

**UNIVERSITY OF SWAZILAND**  
**SUPPLEMENTARY EXAMINATION 2007/8**

TITLE OF PAPER: INTRODUCTORY CHEMISTRY I

COURSE NUMBER: C111

TIME: THREE (3) HOURS

**INSTRUCTIONS:**

There are **six** questions. Each question is worth 25 marks. Answer **any four** questions.

Non-programmable electronic calculators may be used.

**DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.**

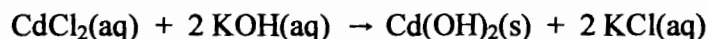
**Question 1 (25marks)**

- a) Explain in molecular terms why the pressure of a gas increases with increasing temperature when the volume is held constant. [3]
- b) A quantity of N<sub>2</sub> gas originally held at 4.75 atm pressure in a 1.00 L container at 26 °C is transferred into a 10.0 L container at 20 °C. A quantity of O<sub>2</sub> gas originally at 5.25 atm and 26 °C in a 5.00 L container is transferred to the same container.  
(i) Calculate the partial pressures of N<sub>2</sub> and O<sub>2</sub> in the new container.  
(ii) Calculate the total pressure. [6]
- c) Vessel A contains CO(g) at 0 °C and 1 atm. Vessel B contains SO<sub>2</sub>(g) at 20 °C and 0.5 atm. The two vessels have the same volume.  
(i) Which vessel contains more molecules?  
(ii) Which contains more mass?  
(iii) In which vessel is the average kinetic energy of the molecules higher? [6]
- d) Hexane burns according to the following equation:  
$$2 \text{C}_6\text{H}_{14}(\text{g}) + 19 \text{O}_2(\text{g}) \rightarrow 12\text{CO}_2(\text{g}) + 14 \text{H}_2\text{O}(\text{g})$$
  
(i) What volume of CO<sub>2</sub> will be formed by burning 9.00 L hexane, with the two volumes being measured under the same conditions?  
(ii) What volume of oxygen will be needed? [5]
- e) Copper oxide can be reduced to copper metal by heating in a stream of hydrogen gas:  
$$\text{CuO}(\text{s}) + \text{H}_2(\text{g}) \xrightarrow{\Delta} \text{Cu}(\text{s}) + \text{H}_2\text{O}(\text{l})$$
  
What volume of hydrogen at 27 °C and 722 Torr would be required to react with 95.0 g of CuO? [5]

**Question 2 (25 marks)**

- a) Distinguish between theoretical yield, actual yield and percent yield. [3]
- b) Phenol (C<sub>6</sub>H<sub>5</sub>OH), often used as a disinfectant in stables and drains is a common water pollutant. It can be converted to less harmful oxalic acid (H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>) by reaction with ozone:  
$$\text{C}_6\text{H}_5\text{OH} + 11 \text{O}_3 \rightarrow 3 \text{H}_2\text{C}_2\text{O}_4 + 11 \text{O}_2$$
  
(i) What mass of ozone would be required to react with 125.0 g of phenol?  
(ii) What mass of oxalic acid would be produced? [7]

- c) Cadmium hydroxide, used in storage battery electrodes, is prepared by precipitation from a solution containing cadmium chloride and potassium hydroxide:

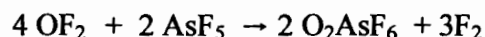


What mass of cadmium hydroxide could be prepared from 125 mL of 0.250 M  $\text{CdCl}_2$  mixed with 125 mL of 0.450 M  $\text{KOH}$ ? [7]

- d) Oxygen difluoride can be prepared by bubbling gaseous fluorine into 0.5 M solution of  $\text{NaOH}$ :



Oxygen difluoride can be used to prepare compounds such as  $\text{O}_2\text{AsF}_6$ , containing the dioxygen cation,  $\text{O}_2^+$ , by the following reaction:



If 14.0 g  $\text{F}_2$  is bubbled through 650 mL of 0.500 M  $\text{NaOH}$  to prepare  $\text{OF}_2$  with a 78.0% yield, how many grams of  $\text{O}_2\text{AsF}_6$  can be prepared? [8]

### Question 3 (25 marks)

- a) (i) What is the frequency of gamma rays having a wavelength  $2.00 \times 10^{-5} \text{ nm}$ ?  
 (ii) What is the energy (in kJ/mol) of this radiation? [5]
- b) Calculate the wavelength of a proton of mass  $1.67 \times 10^{-24} \text{ g}$  having a velocity of  $1.80 \times 10^8 \text{ cm/s}$ . [3]
- c) For Cl in its ground state, indicate how many electrons have each of the following quantum number values:  
 (i)  $n = 2$       (ii)  $l = 3$       (iii)  $m_l = 0$       (iv)  $n = 2$   $m_s = \frac{1}{2}$   
 (v)  $l = 1$   $m_l = -1$       (vi)  $n = 1$   $l = 0$  [6]
- d) Write the electron configurations of the following species  
 (i) Sb      (ii)  $\text{Cr}^{2+}$       (iii)  $\text{C}^{4-}$       (iv) S [8]
- e) Identify the atom represented by the following electron configuration  
 (i)  $[\text{Ar}]4s^23d^1$       (ii)  $[\text{Kr}]5s^24d^{10}5p^5$       (iii)  $1s^22s^22p^63s^23p^64s^1$ . [3]

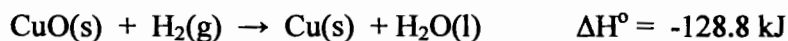
**Question 4 (25 marks)**

- a) Arrange the following species in order of increasing size. In each case give a brief explanation:
- (i) C, N, S, O
  - (ii)  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$
  - (iii)  $\text{Br}^-$ ,  $\text{Cl}^-$ ,  $\text{I}^-$ ,  $\text{F}^-$  [6]
- b) Which of each pair should have the greater first ionization energy? Justify your choice:
- (i) O or F (ii) Si or Ge (iii) N or O [6]
- c) Arrange the following species in order of increasing (more negative) electron affinity: O, S, Se, Cl. Explain briefly. [3]
- d) Which element should be more reactive, O or S? Explain your answer. [3]
- e) Name an element that can be classified as a member of each of the following groups:
- (i) noble gases (ii) alkali metals (iii) halogens (iv) nonmetals
  - (v) transition metals (vi) metalloids (vii) alkaline earth metals [7]

**Question 5 (25 marks)**

- a) Define the terms (i) specific heat capacity (ii) molar heat capacity. [3]

- b) Metallic copper can be produced from copper(II) oxide by the reaction with hydrogen:



If the standard enthalpy of formation of liquid water is  $-285.83 \text{ kJ/mol}$ , what is the standard enthalpy of formation of copper(II) oxide? [4]

- c) Calculate the heat evolved from a reaction mixture of  $13.4 \text{ L}$  of sulphur dioxide at  $1.00 \text{ atm}$  and  $273 \text{ K}$  and  $15.0 \text{ g}$  oxygen in the reaction



- d) Dinitrogen tetroxide reacts with carbon monoxide to form carbon dioxide and a gaseous oxide of nitrogen, which contains 63.65% N and 36.35% O by mass. Known enthalpies of formation are:

<b>Compound</b>	<b><math>\Delta H_f^\circ</math>, kJ/mol</b>
N <sub>2</sub> O <sub>4</sub> (g)	9.7
CO(g)	-110
CO <sub>2</sub> (g)	-393

Under standard conditions, reaction of a mixture of 40.35 g N<sub>2</sub>O<sub>4</sub> and 51.16 g CO in a calorimeter raised the temperature of 3255.0 g water by 25.09 °C. The specific heat of water is 4.184 J g<sup>-1</sup> °C<sup>-1</sup>.

- Determine the formula of the oxide of nitrogen and name it.
- Write a balanced equation for the reaction.
- Determine how much of the oxide of nitrogen is formed.
- How much heat is produced by the reaction?
- Calculate the standard heat of formation of the oxide of nitrogen. [10]

**Question 6 (25 marks)**

- a) Write a complete balanced equation for each of the following reactions:

- When solid sodium hydride is added to water, hydrogen gas is released and aqueous sodium hydroxide is formed
- Solid calcium phosphate reacts with a mixture of solid silicon dioxide and solid carbon to form solid phosphorus, solid calcium silicate and gaseous carbon monoxide. [6]

- b) Copy the following table and fill in the gaps [5]

Symbol	<sup>75</sup> As <sup>3-</sup>			
Protons		28	53	
Neutrons		31	74	118
Electrons		26		76
Net Charge			-1	3+

c) Give the name or chemical formula, as appropriate of the following compounds

(i) cobalt(III) sulphate

(ii)  $\text{HClO}_3(\text{aq})$

(iii) sulphurous acid

(iv) barium carbonate

(v)  $\text{ICl}_3$

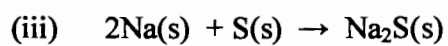
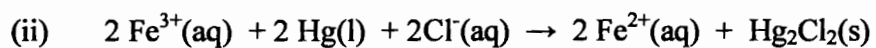
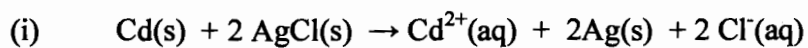
(vi)  $\text{S}_2\text{Cl}_2$

(vii) magnesium hydrogen carbonate

(viii)  $\text{MnO}_2$

[8]

d) Which element is oxidized and which is reduced in the following reactions?



[6]

*The end*

## General data and fundamental constants

Quantity	Symbol	Value
Speed of light	$c$	$2.997\,924\,58 \times 10^8 \text{ m s}^{-1}$
Elementary charge	$e$	$1.602\,177 \times 10^{-19} \text{ C}$
Faraday constant	$F = N_A e$	$9.6485 \times 10^4 \text{ C mol}^{-1}$
Boltzmann constant	$k$	$1.380\,66 \times 10^{-23} \text{ J K}^{-1}$
Gas constant	$R = N_A k$	$8.314\,51 \text{ J K}^{-1} \text{ mol}^{-1}$ $8.205\,78 \times 10^{-2} \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$ $6.2364 \times 10 \text{ L Torr K}^{-1} \text{ mol}^{-1}$
Planck constant	$h$ $\hbar = h/2\pi$	$6.626\,08 \times 10^{-34} \text{ J s}$ $1.054\,57 \times 10^{-34} \text{ J s}$
Avogadro constant	$N_A$	$6.022\,14 \times 10^{23} \text{ mol}^{-1}$
Atomic mass unit	$u$	$1.660\,54 \times 10^{-27} \text{ Kg}$
Mass		
electron	$m_e$	$9.109\,39 \times 10^{-31} \text{ Kg}$
proton	$m_p$	$1.672\,62 \times 10^{-27} \text{ Kg}$
neutron	$m_n$	$1.674\,93 \times 10^{-27} \text{ Kg}$
Vacuum permittivity	$\epsilon_0 = 1/c^2 \mu_0$ $4\pi\epsilon_0$	$8.854\,19 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$ $1.112\,65 \times 10^{-10} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
Vacuum permeability	$\mu_0$	$4\pi \times 10^{-7} \text{ J s}^2 \text{ C}^{-2} \text{ m}^{-1}$ $4\pi \times 10^{-7} \text{ T}^2 \text{ J}^{-1} \text{ m}^3$
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\,02 \times 10^{-24} \text{ J T}^{-1}$
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\,79 \times 10^{-27} \text{ J T}^{-1}$
g value	$g_e$	2.002 32
Bohr radius	$a_0 = 4\pi\epsilon_0\hbar/m_e e^2$	$5.291\,77 \times 10^{-11} \text{ m}$
Fine-structure constant	$\alpha = \mu_0 e^2 c/2h$	$7.297\,35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c \epsilon_0^2$	$1.097\,37 \times 10^7 \text{ m}^{-1}$
Standard acceleration of free fall	$g$	$9.806\,65 \text{ m s}^{-2}$
Gravitational constant	$G$	$6.672\,59 \times 10^{-11} \text{ N m}^2 \text{ Kg}^{-2}$

## Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	$1 \times 10^{-7} \text{ J}$
1 eV	=	$1.602\,2 \times 10^{-19} \text{ J}$	1 eV/molecule	=	96 485 kJ mol <sup>-1</sup>

Prefixes	f	p	n	$\mu$	m	c	d	k	M	G
	femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
	$10^{-15}$	$10^{-12}$	$10^{-9}$	$10^{-6}$	$10^{-3}$	$10^{-2}$	$10^{-1}$	$10^3$	$10^6$	$10^9$

