Fall 2006 Chemistry 101 Midterm 1 (Goldwhite)

Name Instructor's Key SID_____

Name of lab. instructor _____

This exam is closed book/notes. You may have available writing instruments and a calculator.

Check your copy: you should have 5 questions. The last page is a periodic table, which you may remove.

Show how you obtain your answers, so that the grader can give appropriate credit.

Maximum possible is 150 points. Each question is worth 30 points.

Information that may be useful:

NA = 6.022×10^{23} / mol
V of a cylinder of radius r and length l = $2\pi rl$; V of a rectangular prism of width w, height h and length l = whl; iron has a density of 7.86 g/cm3. $\pi = 3.1416$
D = m/v

Significant figures (sf) figure significantly in grading.

5 sf wrong — 1
blunders — 3 sf up } throughout exam

1.1 A cube of iron of mass 75g is placed in a graduated 100.0 mL cylinder containing 25.0 mL of water. What will be the new position of the water meniscus?

$d = \frac{m}{V}$ $V = \frac{m}{d} = \frac{75\,g}{7.86\,g/cm^3} = 9.5\,cm^3 = 9.5\,mL$ (2 s.f. only) ✗

The iron sinks ($d > d_{H_2O}$) so

12 new position of meniscus $= (25.0 + 9.5)\,mL$

$= 34.5\,mL$

1.2 What is the length of the side of the cube of iron in question 1.1?

$V = 9.5\,cm^3 = \ell^3$

So $\ell = \sqrt[3]{V} = V^{\frac{1}{3}} = (9.5\,cm^3)^{1/3}$

$\ell = 2.1\,cm$

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1.3 How many atoms of iron are present in the cube of iron in question 1.1?

n_{Fe} (# mol Fe) $= 75\,g / 55.85\,g/mol\,Fe = 1.34\,mol\,Fe$

10 # atoms Fe $= 1.34\,mol\,Fe \times 6.022 \times 10^{23}\,atoms/mol$

$= 8.1 \times 10^{23}$ atoms (2 s.f.)

2.1 Determine the numbers of protons and neutrons in the nucleus of each of the following isotopes:

a) U-235 b) B-11 c) Mo-96

6 Z= 92 5 42

(1ea) P = Z = 92 5 42

n = A-Z = 235-92 = 143 11-5 = 6 96-42 = 54

2.2 Explain -- in standard prose **EITHER** Rutherford's experiments with alpha particles as projectiles, and the conclusions he drew from his results; **OR** the operation of a mass spectrometer and the data it provides.
Include a sketch of the apparatus in your answer.

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Graded (subjectively!) as an essay.

No sketch -6

A = 18

B = 15

C = 12

3.1 Calculate the % composition by mass for each element in valine, an amino acid found in proteins, of molecular formula $C_5H_{11}NO_2$

Molar mass $= 5(12.011) + 11(1.008) + (14.01) + 2(16.00)$

$= 117.15\ g/mol$

$\%C = (5(12.011)\ g / 117.15\ g/mol) \times 100\% = 51.26$

$\%H = (11(1.008)\ g / 117.15\ g/mol) \times 100\% = 9.46$

$\%N = (14.01\ g / 117.15\ g/mol) \times 100\% = 11.96$

$\%O = (2 \times 16.00\ g / 117.15\ g/mol) \times 100\% = 27.32$

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checks 100.00 !

3.2 Glycine, another amino-acid found in proteins, contains 32.00%C; 6.71% H; 18.66% N; and 42.63% O; Determine the formula of glycine and explain whether this is an empirical or a molecular formula.

Element	% = g/100g	mol/100g	÷ smallest (1.332)
C	32.00	32.00/12.011 =	2.664 2.000
H	6.71	6.71/1.008 =	6.657 5.00
N	18.66	18.66/14.01 =	1.332 1.000
O	42.63	42.63/16.00 =	2.664 2.000

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Empirical formula is $C_2H_5NO_2$

because we have no molar mass data.

No/explanation −5

inadequate

4.1 Determine the molecular formula for a gaseous compound containing only phosphorus and fluorine from the following information.
Reaction of 1.000 g of the compound with excess gaseous hydrogen removed all the fluorine and generated 0.794 of HF. A gas density experiment indicated a molecular weight of the compound of about 126 amu .

$P_xF_y \xrightarrow{H_2} P + yHF$ 1.000g of

mol HF = # mol F in/cpd.

$0.714\,g\,HF / 20.0\,g/mol\,HF = 3.97\times10^{-2}$ mol

Mass of F in the HF (= mass in 1.000g cpd)

$= 3.97\times10^{-2}\,mol\,HF \times \frac{1\,mol\,F}{1\,mol\,HF} \times \frac{19.00\,g\,F}{mol\,F} = 0.754\,g$

Mass of P in 1.000g cpd = $(1.000 - 0.754)\,g = 0.246\,g$

20 # mol P " " = $\frac{0.246\,g\,P}{30.97\,g/mol\,P} = 7.94\times10^{-3}$

So in 1.000g cpd we have $7.94\times10^{-3}\,mol\,P / 3.97\times10^{-2}\,mol\,F$

$= 1:5$ Empirical formula is PF_5

Emp. formula mass = $(30.97 + 5\times19.00)\,g/mol = 126\,g/mol$

So emp formula = molecular formula = PF_5

4.2 Write a balanced equation for the reaction between the compound in 4.1 and molecular hydrogen, H_2 given that phosphorus is produced as P_4 in the reaction.

$4\,PF_5 + 10\,H_2 = P_4 + 20\,HF$

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5. Iron (III) chloride, $FeCl_3$, is an important laboratory reagent that can be made by treating metallic iron, Fe, with gaseous hydrogen chloride, HCl . The other product of this reaction is gaseous hydrogen, H_2.

A mixture of 5.85g of iron and 12.00g of HCl is prepared and heated and reacts to produce as much iron(III) chloride as is possible.

5.1 Write a balanced equation for the reaction.

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$$2Fe + 6HCl = 2FeCl_3 + 3H_2$$
2 mol 6 mol

5.2 Which reagent is limiting? # mol Fe used = 5.85 g / 55.85 g/mol

= 0.105 mol.

8 Needs $0.105 \text{ mol Fe} \times \frac{6 \text{ mol HCl}}{2 \text{ mol Fe}} \times \frac{36.5 \text{ g HCl}}{1 \text{ mol HCl}} = 11.47 \text{ g HCl}$

We have more than this — so Fe is limiting

5.3 What mass of iron chloride is produced?

$$\text{mass } FeCl_3 = 0.105 \text{ mol Fe} \times \frac{2 \text{ mol } FeCl_3}{2 \text{ mol Fe}} \times \frac{162.35 \text{ g } FeCl_3}{\text{mol } FeCl_3}$$

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$$= 17.0 \text{ g } FeCl_3 \text{ (3 s.f.)}$$

5.4 What mass of the non-limiting reagent is left over after the reaction occurs?

From 5.2 11.47 g HCl is used in reaction

So (12.00 − 11.47) g is left over

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$$= 0.53 \text{ g HCl}.$$