

Chemistry 121
The University of British Columbia
Midterm Examination I
October 7, 2015

**Put the first letter
of your family/last
name in this box.**

Time: 60 minutes

Family/Last Name (printed): **ANSWERS**

First Name: _____

Signature: _____

Student Number: _____

Please check \checkmark your lecture section:

101 (MWF 1:00 PM) Rodriguez-Nunez

102 (MWF 2:00 PM) Orvig

103 (MWF 3:00 PM) Orvig

110 (MWF 10:00 AM) Berlinguette

111 (MWF 11:00 AM) MacLachlan

122 (T,Th 2:00 PM) Hudson

133 (T,Th 3:30 PM) McIntosh

188 (T,Th 8:00 AM) Crane

199 (T,Th 9:30 AM) Lindenberg

V01 (MWF 11:00 AM) Lekhi

V02 (MWF 2:00 PM) Lekhi

INSTRUCTIONS

1. Write all answers on this examination paper, and show full details of your solutions for Part 2.
2. Read each question carefully.
3. Check that this examination consists of **12 PAGES PRINTED ON BOTH SIDES**. The last sheet (pages 11 and 12), containing Supplementary Information and the Periodic Table, may be detached for ease of use.
4. The only calculators allowed are the Sharp EL-510 series. All other calculators will be confiscated. Cell phones or other electronic communication devices are not permitted on the examination desks and must be powered off.
5. Unassembled molecular model kits may be used.

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).

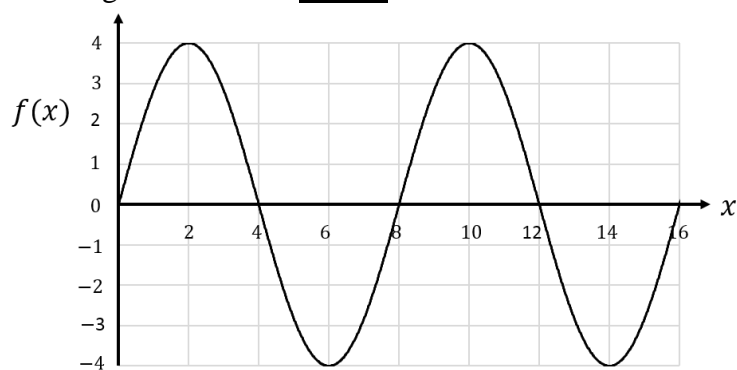
Marks

Part	Page	Possible Marks	Marks
1	3-4	16	
	5-6	14	
2	7	8	
	8	4	
	9	10	
	10	8	
Total		60	

Part 1. Multiple Choice (30 marks total)

For each numbered statement below, write the letter that corresponds to the best answer in the box provided. Use CAPITAL LETTERS only. Only the answer given in the box provided will be marked. There is only one correct answer per question. Each question is worth 2 marks.

1. Consider the following graph of a standing wave described by the function $f(x)$. Which of the following statements is **TRUE**?



- A. The wave has an amplitude of 4 and a wavelength of 4.
 B. The wave has an amplitude of 4 and a wavelength of 8.
 C. The wave has an amplitude of 8 and a wavelength of 8.
 D. The wave has an amplitude of 8 and a wavelength of 4.
 E. The wave has an amplitude of 8 and nodes at all multiples of 4.

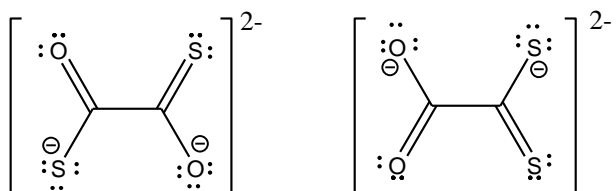
Answer:**B**

2. Which one of the following molecules/ions is a free radical?

- A. O_3
 B. $[\text{NO}_3]^-$ (N is central atom)
 C. $[\text{N}_3]^-$
 D. BF_2
 E. N_2O (N is central atom)

Answer:**D**

3. What is the relationship between the pair of ions shown below?



- A. They are resonance structures.
 B. They are enantiomers.
 C. They are heterotopic diastomers.
 D. They are molecular rotamers.
 E. They are isomers.

Answer:**E**

4. How many double bonds are present in the best Lewis structure of chloric acid, HClO_3 ?

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

Answer:

C

5. What is the smallest approximate Cl-P-Cl angle in PCl_5 ?

A. 45°
B. 72°
C. 90°
D. 109°
E. 120°

Answer:

C

6. Methanol (CH_3OH , 2 mol) reacts with O_2 (1 mol) at high temperature (with a catalyst) to give only water (2 mol) and product X (2 mol). What is the molecular geometry of X?

A. linear
B. bent
C. trigonal planar
D. trigonal pyramidal
E. tetrahedral

Answer:

C

7. What is the wavelength of light with a frequency of 5000 MHz?

A. 3.3×10^{-24} m
B. 2.0 mm
C. 2.0 m
D. 6.0 cm
E. 6.0 m

Answer:

D

8. The N-O bond length in $[\text{NO}]^+$ is 106 pm and the N-O bond length in NO_2 is 124 pm. What is the N-O bond length in $[\text{NO}_2]^+$?

A. 106 pm
B. 124 pm
C. 90 pm
D. 140 pm
E. 115 pm

Answer:

E

9. A scientist accelerates a singly charged ion (X^+) to 2.00×10^4 m/s. Using a diffraction experiment, the scientist determines the de Broglie wavelength of the particle to be 19.8 pm. What is the ion X^+ ?

- A. H^+
 B. He^+
 C. Li^+
 D. Be^+
 E. B^+

Answer:

A

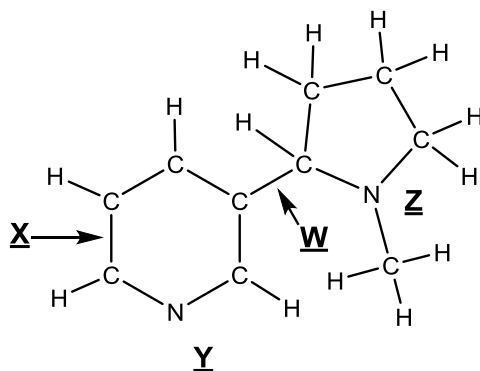
10. The phenomenon where particles undergo constructive and destructive interference when passed through a crystal is called

- A. Heisenberg uncertainty.
 B. diffraction.
 C. dispersion.
 D. reflection.
 E. normal distribution.

Answer:

B

The molecule nicotine is an addictive substance found in tobacco. The skeletal structure of nicotine is shown below. Multiple bonds and lone pairs are not shown. Use this structure to answer questions 11-15.



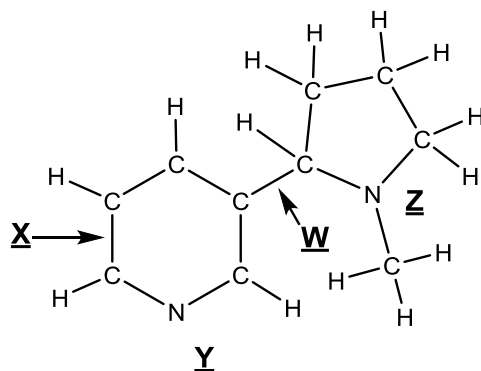
Nicotine

11. In nicotine, the C–C bond labelled “W” is expected to be

- A. the same length as a typical C–C single bond.
 B. between the length of a typical C–C single and double bond.
 C. the same length as a typical C–C double bond.
 D. between the length of a typical C–C double and triple bond.
 E. the same length as a typical C–C triple bond.

Answer:

A



Nicotine

12. In nicotine, the C–C bond labelled “X” is expected to be

- A. the same length as a typical C–C single bond.
- B. between the length of a typical C–C single and double bond.
- C. the same length as a typical C–C double bond.
- D. between the length of a typical C–C double and triple bond.
- E. the same length as a typical C–C triple bond.

Answer:

B

13. In nicotine, the molecular geometry at the N atom labelled “Y” is

- A. linear.
- B. bent.
- C. trigonal planar.
- D. trigonal pyramidal.
- E. tetrahedral.

Answer:

B

14. In nicotine, the molecular geometry at the N atom labelled “Z” is

- A. linear.
- B. bent.
- C. trigonal planar.
- D. trigonal pyramidal.
- E. tetrahedral.

Answer:

D

15. In nicotine, the number of atoms with tetrahedral molecular geometry is

- A. 1.
- B. 4.
- C. 5.
- D. 6.
- E. 10.

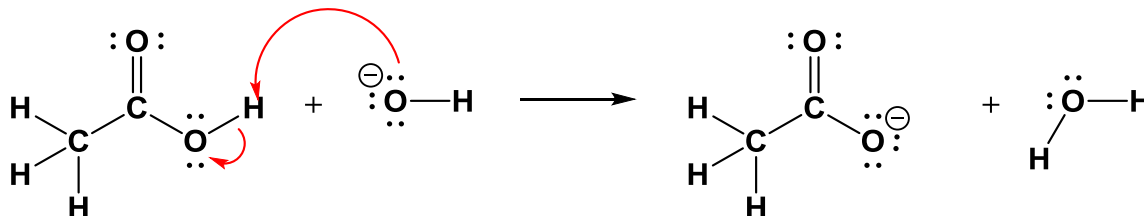
Answer:

C

Part 2. Short Answer Questions

8 marks

1. (a) Using curved-arrow notation, show the movement of electrons for the following reaction:

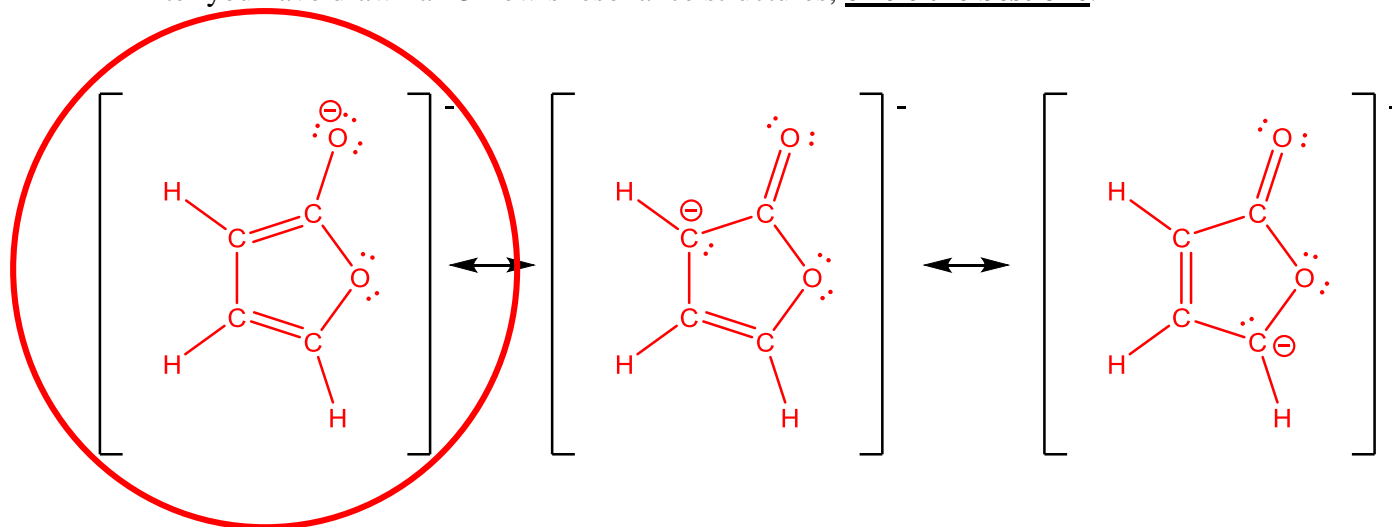


2. Complete the following table by specifying the name of the molecular shape for each species and indicating whether the molecule is polar.

Formula	Name of Molecular Shape	Polar? (YES or NO)
SiCl ₂ F ₂	Tetrahedral	Yes; Polar
IF ₇	Pentagonal Bipyramidal	No; Non-polar
BrF ₃	T-shaped	Yes; Polar

- 4 marks** 3. Draw the 3 most chemically reasonable Lewis structures for a furanolate anion, $[\text{C}_4\text{H}_3\text{O}_2]^-$, using the skeletal structures below. 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.

After you have drawn all 3 Lewis resonance structures, **circle the best one.**



10 marks4. Choose one molecule from the following list that fits each statement:**USE EACH MOLECULE ONLY ONCE.**

The first atom listed is the central atom for each molecule.

(a) Has tetrahedral molecular geometry _____ **XeO₄** _____(b) Contains an atom with an expanded octet _____ **IO₂F** _____(c) Is non-polar _____ **SO₃** _____(d) Has trigonal pyramidal geometry _____ **NF₃** _____(e) Has no lone pairs of electrons _____ **CH₄** _____

- 8 marks** 5. Complete the following table with neutral molecules that are anticipated to be stable (i.e., have valid Lewis structures).

Using only the elements C, F, S, and/or Xe to construct the molecules.

For the Lewis structures, write any non-zero formal charges on the appropriate atoms, show all lone pairs of electrons as pairs of dots and all bond pairs as lines.

The first entry has been completed for you.

Lewis Structure	Molecular Geometry at Central Atom	Perspective Diagram
$\begin{array}{c} \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array}$	Bent	
$\begin{array}{c} \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{C} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array} \quad \text{or} \quad \begin{array}{c} \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{Xe} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \end{array}$ $\text{or} \quad \begin{array}{c} \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array}$	Tetrahedral	
$\begin{array}{c} \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array} \quad \text{or} \quad \begin{array}{c} \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{Xe} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array}$	See-saw	
$\begin{array}{c} \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{Xe} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array}$	Square planar	
$\begin{array}{c} \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array} \quad \text{or} \quad \begin{array}{c} \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{Xe} \\ \cdot\cdot \\ \text{=} \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \text{---} \\ \cdot\cdot \\ \text{F} \\ \cdot\cdot \end{array}$	Octahedral	

END OF EXAMINATION

Supplementary Sheet

Potentially useful constants and conversion factors

$$1 \text{ Hertz} = 1 \text{ Hz} = 1 \text{ s}^{-1} = 10^{-6} \text{ MHz} \quad 1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

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

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

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

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

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

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

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

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

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

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

Potentially useful formulae

$$v = \lambda \nu$$

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

$$E = mc^2$$

$$E = \frac{1}{2}mv^2$$

$$E = h\nu$$

$$E_n = -2.18 \times 10^{-18} \frac{Z^2}{n^2} \quad (n = 1, 2, 3, \text{etc.})$$

$$E_n = \frac{h^2 n^2}{8mL^2} \quad (n = 1, 2, 3, \text{etc.})$$

PERIODIC TABLE OF THE ELEMENTS

Group													17	18																						
1													1	2																						
1.008	H													1.008	He																					
3	Li	4	Be													5	B	6	C	7	N	8	O	9	F	10	Ne									
6.941	6.941	9.012	9.012													10.811	10.811	12.011	12.011	14.007	14.007	15.999	15.999	18.998	18.998	20.179	20.179									
11	Na	12	Mg	24.305													26.982	26.982	28.086	28.086	30.974	30.974	32.064	32.064	35.453	35.453	39.948	39.948								
22.99	22.99	24.305	24.305													26.982	26.982	28.086	28.086	30.974	30.974	32.064	32.064	35.453	35.453	39.948	39.948									
19	K	20	Ca	40.08	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn												
39.098	39.098	40.08	40.08	44.956	44.956	47.9	47.9	50.941	50.941	51.996	51.996	54.938	54.938	55.847	55.847	58.933	58.933	58.7	58.7	63.546	63.546	65.38	65.38													
37	Rb	38	Sr	87.62	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
85.468	85.468	87.62	87.62	88.906	88.906	91.222	91.222	92.906	92.906	95.94	95.94	"(98)"	"(98)"	101.07	101.07	102.9	102.9	106.4	106.4	107.87	107.87	112.41	112.41	114.82	114.82	118.69	118.69	121.75	121.75	127.6	127.6	126.9	126.9	131.3	131.3	
55	Cs	56	Ba	137.33	57	La*	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
132.9	132.9	137.33	137.33	138.91	138.91	178.49	178.49	180.95	180.95	183.85	183.85	186.21	186.21	190.2	190.2	192.22	192.22	195.09	195.09	196.97	196.97	200.59	200.59	204.37	204.37	207.2	207.2	208.98	208.98	"(209)"	"(210)"	"(210)"	"(222)"			
87	Fr	88	Ra	226.03	89	Ac#	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt																		
223	223	226.03	226.03	227.03	227.03	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}	{261}

*	58	59	60	61	62	63	64	65	66	67	68	69	70	71
#	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	140.12	140.91	144.24	145	150.4	151.96	157.25	158.92	162.5	164.93	167.26	168.93	173.04	174.97
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232.04	231.04	238.03	237.05	244	243	247	247	251	252	257	258	259	260