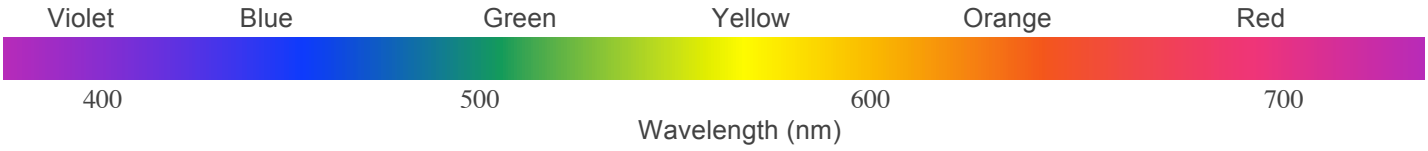
Chemistry 4A **Midterm Exam 2 Version B** **October 17, 2008**
Professor Pines **Closed Book, 50 minutes, 125 points** **5 pages total (including cover)**

Student Name: KEY Student ID#: _____

GSI Name: _____ Lab Section Day/Time: _____

Potentially Useful Information



Light: $\lambda\nu = c$, $E_{photon} = h\nu$, c = 2.99792 x 10^{8} m s^{-1}

N_A = 6.02214 x 10^{23} mol^{-1}

Particle 1D box: $E_n = \frac{h^2 n^2}{8mL^2}$; n = 1, 2, 3...

h = 6.62608 x 10^{-34} J s

Absolute Temperature (Kelvins): T (K) = T (°C) + 273.15

m_e = 9.10938 x 10^{-31} kg

Ideal Gas: PV = nRT $E_{Kin} = \frac{3}{2}nRT$ $v_{rms} = \sqrt{\frac{3RT}{M}}$

R = N_Ak = 8.31447 J K^{-1} mol^{-1} = 0.0820574 L atm K^{-1} mol^{-1}

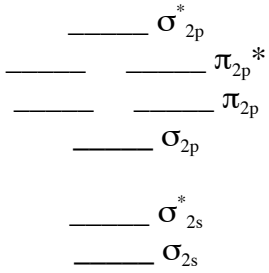
k = 1.38066 x 10^{-23} J K^{-1}

Average Bond Energies (kJ mol^{-1})

H–H	O–H	O–O	O=O
436	463	146	497

C–C	C=C	C≡C	C–H
348	612	838	413

MO Energies for O_2, F_2, Ne_2



Note: Under STP conditions (1 atm, 0 °C), one mole of an ideal gas occupies 22.4 L

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Page 5: 30

B

TOTAL: 125

Multiple Choice Questions 8 questions; **circle one answer** for each question.
(Questions 1–8 are worth 4 points each, 32 points total).

1) The atoms or molecules of which ideal gas have the greatest average kinetic energy?

A) Ar at 200C **B)** He at 400C **C)** He at 100C **D)** H_2 at 200C **E)** H_2 at 100C

2) Which will cause a molecular gas to behave less ideally?

A) Raise T **B)** Increase dipole moment **C)** Lower P **D)** Shrink molecule **E)** None of the above

3) Which of the following is most paramagnetic?

A) F_2 **B)** F_2^- **C)** F_2^{+2} **D)** F_2^+ **E)** F_2^{-2}

4) When acetylene C≡C polymerizes to polyacetylene ⋯C=C–C=C–C=C–C⋯ (Hydrogens not shown), energy is:

A) Created **B)** Destroyed **C)** Released **D)** Absorbed **E)** Can't tell

5) Which gives a linear plot for an ideal gas?

A) P vs 1/V at const T **B)** V vs T at const P **C)** PV vs T **D)** None of them **E)** All of them

6) Which ideal gas has a v_{rms} twice as great as that of Br_2 at 300K ?

A) He **B)** Ne **C)** Ar **D)** Cl **E)** Br

7) What is the oxidation number of N in NO_2^-?

A) 0 **B)** 1 **C)** 2 **D)** 3 **E)** 5

8) Pentane (C_5H_{12}) has 3 structural isomers. How many structural isomers does hexane (C_6H_{14}) have?

A) 4 **B)** 5 **C)** 6 **D)** 7 **E)** 8

Multiple Choice Questions (continued)

9) (2 points each, 10 points total) On the phase diagram for water (below), write the letter corresponding to the following processes in the box at the tail of the appropriate arrow:

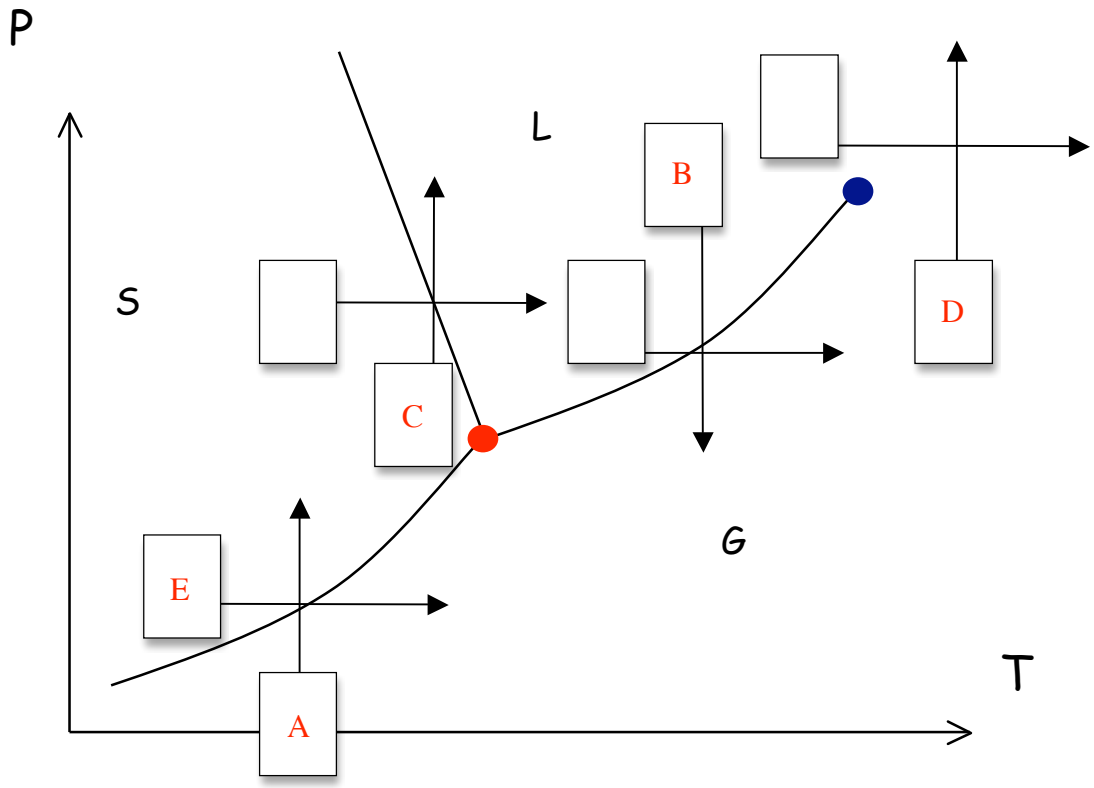
A) The isothermal compression of water vapor to ice

B) Inducing the boiling of water at constant temperature

C) The melting of ice under increasing pressure

D) The isotherm of water with no phase transition

E) Inducing the sublimation of ice to vapor at constant pressure



Write your answers and show your work in the boxes provided. Nothing outside the boxes will be graded.

Short Answer Question #1 [20 points]
A 1 L bulb was filled with a monatomic, ideal gas to 1 atm at 0 °C. The bulb was then cooled so that the gas condensed to a liquid. The mass of the liquid was 5.858 grams. Identify the gas. Show your work.

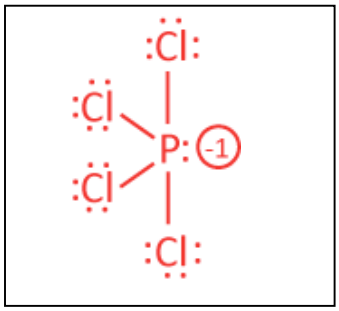
Gas	Show your work
Xenon (Xe)	PV=nRT → $n = \frac{PV}{RT}$; $MM = \frac{mass}{n}$ so, $MM = \frac{mass \cdot RT}{PV} = \frac{(5.858\ g)(0.0820574\ L \cdot atm \cdot K^{-1} \cdot mol^{-1})(273.15\ K)}{(1\ L)(1\ atm)} = 131.3\ g \cdot mol^{-1}$ which is Xe

Short Answer Question #2 [33 points]

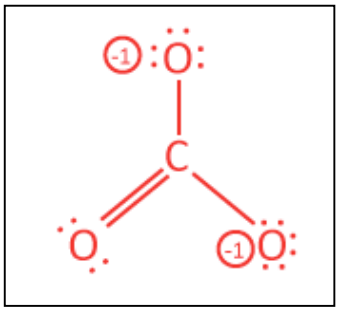
a) [15 points] Draw a Lewis electron dot structure for each of PCl_4^-, CO_3^{2-}, HCN.

On your diagrams, indicate the value of any non-zero formal charges.

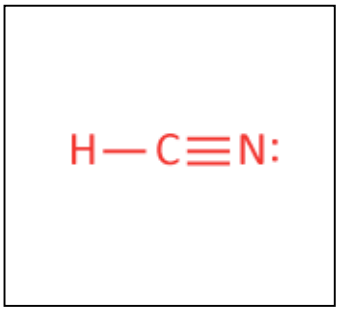
PCl_4^-



CO_3^{2-}



HCN



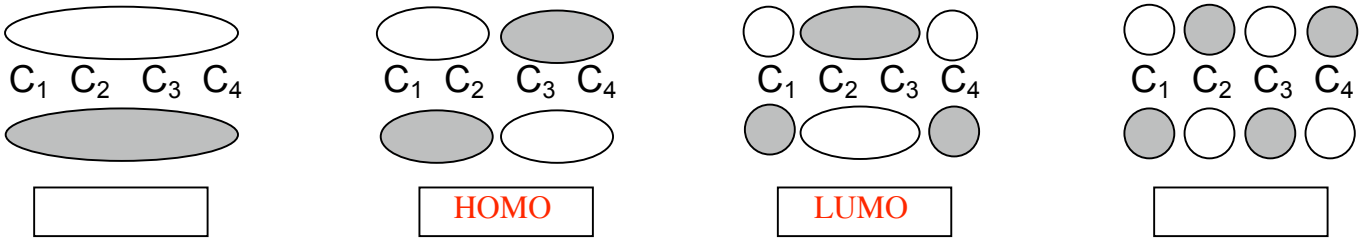
b) [18 points] Based on your Lewis structures, complete the table below.

	PCl_4^-	CO_3^{2-}	HCN
Steric Number (central atom)	5	3	2
Hybridization (central atom)	sp^3d	sp^2	sp
Resonance? (circle one)	Yes **(No)**	**(Yes)** No	Yes **(No)**
Bond Order	(P···Cl) 1	(C···O) 1 1/3	(C···N) 3
Molecular Shape (not including lone pairs)	see-saw	trigonal planar	linear
Electric Dipole? (circle one)	**(Yes)** No	Yes **(No)**	**(Yes)** No

Short Answer Question #3 [30 points]

Write your answers and show your work in the boxes provided. Nothing outside the boxes will be graded.

Shown schematically are the π, π* molecular orbitals of butadiene [C=C–C=C] (Hydrogen atoms not shown).



a) [5 points] Write **HOMO** in the box below the representation of the HOMO (Highest Occupied Molecular Orbital) and write **LUMO** in the box below that of the LUMO (Lowest Unoccupied Molecular Orbital).

b) [10 points] In the HOMO → LUMO transition, the $C_1 \cdots C_2$ bond becomes (Circle one):

weaker and longer **same** **stronger and shorter**

Briefly explain in terms of orbital structure and occupancy.

By promoting an electron from an orbital with electron density between C_1 and C_2 to an orbital with a node between C_1 and C_2, the bond becomes weaker and longer.

c) [15 points] An estimate of the wavelength for the HOMO→LUMO transition in butadiene is ~100 nm. (For butadiene, $n_{HOMO} = 2$, $n_{LUMO} = 3$, the box is 0.40 nm long and contains 4 π electrons.) Will the HOMO→LUMO transition of dodecahexene [C=C–C=C–C=C–C=C–C=C–C=C, 12 carbon atoms] be in the visible range? Use the particle in a one-dimensional box model. Assume all C···C bonds are of length 0.133 nm.

Show your work

Transition in visible range? (circle one)

yes **no**

Use 1D particle-in-a-box $\Delta E_{PIB} = \frac{h^2}{8mL^2}(n_f^2 - n_i^2) = \frac{hc}{\lambda}$;

Therefore, $\lambda = \frac{8mL^2c}{h} \cdot \frac{1}{(n_f^2 - n_i^2)} = \frac{8mL^2c}{h} \cdot \frac{1}{(n_{LUMO}^2 - n_{HOMO}^2)}$

$m = m_{electron}, \quad L = 11(0.133\ nm) = 1.463\ nm, \quad n_{HOMO} = 6, \quad n_{LUMO} = 7$

$$\lambda = \frac{8(9.10938 \times 10^{-31} kg)(1.463 \times 10^{-9} m)^2 (2.99792 \times 10^8 m \cdot s^{-1})}{6.62608 \times 10^{-34} J \cdot s} \cdot \frac{1}{(7^2 - 6^2)}$$

$\lambda = 5.429 \times 10^{-7} m = 542.9\ nm$ which is green-yellow.