Fall 2025 **Chemistry 1000 Final Exam** ____/150 marks

Confidentiality Agreement:
I agree not to discuss (or in any other way divulge) the contents of this exam with (or in the presence of) any CHEM 1000 student who has yet to write it. I understand that breaking this agreement would constitute academic misconduct. The minimum penalty would be a mark of 0/150 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 14 pages of questions (seven pages double-sided).
2) You have also been given a data sheet. It does not have a QR code, so nothing written on it will be graded.
3) **DO NOT WRITE ON ANY QR CODE!!!** Work on pages without a QR code will not be graded. If you require extra space for any answer, use the back of the cover page. Leave a note by the original question so that the person marking that question knows where to find your answer.
4) You may use a calculator but only for calculation. No other electronic devices are allowed.
5) If your work is not legible, it will be given a mark of zero.
6) Show your work. Answers without supporting reasoning or calculations will not get full credit.
7) Marks will be deducted for incorrect information added to an otherwise correct answer.
8) Marks will be deducted for improper use of significant figures and for missing or incorrect units. Show units in every step of all calculations. Significant figures will only be checked in final answers. If a question has subparts (a, b, c, etc.), the answer to each subpart is considered a "final answer".
9) You have 3 hours to complete this test.

Question Breakdown

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17		Total
/17	/ 4	/ 6	/ 6	/ 3	/11	/15	/11	/14	/10	/ 8	/ 9	/10	/ 9	/ 10	/ 6	/ 1		/ 150

1. Fill in each blank with the word, phrase or symbol that best completes the sentence. If options are provided in brackets after a blank; choose one of them to fill the blank. **[17 marks]**

(a) A neutral atom of ^{72}Ge has _____ protons, _____ neutrons and _____ electrons.

(b) Hydrogen has three isotopes: protium, _____ and _____.

(c) In CHEM 1000, we discussed two allotropes of oxygen. They are molecular oxygen (O_2) and _____ (O_3).

(d) Electronegativity is a periodic trend which combines two other periodic trends. Those two periodic trends are _____ and _____.

(e) The formula for the gas made in both a Down's Cell and the Chlor-Alkali industrial process is _____.

(f) CaO would be expected to have a _____ *(larger/smaller)* lattice energy than CaS.

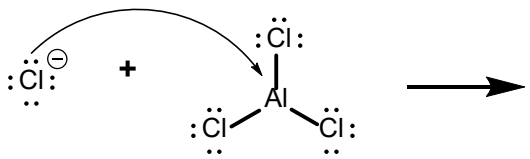
(g) The chemical formula for aluminium oxide is _____. When aluminium oxide is reacted with aqueous hydroxide, a soluble anion is formed which has the chemical formula _____.
For full marks, the chemical formula for the anion must include its charge.

(h) A molecule which has 'see saw' molecular geometry must have _____ electron group geometry.

(i) In B_2H_6, there is an unusual bonding pattern in which a pair of electrons is shared by _____ atoms.

(j) A flask at room temperature contains the five lightest noble gases. The name of the noble gas whose particles have the highest root-mean-square speed is _____.

(k) In the reaction below, the Lewis acid is _____ and the chemical formula for the product is _____.



2. Complete the following table, giving the name and symbol for an element meeting each description. *Misspelled elements will not get full credit.* **[4 marks]**

Description	Symbol	Name
The element with the highest electronegativity		
The halogen that is a liquid at room temperature		
The element that is produced using the Claus process		
The alkali metal that reacts with nitrogen gas		

3. Complete the following table. Names should follow the IUPAC conventions taught in class. **[6 marks]**

Misspelled names will not get full credit.

Chemical Formula	Name
H_2SO_3	
$Mn(NO_3)_2$	
$(NH_4)_2CO_3$	
	copper(I) nitride
	vanadium(V) fluoride
	sodium chlorite

4. Write the ground-state electron configuration for each of the following species. **[6 marks]**

Use the noble gas abbreviation; however, listing only a noble gas is not acceptable; all valence electrons must be explicitly listed.

(a) Ne

(b) In

(c) In^{+}

(d) In^{3+}

5. For each pair, circle the atom/ion with the larger radius. **[3 marks]**

(a) S vs. Se

(b) P vs. P^{3-}

(c) Cs^{+} vs. Ba^{2+}

6. Consider a neutral atom of nickel (Ni) in the ground-state. **[11 marks]**

(a) Write the electron configuration for Ni. Do NOT use the noble gas abbreviation. *[1 mark]*

(b) Write the electron configuration for Ni using the noble gas abbreviation. *[1 mark]*

(c) How many core electrons and how many valence electrons does Ni have? *[2 marks]*

_____ core electrons _____ valence electrons

(d) Draw an orbital occupancy diagram ("orbital box diagram") showing the **<u>valence</u>** electrons of Ni.
Label all subshells. Based on your diagram, is Ni diamagnetic or paramagnetic? *[4 marks]*

(e) Choose any one electron in your orbital occupancy diagram in part (d). Circle it. *[2 marks]*
For the electron you circled, write a complete set of quantum numbers.

(f) Write the electron configuration for Ni^{2+} using the noble gas abbreviation. *[1 mark]*

7. Consider the following coordination complex of nickel: $[Ni(NH_3)_3(CN)(en)]Cl$. **[15 marks]**

"en" stands for ethylenediamine which has the chemical formula $NH_2CH_2CH_2NH_2$

(a) What is the charge of the complex ion $[Ni(NH_3)_3(CN)(en)]^{???}$? *[1 mark]*
In other words, what number should be where ??? is written?

(b) What is the oxidation state of nickel in this complex? *[1 mark]*

(c) What is the coordination number of nickel in this complex? *[1 mark]*

(d) There are two possible stereoisomers for this complex ion. Draw both and label each as *cis*, *trans*, *fac* or *mer*. *[3 marks]*

(e) According to crystal field theory, the $3d$ orbitals of the nickel ion are divided into two groups, each of which has a different energy level. Draw the crystal field splitting diagram for the nickel ion in this complex. Include electrons and label each orbital. *[3 marks]*

(f) Draw a picture of each $3d$ orbital in the lower energy group. *[6 marks]*
For full marks, your diagrams must show axes, phases and nodes, and each orbital must be labeled.

8. The following questions are related to the perbromate ion (BrO_4^-) **[11 marks]**

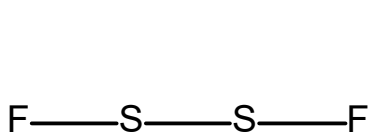
(a) Draw all possible resonance structures of perbromate that have minimized formal charges. *[5 marks]*
Include any non-zero formal charges on the appropriate atom(s).

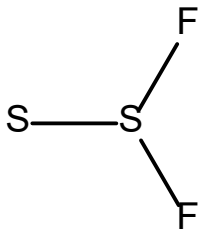
(b) What is the bond order for a Br–O bond in perbromate? *[1 mark]*

(c) Provide the chemical formulas for the other oxoanions that Br can form. *[3 marks]*
Your answers must include the charge of each ion.

(d) Unlike bromine, fluorine can only form one oxoanion. Of the four oxoanions discussed in parts (a) to (c) of this question, which one is still a viable ion when Br is replaced with F? Why are the others impossible? *[2 marks]*

9. Two different structures can be imagined for a molecule with the chemical formula S_2F_2. The connectivity for each is shown below. **[14 marks]**





(a) Convert each of the drawings above into a Lewis diagram for S_2F_2 with <u>minimized formal charges</u>. *Include any non-zero formal charges on the appropriate atom(s).* *[2 marks]*

(b) Complete the following table. *[6 marks]*

Connectivity	**S-S bond order**	**Electron group geometry for central S (in words)**	**Molecular geometry for central S (in words)**
F-S-S-F *(diagram on left)*			
S-SF_2 *(diagram on right)*			

(c) For each of the two Lewis diagrams, draw a VSEPR diagram that clearly shows the molecular geometry. *Lone pairs are only required to be shown on the VSEPR diagrams if they are on a central atom.* *[2 marks]* *Use wedge-and-dash notation if required to show three dimensional geometry.*

(d) On each VSEPR diagram in (c), draw dipole vectors for each polar bond and, next to each molecule, draw its net dipole (if there is one; if not, write "no net dipole"). *[4 marks]*

10. Write balanced chemical equations for each of the following reactions. **[10 marks]**
For reactions performed in aqueous solution, net ionic equations are acceptable (but not required). Include states of matter. Remember that atoms and charges must BOTH be balanced...

(a) Cesium (Cs) metal reacts with water.

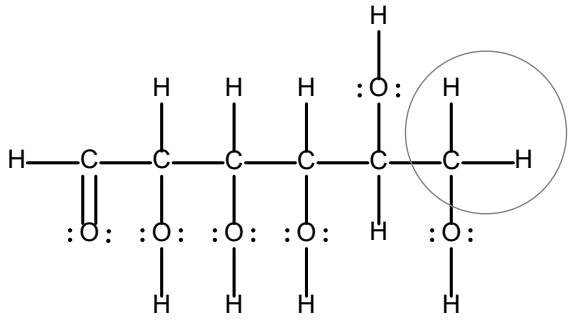
(b) Sulfur trioxide gas reacts with water.

(c) Fluorine gas reacts with water to give hydrofluoric acid and oxygen.

(d) Magnesium metal reacts with aqueous hydrobromic acid.

(e) White phosphorus reacts with chlorine gas to give solid phosphorus pentachloride.

11. A Lewis diagram for glucose $\left(C_6H_{12}O_{6(s)}\right)$ is shown below. **[8 marks]**



(a) What is the molecular geometry of the carbon atom that has a double bond to oxygen? *[1 mark]*

(b) A circle has been drawn around three atoms. What is the approximate $H - C - H$ bond angle involving these atoms? *[1 mark]*

(c) Glucose undergoes a combustion reaction as follows: *[6 marks]*

$$C_6H_{12}O_{6(s)} + 6\,O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(g)}$$

At 25 ℃ and 1.0 bar, what volume of $CO_{2(g)}$ will be produced if 25 g of glucose are fully combusted? *Report your answer in L.*

12. Lead poisoning can result from the ingestion of lead-containing compounds from sources including lead paint and contaminated drinking water. **[9 marks]**

(a) Write the ground-state electron configuration for a neutral atom of lead (Pb). *[2 marks]*

Use the noble gas abbreviation.

(b) Lead can form two stable ions. What are their charges? Clearly explain your choices. *[3 marks]*

(c) Lead has the following isotopic composition. Calculate the average atomic mass for lead. *[3 marks]*

Isotope	Mass (u)	Abundance
$^{204}_{82}Pb$	203.973	1.4 %
$^{206}_{82}Pb$	205.974	24.1 %
$^{207}_{82}Pb$	206.976	22.1 %
$^{208}_{82}Pb$	207.977	52.4 %

(d) This average atomic mass can be used for calculations involving neutral lead atoms or for calculations involving lead ions. Why? *[1 mark]*

13. Beryllium-8 is highly unstable towards decay into alpha particles. **[10 marks]**

Nuclide	Isotopic Mass
$^{4}_{2}He$	4.002 603 254 u
$^{8}_{4}Be$	8.005 305 10 u
$^{12}_{6}C$	12.000 000 00 u

(a) Based on the general properties of nuclides discussed in CHEM 1000, should we expect ^{8}Be to be an unstable nuclide? Briefly explain. *[2 marks]*

(b) Write a balanced nuclear equation for this decay. *[1 mark]*

(c) Calculate the energy released by this decay. *[4 marks]*
Report your answer in Joules.

(d) Carbon-12 has the same N/Z ratio as beryllium-8, but it is stable. Based on the mass defect of the hypothetical decay of ^{12}C into alpha particles, explain why ^{12}C is stable. *[3 marks]*

14. The Potassium-Argon (K-Ar) method is used to estimate the ages of rocks. It is based on the observation that $^{40}_{19}K$ decays to $^{40}_{18}Ar$. **[9 marks]**

The half-life of $^{40}_{19}K$ is $1.248 \times 10^{9}\ years$.

(a) The decay of $^{40}_{19}K$ to $^{40}_{18}Ar$ might occur via either of two possible one-step decay processes. Name those two processes and write a balanced nuclear equation for each. *[4 marks]*

It must be clear which name corresponds to which equation.

(b) Hypothetically, if a piece of Martian rock was found to contain $2.021 \times 10^{-10}\ mol\ ^{40}_{19}K$ at the time of measurement, how many atoms of $^{40}_{19}K$ would have been present in that piece of rock 5.00 billion years $(5.00 \times 10^{9}\ years)$ ago? Assume no other events occur to affect the decay process. *[5 marks]*

15. **[10 marks]**

(a) Write a balanced chemical equation for the fourth ionization of beryllium. *[1 mark]*

(b) Which is larger, the first ionization energy of beryllium or the fourth ionization energy of beryllium? Briefly, justify your answer. *[2 marks]*

(c) Which is easier to calculate, the first ionization energy of beryllium or the fourth ionization energy of beryllium? Briefly, justify your answer. *[2 marks]*

(d) Calculate the ionization energy that was your answer to part (c). *[5 marks]*
Report your answer in kJ/mol.

16. The van der Waals equation of state includes two constants (a and b), the value for each of which is specific to the species being studied. **[6 marks]**

$$\left(P + a\frac{n^2}{V^2}\right)(V - bn) = nRT$$

(a) Would you expect NH_3 or CH_4 to have a larger value for a? Why? What does a correct for? *[3 marks]*

(b) Would you expect NH_3 or CH_4 to have a larger value for b? Why? What does b correct for? *[3 marks]*

17. What was the most useful and/or interesting thing you learned in CHEM 1000? **[1 mark]**

…AND THAT'S ALL FOR CHEM 1000.
HAPPY HOLIDAYS!