Chem 101 General Chemistry
Fall 2009-2010 Final Exam
15-01-2010  8.30-10.30

Student No: Q1  Q2  Q3  Q4  Q5  Q6
Name:        Q2  Q6
Group:       Q3
Signature:   Q4  TOTAL

INSTRUCTIONS:
1. Write your name, surname and group no. on the question booklet.
2. Students who do not write their group number or those who write their group number wrong will lose 3 points.
3. The exam consists of 6 classical type of questions. In order to get full marks you must answer all questions. Show your steps in answering the classical type of questions.
4. The following information and Periodic Table provided may be necessary to answer some of the questions.
5. Use of mobile phones, exchange of calculators or rubbers is not allowed.
6. You can see your papers in the first 10 days after the announcement of the results.

Periodic Table of Elements

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Constants: \( R = 0.0821 \text{ (L.atm)}/(\text{mol.K}) = 8.31 \text{ J/(mol.K)} \)
\( N_A = 6.022 \times 10^{23} \text{ items/mol} \)
Q1. (12 pts)

Give the number of protons and electrons in

a) a C_{60} molecule
\[ \# \text{ of } p = 60 \times 6 = 360 \]
\[ \# \text{ of } e = 360 \]

b) a CN\(^-\) ion
\[ \# \text{ of } p = 6 + 7 = 13 \]
\[ \# \text{ of } e = 14 \]

c) a CO\(_2\) molecule
\[ \# \text{ of } p = 6 + (2 \times 8) = 22 \]
\[ \# \text{ of } e = 22 \]

d) an N\(^+\) ion
\[ \# \text{ of } p = 7 \]
\[ \# \text{ of } e = 10 \]

Q2. (21 pts)

The content of a tank of natural gas at 1.40 atm is analysed. The analysis showed the following mole percent: 65% CH\(_4\), 15% C\(_2\)H\(_6\), and 20% C\(_4\)H\(_{10}\)

a) What is the partial pressure of each gas in the tank?

b) If tank has a tiny hole, at a constant temperature and pressure, which gas will effuse first, second and third? Use the appropriate formula to prove your answer.

c) Find how many CH\(_4\), C\(_2\)H\(_6\), and C\(_4\)H\(_{10}\) molecules are there in the tank (Assume that the total number of moles of three gases is 100)?

\[ \text{Mole percent of gas } X \] = \[ \frac{N_x}{N_T} \] \times 100

\[ \text{Mole fraction of gas } X \] = \[ \frac{N_x}{N_T} \]

Mole percent:
CH\(_4\) = 65% \[ \rightarrow X_{CH_4} = 0.65 \] (3 pts)
C\(_2\)H\(_6\) = 15% \[ \rightarrow X_{C_2H_6} = 0.15 \]
C\(_4\)H\(_{10}\) = 20% \[ \rightarrow X_{C_4H_{10}} = 0.20 \]

Partial pressure of gas \( X \) = \[ P_T \times \text{mole fraction of gas } X \]

\[ P_{CH_4} = 1.40 \text{ atm} \times 0.65 = 0.91 \text{ atm} \] (3 pts)
\[ P_{C_2H_6} = 1.40 \text{ atm} \times 0.15 = 0.21 \text{ atm} \]
\[ P_{C_4H_{10}} = 1.40 \text{ atm} \times 0.20 = 0.28 \text{ atm} \]
Graham's Law: At constant P and T, light molecules effuse more rapidly than heavier ones
\[
\frac{\text{Rate of effusion } B}{\text{Rate of effusion } A} = \left(\frac{M_A}{M_B}\right)^{1/2}
\]

(3 pts) \(M_{\text{CH}_4} = 16 \text{g/mol}\), \(M_{\text{C}_2\text{H}_6} = 30.1 \text{g/mol}\) and \(M_{\text{C}_4\text{H}_{10}} = 58.1 \text{g/mol}\)

\(\text{CH}_4 < \text{C}_2\text{H}_6 < \text{C}_4\text{H}_{10}\). Therefore →

(3 pts) 1st effused gas: \(\text{CH}_4\), 2nd: \(\text{C}_2\text{H}_6\), 3rd: \(\text{C}_4\text{H}_{10}\)

Q3. Answer the following questions:

a) How many unpaired electrons are there in an atom of scandium (Sc)? Explain the reason shortly. (2 pts)

\[\text{Sc} \quad \text{[Ar]} \quad 4s^2 \quad 3d^1\]

b) What is the electron configuration and orbital diagram for Ni? (4 pts)

\(\text{Ni}^0 \quad 1s^2 \quad 2s^2 \quad 2p^6 \quad 3s^2 \quad 3p^6 \quad 3d^8 \quad 4s^2 \quad 3d^1\)

(c) What is the abbreviated electron configuration for \(\text{Ni}^{2+}\) and \(\text{Ni}^{3+}\)? (4 pts)

\(\text{Ni}^{2+} \quad [\text{Ar}] \quad 3d^8\)

\(\text{Ni}^{3+} \quad [\text{Ar}] \quad 3d^7\)

d) What is the electron configuration for \(\text{N}^{3-}\)? (2 pts)

\(\text{N}^{3-} \quad 1s^2 \quad 2s^2 \quad 2p^6\)

e) Write the symbol for the halide (halogen ion) that is isoelectronic to xenon (Xe)? (3 pts)

\(\text{I}^-\)

\(2 - 0\)

Gases → \(n_T = 100\) → \(n_{\text{CH}_4} = 65\), \(n_{\text{C}_2\text{H}_6} = 15\) and \(n_{\text{C}_4\text{H}_{10}} = 20\)

\(\#\) of \(\text{CH}_4\) molecules: 1 mol \(6.022 \times 10^{23}\) molecules

\(\#\) of \(\text{C}_2\text{H}_6\) molecules: 1 mol \(6.022 \times 10^{23}\) molecules

\(\#\) of \(\text{C}_4\text{H}_{10}\) molecules: 1 mol \(6.022 \times 10^{23}\) molecules

\(\#\) of \(\text{CH}_4\) molecules: 65 mol \(3.914 \times 10^{23}\) molecules

\(\#\) of \(\text{C}_2\text{H}_6\) molecules: 15 mol \(9.03 \times 10^{23}\) molecules

\(\#\) of \(\text{C}_4\text{H}_{10}\) molecules: 20 mol \(120.4 \times 10^{23}\) molecules
Q4. When 5 g of acetone (C₃H₆O (l)) burns in air, carbon dioxide (CO₂) gas and liquid water are formed. Enough heat is released to increase the temperature of 1 kg of water from 25 °C to 61.8 °C. The specific heat of water is 4.18 J/g °C.

a) How many kJ of heat are released by the combustion described? (5 pts)
b) How many grams of acetone must be burned to release 5 kJ of heat? (5 pts)
c) Write the thermochemical equation for the combustion of acetone? (8 pts)

\[ Q = m \times c \times \Delta T \]
\[ = 1000 \text{g} \times 4.18 \text{ J/°C} \times (61.8 - 25) \text{ °C} \]
\[ = 154 \text{ kJ} \] (3 pts)

b) 5 g acetone

0.162 g acetone (5 pts)

\[ \text{154 kJ released} \]

\[ \text{5 kJ} \]

\[ \text{154 kJ released} \]

\[ \text{58.1 g} \] (2 pts)

\[ \begin{align*}
\text{C}_3\text{H}_6\text{O}(s) + 4\text{O}_2(g) & \rightarrow 3\text{CO}_2(g) + 3\text{H}_2\text{O}(l) \\
\text{M}_\text{C}_3\text{H}_6\text{O} & = (3 \times 12.01 + 6 \times 1.008 + 16) \text{ g} = 58.1 \text{ g/mol} \\
5 \text{ g acetone} & \rightarrow 154 \text{ kJ released} \\
58.1 \text{ g} & \rightarrow 1.79 \times 10^3 \text{ kJreleased} \\
\text{Thermochemical equation:} & \\
\text{C}_3\text{H}_6\text{O}(s) + 4\text{O}_2(g) & \rightarrow 3\text{CO}_2(g) + 3\text{H}_2\text{O}(l) \Delta H = -1.79 \times 10^3 \text{ kJ} \\
\end{align*} \] (5 pts)
Q5. a) When limestone (CaCO$_3$) is heated to a temperature of 900 °C, it decomposes (separates) to calcium oxide (CaO) and carbon dioxide (CO$_2$).

CaCO$_3$ (s) → CaO (s) + CO$_2$ (g)

How much heat is evolved or absorbed when one gram of CaCO$_3$ decomposes? (10 pts)

$\Delta H^\circ_{f} \text{CaCO}_3(s) = -1207 \text{ kJ/mol}$; $\Delta H^\circ_{f} \text{CaO(s)} = -635 \text{ kJ/mol}$; $\Delta H^\circ_{f} \text{CO}_2(g) = -393.5 \text{ kJ/mol}$

$\Delta H^\circ = \sum \Delta H^\circ_{f} \text{products} - \sum \Delta H^\circ_{f} \text{reactants}$

$\Delta H^\circ = \left[ \text{1 mol} \times -393.5 \frac{\text{kJ}}{\text{mol}} \right] + \left[ \text{1 mol} \times -635 \frac{\text{kJ}}{\text{mol}} \right] - \left[ \text{1 mol} \times -1207 \frac{\text{kJ}}{\text{mol}} \right]$  

$\Delta H^\circ = -1028.5 \text{ kJ} + 1207 \text{ kJ} = +178.5 \text{ kJ} \text{ (uptake)}$

178.5 kJ absorbed by 1000 g CaCO$_3$ per mol CaCO$_3$ (3 pts)

b) Consider the reaction: 2C$_2$H$_2$ (g) + 5O$_2$ (g) → 4CO$_2$ (g) + 2H$_2$O (l)

For this reaction, the enthalpy change is $\Delta H = -2595 \text{ kJ}$. Calculate $\Delta E$ at 25 °C? (8 pts)

$\Delta H = \Delta E + \Delta n_g R T$

$\Delta n_g = 4 - 2 = -2 \text{ mol}$

$-2599 \text{ kJ} = \Delta E + (-2 \text{ mol}) \times 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 298 \text{ K}$

$\Delta E = -7429 \text{ J}$

$\Delta E = -7.429 \text{ kJ}$

$\Delta E = -2591.6 \text{ kJ} \text{ (3 pts)}$
Q6. a) Chloroform (CHCl₃) has a vapour pressure of 197 mmHg at 23 °C and 448 mmHg at 45 °C. Calculate its heat of vaporization (ΔHᵥap)? (8 pts)

\[ \ln \frac{P_2}{P_1} = \frac{\Delta Hᵥap (T_2 - T_1)}{R \times T_1 \times T_2} \]

\[ P_1 = 197 \text{ mmHg} \quad T_1 = 23 \text{°C} = 296 \text{ K} \]
\[ P_2 = 448 \text{ mmHg} \quad T_2 = 45 \text{°C} = 318 \text{ K} \]
\[ R = 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}} \]

\[ \ln \frac{448}{197} = \frac{\Delta Hᵥap (318 - 296) \text{ K}}{8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}} \times 296 \text{ K} \times 318 \text{ K}} \]

\[ \Delta Hᵥap = 29.21 \frac{\text{kJ}}{\text{mol}} \]

b) Classify each of the following solids as metallic, network covalent, ionic or molecular (8 pts)

(i) It melts below 100 °C and is insoluble in water

Molecular

(ii) It conducts electricity only when molten

Ionic

(iii) It is insoluble in water and conducts electricity

Metallic

(iv) It is a hard solid, has very high melting point, non conductor and insoluble in common solvents

Network Covalent