

THE UNIVERSITY OF BRITISH COLUMBIA

CHEM 154 Midterm Examination

November 17, 2023

Time Limit: 60 minutes

Total Marks: 40

Student Number:
(one digit per dash)

Name (printed):

Signature: _____

Section (circle):

111

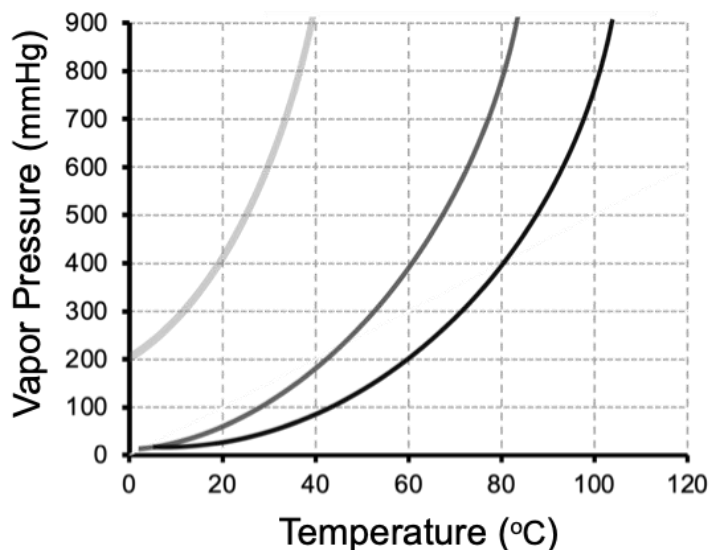
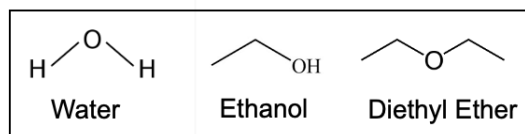
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Examination Rules and Instructions

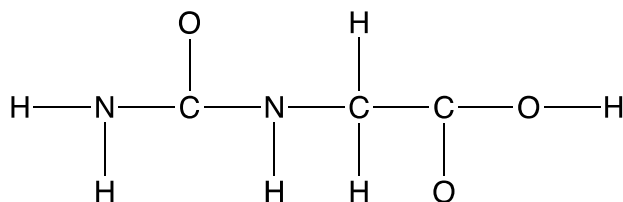
1. Please print your name and student number clearly, both on the first page of the exam as indicated above, and as indicated at the top of each sheet of the exam. Sign the exam on the front page and circle your lecture section.
2. The exam has 6 pages and is printed on both sides of the page. Please check that you have received correctly printed copies of each page, as well as a CHEM 154 Equation Sheet as a separate page.
3. Please read each question carefully, and write your answers only in the spaces provided. These exams will be scanned as part of the marking process and any answers outside the designated spaces will be omitted. You may use the Equation Sheet for rough work.
4. The invigilators will tell you when to start and stop writing the exam. Do not look at any exam questions until the start of the writing of the exam.
5. You must conduct yourself honestly, and follow any rules or directions communicated by the invigilators.
6. You are not allowed to access a computer or any other electronic device from the time you receive the printed copy of the exam until the time the exam is collected by an invigilator.
7. In addition to pens, pencils and erasers, you are allowed to have a scientific calculator with no wireless communication capabilities, as well as an unassembled molecular model kit, if desired.
8. 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. purposely exposing written papers to the view of other examination candidates or imaging devices;
 - ii. purposely viewing the written papers of other examination candidates;
 - iii. 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);
 - iv. distributing in any manner, electronic or otherwise, copies of any part of the exam.
9. If a need arises to contact the invigilator, such as the need to go to the washroom, please raise your hand and wait for an invigilator to meet you.
10. Invigilators are instructed to not provide answers to any questions about the exam content, the interpretation of exam questions, or suspected errors in questions. If you suspect a question to have an error or ambiguity, detail this on your exam paper, and all such issues will be dealt with during the marking of the exam.
11. If you finish writing the exam before the allotted time, please wait in silence at your place of writing until the allotted time has expired.

1. **[4 marks total]** The graph to the right shows plots of the vapour pressure for water, ethanol, and diethyl ether.



- a) Label each plot with the corresponding molecule and in the space below, write the reasons for your assignments.
- b) Estimate the boiling point of water, in °C, when the external pressure is 40 kPa. _____
- c) A beaker of diethyl ether, a beaker of water and two beakers of ethanol are placed inside an initially evacuated container, and heated to 40 °C. After some time, it is observed that all the beakers have liquids and the total pressure inside the container is constant. Calculate the resulting mole fraction of ethanol in the gas phase.

2. **[1 mark total]** The skeletal structure to the right shows the atom connectivity of a neutral molecule. Multiple bonds and lone pair electrons are not shown. Circle all the atoms that could simultaneously lie in the same plane.



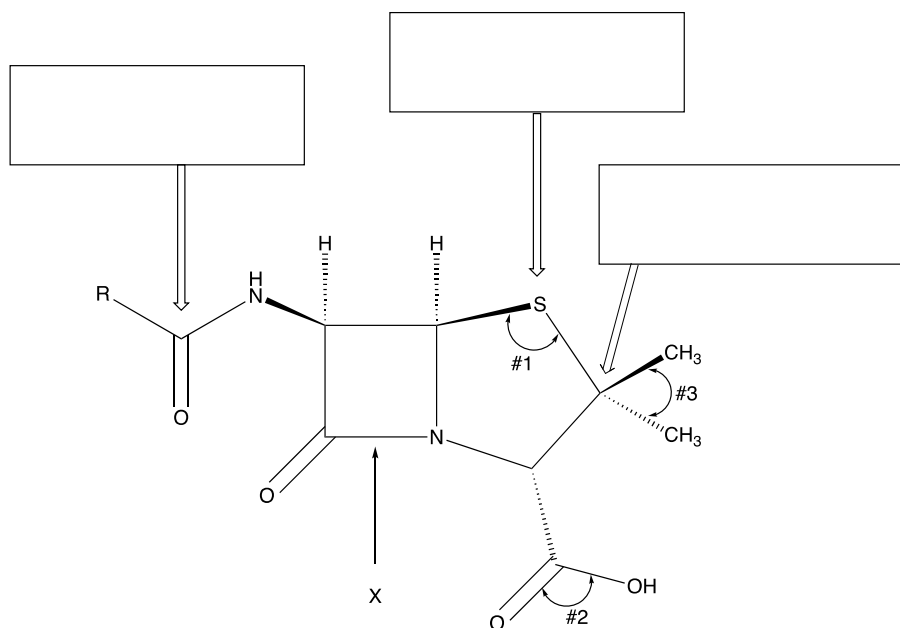
3. [5 marks total] A perspective diagram of penicillin is shown to the right.

- a) In the boxes, write the molecular shape at the indicated atoms.
- b) Enter below the ideal values of the labelled bond angles, in degrees.

#1 _____ #2 _____

#3 _____

- c) Write the electron configuration (using noble gas notation) for a neutral sulphur atom.



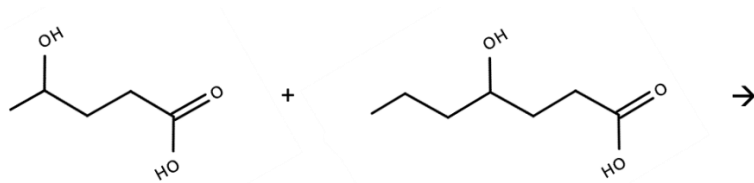
- d) Estimate the bond order of the bond indicated by X (please show your work).

4. [4 marks total] Complete the table below for each molecule by drawing the best Lewis structure and the corresponding perspective diagram, as well as by writing the names of the parent and molecular shapes.

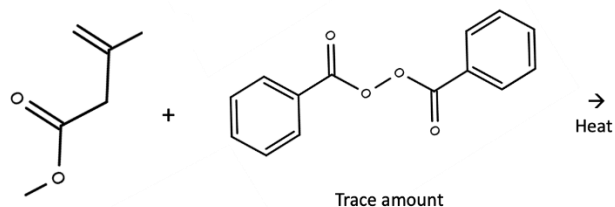
Molecule	Best Lewis structure	Shape	Perspective diagram
SOF₂		Parent: Molecular:	
SCl₄		Parent: Molecular:	

5. **[3 marks total]** Draw all chemically reasonable Lewis structures for ClO_3^- and circle the one(s) that contribute the **least** to the resonance hybrid. Show all lone pairs as dots and indicate formal and overall charges where applicable.

6. **[10 marks total]** Use line-bond drawings to represent chemical structures when answering this question.
- a) For each reaction shown, i) draw the polymer product(s) (if more than one product is possible, draw 2 possible ones), ii) write the type of linkage, and iii) write the names of all the functional groups in the monomer(s).

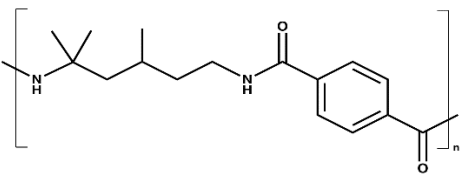
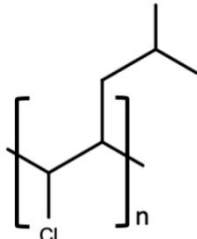


Type of linkage: _____ Functional Group(s): _____



Type of linkage: _____ Functional Group(s): _____

- b) In the table, draw the structure of the smallest possible monomer(s) corresponding to each polymer.
- c) Calculate the average degree of polymerization for a sample of Polymer B with average molecular weight $296,000 \text{ g mol}^{-1}$.

Polymer	Monomer(s)
A 	
B 	

- d) Explain which of the two polymers, A or B, is more flexible.

7. **[13 marks total]** In its standard state allotrope at 80.0°C , elemental phosphorus molecules, $\text{P}_4(\text{l})$, have 4 atoms located at the corners of a tetrahedron (each P is singly bonded to the three others). This liquid was reacted with chlorine gas to produce gaseous PCl_3 in a container with flexible walls, under a constant external pressure of 1.00 bar. Oil circulating through the system kept the temperature constant at 80.0°C . After the reaction, the measured work was 220 J and the heat from the reaction increased the temperature of 2.50 kg of oil by 11.5°C . ($c_{\text{p,oil}} = 1.67 \text{ J/(g K)}$)

- a) Calculate the mass of chlorine gas, in g, that reacted.

- b) Calculate ΔU , in kJ, for the reaction.
- c) Calculate the standard enthalpy of formation for $\text{PCl}_3(\text{g})$ at $80\text{ }^\circ\text{C}$, in kJ/mol.
- d) Calculate the enthalpy, in kJ, for producing 1 mol of $\text{PCl}_3(\text{g})$ from chlorine gas and gaseous $\text{P}_4(\text{g})$, given $\Delta H^\circ_{\text{vap}}(\text{P}_4(\text{l})) = 51.9\text{ kJ/mol}$.
- e) Use the result from d) to calculate the P—P bond enthalpy in $\text{P}_4(\text{g})$, in kJ/mol, given the bond enthalpy for P—Cl is 326 kJ/mol.