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 #1ce, 3c, 6 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 back of the periodic table. 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 75 min to complete the test. *I suggest you scan the whole test quickly before starting & do the 'easy' stuff 1st.*
GOOD LUCK! *Suggestion: spend 1 min / mark ⇨ 25 min left to finish uncertain problems & check.*

LAST NAME: _____ FIRST NAME: _____

STUDENT NUMBER: _____

Mark breakdown:

Page 2.	/ 6
Page 3.	/ 6
Page 4.	/ 11
Page 5.	/ 11
Page 6.	/ 8
Page 7.	/ 9
TOTAL:	/ 50 (max. = 51)
PERCENT:	%

EARNED toward

FINAL GRADE: / 20

 # 1. (__/ 6 marks) Circle the words (IN CAPITALS) that correctly complete the following statements.
[You do not need to explain your choices.]

a) If a reaction that produces a gaseous product occurs in an open container, the expansion of the system causes the system to (GAIN / LOSE) energy in the form of work. Work is an example of a (STATE FUNCTION / PATH FUNCTION).

b) (LONDON DISPERSION FORCES / DIPOLE-DIPOLE INTERACTIONS) are intermolecular forces caused by transient (EXCITATION / POLARIZATION) of the electron clouds in neighbouring molecules.

c) Imagine an elementary step that involves two molecules of the same compound. This process is a (UNIMOLECULAR / BIMOLECULAR) reaction, and it will display (FIRST ORDER / SECOND ORDER) kinetics.

d) The normal boiling point of a substance is the temperature at which the substance's vapour pressure (EQUALS / EXCEEDS) the atmospheric pressure. For this reason, people living high in the mountains must cook their foods for a (LONGER / SHORTER) period of time than people living at sea level.

e) A catalyst (DECREASES / INCREASES) the rate constant of a reaction by decreasing the magnitude of the reaction's (GIBB'S FREE ENERGY CHANGE / ACTIVATION ENERGY) .

f) To be spontaneous, a reaction that involves breaking a stronger covalent bond and forming a weaker covalent bond must be accompanied by a significant (INCREASE / DECREASE) in the randomness of the system.

 # 2. (__/ 6 marks) The hot water heaters in homes are often powered by burning natural gas. The combustion of methane (the principle component of natural gas), is described by the following equation:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H^\circ = -890.3 \text{ kJ}$$

[Note: potentially useful data is available on the formula page.]

a) **(3 marks)** A typical shower uses 9.5 L of water per minute. Imagine you spend 8.5 minutes in the shower. What quantity of heat (in kJ) is required to warm the volume of water you use, if the water starts at 25°C and is heated in the hot water heater to 49°C?

b) **(3 marks)** If we assume the heat released by burning methane gas is transferred with 100% efficiency to the water, what volume of methane gas (at 25°C, 1.0 atm) will provide the amount of heat calculated in part (a)? *[If you could not do part (a), use 13000 kJ…which is <u>not</u> right..to try (b).]*

 # 3. (__/ 11 marks) The Henry's law constant for nitrogen in blood serum is about 8×10^{-7} mol·L^{-1}·mmHg^{-1}.

a) **(3 marks)** If a scuba diver is breathing compressed air at a depth where the total pressure is 2.5 atm, what is the N_2 concentration in the diver's blood? Assume that the air is 78% N_2 by volume.

b) **(3 marks)** If the diver returns to the surface too quickly, what will happen to the dissolved N_2 in his blood, and why? Briefly explain the physical and/or chemical phenomena involved, not the biology.

c) **(5 marks)** If the release of nitrogen gas from the blood is a first order process with a half-life of 9 minutes, how long will it take for 40% of the dissolved nitrogen to leave the diver's blood?
[Note: in reality, this process is <u>much</u> more complicated than what I am suggesting here….]

 # 4. (__/ 11 marks) The carbon in the atmosphere (*i.e.,* CO_2) is thermodynamically less stable than the carbon trapped in limestone (*i.e.,* $CaCO_3$). In this problem, you will calculate thermodynamic quantities that will allow you to confirm or refute the validity of this statement.

Substance	ΔH^o_f (kJ/mol)	S^o_f (J/mol·K)
$CO_2(g)$	-393.51	213.74
CaO(s)	-635.09	39.75
$CaCO_3(s)$	-1206.92	92.9

a) **(1 mark)** Carbon dioxide reacts with lime, CaO(s), to produce $CaCO_3$(s). Write the balanced equation for this process.

b) **(3 marks)** Calculate the standard enthalpy change for this reaction (ΔH^o_{rxn}). What effect would this reaction have on the entropy of its surroundings? Why?

c) **(3 marks)** Calculate the standard entropy change for this reaction (ΔS^o_{rxn}). Would the system become more organized or less organized when this reaction occurs?

d) **(4 marks)** Calculate the standard Gibbs free energy change for this reaction at 298K. Does this confirm or refute the original statement that CO_2 is thermodynamically unstable with respect to $CaCO_3$? Why?

 # 5. (__/ 8 marks) Maple syrup is prepared by heating the sap from the maple tree to evaporate off much of the water. Heating is continued until the syrup's boiling point is about 4.0°C higher than the original sap. For this problem, we will approximate the syrup as being composed only of water and sugar ($C_{12}H_{24}O_{12}$).

[Note: potentially useful data is available on the formula page.]

a) **(2 marks)** What is the molal concentration of sugar in maple syrup?

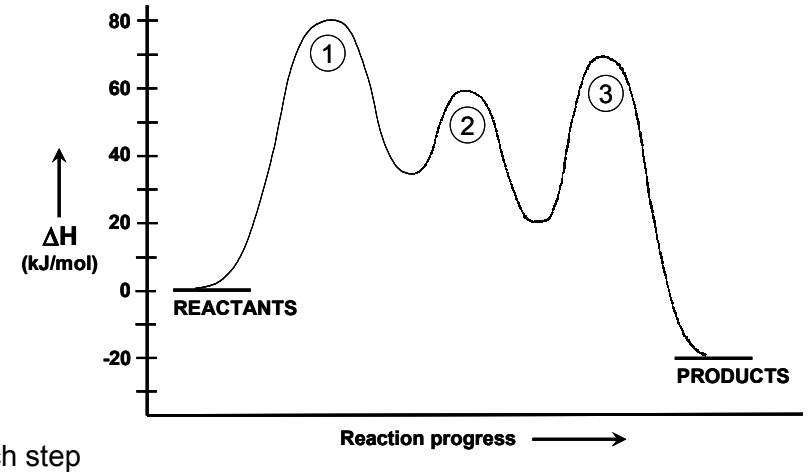
[If you could not answer part (a), use a molal concentration of 5.0 m as a starting point for part (b).]

b) **(6 marks)** What mass of sugar is present in a 35 g portion of maple syrup? *[Hint: what is the mass % composition of the syrup?]*

 # 6. (__/ 9 marks) The reaction coordinate diagram below represents a proposed three-step mechanism for the reaction: $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$.

STEP 1: $2NO \rightarrow N_2O_2$
STEP 2: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$
STEP 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

a) **(1 mark)** Using the diagram, estimate ΔH_{rxn} for the overall reaction, and label this quantity on the diagram.



b) **(2 marks)** According to the diagram, which step is rate-limiting? Estimate the activation energy of the rate-limiting step, and label this quantity on the diagram.

c) **(2 marks)** Assuming the activation energy calculated in part (b) is correct, can you calculate the rate constant for the overall process at 298 K? Why or why not? *[If you could not do (b), use E_a = 45 kJ/mol for part (c).]*

d) **(2 marks)** What rate law is predicted for the reaction if it proceeds via this mechanism? Why?

e) **(2 marks)** If the reaction is experimentally observed to be first order in H_2, would you describe the kinetics to be consistent with the proposed mechanism? Why or why not?

EXTRA SPACE IF YOU NEED IT

POTENTIALLY USEFUL INFORMATION

Constants:

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

1 atm = 760 mm Hg = 760 torr = 101.325 kPa

Data:

Properties of liquid water:

bp (at 1 atm) = 100.00°C

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

$d_{H_2O(l)} = 1.00\ g \cdot mL^{-1}$

$K_{f\ H_2O} = 1.86\ °C \cdot kg \cdot mol^{-1}$

$K_{b\ H_2O} = 0.52\ °C \cdot kg \cdot mol^{-1}$

Properties of solid water:

mp (at 1 atm) = 0.00°C

$C_{H_2O(s)} = 2.06\ J \cdot g^{-1}K^{-1}$

$d_{H_2O(s)} = 0.917\ g \cdot mL^{-1}$

Formulae:

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

$PV = nRT$

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

$P = \chi\ P^o$

$\Delta T = K\ m$

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

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

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

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