

Name: _____

Student Number: _____

CHEMISTRY 1A03/1E03

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MCMASTER UNIVERSITY - TERM TEST # 2 - DURATION: 120 minutes

This test contains **17** numbered pages and **30** multiple-choice questions. Page 15 is extra space for rough work. Page 16 includes some useful data and equations, and there is a Periodic Table on page 17. You may tear off the last pages to view the periodic table and the data provided. **You are responsible for ensuring that your copy of the question paper is complete.** Bring any discrepancy to the attention of your invigilator.

Questions 1-25 are each worth 2 marks, questions 26-30 are each worth 3 marks. The total marks available are 65. There is no penalty for incorrect answers.

These question sheets must be returned with your answer sheet. However, no work written on the question sheets will be marked. You must enter your full name and student number on this question sheet, as well as on the answer sheet. **Your invigilator will be checking your student card for identification.**

Make sure to enter the correct version number of your test (shown at the bottom of each page) in the correct column on the answer sheet (see instructions on page 2).

Answer all questions on the answer sheet, in pencil. Instructions for entering multiple-choice answers are given on page 2. Select **one answer for each question** from the choices (A) through (E).

Only **Casio FX 991 electronic calculators** may be used; but they must NOT be transferred between students. Use of periodic tables or any aids other than those provided, is not allowed.

Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy. Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc.*) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you.

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QUESTIONS 1–25 ARE WORTH 2 MARKS EACH.

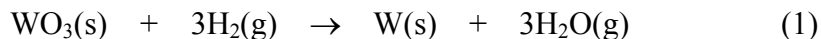
1. Aluminum metal reacts with chlorine gas to form solid aluminum trichloride, AlCl_3 . What mass of chlorine gas (**in g**) is needed to react completely with 163 g of aluminum?

A) 245
B) 489
C) 214
D) 643
E) 321

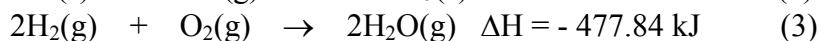
2. PbCl_2 is insoluble in water. What volume (**in mL**) of a 0.750 M $\text{Pb}(\text{NO}_3)_2(\text{aq})$ solution is required to completely precipitate the chloride ions from 0.500 L of a 2.25 M $\text{NaCl}(\text{aq})$ solution?

A) 562
B) 1500
C) 375
D) 750
E) 1000

3. Use Hess's law to calculate the enthalpy change (**in kJ**) for the reaction



from the following data:



- A) 364.9
B) 1207.6
C) -252.9
D) 125.9
E) 252.9
4. Which one of the expressions below is **TRUE** for a system which undergoes an adiabatic change (i.e. without heat transfer) and has work done on it by the surroundings?
- A) $w > \Delta U$
B) $w < 0$ and $\Delta U > 0$
C) $w > 0$ and $\Delta U < 0$
D) $w = \Delta U$
E) $w = -\Delta U$
5. The approximate size of an atomic orbital is associated with
- A) the angular momentum and magnetic quantum numbers, together.
B) the principal quantum number (n).
C) the angular momentum quantum number (l).
D) the magnetic quantum number (m_l).
E) the spin quantum number (m_s).

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6. Considering the positions of aluminum and nitrogen in the periodic table, what would you predict the **empirical formula** of aluminum nitride to be?
- A) AlN_3
 - B) Al_3N
 - C) Al_4N_3
 - D) AlN_2
 - E) AlN
7. According to the Bohr model of the H atom, the difference of energy between the levels $n=1$ and $n=\infty$ corresponds to which of the following?
- A) The energy of the shortest-wavelength photon absorbed by hydrogen in an excited state.
 - B) The electronegativity of hydrogen.
 - C) The ionization energy of hydrogen.
 - D) The electron affinity of hydrogen.
 - E) The energy of the longest-wavelength photon absorbed by hydrogen in its ground state.
8. Vinegar is a solution of acetic acid, CH_3COOH , dissolved in water. A 5.54 g sample of vinegar was neutralized by 30.10 mL of 0.100 M NaOH. What is the **percent by weight** of acetic acid in the vinegar?
- A) 3.26%
 - B) 0.184%
 - C) 9.23%
 - D) 1.63%
 - E) 5.43%
9. In which of the following processes is $\Delta H = \Delta U$?
- A) Calcium carbonate is heated to form calcium oxide and carbon dioxide in an open container.
 - B) A sample of solid carbon dioxide (dry ice) sublimates to the gas phase.
 - C) A sample of steam is condensed into liquid water at 90°C and 1 atm.
 - D) Two moles of hydrogen iodide gas react to form hydrogen and iodine gases in a sealed container at a constant temperature of 400°C .
 - E) A sample of ammonia gas is cooled from 325°C to 300°C at 1 atm.

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10. Electron affinity is the change of energy involved when a gaseous atom forms:

- A) a gas-phase anion
- B) a neutral free radical
- C) a covalent bond
- D) a gas-phase cation
- E) none of the above

11. Calculate the enthalpy change (**in kJ**) for the reaction $\text{K(g)} + \text{I(g)} \rightarrow \text{K}^+(\text{g}) + \text{I}^-(\text{g})$, given the following ionization energy (IE) and electron affinity (EA) values.

	IE (kJ/mol)	EA (kJ/mol)
K	419	-48
I	1,010	-295

- A) 1429
- B) 714
- C) -1429
- D) 124
- E) -714

12. Which one of the following metals is likely to exhibit the most violent and rapid reaction with water?

- A) Magnesium
- B) Calcium
- C) Rubidium
- D) Lithium
- E) Sodium

13. Choose the **CORRECT** statement(s) from the following:

- (i) Sodium has a larger first ionization energy than potassium.
- (ii) Sodium has a larger atomic size than chlorine.
- (iii) Calcium has a larger first ionization energy than fluorine.
- (iv) Sulfur has a larger electronegativity than chlorine.

- A) ii, iv
- B) i, ii
- C) iii, iv
- D) ii
- E) i, iii

14. Which atomic property decreases **down** a group?

- A) the first ionization energy
- B) the atomic radius
- C) the ionic radius
- D) the core charge
- E) the metallic character

15. Choose the **FALSE** statement from the following:

- A) The formal charge on oxygen in F_2O is zero.
- B) All bond angles in SCl_4 are smaller than 109.5° . 2 marks
- C) For an AX_4E molecule, the nonbonding electron pair is in an equatorial position.
- D) BF_3 is a non-polar molecule.
- E) For a given pair of atoms, the bond length decreases as the bond order increases.

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16. Which one of the following molecules has **no** net dipole moment? (Central atoms are underlined.)

- A) NF₃
- B) H₂Se
- C) CH₃Cl
- D) NO₂
- E) SO₃

17. Choose the **FALSE** statement about the Lewis structure of the peroxide anion, O₂²⁻:

- A) Each oxygen atom has 3 nonbonding electron pairs.
- B) Each oxygen atom carries a formal charge of -1.
- C) The oxygen-oxygen bond is a single bond.
- D) Each oxygen atom obeys the octet rule.
- E) Two resonance forms are required to describe bonding in this anion. 2 marks

18. Calculate ΔH (**in kJ**) for $\text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g})$ using the following bond energy data (given in kJ mol^{-1}):

$\text{BE}(\text{H-H}) = 436$, $\text{BE}(\text{O-H}) = 467$, $\text{BE}(\text{C=O}) = 803$, $\text{BE}(\text{C}\equiv\text{O}) = 1075$, $\text{BE}(\text{C-O}) = 360$

- A) +33
- B) +3
- C) -865
- D) +305
- E) +763

19. According to the VSEPR model, which one of the following molecules should be **linear**?

- A) H_2CO
- B) SO_2
- C) H_2S
- D) HCN
- E) BF_3

20. Choose the **TRUE** statement regarding covalent bonds.

- A) A C=O double bond is longer than a C-O single bond.
- B) The bond in I_2 is shorter than the bond in Cl_2 .
- C) An H-I bond is stronger than an H-Cl bond.
- D) The oxygen-oxygen bond in H_2O_2 (HOOH) is longer than in O_2 . 2 marks
- E) A C-H bond is longer than a C-C bond.

21. Which of the following statements are **FALSE** about the BrO_2F molecule? (Br is the central atom.)

- (i) It has a permanent dipole moment.
- (ii) It is T-shaped about Br.
- (iii) There is one lone pair of electrons on Br.
- (iv) The octet rule is violated at Br.
- (v) The oxidation number of Br is +5.
- (vi) The average Br-O bond order is 1.5.

- A) iv, vi
- B) ii, iv
- C) i, v
- D) ii, vi
- E) iii, iv

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22. Calculate ΔS° (in J/K) for the reaction $4\text{Cr(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Cr}_2\text{O}_3\text{(s)}$

Substance	Cr(s)	O ₂ (g)	Cr ₂ O ₃ (s)
S°(J/K·mol)	23.77	205.138	81.2

- A) 310.1
- B) 548.1
- C) -147.7
- D) 147.7
- E) -548.1

23. Choose the expected order of **increasing** molar entropy.

- A) NaCl(s) < Na(s) < NaCl(aq) < Cl₂(g) 1 mark
- B) NaCl(aq) < Na(s) < NaCl(s) < Cl₂(g)
- C) Na(s) < NaCl(s) < NaCl(aq) < Cl₂(g) 2 marks
- D) Na(s) < Cl₂(g) < NaCl(s) < NaCl(aq)
- E) NaCl(s) < NaCl(aq) < Cl₂(g) < Na(s)

24. Identify the **TRUE** statement(s):

- (i) Mixing aqueous solutions of NaCl and KCl at constant T results in a decrease of entropy of the system.
- (ii) S°(chlorine gas) is much smaller than S°(nitrogen gas).
- (iii) The freezing of water at 0°C leads to a decrease in the entropy of the surroundings.
- (iv) Decreasing the temperature of a system increases its entropy.

- A) none
- B) ii, iv
- C) i, ii
- D) i
- E) iii

25. Which of the following is necessary for a process to be spontaneous?

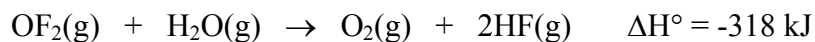
- A) $\Delta U_{\text{univ}} < 0$
- B) $\Delta S_{\text{univ}} > 0$
- C) $\Delta S_{\text{sys}} > 0$
- D) $\Delta S_{\text{surr}} > 0$
- E) $\Delta S_{\text{surr}} < 0$

QUESTIONS 26-30 ARE WORTH 3 MARKS EACH.

26. In which one of the following molecules or ions is the **shortest** Cl-O bond present? (Central atoms are underlined.)

- A) $\underline{\text{Cl}}\text{O}_2^-$
- B) $\underline{\text{Cl}}\text{O}_3^-$
- C) $\text{HO}\underline{\text{Cl}}\text{O}$
- D) $\underline{\text{Cl}}\text{O}_4^-$
- E) $\text{H}\underline{\text{O}}\underline{\text{Cl}}$

27. Oxygen difluoride is an unstable molecule that reacts readily with water. Calculate the bond energy (**in kJ/mol**) of the O-F bond using the standard enthalpy of reaction and the bond energy data provided below.



	Bond energy (kJ/mol):
O-H	467
O=O	498
H-F	565

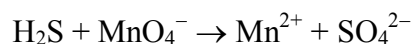
- A) 506
- B) 188
- C) 253
- D) 94
- E) 376

28. Identify the **CORRECT** statement(s):

- (i) ΔS may be given in units of $\text{J}\cdot\text{mol}^{-1}$.
- (ii) $\Delta S(\text{system}) > 0$ for the dissolution of $\text{NaCl}(\text{s})$ in water.
- (iii) The sign of $\Delta S(\text{reaction})$ is determined by the sign of $\Delta H(\text{reaction})$.
- (iv) A reaction is always spontaneous if $\Delta S(\text{reaction}) > 0$.
- (v) $\Delta S(\text{reaction}) = \Sigma S(\text{reactants}) - \Sigma S(\text{products})$.

- A) ii, v
- B) i, v
- C) ii
- D) i, iii
- E) ii, iii, iv

29. Complete and balance the following redox equation **in acidic solution**. What are the coefficient of H_2S and the total number of electrons transferred when the equation is balanced using the **smallest whole-number coefficients**?



- A) 5, 40
- B) 4, 80
- C) 4, 80
- D) 5, 80
- E) 8, 40

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30. Identify the **TRUE** statements:

- (i) Be has a larger atomic radius than B.
- (ii) As an overall trend, electronegativity increases from left to right across a period.
- (iii) F^- has a smaller ionic radius than Na^+ .
- (iv) Rb has a lower first ionization energy than Na.
- (v) All elements in period 2 form acidic oxides.

- A)** ii, iii, v
- B)** i, ii
- C)** i, iv
- D)** i, ii, iv
- E)** iii, v