Concordia University CHEM 205 Winter 2007
Dr. C. Rogers, Section 04 W/F -- 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 ensure 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. 7.9 / 12 = 65.5%
Page 3. 8.2 / 15 = 54.6%
Page 4. 2.1 / 8 = 26.6%
Page 5. 3.9 / 7 = 56.3%
Page 6. 3.2 / 10 = 31.7%

TOTAL: 25.3 / ~~50~~ (MAXIMUM MARK = 52) marked out of 47

PERCENT: % 53.8%

EARNED towards FINAL GRADE: / 20

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PART A: ONLY YOUR FINAL ANSWER WILL BE MARKED

 # 1. (2 marks) Which three elements are likely to have very similar chemical and physical properties?

C
a) sodium, magnesium, and aluminum ×
b) carbon, phosphorus and selenium ×
c) fluorine, chlorine, and bromine all halogens
d) zinc, copper, and nickel ×
e) uranium, plutonium, and americium ×

→ in same group

 # 2. (2 marks) Bromine has two naturally occurring isotopes. If 50.54% of bromine is found as ^{79}Br (78.9183 amu), what is the mass of the other isotope? The average mass of bromine is 79.904 amu.

C
a) 79.82 amu
b) 79.97 amu
c) 80.91 amu
d) 81.93 amu
e) 82.91 amu

$79.904\ amu = 0.5054(78.9183\ amu) + (1-0.5054)x$
$40.0189 = 0.4946x$
$x = 80.91\ amu$

 # 3. (2 marks) You are given a white solid that is either $Pb(NO_3)_2$ or $Zn(NO_3)_2$. Which one of the following reagents (available as aqueous solutions) would allow you to distinguish between these two compounds?

A
a) KBr
b) × HNO_3
c) ×× CH_3CO_2H
d) ××× NH_4ClO_4
e) × $LiNO_3$

Pb^{2+} vs. Zn^{2+}
$PbBr_2$ ↑ exception (insoluble)
$ZnBr_2$ ↑ normal halide (soluble)

× all NO_3 salts = soluble
×× all acetates = soluble
××× all perchlorates = soluble

 # 4. (2 marks) The molecular model below depicts a molecule composed of carbon (black), oxygen (gray), and hydrogen (white) atoms. What is the correct empirical formula?

E
a) CHO
b) $C_6H_6O_2$
c) C_6H_7O
d) C_7H_6O
e) $C_7H_6O_2$

molecular: $C_7H_6O_2$
empirical = same since not possible to simplify ratio more + maintain whole numbers

 # 5. (2 marks) All of the following are examples of *intensive* (also called *intrinsic*) properties EXCEPT

B
a) melting point. ✓
b) mass
c) colour. ✓
d) density. ✓
e) boiling point. ✓

↳ characteristic of substance
≈ independent of sample size

 # 6. (2 marks) Pennies made after 1983 have a mass of 2.46 g and are composed of 97% zinc and 3.0% copper. How many atoms of copper are in a penny?

A
a) 0.0012 mol
b) 0.014 mol
c) 0.038 mol
d) 0.040 mol
e) 25 mol

3.0% = 0.030 of mass

$2.46\ g \times 0.030 = 7.380 \times 10^{-2}\ g\ Cu$

$\#n_{Cu} = \frac{7.380 \times 10^{-2}\ g}{63.546\ g \cdot mol^{-1}} = 1.16 \times 10^{-3}\ mol$

$\doteq 1.2 \times 10^{-3}\ mol$ of atoms

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✓ = 1 ½ = 0.5 ¼ = 0.25

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 # 7. (3 marks) Identify the following statements as true or false. *(Circle T or F.)*

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

(T) / F A solution's pH value always has more digits than the solution's H^+ concentration. eg 1.0×10^{-8} M H^+ ⇒ pH = 8.00 (2 digits 2 SF total; 3 digits (2 S.F.))

T / (F) For the reaction below, 1 gram of C_3H_8 would yield 4 grams of water vapour:

$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$ } mole ratios, not masses!

3

 # 8. (3 marks) Fill in the blanks:

a) An example of an element that exists as free atoms (ie, not molecules): He, Ne, etc (any noble gas, or metal)

b) Liquid nitrogen's boiling point (77 K) in Celsius: −196 °C = (−273) + 77

c) Number of electrons in a ^{48}Ti (titanium-48) atom: 22 = same as atomic number (Z = # p^+)
↳ same as # protons

3

 # 9. (3 marks) Write the missing name or formula, and classify each substance by type:

−0.25 for unnecessary brackets

Substance name	Substance formula	Ionic or molecular substance?
potassium acetate = CH_3COO^-	$KC_2H_3O_2$ 0.75	0.25 ionic (M + NM's)
sulfur trioxide	SO_3 0.75	0.25 molecular (NM + NM)
copper (I) phosphate	Cu_3PO_4 0.75	0.25 ionic (M + NM's)

−0.25 0.25 0.25 0.25

$(PO_4^{3-}) + (Cu^{+}) \times 3$

3

 # 10. (3 marks) Draw particulate-level pictures (*i.e.*, 1 atom = ●) of the molecules involved in a small sample of Br_2 in each of the three states of matter. Use a sample size of approximately 6 molecules.

Br_2 = ●● diatomic ≈ 0.75

Solid state (close-packed)	Liquid state (touching + mobile)	Gaseous state (not touching)
well-ordered crystal	disorganized but still in contact	
0.75	0.75	0.75
−0.25 if ionic	−0.25 if not...	−0.5 if molecules BREAK!!

3

 # 11. (3 marks) Classify the two reactions below, and briefly justify your choices. Use as many of the following "type" labels as apply to each reaction: **precipitation, acid-base, gas-forming *or* redox**.

Reaction	Reaction type(s)	How did you decide?
0.25 $2\ NaBr(aq) + F_2(g) \rightarrow 2\ NaF(aq) + Br_2(\ell)$ (soluble; soluble; not solid)	oxidation-reduction (redox) 0.5	• elemental fluorine F(0) gains e^- to form F(−I) while Br(−I) loses e^- to form Br(0) in Br_2 • change in ox. state ⇒ e^- transfer. 0.75
0.25 $CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(s)$ (solid; liquid; insoluble solid)	acid-base 0.5	• H^+ transferred from H_2O to O^{2-} to form OH^- and OH^- (new bonds to H^+) • H^+ transfer ⇒ acid-base rxn. 0.75

not ppt'n because * ① not simple ion-exchange ② solid reactant, so solid product not obvious!

BUT: get 0.25 if say most OH^- salts are insoluble.

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PART B: Short written answers

 # 12. (4 marks) Sulfuric acid and nitric acid are strong acids but also strong oxidizing agents, while hydrochloric acid is not an oxidizing agent. Explain why the chloride ion is not a strong oxidizing agent like SO_4^{2-} and NO_3^-. Include any relevant calculations.

oxidation states

MUST COMPARE

- strong oxidizing agents (easily reduced)
  - strong ability to steal electrons ✓ from other species (cause oxidation)
  - contain an atom in a relatively high oxidation state ✓, thus can accept e^-s & be converted to a lower oxidation state

Higher ox. # does not guarantee greater oxidizing strength, but often correlates. However, if ox. # is already at element's lowest value, it cannot accept e⁻s!!

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e.g. SO_4^{2-}: $x + 4(-2) = -2$, $x = +6$ ✓, i.e., S^{VI} ✓
$6e^-$ fewer than elemental sulfur, $8e^-$ fewer than S^{2-} ion.

vs. =

NO_3^-: $y + 3(-2) = -1$, $y = +5$ ✓, i.e., N^{V} ✓
$5e^-$ fewer than in N_2, $8e^-$ fewer than in N^{3-} ion

Cl^- (already stable ∴ same e⁻ count as noble gas)
✓ oxidation state −I
✓ already the lowest oxidation state available to Cl,
✓ so cannot be reduced
✓ ∴ cannot act as an oxidant. (It is a reducing agent, actually).

 # 13. (4 marks) Imagine you mix known but unequal quantities of aqueous KCl and aqueous $AgNO_3$ to precipitate out solid AgCl. Explain in detail how you would determine the concentration of excess reactant remaining in the supernatant after the reaction occurs (assume 100% yield).

meaning CALCULATE

✓ $KCl_{(aq)} + AgNO_{3(aq)} \longrightarrow AgCl_{(s)} + KNO_{3(aq)}$

EXPLAIN IN WORDS (or -1)

one of these is limiting reactant, other in excess

AgCl: precipitates out

KNO_3: spectator ions remain dissolved in supernatant solution

4

✓ ① determine which reactant is limiting ⇒ it will ALL be consumed ∴ none remains in supernatant

② based on 1:1 stoichiometry ✓ ✓ amount (moles) of L.R. present is equal to amount (moles) of other reactant actually consumed

③ calculate amount unreacted: ✓ $\text{amount}_{\text{initial}} - \text{amount}_{\text{consumed}} = \text{amount}_{\text{excess}}$

④ Calculate concentration: $\frac{\text{amount}_{\text{excess}}}{\text{total solution volume}}$ ✓ ✓ $= \frac{\text{moles}}{\text{L}}$ of excess reactant

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✓ = 1 mark
✗ = 0.5 mark

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

 # 14. (7 marks) Phosphorus, P, is combined with chlorine, Cl_2, (→ must be excess since mass not given...) to give a gaseous compound with the formula PCl_x. If you start with 2.097 g of P and isolate 9.298 g of PCl_x, what is the value of x? ***Show your calculations, and briefly explain your answer.***

APPROACH #1: molar mass analysis

$P_{(s)} + \left(\frac{x}{2}\right) Cl_{2(g)} \rightarrow PCl_{x(g)}$ ✓ (to balance) (must be balanced (or -0.5))

$m_P = 2.097\,g$; $MM_P = 30.974\,g/mol$ ✗ ; m_{Cl_2} = unknown, assume in excess ; $m_{PCl_x} = 9.298\,g$; MM_{PCl_x} = ? depends on x!

$\#n_P = \frac{2.097\,g}{30.974\,g\cdot mol^{-1}} = 0.06770\,mol$ of P atoms ✓

(all atoms now present in PCl_x (100% yield) ✗)

Every 1 PCl_x molecule contains 1 P atom, ✓

$\therefore \#n_{PCl_x} = \#n_P$ ✓ $= 0.06770\,mol$

Now focus of molar mass of PCl_x:

$MM_{PCl_x} = \frac{m_{PCl_x}}{\#n_{PCl_x}} = \frac{9.298\,g}{0.06770\,mol} \doteq 137.3\,g\cdot mol^{-1}$ ✗

One mole of PCl_x contains 1 mole P and x moles Cl ✓

i.e. $MM_{PCl_x} = MM_P + x\,MM_{Cl}$ ✓

$\therefore x = \frac{MM_{PCl_x} - MM_P}{MM_{Cl}}$

$= \frac{(137.3 - 30.974)\,g\cdot mol^{-1}}{35.45\,g\cdot mol^{-1}}$ ✓

$= 3.000$

$\therefore x \doteq 3$ ✓

Thus: the compound is $PCl_3(g)$.

APPROACH #2: mole fraction ⇒ formula

$P_{(s)} + \left(\frac{x}{2}\right) Cl_{2(g)} \rightarrow PCl_{x(g)}$ ✓ (to balance)

$m_P = 2.097\,g$; Cl_2 (excess) ; $m_{PCl_x} = 9.298\,g$

explanations ✗: PCl_x is composed of phosphorus atoms + chlorine atoms, and assuming we had 100% conversion (yield) of PCl_x from P,

$m_{PCl_x} = m_{P\ atoms\ from\ P\ used} + m_{Cl\ atoms}$ ✗

$\therefore m_{Cl} = m_{PCl_x} - m_P$

$= 9.298\,g - 2.097\,g$

$\therefore m_{Cl} = 7.201\,g$ Cl ✗ (our source of chlorine atoms was Cl_2 gas)

In our sample of PCl_x weighing 9.298 g:

element	mass	$\#n = \frac{mass}{MM}$	mole ratio
P	2.097 g	$\frac{2.097\,g}{30.974\,g\cdot mol^{-1}} = 0.06770$ ✗ moles P atoms	$\frac{0.06770}{0.06770} = 1$ ✗
Cl	7.201 g	$\frac{7.201\,g}{35.45\,g\cdot mol^{-1}} = 0.2031$ ✗ moles Cl atoms	$\frac{0.2031}{0.06770} = 3$ ✗

explanations ✗: We normalize the number of moles of the two elements to find the whole number ratio of elements, which yields the empirical formula: PCl_3 ie: $x = 3$ ✓

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MM = 46.069 g/mol

 # 15. (10 marks total) The alcohol (CH_3CH_2OH) content in a 10.3 g sample of blood from a driver required 2.79 mL of 0.07923 M $K_2Cr_2O_7$ solution to reach the equivalence point in a titration involving the reaction shown below. If the legally allowed limit is 0.10 % alcohol by mass in the blood, should the police charge the driver with drunk driving? ***Show your calculations, and briefly explain your answer.*** (worth 2)

$$3\,CH_3CH_2OH(aq) + 2\,K_2Cr_2O_7(aq) + 8\,H_2SO_4(aq) \rightarrow 3\,CH_3COOH(aq) + 2\,Cr_2(SO_4)_3(aq) + 2\,K_2SO_4(aq) + 11\,H_2O(\ell)$$

m = ?
If > 0.10 % of blood mass is ethanol, must be charged
∴ Find m

$c = 0.07923$ M
$V = 0.00279$ L
(assume excess)

$\#n = C\,(mol/L) \times V\,(L)$
$= (0.07923\,mol/L)(0.00279\,L)$
$= 2.211 \times 10^{-4}$ mol used to consume all the ethanol

2.0

experiment designed to give exact stoich. ratio OR, alcohol was L.R.

Alternate approach to point ②: find 0.10% of blood mass = 0.0010 × 10.3 g = 0.0103 g = maximum allowed ethanol in sample & compare to our sample mass (0.01539) too much.
3.5 marks; 4 for calc. mass eth. + expl.

① According to the reaction's stoichiometry, 2 mol $K_2Cr_2O_7$ consumes 3 mol ethanol:

$$\frac{3\text{ mol ethanol}}{x\text{ mol ethanol}} = \frac{2\text{ mol } K_2Cr_2O_7}{2.211 \times 10^{-4}\text{ mol } K_2Cr_2O_7\text{ used}} \Rightarrow x = 3.317 \times 10^{-4}\text{ mol ethanol was consumed.}$$

2

② This ethanol was present in the blood sample (10.3 g). Must find mass %.

$$\text{mass \% ethanol} = \left(\frac{\text{mass ethanol}}{\text{mass Sample}}\right) \times 100\%$$

eqn

$2MM_C + 6MM_H + 1MM_O = MM_{ethanol}$

$$= \frac{(3.317 \times 10^{-4}\text{ mol})(46.069\text{ g/mol of ethanol})}{10.3\text{ g blood sample}} \times 100\%$$

$$= \frac{0.01528\text{ g ethanol}}{10.3\text{ g blood}} \times 100\%$$

$$\doteq 0.148\ \% > 0.10\ \%$$

4

1 ③ The legal limit is 0.10 %, so this driver should be charged, because their blood alcohol is above the limit.

1 **(1 mark)** What type of reaction is this? Explain your choice.

0.5 Redox reaction, because changes of oxidation states occur (evidence of electron transfer). 0.25

+ proof 0.25 Most obvious: $Cr_2O_7^{2-} \rightarrow Cr_2(SO_4)_3$ chromium was reduced. Something else must have been oxidized (carbon was.)

$2x + 7(-2) = -2$, $\therefore x = +6$

$2y = 3(-2)$, $\therefore y = +3$

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