GENERAL CHEMISTRY II
MIDTERM TEST

Note to students:
This exam covered Ch.6, 9.8, 19.1-19.6, 13.1-13.5, 14 & all of 15.
(questions #1ef, 2d, 6, 7 cover material after 15.3)

INSTRUCTIONS: ***PLEASE READ THIS PAGE WHILE WAITING TO START YOUR EXAM.***

This test paper includes 4 pages (both sides) plus a periodic table; some potentially useful information is given on the last page. Check that your paper is complete before starting. You can remove the periodic table if you wish. Answer all questions inside the space provided. Calculators are permitted; cell phones and electronic dictionaries are not allowed. You have the whole class to complete the test. I suggest you read through the whole test quickly before starting. **GOOD LUCK!**

LAST NAME: _____ FIRST NAME: _____

STUDENT NUMBER: _____

Mark breakdown:

Page 2.	/ 12
Page 3.	/ 10
Page 4.	/ 8
Page 5.	/ 8
Page 6.	/ 6
Page 7.	/ 6 (max. 8)
TOTAL:	/ 50 (max. = 52)
PERCENT:	%
EARNED toward FINAL GRADE:	/ 20

 # 1. (__/ 6 marks) Circle the words (IN CAPITALS) that correctly complete the following statements:

a) When a spontaneous reaction occurs, the system's free energy (INCREASES / DECREASES), which corresponds to an overall (INCREASE / DECREASE) in the entropy of the universe.

b) (HIGHER / LOWER) temperatures make entropically driven processes more thermodynamically favourable, which means their free energy changes have a more (POSITIVE / NEGATIVE) value.

c) When a substance dissolves, its (INTERMOLECULAR / INTRAMOLECULAR) forces are disrupted because of interactions with solvent molecules. During this process, the chemical structures of the dissolved molecules or ions (CHANGE / DO NOT CHANGE).

d) For a solution of two volatile components A and B, the vapour pressure above the solution will be higher than predicted by (RAOULT'S LAW / HENRY'S LAW) if the interactions between molecules A & B are (WEAKER THAN / STRONGER THAN) the average interactions between A & A and B & B.

e) The (RATE CONSTANT / ACTIVATION ENERGY) of a reaction will become smaller if the reaction is performed (AT A HIGHER TEMPERATURE / WITH A CATALYST).

f) A reaction cannot proceed faster than its (RATE-LIMITING STEP / FIRST STEP), which is the step with the (SMALLEST / LARGEST) activation energy.

 # 2. (__/ 6 marks) Alkali metals are often used to remove traces of water from organic solvents, such as diethyl ether. Because the reaction (shown below) is exothermic, care must be taken to make sure the solvent does not "boil over".

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) \qquad \Delta H^\circ_{rxn} = -368.4 \text{ kJ}$$

a) **(2 marks)** How much heat (in kJ) is released via the reaction of 1.00 g of sodium metal with water?

b) **(4 marks)** If this much heat is released into 275 g of diethyl ether initially at 25°C, will the solvent reach its boiling point? Show calculations to support your answer. For diethyl ether: C = 2.51 J/g·K, b.p. = 35°C.

 # 3. (__/ 10 marks) Hydrogen cyanide (HCN) is produced industrially by the following reaction:

$2NH_3(g) + 3O_2(g) + 2CH_4(g) \rightarrow 2HCN(g) + 6H_2O(g)$

Substance	ΔH^o_f (kJ/mol)	S^o_f (J/mol·K)
$NH_3(g)$	-46	193
$O_2(g)$	0	205
$CH_4(g)$	-75	186
HCN(g)	135	202
$H_2O(g)$	-242	189

a) **(2 marks)** Is this reaction endothermic or exothermic? Show a calculation to support your choice.

b) **(2 marks)** Calculate the standard entropy change for this reaction (ΔS^o_{rxn}). Is the reaction entropically favoured or entropically disfavoured?

c) **(3 marks)** Determine whether the reaction is spontaneous or nonspontaneous in the forward direction at 298 K. Support your answer with calculations.

d) **(3 marks)** This reaction is performed industrially at 1000°C with a catalyst. Based on your calculations, is the high temperature needed for thermodynamic reasons or for kinetic reasons? Explain.

 # 4. (__/ 8 marks) Seawater contains many different dissolved salts. It freezes at -2.30°C and has a density of approximately 1.03 g/mL. For water: K_f = 1.86°C/m, m.p. = 0.00°C, d = 1.00 g/mL.

a) **(4 marks)** What is the concentration of solute particles (dissolved ions) in seawater, expressed in molality?

b) **(4 marks)** For seawater, the concentration of solute particles is the approximately the same when expressed in molality and in molarity. Why is this true? Answer this question by providing:

(i) **(1 mark)** the definition of molality (identify solute / solvent / solution where appropriate).

(ii) **(1 mark)** the definition of molarity (identify solute / solvent / solution where appropriate).

(iii) **(2 marks)** a very brief comment about why molality & molarity are essentially equal for seawater.

 # 4. (__/ 3 marks) *CONTINUED FROM PREVIOUS PAGE*

c) **(3 marks)** Marine fish blood has the same osmotic pressure as seawater; we say they are "isotonic". Assuming that molality (from part #4(a)'s answer) and molarity are the same for seawater, what is the osmotic pressure of the blood of a fish at 20.0°C?

NOTE: if you could not answer part (a), use a concentration of 2.0 M (which is NOT right…) to do part (c).

 # 5. (__/ 5 marks) Soft drinks are aqueous solutions that contain a variety of solutes, including carbon dioxide. Explain the nature of the attractive forces that exist between the molecules of water and carbon dioxide in the soft drink, by providing:

a) **(1 mark)** Lewis structures of H_2O and CO_2, labeled with molecular dipoles as appropriate.

b) **(1 mark)** the name of the intermolecular force involved.

c) **(3 marks)** a brief explanation of how the attractive force arises.

 # 6. (__/ 6 marks) Nitrogen oxides, a mixture of NO and NO_2 described as NO_x, are important atmospheric pollutants. During daylight hours, the NO_x in the atmosphere breaks down slowly to N_2 and O_2 via a first-order reaction, with a half life of approximately 3.9 h.

a) **(3 marks)** What is the rate constant k for this reaction?

b) **(3 marks)** How many hours of daylight must a sample be exposed to in order to decrease the NO_x concentration in a sample from 2.0×10^{-5} M to 1.25×10^{-6} M?

 # 7. (__/ 6 marks) Consider the reaction of nitric oxide and chlorine: $2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$

Evaluate the proposed mechanism, by answering parts (a)-(d).

Proposed Mechanism:
STEP 1: $NO(g) + Cl_2(g) \rightarrow NOCl_2(g)$
STEP 2: $NOCl_2(g) + NO(g) \rightarrow 2NOCl(g)$

	Reactant Concentration (M)		Reaction rate (M/s)
Run	$[NO]_o$	$[Cl_2]_o$	$RATE_o$
1	0.13	0.20	1.0×10^{-2}
2	0.26	0.20	4.0×10^{-2}
3	0.13	0.10	5.0×10^{-3}

a) **(1 mark)** What two criteria must be met for the proposed mechanism to be considered "consistent" with experiment?

1:

2:

b) **(2 marks)** Use the initial rates data from the table to determine the observed rate law for this reaction.

c) **(1 mark)** Write the rate law for each elementary step in the proposed mechanism.

STEP 1:

STEP 2:

d) **(2 marks)** For the mechanism to be consistent, which step must be rate-limiting? Explain your choice, using logic and deductive reasoning only (*i.e.,* no algebra).

e) **(*2 bonus marks*)** Derive the rate law you would expect to observe if STEP 2 is the rate-limiting step.

----------THE END----------

POTENTIALLY USEFUL INFORMATION & SPACE FOR ROUGH WORK (NOT MARKED)

$R = 8.314\ J \cdot mol^{-1}K^{-1}$
$= 0.08206\ L \cdot atm \cdot mol^{-1}K^{-1}$

$C(H_2O) = 4.184\ J \cdot g^{-1}K^{-1}$

$\Delta G^o = \Delta H^o - T\Delta S^o$

$PV = nRT$

$C = k\,P$ (or, $S = k\,P$)

$P = \chi\,P^o$

$\Delta T = K\,m$

$k = A\,e^{(-Ea/RT)}$

$[A] = -kt + [A]_o$

$\ln[A] = -kt + \ln[A]_o$

$1/[A] = kt + 1/[A]_o$