Course: CHEMISTRY	**Number:** 205/4	**Section:** 03, 04 and 52	
Instructors: N. Schoonhoven, G. Dénès			
Examination: Final	**Date:** 14th April, 2011	**Time:** 19:00 - 22:00	**# of pages:** 15
Materials Allowed: A data sheet and periodic table are attached to this paper - *no other materials are allowed*. NO BOOKLET. ALL ANSWERS MUST BE ON THE QUESTIONNAIRE. **Calculators Allowed:** Yes (Cell phones or electronic dictionaries may NOT be used as calculators.)			
Special Instructions: This exam contains three sections. ***Please read the instructions before each section carefully.***			

LAST NAME: _____ FIRST NAME: _____

STUDENT NUMBER: _____ SIGNATURE: _____

PLEASE READ THIS PAGE WHILE YOU WAIT TO START.

- ***Check that you have 15 pages including this page. Please write your ID # on all pages.***
- ***A periodic table and "useful information" is provided; you CAN remove the periodic table.***
- ***Non-programmable calculators are allowed; cell phones & electronic dictionaries are not.***
- ***Read ALL questions carefully BEFORE starting the exam, and answer ALL questions.***
- ***Write all answers in the space provided. There is space on pages 13 and 14 for rough work.***
- ***YOU MUST SHOW YOUR WORK FOR ALL CALCULATIONS, except for multiple choice questions, or you will NOT get full marks.***

PLEASE RAISE YOUR HAND IF YOU NEED CLARIFICATION.

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Section I. The following 22 questions are multiple choice. They are worth 2 marks each. You may do rough work on your exam paper, but it will not be marked. You *must* mark your answers *using a soft pencil* on the machine readable answer form provided, *and* circle them on this exam paper. *Do not forget to mark your name and student number (your birth date is not required).*

1. What are the spectator ions in the reaction between aqueous hydrobromic acid and aqueous sodium hydroxide?

   a. Na^+ only
   b. H^+ and OH^-
   c. Na^+ and Br^-
   d. Br^- only
   e. H^+, Br^-, Na^+, and OH^-

2. Which of the following observations is/are examples of a chemical change:

   1. Sodium chloride melts at 801ºC.
   2. The density of water decreases when it changes from a liquid to a solid.
   3. The combustion of propane gas yields carbon dioxide and water.

   a. 1 only
   b. 2 only
   c. 3 only
   d. 1 and 2
   e. 2 and 3

3. Which three elements are likely to have similar chemical and physical properties?

   a. boron, silicon, and germanium
   b. sodium, magnesium, and aluminum
   c. barium, calcium, and strontium
   d. hydrogen, lithium and sodium
   e. carbon, nitrogen, and oxygen

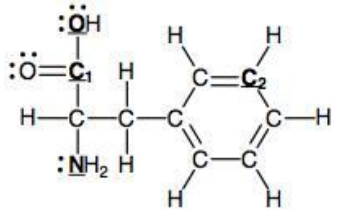
4. What is the net ionic equation for the reaction of aqueous sodium hydroxide and aqueous iron (II) chloride?

   a. $Na^+(aq) + OH^-(aq) \rightarrow NaOH(s)$
   b. $Na^+(aq) + Cl^-(aq) \rightarrow NaCl(s)$
   c. $Fe^{2+}(aq) + 2\ OH^-(aq) \rightarrow Fe(OH)_2(s)$
   d. $Fe^{2+}(aq) + OH^-(aq) \rightarrow FeOH^+(s)$
   e. $Fe^{2+}(aq) + 2\ Cl^-(aq) \rightarrow FeCl_2(s)$

5. An ionic compound has the formula MCl_2. The mass of 0.3011 mol of the compound is 62.69 grams. What is the identity of the metal?

   a. Ni
   b. Cu
   c. Sn
   d. Hg
   e. Ba

6. Which of the underlined atoms (C_1, C_2, N, and O) are sp^2 hybridized?



a. C_1 and C_2
b. C_1, N, and O
c. N and O
d. O and C_2
e. O only

7. Consider the oxidation – reduction reaction shown below and pick the correct statement:

$$2\ C_2H_6(g) \ + \ 7\ O_2(s) \rightarrow \ 4\ CO_2(g) \ + \ 6\ H_2O(g)$$

a. C is reduced, O is oxidized, C_2H_6 is the reducing agent, and O_2 is the oxidizing agent
b. C is oxidized, O is reduced, C_2H_6 is the oxidizing agent, and O_2 is the reducing agent
c. C is oxidized, O is reduced, C_2H_6 is the reducing agent, and O_2 is the oxidizing agent
d. C is reduced, O is oxidized, C_2H_6 is the oxidizing agent, and O_2 is the reducing agent
e. C is oxidized, O is reduced, CO_2 is the reducing agent, and H_2O is the oxidizing agent

8. What is the binding energy of an electron in a photosensitive metal (in kJ/mol) if the longest wavelength of light that can eject an electron from the metal is 238 nm?

a. 139 kJ/mol
b. 503 kJ/mol
c. 835 kJ/mol
d. 1.26×10^{12} kJ/mol
e. 8.35×10^{22} kJ/mol

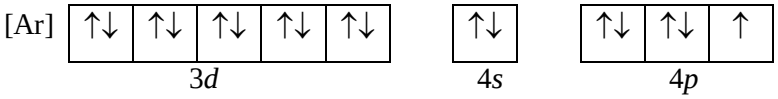
9. If the volume of an ideal gas is reduced to ½ of its original volume while the temperature and the number of moles remain constant, what changes will be observed?

a. The pressure of the gas will increase to twice its original value.
b. The pressure of the gas will remain unchanged.
c. The density of the gas will decrease to ½ its original value.
d. The pressure of the gas will decrease to ½ its original value.
e. The average velocity of the molecules will double.

10. Which of the following elements is the second ionization energy the greatest?

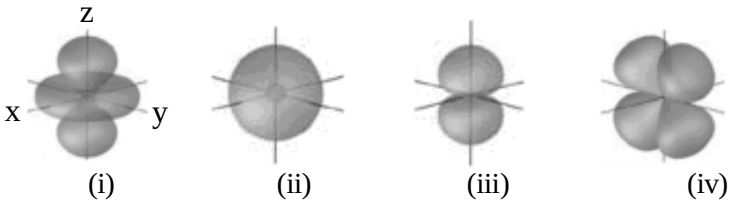
a. Mg
b. Al
c. Na
d. Sc
e. Ti

11. What is a possible set of quantum numbers for the unpaired electron in the orbital box diagram?



a. $n = 1, \ell = 1, m_\ell = -1, m_s = +½$
b. $n = 3, \ell = 2, m_\ell = -1, m_s = –½$
c. $n = 4, \ell = 2, m_\ell = -2, m_s = +½$
d. $n = 4, \ell = 0, m_\ell = 0, m_s = +½$
e. $n = 4, \ell = 1, m_\ell = -1, m_s = +½$

12. Which of the following diagrams represent d-orbitals.



a. i only
b. ii only
c. iii only
d. iv only
e. i and iv

13. Which of the following statements is INCORRECT?

a. It is not possible to know the exact location of an electron and its exact energy simultaneously.
b. The energies of an atom's electrons are quantized.
c. Quantum numbers define the energy states and the orbitals available to an electron.
d. The behaviour of an atom's electrons can be described in Quantum Mechanics (the most modern theory) by circular orbits around a nucleus.
e. Electrons have both wave and particle properties.

14. What is the ground state electron configuration for Co^{3+}?

a. [Ar]
b. [Ar]$3d^{10}4s^2$
c. [Ar]$3d^4 4s^2$
d. [Ar]$3d^{10}$
e. [Ar]$3d^6$

15. Place the following ions in order from smallest to largest ionic radii: Se^{2-}, Sr^{2+}, Y^{3+}, and Br^-.

a. $Se^{2-} < Sr^{2+} < Y^{3+} < Br^-$
b. $Se^{2-} < Br^- < Sr^{2+} < Y^{3+}$
c. $Br^- < Se^{2-} < Y^{3+} < Sr^{2+}$
d. $Y^{3+} < Sr^{2+} < Br^- < Se^{2-}$
e. $Sr^{2+} < Y^{3+} < Se^{2-} < Br^-$

16. Which of the following atoms is paramagnetic?

    a. Zn
    b. Sr
    c. Kr
    d. Te
    e. Ca

17. An aqueous nitric acid solution has a pH of 1.15. What mass of HNO_3 is present in 2.0 L of this solution?

    a. 0.071 g
    b. 0.14 g
    c. 2.2 g
    d. 4.5 g
    e. 8.9 g

18. How many sigma (σ) bonds and pi (π) bonds are in ethene, C_2H_4?

    a. four σ, one π
    b. four σ, two π
    c. five σ, one π
    d. five σ, two π
    e. six σ, zero π

19. An example of a weak base in water is:

    a. KOH
    b. H_2CO_3
    c. LiCl
    d. NH_3
    e. HNO_3

20. If 8.19 g KIO_3 is dissolved in enough water to make 500.0 mL of solution, what is the molarity of the potassium iodate solution?

    a. 1.64×10^{-2} M
    b. 1.91×10^{-2} M
    c. 7.65×10^{-2} M
    d. 3.51 M
    e. 16.4 M

21. Which of the following compounds are soluble in water: K_2CO_3, $CaCO_3$, $NiCO_3$ and $Fe_2(CO_3)_3$.

    a. K_2CO_3
    b. K_2CO_3 and $CaCO_3$,
    c. $CaCO_3$ and $NiCO_3$
    d. $NiCO_3$ and $Fe_2(CO_3)_3$
    e. $CaCO_3$, $NiCO_3$ and $Fe_2(CO_3)_3$

22. A nail is coated with a 0.053 cm thick layer of zinc. The surface area of the nail is 8.59 cm^2. The density of zinc is 7.13 g/cm^3. How many zinc atoms are used in the coating?

    a. 5.9×10^{20} atoms
    b. 3.0×10^{22} atoms
    c. 3.8×10^{22} atoms
    d. 2.0×10^{24} atoms
    e. 1.3×10^{26} atoms

Section II. The following 7 questions require short answers and should be answered in the space provided on this paper. Do not forget to provide a brief explanation where it is requested.

23. (4 marks) Provide the missing name or formula for each substance below:

$Ca(CH_3CO_2)_2$ _____

P_4S_3 _____

_____ silicon tetrachloride

_____ copper (II) bromide

24. (4 marks) Complete the following sentences:

(a) _____ rule states that the most stable arrangement of electrons is that which contains the maximum number of unpaired electrons, all with the same spin direction.

(b) The numbers preceding the formulas in chemical equations are referred to as the _____ coefficients.

(c) The rate of effusion of a gas is inversely proportional to the square root of its _____.

(d) The (group name) _____ are nonmetal elements, and all exist as diatomic molecules.

25. (a) (2 marks) Some plant fertilizers are $(NH_4)_2SO_4$, $Ca_3(PO_4)_2$, K_2O, P_2O_5, and KCl. Which of these compounds contain both covalent and ionic bonding?

(b) (2 marks) Hydrogen peroxide is thermodynamically very unstable with respect to disproportionation (*i.e.*, an oxidation-reduction reaction in which the same element is both oxidized and reduced.):

$$H_2O_2(\mathbf{l}) \rightarrow H_2O(\mathbf{l}) + \tfrac{1}{2}\, O_2(g) \qquad \Delta H = -101 \text{ kJ/mol}$$

Given that the O_2 bond energy is 495 kJ/mol, and the OH bond energy is 467 kJ/mol, estimate the bond energy per mol of the O-O single bond in H_2O_2.

26. (4 marks each part) For each of the molecules depicted below, supply the requested information.
(a) CO_3^{2-}

Draw the Lewis Structure and all possible equivalent resonance structures (show all non-zero Formal charges and all lone pairs electrons)				
Basic (electron pair) Geometry and hybridization	Molecular Geometry	Is the molecular Polar or Non-Polar?	Average bond order of equivalent bonds	Average formal charge on equivalent atoms

(b) ClF_5

Draw the Lewis Structure (show all non-zero Formal charges and all lone pairs electrons)				
Basic (electron pair) Geometry and hybridization	Molecular Geometry	Is the molecular Polar or Non-Polar?	Approximate F-Cl-F Bond Angle	Draw dipole moment orientation of the vector along the Cl-F bond

(c) IF_4^-

Draw the Lewis Structure (show all non-zero Formal charges and all lone pairs electrons)				
Basic (electron pair) Geometry and hybridization	Molecular Geometry	Is the molecular Polar or Non-Polar?	Approximate F-I-F Bond Angle	Draw dipole moment orientation of the vector along the I-F bond

27. (7 marks) Consider the molecule HOCN (exists as HO-CN) and answer the following questions using the expected Lewis structure according to Pauling's electroneutrality principle:

(a) (1 mark) What is the molecular geometr(y/ies) on the carbon and oxygen atoms?

(b) (1 mark) What is the hybridization(s) of the carbon and oxygen atoms?

(c) (1 mark) How many σ and π bonds exist in this molecule?

(d) (1 mark) The H-O bond is formed by the overlap of which hybrid orbitals?

(e) (1 mark) Is the entire molecule polar?

(f) (2 marks) Compare the H-O-C bond angle observed in HOCN to that observed for another molecule with similar hybridization but different molecular geometry (for example to H-C-H in methane (CH_4)). Explain this difference.

Section III. Answer the following 3 questions with *complete* written answers on this exam paper. If you need more space, use the blank space provided on pages 13 and 14. *Be sure to provide adequate explanations or details to justify your answers*

28. (5 marks) Air bags are activated when a severe impact causes a steel ball to compress a spring and electrically ignite a detonator cap. This causes sodium azide (NaN_3) to decompose explosively according to the following reaction:

$$2\ NaN_3\ (s) \rightarrow 2\ Na\ (s) + 3\ N_2\ (g)$$

What mass of NaN_3 (*s*) must be reacted to inflate an air bag to 70.0 L at STP (Standard Temperature and Pressure), 0ºC and 1.00 atm?

29. (10 marks) DTT, an insecticide harmful to fish, birds, and humans, is produced by the following reaction:

$$\underset{\text{chlorobenzene}}{2\ C_6H_5Cl} + \underset{\text{chloral}}{C_2HOCl_3} \rightarrow \underset{\text{DTT}}{C_{14}H_9Cl_5} + H_2O$$

In a government lab, 1142 g of chlorobenzene is reacted with 485 g of chloral.

(a) (6 marks) What mass of DTT is formed?

(c) (2 marks) What mass of the excess reactant is left over?

(d) (2 marks) If the actual yield of DTT is 200.0 g, what is the percentage yield?

30. (10 marks) For the following oxidation-reduction reaction:

$$MnO_4^-(aq) + Br^-(aq) + \rightarrow MnO_2(s) + BrO_3^-(aq)$$

(a) (2 marks) Give the oxidation number of one atom of all elements in each compound of reactants and products.

i. $MnO_4^-(aq) + Br^-(aq) + \rightarrow MnO_2(s) + BrO_3^-(aq)$

(b) (2 marks) Identify the elements that are oxidized and the elements that are reduced, and identify which compounds they belong to.

(c) (2 marks) Identify the oxidizing agents and the reducing agents.

(d) (4 marks) Show, in detail, ***how*** the previous equation can be balanced using the systematic "half-reaction" method. The reaction takes place in ***basic*** solution.

Rough Work

POTENTIALLY USEFUL INFORMATION

Atomic mass unit	1 amu = 1.66054×10^{-27} kg
Avogadro's number	N = 6.022×10^{23} mol^{-1}
Definition of *Joule*	1 J = 1 $kg\cdot m^2\cdot s^{-2}$
Definition of *Pascal*	1 Pa = 1 $kg\cdot m^{-1}\cdot s^{-2}$
Gas constant	R = 0.08206 $L\cdot atm\cdot mol^{-1}K^{-1}$ = 8.314 $J\cdot mol^{-1}K^{-1}$
Planck's constant	h = 6.626×10^{-34} J·s
Pressure units	760 mm Hg = 760 torr = 1 atm = 101.325 kPa = 1.01325 bar
Rydberg constant	R = 1.0974×10^{7} m^{-1}
Speed of light	c = 2.9979×10^{8} $m\cdot s^{-1}$

Rough Work

Periodic Table of the Elements

1																	18
1 **H** 1.008	2											13	14	15	16	17	2 **He** 4.00
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3	4	5	6	7	8	9	10	11	12	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (97.91)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	**La-Lu**	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** 208.98	85 **At** 209.99	86 **Rn** 222.02
87 **Fr** 223	88 **Ra** 226.03	**Ac-Lr**	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)									

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.35	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
89 **Ac** 227.03	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (245)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)