Department of Chemistry
CARNEGIE MELLON UNIVERSITY
Introduction to Modern Chemistry (09-105)

MASTERY EXAM IV
November 19, 2007

Name KEY
Circle Section (see below) A B C D E F G H I J K L

Instructions:

Show all work.
Use significant figures correctly.
Double-check your results!
This EXAM MUST BE RETURNED BY THE END OF CLASS.

1 mL = 0.001 L

Element	Atomic Weight
H	1.0079
C	12.011
N	14.007
O	15.999
P	30.974
S	32.06
Cl	35.453
K	39.098
Ca	40.08

1.________	/25
2.________	/25
3.________	/25
4.________	/25
________	/100

Larry Layne	Niti Garg	Richard Watson	Tudor Constantine	Adam Reeve	Margaret Weddell
A 6:30	C 6:30	E 6:30	G 6:30	I 6:30	K 6:30
B 7:30	D 7:30	F 7:30	H 7:30	J 7:30	L 7:30

1. You have 150.00 grams of a mixture of potassium phosphate, K_3PO_4, and calcium phosphate, $Ca_3(PO_4)_2$. The mixture is reacted with excess quantities of the very strong acid, sulfuric acid, which converts all the phosphate (PO_4^{3-}) into phosphoric acid, H_3PO_4. It is then determined that 86.42 grams of pure phosphoric acid are produced. What is the percent mass composition of the original mixture that is calcium phosphate? Cannot use $K_3PO_4 + Ca_3(PO_4)_2 + \cdots \rightarrow 3H_3PO_4 + \cdots$!!

MW: $K_3PO_4 = 212.26$, $Ca_3(PO_4)_2 = 310.18$, $H_3PO_4 = 97.99$

$$K_3PO_4 + \tfrac{3}{2}H_2SO_4 \rightarrow H_3PO_4 + \tfrac{3}{2}K_2SO_4$$

x gms

$\frac{x}{212.26}$ moles $\rightarrow$ $\frac{x}{212.26}$ moles H_3PO_4 (5)

$$= \left(\frac{x}{212.26}\right)(97.99) = 0.4617x \text{ gms } H_3PO_4$$

$$Ca_3(PO_4)_2 + 3H_2SO_4 \rightarrow 2H_3PO_4 + 3CaSO_4$$

$\frac{150-x}{310.18}$ moles $\rightarrow$ $\frac{2(150-x)}{310.18}$ moles H_3PO_4

$$= \frac{2(150-x)}{310.18}(97.99) = 94.77 - 0.6318x \text{ gms } H_3PO_4 \quad (5)$$

Total mass of H_3PO_4 = 86.42 gms

$$86.42 = 0.4617x + 94.77 - 0.6318x \quad (5)$$

$$0.1701x = 8.35$$

$$x = \frac{8.35}{0.1701} = 49.09 \text{ gms } K_3PO_4$$

$$150.00 - 49.09 = 100.91 \text{ gms } Ca_3PO_4$$

$$\frac{100.91}{150.00} \times 100\% = 67.3\% \ Ca_3PO_4$$

2. Calcium phosphate, $Ca_3(PO_4)_2$, can be prepared from the reaction of calcium chloride, $CaCl_2$, with potassium phosphate, K_3PO_4. The only other product is potassium chloride, KCl. 75.00 grams of calcium chloride and 75.00 grams of potassium phosphate are used in a test procedure. How many grams of what substances remain at the end of the reaction?

unbalanced: $CaCl_2 + K_3PO_4 \rightarrow Ca_3(PO_4)_2 + KCl$

$3\,CaCl_2 + 2\,K_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6\,KCl$ (10)

MWs 110.99 212.26 310.18 74.55

75.00 g → $\frac{75.00\text{ g}}{110.99\text{ g/mol}}$ → 0.6757 mol

75.00 g → $\frac{75.00\text{ g}}{212.26\text{ g/mol}}$ → 0.3533 mol

3 moles requires 2 moles

0.6757 moles " 0.4505 moles (Insufficient K_3PO_4 !)

0.3533 moles consumes 0.5300 moles $CaCl_2$

0.6757 − 0.5300 = 0.1457 moles $CaCl_2$ excess

→ (0.1457 moles)(110.99 g/mol) = **16.18 grams $CaCl_2$** (5)

0.3533 moles K_3PO_4 produce $\frac{0.3533}{2}$ moles $Ca_3(PO_4)_2$

→ $\left(\frac{0.3533}{2}\right)(310.18)$ = **54.79 grams $Ca_3(PO_4)_2$** (5)

and also produce 3(0.3533) moles KCl

→ 3(0.3533)(74.55) = **79.02 grams KCl** (5)

check: 16.18 + 54.79 + 79.02 $\stackrel{?}{=}$ 75.00 + 75.00

149.99 ≃ 150.00 ✓

3. One of the most important physiological substances you might learn about in biology and biochemistry is ATP, a derivative of the compound *adenosine*. Adenosine is found to contain 44.944 % carbon, 4.903 % hydrogen, 26.206 % nitrogen, and 23.947 % oxygen by mass. What is the empirical formula for *adenosine* consistent with the precision of the analysis? (Show all work.)

Assume you have 100.000 gm adenosine

44.944 gm C → $\frac{44.944 \text{ g C}}{12.011 \text{ g C/mol C}}$ = 3.742 mol C

4.903 gm H → $\frac{4.903 \text{ g}}{1.0079 \text{ g/mol}}$ = 4.865 mol H

26.206 gm N → $\frac{26.206 \text{ g}}{14.007 \text{ g/mol}}$ = 1.871 mol N

23.947 gm O → $\frac{23.947 \text{ g}}{15.999 \text{ g/mol}}$ = 1.497 mol O

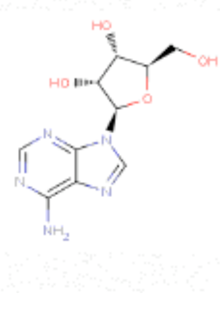
(12)

C : H : N : O = 3.742 : 4.865 : 1.871 : 1.497 (4)

Divide by 1.497
C : H : N : O = 2.500 : 3.250 : 1.250 : 1 (5)

Multiply by 4
C : H : N : O = 10 : 13 : 5 : 4 (1)

$C_{10}H_{13}N_5O_4$ (3)



4. In performing an analytical analysis, you are given 1.342 grams of a solid that contains only potassium phosphate, K_3PO_4, and calcium phosphate, $Ca_3(PO_4)_2$. The sample is dissolved in water and the volume diluted with additional water until it is exactly one liter. Exactly 5.00 mL of this solution is removed and diluted with pure water until the volume of the new solution is 100.00 mL. Using a "micropipette", exactly 100 microliters (100×10^{-6} L) of this last solution are removed and analyzed in a spectrometer that indicates the presence of 2.03 micrograms (2.03×10^{-6} grams) of calcium were delivered by the micropipette. What mass of calcium phosphate was present in the original solid?

x = gms $Ca_3(PO_4)_2$ MW = 310.18

$\frac{x}{310.18}$ moles $Ca_3(PO_4)_2$ (many variations)

(8) → $\frac{3x}{310.18}$ moles Ca

$\frac{3x}{310.18}(40.08) = 0.3876x$ gms Ca in sample sol'n I

$\left(\frac{0.005 L}{1 L}\right)(0.3876x) = 0.001938x$ gms Ca in sol'n II (5 mL diluted to 100 mL)

or $\frac{0.001938x}{100.00}$ gms/mL = 0.01938x gms/L

100 μL = 10^{-4} L are removed and contain

$\left(0.01938x \frac{gms}{L}\right)(10^{-4} L) = (1.938 \times 10^{-6})x$ gms Ca

$1.938 \times 10^{-6} x$ gms = 2.03×10^{-6} gm

$x = \frac{2.03 \times 10^{-6}}{1.938 \times 10^{-6}} = 1.05$ gms

1.05 gms $Ca_3(PO_4)_2$ originally in sample