

Name: _____

**GENERAL CHEMISTRY
CHEM. 111 SEC. 020**

EXAM I

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2nd Summer Session, 2003

Answer all the questions. DO NOT write on this examination paper; use the blank sheets at the end of the exam for your answers. Credit will not be given for numerical questions unless all relevant calculations are shown. Please give answers to numerical questions to 3 significant figures.

1. a) For the following compounds:
- Water
 - Methane (CH₄)
 - Chloroethane (CH₂ClCH₃)
 - Carbon dioxide
- i) Which compounds contain a polar bond? 3 points
- ii) Explain your reasons for your answers in (i). 5 points
- iii) Which compounds are polar? 2 points
- iv) Explain your reasons for your answers in (iii). 5 points
- v) Which compounds have a dipole moment? 2 points
2. a) The average C = O bond length in compounds is 121 pm.
- i) Calculate the dipole moment for a completely ionized C=O bond (C²⁺ O²⁻). 4 points
- ii) If in the compound formaldehyde (CH₂O) the dipole moment is 1.35D, calculate the degree of ionization of the C=O bond. Explain any assumption you made. 4 points

- b) Arrange the following compounds in the order of increasing boiling point.

<u>Compound</u>	<u>Dipole Moment (D)</u>
Methyl Chloride (CH_3Cl)	1.87
Dimethylether (CH_3OCH_3)	1.30
Propane ($\text{CH}_3\text{CH}_2\text{CH}_3$)	0.08
Acetonitrile ($\text{CH}_3\text{C}\equiv\text{N}$)	3.92
Acetaldehyde (CH_3CHO)	2.69

5 points

- c) Explain your order in (b) above.

5 points

3. a) Explain how the following types of forces of intermolecular interaction arise.

- i) London Dispersion
- ii) Dipole - Dipole
- iii) Hydrogen bonding

15 points

- b) Of the three forces of interaction in (a) above, which is the weakest, which is the strongest?

2 points

- c) In the following compounds, which forces of intermolecular interaction would be present?

- 1) Oxygen
- 2) Ammonia
- 3) CH_3F (Fluoromethane)

5 points

- d) Explain the differences between intermolecular and intramolecular interactions.

3 points

- e) Explain why water boils at 100°C , while hydrogen sulfide boils at $\sim -60^\circ\text{C}$.

5 points

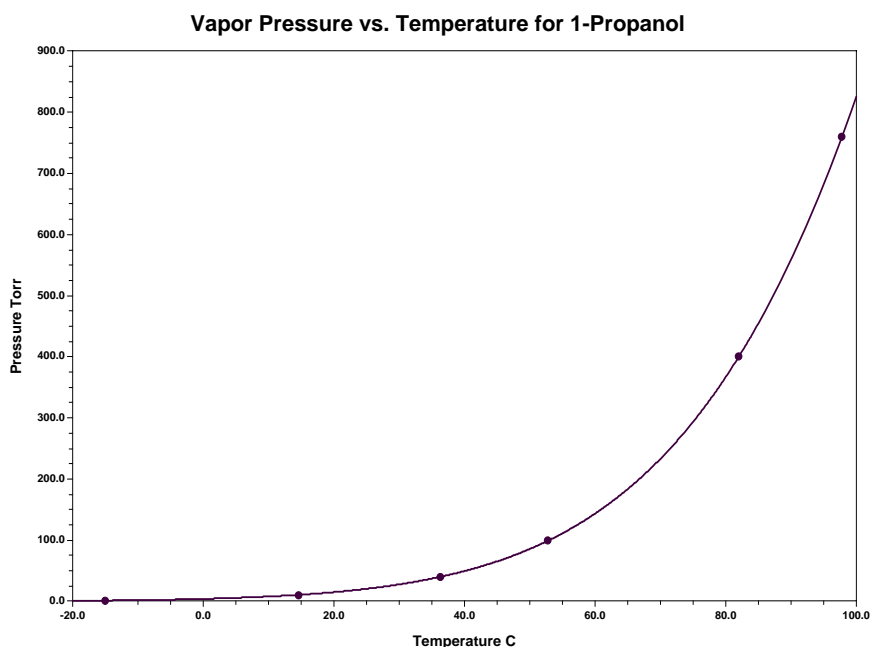
4. a) Sketch a graph of the kinetic energy distribution of atoms or molecules in a gas. Indicate on your graph where approximately the average kinetic energy lies.

4 points

- b) Temperature is a measurement of what?

2 points

c) The following is a vapor pressure curve for 1-Propanol.



- i) At 760 Torr pressure, at what temperature will 1-Propanol boil? 3 points
- ii) At a temperature of 60°C, at what pressure will 1-Propanol exist in a gas/liquid equilibrium? 3 points
- iii) At a pressure of 300Torr, what is the maximum temperature 1-Propanol can exist as a pure liquid? 3 points
- iv) What does the vapor pressure curve represent? 3 points
5. a) State Le Châtelier's Principle. 3 points
- b) What are the conditions necessary for a Dynamic Equilibrium? 3 points
- c)
- i) When a gas is cooled, what type of energy is changing? 1 point
- ii) Explain your answer for (i) above. 3 points
- iii) When a liquid is cooled, what type of energy is changing? 1 point
- iv) Explain your answer to (iii) above. 3 points
- v) When a gas condenses to form a liquid, what type of energy is changing? 1 point
- d) Explain the phenomenon of boiling. 2 points

USEFUL INFORMATION

$$\mu = Qr$$

μ = dipole moment

Q = Charge on each atom in coulombs (C)

r = distance between atoms (bond length) in meters

Charge on an electron $[e] = -1.60 \times 10^{-19}$ C.

ANSWERS

1. a)

i) H_2O , CH_2ClCH_3 , CO_2

ii)

H_2O

In water we have O-H bonds which are polar as O and H have different electronegativities.

CH_2ClCH_3

In chloromethane we have C-H bonds and C-Cl bonds. C-H bonds are non polar as C and H have about the same electronegativity. C-Cl bonds are polar as C and Cl have different electronegativities.

CO_2

In carbon dioxide we have C=O bonds which are polar as C and O have different electronegativities.

iii) H_2O and CH_2ClCH_3

iv) H_2O

Water has a distorted tetrahedral structure with two polar bonds. The polar bonds are arranged such that they reinforce each other giving a polar molecule.

CH_2ClCH_3

Chloroethane has a tetrahedral structure around both carbon atoms. There is a single polar bond in the compound and the compound must therefore be polar.

v) H_2O and CH_2ClCH_3

Any polar compound by definition must have a dipole movement.

2. a)

i) $3.87 \times 10^{-29} \text{C.m.}$

ii) 0.116%

b) Propane ($\text{CH}_3\text{CH}_2\text{CH}_3$)

Dimethyl ether (CH_3OCH_3)

Methyl Chloride (CH_3Cl)

Acetonitrile ($\text{CH}_3\text{C} \equiv \text{N}$)

Acetaldehyde (CH_3CHO)

c) As all the compounds have approximately the same molecular weight any difference in boiling point will depend on the strength of the intermolecular forces in the compounds. The Dipole movement is an indicator of the relative strength of the intermolecular forces and therefore the boiling points should be in the same order as increasing dipole movement.

3. a)

i) London dispersion forces are present in all atoms and molecules. The force is an electrostatic force and arises from the slight transient dipole that is generated in an atom or molecule when two or more atoms or molecules, come close together.

ii) Dipole – Dipole forces are present in all polar molecules (molecules having a permanent dipole movement.) This again is an electrostatic force and arises from the mutual attraction that arise between polar molecules.

iii) Hydrogen – Bonding – This is a force of attraction that occurs when hydrogen is bonded to a small electronegative atom like N, O, F. It is an interaction between the hydrogen atom bonded to a small electronegative atom in one molecule and the small electronegative atom on another molecule.

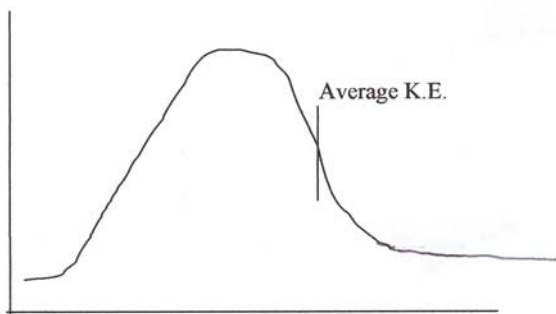
b) London Dispersion – smallest
Hydrogen Bonding – largest

c) O₂ London Dispersion
NH₃ London Dispersion, dipole-dipole, hydrogen bonding
CH₃F London Dispersion, Dipole-Dipole

d) Intermolecular forces are forces between different molecules while intramolecular forces are forces within a single molecule.

e) Water has hydrogen bonding while hydrogen sulfide has only dipole-dipole forces of interaction. Hydrogen bonding is a much stronger force than dipole-dipole so even though water has the smaller molecular weight it has the higher boiling point.

4. a)



b) The average kinetic energy of the atoms or molecules.

c)

i) 98°C

ii) 125 Torr

iii) 75 Torr

iv) The condition under which 1-propanol can exist in equilibrium as a liquid and a gas.

5. a) A system in equilibrium will tend to oppose any constraint that is placed upon it.

b) All the participants in the dynamic equilibrium must be present.

c)

i) KE

ii) Temperature is a measure of the average KE of atoms or molecules. If the temperature decreases so must the KE.

iii) KE

iv) Same as (ii) above

v) PE

d) Boiling occurs when the vapor pressure of a liquid is the same or larger than the external pressure.