Fall 2025 **Chemistry 1000 Midterm #2X** ____/75 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 0/75 on this exam.

Signature: _____ Date: _____

1) Please read the test carefully before starting. It has 8 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.
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**					**Total**
/ 4	/ 6	/ 4	/ 10	/ 4	/ 5	/ 12	/ 9	/ 12	/ 9					/ 75

1. Complete the following table. You may find the partial periodic table (copied from the Data Sheet) helpful. *Misspelled elements will not get full credit.* **[4 marks]**

Atomic Number (*Z*)	Symbol	Name
5	B	boron
18	Ar	argon
22	Ti	titanium
34	Se	selenium

CHEM 1000 Standard Periodic Table

1																	18
1.0079 **H** 1	2											13	14	15	16	17	2
6.94 **Li** 3	9.0122 **Be** 4											5	12.011 **C** 6	14.0067 **N** 7	15.9994 **O** 8	18.9984 **F** 9	10
22.990 **Na** 11	24.3050 **Mg** 12	3	4	5	6	7	8	9	10	11	12	26.9815 **Al** 13	14	30.9738 **P** 15	32.066 **S** 16	35.4527 **Cl** 17	18
39.0983 **K** 19	40.078 **Ca** 20	21	22	23	24	54.9380 **Mn** 25	55.847 **Fe** 26	58.9332 **Co** 27	58.693 **Ni** 28	63.546 **Cu** 29	65.39 **Zn** 30	31	32	33	34	79.904 **Br** 35	36
85.4678 **Rb** 37	87.62 **Sr** 38	88.9059 **Y** 39	91.224 **Zr** 40	92.9064 **Nb** 41	95.95 **Mo** 42	(98) **Tc** 43	101.07 **Ru** 44	102.906 **Rh** 45	106.42 **Pd** 46	107.868 **Ag** 47	112.411 **Cd** 48	114.82 **In** 49	118.710 **Sn** 50	121.757 **Sb** 51	127.60 **Te** 52	126.905 **I** 53	131.29 **Xe** 54
132.905 **Cs** 55	137.327 **Ba** 56	**La-Lu**	178.49 **Hf** 72	180.948 **Ta** 73	183.84 **W** 74	186.207 **Re** 75	190.2 **Os** 76	192.23 **Ir** 77	195.08 **Pt** 78	196.967 **Au** 79	200.59 **Hg** 80	204.38 **Tl** 81	207.19 **Pb** 82	208.980 **Bi** 83	(209) **Po** 84	(210) **At** 85	(222) **Rn** 86
(223) **Fr** 87	(226) **Ra** 88	**Ac-Lr**	(267) **Rf** 104	(268) **Db** 105	(271) **Sg** 106	(272) **Bh** 107	(270) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112	(284) **Nh** 113	(289) **Fl** 114	(288) **Mc** 115	(293) **Lv** 116	(292) **Ts** 117	(294) **Og** 118

Radioactive elements: mass number given for longest lived isotope: e.g. (98)

138.906 **La** 57	140.115 **Ce** 58	140.908 **Pr** 59	144.24 **Nd** 60	(145) **Pm** 61	150.36 **Sm** 62	151.965 **Eu** 63	157.25 **Gd** 64	158.925 **Tb** 65	162.50 **Dy** 66	164.930 **Ho** 67	167.26 **Er** 68	168.934 **Tm** 69	173.05 **Yb** 70	174.967 **Lu** 71
(227) **Ac** 89	232.038 **Th** 90	231.036 **Pa** 91	238.029 **U** 92	(237) **Np** 93	(244) **Pu** 94	(243) **Am** 95	(247) **Cm** 96	(247) **Bk** 97	(251) **Cf** 98	(252) **Es** 99	(257) **Fm** 100	(257) **Md** 101	(259) **No** 102	(262) **Lr** 103

Developed by Prof. R. T. Boeré (updated 2021)

2. Complete the following table, giving the name and symbol for an element meeting each description. *Misspelled elements will not get full credit.* **[6 marks]**

Description	Symbol	Name
The most electronegative element	F	fluorine
The element with a diagonal relationship with magnesium	Li	lithium
One of the two elements whose cation makes water "hard"	Ca	calcium
The other element whose cation makes water "hard"	Mg	magnesium
One of the two elements discussed in CHEM 1000 whose oxide is amphoteric	Al	aluminium *or* aluminum
The other element discussed in CHEM 1000 whose oxide is amphoteric	Be	beryllium

3. Complete the following table. Names should follow the IUPAC conventions taught in class. **[4 marks]**

Misspelled names will not get full credit.

Chemical Formula	Name
Li_2O	lithium oxide
$FeBr_3$	iron(III) bromide
Cu_2S	copper(I) sulfide
KF	potassium fluoride

4. 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. **[10 marks]**

(a) The process where the surface of a metal reacts with air to form a protective layer is called passivation.

(b) The two types of closest packed crystal lattices are cubic closest packed and hexagonal closest packed.

(c) The three products of electrolysis of aqueous sodium chloride are $H_{2(g)}$, $Cl_{2(g)}$, and $NaOH_{(aq)}$. *Provide chemical formulas including states of matter.*

(d) When calcium carbonate is heated to a high enough temperature, it breaks down. The gas produced is CO_2.

(e) An ionic compound has a large lattice energy when the charge of the ions is large *(large/small)* and when the distance between the ions is small *(large/small)*.

(f) Lewis diagrams for the same molecule/ion in which some electrons are drawn in different locations but none of the atoms move are called resonance structures.

5. In the industrial process for refining aluminium, before electrolysis can be performed the impure bauxite ore is treated with aqueous base. Explain what this step accomplishes and write a balanced chemical equation for the reaction. **[4 marks]**

Aluminium ore contains oxides and hydroxides of aluminium which are contaminated by oxides of other metals (e.g. iron(III) oxide).

Aluminium oxides (and hydroxides) are amphoteric. They can react with aqueous acid or aqueous base. Most other metal oxides are basic and will only react with aqueous acid.

When aluminium ore is treated with base, therefore, the aluminium oxides/hydroxides react with it to give a soluble product (the $[Al(OH)_4]^-$ anion) while the other metal oxides remain in the solid state and can be filtered out. This allows separation of aluminium species from all other metal species.

$$Al_2O_3(s) + 2\ OH^-(aq) + 3\ H_2O(l) \rightarrow 2\ [Al(OH)_4]^-(aq)$$

or

$$Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$$

6. **[5 marks]**

(a) Write a balanced chemical equation for the electrolysis of molten* sodium chloride. *[1 mark]*

*Include states of matter. *"Molten" is another word for "melted" or "liquid".*

$$2\ NaCl(l) \rightarrow 2\ Na(l) + Cl_2(g)$$

(b) If we want to make 125 kg of sodium metal, what mass of sodium chloride must be electrolyzed? *Report your answer in kg.* *[4 marks]*

Step 1: Calculate moles of Na to be produced

$$n_{Na} = 125\ kg \times \frac{1\ mol}{22.990\ g} = 5.44\ kmol$$

Step 2: Use mole ratio to calculate moles of $NaCl$ to be consumed

$$n_{NaCl} = 5.44\ kmol\ Na \times \frac{2\ mol\ NaCl}{2\ mol\ Na} = 5.44\ kmol\ NaCl$$

Step 3: Calculate mass of $NaCl$ required

$$m_{NaCl} = 5.44\ kmol \times \frac{58.44\ g}{1\ mol} = 318\ kg$$

7. Write a balanced chemical equation for each of the following reactions if a reaction is expected at room temperature. **[12 marks]**

Include states of matter. If no reaction occurs, write "NO REACTION".

(a) Lithium metal is added to liquid bromine $\left(Br_{2(l)}\right)$.

$2\ Li_{(s)} + Br_{2(l)} \rightarrow 2\ LiBr_{(s)}$

(b) Calcium metal is exposed to nitrogen gas $\left(N_{2(g)}\right)$.

$3\ Ca_{(s)} + N_{2(g)} \rightarrow Ca_3N_{2(s)}$

(c) Potassium metal is added to water.

$2\ K_{(s)} + 2\ H_2O_{(l)} \rightarrow 2\ KOH_{(aq)} + H_{2(g)}$

(d) Aluminium metal is added to water.

no reaction

(e) Beryllium metal is added to concentrated aqueous sodium hydroxide $\left(NaOH_{(aq)}\right)$.

$Be_{(s)} + 2\ NaOH_{(aq)} + 2\ H_2O_{(l)} \rightarrow Na_2[Be(OH)_4]_{(aq)} + H_{2(g)}$

or $Be_{(s)} + 2\ OH^-_{(aq)} + 2\ H_2O_{(l)} \rightarrow [Be(OH)_4]^{2-}_{(aq)} + H_{2(g)}$

(f) Potassium carbonate is added to concentrated aqueous hydrochloric acid $\left(HCl_{(aq)}\right)$.

$K_2CO_{3(s)} + 2\ HCl_{(aq)} \rightarrow 2\ KCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

or $K_2CO_{3(s)} + 2\ H^+_{(aq)} \rightarrow 2\ K^+_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

8. Given the following elements: **[9 marks]**

Al Ca S

(a) Rank the atoms in order of atomic radius, from smallest to largest. *[1 mark]*

smallest radius S Al Ca largest radius

(b) Rank the atoms in order of electron affinity, from smallest to largest. *[1 mark]*

smallest electron affinity Ca Al S largest electron affinity

(c) For each element, write the formula (including charge) for the ion that will be most commonly observed, and write the electron configuration for that ion. Do not use noble gas notation. *[6 marks]*

Al Al^{3+} $1s^2 2s^2 2p^6$

Ca Ca^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6$

S S^{2-} $1s^2 2s^2 2p^6 3s^2 3p^6$

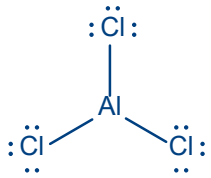
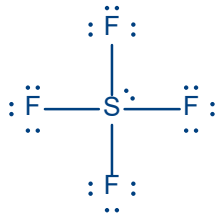
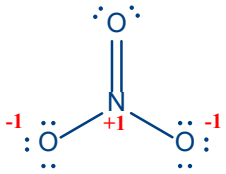
(d) Rank the ions from part (c) in order of radius, from smallest to largest. *[1 mark]*

smallest radius Al^{3+} Ca^{2+} S^{2-} largest radius

9. Complete the table below. **[12 marks]**

Include any non-zero formal charges on the appropriate atom(s).

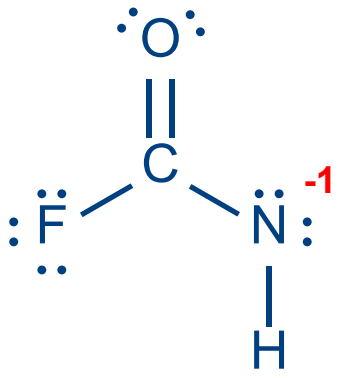
If more than one valid resonance structure can be drawn for a formula, just draw one of them.

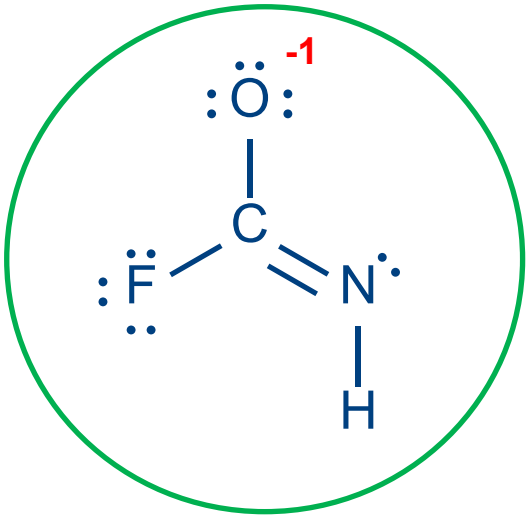
Formula	Lewis Diagram	Electron Group Geometry *(in words)*	Molecular Geometry *(in words)*
$AlCl_3$		trigonal planar	trigonal planar
SF_4		trigonal bipyramidal	seesaw
NO_3^-		trigonal planar	trigonal planar

10. **[9 marks]**

(a) There are two formal-charge-minimized resonance structures for the $CFO(NH)^-$ anion. Draw these resonance structures using the skeletal structures given below as a starting point. *[4 marks]*

Include any non-zero formal charges on the appropriate atom(s).





(b) Assume the two resonance structures contribute equally to the average structure. Give the average bond order for each bond to carbon. *[3 marks]*

$C - O$ bond order is 1.5

$C - N$ bond order is 1.5

$C - F$ bond order is 1

(c) In reality, the two resonance structures do not contribute equally. Circle the resonance structure that is 'better' (contributes more to the averaged molecular structure). *[1 mark]*

see circle in part (a)

(d) Based on your answer in (c), is the real average $C - O$ bond order higher or lower than your answer in (b)? *[1 mark]*

lower

The better resonance structure contributes more to the average and that structure shows the $C - O$ bond as single, so the $C - O$ bond order is closer to 1 than to 2 (and therefore lower than 1.5).