Chem 4A Exam 3

TOTAL POINTS

84 / 100

QUESTION 1

1 1.1 **5 / 5**

- **- 5 pts** incorrect: a
- **- 5 pts** incorrect: b
- **- 5 pts** incorrect: c
- ✓ **- 0 pts correct: d**
- **- 5 pts** incorrect

QUESTION 2

2 1.2 **5 / 5**

- **- 5 pts** incorrect: A
- **- 5 pts** incorrect: B
- ✓ **- 0 pts correct: C**
- **- 5 pts** incorrect: D

QUESTION 3

3 1.3 **5 / 5**

- ✓ **- 0 pts Correct (answer C)**
- **- 5 pts** Incorrect

QUESTION 4

4 1.4 **5 / 5**

- ✓ **- 0 pts Correct (answer C)**
- **- 5 pts** Incorrect

QUESTION 5

5 1.5 **5 / 5**

- ✓ **- 0 pts Correct (answer B)**
- **- 5 pts** Incorrect

QUESTION 6

6 2 **6 / 9**

- **- 3 pts** delta U is supposed to be negative
- **- 3 pts** w is supposed to be negative
- ✓ **- 3 pts delta H is supposed to be negative**
- **- 0 pts** correct

QUESTION 7

7 3.a **3 / 6**

- ✓ **+ 2 pts True**
- **+ 4 pts** Correct Explanation. Includes ideal gas law with p equal to the partial pressure of the gas solved for pressure, showing the expression for pressure includes n/V, which equals concentration
- **+ 2 pts** Explanation correct without explicitly showing that partial pressure is equal to an expression for concentration
- ✓ **+ 1 pts On the right track but no mention of ideal gas law or concentration expression**
- **+ 0 pts** Wrong True/False

QUESTION 8

8 3.b **6 / 6**

- ✓ **+ 2 pts False**
- ✓ **+ 4 pts Correct explanation. Delta H of formation is only zero for elements in the reference state**
- **+ 0 pts** Wrong True/False

QUESTION 9

9 3.c **0 / 6**

- **+ 2 pts** False
- **+ 4 pts** Correct Explanation. Delta H is heat of reaction at constant pressure, can't guarantee sign of heat with varied pressures
- ✓ **+ 0 pts Wrong True/False**
- **+ 2 pts** Discussed mechanism of determining delta H without discussing change in pressure

QUESTION 10

10 4 **8 / 8**

- ✓ **+ 4 pts Correct Mass of Oxygen**
- ✓ **+ 2 pts Correct Moles**
- ✓ **+ 2 pts Correct Manipulation of Ideal Gas Law**

+ **0 pts** Completely Incorrect

- **1 pts** Wrong Temperature Used

- **0.5 pts** Wrong Significant Figures

- **1.5 pts** Wrong Pressure Used

- **1 pts** Calculation Error

+ **0 pts** Click here to replace this description.

QUESTION 11

11 5.a **5 / 5**

✓ + **2 pts** **Recognize constant pressure is higher**

✓ + **3 pts** **Give physical explanation in details**

+ **1 pts** Just give the values of two heat capacities

+ **0 pts** Incorrect Answer

QUESTION 12

12 5.b **5 / 5**

✓ + **2 pts** **Recognize diatomic gas is higher**

✓ + **3 pts** **Give physical explanation in details**

+ **0 pts** Incorrect Answer

QUESTION 13

13 6.a **6 / 6**

✓ + **6 pts** **Correct**

+ **3 pts** Correct heat of reaction, but not for 1 mol octane

+ **0 pts** Incorrect

QUESTION 14

14 6.b **2 / 6**

+ **6 pts** Correct

✓ + **2 pts** **Correct equation, incorrect answer**

+ **0 pts** Incorrect

QUESTION 15

15 7 **8 / 8**

✓ + **8 pts** **Correct**

+ **2 pts** Kinetic Energy = 1/2* M * V^2 with calculations

+ **2 pts** Equipartition Energy = 3/2 RT with calculations

+ **2 pts** Correct units (kg/mol for molecular weight, R = 8.3145, V = 10 m/s, T = 300 K)

+ **2 pts** Algebra+ the final(correct) answer

+ **0 pts** blank/incorrect

+ **6 pts** Per molecule vs per mol

QUESTION 16

16 8 **10 / 10**

+ **0 pts** No answer

✓ + **2 pts** **Correct moles for 10%**

✓ + **2 pts** **Correct moles for 50%**

✓ + **2 pts** **Correct conversion to mass for 10%**

✓ + **2 pts** **Correct conversion to mass for 50%**

✓ + **2 pts** **Correct units (kg or N)**

+ **1 pts** Partially attempted

Midterm 3

Potentially useful equations:

Kinetic energy: $KE = mv^2/2$

Gravitational potential energy: $E_g = mgh$

Result of the kinetic theory of gases: $PV = \frac{1}{3}Nmv^2$

Mean free path of gas molecules: $\lambda = \frac{1}{\sqrt{2}n_V \pi d^2}$

Maxwell–Boltzmann distribution: $f(v) = 4\pi v^2\left[\frac{M}{2\pi RT}\right]^{3/2}\exp\left[-\frac{1}{2}\frac{Mv^2}{RT}\right]$

Van der Waals equation: $\left[P + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT$; "Compressibility Factor": $z = \frac{PV}{nRT}$

Work in reversible isothermal processes: $w = -nRT\ln\frac{V_\infty}{V_1} = -nRT\ln\frac{P_1}{P_\infty}$

Potentially useful constants:

$g = 9.8$ m/s^2; 1 atm ~101325 Pa ~760 mm Hg; 1 bar = 10^5 Pa

$R = 8.314$ J mol^{-1} K^{-1}

$k_B = 1.381 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}

T (0 °C) =273.15 K

1 cal = 4.18 J

Density of liquids: $\rho(H_2O) = 1.00$ g/mL; $\rho(Hg) = 13.6$ g/mL

Relative atomic mass: H=1, C=12, N=14, O=16, Cl =35.5

$N_A = 6.02\times10^{23}$

Full score of this exam is 100 points.

Question 1. Multiple choices (5 pts each question; only one correct answer for each question)

1. The typical air temperature in a hot air balloon is ~100 ˚C (212 ˚F). The mass density of this air should thus be (   ) of the ambient air at ~25 ˚C (77 ˚F).

$\frac{D_2}{D_1} = \frac{m}{1.25V} \cdot \frac{V}{m} = \frac{1}{1.25}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ A. 25% B. 36% C. 50% [✓ D. 80%]

$V_2 = \frac{V_1 T_2}{T_1} = 1.25V_1$ $D_1 = \frac{m}{V_1}$ $D_2 = \frac{m}{V_2} = \frac{m}{1.25V_1}$

2. Given that the root-mean-square velocity of N_2 is ~500 m/s at room temperature, the root-mean-square velocity of H_2 at room temperature can be estimated as: (   )

A. 134 m/s B. 500 m/s [✓ C. 1870 m/s] D. 7000 m/s

$V_{rms} = \sqrt{\frac{3k_BT}{m}}$ $V_{N_2} = \sqrt{\frac{3RT}{28}}$ $V_{H_2} = \sqrt{\frac{3RT}{2}}$ $\sqrt{14} \cdot 500$

3. The electrolysis of water provides a way to generate H_2. At room temperature, to produce 1000 L of H_2 this way would approximately consume this amount of water: (   )

A. 1 mL B. 10 mL [✓ C. 1 L] D. 10 L

$PV = nRT$ $n = \frac{PV}{RT} = \frac{1 \cdot 1000}{0.08205 \cdot 298} \approx 40$ mol H_2 → 40 mol $H_2O \cdot \frac{18g}{mol} = 736g$

4. In the van der Waals equation (Page 1), the factor *a* is introduced to correct for: (   )

A. the volume occupied by the molecules themselves
B. effects due to the distribution of velocity for the different molecules
[✓ C.] effects of (attractive) forces between molecules
D. momentum changes when molecules collide
E. statistical variations resulting from the crooked paths traveled by molecules

5. When the same amount of heat *q* is separately transferred to two copper blocks A and B, the two blocks increased in temperature by 10 ˚C and 20 ˚C, respectively. In a different experiment, the copper blocks A and B are put into contact with each other, and the same amount of heat *q* is transferred to this combined system. We thus expect the temperature change for the system to be: (   )

A. 4 ˚C [✓ B. 6.7 ˚C] C. 15 ˚C D. 30 ˚C

$10Ac = 20Bc$
$A = 2B$

$q = 10Ac = 20Bc$

$q = (A+B)c\Delta T$

$20Bc = (2B+B)c\Delta T$
$20B = 3B\Delta T$ $\Delta T = \frac{20}{3}$

Question 2. (9 pts) An ideal gas system went through **adiabatic ($q = 0$)** expansion at 1 atm external pressure. In this process, what is the sign for each of the below 3 items? Write "+", "0", or "−" for each item.

ΔU —

w —

ΔH 0

Adiabatic process $q = 0$ $w < 0$

$\Delta U = q + w$
$\Delta U = w$
$\Delta U < 0$

$\Delta H = \Delta U - w = \Delta U - \Delta U = 0$

Chemistry 4A, Fall 2019

Name [redacted]

ID # [redacted]

<u>For the below questions, for full credit, please show your work and respond below each question. Work in the margins will not be graded.</u>

Question 3. (6 pts per question) Analysis: Are the following statements true or false? For each statement, first state unequivocally whether the statement is true or false (2 pts). Afterward, for statements you answer "true", discuss the mechanisms. For statements you answer "false", either discuss the mechanisms or give one specific counter-example to disprove the statement. (4 pts for the explanation)

(a) At a given, fixed temperature, the partial pressure of a gas species effectively defines its concentration.

True Daltons law of partial pressure states that the partial pressure of a gas species is equal to its mole fraction times the total pressure, effectively giving a measure of the gas species' concentration

(b) The standard enthalpy of formation is 0 for any pure element.

False, standard enthalpy of formation is defined as 0 for the reference, or most stable state of an element. For example, diamond is pure carbon, but its standard enthalpy of formation is not zero because the reference state of carbon is graphite.

(c) If the calculated Δ*H* for a given reaction is <0, we predict the reaction to be exothermic under any experimental conditions.

True, if a given reaction releases heat, no change in conditions can cause that same reaction to bsorb heat. The heat released or consumed by a reaction is determined by the bonds made or broken in the reaction, which cannot be changed by external conditions

Question 4. (8 pts) A tank of compressed air of a fixed volume of 22.4 L operated at 0 °C. The tank pressure was 100 atm and 50 atm before and after operation, respectively. Calculate the **mass** of oxygen (O_2) released, assuming that the mole fraction of O_2 in the compressed air to be 20%.

$PV = nRT$

$n_i = \frac{PV}{RT} \rightarrow P = P_{O_2} = 0.20 P_{Tot}$

$n_i = \frac{0.20 P_{Tot} V}{RT} = \frac{0.20 \cdot 100\,atm \cdot 22.4\,L}{0.082057 \cdot 273\,K} = 19.999 = 20\,mol\ O_2$

$n_f = \frac{0.20 P_{Tot} V}{RT} = \frac{0.20 \cdot 50\,atm \cdot 22.4\,L}{0.082057 \cdot 273\,K} = 10.044 = 10\,mol\ O_2$

$\therefore n_i - n_f = 20\,mol - 10\,mol = 10\,mol\ O_2$ released

$10\,mol \cdot \frac{31.998\,g\ O_2}{mol\ O_2} = 319.98$

$\approx \boxed{320\,g\ O_2}$

Question 5. (10 pts) When considering the heat capacity of ideal gases:

(a) (5 pts) We showed in our lectures that the heat capacity of 1 mol of monatomic gas at constant pressure to be different from its heat capacity at constant volume. Which one is higher? Why?

Heat capacity at constant pressure is higher than at constant volume, because at constant pressure some of the added heat is expended by the gas expanding and doing work, whereas at constant volume all the heat goes toward raising the temperature.

(b) (5 pts) For the heat capacity of 1 mol of ideal gases at constant volume: is the expected value higher, lower, or the same for a diatomic gas (e.g., N_2) vs. a monatomic gas? Why?

The heat capacity for diatomic gases is expected to be higher because diatomic gases have rotational degrees of freedom, which per the equipartition theorem, have equal energy to the translational degrees of freedom that contribute to temperature.

Question 6. (12 pts) Octane (C_8H_{18}) is a major component of gasoline, and its combustion can be written as:

1 mol octane

$$\underset{1}{2}\,C_8H_{18}(l) + \underset{12.5}{25}\,O_2(g) \longrightarrow \underset{8}{16}\,CO_2(g) + \underset{9}{18}\,H_2O(l)$$

(a) (6 pts) Given $\Delta_f H^\circ[C_8H_{18}(l)] = -250\text{ kJ/mol}, \Delta_f H^\circ[H_2O(l)] = -286\text{ kJ/mol}$, $\Delta_f H^\circ[CO_2(g)] = -394\text{ kJ/mol}$, what is the expected heat of reaction for burning 1 mol octane at 1 atm?

$$\Delta H = 9\,\Delta_f H^\circ[H_2O(l)] + 8\,\Delta_f H^\circ[CO_2(g)] - \Delta_f H^\circ[C_8H_{18}(l)]$$

$$= 9\text{ mol}(-286\text{ kJ/mol}) + 8\text{ mol}(-394\text{ kJ/mol}) - 1\text{ mol}(-250\text{ kJ/mol})$$

$$= -2574\text{ kJ} - 3152\text{ kJ} + 250\text{ kJ} = -5476\text{ kJ} \rightarrow \boxed{-5500\text{ kJ}}$$

(b) (6 pts) Now consider 1 mol octane burnt in a sealed bomb calorimeter at 300 K. How does the reaction heat in this case compare to that in (a), in terms of percentage?

$$\Delta H = \Delta U + \Delta PV = \Delta U + \Delta nRT = \Delta U + RT\Delta n$$

12.5 mol O_2 → 8 mol CO_2

$\Delta n = -4.5$ mol

$\Delta U = q + w$

constant volume, w = 0

$\Delta U = q$

$$\Delta H = -5476\text{ kJ} + 8.314\text{ J/mol K} \cdot 300\text{ K} \cdot (-4.5\text{ mol}) \cdot \frac{1\text{ kJ}}{1000\text{ J}} = -5487\text{ kJ}$$

$$\frac{-5487\text{ kJ}}{-5476\text{ kJ}} \approx 1.00201$$

$\boxed{\Delta H \text{ is } 0.20\% \text{ greater at constant volume}}$

[redacted]

Questions 7 & 8 are brought to us by the good people at PG&E. Power shutdowns were unfortunate carried out due to the concerns of high wind and low humidity conditions. So:

Question 7. (8 pts) Wind power can be modeled as the kinetic energy (*KE*; equation on Page 1) due to the directional motion of the air (MW: 29 g/mol). For a reasonably strong wind of speed *v* of 10 m/s (22.4 mph), how does this energy compare to the microscopic kinetic energy of its gas molecules due to thermal motion at 300 K, in terms of percentage?

$KE = \frac{1}{2}Mv^2 = \frac{1}{2} \cdot 0.029 \frac{kg}{mol} \cdot (10 \, m/s)^2 = 1.45 \, J/mol$

Themal energy: $\frac{3}{2}RT = \frac{3}{2} \cdot 8.314 \cdot 300k = 3741.3 \, J/mol$

$\frac{1.45 \, J/mol}{374.3 \, J/mol} = 0.00038762 \quad \boxed{0.039\%}$

kinetic energy of wind is 0.039% kinetic energy of thermal motion

Question 8. (10 pts) Air humidity is typically reported as the relative humidity (RH), defined as the partial pressure of H_2O (g) in the air divided by the vapor pressure of H_2O at the same temperature. At 300 K, the vapor pressure of H_2O is 0.0349 atm (3540 Pa). For a room of 100 m^3 (10^5 L) volume, what is the total <u>weight</u> of H_2O in the air for low (10%) and moderate (50%) RH, respectively?

$RH = \frac{P_{H_2O}}{P_{vapor}}$

$P_{H_2O} = RH \cdot P_{vapor}$

100% RH: $P_{H_2O} = 0.10 \cdot 0.0349 \, atm = 0.00349 \, atm$

$PV = nRT$

$n = \frac{PV}{RT} = \frac{0.00349 \, atm \cdot 10^5 L}{0.082057 \cdot 300} = 14.18 \, mol \cdot H_2O$

$14.18 \, mol \, H_2O \cdot \frac{18 \, g \, H_2O}{1 \, mol \, H_2O} = \boxed{260 \, g \, H_2O \text{ at } 10\% \, RH}$

500% RH: $P_{H_2O} = 0.50 \cdot 0.0349 \, atm = 0.01745 \, atm$

$n = \frac{PV}{RT} = \frac{0.01745 \, atm \cdot 10^5 L}{0.082057 \cdot 300} = 70.89 \, mol$

$70.89 \, mol \cdot \frac{18 \, g \, H_2O}{1 \, mol \, H_2O} = 1275.44 \rightarrow \boxed{1300 \, g \, H_2O \text{ at } 50\% \, RH}$