

## Chemistry 1105 R11 Fall 2023 Test 3

Friday, November 24, 2023

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: \_\_\_\_\_

This test consists of **ten** 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 **42** marks available. Good luck!

- 1) [3 marks] The latest Apple Watch is water-resistant to a depth of 50 metres. How many bars of pressure is this? Assume water has a density of  $0.998 \text{ g/cm}^3$ .

$$0.998 \frac{\text{g}}{\text{cm}^3} \times \left( \frac{100 \text{ cm}}{1 \text{ m}} \right)^3 \times \frac{1 \text{ kg}}{1000 \text{ g}} = 998 \frac{\text{kg}}{\text{m}^3}$$

$$998 \times 9.80665 \times 50 = 489\,351.835 \text{ Pa}$$

$\uparrow$              $\uparrow$              $\uparrow$   
 D            g            h

$$489\,351.835 \text{ Pa} \times \frac{1 \text{ bar}}{100,000 \text{ Pa}} = \boxed{4.893 \dots \text{ bar}}$$

2) [4 marks] The following apparatus was assembled:

**Flask 1:**

Volume: 8 litres

Contains: HCN

At a pressure of: 6 atm

**Flask 2:**

Volume: 12 litres

Contains: H<sub>2</sub>

At a pressure of: 8 atm

The flasks were connected by a valve of no significant volume. When the valve was opened, the following reaction occurred:



The flasks were kept at a constant temperature of 336.18°C before, during and after reaction. Determine the partial pressures of all species after reaction. Give your answers in atm.

$$n_{\text{HCN}} = \frac{PV}{RT} = \frac{6 \cdot 8}{R \cdot 609.33} = 0.96 \text{ moles}$$

↑  
0.0820...

$$n_{\text{H}_2} = \frac{8 \times 12}{R \times 609.33} = 1.92 \text{ moles}$$

LR check:

$$0.96 \text{ moles HCN} \times \frac{1 \text{ rxn}}{1 \text{ HCN}} = 0.96 \text{ moles rxn}$$

$$1.92 \text{ moles H}_2 \times \frac{1 \text{ rxn}}{3 \text{ H}_2} = 0.64 \text{ moles rxn}$$

LR

$$\text{HCN L.O.} = 0.96 \text{ moles HCN} - 1.92 \text{ moles H}_2 \times \frac{1 \text{ HCN}}{3 \text{ H}_2} = 0.32 \text{ moles}$$

CH<sub>4</sub> + NH<sub>3</sub> made:

$$1.92 \text{ moles H}_2 \times \frac{1 \text{ CH}_4}{3 \text{ H}_2} = 0.64 \text{ moles CH}_4$$

(same moles for NH<sub>3</sub>)

So...

$$P_{\text{HCN}} = \frac{0.32 \times R \times T}{20}$$

$$= 0.8 \text{ atm}$$

$$P_{\text{CH}_4} = P_{\text{NH}_3}$$

$$= 1.6 \text{ atm}$$

- 3) [4 marks] A 200-gram block of iron ( $S = 0.449 \text{ J/g}\cdot^\circ\text{C}$ ) at  $95^\circ\text{C}$  was placed into 3 moles of water ( $\bar{C} = 75.37 \frac{\text{J}}{\text{mol}\cdot^\circ\text{C}}$ ) at  $20^\circ\text{C}$ . The water was contained in a cup with  $C = 20.84 \text{ J/}^\circ\text{C}$ . What was the final temperature of the water?

$$\begin{aligned} q_{\text{Fe}} &= 200 \text{ g} \times 0.449 \frac{\text{J}}{\text{g}\cdot^\circ\text{C}} \times (T - 95)^\circ\text{C} \\ + q_{\text{H}_2\text{O}} &= 3 \text{ moles} \times 75.37 \frac{\text{J}}{\text{mol}\cdot^\circ\text{C}} \times (T - 20)^\circ\text{C} \\ + q_{\text{cup}} &= 20.84 \frac{\text{J}}{^\circ\text{C}} \times (T - 20)^\circ\text{C} \\ \hline 0 \text{ J} & \end{aligned}$$

$$89.8(T - 95) + 226.11(T - 20) + 20.84(T - 20) = 0$$

$$89.8T - 8531 + 226.11T - 4522.2 + 20.84T - 416.8 = 0$$

$$336.75T - 13470 = 0$$

$$\Rightarrow \boxed{T = 40^\circ\text{C}}$$

- 4) [4 marks] When 1.99 g of NaOH (40.0 g/mol) is mixed with 100.0 mL of 0.500 M H<sub>2</sub>SO<sub>4</sub> (S = 4.184 J/g·°C, D = 1.00 g/mL) at 22.68°C, the temperature of the resulting solution increases to 32.01°C. Calculate ΔH for the reaction:



Give your answer in kJ.

$$\begin{aligned}
 q_{\text{sol'n}} &= (100 \text{ mL} \times 1.00 \frac{\text{g}}{\text{mL}} + 1.99 \text{ g}) (4.184 \frac{\text{J}}{\text{g} \cdot ^\circ\text{C}}) (32.01 - 22.68) ^\circ\text{C} \\
 &= 3981.3 \dots \text{J} \\
 + q_{\text{rxn}} &= -3981.3 \dots \text{J} \\
 \hline
 &0 \text{ J}
 \end{aligned}$$

LR check:

$$1.99 \text{ g NaOH} \times \frac{1 \text{ mol}}{40.0 \text{ g}} \times \frac{1 \text{ rxn}}{2 \text{ NaOH}} = 0.024875 \text{ mol rxn}$$

$$100 \times 10^{-3} \text{ L} \times 0.5 \frac{\text{moles H}_2\text{SO}_4}{\text{L}} \times \frac{1 \text{ rxn}}{1 \text{ H}_2\text{SO}_4} = 0.05 \text{ mol rxn}$$

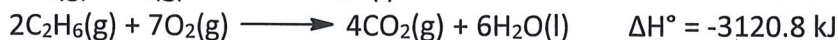
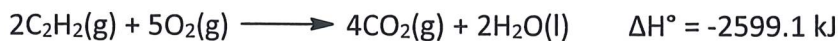
$$\therefore 0.024875 \text{ mol rxn} = -3981.3 \dots \text{J}$$

or

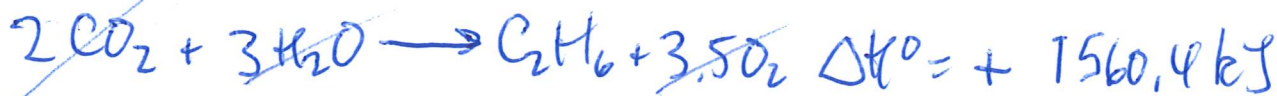
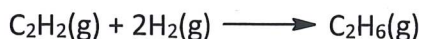
$$1 \text{ mol rxn} = -160,054.4753 \text{ J}$$

$$-160,054 \dots \text{J} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = \boxed{-160.05 \text{ kJ}}$$

5) [3 marks] Given the following reactions:



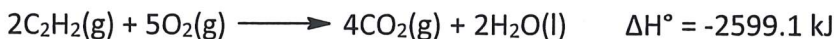
Calculate  $\Delta H^\circ$  for the reaction



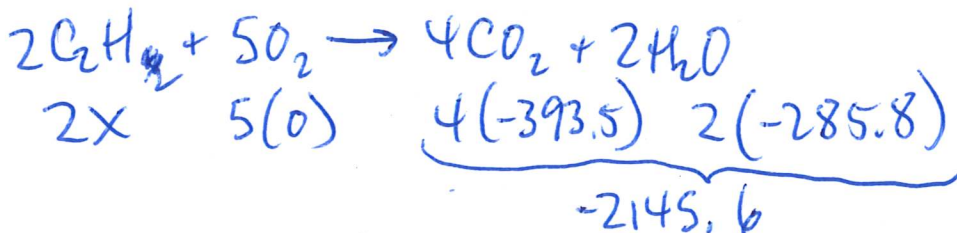
6) [1 mark] Write the thermochemical equation for the formation of  $\text{C}_2\text{H}_6(\text{g})$ , for which  $\Delta H^\circ_f = -84 \text{ kJ/mol}$ .



7) [3 marks] Given that the enthalpy of formation of  $\text{CO}_2(\text{g})$  is  $-393.5 \text{ kJ/mol}$ , and of  $\text{H}_2\text{O}(\text{l})$  is  $-285.8 \text{ kJ/mol}$ , and given the reaction



calculate  $\Delta H^\circ_f$  for  $\text{C}_2\text{H}_2(\text{g})$ . Give your answer in  $\text{kJ/mol}$ .

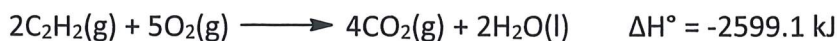


$$-2145.6 - 2x = -2599.1$$

5

$$\Rightarrow x = 226.75 \text{ kJ/mol}$$

8) [3 marks] Given the reaction:

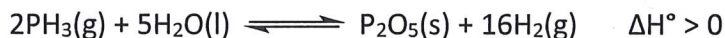


How many kJ of heat will be produced along with 88.02 grams of  $\text{CO}_2$  (44.01 g/mol)?

$$88.02 \text{ g CO}_2 \times \frac{1 \text{ mol}}{44.01 \text{ g}} \times \frac{-2599.1 \text{ kJ}}{4 \text{ mol CO}_2} = -1299.55 \text{ kJ}$$

∴ 1299.55 kJ of heat will be produced.

9) [4 marks] Given the following equilibrium:



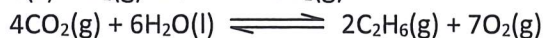
Indicate the effect each of the following changes would have on the value of  $K_c$  and the moles of  $\text{H}_2$  in a reaction initially at equilibrium. Your choices are Increase from the starting value, Decrease from the starting value, or Not Change from the starting value. Circle your choice. You can assume that all changes are carried out at constant temperature unless explicitly stated otherwise.

Action:	Effect on:					
	$K_c$			Mol. $\text{H}_2$		
Increasing the temperature	I	D	NC	I	D	NC
Adding some $\text{P}_2\text{O}_5$	I	D	NC	I	D	NC
Removing some $\text{PH}_3$	I	D	NC	I	D	NC
Decreasing the volume	I	D	NC	I	D	NC

10) [3 marks] Given the following equilibria (and their fictitious equilibrium constants):



$$K_c = 1 \times 10^{30} \text{ at } 27^\circ\text{C}$$

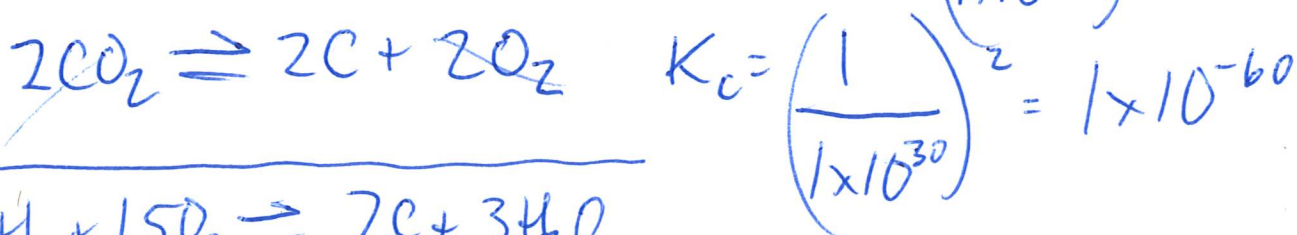
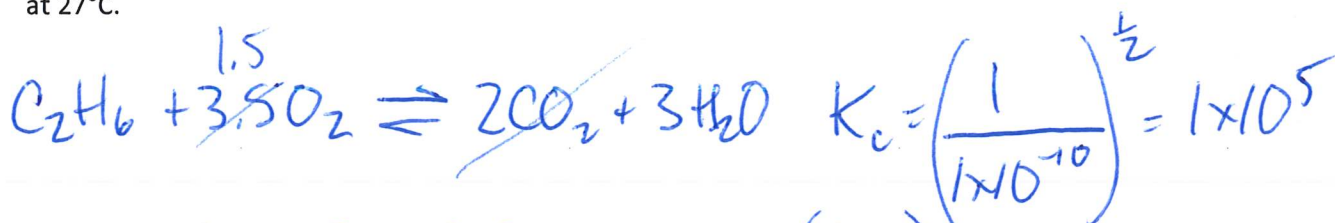


$$K_c = 1 \times 10^{-10} \text{ at } 27^\circ\text{C}$$

Evaluate  $K_c$  for the equilibrium:

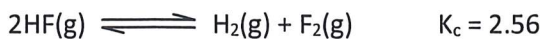


at  $27^\circ\text{C}$ .



$$K_c = 1 \times 10^{-60} \times 1 \times 10^5$$
$$= \boxed{1 \times 10^{-55}}$$

11) [4 marks] A 2-L flask was charged with 4 moles of HF and the equilibrium



established. Calculate the concentrations of all species at equilibrium.



$$i \quad 2\text{M} \quad 0 \quad 0$$

$$c \quad -2x \quad +x \quad +x$$

$$e \quad 2-2x \quad x \quad x$$

$$\frac{x \cdot x}{(2-2x)^2} = 2.56$$

$$\frac{x^2}{(2-2x)^2} = 2.56$$

$$\frac{x}{2-2x} = 1.6$$

$$x = 3.2 - 3.2x$$

$$4.2x = 3.2$$

$$x = \frac{3.2}{4.2} = \frac{16}{21}$$

$$\text{So } [\text{H}_2]_e = [\text{F}_2]_e$$

$$= \frac{16}{21} \text{ M}$$

$$(\sim 0.7619 \text{ M})$$

$$[\text{HF}]_e = 2-2x$$

$$= \frac{10}{21} \text{ M}$$

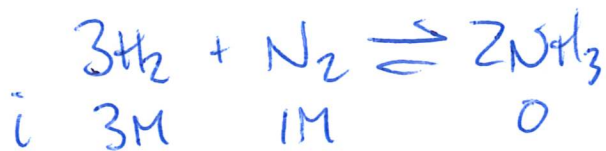
$$(\sim 0.4762 \text{ M})$$



12) [4 marks] A 2-L flask was charged with 6 moles of  $H_2$  and 2 moles of  $N_2$  and the equilibrium



established. Calculate the equilibrium concentrations of all species.



$$\frac{(2x)^2}{(3-3x)^3 \cdot (1-x)} = 1 \times 10^{-5}$$

assume  $1-x \approx 1$ , and  $3-3x \approx 3$  . . . .

$$\frac{(2x)^2}{3^3 \cdot 1} = 1 \times 10^{-5}$$

$$\frac{4x^2}{27} = 1 \times 10^{-5}$$

$$x^2 = \frac{27}{4} \times 10^{-5}$$

$$x = 8.216 \times 10^{-3}$$

So:

$$[N_2]_e = 1M$$

$$[H_2]_e = 3M$$

$$[NH_3]_e = 2x$$

$$= 0.0164 M$$

13) [2 marks] Complete the following table:

Acid	Conjugate Base
$\text{HPO}_4^{2-}$	$\text{PO}_4^{3-}$
$\text{H}_2\text{O}$	$\text{OH}^-$
$\text{NH}_2^-$	$\text{NH}^{2-}$
$\text{CH}_4$	$\text{CH}_3^-$