Name:____ Score:_______________

This exam consists of 14 multiple choice questions worth 3 pts each, 3 short answer questions worth 10 pts each, and 2 problems worth 14 pts each. BUDGET YOUR TIME WISELY. This exam has 13 pages including the cover page, nine pages of questions, two information sheets and a blank scratch sheet.

Multiple Choice Answers:

1.	5.	9.	13.
2.	6.	10.	14.
3.	7.	11.	
4.	8.	12.	

SCORE: Indicate the Letters for Questions 15 and 16 below.

Scores:	
1-14.	/42
15. ( )	/10
15. ( )	/10
15. ( )	/10
16. ( )	/14
16. ( )	/14
Total:	/100

Name____________________________________

Multiple Choice (42 pts): 14 questions. Choose the letter corresponding to the best <u>single</u> answer for each question. Put your answers in the numbered boxes on the cover sheet of this exam.

SAMPLE QUESTIONS:

1.) How many rotational degrees of freedom does butane possess?

(a) 2 (b) 3 (c) 5 (d) 14

(e) 42 (f) 36 (g) 37 (h) 1

2.) In which spectral region would you expect to observe valence electronic transitions?

(a) γ-ray (b) X-ray (c) UV (d) Visible

(e) Infrared (f) Microwave (g) Radio frequency

3.) Which of the following forces are shortest range?

(a) Dipole-Dipole Forces (b) Repulsive forces

(c) London Dispersion Forces (d) Coulomb Forces

15.) Short Answer (30 points): In the space available answer 3 of the following 5 questions. Indicate the questions you want graded on the cover sheet. Use complete sentences! Correct answers expressed in poor grammar will be docked 1 point. Use equations and diagrams where helpful or required. Each question is worth 10 points.

SAMPLE QUESTIONS:

A.) Consider a molecular orbital picture of MgH. If MgH is ionized to form MgH^+ what changes do you expect in the bond length and the vibrational frequency? Why?

B.) Describe hydrogen bonding and explain why it is an important and unique interaction, contrasting it with other Van der Waals interactions. Give two examples illustrating the importance of hydrogen bonding.

16.) (28 pts): In the space available solve 2 of the following 3 problems. Indicate the questions you want graded on the cover sheet. Partial credit will be given for work shown in the indicated area only. You must show how the correct answer was obtained or no credit will be given. Each problem is worth 14 points.

SAMPLE PROBLEM:

B.) The J = 0 to 2 rotational transition of HD is observed in the Raman spectrum at 273.93 cm^{-1}.
(i) Based on this observation what is the bond length in the HD molecule?

(ii) Would you expect to observe the J = 0 to J = 2 transition of H_2 above or below 273.93 cm^{-1} ?
Explain your answer.

Possibly Useful Constants and Quantities and Equations:

Constant or Quantity	SI units
Avogadro's Number (N_o)	6.02214×10^{23} mol^{-1}
Boltzmann's Constant (k)	1.38066×10^{-23} J K^{-1}
Electron Charge (e)	1.602177×10^{-19} C
Electron Mass (m_e)	9.10939×10^{-31} kg
Gas Constant (R)	8.31451 J K^{-1} mol^{-1}
Planck Constant (h)	6.62608×10^{-34} J s
Proton Mass (m_p)	1.67262×10^{-27} kg
Rydberg Constant (R)	1.09677×10^{5} cm^{-1}
Speed of Light in a Vacuum (c)	2.99792458×10^{8} m s^{-1}
Atomic Mass Unit	1.66054×10^{-27} kg
Bohr Radius (a_o)	5.29177×10^{-11} m
Atomic Weight of Hydrogen (^{1}H)	1.007825 amu
AW of Deuterium (^{2}D)	2.014 amu

Photoelectric Effect:

$$h\nu = \Phi + \frac{mv^2}{2}$$

De Broglie Wavelength:

$$\lambda = \frac{h}{mv}$$

Energy Levels:

$$\frac{E_{vib/rot}}{hc} = \bar{\nu}\left(n+\frac{1}{2}\right) + BJ(J+1) + x\bar{\nu}\left(n+\frac{1}{2}\right)^2 - D\left[J(J+1)\right]^2 - \alpha\left(n+\frac{1}{2}\right)J(J+1) +$$

Vibrational Frequency and Rotational Constant:

$$\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}} \qquad B = \frac{h}{8\pi^2 cI} = \frac{h}{8\pi^2 c\mu r_e^2}$$

Beer's Law:

$$A = \varepsilon c l$$

The Particle in a Box, n = 1,2,3,...:

$$\psi_n = \sqrt{\frac{2}{L}}\sin\frac{n\pi}{L}x \qquad E_n = \frac{n^2h^2}{8mL^2}$$

Interaction energies:

Type of Interaction	Energy of Interaction
Covalent Bond	No simple Expression
Ion-Ion	$e^2/\varepsilon r$
Ion-Dipole	$\kappa e\mu/\varepsilon r^2$ κ is geometry dependent.
Dipole-Dipole	$\kappa\mu_A\mu_B/\varepsilon r^3$ κ is geometry dependent.
Ion-Induced Dipole	$\alpha e^2/2\varepsilon r^4$
Dipole-Induced Dipole	$\alpha\mu^2/\varepsilon r^6$
Dispersion	$3I\alpha^2/4r^6$
Hydrogen Bond	No Simple Expression