University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I Examinations 2010

CHEM 10030

Chemistry for Engineers

Professor Wayne

Professor Powell

Professor Waghorne

Dr. Sullivan*
Dr. Baldelli

Time Allowed: 2 Hours

Instructions for Candidates

The assignment of marks to each part of a question is indicated.

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.

Instructions for Invigilators

The use of electronic calculators is permitted
A Periodic Table of the Elements is also attached to these sheets

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Answer ***both*** questions.

Q1. A separate answer book must be used for each question.

Answer any ***three*** sections (a) – (e).

(a) Answer ***all*** parts (i) – (iii).

The Rydberg constant = 2.18×10^{-18} J
Planck's constant = 6.626×10^{-34} Js
$c = 3 \times 10^{8}$ ms^{-1}.

(i) Discuss, with appropriate diagrams, the hydrogen emission spectrum in terms of the Bohr model of an atom. (15)

(ii) What is the maximum number of emission lines that can be expected if electrons relax from the $n = 3$ level of the H atom. Use an energy-level diagram to illustrate your answer. (10)

(iii) For a hydrogen atom, calculate the wavelength of the line in the hydrogen emission spectrum that results from the transition $n = 6$ to $n = 2$. (8)

(b) Answer ***both*** parts (i) and (ii).

(i) Draw and label the apparatus Marie Curie used when she studied the radioactive decomposition of uranium. Clearly label the component parts and ***explain*** the results of the experiment. (20)

(ii) Describe the effect of magnetic or electric fields on the movement of a charged particle. Use diagrams to illustrate the different features you discuss. (13)

Sections (c) to (e) of question 1 are continued on the following pages...

(c) Answer ***both*** parts (i) and (ii).

(i) Given the following data, ***roughly*** sketch (on one plot) the potential-energy curves for the formation of C–O, C=O and C≡O bonds (carbon–oxygen single, double and triple bonds).

	Bond length / pm	Bond strength / kJ mol^{-1}
C−O	141	358
C=O	132	745
C≡O	119	1046

Comment on the relationship between bond order, bond length and bond strength and explain each part of one of the energy profiles in terms of the changes in the attractive and repulsive forces experienced by the components of the atoms as a function of the inter-nuclear distance. (20)

(ii) Explain, in terms of total bond energies of reactants and products, why certain reactions are exothermic and others endothermic. (13)

(d) Answer ***all*** parts (i) – (iv).

$$1 \text{ a.m.u.} = 1.661 \times 10^{-27} \text{ kg}$$
1 neutron has a mass of 1.008665 a.m.u.
1 proton has a mass of 1.007276 a.m.u.
$$c = 3 \times 10^{8} \text{ m s}^{-1}$$
$$1 \text{ kg m}^{2}\text{s}^{-2} = 1 \text{ J}$$

(i) Explain, with relevant diagrams, the principle of operation of a mass spectrometer. (10)

(ii) An element consists of two isotopes. The abundance of one isotope is 95.72% and its atomic mass is 114.9041 a.m.u. The atomic mass of the second isotope is 112.9043 a.m.u. Name the element and determine its average mass? (5)

(iii) Discuss the force which holds the nucleus of an atom together. (10)

(iv) Determine the binding energy (BE) of a Carbon 12 nucleus (in J) assuming its mass is 12.00 a.m.u. (8)

(e) Answer ***both*** parts (i) and (ii).

(i) Draw the Lewis structures and predict the shapes and the bond angles of the following molecules and ions: (20)

(A) CCl_4 **(B)** H_3O^+ **(C)** NO_3^- **(D)** SF_4

(ii) High levels of the aromatic organic compound benzene C_6H_6 are found in unleaded gasoline.

(A) What is the weight % of carbon and hydrogen in benzene? (4)

(B) Write a balanced equation for the combustion of C_6H_6 that takes place in a gasoline engine. (4)

(C) What mass of CO_2 and how many moles of H_2O are formed from the complete combustion of 2 kg of benzene? (5)

Q2. A separate answer book must be used for each question.

Answer ***all*** sections (a) – (c).

(a) Determine the equilibrium constant *K*p of the following reaction:

$$2NH_3(g) \rightleftharpoons N_2(g) + 3NH_2(g)$$

at 400 °C given that, at T = 400 °C, 1 mole of $NH_3(g)$ placed in a 5 L reactor produces an $N_2(g)$ concentration of 0.086 mol dm^{-3} at equilibrium. (40)

$$(R = 8.205\times10^{-2} \text{ dm}^3 \text{ atm K}^{-1}\text{mol}^{-1})$$

Sections (b) and (c) of question 2 are continued on the following page…

(b) Answer ***both*** parts (i) and (ii). (40)

The standard enthalpy change, $\Delta H^{\ominus}_{rxn}$, for the combustion of monoclinic sulphur, S(mon), to sulphur dioxide SO_2(g) is −297.16 kJ mol^{-1} while the standard enthalpy change, $\Delta H^{\ominus}_{rxn}$, for the combustion of rhombic sulphur, S(rhom) to SO_2(g) is −296.83 kJ mol^{-1}.

$$S(mon) + O_2(g) \rightarrow SO_2(g) \quad \Delta H^{\ominus}_{rxn} = -297.16 \text{ kJ mol}^{-1}$$

$$S(rhom) + O_2(g) \rightarrow SO_2(g) \quad \Delta H^{\ominus}_{rxn} = -296.83 \text{ kJ mol}^{-1}$$

(i) Determine the heat (gained or lost) from the transformation of 1.345 g of monoclinic sulphur if the reaction below takes place (assume constant pressure).

$$S(mon) \rightarrow S(rhom)$$

(ii) Is this an endothermic or an exothermic reaction?

(c) Answer ***both*** parts (i) and (ii). (20)

Given the general reaction

$$A \rightarrow P$$

Determine

(i) The initial rate of the reaction, v_i , given that:

$$\textbf{[A]} \text{ (at } t = 0 \text{ s)} = 0.187 \text{ mol L}^{-1}$$
$$\textbf{[A]} \text{ (at } t = 0.44 \text{ s)} = 0.183 \text{ mol L}^{-1}$$

(ii) The average reaction rate in the time period between 60.2s and 80.3s, given that:

$$\textbf{[A]} \text{ (} t = 60.2\text{)} = 0.55 \text{ mol L}^{-1}$$
$$\textbf{[A]} \text{ (} t = 80.3 \text{ s)} = 0.54 \text{ mol L}^{-1}$$

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Periodic Table of the Elements

Group (new notation)
Group (old notation)

N Name **El** Mass	Atomic number Name **Symbol** Atomic mass

1 I	2 II	3	4	5	6	7	8	9	10	11	12	13 III	14 IV	15 V	16 VI	17 VII	18 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											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									

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