Concordia University CHEM 205

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

Wed/Fri

B

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

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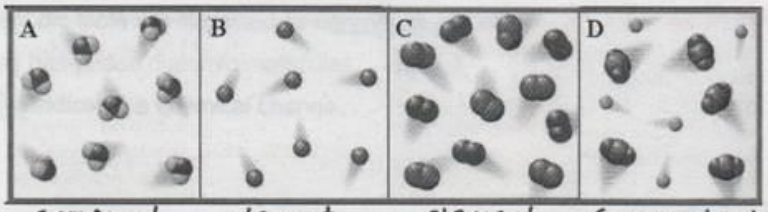
PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

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

A

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



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?

C

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

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

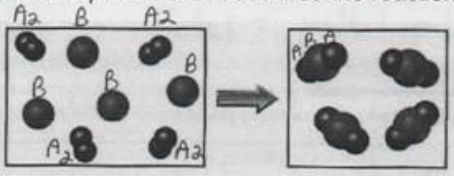
B

a) T J.J. Thomson proposed the plum-pudding model of the atom, based on his cathode-ray tube experiments.
b) The Curies showed that atoms cannot be subdivided, based on their experiments involving radioactivity.
c) T J. Dalton proposed his atomic theory, in which he (incorrectly) postulated that all atoms of the same element are identical.
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.

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

A

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) $A + B_2 \rightarrow A_2B$



Shown: $4A_2 + 4B \rightarrow 4A_2B$

Net rxn: $A_2 + B \rightarrow A_2B$

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

B

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

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

2.0 mol/L → 4.0 mol/L → 6.0 mol/L

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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 homogeneous mixture.
- T / (F) Most elements on the periodic table are classified as nonmetals. metals
- T / (F) Elemental sulfur exists as gas-phase diatomic molecules. $S_{8(s)}$
- T / (F) A change in colour always indicates a chemical change.

all or nothing.

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

4

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 gain electrons during reactions is: any nonmetal eg. F_2

c) The number of protons in an ^{75}As (arsenic-75) atom is: = atomic # = (33 p^+)

d) The name of the phase change from solid to gas: sublimation

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

0.75 – all or nothing 0.25 each

4

Substance name	Substance formula	Ionic or molecular substance?
potassium perchlorate	$KClO_4$	ionic
disulfur trioxide	S_2O_3	molecular
copper (II) phosphate	$Cu_3(PO_4)_2$	ionic
ammonium sulfate	$(NH_4)_2SO_4$	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.

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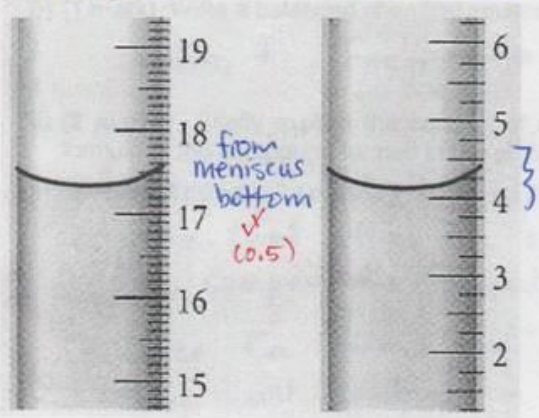
Volume A: 17.34 mL ✓ (0.5)

Volume B: 4.1? 4.13? ✓ (0.5)

Total volume & comments (few words only!):

Total = 4.1 mL + 17.34 mL = 21.44 mL

= 21.4 mL } (*) SF ✓ (0.5)



from meniscus bottom ✓ (0.5)

} estimate level between scale's smallest divisions ✓ (0.5)

(0.5) ✓ explanation

(*) Significant figures for addition limited to # decimal places given in least precise measurement used....

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PART B: Short written answers

 # 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 25.00 mL of glacial acetic acid at 25°C in enough water to make 125.00 mL of solution.

$CH_3COOH \rightarrow MM = 60.05$ g/mol

molarity = concentration (moles solute / liters of solution) $\left[c = \frac{n}{V}\right]$

- Find moles of CH_3COOH used: in our 25.00mL of pure liquid CH_3COOH

$d = \frac{m}{V} \therefore m = d \times V$
$= (1.049\ g/mL)(25.00\ mL)$
$= 26.225\ g\ CH_3COOH$

$n = \frac{m}{MM} \therefore n = \frac{26.225\ g}{60.05\ g/mol}$
$= 0.43672\ mol\ CH_3COOH \Rightarrow$ now dissolve it...

- Calculate molarity: $c = \frac{n}{V}$ ← 125.00 mL solution = 0.12500 L

$= \frac{0.43672\ mol}{0.12500\ L}$

$\therefore c = 3.494\ M$ ⇐ 4 SF (d & V data) (−0.25 if incorrect SF)

4

 # 11. (4 marks) When elemental calcium is reacted with elemental fluorine, a white solid commonly known as the mineral *fluorite* is formed.

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

ionic (metal plus nonmetal yields ionic compound)

b) **(1 mark)** Write a balanced chemical equation for this reaction.

$Ca_{(s)} + F_{2(g)} \rightarrow CaF_{2(s)}$

} charges NOT present until after the rxn!

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.

- electroneutrality: compounds must be composed of ions in a ratio that gives an equal # of ⊕ and ⊖ charges overall. i.e. compound's formula ⇒ neutral crystal is represented
- Since Ca forms Ca^{2+} cations & F forms F^- anions, they must combine in a $1\ Ca^{2+} : 2\ F^-$ ratio ⇒ CaF_2.

4

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

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

- 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 $m_{XCl_3} = 0.2360\,g$
  $0.5000\,g = m_X + m_I$ ✓ and $0.2360\,g = m_X + m_{Cl}$ ✓
  $\therefore m_X = 0.2360\,g - m_{Cl}$
  (combine equations)
  all X converted from XI_3 to XCl_3, so no mass of X lost! (✓)

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

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

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 2.00 g of sodium bicarbonate and 2.00 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.**

• To find limiting reactant, must compare rxn stoichiometry with actual mole quantities of reactants: (several ways to show it...)

(2)

$$\#n_{NaHCO_3} = \frac{2.00\ g}{84.005\ g/mol} = 0.02381\ mol\ NaHCO_3$$

$$\#n_{H_3C_6H_5O_7} = \frac{2.00\ g}{192.117\ g/mol} = 0.01041\ mol\ citric\ acid$$

(4) Reaction requires $\frac{3\ NaHCO_3}{1\ H_3C_6H_5O_7}$ ✓; we have $\frac{0.02381}{0.01041} = \frac{2.29}{1}$

⇒ Not enough $NaHCO_3$ to consume all the citric acid.

∴ $NaHCO_3$ = Limiting reactant (LR)

• Theoretical yield based on LR:

(3) $\frac{\text{Need } 3\ mol\ NaHCO_3}{\text{to make } 3\ mol\ CO_2} = \frac{0.02381\ mol\ used}{x\ mol\ CO_2\ made}$ ⇒ $x = 0.02381\ mol\ CO_2$

(1) Convert to mass in grams:

$$n = \frac{m}{MM} \Rightarrow m = (0.02381\ mol\ CO_2)(44.009\ g/mol\ CO_2)$$

$$= 1.0479\ g$$

∴ $m = 1.05\ g\ CO_2$ 3SF due to m data & ×/÷ SF 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

= 0.01041 − 0.007937

= 0.00247 mol left over

$m = n \times MM$ ∴ $m = (0.00247\ mol)(192.117\ g/mol)$

= 0.475 g remaining (unreacted)

$\frac{1\ H_3C_6H_5O_7}{3\ NaHCO_3} = \frac{y}{0.02381}$

∴ $y = 7.937 \times 10^{-3}$ mol used

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