Concordia University CHEM 205

Fall 2009, Dr. C. Rogers, Section 02, W/F

(Wed/Fri)

A

LAST NAME: Rogers

FIRST NAME:

STUDENT ID:

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 8 pages; please read over the whole test before starting.
- Potentially useful information and a periodic table (incomplete) are included.
- You may detach the periodic table page for easier reference if you wish.
- Please write clearly and organize your work logically.
- Read the instructions to each section carefully.
- **Duration: 70 minutes. GOOD LUCK!**

Mark breakdown:

Page 2.	/ 10
Page 3.	/ 15
Page 4.	/ 8
Page 5.	/ 8
Page 6.	/ 12

TOTAL: / 52 (MAXIMUM MARK = 53)

PERCENT: %

EARNED towards FINAL GRADE: / 15

(A)

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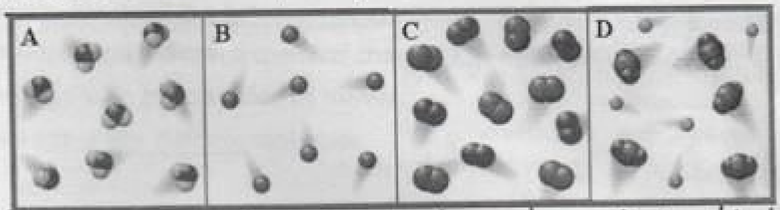
PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

 # 1. (2 marks) The figures below represent four different samples of gas-phase matter. Which figure represents a mixture?

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

D



compound | element | element | compound + element

 # 2. (2 marks) Consider the following statement: "The degree of agreement among several measurements of the same quantity reflects the reproducibility of the given type of measurement." What concept does this statement describe?

a) significance
b) accuracy
(c) precision
d) certainty
e) error

C

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

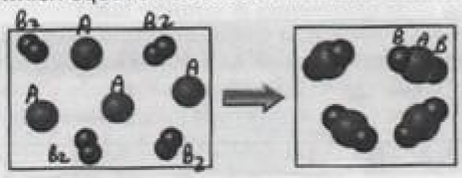
a) T J. Dalton proposed his atomic theory, in which he (incorrectly) postulated that all atoms of the same element are identical.
(b) The Curies showed that atoms cannot be subdivided, based on their experiments involving radioactivity.
c) T J.J. Thomson proposed the plum-pudding model of the atom, based on his cathode-ray tube experiments.
d) T R. Millikan determined the charge and mass of the electron, using his "oil-drop" experiments.
e) T E. Rutherford proposed the nuclear model of the atom, based on his gold-foil experiments.

B

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

a) $A_2 + B \rightarrow A_2B$
b) $2A + B_4 \rightarrow 2AB_2$
c) $A_2 + 4B \rightarrow 2AB_2$
(d) $A + B_2 \rightarrow AB_2$
e) $A + B_2 \rightarrow A_2B$

D



SHOWN: $4A + 4B_2 \rightarrow 4AB_2$ NET: $A + B_2 \rightarrow AB_2$

 # 5. (2 marks) What is the concentration of manganese ions in a 2.0 M solution of $Mn_2(SO_4)_3$?

a) 1.0 mol/L
b) 2.0 mol/L
c) 3.0 mol/L
(d) 4.0 mol/L
e) 6.0 mol/L

D

$Mn_2(SO_4)_3 = 2Mn^{3+} : 3SO_4^{2-}$
2.0 mol/L   4.0 mol/L   6.0 mol/L

i.e. $Mn_2(SO_4)_{3(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 3SO_4^{2-}_{(aq)}$

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 # 6. (4 marks) Identify the following statements as true or false. *(Circle T or F.)*

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- T / (F) When salt dissolves in water, the result is a heterogeneous mixture. Solution = homogeneous
- (T) / F A change in colour does not always indicate a chemical change. e.g. hydrated vs. anhydrous ionic compounds
- (T) / F Most elements on the periodic table are classified as metals.
- T / (F) Elemental sulfur exists as gas-phase diatomic molecules. S_8 molecules, solid phase material
  recall: diatomics = I_2 H_2 N_2 Br_2 O_2 Cl_2 F_2
  (I have no bright or clever friends...)

 # 7. (4 marks) Fill in the blanks:

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a) The melting point of lead (600.61 K) on the Celsius scale is: $600.61 - 273.15 = 327.46\,°C$

b) An element that tends to lose electrons during reactions is: any metal (becomes a cation)

c) The number of neutrons in an ^{75}As (arsenic-75) atom is: $75 - 33\,(p^+) = 42\,n^0$

d) The name of the phase change from gas to liquid: condensation, liquefaction

 # 8. (4 marks) Write the missing name or formula, and classify each substance by type:

0.75 each (all or nothing) — 0.25 each

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Substance name	Substance formula	Ionic or molecular substance?
potassium permanganate	$KMnO_4$	ionic
diphosphorus pentoxide	P_2O_5	molecular (all nonmetals, no ions)
copper (II) sulfate	$CuSO_4$	ionic
ammonium phosphate	$(NH_4)_3PO_4$	ionic

 # 9. (3 marks) Determine the volume of liquid present in each graduated cylinder, and report your measurements with the correct number of significant figures for the equipment. Next, add the two volumes together, and indicate what determined the number of significant figures in the total volume. } in mL

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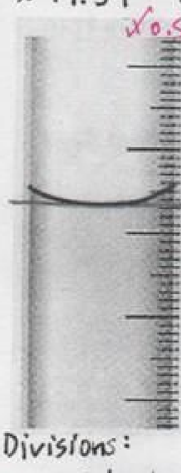
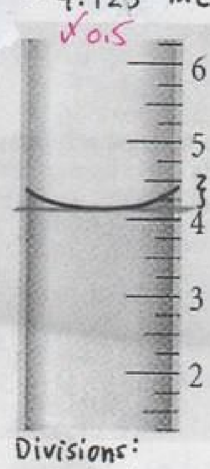
Volume A: ≈ 17.34 mL ✓0.5



Divisions: 0.1 mL

Volume B: ≈ 4.125 mL ✓0.5



Divisions: 0.25 mL

Total volume & comments (few words only!):

+ A	17.34	← ~½ way between 17.3 & 17.4
B	4.125	← ~½ way between 4 & 4.25
total	21.465 mL	← adding rules for SF = maintain lowest # of decimal places from data ✓ (1)
∴ =	21.47 mL	

(no points for simply adding — sorry!)

Note:
- must measure from BOTTOM of meniscus (0.5) ✓
- must estimate last digit, based on liquid's level between the lines on the scale (i.e. 1 more digit than scale's divisions show, in most cases). (0.5) ✓

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(A)

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PART B: Short written answers

CH_3COOH (formula given on board)

 # 10. **(4 marks)** Pure acetic acid, known as glacial acetic acid, is a liquid with a density of 1.049 g/mL at 25°C. Calculate the molarity of a solution of acetic acid made by dissolving 15.00 mL of glacial acetic acid at 25°C in enough water to make 125.00 mL of solution.

✓ molarity (M): $C = \frac{n_{solute}}{V_{solution}}$ (in L) } concentration!

- First: calculate # moles acetic acid in 15.00 mL glacial acetic acid

$\# n = \frac{m}{MM}$ ✓ where: $d = \frac{m}{V}$ ∴ $m = d \times V$ ✓
$= (1.049\ g/mL)(15.00\ mL)$
$= 15.735\ g$ acetic acid ✓ (mass)

$MM_{acetic\ acid} = (2 \times 12.01) + (2 \times 15.999) + (4 \times 1.008)$
$= 60.05\ g/mol$ ✓

$\therefore n = \frac{15.735\ g}{60.05\ g/mol} = 0.2620\ mol$ ✓

- Second: calculate concentration when dissolved in 125.00 mL total.

$C = \frac{0.2620\ mol}{0.12500\ L}$ ✓ $= \boxed{2.096\ M}$ (mol/L) (4 SF due to d & V_{CH_3COOH})
(mL → L ✓)
−0.25 if incorrect

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 # 11. **(4 marks)** When elemental magnesium is ignited in the presence of elemental oxygen, bright light and white smoke (*i.e.*, formation of a white powdery solid) are observed.

a) **(1 mark)** Is the product ionic or molecular in nature? How do you know?

(1) ionic ✓ ∵ reaction of metal + nonmetal ✓ results in ionic compound

b) **(1 mark)** Write a balanced chemical equation for this reaction. — no charges until AFTER rxn.

(1) $2\,Mg_{(s)} + O_{2\,(g)} \longrightarrow 2\,MgO_{(s)}$ OR $Mg_{(s)} + \frac{1}{2}O_{2\,(g)} \rightarrow MgO_{(s)}$

c) **(2 marks)** Briefly explain the concept of electroneutrality and how it helped you determine the formula of the compound formed in the above reaction.

(1) electroneutrality: An ionic compound must be composed of ions that fully compensate each others' charges. i.e. The formula must describe a NEUTRAL crystal.

(1) So, because Mg is known to form Mg^{2+} cations + because O is known to form O^{2-} anions, this means that the compound, magnesium oxide, must consist of a 1:1 ratio of Mg^{2+} : O^{2-} anions to achieve neutrality. Thus, the formula is MgO.

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(A) + (B)

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PART C: Problems – SHOW COMPLETE WORK TO GET FULL CREDIT

#12. (8 marks) An element X forms an iodide XI_3 and a chloride XCl_3. The iodide is quantitatively converted (*i.e.*, with 100 % yield) to the chloride when it is heated in a stream of chlorine gas:

$$2\,XI_3 + 3\,Cl_2 \rightarrow 2\,XCl_3 + 3\,I_2$$

i.e., excess...

If 0.5000 g of XI_3 is treated, 0.2360 g of XCl_3 is obtained. Calculate the atomic mass of the element X, and identify the element. **Include explanatory comments at each step of your calculation.**

- What do we know about our compounds?

XI_3: $MM_{XI_3} = MM_X + 3MM_I$ (✓) $= MM_X + 3(126.90\ g/mol) = MM_X + 380.70\ g/mol$ ✓ ✓ $(m = 0.5000\ g)$

XCl_3: $MM_{XCl_3} = MM_X + 3MM_{Cl}$ (✓) $= MM_X + 3(35.45\ g/mol) = MM_X + 106.35\ g/mol$ ✓ ✓ $(m = 0.2360\ g)$

- Reaction stoichiometry says: ① all X atoms from XI_3 go into XCl_3
  ② 1 XI_3 becomes 1 XCl_3

Thus: $\#n_{XI_3\ used} = \#n_{XCl_3\ formed}$ $(= \#n_X$ atoms$)$

- Use this to solve (algebraically) for X's atomic mass:

$\#n_{XI_3} = \#n_{XCl_3}$ ✓ ⟸ from stoichiometry ✓

$\frac{0.5000\,g\ XI_3}{MM_X + 380.70}$ ✓ $= \frac{0.2360\,g\ XCl_3}{MM_X + 106.35}$ ✓ ⟸ because $\#n = \frac{m}{MM}$ (✓) for each compound

$0.5000\,MM_X + 53.175 = 0.2360\,MM_X + 89.845$

$(0.5000 - 0.2360)\,MM_X = 89.845 - 53.175$

$0.2640\,MM_X = 36.670$ algebra ✓

$\therefore MM_X = 138.90\ g/mol$ ⟸ The element's atomic mass is 138.9 g/mol (4SF data)

This atomic mass is close to 2 metals: 137.33 g/mol = Ba
conclusion ✓ ⊛ 138.91 g/mol = La (✓)

But, Ba is an alkali earth metal, so forms +2 cations, not +3.
Thus, the element must be La (lanthanum), which in fact does typically form +3 cations (but not needed to solve problem).

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⊛ PRACTICE Ch.3 END-OF-CHAPTER PROBLEMS (near end)

Alternate solution

- From stoich.: $2\,XI_3 : 2\,XCl_3 = 1:1$ ratio ✓
  i.e. $n_{XI_3} = n_{XCl_3}$ ✓

- $m_{XI_3} = 0.5000\,g$ and $m_{XCl_3} = 0.2360\,g$
  $0.5000\,g = m_X + m_I$ ✓ $\quad 0.2360\,g = m_X + m_{Cl}$ ✓
  $\therefore m_X = 0.2360\,g - m_{Cl}$

  all X converted from XI_3 to XCl_3, so no mass of X lost! (✓)

  combine equations

$$0.5000\,g = 0.2360\,g - m_{Cl} + m_I$$
$$0.2640\,g = m_I - m_{Cl}$$ ⇐ now, recall $\# n_{XI_3} = \# n_{XCl_3}$
$$= n_I\left(126.9\,\frac{g}{mol\,I}\right) - n_{Cl}\left(35.45\,\frac{g}{mol\,Cl}\right)$$ ⇐ so, $\# n_I = \# n_{Cl}$
$$= \left(126.9\,\frac{g}{mol}\right)n - \left(35.45\,\frac{g}{mol}\right)n$$
$$0.2640\,g = \left(91.45\,\frac{g}{mol}\right)n$$
$$n = 2.887\times10^{-3}\,mol$$ ✓ (I atoms, Cl atoms)
$$\therefore n_X = \tfrac{1}{3}n_I = 9.623\times10^{-4}\,mol \text{ of } X$$ ✓ $(= \# n_{XI_3} = \# n_{XCl_3})$

- Will use $\# n_I$ to reconstruct composition of XI_3
$$0.5000\,g = m_X + (2.887\times10^{-3}\,mol\,I)\left(126.9\,\frac{g}{mol\,I}\right)$$
$$m_X = 0.5000 - 0.3664\,g$$
$$m_X = 0.1336\,g$$ ✓
  ↳ due to 9.720×10^{-4} mol X atoms ... ∴ $n = \frac{m}{MM}$ ...

Thus $\boxed{MM_X = \frac{m_X}{n_X}} = \frac{0.1336\,g}{9.623\times10^{-4}\,mol}$ ✓

$= 138.9\,g/mol$ ⇐ closest element = La

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MM = 84.005 g/mol MM = 192.117 g/mol

 # 13. (12 marks) The fizz produced when an Alka-Seltzer® antacid tablet is dissolved in water is due to the reaction between sodium bicarbonate, $NaHCO_3$, and citric acid, $H_3C_6H_5O_7$:

$$3\ NaHCO_3(aq) + H_3C_6H_5O_7(aq) \rightarrow 3\ CO_2(g) + 3\ H_2O(\ell) + Na_3C_6H_5O_7(aq)$$

In a certain experiment, imagine you mix 1.00 g of sodium bicarbonate and 1.00 g of citric acid.

a) **(10 marks)** Assuming the reaction proceeds with 100% yield, how many grams of CO_2 form? **Include explanatory comments with your calculations.**

- The reaction consumes 3 mol $NaHCO_3$ for every 1 mol citric acid. So, we must convert our masses to moles & determine which reactant is limiting the product yield (i.e., runs out first!).

(2) moles

$$\# n_{NaHCO_3} = \left(\frac{1.00\ g}{84.005\ g/mol}\right) \doteq 0.01190\ mol\ NaHCO_3$$

$$\# n_{H_3C_6H_5O_7} = \left(\frac{1.00\ g}{192.117\ g/mol}\right) \doteq 0.005205\ mol\ citric\ acid$$

(4) LR

Thus, we have a $\frac{0.01190}{0.005205} \doteq \frac{2.29}{1}$ ratio but need $\frac{3\ NaHCO_3}{1\ citric\ acid}$

Thus, we will not have enough $NaHCO_3$ to use all the citric acid. ∴ $NaHCO_3$ is LIMITING REACTANT

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- Now, determine theoretical (based on LR) yield:

(3) yield

$\frac{\text{Rxn needs 3 mol } NaHCO_3}{\text{Have } 0.01190 \text{ mol } NaHCO_3} = \frac{\text{to make 3 mol } CO_2}{\text{will get } x \text{ mol } CO_2} \Rightarrow x = 0.01190$ mol CO_2 forms.

- Convert to mass:

(1) mass

$n = \frac{m}{MM}$ ∴ $m = n \times MM_{CO_2}$
$= (0.01190\ mol)(44.009\ g/mol\ CO_2)$
$= 0.5237$ g of CO_2 forms

-0.25 SF errors

∴ $m \doteq 0.524$ g ⟸ 3 SF because of mass data & ×/÷ rules.

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b) **(2 marks)** Calculate how much excess reactant remains after the reaction is complete.

Excess citric acid = original − amount used
= 0.005205 − 0.003967 mol
= 0.00124 mol left over.

used: $\frac{1\ \text{citric acid}}{3\ NaHCO_3} = \frac{y}{0.01190}$ ∴ $y = 3.967 \times 10^{-3}$ mol

∴ $m_{excess\ cit.acid} = (0.00124\ mol)(192.117\ g/mol)$
$= 0.238$ g remains unreacted. (ok if left in mol)

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