School of Chemistry, UNIVERSITY OF KWAZULU-NATAL PIETERMARITZBURG
SUBJECT, COURSE & CODE: CHEM099 and CHEM199 : FOUNDATION CHEMISTRY
JANUARY 2009 EXAMINATION

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Duration: 3 Hours Total Marks: 100

Instructions to Candidates:

- Answer all 5 questions on the paper provided and show your working clearly. Marks are given in brackets after each question and all questions are marked out of 20.
- The question paper consists of 12 pages including a Periodic Table, a Data Sheet and a Table of Electro-negativities
- Please check that you have them all.

Question One [20 marks]

1.1 One source of methane gas (CH_4) is from the decaying organic wastes of solid waste. Durban's Mariannhill landfill (dumping) site can produce up to 2.46×10^{25} molecules of methane gas a day.

(a) How many moles of methane gas is this landfill site expected to produce in a day?

(2)

(b) Calculate the mass (in grams) of 1 mole of gas.

(1)

(c) What volume would the gas produced each day occupy at 25 °C and 1 atm?

(2)

1.2 Vinegar is produced by the fermentation of ethanol. A vinegar stock solution has a concentration of 1.00 mol dm^{-3} of acetic acid (CH_3COOH). This solution is used to prepare a diluted vinegar solution that contains 3.05 g of acetic acid in every 100 ml of water.

(a) What is the molar concentration of the diluted vinegar solution?

(3)

(b) How many millilitres of the 1.00 mol dm^{-3} stock solution is required to prepare 100 ml of the diluted vinegar solution?

(2)

(c) How many grams of carbon are present in 3.05 g of acetic acid?

(3)

1.3 Nicotine is one of the addictive chemicals found in tobacco and it has a molar mass of 163 g mol^{-1}.

(a) State the difference between an empirical and a molecular formula.

(1)

(b) The percentage composition of nicotine is known to be 74.0 % carbon, 8.7 % hydrogen and 17.3 % nitrogen. Determine its molecular formula.

(6)

Question 2 [20 marks]

2.1 Major environmental pollutant gases, carbon dioxide and sulfur dioxide, are produced when carbon disulfide burns in oxygen according to the following reaction equation:

$$CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$$

A sample of 292.08 g of sulfur dioxide gas was recorded in one reaction.

(a) What mass of oxygen was used up to produce this mass of sulfur dioxide?

(3)

(b) How many atoms of oxygen does this sample of sulfur dioxide contain?

(2)

(c) If this mass of sulfur dioxide was dissolved in water and made up to a volume of 1255 ml, calculate the molar concentration of sulfurous acid, H_2SO_3, formed.

(2)

2.2 Phosphorus pentachloride reacts with water (rather than dissolving in it) according to the following balanced equation:-

$$PCl_5(s) + 4H_2O(l) \rightarrow 5HCl(aq) + H_3PO_4(aq)$$

17.03 g of water was mixed with 47.90 g of phosphorus pentachloride.

(a) Determine the reagent which is limiting.

(5)

(b) Is this the most economically sensible limiting reagent for this reaction? Explain your answer.

(1½)

(c) Calculate the mass of the excess reagent that remains at the end of the reaction.

(2½)

(d) Calculate the percentage yield of hydrogen chloride, if 24.45 g is obtained from this reaction mixture.

(4)

Question 3 [20 marks]

Use your Periodic Table to answer the following questions:

3.1 Consider the element whose electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^4$.

(a) In which period, AND in which group, is this element found?

(1)

(b) How many unpaired electrons does this element have?

(1)

(c) How many electrons are in the core shells?

(1)

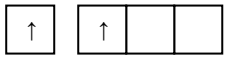
3.2 (a) Write out the tabular/orbital electronic configuration of the ion of sulfur.

(1)

(b) Identify the element represented by the following electronic configuration: [Ar] $4s^2 3d^{10} 4p^3$

(1)

c)

i) What element has the excited state electronic configuration of [Ne]  ?

(0.5)

ii) Is this element a metal or a non-metal?

(0.5)

iii) What is the common name of the group to which this element belongs?

(1)

(d) Write the general spectroscopic electronic configuration of the valence shell of any noble gas besides helium.

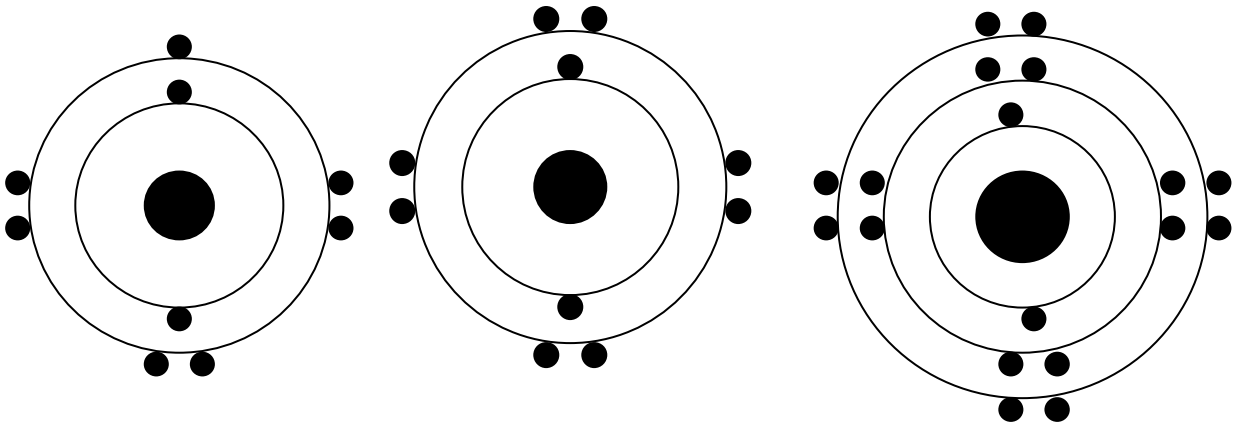
(1)

(e) Consider a metalloid whose outermost principal energy level is the 5^{th} level. Give the symbol of this element.

(0.5)

(f) Not all elements obey the octet rule when they form ions. Explain your answer by referring to an example of an anion AND a cation of your choice.

(2)



1 **2** **3**

(g) Which diagram(s) above are possibly representations of ions? (1)

3.3 (a) How many protons, electrons and neutrons does the +3 ion of ^{56}Fe have?

(1.5)

(b) Write down two other atomic notations for this isotope of iron.

(1)

3.4 (a) Define the term "degenerate orbitals" and give an example to explain your answer.

(2)

(b) State Pauli's Exclusion Principle.

(1)

(c) i) Give the symbol of the element which has 7 valence electrons in its second energy level.

(1)

ii) Write out its spectroscopic sub-level electronic configuration.

(1)

iii) Write the symbol and charge of the ion of this element

(1)

Question 4 [20 marks]

4.1 Study the following statements and correct them where necessary:

(a) Aluminium nitrate has the formula $AlNO_3$

(2)

(b) Chromium (III) oxide has the formula Cr_3O_2

(2)

4.2 Read each of the following statements. Decide if they are true or false. If false, correct the statement.

(a) Lewis dot structures are useful because they indicate all the electrons of a neutral element.

(2)

b) A polar covalent bond forms when ions of opposite charge are attracted to one another whereas a non-polar covalent bond forms when two atoms share electrons unequally with one another.

(2)

4.3

(a) Explain the concept of electro-negativity using covalent bonds.

(2)

(b) Using ΔEN values of two compounds of your choice, explain the difference between an ionic and a covalent bond.
(Note: ΔEN means difference in electro-negativities. A Table of Electronegativity Values is supplied)

(4)

4.4 Study the following table of compounds, and then answer the questions that follow.

- Each formula can be used more than once in answering questions a to f
- Write the **full formula** for each answer
- Some questions may have more than one answer, and some may have no answer, in which case say '**none**' or '**no answer**'
- Each question is worth **one mark**
- **The mark will be assigned only if the complete answer is given**

CO	CH_3OH	Fe_2O_3
NH_4OH	PCl_3	MgS
$Sr(NO_3)_2$	$CuSO_4.5H_2O$	KI(aq)

(a) Write down the formula(e) for all the substances in aqueous solution.

(b) Write down the formula(e) for all the compounds containing a +2 cation

(c) Write down the formula(e) for all the compounds containing an element(s) from Period 3 of the Periodic Table

(d) Write down the formula(e) for all the compounds which can produce -1 polyatomic anions

(e) Write down the formula(e) for all the molecular compounds

(f) Write down the formula(e) for all the diatomic formula units

(6)

Question 5 [20 marks]

Antacids are designed to neutralize stomach acid (hydrochloric acid, HCl). Most antacids are water insoluble and thus difficult to analyze directly. Usually a two-step indirect method, known as a **back titration**, is used.

Firstly, the antacid is reacted with a known amount of HCl which is in excess. Secondly, the HCl that did not react with the antacid is titrated with sodium hydroxide (NaOH). The amount of HCl that reacts with the antacid can then be calculated by difference. This information enables one to calculate the exact amount of antacid present in the sample.

A chemist added exactly 120 ml of 0.1090 M HCl to a single 0.275 g tablet of the antacid Gaviscon. The unreacted (excess) HCl was titrated with **0.1114 M NaOH** standard solution**.** The procedure was repeated three times. The results are given in the table below:

Titration Results - Volume of 0.1114 M NaOH	
1st titre	28.92 ml
2nd titre	28.75 ml
3rd titre	28.88 ml

(a) What is a standard solution?

(1)

(b) The titration of acids and bases can be a problem as they are generally colourless solutions. Explain, using an example, how you can overcome this problem.

(2)

(c) Write out a balanced chemical equation for the reaction between HCl and NaOH.

(2)

(d) What would you do in the laboratory to increase the rate at which the antacid dissolves in the excess HCl?

(1)

(e) Determine the total number of moles of HCl that was allowed to react with the antacid tablet.

(2)

(f) From suitable titration values calculate the number of moles of HCl that remains unreacted.

(6)

(g) Now determine the number of moles of HCl that actually reacted with the Gaviscon tablet and then calculate the mass of this HCl.

(3)

(h) If the mass of antacid in one Gaviscon tablet is found to be 0.256 g calculate the percentage of antacid in each tablet.

(1)

(i) Another brand, Maalox, is tested in a similar way and a 0.325 g tablet is found to contain 0.314 g of active antacid. Determine which of the two brands would be more effective in neutralizing stomach acid. Explain your reasoning.

(2)

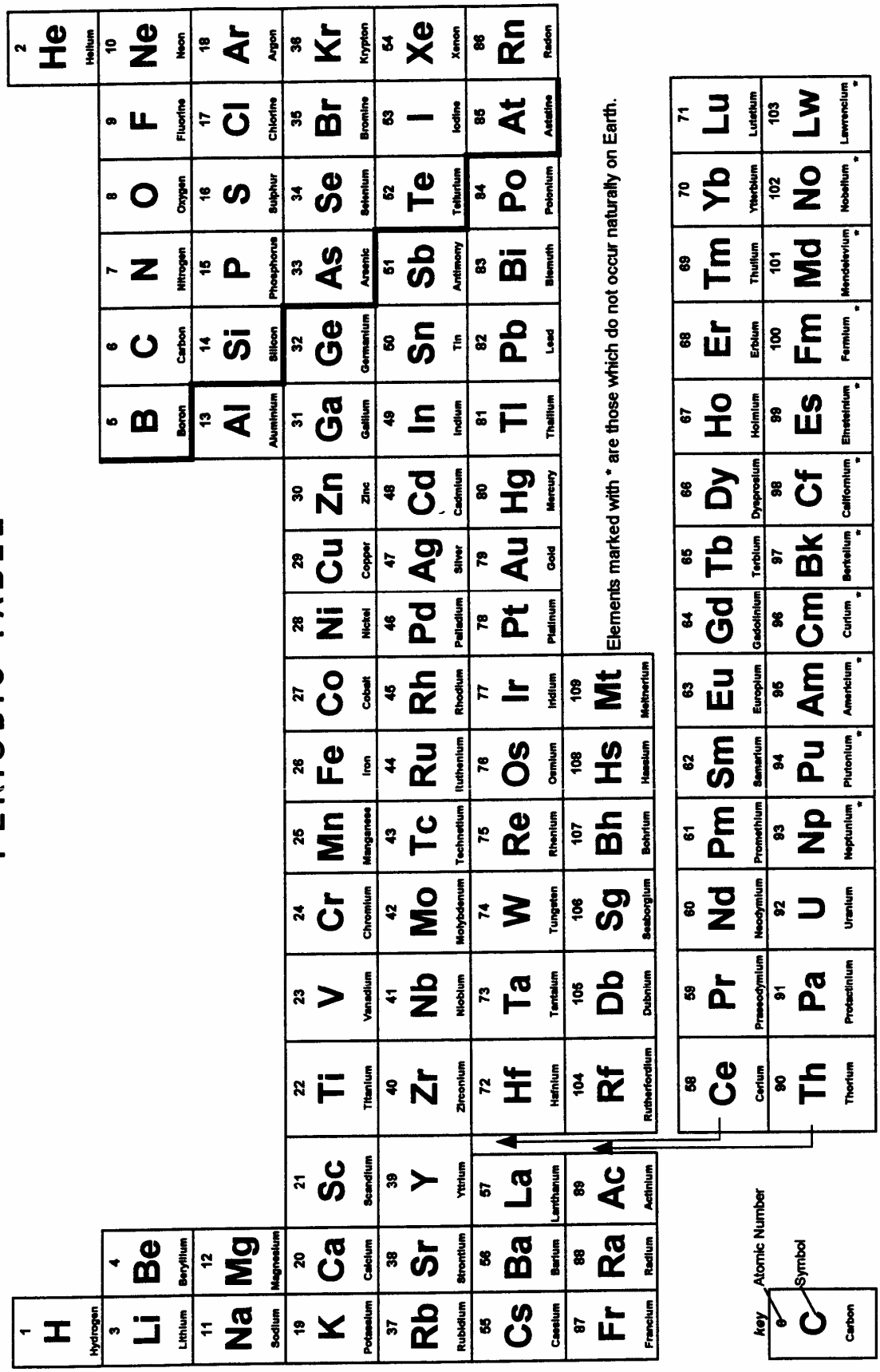

PERIODIC TABLE
Elements marked with * are those which do not occur naturally on Earth.
key
Atomic Number
Symbol
Carbon

TABLE OF RELATIVE ATOMIC MASSES (Based on Carbon-12)

	Symbol	Atomic No.	Atomic Mass
Actinium	Ac	89	[227]
Aluminium	Al	13	26.98
Americium	Am	95	[243]*
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	[210]
Barium	Ba	56	137.34
Berkelium	Bk	97	[247]
Beryllium	Be	4	9.012
Bismuth	Bi	83	208.98
Boron	B	5	10.81
Bromine	Br	35	79.90
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Californium	Cf	98	[251]
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Cesium	Cs	55	132.91
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.55
Curium	Cm	96	[247]
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	[252]
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	[257]
Fluorine	F	9	190.00
Francium	Fr	87	[223]
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.01
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.22
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	[260]
Lead	Pb	82	207.20
Lithium	Li	3	6.94
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Mendelevium	Md	101	[258]

	Symbol	Atomic No.	Atomic Mass
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.18
Neptunium	Np	93	[237]58
Nickel	Ni	28	.69
Niobium	Nb	41	92.91
Nitrogen	N	7	14.01
Nobelium	No	102	[259]
Osmium	Os	76	190.20
Oxygen	O	8	16.00
Palladium	Pd	46	106.42
Phosphorus	P	15	30.97
Platinum	Pt	78	195.08
Plutonium	Pu	94	[244]
Polonium	Po	84	[210]
Potassium	K	19	39.10
Praseodymium	Pr	59	140.91
Promethium	Pm	61	[145]
Protactinium	Pa	91	231.04
Radium	Ra	88	226.03
Radon	Rn	86	[222]
Rhenium	Re	75	186.21
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.36
Scandium	Sc	21	44.96
Selenium	Se	34	78.96
Silicon	Si	14	28.09
Silver	Ag	47	107.87
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulfur	S	16	32.07
Tantalum	Ta	73	180.95
Technetium	Tc	43	[98]
Tellurium	Te	52	127.60
Terbium	Tb	65	158.93
Thallium	Tl	81	204.37
Thorium	Th	90	232.04
Thulium	Tm	69	168.93
Tin	Sn	50	118.71
Titanium	Ti	22	47.88
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.94
Xenon	Xe	54	131.29
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.91
Zinc	Zn	30	65.39
Zirconium	Zr	40	91.22*

A value given in brackets denotes the mass of the longest-lived or best-known isotope,

Electro-negativity values for selected elements

(in order of Atomic Number)

Element	Electro-negativity value
H	2.1
He	0
Li	0.98
Be	1.57
B	2.04
C	2.55
N	3.04
O	3.44
F	3.98
Ne	0
Na	0.93
Mg	1.31
Al	1.61
Si	1.9
P	2.19
S	2.58
Cl	3.16
Ar	0
K	0.82
Ca	1
Br	2.96