

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Chemistry


Chemistry 121 Midterm Examination

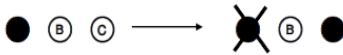
SOLUTIONS

October 9, 2018

Time Limit: 60 minutes

INSTRUCTIONS:

1. Check that this examination paper consists of **10 pages total, printed on both sides**.
2. Answer all questions on the separate bubble sheet.
Any answers written on this examination paper will NOT be graded.
3. The last page of this examination paper is a sheet of supplementary information and the Periodic Table. You may detach this page.
4. The only calculators permitted are the Sharp EL-510 series. All other calculators will be confiscated by the invigilators.
5. Unassembled model kits are allowed. Models cannot have writing/marks on them. Instruction sheets are NOT permitted.
6. No electronic communication devices are permitted on writing desks. Your electronics must be powered off and out of reach.
7. When handing in your exam, please place all loose pages inside the examination paper. This examination paper **will NOT be returned**.
8. **Do NOT fold** the bubble sheet.
9. For bubble responses, *completely* fill in the bubble in dark pencil or ink and leave the rest blank:


Selecting option "D"
10. If you've written in pen and want to change your response, then draw a neat "X" over the response you do NOT want marked and fill in your new response.


Pen: Changing an answer from "A" to "C"

RULES GOVERNING FORMAL EXAMINATIONS

1. Each examination candidate must be prepared to produce, upon the request of the invigilator or examiner, his or her UBCCard for identification.
2. Examination candidates are not permitted to ask questions of the examiners or invigilators, except in cases of supposed errors or ambiguities in examination questions, illegible or missing material, or the like.
3. No examination candidate shall be permitted to enter the examination room after the expiration of one-half hour from the scheduled starting time, or to leave during the first half hour of the examination. Should the examination run forty-five (45) minutes or less, no examination candidate shall be permitted to enter the examination room once the examination has begun.
4. Examination candidates must conduct themselves honestly and in accordance with established rules for a given examination, which will be articulated by the examiner or invigilator prior to the examination commencing. Should dishonest behaviour be observed by the examiner(s) or invigilator(s), pleas of accident or forgetfulness shall not be received.
5. Examination candidates suspected of any of the following, or any other similar practices, may be immediately dismissed from the examination by the examiner/invigilator, and may be subject to disciplinary action:
 - i. speaking or communicating with other examination candidates, unless otherwise authorized;
 - ii. purposely exposing written papers to the view of other examination candidates or imaging devices;
 - iii. purposely viewing the written papers of other examination candidates;
 - iv. using or having visible at the place of writing any books, papers or other memory aid devices other than those authorized by the examiner(s); and,
 - v. using or operating electronic devices including but not limited to telephones, calculators, computers, or similar devices other than those authorized by the examiner(s)—(electronic devices other than those authorized by the examiner(s) must be completely powered down if present at the place of writing).
6. Examination candidates must not destroy or damage any examination material, must hand in all examination papers, and must not take any examination material from the examination room without permission of the examiner or invigilator.
7. Notwithstanding the above, for any mode of examination that does not fall into the traditional, paper-based method, examination candidates shall adhere to any special rules for conduct as established and articulated by the examiner.
8. Examination candidates must follow any additional examination rules or directions communicated by the examiner(s) or invigilator(s).

PART I. Multiple Choice [34 marks total]

For each numbered statement below, identify the letter that corresponds to the best answer. There is only one correct answer per question. Record your responses on the separate bubble sheet. Only responses given on the bubble sheet will be marked.

- [2 marks]** Which one of the following neutral elements does NOT have an equal number of electrons and neutrons in its most naturally abundant isotopic form?
 - He
 - N
 - O
 - F**
 - Ne

- [2 marks]** Which one of the following bonds has the highest percent ionic character?
 - RbCl**
 - CO
 - N₂
 - HF
 - NO

- [2 marks]** Which one of the following series lists the atoms (from molecules) in order of increasing electronegativity?
 - F < O < N < C < B
 - C < N < O < F < Ne
 - Na < S < P < Si < Cl
 - Ra < B < Sr < Ca < Mg
 - Tl < Sn < Ge < As < S**

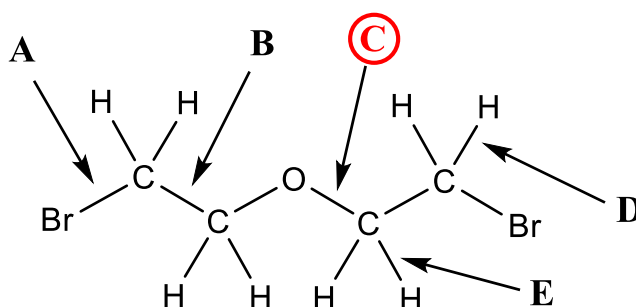
- [2 marks]** Nitric oxide can exist as NO, [NO]⁺, and [NO]⁻. Which of these three forms has the shortest bond length?
 - NO
 - [NO]⁻
 - [NO]⁺**
 - None; they are all the same length.
 - Cannot determine with information provided.

- [2 marks]** Which one of the following molecules/ions is a free radical?
 - [C₂H₅O]⁻
 - CH₃NO
 - C₂H₅S**
 - [CH₃NH₃]⁺
 - SO₃

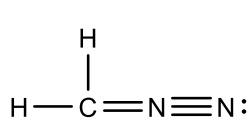
6. [2 marks] In the methyloxonium cation, $[\text{CH}_3\text{OH}_2]^+$, the oxygen has:

- A. oxidation state = -2, formal charge = -1, and a negative partial charge
- B. oxidation state = +2, formal charge = -1, and a positive partial charge
- C. oxidation state = -2, formal charge = 0, and no partial charge
- D. oxidation state = +2, formal charge = +1, and a positive partial charge
- E. oxidation state = -2, formal charge = +1, and a negative partial charge**

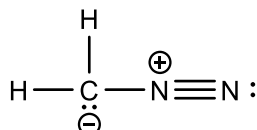
7. [2 marks] Out of the five bonds labelled A-E on the molecule below, which one has the largest bond dipole?



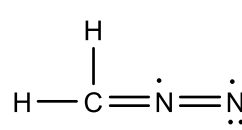
8. [2 marks] Which one of the following options is the best Lewis structure of CH_2N_2 ?



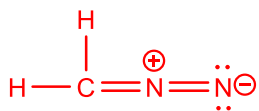
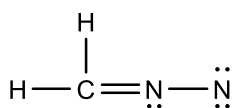
A.



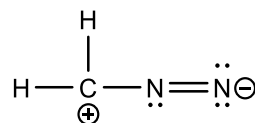
B.



C.

**D.**

E.



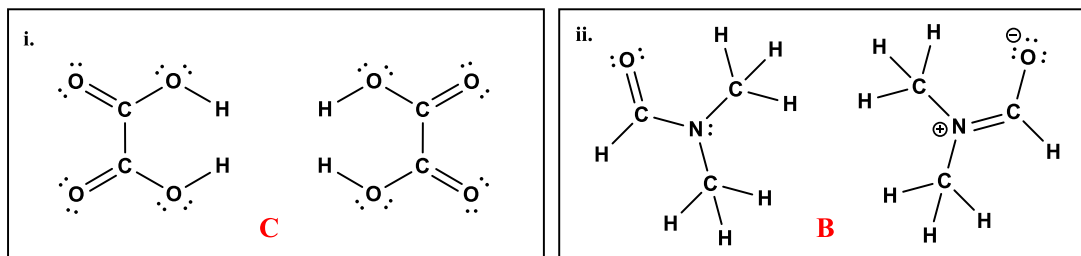
F.

9. [2 marks] How many single bonds are there in the best Lewis structure of carbonic acid, H_2CO_3 ?

- A. 4**
- B. 3
- C. 2
- D. 1
- E. 0

10. [2 marks] For each part, i-ii, classify the pair of molecules below as:

- A. isomers
- B. resonance structures
- C. the same molecule
- D. no relationship



11. [2 marks] A central atom that is singly bonded to three other atoms and has two lone pairs will have which molecular shape?

- A. T-Shaped
- B. Trigonal Bipyramidal
- C. Trigonal Planar
- D. Trigonal Pyramidal
- E. Tetrahedral

12. [2 marks] Which of the four compounds below contain at least one fluorine–central atom–fluorine bond angle measuring approximately 90° ?



- A. XeF_4 and SeF_4 only
- B. XeF_4 , SeF_4 , and SF_4 only
- C. SeF_4 and SF_4 only
- D. SeF_4 , SF_4 , and BrF_3 only
- E. all four compounds

13. [2 marks] Which one of the following molecules has octahedral parent shape and is polar? The central atoms are underlined.

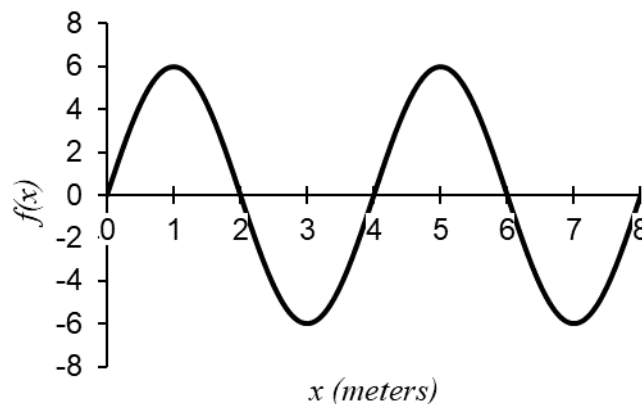
- A. P Cl_3
- B. I Cl_3
- C. Br Cl_5
- D. P Cl_5
- E. S F_6

14. [2 marks] What is the maximum number of coplanar atoms in $\underline{\text{Xe}}\text{O}_2\text{F}_2$? The central atom is underlined.

- A. 2
- B. 3
- C. 4
- D. 5
- E. Impossible to determine

15. [2 marks] The graph below shows a transverse wave travelling to the right at a speed of 12 m/s. What is its frequency?

- A. 2 Hz
- B. 3 Hz
- C. 4 Hz
- D. 6 Hz
- E. 12 Hz



16. [2 marks] An electron is in the $n = 3$ state of a one-dimensional box with $L = 24.0$ nm. What is the probability (as a percentage) of finding the electron between $x = 0.0$ nm and $x = 8.0$ nm?

- A. 0%
- B. 10%
- C. 25%
- D. 33%
- E. 50%

17. [2 marks] A particle is accelerated to a speed of 1.00×10^4 m/s. In a diffraction experiment, its de Broglie wavelength was determined to be 9.98 pm. What is the identity of this particle?

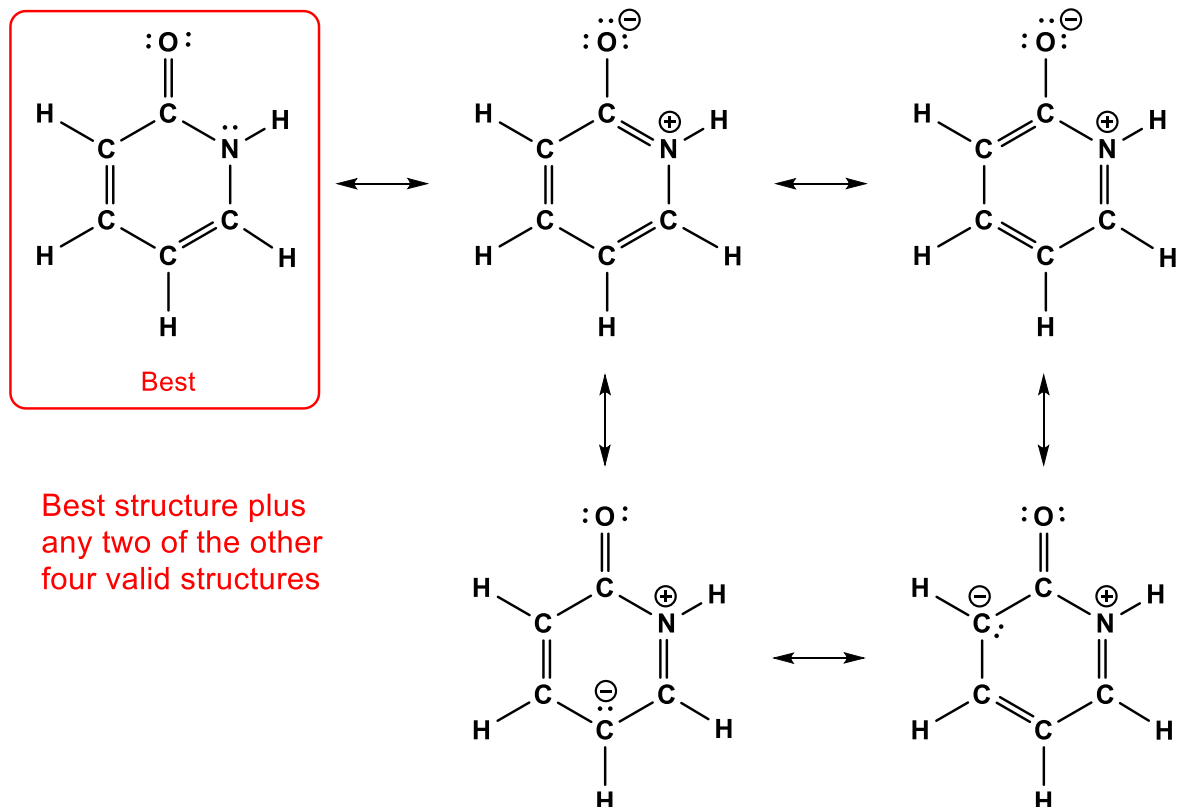
- A. An electron
- B. A proton
- C. An alpha particle (a ${}^4\text{He}$ nucleus)
- D. An ammonium ion, $[\text{NH}_4]^+$
- E. An $[\text{O}_2]^-$ ion

PART II. Short Answer Questions [23 marks total]

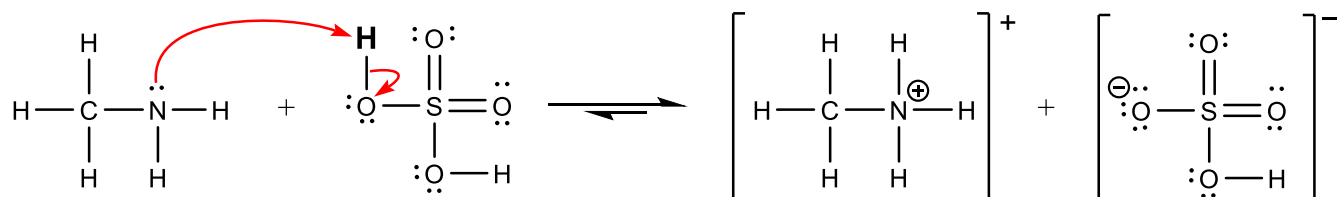
Write all answers *in the appropriate box on the separate bubble sheet.*

Only answers given on the bubble sheet will be marked. You may use the templates provided here for rough work.

18. [4 marks] Complete the skeletal structures of 2-pyridinone to give three valid Lewis resonance structures. Show all lone pairs of electrons as pairs of dots and all additional bonds as lines. Write any non-zero formal charges on the appropriate atoms. Circle the best Lewis resonance structure.



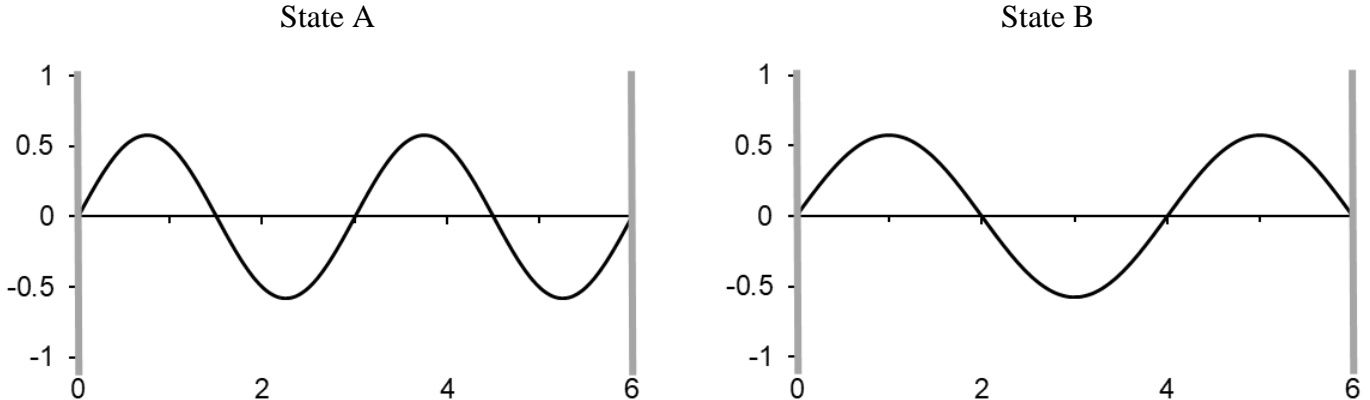
19. [2 marks] Consider the Brønsted-Lowry acid-base reaction shown below. In the appropriate box on the bubble sheet, use curved arrow notation on the reactants to show how the products are formed in this proton transfer reaction. The acidic hydrogen is shown in bold.



20. [9 marks] Complete the table for the following molecules on the separate bubble sheet. The central atom in each molecule is underlined. For Lewis structures, be sure to show all lone pairs of electrons as pairs of dots and to indicate any non-zero formal charges on the appropriate atoms.

	Best Lewis Structure	Perspective Diagram	Molecular Shape
$[\underline{\text{O}}\text{CN}]^-$		$\text{O} - \text{C} - \text{N}$	Linear
$\underline{\text{As}}\text{F}_5$			Trigonal Bipyramidal
$\underline{\text{P}}\text{Br}_3$			Trigonal Pyramidal
$[\underline{\text{Se}}\text{SO}_3]^{2-}$			Tetrahedral

21. An electron is in a one-dimensional box with a length of 6.0 \AA . The plots below show the wavefunction of the electron in State A (left) and State B (right).



- (a) [1 mark] What is n for State A? $n = \underline{4}$
- (b) [1 mark] What is n for State B? $n = \underline{3}$
- (c) [1 mark] If the electron transitions from State A to State B, does the energy of the electron increase or decrease? Circle your answer on the bubble sheet.

Increases

Decreases

- (d) [3 marks] Calculate the energy change, ΔE , for the process described in part (c). On the bubble sheet, show your work and give your answer in joules to 3 significant figures.

$$\Delta E = \frac{h^2}{8mL^2} (n_f^2 - n_i^2) = \frac{(6.626 \times 10^{-34})^2}{8(9.11 \times 10^{-31})(6.0 \times 10^{-10})^2} (3^2 - 4^2) = \frac{(4.39039 \times 10^{-67})}{(2.62368 \times 10^{-48})} (-7) = -1.17 \times 10^{-18} \text{ J}$$

$$|\Delta E| = 1.17 \times 10^{-18} \text{ J}$$

- (e) [2 marks] From State B, the electron relaxes into the ground state. What is the energy of the electron in the ground state? Give your answer in joules to 3 significant figures.

$$E_1 = \frac{h^2(1)^2}{8mL^2} = \frac{(6.626 \times 10^{-34})^2(1)^2}{8(9.11 \times 10^{-31})(6.0 \times 10^{-10})^2} = 1.67 \times 10^{-19} \text{ J}$$

END OF EXAMINATION

Supplementary Information

Potentially useful constants and conversion factors

$$1 \text{ Hertz} = 1 \text{ Hz} = 1 \text{ s}^{-1} = 10^{-6} \text{ MHz}$$

$$1 \text{ m} = 10^6 \mu\text{m} = 10^9 \text{ nm} = 10^{10} \text{ \AA} = 10^{12} \text{ pm}$$

$$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ J s}$$

$$N_A = \text{Avogadro's number} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$c = \text{speed of light} = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$1 \text{ amu} = 1 \text{ u} = \text{atomic mass unit} = 1.66 \times 10^{-27} \text{ kg}$$

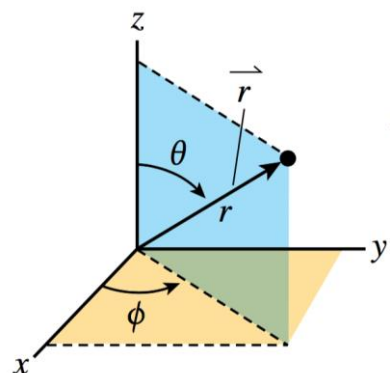
$$\text{electron mass} = 9.11 \times 10^{-31} \text{ kg}$$

$$\text{proton mass} = 1.67 \times 10^{-27} \text{ kg}$$

$$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$$

$$a_0 = \text{Bohr radius} = 0.53 \text{ \AA}$$

$$R_H = \text{Rydberg constant} = 2.18 \times 10^{-18} \text{ J}$$



Spherical polar coordinates

$$\begin{aligned} x^2 + y^2 + z^2 &= r^2 \\ x &= r \sin \theta \cos \phi \\ y &= r \sin \theta \sin \phi \\ z &= r \cos \theta \end{aligned}$$

Potentially useful formulae

$$v = \lambda \nu$$

$$f(x) = A \sin(2\pi x/\lambda)$$

$$\lambda = h/p = h/mv$$

$$E = mc^2$$

$$E_K = mv^2/2$$

$$E = h\nu$$

$$\Psi_n(x) = (2/L)^{1/2} \sin(n\pi x/L) \quad (n = 1, 2, 3, \dots)$$

$$E_K = E_{\text{light}} - E_{\text{binding}} = h(\nu - \nu_0)$$

$$E_n = h^2 n^2 / 8mL^2$$

$$E_n = -(2.18 \times 10^{-18} \text{ J}) Z^2/n^2$$

