Concordia University CHEM 205

Fall 2009, Dr. C. Rogers, Section 01 T/J (Tues/Thurs)

A

LAST NAME: Rogers

FIRST NAME: marking scheme

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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Dr. C. Rogers, Section 01 T/J

(A)

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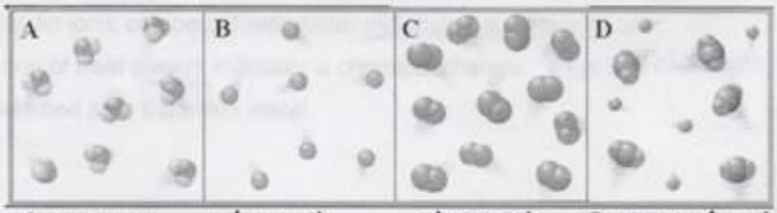
PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

 # 1. (2 marks) The figures below represent four 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 total mass of materials is not affected by a chemical change of those materials." What kind of statement is this?

D

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?

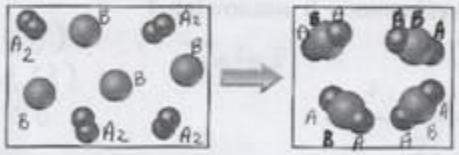
D

a) T J. Dalton proposed his atomic theory, in which he (incorrectly) postulated that all atoms of the same element are identical.
b) T The Curies showed that atoms are made of smaller particles, based on their observations of radioactive decay.
c) T J.J. Thomson proposed the plum-pudding model of the atom, based on his cathode-ray tube experiments.
d) F R. Millikan determined the charge and mass of the proton, 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. Based on the diagram, which equation best describes the reaction?

B

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



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

Net rxn: $A_2 + B \rightarrow A_2B$

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

E

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

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

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.)*

T / (F) A temperature change will be greater if expressed in Kelvins compared to Celsius. (ΔT, × same)

(T) / F A hydrated compound is an ionic compound with water molecules in its crystal. ✓

T / (F) The release or absorption of heat always indicates a chemical change. phase changes too!

(T) / F Manganese (Mn) is classified as a transition metal.

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

a) An example of a lab technique used to separate mixtures is: filtration, distillation, chromatography...

b) The melting point of lead (327.46°C) on the Kelvin scale is: 327.46 + 273.15 = 600.61 K

c) The number of neutrons in a ^{31}P (phosphorus-31) atom is: 31 − 15 p^+ = 16 n^0

d) An element that tends to gain electrons in reactions is: a nonmetal eg. F_2, O_2 etc

4

 # 8. (4 marks) Write the missing name or formula, and classify each substance by type: 0.25 all-or-nothing 0.25

Substance name	Substance formula	Ionic or molecular substance?
cobalt (III) nitrate	$Co(NO_3)_3$	ionic
ammonium hydrogen phosphate	$(NH_4)_2HPO_4$	ionic
dinitrogen tetroxide	N_2O_4	molecular
potassium sulfide	K_2S	ionic

4

 # 9. (3 marks) Determine the volume (mL) 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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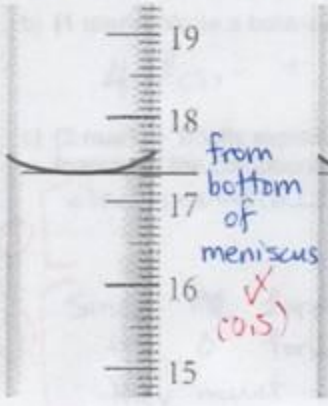
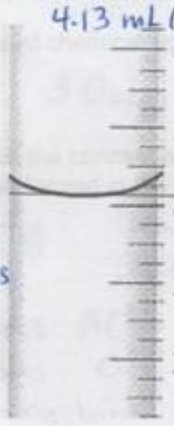
Volume A: 17.31 mL ✓ (0.5)



Volume B: ≈ 4.1 mL (?) ✓ (0.5) 4.13 mL (?)



Total volume & comments (a few words!):

Total = 17.31 mL + 4.1 = 21.41 mL ≈ 21.4 mL

↑ SF ✓ (0.5)

explain ✓ (0.5) for addition, SF are limited by # of decimal places in least precise measurement used.

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PART B: Short written answers

 # 10. (4 marks) Glycerol, $C_3H_8O_3$, is a substance used extensively in the manufacture of cosmetics, foodstuffs, antifreeze and plastics. Glycerol is a water-soluble liquid with a density of 1.2656 g/mL at 15°C. Calculate the molarity of a solution of glycerol made by dissolving 40.00 mL of glycerol at 15°C in enough water to make 250.00 mL of solution.

→ MM = 92.094 g/mol

molarity = concentration (n_{solute} / $V_{solution}$ ⇐ in L) moles/L

$c = \frac{n}{V}$

- Find # mol of glycerol dissolved (i.e. in 40.00mL liquid glycerol)

use $d = \frac{m}{V}$ ∴ $m = dxV$ = (1.2656 g/mL)(40.00 mL)

= 50.624 g glycerol

and $n = \frac{m}{MM}$ ∴ $n = \frac{50.624\ g}{92.094\ g \cdot mol^{-1}}$

= 0.54970 mol glycerol.

−0.25 for any premature rounding

- Calculate concentration when this is dissolved in water

$c = \frac{n}{V} = \frac{0.54970\ mol\ glycerol}{0.25000\ L\ solution}$ ← 250.00mL × 1 L / 1000 mL

= 2.1988 mol/L

−0.25 if error in SF

∴ C = 2.199 M ⇐ 4SF due to $V_{glycerol}$ data (×/÷ rules)

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 # 11. (4 marks) When elemental aluminum reacts with elemental oxygen, a white solid is formed.

Al(s) reacts with $O_{2(g)}$ ⇒ neither element charged yet.

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

ionic: metal + nonmetal. (yields electron transfer → ions)

1

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

$4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$

1

- No CHARGES until AFTER the reaction!
- atoms must balance

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.

2

① electroneutrality: total charge on ions in crystal must balance such that formula of compound appears neutral.

① Since Al forms Al^{3+} (loses $3e^-$ when forms cation) + O forms O^{2-} (gains $2e^-$ when forms anion), they must combine in a $\underbrace{2Al^{3+}}_{6+} : \underbrace{3O^{2-}}_{6-}$ ratio, hence Al_2O_3.

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(A) + (B)

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

#12. (8 marks) The minerals calcite ($CaCO_3$), magnesite ($MgCO_3$) and dolomite (1:1 $CaCO_3$:$MgCO_3$) decompose when strongly heated to form the corresponding metal oxide(s) and carbon dioxide gas.

A 1.000 g sample known to be one of these minerals was strongly heated and 0.477 g of CO_2 was obtained. Which of the three minerals was it?

WORTH 1

Include balanced chemical equations, and explanatory comments at each step of your calculation.

OPTION ① ✓ $CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$

$m = 1.000\ g$
$MM = 100.09\ g/mol$ ✓

$m = 0.477\ g$
$MM = 44.01\ g/mol$ ✓

$\#n_{CO_2} = 0.01084$ mol CO_2 formed ✓

(1) + (2) + (0.5)

The reaction stoichiometry indicates a 1:1 ratio between CO_2 formed & $CaCO_3$ consumed. ✓ So, if our 1-g mineral sample was calcite, it must have contained 0.01084 mol of $CaCO_3$.

Let's check: $\#n_{CaCO_3} = \frac{1.000\ g}{100.09\ g \cdot mol^{-1}} = 9.99 \times 10^{-3}$ mol ✓

✓ close but not 0.01084 mol
∴ probably not calcite.

OPTION ② ✓ $MgCO_{3(s)} \longrightarrow MgO_{(s)} + CO_{2(g)}$

(2) $m = 1.000\ g$
$MM = 84.313\ g/mol$ ✓
$\therefore n = 0.01186$ mol ✓ ⇐ Similarly, likely not magnesite ✓

OPTION ③ ✓ $CaCO_3 : MgCO_3$

i.e. $CaMg(CO_3)_2{}_{(s)} \longrightarrow CaO_{(s)} + MgO_{(s)} + 2\,CO_{2(s)}$

(2) + (0.5) $m = 1.000\ g$
$MM = 184.403\ g/mol$ ✓
$\therefore n = 5.423 \times 10^{-3}$ mol ✓ ⇐ But, get 2x that much CO_2 ✓ since 1 dolomite : $2CO_2$ ∴ 0.01085 mol

∴ the mineral = DOLOMITE ✓

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"Brute force method" (i.e. trial-and-error), but it's simple. Could also do it via calculating theoretical yield of CO_2 from each (almost same as done here, just other direction of thinking.).

(#12) 3 possibilities:

calcite: $CaCO_{3(s)} \xrightarrow{HEAT} CaO_{(s)} + CO_{2(g)}$

magnesite: $MgCO_{3(s)} \xrightarrow{HEAT} MgO_{(s)} + CO_{2(g)}$

dolomite: $CaMg(CO_3)_{2(s)} \xrightarrow{HEAT} CaO_{(s)} + MgO_{(s)} + 2\,CO_{2(g)}$

Sample releases 0.477g CO_2 via decomposition (i.e. all atoms from CO_2 came directly from the mineral itself). Thus, can analyze mass % CO_2 in each mineral to identify it.

calcite: $\frac{MM_{CO_2}}{MM_{CaCO_3}} \times 100\% = \frac{44.01}{100.09} \times 100\% = 44.0\%$

magnesite: $\frac{MM_{CO_2}}{MM_{MgCO_3}} \times 100\% = \frac{44.01}{84.313} \times 100\% = 52.2\%$

dolomite: $\frac{(MM_{CO_2}) \times 2}{MM_{CaMg(CO_3)_2}} \times 100\% = \frac{88.02}{184.403} \times 100\% = 47.7\%$

↑ because...

and our sample was: 1.000g total $\Rightarrow \frac{0.477g\ CO_2}{1.000g\ total} = 47.7\%\ CO_2$

Thus: the mineral was DOLOMITE.

#12. Carbonate Mineral $\xrightarrow{\text{heat}}$ metal oxide + $CO_{2(g)}$

$$MCO_{3(s)} \longrightarrow MO_{(s)} + CO_{2(g)}$$

$MM = MM_{M^{2+}} \; MM_{CO_3^{2-}}$

M^{2+}: metal ion one of Ca, Mg or "$\frac{1}{2}Ca\,\frac{1}{2}Mg$"

$MM = 44.01$ g/mol

$m = 0.477$ g

$\therefore n_{CO_2} = \frac{0.477\text{ g}}{44.01\text{ g/mol}} \doteq 0.01084$ mol CO_2

Stoichiometry indicates 1 CO_2 : 1 MCO_3 decomposed

$\therefore n_{MCO_3} = 0.01084$ mol $\}$ $n = \frac{m}{MM}$ ...

given $m = 1.000$ g

$\therefore MM_{MCO_3} = \frac{1.000\text{ g}}{0.01084\text{ mol}} \doteq 92.251$ g/mol of MCO_3

$MM_{M^{2+}} = 92.251 - MM_{CO_3^{2-}} = 92.251 - 60.008$

$= 32.243$ g/mol of M^{2+}

NOTE: if mineral is calcite, $M^{2+} = Ca^{2+}$ 40.08 g/mol ⊗

magnesite, $M^{2+} = Mg^{2+}$ 24.305 g/mol ⊗

What if it's dolomite: 1 $CaCO_3$: 1 $MgCO_3$ $\}$ "M" is half Ca & half Mg

OR $CaMg(CO_3)_2(s)$

i.e. $M_M = \frac{1}{2}(40.08) + \frac{1}{2}(24.305)$

$= 32.19$ g/mol ✓

proof (2)

Another proof that it's dolomite:

proof (2)

$CaMg(CO_3)_{2(s)} \longrightarrow CaO_{(s)} + MgO_{(s)} + 2CO_{2(g)}$ EQN CHOSEN

$MM = 184.401$ g/mol

$m = 1.000$ g

$\therefore n = 5.423 \times 10^{-3}$ mol, but 1 dolomite : 2 CO_2 via reaction

$\therefore n_{CO_2} = 2 \times (5.423 \times 10^{-3}\text{ mol}) = 0.01085$ mol CO_2 forms ✓

= observed quantity

 # 13. **(12 marks)** One of the steps in the commercial process for converting ammonia to nitric acid involves the conversion of ammonia to nitrogen monoxide:

$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$$

In a certain experiment, imagine you mix 2.50 g of NH_3 with 2.85 g of O_2, and obtain 100% yield. } mass data has 3 SF...

a) **(10 marks)** How many grams of NO form? **Show all work & include explanatory comments.**

- First must identify limiting reactant: (several ways to do this ...)

(2) Have: $n_{NH_3} = \frac{2.50\ g}{17.031\ g/mol} \doteq 0.1468\ mol$ ✓ DO NOT round: MM's! or intro. calculations below "SF+1" limit!

$n_{O_2} = \frac{2.85\ g}{31.998\ g/mol} \doteq 0.08907\ mol$ ✓ ← we don't have enough! ✓

(4) To use all the NH_3 (i.e. let's check if it is L.R...):

4 mol NH_3 needed ✓ = if 0.1468 mol NH_3 used ✓ ⇒ $x = 0.1835$ ✓ mol O_2
to use 5 mol O_2 — then x mol O_2 needed

Thus: O_2 is LIMITING ✓ REACTANT
NH_3 is in EXCESS! ✓

- Now can calculate theoretical yield of NO, based on using all the LR:

(3) if use 5 mol O_2 = form 4 mol NO ⇒ $y = 0.07125$ mol NO ✓
have 0.08907 mol — y mol NO forms ✓

(1) ∴ mass of NO produced = $n \times MM_{NO}$
$= (0.07125\ mol)(30.0057\ g/mol)$
$= 2.1379\ g$

$\therefore m_{NO} \doteq 2.14\ g$ (3SF due to reactant mass data)

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

(2) unreacted NH_3 = initial NH_3 − consumed NH_3 } for 4 mol NH_3 need 5 mol O_2 ✓ = Z mol NH_3 used / 0.08907 mol O_2 used

$= 0.1468 - 0.07125$ mol

$= 0.07555$ mol NH_3 remains.

∴ Z = 0.07125 mol NH_3 consumed.

OR $m_{NH_3} = 1.29$ g unreacted NH_3. // (1.21 g used)

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