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 FIRST NAME: Rogers  
 STUDENT ID:

PART A: MULTIPLE-CHOICE QUESTIONS

02

Chem 205 - GENERAL CHEMISTRY I

MIDTERM EXAMINATION

PLEASE READ THIS BOX WHILE WAITING TO START

INSTRUCTIONS:

- Calculators are permitted; cell phones and other electronic devices are not allowed.
- This test paper includes 9 pages; please read over the whole test before starting.
- A periodic table (incomplete) is included and may be detached (not graded).
- Answer the multiple-choice questions on the scan sheet, in pencil.
- Please write clearly and organize your work logically.
- Read the instructions to each section carefully.
- Duration: 70 minutes. GOOD LUCK!

Professor use - Grades:

Page 2. / 10

Page 3. / 10

Page 4. / 12

Page 5. / 11

Page 6. / 8

Page 7. / 10

TOTAL: / 60 (MAX. 61)

PERCENT: %

**PART A: MULTIPLE-CHOICE QUESTIONS (answer on scan sheet, in pencil)**

# 1. (2 marks) Which of the following figures represents a compound?

a) A  
 b) B  
 c) C  
 d) D  
 e) They all do.

molecules made of 2 elements, not just 1.

compound      element      mixture      element

A                      B                      C                      D

# 2. (2 marks) What type of statement is this? "The total mass of materials is not affected by a chemical change in those materials".... Law of Conservation of Mass

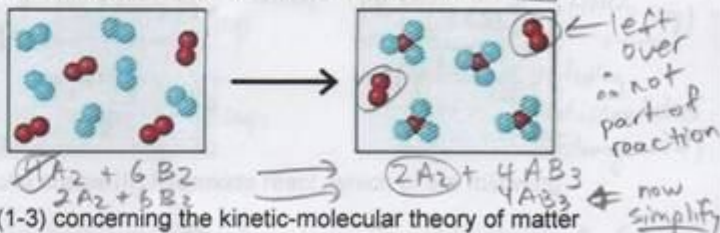
- a) a measurement  
 b) an observation  
 c) an experiment  
 d) a natural law  
 e) a theory

# 3. (2 marks) The statements below summarize various scientists' contributions to the understanding of atomic structure. Which statement incorrectly describes the scientist's work?

- a) J. Dalton proposed his atomic theory, in which he (incorrectly) postulated that all atoms of the same element are identical.  
 b) The Curies showed that some types of atoms can spontaneously disintegrate, based on their experiments involving radioactivity.  
 c) J.J. Thomson proposed the law of conservation of mass, based on his cathode-ray tube experiments. *Lavoisier!*  
 d) R. Millikan determined the charge and mass of the electron, using his "oil-drop" experiments.  
 e) E. Rutherford proposed the nuclear model of the atom, based on his gold-foil experiments.

# 4. (2 marks) The reaction between reactant A (darker spheres) and reactant B (lighter spheres) is shown in the diagram below. Based on the diagram, which balanced equation best describes the reaction?

- a)  $3A + B \rightarrow A_3B$   
 b)  $A + 3B \rightarrow AB_3$   
 c)  $A_2 + 3B_2 \rightarrow 2AB_3$   
 d)  $8A + 12B \rightarrow 4AB_3 + 2A_2$   
 e)  $4A_2 + 6B_2 \rightarrow 4AB_3 + 2A_2$



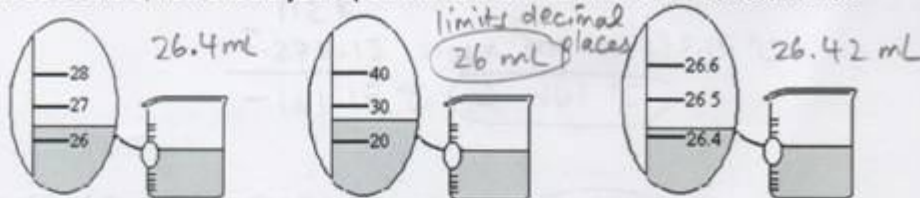
# 5. (2 marks) Which of the following statements (1-3) concerning the kinetic-molecular theory of matter is/are CORRECT?

- a) 1 only  
 b) 2 only  
 c) 3 only  
 d) 1 and 2  
 e) 1, 2 and 3
1.  Particles in a gas move faster as the temperature increases.  
 2.  Particles in a liquid are packed closely together, but are not confined to specific positions.  
 3.  Particles in a gas vibrate back and forth about an average position. (solids!)

$$\begin{array}{r} 26.4 \\ + 26 \\ \hline 26.42 \\ \hline 78.82 \text{ mL} \approx 79 \text{ mL} \end{array}$$

# 6. (2 marks) Suppose you pour the water from the three beakers shown below into one container. Based on the precision of the three beakers, how should you report the new total volume to the correct number of significant figures?

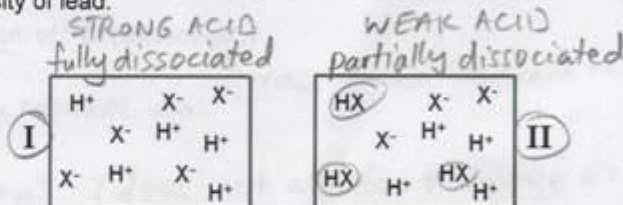
- a) 78.817 mL  
b) 78.82 mL  
c) 78.8 mL  
d) 80 mL  
e) 79 mL



# 7. (2 marks) Which one of the following statements is not a comparison of physical properties?

- a)  The reaction of potassium with water is faster than the reaction of calcium with water.  
b)  The solubility of NaCl in hot water is greater than the solubility in cold water.  
c)  The conductivity of aluminum is greater than the conductivity of copper.  
d)  The boiling point of water is greater than the boiling point of ethanol.  
e)  The density of copper is less than the density of lead.

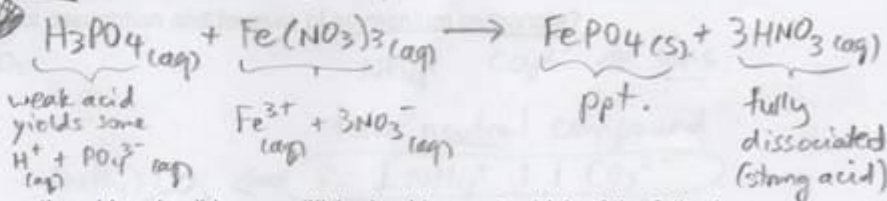
# 8. (2 marks) When an acid HX is mixed with water, one of two possible solutions forms (shown in diagrams I & II; water molecules omitted for simplicity). Which of the statements below is true?



- a)  In case I, HX is behaving like a strong acid, and in case II, HX is behaving like a weak acid.  
b)  In case I, HX is behaving like a weak acid, and in case II, HX is behaving like a strong acid.  
c)  In both cases, HX is behaving like a strong acid.  
d)  In both cases, HX is behaving like a weak acid.  
e)  In both cases, HX is behaving like a base.

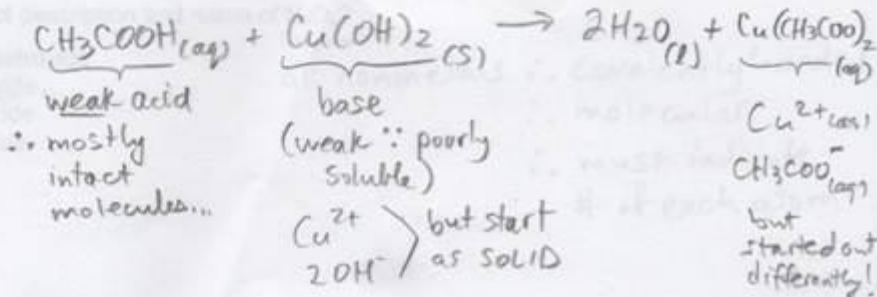
# 9. (2 marks) When solutions of phosphoric acid and iron(III) nitrate react, which of the following terms will be present in the balanced molecular equation? showing compounds as neutral species.

- a)  HNO<sub>3</sub>(aq)  
b)  3 HNO<sub>3</sub>(aq)  
c)  2 FePO<sub>4</sub>(s)  
d)  3 FePO<sub>4</sub>(s)  
e)  2 HNO<sub>3</sub>(aq)



# 10. (2 marks) When aqueous acetic acid and solid copper(II) hydroxide react, which of the following species are spectator ions?

- a)  hydroxide ion  
b)  hydrogen ion  
c)  copper(II) ion  
d)  acetate ion  
e)  none of these



# 11. (2 marks) What is the boiling point of methane (112 K) on the Celsius scale?

- B
- a) -186 °C
  - b) -161 °C
  - c) -112 °C
  - d) 112 °C
  - e) 434 °C

$$\begin{array}{r} 112 \text{ K} \\ - 273.15 \\ \hline -161.15 \text{ }^\circ\text{C} \end{array} \text{ since } 0 \text{ K} = -273.15 \text{ }^\circ\text{C}$$

$\approx -161 \text{ }^\circ\text{C}$

# 12. (2 marks) Which one of the following properties is not characteristic of nonmetals?

- D
- a)  tend to form negative ions in chemical reactions with metals
  - b)  appear in the upper right-hand corner of the periodic table
  - c)  often bond to each other by forming covalent bonds
  - d) typically have a shiny (lustrous) appearance → that's characteristic of METALS
  - e)  are poor conductors of electricity

# 13. (2 marks) How many electrons are in a neutral atom of  $^{37}\text{Cl}$  (chlorine-37)?

- C
- a) 0
  - b) 7
  - c) 17
  - d) 20
  - e) 37

↑  
Same as # protons in NEUTRAL atom  
 $Z = 17$  for Cl  
 $\therefore \#p = 17 = \#e^-$  (does not ask for # valence  $e^-$ )

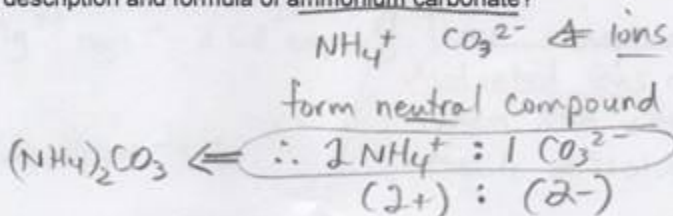
mass #, not relevant here

# 14. (2 marks) Which one of the following statements about atomic structure is false?

- A
- a) The number of protons and neutrons is always the same in the neutral atom.
  - b)  Almost all of the mass of the atom is concentrated in the nucleus.
  - c)  The protons and neutrons in the nucleus are very tightly packed.
  - d)  Protons and neutrons have approximately the same mass. (individually...)
  - e)  An atom is mostly empty space.

# 15. (2 marks) What is the correct description and formula of ammonium carbonate?

- D
- a)  molecular,  $(\text{NH}_4)_2\text{CO}_3$
  - b)  molecular,  $\text{NH}_4\text{CO}_3$
  - c)  ionic,  $\text{NH}_4(\text{CO}_3)_2$
  - d) ionic,  $(\text{NH}_4)_2\text{CO}_3$
  - e)  ionic,  $\text{NH}_4\text{CO}_3$



# 16. (2 marks) What is the correct description and name of  $\text{N}_2\text{O}_4$ ?

- A
- a) molecular, dinitrogen tetroxide
  - b)  molecular, nitrogen oxide
  - c)  ionic, dinitrogen tetroxide
  - d)  ionic, nitrogen (IV) oxide
  - e)  ionic, nitrogen oxide

$\underbrace{\text{N}_2\text{O}_4}$   
all nonmetals  $\therefore$  covalently bonded  
 $\therefore$  molecular  
 $\therefore$  must indicate # of each atom

# 17. (2 marks) Elemental oxygen ( $O_2$ ) is abundant in our atmosphere because it is not very reactive.

- B a) True
- b) False

No; because photosynthesis keeps making more of it!  
 $O_2$  is VERY reactive.

# 18. (2 marks) When sugar ( $C_{12}H_{24}O_{12}$ ) is melted, covalent bonds within the molecules are broken.

- B a) True
- b) False

No, only interactions between molecules are broken, because molecules have enough kinetic energy to overcome weak forces of attraction

# 19. (2 marks)  $H_3PO_4$ , HF and  $NH_3$  are all examples of weak electrolytes.

- A a) True
- b) False

weak acids      weak base } all yield low proportion of ions when dissolve in water (due to reaction with water in fact...)

**PART B: DRAWINGS & SHORT WRITTEN ANSWERS (answer on exam)**

# 20. Think about magnesium chloride ( $MgCl_2$ ) dissolving in water.



a) (1 mark) Which substance is the solute and which substance is the solvent?

$MgCl_2$        $H_2O$

b) (1 mark) Is the solute molecular or ionic in nature? How do you know?

(Mg is a metal; Cl is a nonmetal) This indicates that they would NOT share electrons, but would exist as IONS (metal loses  $e^-$ , nonmetal gains).

c) (3 marks) Which diagram (a-d) best represents aqueous magnesium chloride? Explain.

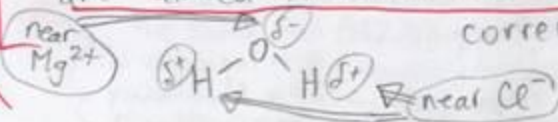


$MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq)$

⇒ (c) and (d) show this

Three independently solvated ions are formed when the ionic solute  $MgCl_2$  dissolves.

Water's polarity dictates that it arranges itself around the solute ions such that the  $\delta^-$  region of the water molecules are aimed towards the solute cations, and the  $\delta^+$  regions are aimed towards the solute anions. This is shown correctly in (c), but it is reversed in (d).



So, (c) is the most accurate diagram.

**PART C: SHOW COMPLETE WORK TO GET FULL CREDIT (answer on exam)**

#21. (8 marks) Cortisol (MM 362.47 g/mol) is an important steroid hormone that is used as a medicine to treat inflammatory diseases such as rheumatoid arthritis. Cortisol is 69.6% carbon, 8.34% hydrogen and 22.1% oxygen by mass. What is its molecular formula?

Include explanatory comments at each step of your calculation.

• Molecular formula = (empirical formula)<sub>n</sub> ← an integer.

Ratio of different atoms in molecule.

Simplest whole-number ratio of atoms of different elements in substance, which can be determined via mass % data...

• To find empirical formula: convert mass % to mass in arbitrary sample, then to moles, then normalize to make it easier to see the mole ratio of elements... which is same as atom ratio

Element (mass %)	Mass in a 100g sample	Molar mass of element	Moles in 100g	Normalized to smallest moles	Whole # mole ratio
Carbon (69.6%)	$0.696 \times 100\text{g} = 69.6\text{g}$ ✓	12.011 g/mol	$\frac{69.6\text{g C}}{12.011\text{g/mol C}} = 5.795\text{ mol}$ ✓	$\frac{5.795\text{ mol}}{1.381\text{ mol}} = 4.196 \approx 4.2$ ✓	$4.2 \times 5 = 21$ ✓
Hydrogen (8.34%)	$0.0834 \times 100\text{g} = 8.34\text{g}$ ✓	1.008 g/mol	$\frac{8.34\text{g H}}{1.008\text{g/mol H}} = 8.274\text{ mol}$ ✓	$\frac{8.274\text{ mol}}{1.381\text{ mol}} = 5.991$ ✓	$5.991 \times 5 = 30$ ✓
Oxygen (22.1%)	$0.221 \times 100\text{g} = 22.1\text{g}$ ✓	15.999 g/mol	$\frac{22.1\text{g O}}{15.999\text{g/mol O}} = 1.381\text{ mol}$ ✓	$\frac{1.381\text{ mol}}{1.381\text{ mol}} = 1.000$ ✓	$1.000 \times 5 = 5$ ✓

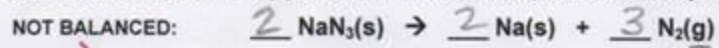
Note: If you rounded earlier to empirical formula of  $\text{C}_4\text{H}_6\text{O}$ , then compared the known MM (362.47 g/mol) to empirical MM (70.091 g/mol), you'd find  $n \approx 5$ ... which yields  $\text{C}_{20}\text{H}_{30}\text{O}_5$  → close but incorrect.

⇒ Empirical formula =  $\text{C}_{21}\text{H}_{30}\text{O}_5$   
 Empirical molar mass = 362.466 g/mol ✓  
 Same as given molar mass ∴  $n = 1$  ✓  
 ∴ Molecular formula =  $\text{C}_{21}\text{H}_{30}\text{O}_5$  ✓

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**PART C: SHOW COMPLETE WORK TO GET FULL CREDIT (answer on exam)**

# 22. (10 marks) Sodium azide,  $\text{NaN}_3$ , is used in automobile air bags because of its predictable explosive properties. When heated strongly, sodium azide decomposes suddenly via the following reaction:



1 a) (1 mark) Fill in the missing stoichiometric coefficients needed to balance the reaction equation.

b) (3 marks) What type of reaction is this? Circle all that apply, and explain your choice(s).

acid-base  gas-forming  oxidation-reduction  precipitation

3 max

- Gas forming: Nitrogen gas forms from reactants that did not include any gases - so, noticeable expansion would occur.
- Oxidation-reduction: Electrons are transferred in this reaction, as evidenced by the fact that elements have been formed from a compound.  $\text{Na}^+$  gains electrons (is reduced) and  $\text{N}_3^-$  loses electrons (is oxidized) during this process:  $2 \text{Na}^+ + 2\text{e}^- \rightarrow 2 \text{Na}(\text{s})$  (easily identified) and  $2 \text{N}_3^- \rightarrow 3 \text{N}_2(\text{g}) + 2\text{e}^-$  (harder to see)

c) (4 marks) Using this reaction, about 90 g of  $\text{NaN}_3$  is sufficient to inflate a standard car air bag. The filled air bag contains approximately 45.5 L of  $\text{N}_2$  gas, which has a density of  $1.61 \times 10^{-3} \text{ g/L}$  at  $22^\circ\text{C}$ . How many molecules of nitrogen is this? Show your work.

Start by finding mass of  $\text{N}_2$  in the air bag, via density of gas:  
 $(1.61 \times 10^{-3} \frac{\text{g}}{\text{L}})(45.5 \text{ L}) = 0.07326 \text{ g of } \text{N}_2$

4

Convert to moles using molar mass of  $\text{N}_2$ :  $\text{MM} = 2(14.007 \text{ g/mol}) = 28.014 \text{ g/mol}$   
 $\frac{0.07326 \text{ g}}{28.014 \text{ g/mol}} = 2.615 \times 10^{-3} \text{ mol}$  (identity of "nitrogen" =  $\text{N}_2$ )

Convert to molecules using Avogadro's number:  
 $(6.022 \times 10^{23} \text{ molecules}) \times 2.615 \times 10^{-3} \text{ mol} = 1.575 \times 10^{21} \text{ molecules}$   
 $\approx 1.58 \times 10^{21} \text{ molecules}$   
(3SF) - limited by gas volume using X/S rules for SF

d) (2 marks)  $\text{NaN}_3$  contains the azide ion, a polyatomic ion made of three nitrogen atoms covalently bonded together to make a short chain. Based on your knowledge of ionic compounds, what must be the charge on the azide ion? Explain in a few key words.

2

Ionic compounds are composed of ions in a ratio that yields a neutral substance, i.e., total positive charge of the cations must balance total negative charge of the anions. Because sodium is an alkali metal, its ions have +1 charge ( $\text{Na}^+$ ). The formula for sodium azide is  $\text{NaN}_3$ , which implies that the ratio of  $\text{Na}^+ : \text{N}_3^-$  is 1:1. Thus, the " $\text{N}_3^-$ " ion must bear a negative charge of same magnitude as  $\text{Na}^+$ 's positive charge:  $\text{N}_3^-$

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