Faculty of Science

Practice Exam and Answer Key

CHEM 1503
Chemical Bonding and Organic Chemistry

THOMPSON RIVERS UNIVERSITY
OPEN LEARNING

THOMPSON RIVERS UNIVERSITY, OPEN LEARNING

CHEM 1503 • CHEMICAL BONDING AND ORGANIC CHEMISTRY

PRACTICE EXAMINATION

TIME ALLOWED: 3 HOURS

TOTAL PAGES (INCLUDING THIS PAGE): 13

TOTAL MARKS: 100

MATERIALS PERMITTED:
- Calculator
- Course materials are **not** permitted

MATERIALS PROVIDED:
- Two exam answer booklets
- Formula list
- Periodic Table of the Elements
- Physical and Chemical Constants
- Electronegativities of the Elements

STUDENT: PLEASE COMPLETE THIS SECTION—*PRINT CLEARLY*.

Surname

_____

First Name

_____

Student Number

_____

Open Learning Faculty Member's Name

_____

Student's Signature (required)

_____

Date

_____

OPEN LEARNING FACULTY MEMBER: PLEASE COMPLETE THIS SECTION—*PRINT CLEARLY*.

Student's Mark_____%

Name

_____

I.D. Number

_____

Signature

_____

Date

_____

Entered Into Portal: ___ Yes ___ No

Instructions

- Unless otherwise indicated, write all your answers in the exam answer booklets provided.
- When you have finished, **return all papers, including the exam and the exam answer booklets, in the envelope.** ***Failure to do so may result in a FAIL grade.***

Exam Instructions

You may use a calculator, but no other materials are permitted during this examination.

At the back of this exam you will find:

a. A list of various formulas

b. A complete periodic table of the elements

c. A table of physical and chemical constants

d. A table showing electronegativities of the elements

This examination is in two parts and all of the questions total 100 marks.

- Part I consists of ten short-answer questions worth 30 marks.
- Part II consists of five questions that require calculations, outlining mechanisms, or short paragraph answers. Each question in Part II is worth 14 marks. Before going on, check to see that you have both parts of the examination.

PART I—Short-Answer Questions *(30 marks total)*

Give short-answers (two to three sentences) to the following questions. Give examples, diagrams, or show calculations with appropriate significant figures where appropriate. *(3 marks each)*

1. Give the International Union of Pure and Applied Chemistry (IUPAC) name for each of the following compounds: *(3 marks)*

   a. $Al_2(Cr_2O_7)_3$ b. $Ti(CO_3)_2$
   c. IBr_3 d. $NaHCO_3$

2. Calculate the wavelength of light (in nanometres) for a transition of the hydrogen atom from $n = 5$ to $n = 3$. Is this an absorption or an emission of light? *(3 marks)*

3. Of the following four sets of quantum numbers, indicate which are allowable and which are not allowable, and for any not allowable write a correct and allowable set. *(3 marks)*

   a. $n = 1, \quad \ell = 1, \quad m_\ell = 0, \quad m_S = -\frac{1}{2}$
   b. $n = 3, \quad \ell = 2, \quad m_\ell = 1, \quad m_S = 0$
   c. $n = 2, \quad \ell = 1, \quad m_\ell = -1, \quad m_S = -\frac{1}{2}$
   d. $n = 4, \quad \ell = 5, \quad m_\ell = 3, \quad m_S = \frac{1}{2}$

4. a. Explain which of the following elements would have the larger atomic radius:
   (3 marks)

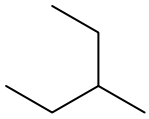
      i. Al or Cl
      ii. Al or Tl

b. If an element has the following four ionization energies, explain what the most likely charge on its cation would be.

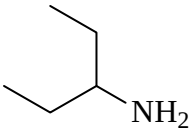
1st I.E.	577 kJ/mol
2nd I.E.	1816 kJ/mol
3rd I.E.	2744 kJ/mol
4th I.E.	11 575 kJ/mol

5. Predict the shapes of the molecules iodine trifluoride and boron trifluoride and indicate if you would expect either to have a dipole moment. *(3 marks)*

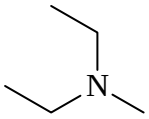
6. Name the major intermolecular forces present in the following compounds and then arrange them in order of increasing boiling points. *(3 marks)*



A

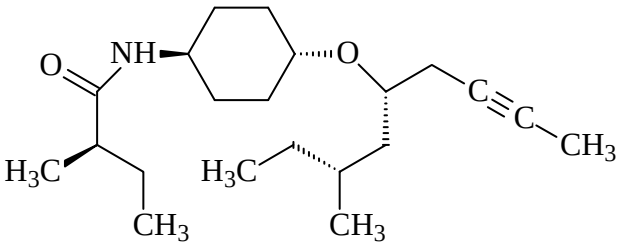


B

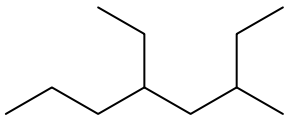


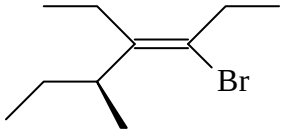
C

7. For the following molecule, determine the R/S configuration of each stereogenic carbon atom then circle and name the various functional groups present. *(3 marks)*



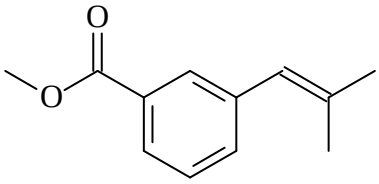
8. a. Name the following molecules according to the IUPAC rules, including the appropriate *R*/*S* or *E*/*Z* descriptors. *(3 marks)*

i. 

ii. 

b. Draw the molecular structure for ***trans*-1-ethyl-3-propylcyclopentane.**

9. For the following compound, determine the: *(3 marks)*

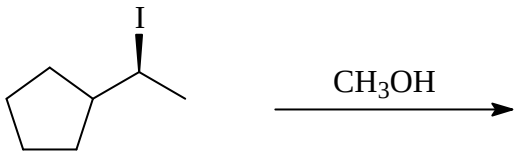


a. Number of sigma bonds

b. Number of pi bonds

c. Hybridization of each carbon atom

10. For the following reaction, determine: *(3 marks)*



a. What the product(s) will be

b. Whether it is an S_N1 or S_N2 reaction

c. What is the leaving group

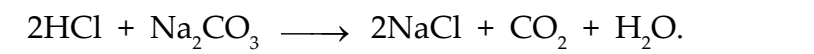
d. What is the nucleophile

e. Whether the solvent for the reaction is protic or aprotic

PART II *(70 marks total)*

Each question is worth a total of 14 marks. The mark allocation for each part of a question is shown in parentheses at the end of the question.

1. a. During a lab session, a bottle containing 0.500 L of 35% (w/v) hydrochloric acid was spilled. In an effort to clean up the spill before the teaching assistant observed it, a student dissolved 195 g of sodium carbonate in 0.50 L of water and poured the resultant solution over the acid. The following reaction occurred: *(7 marks)*



$$2HCl + Na_2CO_3 \longrightarrow 2NaCl + CO_2 + H_2O.$$

i. Explain if sufficient base was added to neutralize all of the acid; show your calculations.

ii. How many grams of sodium chloride were formed?

b. 1.4 g of a compound composed only of carbon, hydrogen, and oxygen was burned in air to form 2.2 g of CO_2 and 0.90 g of H_2O. The molecular weight was found by experiment to be 60 g/mol. *(7 marks)*

i. Determine the empirical and molecular formulas of the compound.

ii. Write the balanced chemical equation for the burning reaction.

2. a. Explain which of the elements, oxygen or fluorine, has the higher electron affinity. *(4 marks)*

b. Write the complete expanded electron configuration for krypton and name a cation and an anion isoelectronic to it. *(3 marks)*

c. Write the quantum numbers which define each *p* electron in the element phosphorus. *(3 marks)*

d. Phosphorus forms a tribromide and a pentabromide. Explain whether you would expect nitrogen and arsenic to form analogous compounds. *(4 marks)*

3. a. Explain which of the following species will be paramagnetic: *(4 marks)*

   V^{4+}, F_2^+, and CO.

   b. For each of the following pairs of species, explain which of the following would be expected to have the longer bond length: *(3 marks)*

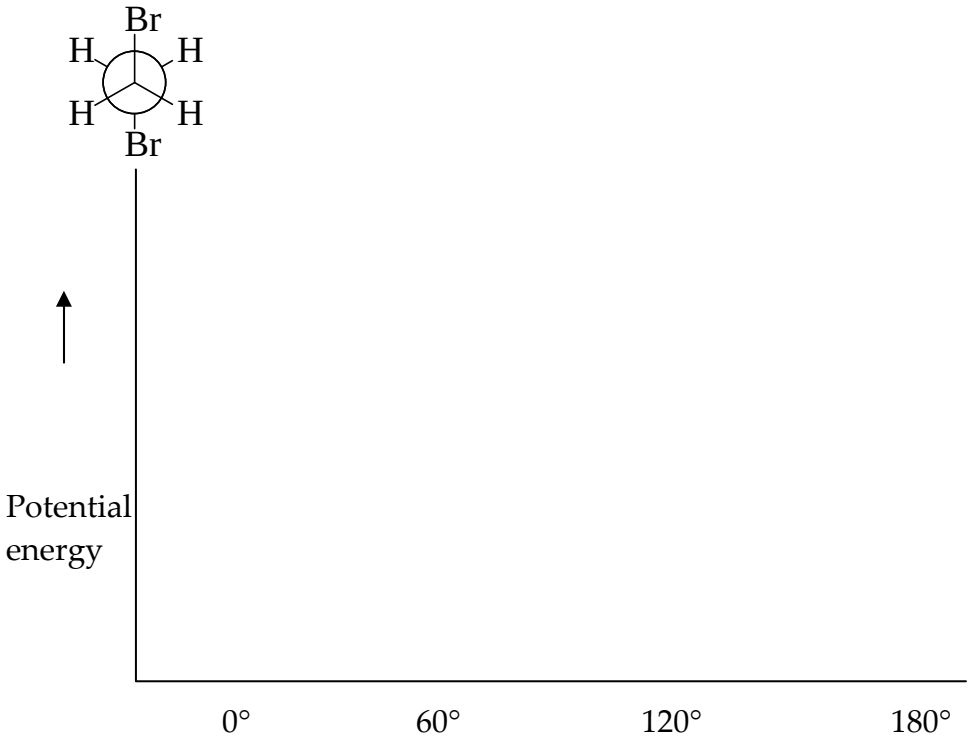
      i. Ne_2 and Ne_2^+
      ii. Carbon-carbon bond length in ethene compared to ethyne
      iii. Nitrogen-nitrogen bond length in N_2 compared to N_2H_4

   c. Predict the shape of the following compounds and ions, and describe the hybridization at the central atom: *(4 marks)*

   NO_3^-, XeF_4, CO_2, and IBr_2^-.

   d. Draw three possible resonance hybrids for carbon dioxide and use formal charges to show which, if any, is likely to be predominant. *(3 marks)*

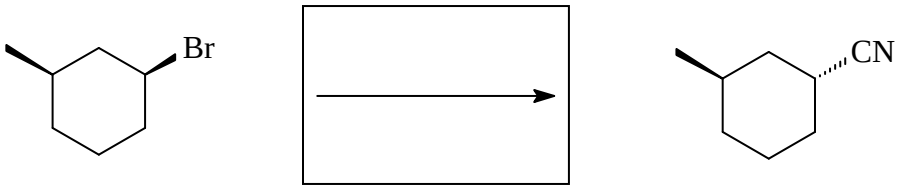
4. a. Starting with the given Newman projection and rotating the front carbon-carbon bond 60°, 120°, and 180°, draw each separate Newman projection and indicate their energies on the potential energy profile diagram. Label each Newman projection with its appropriate conformational name. *(7 marks)*



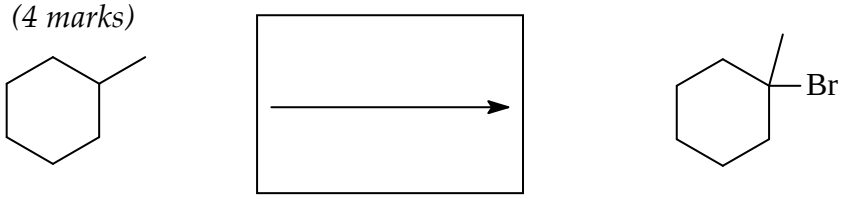
b. Draw the two chair conformations for *cis*-1-amino-3-methylcyclohexane and explain which one you would predict would be more stable. *(7 marks)*

5. For each of the following reactions,

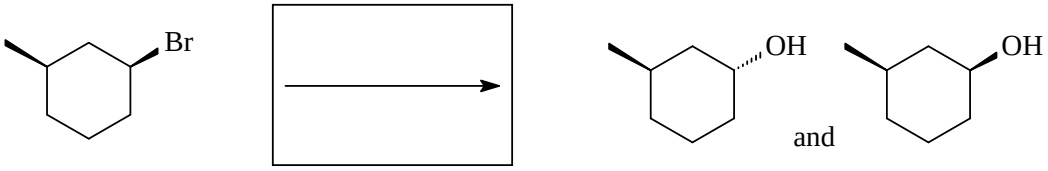
a. *(4 marks)*



b. *(4 marks)*



c. *(6 marks)*



i. Complete the box by providing the complete reaction conditions to form the given product.

ii. Show the reaction mechanism using the appropriate curved arrows notation.

Formula List

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad c = \lambda\nu \qquad \Delta E = R_H\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$M_1V_1 = M_2V_2 \qquad E = h\nu = \frac{hc}{\lambda} \qquad \lambda = \frac{h}{mu}$$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A	2A	3A	4A	5A	6A	7A	8A			1B	2B	3B	4B	5B	6B	7B	8B
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.99	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.921	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La* 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.03	89 Ac** 227.03	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)									

*	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
**	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

Physical and Chemical Constants

Quantity	Symbol	Value
Atomic mass unit	amu	1.661×10^{-27} kg
Avogadro constant	N or N_A	6.022×10^{23} mol^{-1}
Planck constant	h	6.63×10^{-34} J s
Rydberg constant	R_H	2.18×10^{-18} J
Speed of light in a vacuum	c	3.00×10^{8} m s^{-1}

Electronegativities of the Elements

H 2.2															
Li 1.0	Be 1.6											B 2.0	C 2.6	N 3.0	O 3.4	F 4.0
Na 0.9	Mg 1.3											Al 1.6	Si 1.9	P 2.2	S 2.6	Cl 3.2
K 0.8	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.6	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.7	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 1.9	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 1.8	Sb 2.1	Te 2.1	I 2.7
Cs 0.7	Ba 0.9	La 1.0	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.3	Au 2.5	Hg 2.0	Tl 1.6	Pb 1.9	Bi 2.0		