINC	GALLIUM	GERMANIUM	ARSENIC	SELENIUM	BROMINE	KRYPTON
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
85.468	87.62	88.906	91.224	92.906	95.94	(98)	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
RUBIDIUM	STRONTIUM	YTRIUM	ZIRCONIUM	NIOBIUM	MOLYBDENUM	TECHNETIUM	RUTHENIUM	RHODIUM	PALLADIUM	SILVER	CADMIUM	INDIUM	TIN	ANTIMONY	TELLURIUM	IODINE	XENON
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
132.91	137.33	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Caesium	Barium	Lanthanide	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr	Ra	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt	Uub	Uut	Uuq	Uup	Uuh	Uus	Uut	Uuq	Uup
FRANCIUM	RADIUM	ACTINIDE	RUTHENIUM	DUBNIUM	SEABORGIUM	BOHRIUM	HASSIUM	METTERIUM	UNUNILLIUM	UNUNQUADRIUM	UNUNQUINQUAM	UNUNSEXTIUM	UNUNSEPTIUM	UNUNOCTIUM	UNUNNONIUM	UNUNDECADIUM	UNUNBICADIUM
LANTHANIDE																	
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
LANTHANUM	CERIUM	PRASEODYMIUM	NEODYMIUM	PROMETHIUM	SAMARIUM	EUROPIUM	GADOLINIUM	TERBIUM	DYSPROSIUM	HOLMIUM	ERBIUM	THULIUM	YTERBIUM	LUTETIUM			
ACTINIDE																	
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103			
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			
ACTINIUM	THORIUM	PROTACTINIUM	URANIUM	NEPTUNIUM	PLUTONIUM	AMERICIUM	CURIUM	BERKELIUM	CALIFORNIUM	EINSTEINIUM	FERMIUM	MEYERBERGIUM	NOBELIUM	LAWRENCIUM			

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)

Relative atomic mass is shown with five significant figures. For elements having no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However, three 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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