CHEMISTRY 1E03 **7 NOVEMBER 2008**

Instructors: J. Barbier, R. Dumont

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

This test contains 17 pages and **30** multiple-choice questions. The last five pages include three blank pages for rough work, a page with some useful data and equations, and a Periodic Table. You may tear off the last five pages. **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. There is no penalty for incorrect answers.

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-E.

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).

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.**

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.

Note: 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 a problem arises, please ask an invigilator to deal with it for you.

QUESTIONS 1–25 ARE WORTH 2 MARKS EACH.

1. Aluminum oxide(Al_2O_3) can be reduced to aluminum metal using carbon, the other reaction product being carbon monoxide gas (CO). Determine the enthalpy change (**$\Delta H°$ in kJ**) when 12.5 g of aluminum metal is produced by this method.
[$\Delta H°_f(CO) = -110.5$ kJ/mol; $\Delta H°_f(Al_2O_3) = -1669.8$ kJ/mol]

A) 310
B) –310
C) 361
D) 620
E) –725

2. A atom of iron (Fe) in its ground-state has ___ unpaired electrons and is _____.

A) 3, paramagnetic
B) 4, paramagnetic
C) 5, paramagnetic
D) 6, diamagnetic
E) 0, diamagnetic

3. A 100 mL sample of 0.200 M hydrochloric acid, HCl(aq), is added to 100 mL of 0.200 M aqueous ammonia, NH_4OH(aq), in a calorimeter whose heat capacity is 480. J/K (for the container only, excluding the water) . The temperature increase is 2.34°C. Calculate ΔH for the reaction (**in kJ per mole of acid reacted**).

A) – 485
B) –1.96
C) + 485
D) –154
E) + 154

4. Electrons are ejected from cesium metal (Cs) when 500 nm light shines on it. Which one of the following statements is **FALSE**?

A) 400 nm light will also eject electrons from cesium metal.
B) The energy of each photon of 500 nm light is 3.97×10^{-19} J.
C) The kinetic energy of each ejected electron is less than 3.97×10^{-19} J.
D) 450 nm light will eject electrons with less kinetic energy than 500 nm light
E) The frequency of 500 nm light is 6.00×10^{14} Hz (or s^{-1})

5. Identify the **FALSE** statement concerning the following three chemical reactions:
(i) $LiOH(s) + HOCl(aq) \rightarrow LiOCl(aq) + H_2O(l)$
(ii) $C(s) + O_2(g) \rightarrow CO_2(g)$
(iii) $KHSO_4(aq) + KCH_3COO(aq) \rightarrow K_2SO_4(aq) + CH_3COOH(aq)$

A) CH_3COO^- acts as a base in reaction (iii).
B) HOCl acts as an acid in reaction (i).
C) Reaction (ii) is an oxidation reduction.
D) $SO_4^{2-}(aq)$ is a spectator ion in reaction (iii).
E) Reaction (ii) is exothermic.

6. Which one of the following statements is **FALSE**?

A) When copper reacts with nitric acid, both nitrogen dioxide and hydrogen gas are produced.
B) A brown gas is observed when copper reacts with nitric acid.
C) Copper oxide dissolves in concentrated sulfuric acid.
D) When zinc reacts with hydrochloric acid, the only gas produced is hydrogen gas.
E) Zinc can be used to reduce Cu^{2+} ions to copper.

7. Which of the following contains the greatest number of atoms?

A) 5 g He
B) 100 g Pb
C) 2 mol Ar
D) 1 mL H_2 gas at 25 °C and 1 atm
E) 0.5 mol H_2O

8. Calculate the amount of work done (**in kJ**) when 27 mL of water vaporize into steam at 1.00 atm and 25°C. Assume that the volume of liquid water is negligible compared to that of steam.

A) 3670
B) 0.037
C) 36.7
D) 3.7
E) 3718

9. Which one of the elements listed below has the following pattern for its first six ionization energies?
$\boldsymbol{I_1 < I_2 < I_3 < I_4 << I_5 < I_6}$ (where I_1 = first ionization energy for $A \rightarrow A^+ + e^-$, I_2 = second ionization energy for $A^+ \rightarrow A^{2+} + e^-$, etc.)

A) Si
B) P
C) Ca
D) Al
E) Se

10. Which atomic property **decreases** from the top to the bottom of a group?

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

11. 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
B) i, ii
C) iii, iv
D) i, iii
E) i, iv

12. Which of the following statements about periodic trends are **TRUE**?
(i) $Br^- > Rb^+ > Sr^{2+}$ is the correct sequence for decreasing ionic radius.
(ii) The ground-state electron configuration of silicon has no unpaired electrons.
(iii) Calcium oxide is a basic oxide.
(iv) Sodium is oxidized more easily than lithium.
(v) The electronegativity of chlorine is smaller than that of phosphorus.

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

13. Which of the elements listed below has the **highest** first ionization energy?

A) Ga
B) K
C) As
D) Cs
E) Bi

14. Which one of the following statements is **FALSE** regarding the Lewis structures of SF_4 and PCl_4^+ ?

A) One species has a square-planar shape.
B) There is no nonbonding pair on P in PCl_4^+.
C) PCl_4^+ and SF_4 have different numbers of nonbonding pairs.
D) There are only single bonds in both species.
E) The two species have different VSEPR shapes.

15. Find the **FALSE** statements regarding molecular geometries (central atoms are underlined).
(i) The shape of $\underline{Xe}OF_4$ is square pyramidal.
(ii) The O-Xe-F bond angles in $\underline{Xe}OF_4$ are greater than 90º.
(iii) The shape of $\underline{Br}F_3$ is trigonal pyramidal.
(iv) The bond angles in $\underline{Br}F_3$ are less than 90º.
(v) The Xe-F bonds in $\underline{Xe}OF_4$ and the Br-F bonds in BrF_3 have different bond orders.

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

16. Which of the following geometries describes the shape of the NH_2Cl molecule as predicted by the VSEPR model (N is the central atom, and all other atoms are bonded to N)?

A) T-shaped
B) trigonal pyramidal
C) linear
D) tetrahedral
E) trigonal planar (or triangular)

17. Calculate ΔH (**in kJ**) for $CO_2(g) + H_2(g) \rightarrow CO(g) + H_2O(g)$ using the appropriate bond energy data (given in kJ mol^{-1}): D(H-H) = 436, D(O-H) = 467, D(C=O) = 803, D(C≡O) = 1075, D(C-O) = 360 (D stands for bond dissociation energy and is equivalent to bond energy, BE).

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

18. Determine the **average S-O bond order** in the sulfite anion, SO_3^{2-} (S is the central atom), and the molecular geometry.

A) 1/3, T-shape
B) 4/3, trigonal pyramidal
C) 5/3, tetrahedral
D) 4/3, trigonal planar
E) 2/3, triangular

19. Identify the correct order of **increasing MAGNITUDE of lattice energy** (i.e. from smallest |lattice energy| to largest).

A) KBr < MgO < KI < NaBr
B) KI < KBr < NaBr < MgO
C) MgO < NaBr < KBr < KI
D) NaBr < KBr < MgO < KI
E) KI < NaBr < KBr < MgO

20. N is the central atom in the fulminate anion, CNO^-. The best resonance Lewis structure shows the following **C, N, O formal charges**, respectively:

A) -1, 0, 0
B) -1, +1, -1
C) 0, +1, -2
D) 0, 0, -1
E) -2, +1, 0

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

A) $\underline{Xe}F_4$
B) $\underline{N}O_2$
C) $\underline{As}F_3$
D) $\underline{S}OCl_2$
E) $H_2\underline{Se}$

22. A self-contained breathing device uses the following chemical equilibrium involving potassium superoxide, $KO_2(s)$:

$$4\ KO_2(s) + 2\ CO_2(g) \leftrightarrow 2\ K_2CO_3(s) + 3\ O_2(g) \quad \text{for which } K_p = 28.5$$

To simulate normal breathing conditions, the equilibrium partial pressure of $O_2(g)$ must equal 0.20 atm. What is the **equilibrium partial pressure of CO_2(g) (in atm)** needed for these conditions?

A) 0.48
B) 7.0×10^{-3}
C) 0.015
D) 0.017
E) 0.022

23. The dissociation of solid silver chloride, AgCl(s), in water to produce silver ions and chloride ions has an equilibrium constant of 1.8×10^{-18} at room temperature. Calculate the **equilibrium concentration of Ag^+ ions (in mol/L)** in solution.

A) 1.8×10^{-18}
B) 1.3×10^{-9}
C) 9.0×10^{-19}
D) 1.8×10^{-9}
E) 3.6×10^{-18}

24. The equilibrium constant, K_p, for the reaction $H_2(g) + I_2(g) \leftrightarrow 2\ HI(g)$ is 55.2 at 425°C. A rigid cylinder at that temperature contains a mixture with the following partial pressures: 12.88 kPa of hydrogen, 13.57 kPa of iodine, and 106.87 kPa of hydrogen iodide. Identify the **TRUE** statement below.

A) Both the forward and reverse reactions will proceed to establish equilibrium.
B) The initial total pressure in the cylinder is 240.19 kPa.
C) The partial pressure of $H_2(g)$ will be greater than the partial pressure of $I_2(g)$ at equilibrium.
D) The partial pressures of $H_2(g)$, $I_2(g)$ and HI(g) will be equal at equilibrium.
E) The reverse reaction will proceed to establish equilibrium.

25. Methanol can be synthesized by combining carbon monoxide and hydrogen.
$CO(g) + 2\ H_2(g) \leftrightarrow CH_3OH(g)\quad \Delta H°_{rxn} = -90.7$ kJ
A reaction vessel of constant volume contains these three gases at equilibrium. What effect will be seen when equilibrium is re-established after **decreasing the temperature** by 45°C?

A) The partial pressure of hydrogen will increase.
B) The partial pressure of carbon monoxide will decrease.
C) The partial pressure of methanol will decrease.
D) The partial pressures of hydrogen and methanol will decrease.
E) All the partial pressures will decrease.

QUESTIONS 26-30 ARE WORTH 3 MARKS EACH.

26. Which two of the following species belong to the **same AX_nE_m VSEPR class**? (The central atoms are underlined.)
(i) $\underline{Be}Cl_2$ (ii) $\underline{As}O_4^{3-}$ (iii) $\underline{N}O_2^-$ (iv) $\underline{S}F_4$ (v) $\underline{Al}H_4^-$ (vi) $\underline{I}_3^-$

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

27. Use the following data to calculate the **electron affinity of S(g) (in kJ mol^{-1})**.
Lattice enthalpy (same as lattice energy) of $K_2S = -2052$ kJ/mol
Formation enthalpy of $K_2S(s) = -365$ kJ/mol
Sublimation enthalpy of $K = +90$ kJ/mol
First ionization enthalpy of $K = +419$ kJ/mol
Formation enthalpy of $S(g) = +277$ kJ/mol
Electron affinity of $S^-(g) = +592$ kJ/mol (enthalpy change for the reaction $S^-(g) + e^- \rightarrow S^{2-}(g)$)

A) – 200
B) +200
C) +309
D) +286
E) –286

28. The concentration of a potassium oxalate ($K_2C_2O_4$) solution can be determined by titration with a solution of potassium permanganate ($KMnO_4$) of known concentration. The balanced equation for this reaction is:

$$2\ KMnO_4 + 5\ K_2C_2O_4 + 16\ HCl(aq) \rightarrow 2\ MnCl_2(aq) + 10\ CO_2(g) + 8\ H_2O + 12\ KCl(aq).$$

A 30.00 mL sample of an oxalate solution is found to react completely with 21.93 mL of a 0.1725 M solution of permanganate. Calculate the oxalate ion concentration in the sample and determine the number of electrons transferred during the reaction as written above.

A) 0.1821 M, 2 electrons
B) 0.3152 M, 5 electrons
C) 0.3152 M, 10 electrons
D) 0.4312 M, 3 electrons
E) 0.1821 M, 4 electrons

29. Choose the **TRUE** statements regarding chemical equilibrium.
(i) When the reaction quotient is greater than the equilibrium constant, there is net reverse reaction.
(ii) Increasing the temperature always increases the equilibrium constant.
(iii) A system has reached equilibrium when the forward and reverse reactions both stop.
(iv) The equilibria $H_2(g) + 1/2\ O_2(g) \leftrightarrow H_2O(g)$ and $2\ H_2(g) + O_2(g) \leftrightarrow 2\ H_2O(g)$ have different values of K_p.
(v) Away from equilibrium, the forward and reverse reactions proceed at different rates.

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

30. A single pulse of a laser yields an average of 5.00×10^{18} photons with a wavelength $\lambda = 633$ nm. If melting ice to water at 0°C requires 6.01 kJ/mol, what is the **minimum number of laser pulses** needed to melt 10.0 g of ice?

A) 3340
B) 38300
C) 2128
D) 213
E) 3830