

*Reminder: This examination is for credit. Any breach of academic honesty\* will result in a failing grade.*

The exam will be marked out of a total of 40 points. Each question is worth 10 points. You are free to attempt them all, if you have time, but only the best four marks will be used for your total.

1. Sketch a typical microwave rotational spectrum (intensity versus frequency) for a diatomic molecule. A stick plot is sufficient, but take care to indicate the relative spacing and intensities of the lines. Explain the pattern of intensities.
2. Given that the bond length of NO is 0.115 nm, calculate the frequency of the 20<sup>th</sup> line in the rotational spectrum. Give your answer in units of  $\text{cm}^{-1}$ .
3. A series of lines in the spectrum of atomic hydrogen starts at 1876 nm and goes to smaller wavelengths. Which transition (quantum numbers) does that first line correspond to? What is the wavelength of the next line in the series? What is the wavelength of the last line in the series? [You may assume the value of the Rydberg constant.]
4. Explain the connection or difference between the following pairs of terms. Use words, diagrams, mathematical equations and/or examples, as appropriate.
  - (a) Boundary condition and quantization.
  - (b) Eigenvalue and expectation value.
  - (c) Degeneracy and symmetry.
5. Explain briefly how experimental observations of the photoelectric effect support the concept of quantization of energy. Your answer should include discussion of the effects of both intensity and frequency of light.

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Speed of light in vacuum  $c = 2.9979 \times 10^8 \text{ m s}^{-1}$

Planck Constant  $h = 6.6262 \times 10^{-34} \text{ J s}$

Planck Constant/ $2\pi$   $\hbar = 1.0546 \times 10^{-34} \text{ J s}$

Elementary Charge  $e = 1.6022 \times 10^{-19} \text{ C}$

Electron Mass  $m_e = 9.109 \times 10^{-31} \text{ kg}$

Atomic Mass Unit  $u = 1.6606 \times 10^{-27} \text{ kg}$

Avogadro Constant  $L = 6.0221 \times 10^{23} \text{ mol}^{-1}$

Boltzmann Constant  $k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$

Rydberg constant  $R_H = 109677 \text{ cm}^{-1}$

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\* *The fine print:* Academic dishonesty includes use of any unauthorized aid or communication. In this exam the only permitted aids are (1) a single sheet of notes; (2) a calculator.