CHEMISTRY 1E03   9 NOVEMBER 2007

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

This test contains **16** pages and **30** multiple-choice questions. The last four pages include two extra blank pages for rough work, a page with some useful data and equations, and a Periodic Table. You may tear off the last four 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.

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.

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. Ethanol, C_2H_5OH, is being promoted as a clean fuel and is used as an additive in many gasoline mixtures. Calculate the **ΔH°$_{rxn}$** for the combustion of ethanol. ΔH°$_f$ [$C_2H_5OH(l)$] = -277.7 kJ/mol; ΔH°$_f$ [$CO_2(g)$] = -393.5 kJ/mol; ΔH°$_f$ [$H_2O(g)$] = -241.8 kJ/mol

   A) 357.6 kJ
   B) -357.6 kJ
   C) 1234.7 kJ
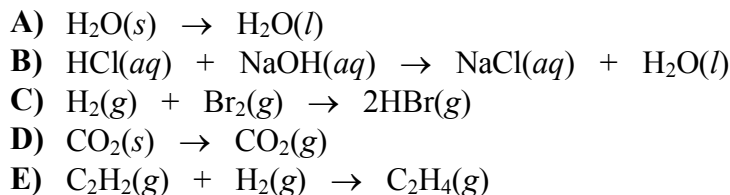   D) -751.1 kJ
   E) -1234.7 kJ

2. How many mL of concentrated nitric acid (HNO_3, 16.0 M) should be diluted with water in order to make 2.00 L of 2.00 M solution?

   A) 500. mL
   B) 250. mL
   C) 62.5 mL
   D) 32.0 mL
   E) 125 mL

3. The minimum energy (in J) needed to ionize a hydrogen atom **from the $n = 2$ energy level** is

   A) 1.64×10^{-18} J
   B) 3.03×10^{-19} J
   C) 2.18×10^{-18} J
   D) 5.45×10^{-19} J
   E) none of the above

4. In which one of the following reactions would you expect ΔH to be substantially **greater** than ΔU (i.e. $\Delta H > \Delta U$)?

A) $H_2O(s) \rightarrow H_2O(l)$
B) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
C) $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$
D) $CO_2(s) \rightarrow CO_2(g)$
E) $C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g)$

5. Balance the following redox equation using the smallest integers possible and select the correct coefficient for the hydrogensulfite ion.

$$MnO_4^-(aq) + HSO_3^-(aq) + H^+(aq) \rightarrow Mn^{2+}(aq) + SO_4^{2-}(aq) + H_2O(l)$$
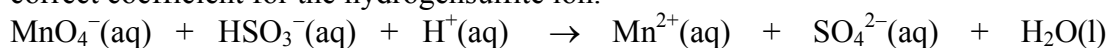
A) 10
B) 5
C) 1
D) 3
E) 2

6. Select the correct set of quantum numbers (n, l, m_l, m_s) for the **highest-energy electron** in the ground state of indium, In.

A) 5, 2, 0, ½
B) 5, 2, 1, ½
C) 5, 2, -1, -½
D) 5, 1, 2, -½
E) 5, 1, 0, ½

7. A system absorbs 21.6 kJ of heat while performing 6.9 kJ of work on the surroundings. If the initial internal energy, U, is 61.2 kJ, **what is the final value of U?**

A) 75.9 kJ
B) 32.7 kJ
C) 89.7 kJ
D) 46.5 kJ
E) 82.8 kJ

8. Select the **diamagnetic** ion.

   A) V^{4+}
   B) Cu^{2+}
   C) Fe^{3+}
   D) Ni^{2+}
   E) Sc^{3+}

9. Which of the following is a **basic** oxide?

   A) SO_2
   B) NO_2
   C) CaO
   D) CO_2
   E) H_2O

10. The successive ionization energies of a certain element are $I_1 = 577.9$ kJ/mol, $I_2 = 1820$ kJ/mol, $I_3 = 2750$ kJ/mol, $I_4 = 11,600$ kJ/mol, and $I_5 = 14,800$ kJ/mol. **Based on the shell structure of atoms**, this pattern of ionization energies suggests that the unknown element is

    A) Kr
    B) K
    C) Se
    D) Al
    E) Cl

11. Which one of the following is most likely to be a **covalent** compound?

    A) $CaSO_4$
    B) KF
    C) $CaCl_2$
    D) SF_4
    E) Al_2O_3

12. Which of the following elements has the **smallest** first ionization energy?

   A) Na
   B) Be
   C) K
   D) As
   E) Cl

13. Calculate the energy required for the gas phase process represented by
   $Na(g) + Br(g) \rightarrow Na^+(g) + Br^-(g)$

   Given:
   First ionization energy (Na) = +496 kJ/mol
   First ionization energy (Br) = +1140 kJ/mol
   Electron affinity (Br)   = − 324 kJ/mol
   Electron affinity (Na)   = − 53 kJ/mol

   A) +172 kJ/mol
   B) −172 kJ/mol
   C) +1636 kJ/mol
   D) −820 kJ/mol
   E) +820 kJ/mol

14. The total number of **lone pairs** (or non-bonding electron pairs) in NCl_3 is

   A) 1
   B) 10
   C) 6
   D) 9
   E) 20

15. Which one of the following molecules has a **zero** molecular dipole moment?

  A) SO_2
  B) CO
  C) SF_4
  D) XeF_4
  E) CH_2Cl_2

16. Predict the geometry and polarity of the **CS$_2$** molecule.

  A) linear, nonpolar
  B) tetrahedral, nonpolar
  C) bent, polar
  D) linear, polar
  E) bent, nonpolar

17. The bond angle in Cl_2O is expected to be **closest** to

  A) 120°
  B) 90°
  C) 180°
  D) 109.5°
  E) 145°

18. Use a Born-Haber cycle to calculate the **lattice energy of NaBr(s)** given the following data:

Enthalpy of sublimation (ΔH_{sub}) of Na(s) = +177.8 kJ/mol
First ionization energy of Na = +495.9 kJ/mol
Bond energy (Br–Br) = +192.5 kJ/mol
Electron affinity of Br = – 325 kJ/mol
Enthalpy of formation (ΔH_f) of NaBr(s) = – 361.1 kJ/mol
Enthalpy of vaporization (ΔH_{vap}) of Br_2(l) = +30.9 kJ/mol

A) –450 kJ/mol
B) –1456 kJ/mol
C) –821 kJ/mol
D) –709 kJ/mol
E) –806 kJ/mol

19. According to the VSEPR theory, what is the shape of a molecule with the general formula AX_2E_3 ?

A) T-shaped
B) trigonal pyramidal
C) bent
D) linear
E) trigonal planar

20. Which of the following molecules have the **same** geometries?

A) PCl_3 and $BrCl_3$
B) N_2O and NO_2
C) BeF_2 and H_2O
D) SF_4 and CH_4
E) CO_2 and BeH_2

21. Use the following bond energies to estimate the **enthalpy of formation** of HBr(g).
   D(H–H) = 436 kJ/mol
   D(Br–Br) = 192 kJ/mol
   D(H–Br) = 366 kJ/mol

   A) −52 kJ/mol
   B) +104 kJ/mol
   C) +262 kJ/mol
   D) +52 kJ/mol
   E) −104 kJ/mol

22. The equilibrium constant, K_p, for the reaction $CO(g) + H_2O(g) \leftrightarrow CO_2(g) + H_2(g)$
   at 986°C is equal to 0.63. A rigid cylinder at that temperature contains 1.2 atm of
   carbon monoxide, 0.20 atm of water vapor, 0.30 atm of carbon dioxide, and 0.27 atm of
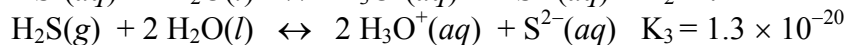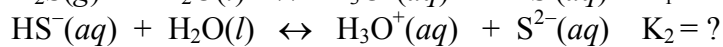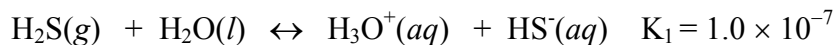   hydrogen. Is the system at equilibrium?

   A) No, the forward reaction must proceed to establish equilibrium.
   B) Need to know the starting concentrations of all substances before deciding.
   C) Yes.
   D) No, the reverse reaction must proceed to establish equilibrium.
   E) Need to know the volume of the container before deciding.

23. Consider the following reaction at equilibrium: $2 SO_2(g) + O_2(g) \leftrightarrow 2 SO_3(g)$, with
   $\Delta H°_{rxn} = -198$ kJ/mol.
   If the volume of the system is decreased at constant temperature, what change will occur
   in the position of the equilibrium?

   A) A shift to produce more SO_3
   B) A shift will occur in the endothermic direction
   C) A shift to produce more O_2
   D) No change
   E) A shift to produce more SO_2

24. Hydrogen sulfide will react with water as shown in the following reactions. What is the value of K_2?

$H_2S(g)$ + $H_2O(l)$ ↔ $H_3O^+(aq)$ + $HS^-(aq)$ $K_1 = 1.0 \times 10^{-7}$
$HS^-(aq)$ + $H_2O(l)$ ↔ $H_3O^+(aq)$ + $S^{2-}(aq)$ $K_2 = ?$
$H_2S(g)$ + $2 H_2O(l)$ ↔ $2 H_3O^+(aq)$ + $S^{2-}(aq)$ $K_3 = 1.3 \times 10^{-20}$

A) 7.7×10^{12}
B) 1.3×10^{-27}
C) 7.7×10^{26}
D) 1.3×10^{-13}
E) 2.3×10^{-7}

25. When the following reaction is at equilibrium, which of these relationships is **always true**?

$$2 NOCl(g) ↔ 2 NO(g) + Cl_2(g)$$
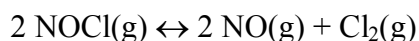
A) $p(NOCl) = p(NO)$
B) $p(NO) = 2 p(Cl_2)$
C) $K_p p(NO)^2 p(Cl_2) = p(NOCl)^2$
D) $p(NO)^2 p(Cl_2) = K_p p(NOCl)^2$
E) $p(NO) p(Cl_2) = p(NOCl)$

QUESTIONS 26-30 ARE WORTH 3 MARKS EACH.

26. Which ones of the following statements are **TRUE**?

i) Copper metal does not react with hydrochloric acid.
ii) Zinc metal reacts with hydrochloric acid and chlorine gas is evolved.
iii) An oxidation-reduction reaction takes place between zinc metal and copper(II) ions in aqueous solution.
iv) Copper metal reacts with nitric acid producing copper nitrate and hydrogen gas.
v) When aqueous sodium hydroxide is added to aqueous copper(II) sulfate and the solution is heated, copper(II) oxide is formed.

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

27. A **pure** sample of $NO_2(g)$ is introduced in an evacuated container at 1000 K. $NO_2(g)$ decomposes according to the reaction $2\ NO_2(g) \leftrightarrow 2\ NO(g) + O_2(g)$, with an equilibrium constant $K_p = 158$ at 1000 K. When equilibrium is reached, the partial pressure of $O_2(g) = 0.25$ atm. What are the equilibrium partial pressures (in atm) of $NO(g)$ and $NO_2(g)$ (in that order)?

A) 0.250, 2.0×10^{-2}
B) 0.50, 2.0×10^{-2}
C) 0.125, 4.0×10^{-4}
D) 0.50, 4.0×10^{-4}
E) 0.125, 2.0×10^{-2}

28. Which of the following statements are **TRUE** about SO_2Cl_2? (S is the central atom and is bonded to 2 O and 2 Cl atoms.)

(i) The molecule has a permanent dipole moment.
(ii) The molecule has a square pyramidal geometry about S.
(iii) There is one lone pair of electrons on S.
(iv) All the atoms have a formal charge of zero in the charge-minimized Lewis structure..
(v) The oxidation number of sulfur is +4.
(vi) The molecule belongs to the AX4 VESPR class.

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

29. For the molecular ions NO^+, NO_2^- and NO_3^-, what is the correct order of **decreasing bond length**?

A) $NO_3^- > NO_2^- > NO^+$
B) $NO_2^- > NO_3^- > NO^+$
C) $NO_3^- > NO^+ > NO_2^-$
D) $NO^+ > NO_2^- > NO_3^-$
E) $NO_2^- > NO^+ > NO_3^-$

30. Which of the following statements about periodic trends are **TRUE**?

(i) The correct sequence for decreasing ionic radius is: $Br^- > Rb^+ > Sr^{2+}$.
(ii) The ground-state electron configuration of bromine has no unpaired electrons.
(iii) The oxide of strontium is a basic oxide.
(iv) Rubidium is oxidized more easily than sodium.
(v) The electronegativity of chlorine is smaller than that of phosphorus.

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