

AP Chemistry
1st Semester Exam
December 19, 2013

Student's Name Key
Teacher's Name _____
Period Taught _____

AP Chemistry Exam

2013

Section I: Multiple Choice - 40 Questions (40 points total, 1 point each)

Section II: Free-response - 3 Questions (30 points total, 10 points each)

*A Pencil, eraser, scantron, exam paper, and scratch paper
A Graphing or Scientific Calculator is Permitted*

Complete the multiple choice questions in section I and place the answers on the scantron provided. Answers in the test booklet or on scratch paper will not be graded. For section II questions 1-3, complete the free-response questions on the exam paper provided.

Be sure to put your name on the scantron, the exam paper, and the test booklet. When finished, place your scantron in a pile, the exam paper in a pile, and your test in separate piles. If you use multiple sheets of exam paper, they should be stapled together. Good luck.

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CHEMISTRY
Section I

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmosphere, and solutions are aqueous unless otherwise specified.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

T	= temperature	m	= molal
P	= pressure	L, mL	= liter(s), milliliter(s)
V	= volume	g	= gram(s)
S	= entropy	nm	= nanometer(s)
H	= enthalpy	atm	= atmosphere(s)
G	= free energy	J, kJ	= joule(s), kilojoule(s)
R	= molar gas constant	V	= volt(s)
n	= number of moles	mol	= mole(s)
M	= molar		

Part A

Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best fits each statement and then blacken the corresponding space on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1–4 refer to the following types of energy.

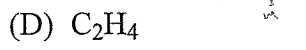
- (A) Activation energy
- (B) Free energy
- (C) Ionization energy
- (D) Kinetic energy
- (E) Lattice energy

- C 1. The energy required to convert a ground-state atom in the gas phase to a gaseous positive ion
- E 2. The energy change that occurs in the conversion of an ionic solid to widely separated gaseous ions
- B 3. The energy in a chemical or physical change that is available to do useful work
- A 4. The energy required to form the transition state in a chemical reaction

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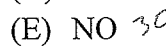
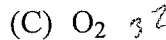
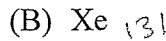
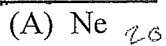
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Questions 5–7 refer to the following molecules.



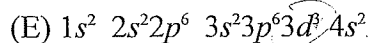
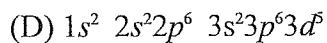
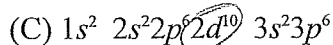
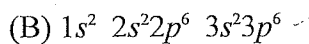
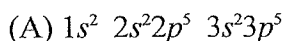
- D 5. The molecule with only one double bond
- B 6. The molecule with the largest dipole moment
- E 7. The molecule that has trigonal pyramidal geometry

Questions 8–10 refer to the following gases at 0°C and 1 atm.



- A 8. Has the greatest rate of effusion through a pinhole *smallest*
- B 9. Has the greatest density *28*
- D 10. Has an average atomic or molecular speed closest to that of N₂ molecules at 0°C and 1 atm

Questions 11–14



- C 11. An impossible electronic configuration
- B 12. The ground-state configuration of a negative ion of a halogen *Full*
- B 13. The ground-state configuration of a common ion of an alkaline earth element
- E 14. The ground-state configuration for the atoms of a transition element

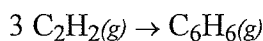
Part B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

15. Approximately what mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (250 g mol^{-1}) is required to prepare 250 mL of 0.10 M copper(II) sulfate solution?

- (A) 4.0 g
(B) 6.2 g
(C) 34 g
(D) 85 g
(E) 140 g

$$0.250 \text{ L} \left(\frac{0.10 \text{ mol}}{\text{L}} \right) \left(\frac{250 \text{ g}}{\text{mol}} \right) = 6.25 \text{ g}$$



16. What is the standard enthalpy change, ΔH° , for the reaction represented above? (ΔH_f° of $\text{C}_2\text{H}_2(\text{g})$ is 230 kJ mol^{-1} ; ΔH_f° of $\text{C}_6\text{H}_6(\text{g})$ is 83 kJ mol^{-1} .)

- (A) -607 kJ
(B) -147 kJ
(C) -19 kJ
(D) $+19 \text{ kJ}$
(E) $+773 \text{ kJ}$

$$83 - 3(230) = -607 \text{ kJ}$$

17. Of the following molecules, which has the largest dipole moment?

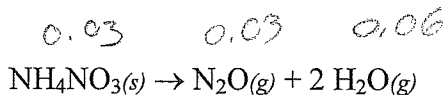
- (A) CO
(B) CO_2
(C) O_2
(D) HF
(E) F_2

18. In the periodic table, as the atomic number increases from 11 to 17, what happens to the atomic radius?

- (A) It remains constant.
(B) It increases only.
(C) It increases, then decreases.
(D) It decreases only.
(E) It decreases, then increases.

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19. A 0.03 mol sample of $\text{NH}_4\text{NO}_3(s)$ is placed in a 1 L evacuated flask, which is then sealed and heated. The $\text{NH}_4\text{NO}_3(s)$ decomposes completely according to the balanced equation above. The total pressure in the flask measured at 400 K is closest to which of the following? (The value of the gas constant, R , is $0.082 \text{ L atm mol}^{-1} \text{ K}^{-1}$.)

- (A) 3 atm
 (B) 1 atm
 (C) 0.5 atm
 (D) 0.1 atm
 (E) 0.03 atm

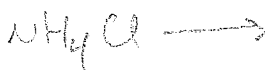
$PV = nRT$

$P = \frac{nRT}{V} = \frac{(0.09 \text{ mol})(0.0821 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K})(400 \text{ K})}{1 \text{ L}}$

20. When solid ammonium chloride, $\text{NH}_4\text{Cl}(s)$, is added to water at 25°C it dissolves and the temperature of the solution decreases. Which of the following is true for the values of ΔH and ΔS for the dissolving process?

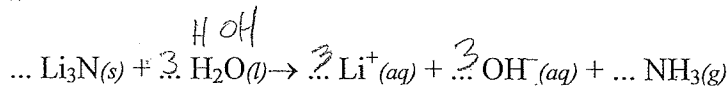
- | | | |
|--------------|---------------|---------------|
| | ΔH | ΔS |
| (A) Positive | Positive | Positive |
| (B) Positive | Negative | Negative |
| (C) Positive | Equal to zero | Equal to zero |
| (D) Negative | Positive | Positive |
| (E) Negative | Negative | Negative |

$\Delta G = \Delta H - T\Delta S$



21. In which of the following processes are covalent bonds broken?

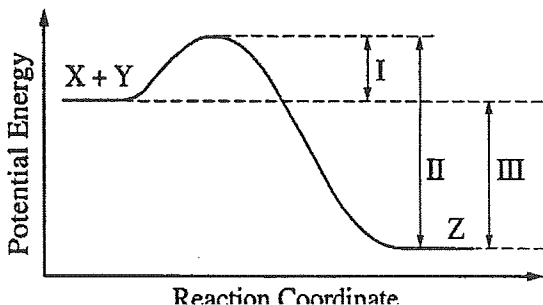
- (A) $\text{I}_2(s) \rightarrow \text{I}_2(g)$
 (B) $\text{CO}_2(s) \rightarrow \text{CO}_2(g)$
 (C) $\text{NaCl}(s) \rightarrow \text{NaCl}(l)$
 (D) $\text{C}(\text{diamond}) \rightarrow \text{C}(g)$
 (E) $\text{Fe}(s) \rightarrow \text{Fe}(l)$



22. When the equation above is balanced and all coefficients reduced to lowest whole-number terms, the coefficient for $\text{OH}^-(aq)$ is

- (A) 1
 (B) 2
 (C) 3
 (D) 4

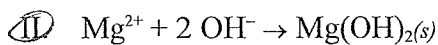
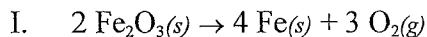
(E) 6



23. The energy diagram for the reaction $X + Y \rightarrow Z$ is shown above. The addition of a catalyst to this reaction would cause a change in which of the indicated energy differences?

- (A) I only
- (B) II only
- (C) III only
- (D) I and II only
- (E) I, II, and III

24. For which of the following processes would ΔS° have a negative value?



↓ Entropy

- (A) I only
- (B) I and II only
- (C) I and III only
- (D) II and III only
- (E) I, II, and III

25. When hafnium metal is heated in an atmosphere of chlorine gas, the product of the reaction is found to contain 62.2 percent Hf by mass and 37.4 percent Cl by mass. What is the empirical formula for this compound?

- (A) HfCl
- (B) HfCl₂
- (C) HfCl₃
- (D) HfCl₄
- (E) Hf₂Cl₃

$$37.4 \text{ g} \left(\frac{1 \text{ mol}}{35.45 \text{ g Cl}} \right) = 1.055 \text{ mol} = 3$$

$$62.2 \text{ g} \left(\frac{1 \text{ mol}}{178.49 \text{ Hf}} \right) = 0.348 \text{ mol} = 1$$

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26. A sample of an ideal gas is cooled from 50.0°C to 25.0°C in a sealed container of constant volume. Which of the following values for the gas will decrease?

- ~~I.~~ The average molecular mass of the gas
- II. The average distance between the molecules
- III. The average speed of the molecules

- (A) I only
- (B) II only
- (C) III only
- (D) I and III
- (E) II and III

27. Which of the following has the lowest conductivity?

of ions

- (A) 0.1 M CuSO₄ 2
- (B) 0.1 M KOH 2
- (C) 0.1 M BaCl₂ 3
- (D) 0.1 M HF 1
- (E) 0.1 M HNO₃ 2

28. If 200. mL of 0.60 M MgCl₂(aq) is added to 400. mL of distilled water, what is the concentration of Mg²⁺(aq) in the resulting solution? (Assume volumes are additive.)

- (A) 0.20 M
- (B) 0.30 M
- (C) 0.40 M
- (D) 0.60 M
- (E) 1.2 M

$MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$

$M_1V_1 = M_2V_2$

$\frac{(200\text{ mL})(0.600\text{ M})}{(600\text{ mL})} =$

29. When solid NH₄SCN is mixed with solid Ba(OH)₂ in a closed container, the temperature drops and a gas is produced. Which of the following indicates the correct signs for ΔG, ΔH, and ΔS for the process?

- | | <u>ΔG</u> | <u>ΔH</u> | <u>ΔS</u> |
|-----|-----------|-----------|-----------|
| (A) | — | — | — |
| (B) | + | — | — |
| (C) | — | + | + |
| (D) | — | + | — |
| (E) | + | — | + |

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33. Types of hybridization exhibited by the C atoms in propene, CH_3CHCH_2 , include which of the following?

I. sp

II. sp^2

III. sp^3

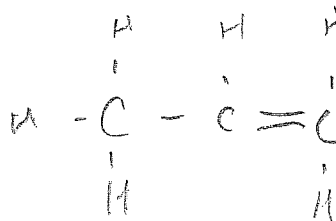
(A) I only

(B) III only

(C) I and II only

(D) II and III only

(E) I, II, and III



Ionization Energies for element X (kJ mol^{-1})				
First	Second	Third	Fourth	Fifth
580	1,815	2,740	11,600	14,800

34. The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

(A) Na

(B) Mg

(C) Al

(D) Si

(E) P

35. Which of the following techniques is most appropriate for the recovery of solid KNO_3 from an aqueous solution of KNO_3 ?

(A) Paper chromatography

(B) Filtration

(C) Titration

(D) Electrolysis

(E) Evaporation to dryness

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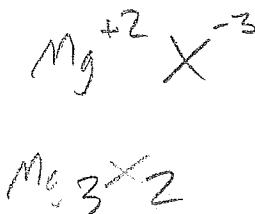
36. Which of the following represents a pair of isotopes?

		Atomic Number	Mass Number
(A)	I.	6	14
	II.	7	14
(B)	I.	6	7
	II.	14	14
(C)	I.	6	14
	II.	14	28
(D)	I.	7	13
	II.	7	14
(E)	I.	8	10
	II.	16	20

37. $1s^2 2s^2 2p^6 3s^2 3p^3$

Atoms of an element, X, have the electronic configuration shown above. The compound most likely formed with magnesium, Mg, is

- (A) MgX
(B) Mg₂X
(C) MgX₂
(D) MgX₃
(E) Mg₃X₂



38. A sample of 3.30 grams of an ideal gas at 150.0°C and 1.25 atmospheres pressure has a volume of 2.00 liters. What is the molar mass of the gas? The gas constant, R, is 0.0821 (L·atm)/(mol·K).

- (A) 0.0218 gram/mole
(B) 16.2 grams/mole
(C) 37.0 grams/mole
(D) 45.8 grams/mole
(E) 71.6 grams/mole

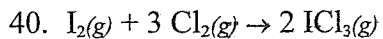
$PV = nRT$ $n = \frac{\text{mass}}{MM}$
 $PV = \frac{\text{mass}RT}{MM}$ $MM = \frac{\text{mass}RT}{PV}$

39. In which of the following groups are the three species isoelectronic; i.e., have the same number of electrons?

- (A) S²⁻, K⁺, Ca²⁺
(B) Sc, Ti, V²⁺
(C) O²⁻, S²⁻, Cl⁻
(D) Mg²⁺, Ca²⁺, Sr²⁺
(E) Cs, Ba²⁺, La³⁺

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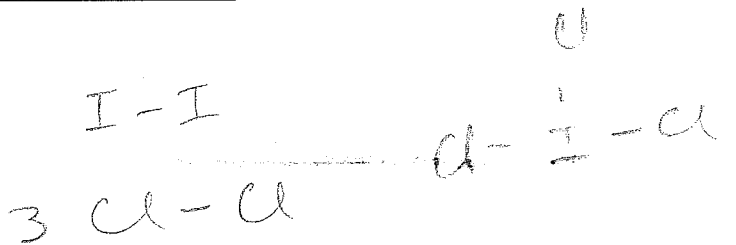
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According to the data in the table below, what is the value of ΔH° for the reaction represented above?

Bond	Average Bond Energy (kJ/mole)
I-I	149
Cl-Cl	239
I-Cl	208

- (A) -860 kJ
- (B) -382 kJ
- (C) +180 kJ
- (D) +450 kJ
- (E) +1,248 kJ



$$149 + 3(239) - 6(208) =$$

CHEMISTRY
Section II

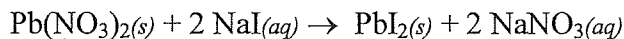
CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write all your answers to the questions on the exam paper. Do NOT write your answers in this test for questions 1 and 2.

Answer Questions 1, 2, and 3. The questions in section II are worth 10 points each.

Remember to answer on EXAM paper.

1. A 0.150 g sample of solid lead(II) nitrate is added to 125 mL of 0.100 M sodium iodide solution. Assume no change in volume of the solution. The chemical reaction that takes place is represented by the following equation.



(a) List an appropriate observation that provides evidence of a chemical reaction between the two compounds. *yellow solid forms. signs of a chemical rxn include*

(b) Calculate the number of moles of each reactant. *1) Energy change (Heat, Light) 2) Gas forms 3) Precipitate forms 4) color change*

(c) Identify the limiting reactant. Show calculations to support your identification.

(d) Calculate the molar concentration of NO_3^- (aq) in the mixture after the reaction is complete.

(e) Draw a diagram of the mixture at the molecular level. Explain the reasoning used in making your choice.

$$B.) \quad 0.150 \text{ g Pb}(\text{NO}_3)_2 \left(\frac{1 \text{ mol Pb}(\text{NO}_3)_2}{331.21 \text{ g}} \right) = 4.53 \times 10^{-4} \text{ mol Pb}(\text{NO}_3)_2$$

$$0.125 \text{ L} \left(\frac{0.100 \text{ mol NaI}}{\text{L}} \right) = 0.0125 \text{ mol NaI}$$

C.) I need twice as much NaI as $\text{Pb}(\text{NO}_3)_2$ because of the mole ratio. Because $0.0125 \text{ mol NaI} \left(\frac{1 \text{ mol Pb}(\text{NO}_3)_2}{2 \text{ mol NaI}} \right) = 0.00625 \text{ mol Pb}(\text{NO}_3)_2$ I do not have enough $\text{Pb}(\text{NO}_3)_2$ therefore it is the L.R.

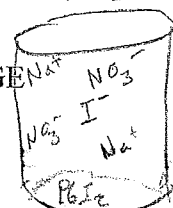
D) spectator ion not used

E) not excess I^-

In reaction: $\text{Pb}(\text{NO}_3)_2 \rightarrow \text{Pb}^{2+} + 2\text{NO}_3^-$

$$4.53 \times 10^{-4} \text{ mol Pb}(\text{NO}_3)_2 \left(\frac{2 \text{ mol NO}_3^-}{1 \text{ mol Pb}(\text{NO}_3)_2} \right) = \frac{9.06 \times 10^{-4} \text{ mol}}{0.125 \text{ L}} = 0.00725 \text{ M} = [\text{NO}_3^-]$$

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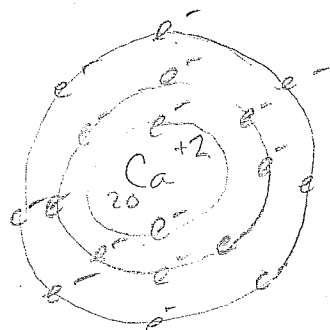
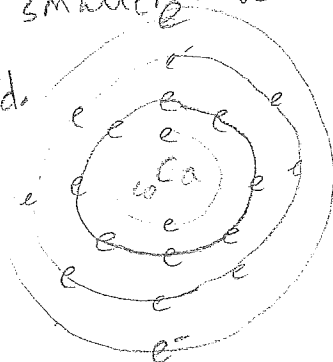
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2. Use principles of atomic structure and/or chemical bonding to answer each of the following.
- (a) The radius of the Ca atom is 0.197 nanometer; the radius of the Ca²⁺ ion is 0.099 nanometer. Account for this difference.
- (b) The lattice energy of CaO(s) is -3,460 kilojoules per mole; the lattice energy for K₂O(s) is -2,240 kilojoules per mole. Account for this difference.

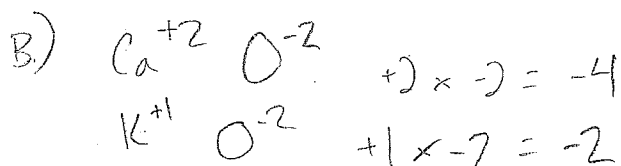
	Ionization Energy (kJ/mol)	
	First	Second
K	419	3,050
Ca	590	1,140

- (c) Explain the difference between Ca and K in regard to
- their first ionization energies,
 - their second ionization energies.
- (d) The first ionization energy of Mg is 738 kilojoules per mole and that of Al is 578 kilojoules per mole. Account for this difference.

A) Ca⁺² is smaller because the entire outer shell is removed.



missing outer layer n=4



Due to the charges CaO is more exothermic therefore more stable than K₂O.

C) i) Calcium has an additional Proton and electron than potassium within the same energy level pulling it closer due to the attractive forces.

ii) Potassium has 1 v.e. whereas calcium has two v.e. The large jump in 1st to 2nd IE in potassium is because the second is a core electron.

D) The Al electron has 1 e⁻ in the p orbital and Mg does not, Mg has 2 electrons paired and stable.

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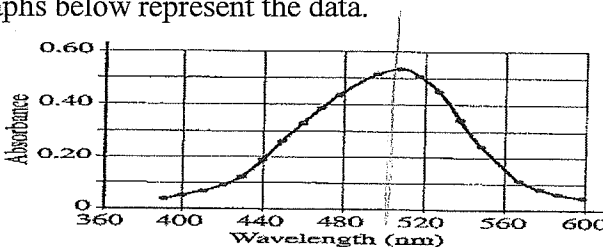
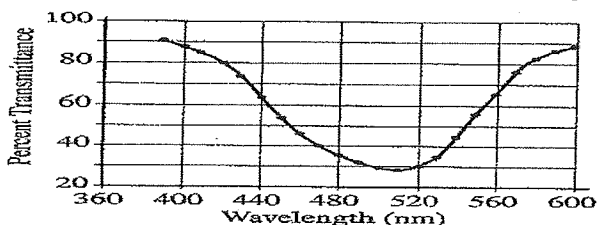
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3. A student is instructed to determine the concentration of a solution of CoCl_2 based on absorption of light (spectrometric/colorimetric method). The student is provided with a 0.10 M solution of CoCl_2 with which to prepare standard solutions with concentrations of 0.020 M, 0.040 M, 0.060 M and 0.080 M.

$$M_1 V_1 = M_2 V_2 \quad V_1 = \frac{(0.020\text{M})(100\text{mL})}{(0.100\text{M})}$$

$$V_1 = 20\text{mL}$$

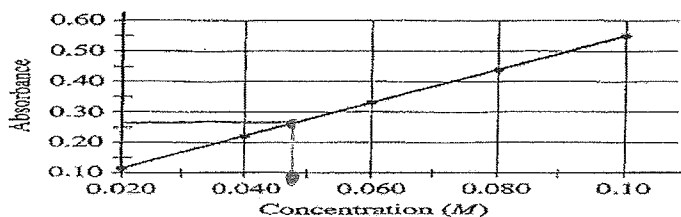
- (a) Describe the procedure for diluting the 0.10 M solutions to a concentration of 0.020 M using distilled water, a 100 mL volumetric flask, and a pipet or buret. Include specific amounts where appropriate. Place 20 mL of concentrated solution using a pipet into the 100 mL volumetric flask. Fill up to the line with distilled water. The student takes the 0.10 M solution and determines the percent transmittance and the absorbance at various wavelengths. The two graphs below represent the data.



- (b) Identify the optimum wavelength for the analysis.

Highest Absorption

The student measures the absorbance of the 0.020 M, 0.040 M, 0.060 M, 0.080 M and 0.10 M solutions. The data are plotted below.



- (c) The absorbance of the unknown solution is 0.275. What is the concentration of the solution?

~ 0.048 M Look at graph.

- (d) Beer's Law is an expression that includes three factors that determine the amount of light that passes through a solution. Identify two of these factors.

$A = \text{constant for molecule}$ $B = \text{Path length}$ $C = \text{concentration}$ Absorbance = ABC

- (e) The student handles the sample container (e.g., test tube or cuvette) that holds the unknown solution and leaves fingerprints in the path of the light beam. How will this affect the calculated concentration of the unknown? Explain your answer.

Finger prints block the light increasing the absorbance and make the calculated concentration too high.

