Estudy Natural Sciences 2023 December

Chemistry Paper 1

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Question 1

Given the reaction

$2H_2(g)+O_2(g)\rightarrow 2H_2O(l)$:

If 6.0 moles of hydrogen gas react with 3.5 moles of oxygen gas, answer the following:

(a) Determine the limiting reagent.

(b) Calculate the theoretical yield of water in grams.

(c) If the actual yield obtained from the experiment is 12.5 grams, determine the percentage yield.

(d) How many moles of excess reagent are left after the reaction?

(e) If the quantities of hydrogen gas and oxygen gas are doubled, what changes in terms of the limiting reagent, theoretical yield, and excess reagent?

Question:2

Suppose an unknown element X has three naturally occurring isotopes with masses and abundances as follows:

- X-10 with a mass of 10.012 amu and an abundance of 35.00%.

- X-11 with a mass of 11.009 amu and an abundance of 25.00%.

- X-12 with a mass of 12.014 amu.

Determine the percentage abundance of the X-12 isotope.

Question 3

An unknown organic compound is analyzed and found to contain carbon (C), hydrogen (H), nitrogen (N), and oxygen (O). The compound's elemental analysis reveals the following percentages by mass: carbon (55.0%), hydrogen (3.0%), nitrogen (15.0%), and oxygen (27.0%).

1) Determine the empirical formula of this compound.
2) Upon finding the empirical formula, the molar mass of the compound is experimentally determined to be 120 g/mol. If the empirical formula has a molar mass of 90 g/mol, calculate the molecular formula of the compound.

Question 4

Answer the following questions from (a) to (e) related to quantum numbers and electron configurations. [5 marks]

(a) What is the maximum number of subshells/sublevels associated with the principal quantum number (n) equal to three (n = 3)?

(b) What is the maximum number of electrons each orbital can accommodate?

(c) What formula can be used to calculate the maximum number of electrons that each principal quantum number can accommodate?

(d) How many magnetic quantum numbers (m_l) are associated with the angular (azimuthal) quantum number (l) equal to 1 (l = 1)?

(e) What is the maximum number of allowed magnetic spin quantum number (m_s) values for electrons?

Question 5

Compare and contrast the shielding effects experienced by 3s and 3p electrons in a phosphorus atom, and explain how these differences impact the chemical behavior of phosphorus.

Question 6

Complete the following table

Hybridization	Sigma Bonds	Lone Pairs	Geometry	Bond Angle
Sp^3	4	0	Tetrahedral	109.5°
Sp^2	?	?	?	?
Spd^3	2	?	?	?

Question 7

Given the electronegativity values of the following elements: O (3.5), N (3.0), Li (1.0), F (4.0), and S (2.5), determine whether the bonds in the following compounds are polar covalent, non-polar covalent, or ionic bonds:

(a) LiF

(b) H_2O

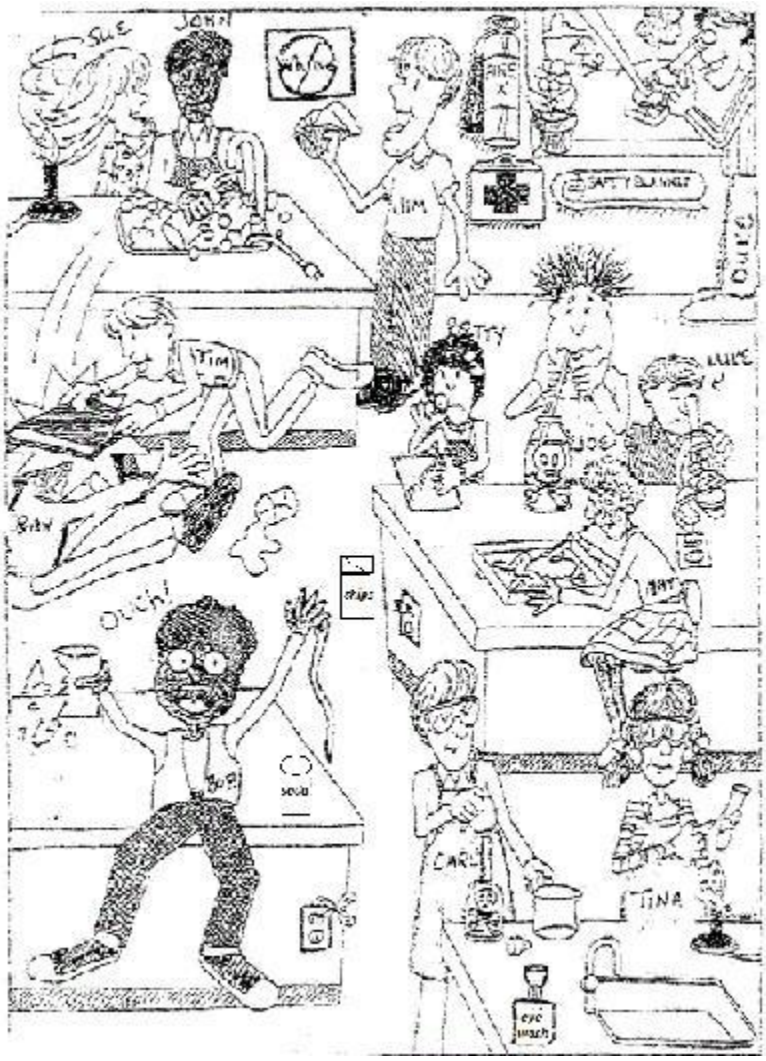
(c) NF_3

Question 8

Calculate the amount of aluminum (Al) metal produced by passing a current of 3.0 A through molten Al_2O_3 for 4.5 hours. (Given: Faraday's constant = 96,485 C/mol)

SECTION B

Study the diagram below and answer the questions that follow



1. List 3 unsafe activities show in in the illustration and explain why each is unsafe.
2. **List 3 correct lab procedures depicted in the illustration**
3. What should Bob do after the accident?
4. What should Sue have done to avoid an accident?
5. Compare Luke and Duke's lab techniques. Who is following the rules?
6. What are three things shown in the lab that should not be there?

Question B2

Consider an electron transition in a hydrogen-like atom from an orbit with $n = 4$ to an orbit with $n = 2$.

(a)(i) Calculate the energy (in joules) released during this electron transition.

(ii) Determine the wavelength (in meters) and frequency (in Hertz) of the emitted radiation.

(b) Discuss two limitations or failures of the Bohr model in describing atomic structure and electron behavior.

(c) Explain the differences between the Bohr model and the modern quantum mechanical model in how they depict the behavior and position of electrons in an atom.

(d) Calculate the wavelength (to 3 significant figures) of an electron moving at a speed of 3.0×10^6 m/s within a hydrogen-like atom.

Question B3

(a) Determine the oxidation numbers for all atoms in the following compounds:

(i) $Na_2S_2O_6$
(ii) HNO_3
(iii) $K_2Cr_2O_7$

(b) Consider the reaction:

$$\mathrm{MnO_4^- + H_2C_2O_4 \rightarrow Mn^{2+} + CO_2}$$

If 0.85 mol of potassium permanganate ($\mathrm{KMnO_4}$) and 25.0 g of oxalic acid ($\mathrm{H_2C_2O_4}$) react,

(i) Determine the limiting reagent.
(ii) Calculate the mass of carbon dioxide ($\mathrm{CO_2}$) produced.

(c) Balance the following redox equation in basic medium:

$$\mathrm{Cr_2O_7^{2-} + C_2H_5OH \rightarrow Cr^{3+} + CO_2}$$

Question B4

Consider the following cell reactions:

$$2\mathrm{MnO}_4^-(aq) + 3Zn(s) + 8H_2O(l) \rightarrow 2\mathrm{MnO}_2(s) + 3Zn(OH)_2(aq) + 4H^+(aq)$$

(a) Write two half-reactions and determine which one is the oxidation and which one is the reduction reaction.

(b) Using a Pt electrode as the cathode and C as the anode, draw a galvanic cell, highlighting essential components such as the direction of electrons, charge, reactions on the cathode and anode, and a salt bridge using KNO_3 (indicating the direction of charges).

(c) Write the cell notation for the constructed cell.

(d) Determine the pH of the cell if the cell potential is 2.93 V, the concentration of MnO_4^- (aq) is 0.01 M, and $Zn(OH)_3$^- (aq) is 0.10 M. Given that $E^\circ_{\mathrm{MnO}_4^-/\mathrm{MnO}_2} = 1.70$ V and $E^\circ_{\mathrm{Zn}/\mathrm{Zn}^{2+}} = -0.76$ V.

Periodic Table of the Elements

1																	18
1 H Hydrogen 1.008	2											13	14	15	16	17	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3	4	5	6	7	8	9	10	11	12	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molibdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]