Fall 2025 **Chemistry 1000 Midterm #1X** ____/66 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 0/66 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 6 pages of questions (three 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.
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 90 minutes to complete this test.

Question Breakdown

Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**				**Total**
/ 8	/ 3	/ 3	/ 4	/ 6	/ 2	/ 4	/ 6	/ 10	/ 6	/ 14				/ 66

1. Fill in each blank with the word, phrase or symbol that best completes the sentence. **[8 marks]**

(a) The charge for the most common monoatomic ion formed from oxygen is _____. The electron configuration for that ion is _____. *Do not use the noble gas abbreviation.*

(b) An atomic orbital with $n = 5$ and $l = 3$ would be referred to as the _____ orbital. It would have _____ planar node(s) and _____ radial node(s).

(c) Wave-particle duality is an important concept in quantum theory.

The photoelectric effect experiment demonstrated that light can act as _____.

The fact that electrons can be diffracted demonstrated that they can act as _____.

(d) According to Heisenberg's Uncertainty Principle, increasing the precision with which an electron's momentum is known must decrease the precision with which its _____ can be known.

2. Complete the following table with the number of protons, neutrons and electrons in each species.

[3 marks]

Ion	# protons	# neutrons	# electrons
$^{96}_{42}Mo$			
$^{96}_{42}Mo^{2+}$			

3. ^{6}He is an unstable nuclide. **[3 marks]**

(a) Calculate the N/Z ratio for ^{6}He. *[1 mark]*

(b) Predict the most likely mode of decay for ^{6}He. *[1 mark]*

If there is more than one equally likely mode, choose one.

(c) Write a balanced nuclear equation for the decay of ^{6}He. *[1 mark]*

4. Carbon has three naturally occurring isotopes with the following isotopic masses: **[4 marks]**

- carbon-12 has an isotopic mass of 12.000 000 u
- carbon-13 has an isotopic mass of 13.003 355 u
- carbon-14 has an isotopic mass of 14.003 242 u

The natural abundance of carbon-13 varies according to location. At the bottom of the northern Pacific Ocean, the abundance is at its lowest (no pun intended), at 0.9629%. The average atomic mass of carbon in the area is 12.00966 u.

Is carbon-14 measurably contributing to this average atomic mass?

Hint: What would the average atomic mass be if there wasn't any carbon-14 at all?

5. Sketch each of the following atomic orbitals. It is **not** necessary to draw radial nodes. **[6 marks]**
Each diagram should include:

- a drawing of the orbital on clearly labeled axes so that its orientation is clear, and
- relative phases shown using appropriate shading or colours.

(a) $2p_y$

(b) $3d_{xz}$

(c) $3d_{x^2-y^2}$

6. For each of the following reactions, indicate whether the energy change can be calculated using Bohr's equation by writing either "YES" or "NO" next to the equation. **[2 marks]**

YOU ARE **NOT** BEING ASKED TO *DO THE CALCULATION!!! Just to say if it can be done using this equation.*

(a) $Rb^{36+} \rightarrow Rb^{37+} + e^{-}$

(b) $Al^{2+} \rightarrow Al^{3+} + e^{-}$

7. Neither of the following sets of quantum numbers can correspond to any electron. For each set, briefly explain which number is wrong and how it can be changed to give an allowed set of quantum numbers. *If there is more than one way to "fix" the set of quantum numbers, choose one.* **[4 marks]**

(a) $n = 3, l = 1, m_l = 0, m_s = -1$

(b) $n = 4, l = 1, m_l = 2, m_s = +\frac{1}{2}$

8. Neither of the following electron configurations can correspond to any ground state atom. For each electron configuration, explain what is wrong, give the correct electron configuration for a ground state atom with the same number of electrons and identify the corresponding neutral element. **[6 marks]**

Incorrect electron configuration	**Why is it incorrect?**	**Correct electron configuration**	**Element symbol**
$1s^2 2p^1$			
$1s^2 2s^2 2p^6 3s^3$			

9. Consider a neutral atom of cobalt (Co) in the ground-state. **[10 marks]**

(a) Explain the difference between the terms "diamagnetic" and "paramagnetic". *[2 marks]*

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

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

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

(e) Write the electron configuration for Co^{3+} using the noble gas abbreviation. *[2 marks]*

10. My favorite transition metal has a threshold energy (also called "work function") of 716.0 kJ/mol. Calculate the wavelength of the photon that represents the minimum energy needed for a "positive" photoelectric effect. *Report your answer in nm.* **[6 marks]**

11. Bismuth only has one naturally occurring isotope, bismuth-209 $\left({}^{209}Bi\right)$. It was once believed that this was the heaviest stable isotope. However, in 2003, it was reported that ${}^{209}Bi$ undergoes alpha decay, with a half-life of 1.9×10^{19} years. This was discovered by measuring decay from 136.9 g of BGO $(Bi_4Ge_3O_{12})$.

[14 marks]

(a) How many atoms of bismuth-209 were present in the 136.9 g sample of BGO? *[4 marks]*

(b) Calculate the decay constant for ${}^{209}Bi$. *[2 marks]*

Report your answer in $years^{-1}$.

(c) How long would it take for the bismuth in the 136.9 g sample of BGO to emit exactly 10^{22} alpha particles? *[3 marks]*

Report your answer in years.

continued on next page…

11. *…continued from previous page*

(d) Calculate the energy released by alpha decay of bismuth-209. *[5 marks]*

Report your answer in J/mol.

$^{209}_{84}Po$	208.982 431 u
$^{209}_{83}Bi$	208.980 399 u
$^{209}_{82}Pb$	208.981 090 u
$^{205}_{81}Tl$	204.974 428 u
$^{4}_{2}He$	4.002 603 254 u