Concordia University CHEM 205 Fall 2006
Dr. C. Rogers, Section 01 T/J -- MIDTERM EXAM

Student ID #: Rogers

Chem 205: GENERAL CHEMISTRY I
MIDTERM EXAMINATION

PLEASE READ THIS PAGE WHILE WAITING TO START

INSTRUCTIONS: This test paper includes 8 pages, including a periodic table; please check that your paper is complete. You may detach the periodic table if you wish. For Part A, you do not need to show calculations; for Part C, you must show your calculations to receive full marks. Please write clearly and organize your work logically. Non-programmable calculators are permitted; book-style translation dictionaries are allowed, but electronic dictionaries and cell phones are not allowed.
Duration: 70 minutes - spend at least half that time on Parts B & C. **GOOD LUCK!**

LAST NAME: marking scheme FIRST NAME: _____

STUDENT NUMBER: _____

Mark breakdown:

	Averages	%
Page 2.	8.5 / 14	61.0
Page 3.	5.1 / 10	50.6
Page 4.	3.9 / 6	64.5
Page 5.	4.6 / 11	42.1
Page 6.	4.3 / 10	42.5
	26.3	

TOTAL: ~~___~~ / 50 (MAXIMUM MARK = 51) 48

PERCENT: ~~___~~ % 55%

EARNED towards FINAL GRADE: ~~___~~ / 20 = 11/20.

counted in my records as graded out of 48

(so, recalculate your grade yourselves)

adjusted average

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PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

 # 1. (__/ 3 marks) Identify the following statements as true or false. *(Circle T or F.)*

F T / (F) The last digit in any measurement is estimated, so it is uncertain and not significant.

T (T) / F A sample containing 1.2×10^{15} atoms could be described as 2.0 nanomoles of atoms. $= 2.0 \times 10^{-9}$ mol

F T / (F) When sugar melts, the arrangement and composition of the sugar molecules change.
physical change

 # 2. (__/ 3 marks) Fill in the blanks:

a) Number of neutrons in ^{197}Au (*i.e.*, gold-197) 118 $= 197 - 79p^+$

b) Formula of a common strong base NaOH

c) Products of the decomposition of H_2CO_3 $CO_{2(g)} + H_2O_{(l)}$ ← 0.5 each

 # 3. (__/ 4 marks) Write each compound's formula or name, **and** circle *ionic* or *molecular* to describe each:

a) potassium phosphate K_3PO_4 (ionic) / molecular ? M + NM's

b) carbon tetrachloride CCl_4 ionic / (molecular) ? NM + NM

c) $Cr_2(SO_4)_3$ chromium (III) sulfate (ionic) / molecular ? M + NM's

d) N_2O dinitrogen monoxide ionic / (molecular) ? NM + NM

no part marks except forgive absent brackets -0.25 0.5 each 0.5 each

 # 4. (__/ 2 marks) Which of the following groups of elements is so reactive towards water and/or oxygen that they are never found in elemental form in nature?

D
a) X group 14 (4A) Carbon etc
b) X group 15 (5A): pnictogens N_2, etc.
c) X group 16 (6A): chalcogens S_8 etc
(d) alkali metals Na, K...
e) X transition metals

if one wrong also, -1 per wrong one...

 # 5. (__/ 2 marks) All of the following statements are true EXCEPT

B
a) ✓ for any neutral element, the number of protons and electrons are equal.
(b) X electrons and protons have equal mass, but opposite charges.
c) ✓ the mass number is the sum of the number of protons and neutrons.
d) ✓ the atomic number equals the number of protons.
e) ✓ isotopes of an element have identical atomic numbers.

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 # 6. (__/ 2 marks) You are given an unknown white solid that may be either $Pb(NO_3)_2$ or $Zn(NO_3)_2$. If you prepare an aqueous solution of the unknown and test it by adding the various reagents listed below, which reagent will allow you to distinguish between the two compounds?

A

a) KBr — $PbBr_2$ insoluble $ZnBr_2$ soluble → make insoluble Pb^{2+} or Zn^{2+} salt...
b) HNO_3 — nitrates all soluble
c) CH_3CO_2H — acetates (if can make them...) all soluble
d) NH_4ClO_4 — perchlorates all soluble
e) $LiNO_3$ — nitrates all soluble

 # 7. (__/ 2 marks) What is the net ionic equation for the reaction of aqueous lithium hydroxide and aqueous nitric acid?

B

a) ✗ $H^+(aq) + LiOH(aq) \rightarrow H_2O(\ell) + Li^+(aq)$
b) $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
c) ✗ $HNO_3(aq) + LiOH(aq) \rightarrow H_2O(\ell) + LiNO_3(aq)$ molecular!
d) $Li^+(aq) + NO_3^-(aq) \rightarrow LiNO_3(aq)$ spectators!
e) ✗ $LiOH(aq) + H_2O(\ell) \rightarrow H^+(aq) + Li(OH)_2(s)$

$LiOH \quad HNO_3$
$Li^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + NO_3^-{}_{(aq)}$
$H_2O_{(l)} + Li^+_{(aq)} + NO_3^-{}_{(aq)}$

 # 8. (__/ 2 marks) Which one of the following chemical equations is an acid-base reaction? (H^+ from acid to base)

B

a) ✗ $2\,HCl(aq) + Zn(s) \rightarrow H_2(g) + ZnCl_2(aq)$ redox.
b) $HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$
c) ✗ $HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$ precipitation (no base... only acid)
d) $Ba(OH)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2\,NaOH(aq)$ precipitation (no acid, only base)
e) $2\,NaOH(aq) + CuCl_2(aq) \rightarrow Cu(OH)_2(s) + 2\,NaCl(aq)$ precipitation (no acid, only base)

 # 9. (__/ 2 marks) From the results of his gold foil experiment, Ernest Rutherford concluded that

E

a) ✗ electrons have a charge of -1.602×10^{-19} C.
b) atoms contain equal numbers of protons and electrons.
c) ✗ uranium ores emit a form of radiation that affect photographic plates. Curie
d) ✗ alpha particles are helium nuclei.
e) atoms are composed of a small, dense nucleus surrounded by a cloud of electrons.

 # 10. (__/ 2 marks) The density of lithium is 0.546 g/cm^3. What volume is occupied by 1.96×10^{23} Li atoms?

C

a) 0.0859 cm^3
b) 0.596 cm^3
c) 4.14 cm^3
d) 5.63 cm^3
e) 39.0 cm^3

① Find mass of 1.96×10^{23} Li atoms:

$$m = 1.96\times10^{23}\ \text{atoms} \times \frac{1\ \text{mole}}{6.022\times10^{23}\ \text{atoms}} \times \frac{6.941\ \text{g}}{1\ \text{mole}} = 2.259\ \text{g}$$

② Find volume using density:

$d = m/V$

$$\therefore V = m/d = \frac{2.259\ \text{g}}{0.546\ \text{g cm}^{-3}} = 4.137\ \text{cm}^3 \doteq 4.14\ \text{cm}^3$$

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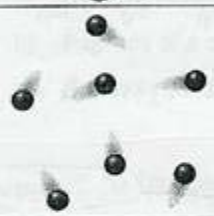
PART B: Check the right boxes...

 # 11. (__/ 6 marks) In the table, check (✓) ALL boxes that apply to the pictures in the boxes to the left. (Note: marks will be deducted for wrong choices.) ie: if choose ALL boxes, or if choose 2 states

	Solid	Liquid	Gas	Element	Ionic Compound	Covalent Compound	Mixture
	...STATES... WORTH 0.5			...SUBSTANCES PRESENT... WORTH 0.5 (all or nothing)			
	✓				✓		
			✓	✓			
			✓	✓		✓	✓
			✓			✓	
		✓		✓			
	✓			✓			

one from here WORTH 0.5

at least one from here (but must be all correct) WORTH 0.5

6

✓ = 0.5 marks
✓ = 0.25 marks

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PART C: Written answers & problems (detailed calculations & comments)

#12. (__/ 4 marks) Consider the following compounds: C_2H_5OH, C_3H_8, and $CH_3CH_2COCH_3$. If 1.5 mol of each compound is burned with excess oxygen, which one will produce the largest number of moles of H_2O? Which will produce the least? Explain, and include relevant chemical equations BALANCED

limiting reactant

4

eqn ✓ $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ ✓✓ LEAST H's...

Every 1 mol burned will yield 3 mol H_2O, so burning 1.5 mol will yield $3 \times 1.5 = 4.5$ mol H_2O. (least H_2O formed)

eqn ✓ $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ ✓ TIED FOR MOST ✓

eqn ✓ $2CH_3CH_2COCH_3 + 11O_2 \rightarrow 8CO_2 + 8H_2O$

$CH_3CH_2COCH_3 + \frac{11}{2}O_2 \rightarrow 4CO_2 + 4H_2O$ ✓

Every 1 mol substance burned will yield 4 mol H_2O, so 1.5 mol either substance will yield 6 mol H_2O.

The equations must be balanced to answer this question ✓ → worth 1.5

If only explained using # of H's in compounds, max = 2/4.

#13. (__/ 7 marks) A compound with formula $KBrO_x$ is analyzed and found to contain 52.92% Br by mass. Determine the value of x, and write the complete formula and name for this compound.

Plan: From formula, have 1:1 mol ratio of Br to K, but unknown O.

There are many possible routes...

① calculate # mol of Br in 100 g sample, = # mol K.
② calculate mass of K in 100 g sample, because $m_K + m_{Br} + m_O = 100\,g$
③ calculate mass of O, then # mol O
④ normalize # mol to Br (or K, same) to deduce x & formula

2.25 **Step ① $\#n_{Br} = \#n_K$ in sample of 100 g mass**

$m_{Br} = 0.5292 \times 100\,g = 52.92\,g$ Br ✓

$\#n_{Br} = \frac{52.92\,g}{79.904\,g\,mol^{-1}}$ ✓ $= 0.66229$ mol Br ✓

= # mol K since in 1:1 ratio in $KBrO_x$ ✓✓

0.75 **Step ② mass of K in sample**

$m_K = (0.66229\ mol\ K)(39.0983\ g\ mol^{-1})$ ✓✓

$= 25.895\,g$ K

1.25 **Step ③ mass of O in sample, + moles**

$m_O = 100\,g - 52.92\,g - 25.895\,g$ ✓

$= 21.185\,g$ O

$\#n_O = \frac{21.185\,g}{15.9994\,g\,mol^{-1}}$ ✓ $= 1.3241$ mol O

+2
+0.75
11

Step ④ normalize to find mol ratio

$\frac{\#n_O}{\#n_{Br}} = \frac{1.3241}{0.66229} \div 2$ ✓ i.e. x = 2

↑ same as $\#n_K$ ↕ same

⇒ So: have 1 Br : 1 K : 2 O ✓

⇒ Formula is $KBrO_2$ ✓

Name is potassium ✓ bromite ✓

hypobromite	BrO^-
bromite	BrO_2^-
bromate	BrO_3^-
perbromate	BrO_4^-

one of many...

Alternate approach to #13 (very efficient...)

Since 52.92% of $KBrO_x$'s mass is due to Br ($MM_{Br} = 79.904\ g/mol$) and every 1 mol $KBrO_x$ contains 1 mol Br...

2 [

$$\frac{52.92}{100} = \frac{79.904\ g \cdot mol^{-1}}{MM_{KBrO_x}} \Rightarrow MM_{KBrO_x} = 150.990\ g/mol$$

The mass of one mole of $KBrO_x$ consists of:

$$MM_{KBrO_x} = 1MM_K + 1MM_{Br} + x\,MM_O$$

(-1) if do not provide any labels

(-0.5) for excessive rounding!

3.75 $\Rightarrow 150.990 = 39.098 + 79.904 + 15.9994\,x$

$15.9994x = 31.988$

$x = 1.999$

$\doteq 2$

1.25]

$\therefore$ Formula is $KBrO_2$

Name is potassium bromite

(K^+) (BrO_2^-)

Another version:

Directly solve for mass of K in sample...

$$\frac{Br}{K} = \frac{79.904\ g \cdot mol^{-1}}{39.098\ g \cdot mol^{-1}} = \frac{0.5292}{y} \quad \therefore y = 0.2589$$

ie: 25.89% K by mass

Now: $100\% = 52.92\%\ Br + 25.89\%\ K + x\%\ O$

$x = 21.19\%\ O$ by mass

& can use to calculate moles + mole ratios...

√ = 1 mark √ = 0.5 marks √ = 0.25 marks −0.25 wrong SF −0.25 rounding error −0.5 math error

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 # 14. (__/ 10 marks) Lithium nitride is used to store hydrogen in a solid form via the following reaction:

$$Li_3N(s) + 2\,H_2(g) \rightarrow LiNH_2(s) + 2\,LiH(s)$$

(+I, −III; 0; +I, −III; +I; +I, −I) } oxidation states change, although only for hydrogen.

a) **(1 mark)** What type of reaction is this? *(circle all that apply)*

1 — acid-base (also correct) — gas-forming — (oxidation-reduction) — precipitation — none of these

b) **(2 marks)** Which reactants *(if any)* can be described by each term below? How you can tell (be specific!)?

2 — Acid: H_2 loses H^+ to form H^- — any of this is fine

Base: Li_3N (0.5) → gains H^+ (twice) (0.5)

Oxidizing agent: H_2 ⇒ because 1H is reduced (ox.# 0 → −I in LiH) by stealing $1e^-$

Reducing agent: H_2 ⇒ because 1H is oxidized (ox. # 0 → +I in $LiNH_2$) by losing $1\,e^-$ (0.5) (0.5)

c) **(7 marks)** The reaction can proceed in reverse if the solid products are heated, which releases the stored hydrogen. If the reverse reaction occurs in 92% yield, how many grams of H_2 would be released by heating a mixture of 33.6 g of $LiNH_2(s)$ and 12.3 g of LiH(s)?

0.5 $LiNH_2(s) + 2\,LiH(s) \rightarrow Li_3N(s) + 2\,H_2(g)$ in 92% yield.

$m = 33.6\,g$, $MM = 22.964\,g/mol$ — $m = 12.3\,g$, $MM = 7.949\,g/mol$ — $m = ?$, $MM = 2.016\,g/mol$

① Find quantities of reactants

1.5 $n_{LiNH_2} = \frac{33.6\,g}{22.964\,g/mol} = 1.463\,mol\ LiNH_2$ ✓ $n_{LiH} = \frac{12.3\,g}{7.949\,g/mol} = 1.547\,mol\ LiH$ ✓

② Find limiting reactant:

If use 1 mol $LiNH_2$ (1.463 mol) : need 2 mol LiH (x) ✓

2.0 ⇒ need $x = 2.926$ mol LiH to use up $LiNH_2$ ✓

have 1.547 mol ✓ LiH (not enough)

∴ LiH(s) is limiting reactant ✓

Alternate approach to L.R.:

Need 1 mol $LiNH_2$ ✓ : Have 1.463 mol ✓ / 1.547 mol

2 mol LiH

$= \frac{1}{1.058}$

⇒ not enough LiH ✓

∴ LiH(s) is limiting reactant ✓

③ Find theoretical yield using L.R. ✓

2.0 use 2 mol LiH (1.547 mol) : produce 2 mol H_2 (x) ✓

1.0 ⇒ produce $x = 1.547$ ✓ mol H_2 max.

$m_{H_2} = (1.547\,mol)(2.016\,g \cdot mol^{-1})$ ✓

$= 3.119\,g$ theoretical yield.

④ Find actual yield expected:

$0.92 = \frac{\text{actual yield}}{\text{theoretical yield}}$ ✓ (2SF)

∴ actual $= (0.92)(3.119\,g)$

$= 2.87\,g$ ✓ (2SF...)

∴ We expect to form 2.9 g of $H_2(g)$.

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Please see comments on following page

Re: Question # 14, parts (a) and (b).

This reaction is an unusual reaction in that it can be correctly classified in two different ways (*i.e.,* two fundamentally different basic types of reaction).

1.) Oxidation-reduction: involves transfer of electrons, thus results in changes in oxidation states

This part I was expecting you to be able to work out – it is clearly redox, since you start with elemental hydrogen and end with hydrogen in compounds. The hard part of this question is identifying the oxidizing agent and reducing agent, which is not as easy for this reaction as it is for many reactions.

- Hydrogen changes oxidation state from (0) in $H_2(g)$ to (+I) in $LiNH_2$ and (-I) in LiH.
- One atom of H is oxidized (0 → +I) & the other atom of H is reduced (0 → -I).
- No other elements change oxidation state during the reaction.
- $H_2(g)$ is <u>both</u> the oxidizing agent (causes oxidation, thereby itself gains electron(s) & is reduced) & the reducing agent (causes reduction, thereby itself loses electron(s) & is oxidized).
- When two atoms of the same element in the same molecule trade electrons with each other, the phenomenon is called disproportionation (not a term we learned in this class).
- Another example of disproportionation is a reaction we did see in class: $H_2O_2 \rightarrow H_2O + \frac{1}{2} O_2$, where one atom of O(-I) in hydrogen peroxide is reduced to O(-II) in water and the other atom O(-I) is oxidized to O(0) in oxygen gas.

2.) Acid-base: involves transfer of protons (H+)

I was not expecting you to notice this classification.

- The N^{3-} anion in Li_3N takes H^+ from H_2 to form NH^{2-}, leaving behind H^- (what is left of H-H after H^+ has been removed).
- This NH^{2-} reacts with another H_2 (by removing a H^+) to form NH_2^-, leaving behind a second H^-.
- The H- anions formed end up as LiH, and the NH^{2-} anions end up as $LiNH_2$.
- THUS: the nitride anion acted as a base, while the hydrogen gas acted as an acid (unusual).