Winter 2025 **Chemistry 2000 Midterm #2** ____/60 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 2000 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 0/60 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 7 pages of questions (four 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. Any non-trivial use of a calculator must be described. For example, if you use a calculator to solve a nonlinear equation, you need to make it clear what equation was solved, and provide any other inputs you used to the calculation
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**									**Total**
/ 12	/ 7	/ 15	/ 14	/ 12									/ 60

1. The following data were obtained for carbon dioxide (CO_2). **[12 marks]**

	temperature (°C)	pressure (bar)
triple point	-56.60	5.18
critical point	31.98	73.74

(a) Define the term "triple point". *[1 mark]*

(b) Define the term "critical point". *[1 mark]*

(c) Sketch a phase diagram for carbon dioxide. On your diagram, you must label: *[4 marks]*

- both axes
- the triple point and critical point
- regions corresponding to the <u>four</u> states of matter discussed in class

Your sketch does not need to be to-scale; however, it must be neat and all points used to make it must be clearly labeled. Relative values must be preserved. In other words, it must be clear which pressures/temperatures are larger/smaller/approximately the same.

(d) On your phase diagram, draw a line of constant pressure (arrow labeled (d)) where only sublimation occurs. Over what temperature range is this possible? *[2 marks]*

(e) On your phase diagram, draw a line of constant temperature (arrow labeled (e)) where condensation occurs. Over what temperature range is this possible? *[2 marks]*

(f) Is pressure-induced melting possible for carbon dioxide? Why or why not? *[2 marks]*

2. Predict the sign of the entropy change for each of the following reactions. Justify your answer, and state whether you expect the entropy change to be large or small. **[7 marks]**

(a) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ *[2 marks]*

(b) $Hg_{(l)} \rightarrow Hg_{(s)}$ *[2 marks]*

(c) $HF_{(g)} + H_2O_{(l)} \rightarrow H^+_{(aq)} + F^-_{(aq)} + H_2O_{(l)}$ *[3 marks]*

For full marks, your answer must address two factors affecting the entropy change and identify which of the two factors will dominate.

3. Consider the following phase change: **[15 marks]**

$$H_2O_{(l)} \rightarrow H_2O_{(g)}$$

(a) Calculate the standard Gibbs free energy change for this phase change at 25 ℃. *[6 marks]*

(b) Assuming that the enthalpy and entropy change for this process are not very temperature sensitive, use the standard values to calculate a predicted normal boiling point for water. Comment on this value. *[5 marks]*

(c) Calculate the standard Gibbs free energy change for this phase change at 90 ℃. Is the forward reaction thermodynamically favoured at this temperature? Why or why not? *[2 marks]*

(d) Calculate the standard Gibbs free energy change for this phase change at 110 ℃. Is the forward reaction thermodynamically favoured at this temperature? Why or why not? *[2 marks]*

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3. *…continued*

4. Consider the following reaction: **[14 marks]**

$$NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)}$$

(a) Calculate the standard Gibbs free energy change for this reaction at 25 ℃. *[2 marks]*

(b) Calculate equilibrium constant (K) for this reaction at 25 ℃. *[2 marks]*

(c) Write the reaction quotient (Q) expression for this reaction. *[1 mark]*

(d) Calculate the Gibbs free energy change for this reaction at 25 ℃ when $P_{NO_2(g)} = 5.00\ bar$ and $[HNO_{3(aq)}] = 0.0100\ M$? *[4 marks]*

(e) At what temperature will the equilibrium constant for this reaction be double your answer to part (b)? *[5 marks]*

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4. *…continued*

5. For the following electrochemical cell, $E° = -0.5768\ V$ at 25 °C. **[12 marks]**

$$Ag(s)\ |\ Ag^{+}(aq)\ 1.00\ M\ \|\ Cl^{-}(aq)\ 1.00\ M\ |AgCl\ (s), Ag(s)$$

(a) Identify the cathode **and** write a balanced equation for its half-reaction. *[2 marks]*

(b) Identify the anode **and** write a balanced equation for its half-reaction. *[2 marks]*

(c) Write a balanced chemical equation for the overall reaction occurring in this electrochemical cell **and** provide a numerical value for v_e. *[2 marks]*

(d) Write a balanced chemical equation for the dissolution of solid $AgCl$ in water **and** write the equilibrium constant expression for this reaction (K_{sp} expression for $AgCl$). *[2 marks]*

(e) Calculate a numerical value for the K_{sp} of $AgCl$ at 25 °C. *[4 marks]*