

Last name : _____ Given name : _____

Student number: _____

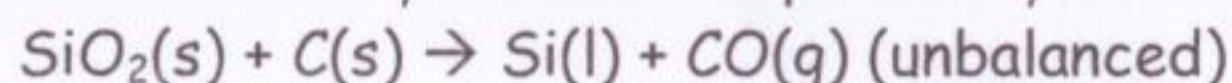
Lab Section: _____ Lab TA: _____

Chemistry 1311D

Test 1 V1

October 10, 2013

1. (5 points) Computer chips are made from silicon, which occurs in nature as silicon dioxide (sand). When silicon dioxide is heated to melting it reacts with carbon to form liquid silicon and carbon monoxide gas. If 155.8 kg of silicon dioxide, SiO_2 , reacts with 78.3 kg of carbon, $\text{C}(\text{s})$ to produce 66.1 kg of silicon, determine the theoretical yield and the percent yield for the reaction.



$$\text{SiO}_2(\text{s}) + 2\text{C}(\text{s}) \rightarrow \text{Si}(\text{l}) + 2\text{CO}(\text{g})$$

155.8 kg SiO_2 ; 60.084 g/mol; $n = \text{mass}/M = \frac{155.8 \times 10^3 \text{g}}{60.084 \text{g/mol}} = 2593 \text{ moles}$

78.3 kg C ; 12.011 g/mol; $n = \frac{78.3 \times 10^3 \text{g}}{12.011 \text{g/mol}} = 6519 \text{ moles}$

66.1 kg Si ; 28.086 g/mol

If all SiO_2 used $2593 \text{ moles } \text{SiO}_2 \times \frac{1 \text{ Si}}{1 \text{ SiO}_2} = 2593 \text{ moles Si}$

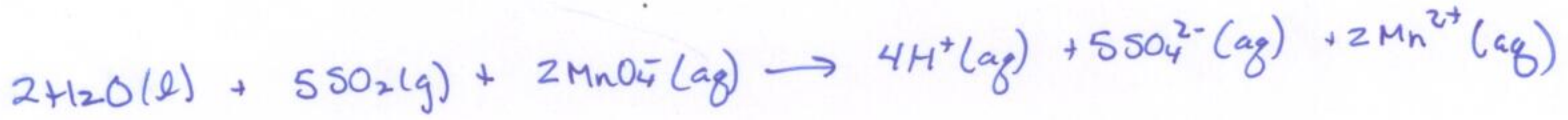
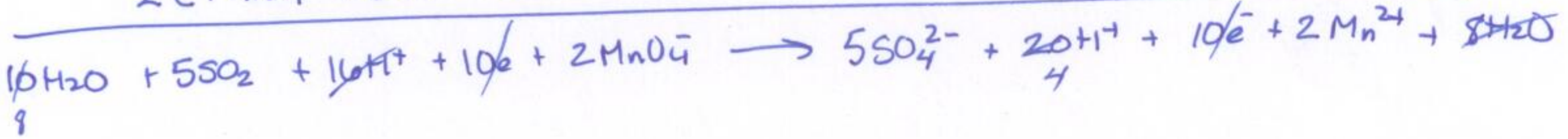
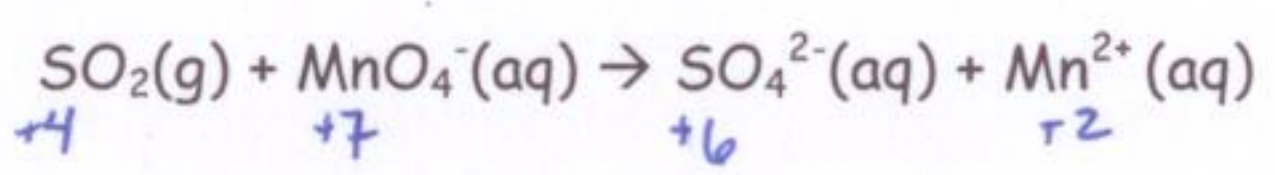
If all $\text{C}(\text{s})$ used $6519 \text{ moles} \times \frac{2 \text{ Si}}{2 \text{ C}} = 3260 \text{ moles Si}$

$\therefore \text{SiO}_2$ is limiting

Theoretical yield $2593 \text{ moles } \text{SiO}_2 \times \frac{1 \text{ Si}}{1 \text{ SiO}_2} \times 28.086 \text{ g/mol} = \underline{72.8 \text{ kg}}$

% yield = $\frac{66.1 \text{ kg}}{72.8 \text{ kg}} \times 100 = 90.8\%$

2.a) (4 points) The SO₂ present in air is mainly responsible for the acid rain phenomenon. The SO₂ concentration can be determined by reacting it with permanganate (MnO₄⁻) in a potassium permanganate, KMnO₄(aq), solution. Balance the following reaction:



b) (4 points) Calculate the number of grams of SO₂ in a sample of air if 7.37ml of 0.0800 M potassium permanganate, KMnO₄(aq), solution are need to fully react with the SO₂.

$$n_{\text{MnO}_4^-} = n_{\text{KMnO}_4} = [C]V = 0.0800 \frac{\text{moles}}{\text{l}} \times 7.37 \times 10^{-3} \text{l} = 5.896 \times 10^{-4} \text{ moles}$$

$$n_{\text{SO}_2} = n_{\text{MnO}_4^-} \times \frac{5\text{SO}_2}{2\text{MnO}_4^-} = 5.896 \times 10^{-4} \times \frac{5}{2} = 1.474 \times 10^{-3} \text{ moles}$$

$$\begin{aligned} \text{mass SO}_2 &= n_{\text{SO}_2} \times M_{\text{SO}_2} = 1.474 \times 10^{-3} \text{ moles} \times 64.064 \text{ g/mole} \\ &= 0.0944 \text{ g} \\ &= 94.4 \text{ mg} \end{aligned}$$

3. The odour from pineapple is due to the presence of the compound ethyl butyrate, which contains only carbon, hydrogen and oxygen. Combustion of 2.78 g of ethyl butyrate at 20 °C and 1 bar pressure produces 3.50 L of CO₂ (g) and 2.584 ml of H₂O(l). The density of water at 20 °C is 0.99820 g/ml.

a) (2.5 points) Determine the % weight of carbon in ethyl butyrate. $mass\ C \leftarrow n\ C \leftarrow n\ CO_2$

$$n_{CO_2} = \frac{PV}{RT} = \frac{(1\ bar)(3.5\ L)}{0.08314\ \frac{bar\ L}{mol\ K}(293)} = 0.1437\ \text{moles}\ CO_2 = 0.1437\ \text{moles}\ C$$

$$m_C = 0.1437\ \text{moles}\ C \times 12.011\ \text{g/mol} = 1.73\ \text{g}$$

$$\%wt = \frac{1.73\ \text{g}}{2.78\ \text{g}} \times 100 = 62.1\%$$

b) (2.5 points) Determine the % weight of hydrogen in ethyl butyrate. $V_{H_2O} \rightarrow m_{H_2O} \rightarrow n_{H_2O} \rightarrow n_H \rightarrow m_H$

$$m_{H_2O} = V \times d = 2.584\ \text{ml} \times 0.99820\ \text{g/ml} = 2.579\ \text{g}$$

$$n_{H_2O} = \frac{mass}{m} = \frac{2.579\ \text{g}}{18.015\ \text{g/mol}} = 0.1432\ \text{moles}\ H_2O; n_H = 2n_{H_2O} = 2 \times 0.1432 = 0.2863\ \text{moles}\ H$$

$$mass\ H = 0.2863\ \text{moles} \times 1.008\ \text{g/mol} = 0.2886\ \text{g}$$

$$\%wt = \frac{0.2886\ \text{g}}{2.78\ \text{g}} \times 100 = 10.4\%$$

c) (1 points) Determine the % weight of oxygen in ethyl butyrate.

$$100 - 10.4 - 62.1 = 27.5\% O$$

$$mass\ O = 0.275(2.78\ \text{g}) = 0.7645\ \text{g}$$

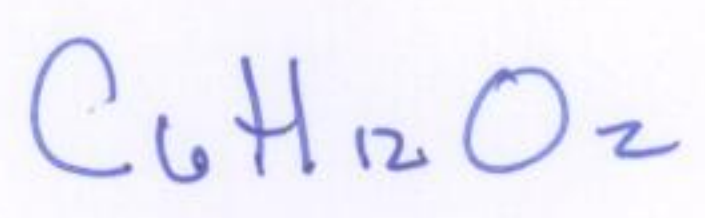
$$n_O = \frac{mass}{m} = \frac{0.7645\ \text{g}}{15.999\ \text{g/mol}} = 0.04778\ \text{moles}$$

d) (2 points) What is the empirical formula for ethyl butyrate?

$$\frac{C_{0.1437}}{0.04778} \quad \frac{H_{0.2863}}{0.04778} \quad \frac{O_{0.04778}}{0.04778} \quad ; \quad C_{3.00} H_{5.99} O_1 \quad \approx \quad C_3 H_6 O$$

e) (2 points) Determine the molecular formula of ethyl butyrate given that the molar mass is 116.16 g/mol.

$$Factor = \frac{M}{EF_{mass}} = \frac{116.16\ \text{g/mol}}{59\ \text{g/mol}} = 1.99 \approx 2$$



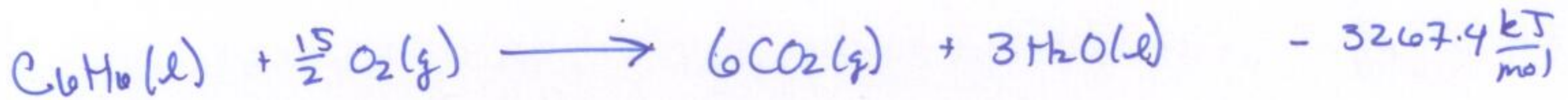
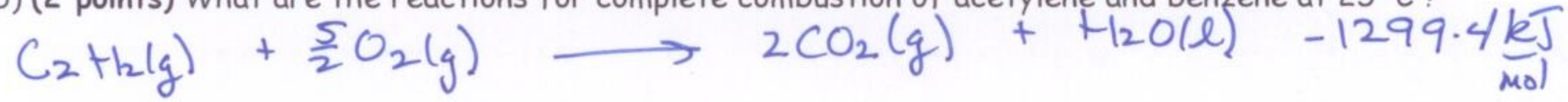
4. Consider the organic compounds acetylene, C₂H₂(g) and benzene, C₆H₆(l). Acetylene can be converted to benzene as shown below:



a) (1 point) What are the empirical formulae for acetylene and benzene ?



b) (2 points) What are the reactions for complete combustion of acetylene and benzene at 25 °C ?



c) (3 points) The enthalpy for complete combustion of acetylene is -1299.4 kJ/mol and of benzene is -3267.4 kJ/mol. Using this information and the standard heats of formation below determine the enthalpy of formation of acetylene and benzene and the enthalpy change for the formation of C₆H₆ from C₂H₂ (RXN 4.1 above).

- CO₂(g) Δ_fH = -393.5 kJ/mol
- H₂O(g) Δ_fH = -241.8 kJ/mol
- CO₂(aq) Δ_fH = -412.9 kJ/mol
- H₂O(l) Δ_fH = -285.8 kJ/mol

acetylene

-1299.4 = Δ_fH(H₂O(l)) + 2Δ_fH(CO₂(g)) - Δ_fH(C₂H₂(g))

Δ_fH(C₂H₂(g)) = -285.8 - 2(-393.5) + 1299.4 = 226.6 kJ mol⁻¹

benzene

-3267.4 = 3Δ_fH(H₂O) + 6Δ_fH(CO₂) - Δ_fH(C₆H₆)

Δ_fH(C₆H₆) = 3(-285.8) + 6(-393.5) + 3267.4 = +49 kJ mol⁻¹



Δ_{rxn}H = Δ_fH(C₆H₆) - 3(Δ_fH(C₂H₂)) = 49 - (3(226.6)) = -630.8 kJ

d) (2 points) If the acetylene was converted to benzene under constant pressure conditions, would you expect Δ_{rxn}U to be more positive than, more negative than or equal to Δ_{rxn}H ? Explain briefly.

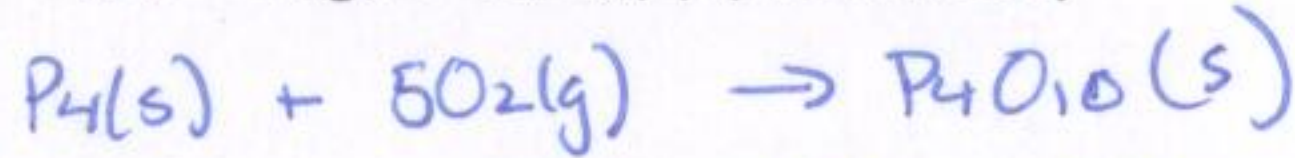
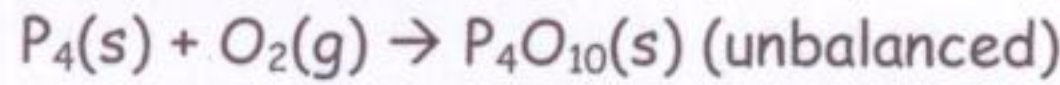
q_{p rxn} = Δ_{rxn}H = -630.8 kJ

w → g turns to l, compression, +ve

ΔU = q_p + w = (-ve) + (+ve)

Δ_{rxn}U is more positive than q_p & Δ_{rxn}H.

5. (4 points) The reaction of 124 g of solid P₄ with 61.9 L of O₂ at 25 °C and 1 bar results in the formation of P₄O₁₀(s). The reaction generates enough heat to raise the temperature of 1475 g of water from 19.0 °C to 39.0°C. Calculate the enthalpy of formation P₄O₁₀(s). Some things you may (or may not) be interested in include: Heat capacity of liquid water is 4.18 J °C⁻¹g⁻¹; of ice 2.05 J °C⁻¹ g⁻¹; of steam 1.996 J °C⁻¹ g⁻¹; ΔH_{vap} 40.7 kJ mol⁻¹; ΔH_{fusion} = 6.0kJ mol⁻¹



124 g P₄ $m = 123.8948 \text{ g/mol}$

$n_{P_4} = 124 / 123.8948 = 0.999 \text{ moles} \rightarrow 0.999 \text{ moles P}_4\text{O}_{10}$

61.9 L of O₂ @ 298K, 1 bar

$n_{O_2} = \frac{PV}{RT} = \frac{1 \text{ bar} (61.9 \text{ L})}{0.08314 \text{ L bar} (298 \text{ K})} = 2.498 \text{ moles O}_2$

M_{H₂O} = 1475g

$n_{P_4O_{10}} = 2.498 \text{ moles O}_2 \times \frac{1 \text{ P}_4\text{O}_{10}}{5 \text{ O}_2} = 0.4996$

ΔT = 20°C

O₂ limiting!

$q_{H_2O} = m C \Delta T$

$q_{H_2O} = 1475 \text{ g} (4.18 \frac{\text{J}}{\text{°C g}}) (20 \text{ °C}) = 123 \text{ kJ}$

For 0.4996 moles P₄O₁₀(s) product.

$\Delta_f H_{P_4O_{10}} = - \frac{123 \text{ kJ}}{0.4996 \text{ moles}} = -246.6 \text{ kJ/mol}$

6. (5 points) A solution of hexane, C₆H₁₄, in heptane, C₇H₁₆, is prepared with a concentration of X_{hexane} = 0.20. Given the density of hexane, 0.6548 g/ml and of heptanes, 0.6840 g/ml determine the molality and molarity of the solution. Assume volume of the final solution is equal to volumes of components.

X_{C₆} = 0.2 moles

X_{C₇} = 0.8 mole

molality = $\frac{n_{C_6}}{\text{kg C}_7}$

d_{C₆} = 0.6548 g/ml

d_{C₇} = 0.6840 g

molarity = $\frac{n_{C_6}}{V_{\text{sol}}}$

M_{C₆} = 86.172 g/mol

M_{C₇} = 100.198 g/mol

mass = n × M = 0.2 (86.172 g/mol) = 17.2344 g

mass = 0.8 (100.198) = 80.158 g

V = $\frac{\text{mass}}{d} = \frac{17.2344 \text{ g}}{0.6548 \text{ g/ml}}$

V = $\frac{80.158 \text{ g}}{0.6840}$

Molarity = $\frac{0.2}{(26.32 + 117.19) \times 10^{-3} \text{ L}} = 1.39 \text{ moles/l}$

= 26.32 ml

= 117.19 ml

Bonus: What is the density of the solution?

Density = $\frac{\text{mass}}{\text{volume}} = \frac{17.23 + 80.16 \text{ g}}{26.32 + 117.19 \text{ ml}} = 0.6786 \text{ g/ml}$

Molality = $\frac{0.2}{80.158 \times 10^{-3} \text{ kg}} = 2.5 \frac{\text{moles}}{\text{kg C}_7\text{H}_{16}}$