Concordia University CHEM 205

Fall 2009, Dr. C. Rogers, Section 01 T/J

Tues/Thurs

B

LAST NAME: Rogers

FIRST NAME:

STUDENT ID: marking scheme

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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(B)

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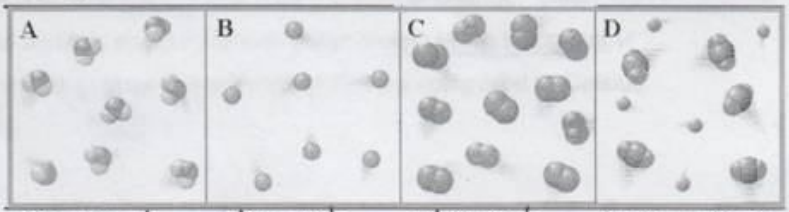
PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

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

D

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



 # 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?

B

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

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

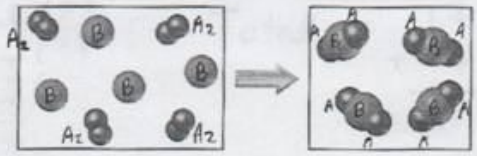
E

a) T The Curies showed that atoms are made of smaller particles, based on their observations of radioactive decay.
b) T J. Dalton proposed his atomic theory, in which he (incorrectly) postulated that all atoms of the same element are identical.
c) T J.J. Thomson proposed the plum-pudding model of the atom, based on his cathode-ray tube experiments.
d) T E. Rutherford proposed the nuclear model of the atom, based on his gold-foil experiments.
e) F R. Millikan determined the charge and mass of the proton, using his "oil-drop" 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?

D

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



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 $Mn_2(SO_4)_3$?

A

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

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

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.)*

4

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

T / (F) The release or absorption of heat always indicates a chemical change. what about phase changes?

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

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

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

4

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

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

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

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

 # 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?
dinitrogen tetroxide	N_2O_4	molecular
potassium hydrogen phosphate	K_2HPO_4	ionic
Cobalt (III) nitrate	$Co(NO_3)_3$	ionic
ammonium sulfide	$(NH_4)_2S$	ionic

 # 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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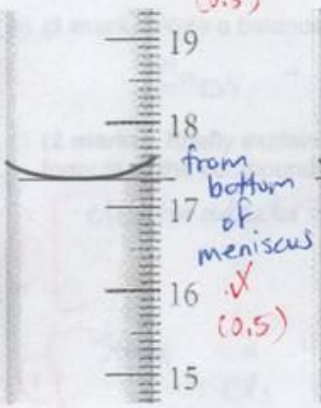
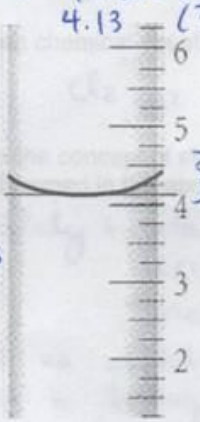
Volume A: 17.31 mL ✓ (0.5)



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



Total volume & comments (a few words!):

Total = 17.31
+ 4.1
21.1 = 21.4 mL
✓ (0.5) ↑ SF!

(0.5) ✓ explain
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 30.00 mL of glycerol at 15°C in enough water to make 250.00 mL of solution.

molarity = concentration in $\frac{\text{moles}}{\text{L}}$ ← solute ✓ ← solution ie: $c = \frac{n}{V}$

- Find # mol glycerol (solute) ← provided by the 30.00mL used.

$d = \frac{m}{V} \Rightarrow m = dxV$ ✓ $= (1.2656\ \frac{g}{mL})(30.00\ mL)$

$= 37.968\ g$ ✓ glycerol dissolved

and $n = \frac{m}{MM}$ ✓ $\Rightarrow n = \frac{37.968\ g}{92.094\ g \cdot mol^{-1}}$ ✓

$= 0.4123$ ✓ mol glycerol dissolved

−0.25 for any premature rounding

- Calculate concentration now that this glycerol is in 250.00mL solution.

$c = \frac{n}{V} = \frac{0.4123\ mol\ glycerol}{0.25000\ L\ solution}$ ← $250.00\ mL \times \frac{1\ L}{1000\ mL}$ ✓

$= 1.649\ mol/L$ ✓

$\therefore c = 1.649\ M$ ⇐ 4 SF due to $V_{glycerol}$ used (x/÷ rules)

−0.25 if SF error

4

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

$Ca_{(s)}$ reacts with $Cl_{2(g)}$ ⇒ neither charged yet.

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

1 ionic because Ca = metal, Cl_2 = nonmetal } always yield ionic compound (via e^- transfer to form ions)

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

1 $Ca_{(s)} + Cl_{2(g)} \longrightarrow CaCl_{2(s)}$

- NO charges until AFTER the reaction!
- atoms must balance.

4

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: total charge on ions in an ionic compound's crystal must balance out to yield a neutral substance over all

① Since Ca is an alkali earth metal, it loses $2e^-$ to form Ca^{2+}
Cl_2 is a halogen, each Cl atom gains $1e^-$ to form Cl^-
∴ need 1 Ca^{2+} : 2 Cl^- to yield a neutral formula
(2+) (2−)
∴ $CaCl_2$

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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 2.85 g of NH_3 with 2.50 g of O_2, and obtain 100% yield.

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

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

(2) Have: $n_{NH_3} = \frac{2.85\ g}{17.031\ g/mol} = 0.1673\ mol$

$n_{O_2} = \frac{2.50\ g}{31.998\ g/mol} = 0.07813\ mol$

present in ratio $\frac{n_{NH_3}}{n_{O_2}} = \frac{2.14}{1}$ (normalized moles)

(4) Need: $\frac{n_{NH_3}}{n_{O_2}} = \frac{4}{5}$ from rxn stoich. $\Rightarrow \frac{0.8}{1}$ ratio needed

Compare: in order to use all the O_2, we need 0.8× as much NH_3 and we have 2.14× as much ∴ excess NH_3

∴ LR = O_2.

- Now can calculate theoretical yield, based on using up the LR:

(3) if use 5 mol O_2 = form 4 mol NO
we have 0.07813 mol = x mol NO
$\Rightarrow x = 0.06250\ mol\ NO$

(1) ∴ mass of NO formed = $n \times MM_{NO}$
$= (0.06250\ mol)(30.0057\ g/mol)$
$= 1.875\ g$

$\therefore m_{NO} = 1.88\ g$ ← 3 sf (from mass data provided)

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

- Unreacted NH_3 = Original NH_3 − amount NH_3 consumed
$= 0.1673\ mol - 0.06250\ mol$
$= 0.105\ mol$ left.

for 4 mol NH_3 = y mol NH_3 used
need 5 mol O_2 = 0.07813 mol O_2 used
$y = 0.06250\ mol\ NH_3$ used

- if convert to mass: 1.78 g leftover NH_3 //

2/12