Copy of 12

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 g/cm^3.

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

$$998 \times 9.80665 \times 50 = 489\,351.835\ Pa$$

D g h

$$489\,351\ldots\ Pa \times \frac{1\ bar}{100{,}000\ Pa} = \boxed{4.893\ldots\ bar}$$

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_2
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:

$$HCN(g) + 3H_2(g) \longrightarrow CH_4(g) + NH_3(g)$$

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.

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

$R = 0.0820\ldots$

$n_{H_2} = \frac{8 \times 12}{R \times 609.33} = 1.92$ moles

LR check:

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

1.92 moles H_2 (LR) $\times \frac{1\ rxn}{3\ H_2} = 0.64$ moles rxn

So... $P_{HCN} = \frac{0.32 \times R \times T}{20} = 0.8$ atm

$P_{CH_4} = P_{NH_3} = 1.6$ atm

HCN L.O. $= 0.96$ moles HCN $- 1.92$ moles $H_2 \times \frac{1\ HCN}{3\ H_2} = 0.32$ moles

CH_4 + NH_3 made:

1.92 moles $H_2 \times \frac{1\ CH_4}{3\ H_2} = 0.64$ moles CH_4

(same moles for NH_3)

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

$$q_{Fe} = 200\,g \times 0.449 \frac{J}{g \cdot °C} \times (T - 95)°C$$

$$+ q_{H_2O} = 3\,moles \times 75.37 \frac{J}{mol \cdot °C} \times (T - 20)°C$$

$$+ q_{cup} = 20.84 \frac{J}{°C} \times (T - 20)°C$$

$$0\,J$$

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

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

$$336.75T - 13470 = 0$$

$$\Rightarrow \boxed{T = 40°C}$$

4) **[4 marks]** When 1.99 g of NaOH (40.0 g/mol) is mixed with 100.0 mL of 0.500 M H_2SO_4 (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:

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

Give your answer in kJ.

$q_{soln} = (100\,mL \times 1.00\frac{g}{mL} + 1.99\,g)(4.184\frac{J}{g\cdot°C})(32.01 - 22.68)°C$

$= 3981.3\ldots J$

$+q_{rxn} = -3981.3\ldots J$

$0\,J$

LR check:

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

$100 \times 10^{-3}\,L \times 0.5\frac{moles\,H_2SO_4}{L} \times \frac{1\,rxn}{1\,H_2SO_4} = 0.05\,mol\,rxn$

$\therefore 0.024875\,mol\,rxn = -3981.3\ldots J$

or

$1\,mol\,rxn = -160,054.4753\,J$

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

5) **[3 marks]** Given the following reactions:

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$ $\quad \Delta H° = -2599.1$ kJ
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ $\quad \Delta H° = -571.6$ kJ
$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l)$ $\quad \Delta H° = -3120.8$ kJ

Calculate $\Delta H°$ for the reaction

$C_2H_2(g) + 2H_2(g) \longrightarrow C_2H_6(g)$

$C_2H_2 + 2.5O_2 \rightarrow 2CO_2 + H_2O \quad \Delta H° = -1299.55$ kJ

$2H_2 + O_2 \rightarrow 2H_2O \quad \Delta H° = -571.6$ kJ

$2CO_2 + 3H_2O \rightarrow C_2H_6 + 3.5O_2 \quad \Delta H° = +1560.4$ kJ ← note!

$C_2H_2 + 2H_2 \rightarrow C_2H_6 \quad \boxed{\Delta H° = -310.75 \text{ kJ}}$

6) **[1 mark]** Write the thermochemical equation for the formation of $C_2H_6(g)$, for which $\Delta H°_f = -84$ kJ/mol.

$2C(s, \text{graphite}) + 3H_2(g) \longrightarrow C_2H_6(g) \quad \Delta H° = -84$ kJ

7) **[3 marks]** Given that the enthalpy of formation of $CO_2(g)$ is -393.5 kJ/mol, and of $H_2O(l)$ is -285.8 kJ/mol, and given the reaction

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l) \quad \Delta H° = -2599.1$ kJ

calculate $\Delta H°_f$ for $C_2H_2(g)$. Give your answer in kJ/mol.

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

$2x \quad 5(0) \quad 4(-393.5) \quad 2(-285.8)$

-2145.6

$-2145.6 - 2x = -2599.1$

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

8) **[3 marks]** Given the reaction:

$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l) \qquad \Delta H° = -2599.1\ kJ$

How many kJ of heat will be produced along with 88.02 grams of CO_2 (44.01 g/mol)?

$88.02\ g\ CO_2 \times \frac{1\ mol}{44.01\ g} \times \frac{-2599.1\ kJ}{4\ mol\ CO_2} = -1299.55\ kJ$

∴ 1299.55 kJ of heat will be produced.

9) **[4 marks]** Given the following equilibrium:

$2PH_3(g) + 5H_2O(l) \rightleftharpoons P_2O_5(s) + 16H_2(g) \qquad \Delta H° > 0$

Indicate the effect each of the following changes would have on the value of K_c and the moles of H_2 in a reaction initially at equilibrium. Your choices are **I**ncrease from the starting value, **D**ecrease from the starting value, or **N**ot **C**hange from the starting value. Circle your choice. You can assume that all changes are carried out at constant temperature unless explicitly stated otherwise.

	Effect on:					
Action:	**K_c**			**Mol. H_2**		
Increasing the temperature	(I)	D	NC	(I)	D	NC
Adding some P_2O_5	I	D	(NC)	I	D	(NC)
Removing some 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):

$C(s) + O_2(g) \rightleftharpoons CO_2(g)$ $\quad K_c = 1 \times 10^{30}$ at 27°C

$4CO_2(g) + 6H_2O(l) \rightleftharpoons 2C_2H_6(g) + 7O_2(g)$ $\quad K_c = 1 \times 10^{-10}$ at 27°C

Evaluate K_c for the equilibrium:

$C_2H_6(g) + 1.5O_2(g) \rightleftharpoons 2C(s) + 3H_2O(l)$

at 27°C.

$C_2H_6 + 3.5O_2 \rightleftharpoons 2CO_2 + 3H_2O \quad K_c = \left(\frac{1}{1\times10^{-10}}\right)^{\frac{1}{2}} = 1\times10^{5}$

$2CO_2 \rightleftharpoons 2C + 2O_2 \quad K_c = \left(\frac{1}{1\times10^{30}}\right)^{2} = 1\times10^{-60}$

$C_2H_6 + 1.5O_2 \rightleftharpoons 2C + 3H_2O$

$K_c = 1\times10^{-60} \times 1\times10^{5}$

$= \boxed{1\times10^{-55}}$

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

$2HF(g) \rightleftharpoons H_2(g) + F_2(g)$ $\quad K_c = 2.56$

established. Calculate the concentrations of all species at equilibrium.

	$2HF$	$\rightleftharpoons$	H_2	+	F_2
i	2M		0		0
c	$-2x$		$+x$		$+x$
e	$2-2x$		x		x

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

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

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

$$x = 3.2 - 3.2x$$

$$4.2x = 3.2$$

$$x = \frac{32}{42} = \frac{16}{21}$$

So $[H_2]_e = [F_2]_e$

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

$(\approx 0.7619\ M)$

$[HF]_e = 2-2x$

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

$(\approx 0.4762\ M)$

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

$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$ $\quad K_c = 1.00 \times 10^{-5}$

established. Calculate the equilibrium concentrations of all species.

$3H_2 + N_2 \rightleftharpoons 2NH_3$

i	3M	1M	0
c	$-3x$	$-x$	$+2x$
e	$3-3x$	$1-x$	$2x$

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

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

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

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

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

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

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
HPO_4^{2-}	PO_4^{3-}
H_2O	OH^-
NH_2^-	NH^{2-}
CH_4	CH_3^-