Lester B. Pearson School Board

Commission scolaire Lester-B.-Pearson

JUNE 2011

CHEMISTRY

Secondary 5

551-504

Theory Examination

Question Booklet

Time: 3 hours

GRICS BIM

Instructions

1. Fill in the required information on the title page of the ***Answer Booklet***.

2. You are permitted to use drawing instruments, graph paper, and a scientific calculator with or without graphic display.

3. You may refer to the Periodic Table of the Elements and lists of Formulas and Quantities included in the Appendices to this ***Question Booklet***. The use of any other reference material is **strictly** forbidden.

4. Write your answers in the ***Answer Booklet***.

5. Show all your work needed to solve the problem: data given, explanations, formulas and calculations. You will be given no marks if you provide the right answer without showing your work. However, you will be given part marks for work that is partially correct. Where necessary, the correct unit of measurement must be included in the answer.

6. **The rules of significant figures should be applied to all final statements.** A total of 2 marks have been allocated to the consistent use of significant figures throughout the examination.

7. This examination is made up of 13 questions and is worth 60 marks.

Note: Figures are not necessarily drawn to scale.

TIME: 3 hours

Part A: Chemistry of Aquarium Gases

Context for Questions 1- 4

There can be several gases dissolved in an aquarium. These gases include oxygen, O_2, nitrogen, N_2, water vapour, H_2O, and ammonia, NH_3. The presence of ammonia can be a problem as ammonia poisoning is one of the biggest killers of aquarium fish. If the ammonia concentration in the aquarium rises above 5.88×10^{-5} mol/L, the fish will begin to show symptoms of ammonia poisoning.

Question 1

Both oxygen and ammonia can behave as ideal gases.

Using the kinetic molecular theory, state four behaviours of oxygen and ammonia gas molecules.

Question 2

Rank the gases oxygen, water vapour, nitrogen and ammonia in increasing order of rates of diffusion.

Justify your answer.

Question 3

A 40.0 L aquarium is located in a room at SATP, standard ambient temperature and pressure (see formula sheet).

Assume that the total pressure of dissolved gases in the aquarium is equivalent to the atmospheric pressure in the room, and that the volume of the dissolved gases in the aquarium is 0.303 L.

The table below provides the partial pressures of the four gases dissolved in the aquarium water.

Partial Pressures of Gases Dissolved in the Aquarium

Dissolved Gas in Aquarium	Partial Pressure (kPa)
Oxygen (O_2)	36.1
Water vapour (H_2O)	0.600
Nitrogen (N_2)	63.3 kPa
Ammonia (NH_3)	?

a) Determine the partial pressure of ammonia gas.

b) Determine the number of moles of oxygen and ammonia gas dissolved in the aquarium water.

Question 4

Unfortunately, the ammonia concentration in the 40.0 L aquarium has risen to 5.88×10^{-5} mol/L and the fish are in jeopardy. The fish are temporarily removed from the aquarium.

Fortunately, oxygen gas can react with the ammonia, reducing the toxicity of the water.

The balanced chemical equation for this reaction is:

$$4\ NH_{3(g)} + 7\ O_{2(g)} \rightarrow 4\ NO_{2(g)} + 6\ H_2O_{(g)} + \text{energy}$$

Determine the volume of oxygen gas at SATP required to remove all of the ammonia from the aquarium.

Part B: Natural Gas and Energy

Natural gas, a mixture of butane, methane, propane and ethane, is a vital component of the world's energy resources. These gases are used as an energy source for many uses as each of these gases emits large quantities of energy through combustion.

Question 5

Butane (C_4H_{10}) is commonly used as a fuel for camping stoves.

The balanced chemical equation for the combustion of butane is below:

$$C_4H_{10(g)} + \frac{13}{2}O_{2(g)} \rightarrow 4\ CO_{2(g)} + 5\ H_2O_{(g)} + 2657.4\ \text{kJ}$$

A butane camping stove is used to heat 1.0 L of water at an initial temperature of 20.0°C.

Determine the final temperature of the water when 5.8 g of the butane gas is burned in the camping stove.

Assume that no heat is lost to the surroundings.

Question 6

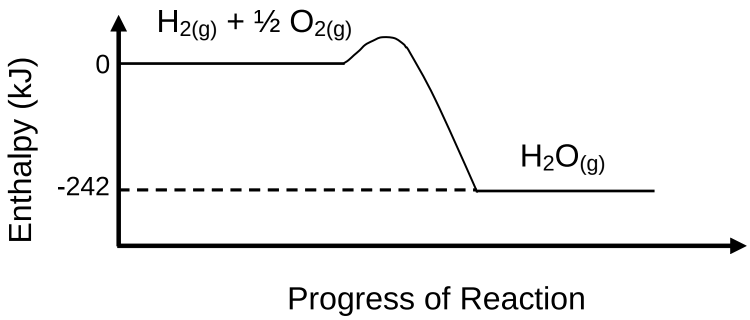
A scientist gathered some data to help her calculate the amount of heat released during the combustion of methane (CH_4). The data are given below:

$$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$$

1. $C_{(s)} + 2\ H_{2(g)} \rightarrow CH_{4(g)} + 74.6\ kJ$

2. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + 393.5\ kJ$

3. Enthalpy vs. Progress of Reaction



Determine the molar heat of combustion of methane.

Question 7

Ethane (C_2H_6) is the second largest component of natural gas.

The chemical equation for the combustion of ethane is given below. The activation energy for this reaction is 102 kJ.

$$C_2H_{6(g)} + \frac{7}{2}O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)} + 1560\ kJ$$

a)	Plot the energy diagram for the combustion of ethane.

b)	Determine the change in enthalpy, ΔH, and the activation energy, E_a, for the ***reverse*** reaction.

Part C: Reaction Rates and the Human Body

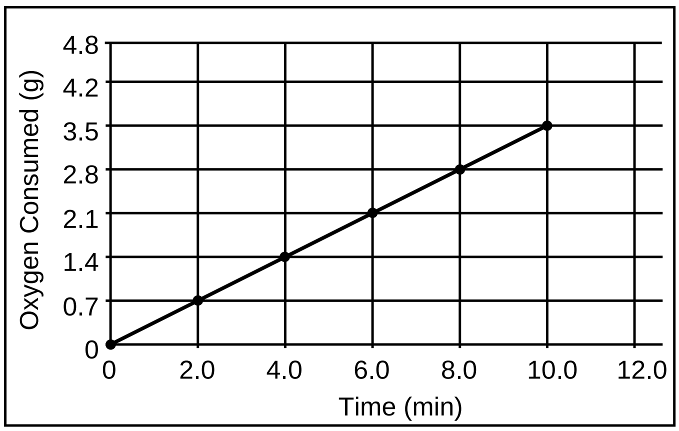
Question 8

Cellular respiration is the process by which oxygen reacts with glucose, $C_6H_{12}O_6$, releasing energy. The balanced chemical equation for cellular respiration is:

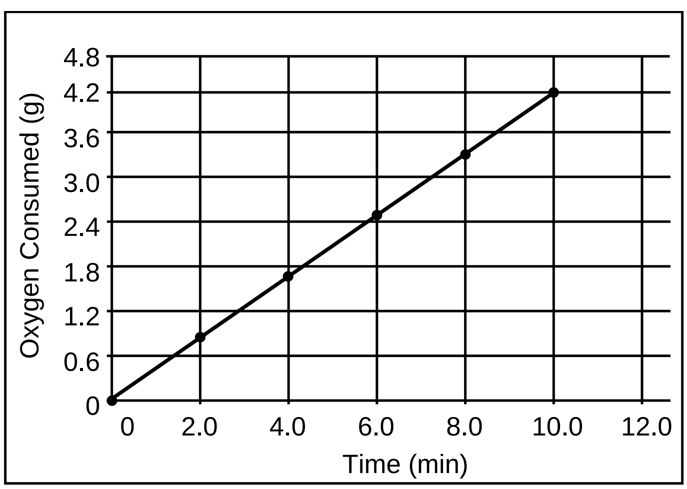
$$C_6H_{12}O_{6(aq)} + 6\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 6\ H_2O_{(\ell)} + \text{Energy}$$

The oxygen consumption of two men with different body masses, 75 kg and 100 kg, were studied. The results are shown below:

Graph 1 – Oxygen Consumption vs. Time for 75 kg Male



Graph 2 – Oxygen Consumption vs. Time for 100 kg Male



a) How many moles of glucose does each male use in 10 minutes?

Justify your answer.

Assume that all the oxygen consumed by each male is used for cellular respiration.

b) If cellular respiration occurred in one step, what would the rate law expression be for the reaction?

c) Compare the rate law expression for the 75 kg man and the 100 kg man.

Question 9

The reaction between marble chips ($CaCO_3$) and hydrochloric acid (HCl) is shown by the equation below.

$$CaCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(g)} + CaCl_{2(aq)}$$

Use the collision theory to explain three methods to increase the rate of production of carbon dioxide.

Part D: Chemical Equilibrium in the Blood

Question 10

A marathon is being held at a high altitude, where there is less oxygen.

Some runners experience ***hypoxia*** at high altitudes. Hypoxia can be caused by a reduction of the oxygen-carrying capacity of the blood. Symptoms may include headaches, fatigue, and nausea.

Oxygen is transported in the blood by a complex protein found in the red blood cells called hemoglobin. The hemoglobin molecule is represented by "Hb". Hemoglobin transports oxygen by combining with it to form oxyhemoglobin (HbO_2).

The equilibrium reaction for the transport of oxygen by the hemoglobin molecule (Hb) can be represented as:

$$Hb_{(aq)} + O_{2(g)} \leftrightharpoons HbO_{2(aq)}$$

a) Explain using Le Chatelier's Principle why athletes unaccustomed to high altitudes experience hypoxia.

b) Explain using Le Chatelier's Principle a possible remedy for a patient suffering from hypoxia.

Question 11

It is important that the pH of the blood is regulated so that it remains within a normal range. Changes in the blood pH can result in health conditions described in the table below.

Table 1: Blood pH

Blood pH	Condition
pH lower than 7.35	Acidosis
pH range of 7.35 – 7.45	Normal
pH greater than 7.45	Alkalosis

In both acidosis and alkalosis, the buffering system in the blood is disrupted.

One of the steps involved in this buffering process is shown below.

$$H_2CO_{3(aq)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3(aq)} \qquad \mathbf{K_a = 7.94 \times 10^{-7}}$$

(carbonic acid) (bicarbonate ion)

An emergency medical team has analyzed a blood sample from an athlete who is not feeling well.

The equilibrium concentration of carbonic acid (H_2CO_3) was 1.10×10^{-3} mol/L, and the equilibrium concentration of the bicarbonate ion (HCO_3^-) was 2.77×10^{-2} mol/L.

Note: *The equilibrium concentrations of* H^+ *and* HCO_3^- *are* ***not*** *equal.*

a) Determine whether or not the athlete is suffering from acidosis, alkalosis, or has a normal blood pH.

Justify your answer.

b) How could changing the bicarbonate ion concentration in the blood be used as a treatment for alkalosis?

Refer to Le Chatelier's Principle in your answer.

Question 12

The fluoride ion can be toxic to humans. Fluoride ions can form a precipitate with calcium ions in the blood, resulting in various health problems.

The solubility equilibrium for calcium fluoride, CaF_2, is represented by the reaction below.

$$CaF_{2(s)} \leftrightharpoons Ca^{2+}_{(aq)} + 2\ F^{-}_{(aq)} \qquad K_{sp} = 3.9 \times 10^{-11}$$

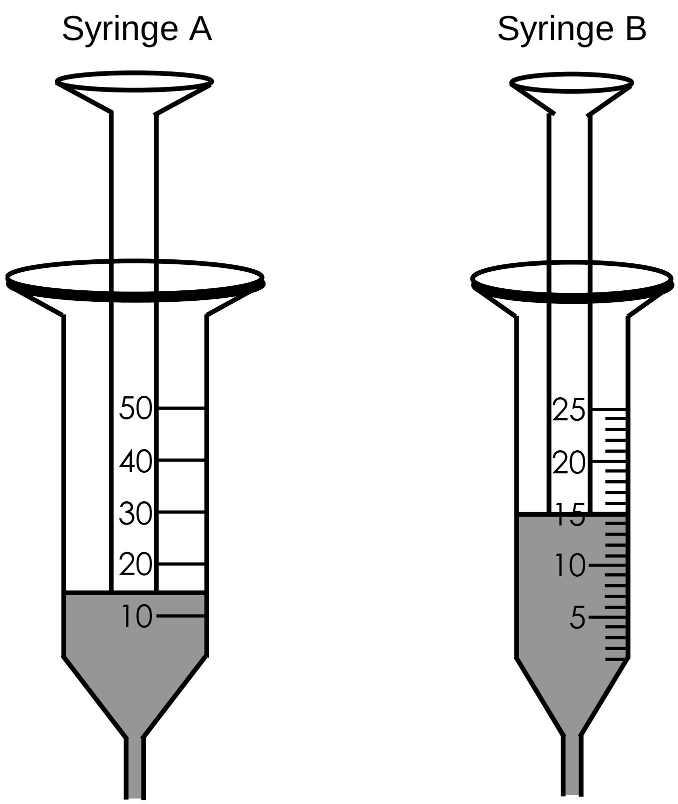
What is the concentration of fluoride ions in a saturated solution of calcium fluoride?

Justify your answer.

Use the following information to answer Question 13.

Question 13

Below is a diagram of two syringes used to collect gases. The gases are represented by the shaded portion in the syringe.



Indicate the volume of each gas as measured by the two syringes.

Observe the conventions regarding significant figures, and give the uncertainty of the measurement.

PERIODIC TABLE OF THE ELEMENTS

Key: Element Symbol — H; Atomic number — 1; Atomic Mass — 1.01

	IA 1	II A 2	III B 3	IV B 4	V B 5	VI B 6	VII B 7	VIII 8	VIII 9	VIII 10	I B 11	II B 12	III A 13	IV A 14	V A 15	VI A 16	VII A 17	VIII A 18
1	1 **H** 1.01																	2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.40	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
6	55 **Cs** 132.91	56 **Ba** 137.33	57-71 **La-Lu**	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.20	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.20	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89-103 **Ac-Lr**	104 **Rf** (261)	105 **Ha** (262)													

6	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 145	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
7	89 **Ac** 227.03	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

FORMULAS

$$Q = mc\Delta T$$

$$PV = n\,RT$$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$$P_T = P_A + P_B + P_C + \ldots$$

$$P_A = P_T\,\frac{n_A}{n_T}$$

PHYSICAL CONSTANTS

SYMBOL	NAME	VALUE
c_{H_2O}	Specific heat capacity of water	4190 J/(kg•°C) or 4.19 J/(g•°C)
ρ_{H_2O}	Density of water	1.00 g/mL
R	Molar gas constant	8.31 kPa • L/(mol•K)
SATP	Standard ambient temperature and pressure	Temperature: 25.0°C Pressure: 101.3 kPa