University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II RESIT EXAMINATION - 2010

CHEM 10030

Chemistry For Engineers

Professor Wayne

Professor Waghorne

Dr. Sullivan *

Dr Quinn *

Time Allowed: 2 hours

Instructions for Candidates

Use a separate answer book provided for each question.

No loose rough work sheets are to be used. The rough work for each question should be included in the answer book for that question.

ONLY STUDENTS SEEKING TO IMPROVE THEIR LABORATORY GRADE SHOULD ATTEMPT QUESTION 3

Instructions for Invigilators

The use of electronic calculators is permitted
A Periodic Table of the Elements is attached to these sheets
Graph paper should be provided

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Answer ***both questions 1 and 2***

Students seeking to improve their laboratory grade should also answer question 3

Question 1

Answer any ***three*** of the following (a) – (e)

(a) Answer ***all*** sections (i) – (iii)

(i) Draw a diagram of the apparatus used to generate a hydrogen emission spectrum. (10)

(ii) Explain, at an atomic level, the processes taking place during the absorption and emission of energy during this experiment. (10)

(iii) Determine the energy (in J) of the light emitted when an electron makes a transition from the $n = 4$ orbital to the $n = 3$ orbital in a hydrogen atom. (13.3)

$$\text{Rydberg constant} = 2.18\times10^{-18}\ \text{J molecule}^{-1}$$

(b) Answer ***all*** sections (i) – (iii)

(i) Order the following regions of the electromagnetic spectrum in increasing order of energy: γ Ray, Ultra Violet, Microwave, Infra red, X Ray, Radiowave. (10)

(ii) Write an equation expressing the relationship between the wavelength of light and its energy. (5)

(iii) Explain why electromagnetic radiation with a high frequency may be considered dangerous. (5)

(iv) Microwave ovens operate at a frequency of 2.45 GHz (Giga = 10^9). What is the wavelength of this radiation? What is its energy per photon? (13.3)

The speed of light is 3×10^8 m s^{-1} and Planck's constant is 6.626×10^{-34}J s.

(c) Answer ***all*** sections (i) – (ii)

(i) The conversion of $C_6H_6 + O_2$ mixtures into $CO_2 + H_2O$ mixtures is an exothermic process. What does this suggest about the relative strengths of the C – C, C—H, C = O and O – H bonds in the C_6H_6, O_2, H_2O and CO_2. (20)

(ii) Determine the number of moles of H_2O and the mass of CO_2 formed following the combustion of 500kg of C_6H_6. (13.3)

(d) Answer ***all*** sections

Draw Lewis structures and predict the shapes of the following molecules:

NH_3	(5)
CH_4	(5)
H_2O	(5)
PCl_5	(5)
BrF_5	(7)
SF_4	(7.3)

(e) Answer ***all*** sections (i) – (iii)

(i) Draw a diagram showing the experiment that Rutherford performed using gold foil and α particles and explain how his conclusions following this experiment furthered the development of modern atomic theory. (20)

(ii) Explain how Rutherford would have produced a stream of α particles for use in the experiment described in section (i). (13.3)

Question 2

Answer any ***two*** of the following (a) – (c)

(a) For the endothermic reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$$

Write and expression for the equilibrium constant in terms of concentrations.

At 2010 K, the equilibrium constant, K_c for the reaction is 4.0×10^{-4}. If the equilibrium concentrations of N_2 and O_2 are 0.28 mol/L and 0.38 mol/L at 2010 K in a 1 L flask, what is the equilibrium concentration of NO?

Predict the effect on amount of NO in the system when the reaction temperature is increased. Explain your reasoning.

Would you expect the equilibrium constant to be the same for a 50 L flask? (50)

(b) Answer ***all*** parts (i), (ii) ***and*** (iii).

(i) Define the standard enthalpy of formation of a compound $\Delta H_f^{\ominus}$;

(ii) State Hess's Law;

(iii) Given the following information:

$$4CO_2(g) + 6H_2O(l) \rightarrow 2C_2H_6(g) + 7\,O_2(g) \quad \Delta_r H^{\ominus} = +3120 \text{ kJ mol}^{-1}$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta_r H^{\ominus} = -394 \text{ kJ mol}^{-1}$$

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g) \quad \Delta_r H^{\ominus} = +572 \text{ kJ mol}^{-1}$$

Calculate the standard enthalpy of formation of ethane $C_2H_6(g)$ (50)

(c) Answer ***all*** parts (i), (ii) ***and*** (iii).

(i) Explain briefly the meaning of the following terms in chemical kinetics:

Rate equation *Reaction half-life* *Rate determining step*

(ii) The complex reaction: $O_3\,(g) + 2\,NO_2\,(g) \rightarrow N_2O_5(g) + O_2(g)$

Is proposed to occur by the following two ELEMENTARY reactions:

$O_3\,(g) + NO_2\,(g) \rightarrow NO_3\,(g) + O_2\,(g)$ slow, rate constant k_1

$NO_3\,(g) + NO_2\,(g) \rightarrow N_2O_5\,(g)$ fast, rate constant k_2

Write the rate equation for the complex reaction.

(iii) Molecular iodine dissociates at 625 K with a first-order rate constant of $0.27\ s^{-1}$. What is the half-life of this reaction? (50)

Question 3

ONLY ANSWER THIS QUESTION IF YOU ARE SEEKING TO IMPROVE YOUR LABORATORY MARK FOR THE MODULE.

Design an experiment that will measure the concentrations of sodium carbonate and sodium bicarbonate in a solid sample of unknown composition.

Discuss the chemical principles behind the experiment, the chemicals and apparatus that you will require, as well as the modes of data collection and analysis that will yield a reasonable result. (50)

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Periodic Table of the Elements

1	2											13	14	15	16	17	18
I	II											III	IV	V	VI	VII	VIII
1 Hydrogen **H** 1.0079																	2 Helium **He** 4.0026
3 Lithium **Li** 6.941	4 Beryllium **Be** 9.0122											5 Boron **B** 10.811	6 Carbon **C** 12.0112	7 Nitrogen **N** 14.0067	8 Oxygen **O** 15.9994	9 Fluorine **F** 18.9984	10 Neon **Ne** 20.18
11 Sodium **Na** 22.989	12 Magnesium **Mg** 24.305	3	4	5	6	7	8	9	10	11	12	13 Aluminium **Al** 26.9815	14 Silicon **Si** 28.086	15 Phosphorus **P** 30.9738	16 Sulfur **S** 32.066	17 Chlorine **Cl** 35.453	18 Argon **Ar** 39.948
19 Potassium **K** 39.0983	20 Calcium **Ca** 40.08	21 Scandium **Sc** 44.956	22 Titanium **Ti** 47.87	23 Vanadium **V** 50.942	24 Chromium **Cr** 51.996	25 Manganese **Mn** 54.938	26 Iron **Fe** 55.847	27 Cobalt **Co** 58.933	28 Nickel **Ni** 58.69	29 Copper **Cu** 63.546	30 Zinc **Zn** 65.39	31 Gallium **Ga** 69.723	32 Germanium **Ge** 72.61	33 Arsenic **As** 74.922	34 Selenium **Se** 78.96	35 Bromine **Br** 79.904	36 Krypton **Kr** 83.80
37 Rubidium **Rb** 85.468	38 Strontium **Sr** 87.62	39 Yttrium **Y** 88.905	40 Zirconium **Zr** 91.224	41 Niobium **Nb** 92.906	42 Molybdenum **Mo** 95.94	43 Technetium **Tc** 98	44 Ruthenium **Ru** 101.07	45 Rhodium **Rh** 102.905	46 Palladium **Pd** 106.42	47 Silver **Ag** 107.868	48 Cadmium **Cd** 112.411	49 Indium **In** 114.82	50 Tin **Sn** 118.71	51 Antimony **Sb** 121.75	52 Tellurium **Te** 127.60	53 Iodine **I** 126.904	54 Xenon **Xe** 131.29
55 Cesium **Cs** 132.905	56 Barium **Ba** 137.34	57 Lanthanum **La** 138.91	72 Hafnium **Hf** 178.49	73 Tantalum **Ta** 180.948	74 Tungsten **W** 183.85	75 Rhenium **Re** 186.207	76 Osmium **Os** 190.2	77 Iridium **Ir** 192.22	78 Platinum **Pt** 195.09	79 Gold **Au** 196.967	80 Mercury **Hg** 200.59	81 Thallium **Tl** 204.38	82 Lead **Pb** 207.19	83 Bismuth **Bi** 208.98	84 Polonium **Po** 209	85 Astatine **At** 210	86 Radon **Rn** 222
87 Francium **Fr** 223	88 Radium **Ra** 226	89 Actinium **Ac** 227	104 Rutherfordium **Rf** 261	105 Dubnium **Db** 262	106 Seaborgium **Sg** 266	107 Bohrium **Bh** 264	108 Hassium **Hs** 269	109 Meitnerium **Mt** 268									

N Name El Mass — Atomic number, Name, Symbol, Atomic mass

Lanthanides	58 Cerium **Ce** 140.12	59 Praesodymium **Pr** 140.907	60 Neodymium **Nd** 144.24	61 Promethium **Pm** 144.913	62 Samarium **Sm** 150.35	63 Europium **Eu** 151.96	64 Gadoloinium **Gd** 157.25	65 Terbium **Tb** 158.925	66 Dysprosium **Dy** 162.50	67 Holmium **Ho** 164.93	68 Erbium **Er** 167.26	69 Thulium **Tm** 168.934	70 Ytterbium **Yb** 173.04	71 Lutetium **Lu** 174.97
Actinides	90 Thorium **Th** 232.038	91 Proactinium **Pa** 231.036	92 Uranium **U** 238.03	93 Neptunium **Np** 237.048	94 Plutonium **Pu** 244.064	95 Americium **Am** 243	96 Curium **Cm** 247	97 Berkelium **Bk** 247	98 Californium **Cf** 242.058	99 Einsteinium **Es** 254	100 Fermium **Fm** 257.095	101 Mendelevium **Md** 258.10	102 Nobelium **No** 259.101	103 Lawrencium **Lr** 260.105