

Course: CHEMISTRY	Number: 205/4	Section: 03, 04 and 52	
Instructors: P.H. Bird, G. Dénès			
Examination: Final	Date: 28 th April, 2010	Time: 19:00 - 22:00	# of pages: 15
Materials Allowed: A data sheet and periodic table are attached to this paper - <i>no other materials are allowed.</i>			
Calculators Allowed: Yes (Cell phones or electronic dictionaries may NOT be used as calculators.)			
Special Instructions: This exam contains three sections. <i>Please read the instructions before each section carefully.</i>			

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.

Please leave blank

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).

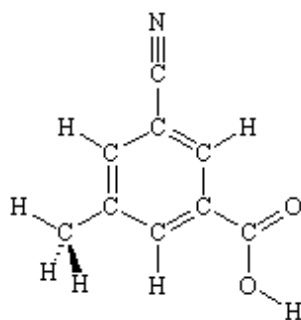
1. A lump of magnesium metal weighing 11.81 g is dropped into a graduated cylinder containing 21.3 mL of water. The level of water in the cylinder rises to 28.1 mL. What is the density of magnesium?
 - a. 0.58 g cm^{-3}
 - b. 0.58 cm g^3
 - c. 1.7 g cm^{-3}
 - d. 1.74 g cm^{-3}
 - e. 1.7 cm g^{-3}
2. Which *one* of the following statements is *correct*:
 - a. Pure substances may be separated by filtration or distillation into at least two components.
 - b. A heterogeneous mixture is also known as a solution.
 - c. A heterogeneous mixture is composed of two or more substances in the same phase.
 - d. The composition is uniform throughout a homogeneous mixture.
 - e. A combination of two or more liquids always results in a homogeneous mixture.
3. Based on their position in the periodic table, which of these pairs of elements would you expect *both* to be malleable and good electrical conductors?
 - a. phosphorus and rubidium
 - b. copper and lead
 - c. iodine and selenium
 - d. calcium and boron
 - e. sulphur and germanium
4. Consider the following description of the element, sulphur:
 1. Sulphur is a yellow non-metallic element.
 2. It burns in oxygen to form a choking gas, SO_2 .
 3. SO_2 reacts with water to produce acid rain.
 4. Sulphur is produced commercially by injecting steam into deposits of it underground to melt it.
 5. It is then carried by the steam to the surface, where it separates from the water after cooling.

Which of the above statements refer to chemical reactions, and which to physical properties or changes?

- | Chemical | Physical |
|------------------------------|-----------------------|
| a. Statements 2, 3, 4, and 5 | Statements 1 only |
| b. Statements 2 and 3 | Statements 1, 4 and 5 |
| c. Statements 2, 3 and 4 | Statements 1 and 5 |
| d. Statements 2, 3 and 5 | Statements 1 and 4 |
| e. Statements 1, 4 and 5 | Statements 2 and 3 |

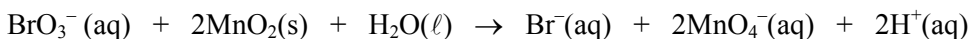
5. Blue crystals of copper(II) sulphate have the formula: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. What is the percentage by mass of water in this substance?
- 63.90%
 - 56.42%
 - 1.772%
 - 2.772%
 - 36.10%

6. How many sigma (σ) bonds and pi (π) bonds are in the molecule below?



- thirteen σ and four π
- thirteen σ and six π
- nineteen σ and one π
- nineteen σ and six π
- six σ and nineteen π

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



- Bromine is oxidized and hydrogen is reduced.
 - Bromine is reduced and hydrogen is oxidized.
 - Bromine is reduced and manganese is oxidized
 - The reaction is an acid – base reaction, NOT an oxidation – reduction reaction!
 - Manganese is oxidized and hydrogen is reduced.
8. A red laser pointer emits light at a wavelength of 652 nm. If the laser emits 9.0×10^{-4} J of energy per second in the form of visible radiation, how many photons per second are emitted?
- 3.4×10^{-6} photons/sec
 - 4.1×10^{11} photons/sec
 - 8.9×10^{14} photons/sec
 - 2.9×10^{15} photons/sec
 - 5.1×10^{17} photons/sec
9. The correct order of types of electromagnetic radiation from shortest to longest wavelength is:
- radio < microwave < infrared < visible < ultraviolet < X-ray < gamma ray
 - gamma ray < radio < infrared < ultraviolet < visible < microwave < X-ray
 - visible < radio < infrared < ultraviolet < microwave < X-ray < gamma ray
 - gamma ray < X-ray < ultraviolet < visible < infrared < microwave < radio
 - X-ray < ultraviolet < visible < infrared < microwave < radio < gamma ray

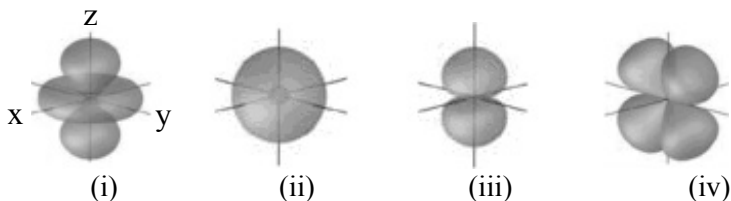
10. Which of the following cations has 4 unpaired electrons?

- Ni^{2+}
- Fe^{2+}
- Pb^{2+}
- Mn^{2+}
- Cu^{2+}

11. Which combination of the quantum numbers n , ℓ , m_ℓ , and m_s can an electron in a 4d orbital take?

	n	ℓ	m_ℓ	m_s
a.	4	3, 2, 1 or 0	3, 2, 1, 0, -1, -2 or -3	$+\frac{1}{2}$ or $-\frac{1}{2}$
b.	4	2	2, 1, 0, -1 or -2	$+\frac{1}{2}$ or $-\frac{1}{2}$
c.	$>$ or $= 0$	2	0	$+\frac{1}{2}$ or $-\frac{1}{2}$
d.	$>$ or $= 4$	2	2, 1, 0, -1 or -2	$+\frac{1}{2}$ or $-\frac{1}{2}$
e.	$<$ or $= 4$	2, 1 or 0	2, 1, 0, -1 or -2	$+\frac{1}{2}$ or $-\frac{1}{2}$

12. The following diagrams represent atomic orbitals. (The axes are labeled as shown on orbital (i).)



Which of the following statements is INCORRECT:

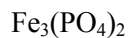
- Orbital (i) has a “donut” (toroidal) shaped region of electron density .
 - Diagram (ii) represents the 2s orbital.
 - Orbital (iii) represents the $2p_x$ orbital.
 - Orbital (iv) has nodes in the xz and xy planes.
 - Diagrams (i) and (iv) represent 3d orbitals.
13. In the Bohr model of the hydrogen atom, the electron was assumed to travel in circular (or elliptical) orbits. Which of the following statements is INCORRECT?
- Bohr theory cannot handle systems with more than one electron.
 - Bohr theory treats the electron as a particle.
 - Bohr theory predicts the wavelengths of the lines in the emission spectrum of hydrogen.
 - Bohr theory successfully explains the existence of molecular hydrogen, H_2 .
 - Bohr theory states that only certain orbital radii are possible.
14. Which $2+$ ion has the ground state electronic configuration $[\text{Xe}] 5d^{10} 4f^{14} 6s^2$?
- Barium
 - Mercury(I)
 - Mercury(II)
 - Lead(II) – Plumbous
 - Lead(IV) – Plumbic

15. Place the following atoms in order from smallest to largest (first) ionization energy: Al, Si, P, S and Cl.
- Al < Si < P < S < Cl
 - Cl < S < P < Si < Al
 - Al < Si < P < Cl < S
 - Al < P < Si < S < Cl
 - Al < Si < S < P < Cl
16. Place the ion pairs NaF, KF and MgO in order of increasing coulombic attraction.
- NaF < KF < MgO
 - MgO < KF < NaF
 - KF < NaF < MgO
 - KF = NaF < MgO
 - MgO < KF = NaF
17. An aqueous sodium hydroxide solution has a pH of 12.43. What concentration of H^+ is present in 250. mL of this solution?
- $1.6 \times 10^{-12} M$
 - $2.5 \times 10^{12} M$
 - $1.0 \times 10^{-13} M$
 - $9.3 \times 10^{-14} M$
 - $3.7 \times 10^{-13} M$
18. An example of a non-electrolyte in water is:
- NH_4NO_3
 - HCl
 - NaOH
 - K_2SO_4
 - Br_2
19. An example of a weak acid in water is:
- HNO_3
 - HBr
 - NH_3
 - H_2SO_4
 - CH_3COOH
20. Which of the following statements concerning real gases is or are CORRECT?
- Real gases are always liquids or solids at temperatures below 273.15 K.
 - The pressure of a real gas is higher than predicted by the ideal gas law.
 - The molecules in a real gas are attracted to each other.
- 1 only
 - 2 only
 - 3 only
 - 2 and 3
 - 1, 2 and 3

21. Which of the following statements is or are CORRECT?
1. All ionic compounds that are soluble in water are electrolytes.
 2. All ionic compounds dissolve in water.
 3. Molecular compounds are never soluble in water.
- a. 1 only
 - b. 2 only
 - c. 3 only
 - d. 2 and 3
 - e. 1 and 3
22. How long will it take 10.0 mL of H_2 gas to effuse through a porous barrier if it has been observed that 166 minutes are required for 10.0 mL of CH_4 gas to effuse through the same barrier?
- a. 2.62 min
 - b. 20.9 min
 - c. 58.9 min
 - d. 468 min
 - e. 1.05×10^4 min

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:



_____ tetraphosphorus decoxide

_____ magnesium nitrate

24. (3 marks) The diagram to the right represents the gas-phase reaction of A_2 (darker spheres) with B_2 (lighter spheres). Write a balanced equation for the reaction, and identify the limiting reactant (reagent). Explain briefly.



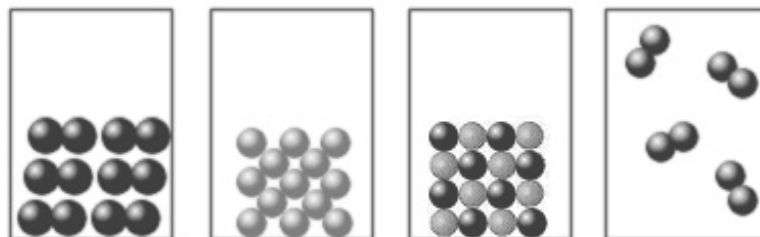
Balanced Equation:

Limiting reactant:

25. (2 marks) The pictures to the right represent samples of each of the following substances at 25°C :

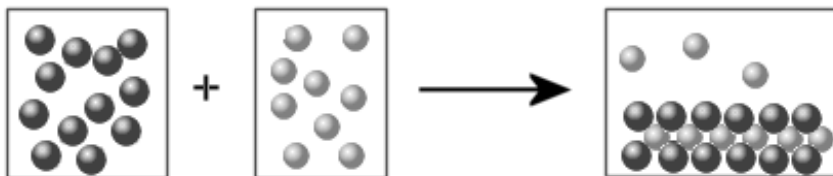
sodium, chlorine, iodine, sodium chloride

Label each picture with the name and state of the substance it represents:



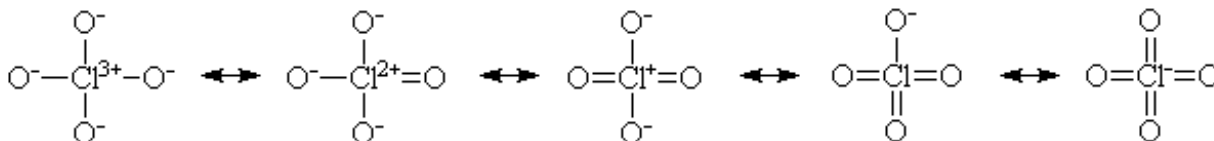
26. (4 marks) Assume that an aqueous solution containing cations (dark spheres) is allowed to mix with a solution containing anions (light spheres), and that the following result is obtained (diagram). The water molecules and spectator ions are not shown.

Which combination(s) of cation and anion, chosen from the following lists, are compatible with the observed results? Explain briefly.



Cations: Na^+ , Ca^{2+} , Ag^+ , Ni^{2+}
 Anions: Cl^- , CO_3^{2-} , CrO_4^{2-} , NO_3^-

27. (2 marks each part) The diagrams below show a series of *non-equivalent* resonance (canonical) structures for the perchlorate ion, ClO_4^- . Supply the requested information.



a. On each diagram, *clearly* mark in the lone pairs on the oxygen atoms as appropriate.

b. In each space below, say how many *equivalent* resonance structures there are for each structure directly above the space, *including the one shown*.

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c. In each space below, specify the average Cl – O bond order for the set of equivalent structures in part a.

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d. In each space below specify the average charge on oxygen for the set of equivalent structures in part a.

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28. (2 marks each part) For each of the molecules depicted below, supply the requested information.

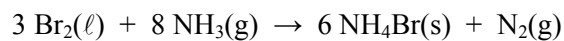
a. On each diagram, mark the lone pairs on the central atom. Assume each species is neutral (not an ion).				
b. In each space below, specify the basic “electron-pair” geometry of the molecule above it.				
c. In each space below, specify the molecular geometry of the molecule above it.				
d. In each space below, specify the appropriate hybridization of the atomic orbitals of the central atom.				
e. In each space below, indicate whether the molecule above it is polar or non-polar.				

29. (2 marks each part) Consider the molecule SF₄ in question 28:

- What are the formal charges on sulphur and fluorine?
- What are the oxidation numbers of sulphur and fluorine?
- How are the S – F bonds polarized: S(δ^+) – F(δ^-) or S(δ^-) – F(δ^+)? (Explain in one sentence.)
- Is the entire molecule polar? (Explain in one sentence.)
- The experimentally observed molecular geometry of SF₄ is shown in the diagram, but there is another possibility consistent with the Lewis structure and basic geometry which is not observed. What is it, and why is it not observed?

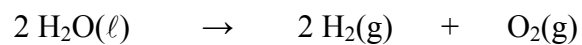
Section III. Answer the following 3 questions with *complete* written answers on this exam paper. If you need more space, use the blank space provided on pages 13 and 14. Be sure to provide adequate explanations or details to justify your answers

30. (a) (5 marks) If 5.00 g Br₂ and 3.00 g NH₃ react according to the equation below, what is the maximum mass of ammonium bromide that could be produced?

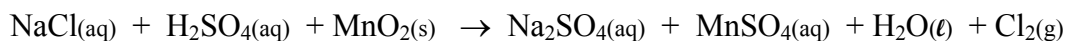


- (b) (1 mark) If 4.71 g of ammonium bromide is isolated from the reaction, what is the percentage yield?

31. (5 marks) Water can be decomposed by electrolysis into hydrogen gas and oxygen gas. What mass of water must decompose to fill a 5.00 L pressure resistant cylinder to a total pressure of 2.50 atm at 298 K with a mixture hydrogen and oxygen? (By the way, this could be a pretty stupid thing to do – suggest why.)



32. Chlorine gas was first prepared in 1774 by C. W. Scheele by the reaction of sodium chloride with manganese(IV) oxide in aqueous sulfuric acid, according to the reaction described by the following unbalanced equation:



- (1 mark) Write the unbalanced *complete ionic* equation.
- (1 mark) Write the unbalanced *net ionic* equation
- (1 mark) Give the oxidation number of one atom of all elements in each compound of reactants and products in the *net ionic* equation.
- (1 mark) Identify the elements that are oxidized and the elements that are reduced.
- (1 mark) Identify the oxidizing agents and the reducing agents.
- (4 marks) Balance the *net ionic* equation using the half reactions method.

POTENTIALLY USEFUL INFORMATION

Atomic mass unit	$1 \text{ amu} = 1.66054 \times 10^{-27} \text{ kg}$
Avogadro's number	$N = 6.022 \times 10^{23} \text{ mol}^{-1}$
Definition of <i>Joule</i>	$1 \text{ J} = 1 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$
Definition of <i>Pascal</i>	$1 \text{ Pa} = 1 \text{ kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2}$
Gas constant	$R = 0.08206 \text{ L} \cdot \text{atm} \cdot \text{mol}^{-1} \text{K}^{-1} = 8.314 \text{ J} \cdot \text{mol}^{-1} \text{K}^{-1}$
Planck's constant	$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$
Pressure units	$760 \text{ mm Hg} = 760 \text{ torr} = 1 \text{ atm} = 101.325 \text{ kPa} = 1.01325 \text{ bar}$
Rydberg constant	$R = 1.0974 \times 10^7 \text{ m}^{-1}$
Speed of light	$c = 2.9979 \times 10^8 \text{ m} \cdot \text{s}^{-1}$
Temperature	$0 \text{ K} = -273.15 \text{ }^\circ\text{C}$

Periodic Table of the Elements

18

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008	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	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)