University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER I EXAMINATION - 2009

CHEM 10030

Chemistry For Engineers

Professor Powell

Professor Wayne

Professor Waghorne

Dr. Sullivan *

Dr. Quinn

Time Allowed: 2 hours

Instructions for Candidates

All questions carry equal marks; the approximate assignment of marks to parts of a question is indicated (as a percentage) in parentheses.

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 attached to these sheets
Graph paper should be provided

S3431

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

Question 1

Answer any ***four*** of the following (a) – (f)

(a) Answer *both* sections (i) and (ii)

(i) Draw a schematic diagram of the cathode-ray tube apparatus used by Thompson and explain how his experiments furthered the development of atomic theory; (15)

(ii) Draw a schematic diagram of the experiment that confirmed the existence of the nucleus and label the individual components. (10)

(b) Answer ***both*** sections (i) and (ii)

(i) Explain the principle of operation of a mass spectrometer;

(ii) An element exists as one of four possible isotopes. 83.7% of all atoms of the element have a relative atomic mass of 51.94, 4.3% have a mass of 49.95, 9.5% have a mass of 52.94 and the remainder has a relative atomic mass of 53.94. Identify the element and determine its average relative atomic mass. (15)

(10)

Continued.....

(c) Answer ***both*** sections (i) and (ii)

(i) Draw and label (using the graph paper provided) a potential energy diagram showing PE as a function of inter atomic distance for two Br atoms given that the bond strength of a Br–Br bond is 193 kJ mol^{-1} and the inter nuclear distance is 229 pm. (15)

(ii) Explain the magnitude of the PE when the two Br nuclei are (a) 1 m, (b) 229 pm and (c) 25 pm apart. (10)

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

Draw Lewis structures and VSEPR models of the following molecules. Ensure that you show electron counts, discriminate between lone pairs and bonding pairs of electrons, and state the final shapes of the molecules.

BF_3	(5)
SF_6	(5)
C_2H_4	(5)
H_2O	(5)
PCl_5	(5)

(e) Answer ***both*** sections (i) and (ii)

(i) Explain why heat is given out when a hydrocarbon reacts with O_2 to form CO_2 and H_2O. (15)

(ii) Determine the mass of CO_2 and the number of moles of H_2O formed when 20kg of octane (C_8H_{18}) is fully burned. (10)

Section (f) is on the following page.....

Continued.....

(f) Answer ***both*** sections (i) and (ii)

(i) Explain the appearance of the hydrogen emission spectrum using the Bohr model of the atom. (15)

(ii) Determine the wavelength of the photon emitted when an electron in a H atom falls from the n=5 to the n=2 level. In what region of the electromagnetic spectrum would light of this wavelength be found?

Planck's constant, $h = 6.626 \times 10^{-34}$ J s.
Rydberg constant, $R = 2.18 \times 10^{-18}$ J.
Speed of light, $c = 3 \times 10^{8}$ m s^{-1}. (10)

Question 2 is on the next page.....

Question 2

Answer all parts (a)-(c)

(a) Answer ***all*** parts (i), (ii) ***and*** (iii)

(i) State Hess's Law;

(ii) Define the standard state of an element;

(iii) Given the following information:

$TiO_2(s) + 4\,HCl(g) \rightarrow TiCl_4(l) + 2\,H_2O(l)$ $\Delta_r H^{\ominus} = -22$ kJ mol^{-1}

$Ti(s) + 2\,Cl_2(g) \rightarrow TiCl_4(l)$ $\Delta_r H^{\ominus} = -763$ kJ mol^{-1}

$H_2O(l) \rightarrow H_2(g) + \frac{1}{2}\,O_2(g)$ $\Delta_r H^{\ominus} = +286$ kJ mol^{-1}

$\frac{1}{2}\,H_2(g) + \frac{1}{2}\,Cl_2(g) \rightarrow HCl(g)$ $\Delta_r H^{\ominus} = -92$ kJ mol^{-1}

Calculate the standard enthalpy of formation of TiO_2; (33.3)

(b) For the exothermic reaction:

$$2\,HI(g) \rightleftharpoons I_2(g) + H_2(g)$$

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

When 0.2 moles of pure HI is added to a 2 L flask at 726 K it was found that 0.156 moles of HI remained when equilibrium was reached.

What are the equilibrium concentrations of I_2 and H_2?

Calculate the equilibrium constant.

What effect would increasing the reaction temperature have on the amount of I_2 at equilibrium? Explain your reasoning. (33.3)

Continued.....

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

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

Rate equation *Activation energy* *Reaction half-life*

(ii) The radioactive isotope ^{123}I breaks down in a first-order process with a half-life of 4.7×10^4 s at 25 °C. Calculate the rate constant for the decay.

(iii) Using a reaction-energy diagram briefly explain how a catalyst increases the rate of reaction. (33.3)

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Periodic Table of the Elements

1	2											13	14	15	16	17	18
I	II					Group (new notation)						III	IV	V	VI	VII	VIII
						Group (old notation)											
1 Hydrogen **H** 1.0079						N Name **El** Mass	Atomic number Name **Symbol** Atomic mass										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									

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