# CAPE BRETON UNIVERSITY 

Chem 1105-Midterm<br>Date: July 18, 2016

Instructor: Calvin Howley<br>Time Period: 3 hour

Student:
Student \#: $\qquad$

## Instructions:

Please turn off all cell phones. Only scientific calculators are allowed in the exam room. Students found to be using any electronic organizer or other electronic device during the exam will be given a grade of zero and asked to leave the testing area.

All answers are to be done on test paper. If more room is needed use the back side of the paper and indicate.

Read all questions carefully.
Answer all questions for full point value. Partial marks may be awarded for incomplete questions.

Make sure you have all data sheets and test pages.
Complete as many questions as soon as possible and then go back to incomplete questions.

Test papers not turned in to the instructor at the end of the test period will not be accepted.

## Part I: Short Answer

Instructions: Circle the correct answer or fill your answer in the space provided.

1. Which of the following is not a type of energy or energy transfer?
a) chemical energy
b) heat
c) temperature
d) work
2. The first law of thermodynamics
a) defines chemical energy.
b) defines entropy
c) is a statement of conservation of energy.
d) provides a criterion for spontaneity of a reaction.
3. In which case is the work done on the system positive?
a) $\Delta \mathrm{E}>0$
b) $\Delta V>0$
c) $\Delta V=0$
d) $\Delta$ V $<0$
4. A gas expands against a nonzero external pressure while in thermal isolation from the surroundings. For the expansion
a) $\Delta E$ increases
b) $\Delta \mathrm{E}$ does not change
c) $\Delta E$ decreases
d) $\Delta E=q$
5. Which of the following statements is not true?
a) The reverse of a spontaneous reaction is always nonspontaneous.
b) A spontaneous process always moves towards equilibrium.
c) A nonspontaneous process cannot be caused to occur.
d) A highly spontaneous process need not occur rapidly.
6. Entropy is a measure of
a) free energy.
b) the heat of reaction.
c) molecular randomness.
d) the rate of reaction.
7. Molecular hydrogen can be made from methane gas by the reaction below. How is the rate of disappearance of $\mathrm{CH}_{4}$ related to the rate of appearance of $\mathrm{H}_{2}$ ? $\frac{\Delta\left[C \mathrm{CH}_{4}\right]}{\Delta t}=$ ?

$$
\mathrm{CH}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightarrow \mathrm{CO}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g})
$$

a) $+\frac{\Delta\left[H_{2}\right]}{\Delta t}$
b) $+\frac{1 \Delta\left[\mathrm{H}_{2}\right]}{3 \Delta t}$
c) $+3 \frac{\Delta\left[H_{2}\right]}{\Delta t}$
d) none of these
8.A mechanism for a naturally occurring reaction that destroys ozone is:

$$
\begin{aligned}
& \text { Step 1: } \mathrm{O}_{3}(\mathrm{~g})+\mathrm{HO}(\mathrm{~g}) \rightarrow \mathrm{HO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \\
& \text { Step 2: } \mathrm{HO}_{2}(\mathrm{~g})+\mathrm{O}(\mathrm{~g}) \rightarrow \mathrm{HO}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g})
\end{aligned}
$$

Which species is an intermediate?
a) HO
b) $\mathrm{HO}_{2}$
c) O
d) $\mathrm{O}_{3}$
9. "Isotopes" are atoms with the same number of $\qquad$ but different number of
$\qquad$ .
a) electrons, protons
b) neutrons, protons
c) protons, electrons
d) protons, neutrons
10. As the atomic number of the elements increases, the ratio of neutrons to protons in stable nuclei
a) decreases
b) stays the same.
c) increases.
d) is unrelated to stability.

## Part II: Long Answer

Instructions: Fill your answer in the space provided. Show all work for full point value. A. Energy Relationships, Calorimetry, Entropy, Gibbs Energy
1.a) Mothballs are composed primarily of the hydrocarbon naphthalene $\left(\mathrm{C}_{10} \mathrm{H}_{8}\right)$. When 1.025 g of naphthalene is burned in a bomb calorimeter, the temperature rises from $24.25^{\circ} \mathrm{C}$ to $31.28^{\circ} \mathrm{C}$. The heat of combustion of naphthalene is $5153.9 \mathrm{~kJ} / \mathrm{mole}$. Determine the heat capacity of the bomb calorimeter with the proper units
b) When 0.514 g of biphenyl $\left(\mathrm{C}_{12} \mathrm{H}_{10}\right)$ undergoes combustion in the same bomb calorimeter from part a), the temperature rises from $25.80^{\circ} \mathrm{C}$ to $29.40^{\circ} \mathrm{C}$. Find the heat of combustion of biphenyl in $\mathrm{kJ} /$ mole.
2. Using Hess's law calculate $\Delta \mathrm{H}$ for the reaction

$$
5 \mathrm{C}(\mathrm{~s})+6 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{C}_{5} \mathrm{H}_{12}(\mathrm{l})
$$

Given these reactions and their $\Delta H$ 's.

1. $\mathrm{C}_{5} \mathrm{H}_{12}(\mathrm{l})+8 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 5 \mathrm{CO}_{2}(\mathrm{~g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})$
$\Delta \mathrm{H}=-3505.8 \mathrm{~kJ}$
2. $\mathrm{C}(\mathrm{s})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g})$
$\Delta \mathrm{H}=-393.5 \mathrm{~kJ}$
3. $2 \mathrm{H}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})$
$\Delta \mathrm{H}=-483.5 \mathrm{~kJ}$
4. Use the given standard enthalpies of formation and entropy values to calculate

$$
3 \mathrm{Fe}_{2} \mathrm{O}_{3}(\mathrm{~s})+\mathrm{CO}(\mathrm{~g}) \rightarrow 2 \mathrm{Fe}_{3} \mathrm{O}_{4}(\mathrm{~s})+\mathrm{CO}_{2}(\mathrm{~g})
$$

| Compound | $\Delta \mathrm{H}_{\mathrm{f}}{ }^{\circ}(\mathrm{kJ} / \mathrm{mole})$ | $\Delta \mathrm{S}^{\circ}(\mathrm{J} / \mathrm{K} \cdot \mathrm{mole})$ |
| :---: | :---: | :---: |
| $\mathrm{CO}(\mathrm{g})$ | -110.5 | 197.7 |
| $\mathrm{CO}_{2}(\mathrm{~g})$ | -393.5 | 213.8 |
| $\mathrm{Fe}_{2} \mathrm{O}_{3}(\mathrm{~s})$ | -824.2 | 87.4 |
| $\mathrm{Fe}_{3} \mathrm{O}_{4}(\mathrm{~s})$ | -1118.4 | 146.4 |

a) $\Delta \mathrm{H}^{\circ}, \Delta \mathrm{S}^{\circ}$, and $\Delta \mathrm{G}^{\circ}$ for the following reaction at $25^{\circ} \mathrm{C}$ and state the significance of each.
b) Assuming the change in $\Delta \mathrm{H}^{\circ}$ and $\Delta \mathrm{S}^{\circ}$ are independent of temperature determine the temperature dependence of spontaneity for the following reaction at high and low temperatures.

## B. Kinetics

4. This diagram shows the energy of a reaction as the reaction progresses. Label each area(?) in the diagram.

reaction progress
5. 
6. $\qquad$
7. 

$\qquad$
4. $\qquad$
5. Using the method of initial rates and the data for the following reaction at $25^{\circ} \mathrm{C}$ :

$$
\mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{3}(\mathrm{~g}) \rightarrow \mathrm{SO}_{3}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g})
$$

| $\left[\mathrm{SO}_{2}\right](\mathrm{M})$ | $\left[\mathrm{O}_{3}\right](\mathrm{M})$ | Initial Rate(M/s) |
| :---: | :---: | :---: |
| 0.25 | 0.40 | 0.118 |
| 0.25 | 0.20 | 0.118 |
| 0.75 | 0.20 | 1.062 |

a) Determine the order with respect to each reactant.
b) Determine the overall reaction order.
c) Write the rate law for the reaction.
d) Determine the value of the rate constant.
6. The following reaction was monitored as a function of time:

$$
\mathrm{A} \rightarrow \mathrm{~B}+\mathrm{C}
$$

A plot of $\operatorname{In}[\mathrm{A}]$ versus time yields a straight line with a slope of $-0.0045 \mathrm{~s}^{-1}$.
a) What is the value of the rate constant (k) for this reaction at this temperature?
b) Write the rate law for this reaction.
c) What is the half-life?
d) If the initial concentration of A is 0.250 M , what is the concentration after 225 s ?

## C. Nuclear Chemistry

7. Fill in the missing particles in each nuclear equation.
a) $\qquad$ $\rightarrow{ }_{85}^{217} \mathrm{At}+{ }_{2}^{4} \mathrm{He}$
b) ${ }_{94}^{241} \mathrm{Pu} \rightarrow{ }_{95}^{241} \mathrm{Am}+$ $\qquad$
c) ${ }_{11}^{19} \mathrm{Na} \rightarrow{ }_{10}^{19} \mathrm{Ne}+$ $\qquad$
d) ${ }_{34}^{75} \mathrm{Se}+$ $\qquad$ $\rightarrow{ }_{33}^{75} \mathrm{As}$
8. Which member of each pair of nuclides would you expect to have the longest half-life? Be sure to justify your answer.
a) $\mathrm{Cs}-113$ or $\mathrm{Cs}-125$
b) $\mathrm{Fe}-62$ or $\mathrm{Fe}-70$
9. An ancient skull has a carbon-14 decay rate of 0.85 disintegrations per minute per gram of carbon( $0.85 \mathrm{dis} / \mathrm{min} \cdot \mathrm{g} \mathrm{C}$ ). Assume that living organisms have a carbon-14 decay rate of $15.3 \mathrm{dis} / \mathrm{min} \cdot \mathrm{g} \mathrm{C}$ and that carbon-14 has a half-life of 5730 yr . How old is the skull?

## Grade Sheet

The points awarded for this exam are outlined below. Please review. If there are any questions or possible corrections please consult the instructor.

| Question | Points Awarded |
| :---: | :---: |
| Part I |  |
| $1-10$ |  |
| Part II |  |
| $1-3$ | A |
|  |  |
| $4-6$ | B |
| $7-9$ |  |
| Total |  |

Comments:

## Some Useful Data or Not!

## Constants:

1 mole $=6.022 \times 10^{23}$ elementary particles

$$
\begin{gathered}
\mathrm{N}_{\mathrm{a}}=6.0223 \times 10^{23} \\
1000 \mathrm{~g}=1 \mathrm{~kg} \\
1 \mathrm{~g}=1000 \mathrm{mg}=0.001 \mathrm{~kg} \\
1 \mathrm{lb}=453.6 \mathrm{~g} \\
1 \mathrm{pg}=1 \times 10^{-12} \mathrm{~g} \\
1 \mu \mathrm{~g}=1 \times 10^{-6} \mathrm{~g} \\
1 \mathrm{~km}=1000 \mathrm{~m} \\
1 \mathrm{~cm}=0.01 \mathrm{~m} \\
1 \mathrm{~nm}=1 \times 10^{-9} \mathrm{~m} \\
1 \mathrm{pm}=1 \times 10^{-12} \mathrm{~m}
\end{gathered}
$$

$$
\begin{gathered}
1 \mu \mathrm{~m}=1 \times 10^{-6} \mathrm{~m} \\
1 \mathrm{~L}=1000 \mathrm{~mL} \\
\mathrm{R}=0.0821 \mathrm{~L} \cdot \mathrm{~atm} / \mathrm{K} \cdot \text { mole } \\
\mathrm{R}=8.314 \mathrm{~J} / \mathrm{K} \cdot \mathrm{~mole} \\
\mathrm{R}=8.314 \mathrm{~kg} \cdot \mathrm{~m}^{2} / \mathrm{s}^{2} \cdot \mathrm{~K} \cdot \mathrm{~mole} \\
1 \mathrm{~kJ}=1000 \mathrm{~J} \\
1 \mathrm{cal}=4.184 \mathrm{~J} \\
1 \mathrm{~Bq}=1 \text { disintegration per second }(\mathrm{d} / \mathrm{s}) \\
1 \mathrm{Ci}=3.70 \times 10^{10} \mathrm{~d} / \mathrm{s} \\
\mathrm{mCi}=1 \times 10^{-3} \mathrm{Ci} \\
\mu \mathrm{Ci}=1 \times 10^{-6} \mathrm{Ci}
\end{gathered}
$$

Equations:

$$
\begin{aligned}
& \mathrm{T}^{\circ} \mathrm{C}=\left(5^{\circ} \mathrm{C} / 9^{\circ} \mathrm{F}\right) \times\left(\mathrm{T}^{\circ} \mathrm{F}-32^{\circ} \mathrm{F}\right) \quad \mathrm{T}(\mathrm{~K})=\mathrm{T}\left({ }^{\circ} \mathrm{C}\right)+273.15^{\circ} \mathrm{C} \\
& \Delta G=\Delta H-T \Delta S \\
& \Delta \mathbf{E}=\mathbf{q}+\mathbf{w} \\
& \Delta \mathbf{G}^{\circ}=\text {-RTInK } \\
& \Delta G^{\circ}=\Delta H^{\circ}-T \Delta S^{\circ} \\
& \Delta H=\mathbf{q}_{\mathrm{p}} \quad \Delta E=\mathbf{q}_{\mathrm{v}} \\
& \Delta G=\Delta \mathbf{G}^{\circ}+\text { RTIn } Q \\
& \Delta \mathrm{~S}=\frac{\Delta \mathrm{H}}{\mathrm{~T}} \\
& w=-P \Delta V \\
& \text { C }=\text { mass } \times s p \_ \text {heat } \\
& \Delta H=\Delta E+\Delta n R T \\
& \mathbf{q}=\mathbf{C} \Delta \mathbf{t} \\
& -q_{\text {rxn }}=q_{c a l} \\
& \operatorname{In} \frac{[\mathrm{~A}]_{\mathrm{t}}}{[\mathrm{~A}]_{\mathrm{o}}}=-\mathrm{kt} \\
& \operatorname{In} \frac{N_{t}}{N_{o}}=\operatorname{In} \frac{A_{t}}{A_{o}}=-k t \\
& q_{\text {cal }}=C_{c a 1} \Delta t \\
& t_{1 / 2}=\frac{1}{k[A]_{0}} \\
& \mathrm{t}_{1 / 2}=\frac{\operatorname{In} 2}{\mathrm{k}}=\frac{0.693}{\mathrm{k}} \\
& \mathbf{A}=\mathbf{k} \mathbf{N} \\
& \operatorname{Ink}=\frac{-\mathrm{E}_{\mathrm{A}}}{\mathrm{RT}}+\operatorname{InA} \quad \operatorname{In} \frac{\mathrm{k}_{2}}{\mathrm{k}_{1}}=\frac{\mathrm{E}_{\mathrm{A}}}{\mathrm{R}}\left(\frac{1}{\mathrm{~T}_{1}}-\frac{1}{\mathrm{~T}_{2}}\right) \quad \frac{1}{[\mathrm{~A}]_{\mathrm{t}}}=\mathrm{kt}+\frac{1}{[\mathrm{~A}]_{\mathrm{o}}}
\end{aligned}
$$

## Answer Set For Chem 1105-Midterm:

## Part I

1.c)
2.c)
3.d)
4.c)
5.c)
6.c)
7. b) or d)
8.b)
9.d)
10.c)

## Part II

1.a) $5.86 \mathrm{~kJ} /{ }^{\circ} \mathrm{C}$; b) $-6330 \mathrm{~kJ} / \mathrm{mole}$
2. 87.8 kJ
3.a) $\Delta \mathrm{H}^{\circ}=-47.2 \mathrm{~kJ}$ (exothermic), $\Delta \mathrm{S}^{\circ}=46.7 \mathrm{~J} / \mathrm{K}$ (disorder increases),
$\Delta \mathrm{G}^{\circ}=-61.1 \mathrm{~kJ}$ (spontaneous)
b) Spontaneous at all temperatures.
4.1) reactants; 2) activation energy; 3) change in enthalpy; 4) products
5.a) Second order with respect to $\mathrm{SO}_{2}$, zero order with respect to $\mathrm{O}_{3}$.
b) Second order overall.
c) rate $=\mathrm{k}\left[\mathrm{SO}_{2}\right]^{2}\left[\mathrm{O}_{3}\right]^{0}$ or rate $=\mathrm{k}\left[\mathrm{SO}_{2}\right]^{2}$
d) $1.9 \mathrm{M}^{-1} \cdot \mathrm{~s}^{-1}$
6.a) $0.0045 \mathrm{~s}^{-1}$; b) rate $=0.0045 \mathrm{~s}^{-1}[\mathrm{~A}]$; c) $1.5 \times 10^{2} \mathrm{~s}$; d) 0.0908 M
7.a) ${ }_{87}^{221} \mathrm{Fr}$; b) ${ }_{-1}^{0} e$; c) ${ }_{+1}^{0} e$; d) ${ }_{-1}^{0} e$
8.a) $\mathrm{Cs}-125$; b) $\mathrm{Fe}-62$

The closer the atomic mass of the isotope is to the atomic mass of the element listed in the periodic table, the more stable the nucleide and the larger the half-life.
a) $\mathrm{Cs}-125$ has a $\mathrm{Z} / \mathrm{N}=1.27$ which is closer to the ratio for a stable nuclei of an atom of this size and thus the larger half-life.
b) Fe-62 has a $\mathrm{Z} / \mathrm{N}=1.38$ which is closer to the ratio for a stable nuclei of an atom of this size and thus the larger half-life.
9. $2.4 \times 10^{4} \mathrm{yr}$

