Chemistry 1105 R11 Fall 2023 Test 2

Friday, October 27, 2023

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: ____________________

This test consists of ***nine*** *pages of questions, a page containing useful constants and conversions, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me* ***immediately****. There are* ***49*** *marks available. Good luck!*

1) **[4 marks]** Give the oxidation number of sulphur (S) in the following compounds or ions:

SO_2^{2+} +6 SO_4^{2-} +6 SO_2F_2 +6 K_2SOF_2 +2

2) **[5 marks total]** Given the following (unbalanced) redox reaction, occurring in acidic solution:

$Cr_2O_7^{2-} + C_6H_6 \longrightarrow CO_2 + Cr^{3+}$

a) **[3 marks]** Balance the reaction.

$(6e^- + 14H^+ + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O) \times 5$

$12H_2O + C_6H_6 \longrightarrow 6CO_2 + 30H^+ + 30e^-$

$\cancel{30e^-} + \cancel{70H^+}\ 40 + 5Cr_2O_7^{2-} + \cancel{12H_2O} + C_6H_6 \rightarrow 10Cr^{3+} + \cancel{35H_2O}\ 23 + 6CO_2 + \cancel{30H^+} + \cancel{30e^-}$

$40H^+ + 5Cr_2O_7^{2-} + C_6H_6 \longrightarrow 10Cr^{3+} + 6CO_2 + 23H_2O$

b) **[0.5 marks]** Identify the oxidizing agent.

$Cr_2O_7^{2-}$

c) **[0.5 marks]** Identify the species being reduced.

$Cr_2O_7^{2-}$

d) **[1 mark]** How many electrons are transferred in the overall process?

30

3) **[3 marks]** A 1456.6-mg sample of a compound of formula M_3PO_4 (where M is an unknown element) was reacted with excess $CaCl_2$ and 790.9 mg of $Ca_3(PO_4)_2$ (310.174 g/mol) collected:

$$2M_3PO_4(aq) + 3CaCl_2(aq) \longrightarrow 6MCl(aq) + Ca_3(PO_4)_2(s)$$

What is the metal, M?

$$790.9\ mg\ Ca_3(PO_4)_2 \times \frac{1\ mol}{310.174\ g} \times \frac{2M_3PO_4}{1Ca_3(PO_4)_2} = 5.09...\ mmol\ M_3PO_4$$

$$\frac{1456.6\ mg}{5.09...\ mmol} = 285.6...\ \frac{g}{mol}$$

$$3M + 30.974 + 4\times15.999 = 285.6...$$

$\Rightarrow M = 63.55$, close to **Cu**

4) **[4 marks]** A certain volume of 12.4 M HCl was taken and diluted to 200.0 mL to make solution A. 25.00 mL aliquot of solution A was then taken and diluted to 500.0 mL to form solution B. The concentration of solution B was found to be 0.0310 M. How many mL of 12.4 M HCl were used to make solution A?

$$\frac{X\ mL \times 12.4\ \frac{moles}{L}}{200\ mL} \times \frac{25.00\ mL}{500.0\ mL} = 0.031\ M$$

$$\frac{12.4X}{200} \times \frac{25}{500} = 0.031$$

$\Rightarrow X =$ **10 mL**

5) **[3 marks]** A 102.5-mg sample of KHP (204.2 g/mol) required 26.70 mL of $Ca(OH)_2$ to titrate:

$$Ca(OH)_2(aq) + 2KHP(aq) \longrightarrow Ca(KP)_2(aq) + 2H_2O(l)$$

What was the concentration of the $Ca(OH)_2$? Give your answer in moles/L.

$$\frac{102.5 \text{ mg KHP} \times \frac{1 \text{ mol}}{204.2 g} \times \frac{1\ Ca(OH)_2}{2 KHP}}{26.70 \text{ mL}}$$

$= \boxed{0.00940 M}$

6) **[2 marks]** Calculate the percent by mass of sulphur in $Al_2(SO_4)_3$.

2×26.982
$+ 3 \times 32.065$
$+ 12 \times 15.999$

342.147

$$\frac{3 \times 32.065}{342.147} \times 100\% = \boxed{28.115\%}$$

7) **[6 marks]** Zonisamide is an antibiotic – a "sulfa drug" in particular. It consists of 45.276% carbon, 3.799% hydrogen, 13.200% nitrogen, 22.616% oxygen, and (maybe obviously) the rest Sulphur, all by mass.

a) What is the empirical formula of Zonisamide?

% S = 100 − 45.276 − 3.799 − 13.200 − 22.616
= 15.109

assume 100 g sample

$45.276\,g\,C \times \frac{1\,mol}{12.011\,g} = 3.76...\,mol\,C$

$3.799\,g\,H \times \frac{1\,mol}{1.0079\,g} = 3.76...\,mol\,H$

$13.200\,g\,N \times \frac{1\,mol}{14.007\,g} = 0.94...\,mol\,N$

$22.616\,g\,O \times \frac{1\,mol}{15.999\,g} = 1.4135...\,mol\,O$

$15.109\,g\,S \times \frac{1\,mol}{32.065\,g} = 0.47...\,mol\,S$

$C_{3.76...}H_{3.76}N_{0.94}O_{1.41}S_{0.47}$

⇓

$C_8H_8N_2O_3S$

b) If Zonisamide were a gas, it would have a density of 0.100 g/L at 8.81 torr pressure and 26.66°C. What is the molecular formula of Zonisamide?

$MM = \frac{(0.1)(62.36...)(299.81)}{8.81} = 212.2273...$

×12.011
×1.0079
×14.007
×15.999
×32.065
212.2272

$\frac{212.2273...}{212.2272} \approx 1$, so EF = MF =

$C_8H_8N_2O_3S$

8) **[6 marks]** Ibuprofen is an anti-inflammatory drug. It consists of carbon, hydrogen, and oxygen.

a) If you burn a 1237.7-mg sample of ibuprofen, you'll collect 3432.7 mg of CO_2 (44.009 g/mol) and 972.8 mg of H_2O (18.015 g/mol). What is the empirical formula of ibuprofen?

$3432.7 \text{ mg} \times \frac{1 \text{ mol}}{44.009 \text{ g}} \times \frac{1 C}{1 CO_2} = \sim 78 \text{ mmol C} = 936.8 \ldots \text{ mg C}$

$972.8 \text{ mg } H_2O \times \frac{1 \text{ mol}}{18.015 \text{ g}} \times \frac{2H}{1 H_2O} = \sim 108 \text{ mmol H} = 108.8 \ldots \text{ mg H}$

$1237.7 - 936.8 - 108.8 = 191.99 \ldots \text{ mg O} = \sim 12 \text{ mmol O}$

$C_{78}H_{108}O_{12} \Rightarrow C_{6.5}H_9O \Rightarrow \boxed{C_{13}H_{18}O_2}$

b) Ibuprofen is mildly acidic and, as an acid, reacts with bases like $Mg(OH)_2$ according to the balanced equation:

$$2(\text{Ibuprofen}) + Mg(OH)_2 \longrightarrow \text{products}$$

A fresh 226.9-mg sample of ibuprofen required 27.50 mL of 0.0200 M $Mg(OH)_2$ for complete reaction. What is the molecular formula of ibuprofen?

13×12.011
18×1.0079
2×15.999
206.2832

$27.50 \text{ mL} \times \frac{0.02 \text{ moles } Mg(OH)_2}{L} \times \frac{2 \text{ Ib}}{1 Mg(OH)_2} = 1.1 \text{ mmol Ib}$

$\frac{226.9 \text{ mg}}{1.1 \text{ mmol}} = 206.2727\ldots$

$\frac{206.2727\ldots}{206.2832} \cong 1$, so MF is $\boxed{C_{13}H_{18}O_2}$

9) **[3 marks]** A solution of H_2SO_4 (98.077 g/mol) has a density of 1.0234 g/mL. A 20.00-mL aliquot of this solution required 32.38 mL of 0.5156 M NaOH for complete reaction:

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

What is the percent by mass of H_2SO_4 in the original H_2SO_4 solution?

$$20\ mL \times 1.0234 \frac{g}{mL} = 20.468\ g$$

$$32.38 \times 10^{-3}\ L \times 0.5156 \frac{moles\ NaOH}{L} \times \frac{1\ H_2SO_4}{2\ NaOH} \times \frac{98.077\ g}{mol}$$

$$= 0.8187\ldots g$$

$$\frac{0.8187\ g}{20.468\ g} \times 100\% = \boxed{4\%}$$

10) **[3 marks]** How many grams of 80.00-percent pure NaCl (58.443 g/mol) are required to collect exactly 10.00 grams of $PbCl_2$ (278.1 g/mol) if the reaction

$$2NaCl(aq) + Pb(NO_3)_2(aq) \longrightarrow PbCl_2(s) + 2NaNO_3(aq)$$

proceeds with a 62.50 percent yield?

$$10\ g \times \frac{100\ g}{62.50\ g} \times \frac{1\ mol}{278.1\ g} \times \frac{2\ NaCl}{1\ PbCl_2} \times \frac{58.443\ g}{1\ mol} \times \frac{100}{80} = \boxed{8.406\ g}$$

11) **[4 marks]** If you mix 20.00 mL of 0.00300 M $Mg(OH)_2$ with 20.00 mL of 0.00150 M H_3PO_4:

$$3Mg(OH)_2(aq) + 2H_3PO_4(aq) \longrightarrow Mg_3(PO_4)_2(s) + 6H_2O(l)$$

How many mL of H_2O (18.015 g/mol) should be produced? The density of H_2O is 0.9984 g/mL.

$$20\text{ mL} \times \frac{3\times10^{-3}\text{ moles } Mg(OH)_2}{L} \times \frac{1\text{ rxn}}{3\,Mg(OH)_2} = 0.02\text{ mmoles rxn}$$

$$20\text{ mL} \times \frac{1.5\times10^{-3}\text{ moles } H_3PO_4}{L} \times \frac{1\text{ rxn}}{2\,H_3PO_4} = 0.015\text{ mmoles rxn}$$

$$0.015\text{ mmoles rxn} \times \frac{6\,H_2O}{1\text{ rxn}} \times \frac{18.015\text{ g}}{\text{mol}} \times \frac{1\text{ mL}}{0.9984\text{ g}}$$

$$= \boxed{1.6239\times10^{-3}\text{ mL}}$$

12) **[6 marks total]** The air we breathe has X_{O2} = 0.21 and X_{N2} = 0.79 (approximately). Imagine you had a room (filled with air) at 22.8°C at a total pressure of 758.9 torr. The room has a height of 3 metres, a length of 6 metres, and a depth of 8 metres.

a) **[4 marks]** How many kg of oxygen and of nitrogen would be in the room? The volume of the room is given by length x width x depth, and 1 L = 1 dm^3

$3\,m \times \frac{1\,dm}{0.1\,m} = 30\,dm$

$6\,m \times \frac{1\,dm}{0.1\,m} = 60\,dm$

$8\,m \times \frac{1\,dm}{0.1\,m} = 80\,dm$

$V = 30\,dm \times 60\,dm \times 80\,dm$

$= 144{,}000\,dm^3 = 144{,}000\,L$

$n_{TOT} = \frac{(758.9)(144{,}000)}{(62.3635982)(295.95)}$

$= 5921.03...$

So $n_{O_2} = 0.21\,n_{TOT}$

$= 1243.4$

and $n_{N_2} = 4677.6...$

$1243.4\text{ moles } O_2 \times \frac{31.998\,g}{mol} \times \frac{1\,kg}{1000\,g}$

$= 39.8\text{ kg } O_2$

$4677.6\text{ moles } N_2 \times \frac{28.014\,g}{mol} \times \frac{1\,kg}{1000\,g}$

$= 131.0\text{ kg } N_2$

b) **[2 marks]** Calculate the partial pressures of O_2 and N_2 in the room. Give your answer in torr.

$P_{O_2} = 758.9 \times 0.21 = 159.369$ torr

$P_{N_2} = 758.9 \times 0.79 = 599.531$ torr