GD298

Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

SUMMER EXAMINATIONS 2000

FIRST EXAMINATION IN SCIENCE INCLUDING APPLIED PHYSICS AND ELECTRONICS/EXPERIMENTAL PHYSICS, CHEMISTRY AND APPLIED CHEMISTRY, EARTH SCIENCES

CH101

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CHEMISTRY
Time Allowed: Three Hours

Answer Five questions and include at least one from each Section.
Use a separate answer book for each Section.
Leave the first page of the Answer Book blank and list on it clearly the numbers of the questions attempted.
All questions carry equal marks. (For a question with a choice between parts, all parts of that question carry equal marks).

Universal Gas Constant: R = 8.31 $kPadm^3K^{-1}mol^{-1}$ ($J\ K^{-1}mol^{-1}$)
Standard Temperature: 273K
Atomic Masses (a.m.u.): H, 1.0; C, 12.0; N, 14.0; O, 16.0; F, 19.0; Mg, 24.3; S, 32.0; Cl, 35.5; Ar, 40.0.
Charge of the Electron: -1.6×10^{-19}C; Mass of the electron: 9.109×10^{-31}kg.
Faraday: 96500C
Avogadro Number: 6.022×10^{23}
Planck Constant: h: 6.626×10^{-34} J.s.; ($kg.m^2.s^{-2}$);
Velocity of light, c:2.997×10^8 $m.s.^{-1}$

Section A
(Atomic and Molecular Structure)

1. Answer <u>each</u> of the following:

(i) Explain the main points of the Bohr Theory of atomic structure and use it to derive an expression for the radii of the Bohr energy levels of the H atom.

(ii) Explain the term "covalent radius" as applied to a neutral atom. Comment briefly on trends in the covalent radii of atoms in the Periodic Table.

(iii) Write the atomic orbital configuration of the ground state of the N atom (atomic number 7) and list the four quantum numbers for each electron in the atom.

(iv) Use the electronic structure of the sodium atom (atomic number 11) to explain the origin of the yellow sodium light of street lamps.

2. Answer <u>any two</u> of the following:

(i) Outline the main points of the Theory of Resonance in the electronic structure of molecules and explain the structure of the formate anion, HCO_2^- and the benzene molecule, C_6H_6.

(ii) Briefly explain the valence shell (domain) electron pair repulsion theory and explain the structures of the following molecules:

$$PCl_5 \quad ; \quad PCl_3 \quad ; \quad HNO_3$$

(iii) Account for the existence and stabilities of the following gaseous molecules: H_2, H_2^+, He_2^+ and the non-existence of the molecule He_2.
Explain which of these would be paramagnetic and determine the expected magnetic moments in Bohr magnetons.

3. Answer any <u>three</u> of the following:

(i) Explain the structure of the unit cell of NaCl(s) and describe what happens when sodium chloride dissolves in water. Account for the high solubility of NaCl(s) in water at 25°C and 1 atm. Pressure and the very low solubility of AgCl(s).

(ii) Describe the supramolecular structure of water ice and explain how hydrogen bonding influences important physical properties of water.

(iii) If the electronegativity of H is 2.1 and O is 3.5
(a) Calculate the ionic character of the O–H bond in H_2O and
(b) Determine the dipole moment of the individual covalent of OH bond in the isolated water molecule.

(iv) Use the Kinetic Theory of Gases to derive the equation of state for an ideal gas ($PV = nRT$).

(v) How much carbon monoxide (CO) is present on average in cigarette smoke? Explain how the electronic structure of CO makes it poisonous.

Section B
(Organic Chemistry)

4 **Answer <u>each</u> of the following:**

(i) Describe the preparation, properties of methylmagnesium iodide and its reaction with carbon dioxide.

(ii) Give a brief account of the preparation and reactions of ethers.

(iii) Briefly discuss the three dimensional structure of methane. Draw and give the systematic names for all isomeric alkanes of molecular formula C_5H_{12}.

5 **Answer any <u>two</u> of the following:**

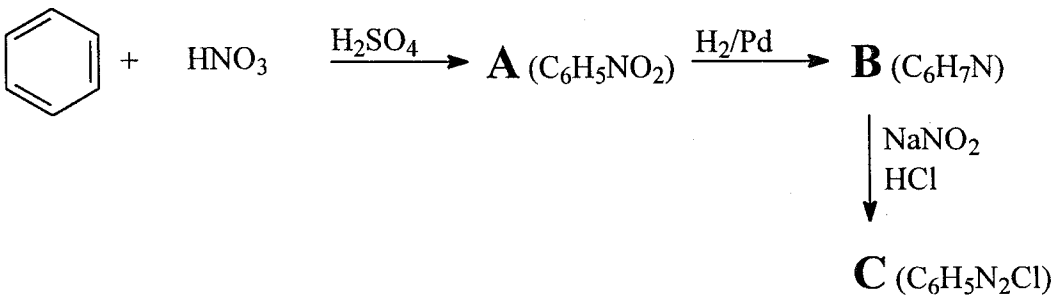
(i) Describe the S_N2 mechanism for the nucleophilic substitution of an alkyl halide. Include in your answer the consequences of this mechanism with regard to stereochemistry.

(ii) Draw the structure of a primary, secondary and tertiary alcohol. Give an account, including appropriate chemical equations, of the reactivity of alcohols.

(iii) The addition of HCl to 2-methylpropene gives two isomeric chloroalkanes. Draw the structure of each, account for their formation and indicate which would be the major product.

(iv) Briefly discuss the preparation and reactions of carboxylic acids. Illustrate your answer with appropriate chemical equations.

6 Describe the structure, and account for the extra stability of benzene. Explain why it undergoes substitution and not addition reactions. Draw the structures of **A**, **B** and **C**. What is the electrophilic species involved in the formation of **A**?



Section C
(Inorganic Chemistry)

7. "Carbon based molecules form the chemical basis of life, while silicon based molecules are the constituents of rocks, earth and sand"
With reference to the above statement, **answer <u>each</u> of the following:**

(i) Discuss the variety of 'carbon chemicals' found in living organisms, illustrating your answer by sketching some of these molecules.

(ii) Describe some of the silicon compounds that are found in 'rock' material, including in your answer sketches of their structures.

8. **Answer <u>each</u> of the following:**

(i) Describe the chemistry used in the industrial preparation of chlorine gas.

(ii) Identify the products that accompany chlorine in its industrial preparation. Give some of their uses.

(iii) Describe the chemical composition and the preparation of 'household bleach'.

(iv) Give examples of compounds of chlorine that exhibit oxidation numbers, -1, +3, and +5.

9. **Answer <u>each</u> of the following:**

(i) Describe the typical physical and chemical properties of metals. Show how the physical properties are related to the underlying structure.

(ii) Describe the chemical composition for some metal ores found in nature. Describe the chemistry used to extract the metals from these ores.

Section D
(Physical Chemistry)

10. Answer <u>any two</u> of the following:

(i) Write an explanatory note on "like dissolves like"

(ii) Discuss the phase diagram for H_2O

(iii) At 25°C, K_c= 0.145 for the following reaction in the solvent CCl_4.

$$2BrCl \Leftrightarrow Br_2 + Cl_2$$

If the initial concentration of each substance in a solution is 0.0400 *M*, what will their equilibrium concentrations be?

11. Answer <u>any two</u> of the following:

(i) Explain the Principle of Le Chatelier for systems in dynamic equilibrium.

(iii) Calculate the pH of a 0.5mol dm^{-3} aqueous solution of methanoic acid (formic acid) given that its pK_a is 3.75 at 25°C. Explain the significance of the K_a value for this acid.

(iv) Glycerol, $C_3H_8O_3$ (molecular mass 92) is a nonvolatile liquid that is soluble in water. A solution is made by dissolving 46.0 g glycerol in 250 g water. Estimate the following:
(a) its freezing point (K_f for water is 1.86°C kg mol^{-1})
(b) its vapour pressure, in torr, at 25°C (vapour pressure of water at this temperature is 23.8 torr)

12. Answer <u>any two</u> of the following:

(i) Explain the difference between Galvanic and electrolytic cells. Explain the term "standard reduction potential" and describe how such values are measured.

(ii)
(a) If the concentration of a reactant is doubled what is the order of the reaction with respect to that reactant if the reaction rate also doubles?
(b) If the concentration of a reactant is doubled by what factor will the rate increase if the reaction is second order with respect to that reactant?
(c) What would the half life of a reaction be if the rate constant for the reaction was 1.6 x 10^{-3} s^{-1}?

(iii) A sample consisting of 1.00 mol Ar is expanded isothermally at 0°C from 22.4 to 224 dm^3. Calculate the change in internal energy if the expansion is:
(a) reversible;
(b) against a constant external pressure equal to the final pressure of the gas;
(c) against zero external pressure (free expansion).