DO NOT MARK ON THIS QUESTION BOOKLET

Chemistry Lab

Exam

Booklet

April 2nd, 2016

State Tournament

University of Wisconsin - Stout

Instructions: This exam consists of a gas law experiment worth 100 points, a chemical kinetics experiment worth 100 points, and a multiple choice exam worth 100 points (300 points total). Students may NOT write on the Experiment or Exam Booklet. Students may **only mark on their answer sheets. Gases Questions 1 – 50, Kinetics Questions 51 – 100.**

Multiple choice questions are scored as:

Number Correct – 0.2 (Number Incorrect)

As a result, you will not receive any credit for randomly guessing answers to the questions.

Be strategic, figure out the way that you and your team can bank as many points as possible in the time given. Place the answers to the lab experiments and multiple choice exam on the provided answer sheets. Answers not placed on the answer sheet will not be scored.

Ties will be broken by first the quality and accuracy of the kinetics experimental data, followed by the quality and accuracy of the gas law experimental data.

DO NOT MARK ON THIS QUESTION BOOKLET

Potentially Useful Information

1 atm = 760 mm Hg = 101.325 kPa = 1.01325 bar = 14.7 psi

STP: T = 0 °C = 273.15 K; P = 1 atm

P · V = n · R · T

$$R = 0.082057 \frac{L \cdot atm}{K \cdot mol}$$

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$

$$\rho_{gas} = \frac{P \cdot MW}{R \cdot T}$$

$$T(°C) = [T(°F) - 32°F] \times \frac{5(°C)}{9(°F)}$$

$$T(°F) = \left[T(°C) \times \frac{9(°F)}{5(°C)}\right] + 32°F$$

$$T(K) = [T(°C) + 273.15(°C)] \times \frac{1(K)}{1(°C)}$$

$$T(°C) = [T(K) - 273.15(K)] \times \frac{1(°C)}{1(K)}$$

There are two kinds of rate laws: the differential rate law (or just rate law) and the integrated rate law. The rate law for a reaction of the type

$$aA \longrightarrow \text{products}$$

describes the dependence of the rate on the concentration of A:

$$\text{Rate} = -\frac{\Delta[A]}{\Delta t} = k[A]^n$$

where k is called the rate constant and n is the order of the reaction in A. The rate is defined as the negative of $\Delta[A]/\Delta t$ because [A] is decreasing (as the reactants are used up in the reaction). The value for n (the order) cannot be determined from the balanced equation for the reaction but must be found experimentally. For a first-order reaction n is 1 and the rate = k[A]. For a second-order reaction n is 2 and the rate = $k[A]^2$. For a zero-order reaction n is 0 and the rate = k.

A common experimental method for determining the rate law is the method of initial rates in which several runs are carried out with different initial concentrations, and the rate is measured for each at a value of t close to $t = 0$.

An integrated rate law expresses reactant concentrations as a function of time. The integrated rate law for a first-order reaction is

$$\ln[A] = -kt + \ln[A]_0$$

where $[A]_0$ is the initial concentration of A. Thus we can calculate [A] at any time, given $[A]_0$ and k. For a reaction that shows first-order kinetics, a plot of ln[A] versus time is a straight line.

Table 12.6 Summary of the Kinetics for Reactions of the Type aA → Products That Are Zero, First, or Second Order in [A]

	Order		
	Zero	*First*	*Second*
Rate law:	Rate = k	Rate = $k[A]$	Rate = $k[A]^2$
Integrated rate law:	$[A] = -kt + [A]_0$	$\ln[A] = -kt + \ln[A]_0$	$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$
Plot needed to give a straight line:	[A] versus t	ln[A] versus t	$\frac{1}{[A]}$ versus t
Relationship of rate constant to the slope of straight line:	Slope = $-k$	Slope = $-k$	Slope = k
Half-life:	$t_{1/2} = \frac{[A]_0}{2k}$	$t_{1/2} = \frac{0.693}{k}$	$t_{1/2} = \frac{1}{k[A]_0}$

DO NOT MARK ON THIS QUESTION BOOKLET

MULTIPLE CHOICE EXAM (100 Points)

Multiple Choice Answers must be placed on Answer Sheet provided.

Multiple Choice is scored as:

Number Correct – 0.2 (Number Incorrect)

GASSES

1) Which of the following statements about gases is false?
A) Gases are highly compressible.
B) Distances between molecules of gas are very large compared to bond distances within molecules.
C) Non-reacting gas mixtures are homogeneous.
D) Gases expand spontaneously to fill the container they are placed in.
E) All gases are colorless and odorless at room temperature.

2) One significant difference between gases and liquids is that __________.
A) a gas is made up of molecules
B) a gas assumes the volume of its container
C) a gas may consist of both elements and compounds
D) gases are always mixtures
E) All of the above answers are correct.

3) Gaseous mixtures __________.
A) can only contain molecules
B) are all heterogeneous
C) can only contain isolated atoms
D) are all homogeneous
E) must contain both isolated atoms and molecules

4) Which of the following equations shows an incorrect relationship between pressures given in terms of different units?
A) 1.20 atm = 122 kPa
B) 152 mm Hg = 2.03×10^4 Pa
C) 0.760 atm = 578 mm Hg
D) 1.0 torr = 2.00 mm Hg
E) 1.00 atm = 760 torr

DO NOT MARK ON THIS QUESTION BOOKLET

5) The pressure exerted by a column of liquid is equal to the product of the height of the column times the gravitational constant times the density of the liquid, P = *ghd*. How high a column of water (d = 1.0 g/mL) would be supported by a pressure that supports a 713 mm column of mercury (d = 13.6 g/mL)?
A) 14 mm
B) 52 mm
C) 713 mm
D) 1.2×10^4 mm
E) 9.7×10^3 mm

6) The pressure exerted by a column of liquid is equal to the product of the height of the column times the gravitational constant times the density of the liquid, P = *ghd*. How high a column of methanol (d = 0.79 g/mL) would be supported by a pressure that supports a 713 mm column of mercury (d = 13.6 g/mL)?
A) 713 mm
B) 41 mm
C) 1.2×10^4 mm
D) 9.7×10^3 mm
E) 17 mm

7) Which statement about atmospheric pressure is false?
A) As air becomes thinner, its density decreases.
B) Air actually has weight.
C) With an increase in altitude, atmospheric pressure increases as well.
D) The warmer the air, the lower the atmospheric pressure.
E) Atmospheric pressure prevents water in lakes, rivers, and oceans from boiling away.

8) The first person to investigate the relationship between the pressure of a gas and its volume was __________.
A) Amadeo Avogadro
B) Lord Kelvin
C) Jacques Charles
D) Robert Boyle
E) Joseph Louis Gay-Lussac

DO NOT MARK ON THIS QUESTION BOOKLET

9) Of the following, __________ is a correct statement of Boyle's law.

A) PV = constant

B) $\frac{P}{V}$ = constant

C) $\frac{V}{P}$ = constant

D) $\frac{V}{T}$ = constant

E) $\frac{n}{P}$ = constant

10) Of the following, __________ is a valid statement of Charles' law.

A) $\frac{P}{T}$ = constant

B) $\frac{V}{T}$ = constant

C) PV = constant

D) V = constant × n

E) V = constant × P

11) Which one of the following is a valid statement of Avogadro's law?

A) $\frac{P}{T}$ = constant

B) $\frac{V}{T}$ = constant

C) PV = constant

D) V = constant × n

E) V = constant × P

12) The volume of an ideal gas is zero at __________.

A) 0 °C

B) -45 °F

C) -273 K

D) -363 K

E) -273 °C

DO NOT MARK ON THIS QUESTION BOOKLET

13) Of the following, only __________ is impossible for an ideal gas.

A) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

B) $V_1T_1 = V_2T_2$

C) $\frac{V_1}{V_2} = \frac{T_1}{T_2}$

D) $V_2 = \frac{T_2}{T_1} V_1$

E) $\frac{V_1}{V_2} = \frac{T_1}{T_2} = 0$

14) The molar volume of a gas at STP is __________ L.

A) 0.08206
B) 62.36
C) 1.00
D) 22.4
E) 14.7

15) How many moles of gas are there in a 50.0 L container at 22.0°C and 825 torr?

A) 2.29×10^4
B) 1.70×10^3
C) 2.23
D) 0.603
E) 18.4

16) The volume of 1.20 mol of gas at 61.3 kPa and 25.0°C is __________ L.

A) 135
B) 48.5
C) 52.4
D) 108
E) 55.7

17) Sodium bicarbonate is reacted with concentrated hydrochloric acid at 25.0°C and 1.50 atm. The reaction of 7.75 kg of bicarbonate with excess hydrochloric acid under these conditions will produce __________ L of CO_2.

A) $1.82 \text{ x } 10^3$
B) $2.85 \text{ x } 10^4$
C) $1.82 \text{ x } 10^4$
D) $1.50 \text{ x } 10^3$
E) $8.70 \text{ x } 10^2$

DO NOT MARK ON THIS QUESTION BOOKLET

18) The volume of a sample of gas (2.49 g) was 752 mL at 1.98 atm and 62°C. The gas is __________.

A) SO_2

B) SO_3

C) NH_3

D) NO_2

E) Ne

19) Of the following gases, __________ will have the greatest rate of effusion at a given temperature.

A) NH_3

B) CH_4

C) Ar

D) HBr

E) HCl

20) Arrange the following gases in order of increasing average molecular speed at 25°C.

Cl_2, O_2, F_2, N_2

A) $Cl_2 < F_2 < O_2 < N_2$

B) $Cl_2 < O_2 < F_2 < N_2$

C) $N_2 < F_2 < Cl_2 < O_2$

D) $Cl_2 < F_2 < N_2 < O_2$

E) $F_2 < O_2 < N_2 < Cl_2$

21) Which one of the following gases would have the <u>highest</u> average molecular speed at 25°C?

A) O_2

B) N_2

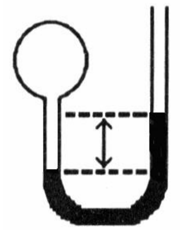
C) CO_2

D) CH_4

E) SF_6

DO NOT MARK ON THIS QUESTION BOOKLET

22) A gas vessel is attached to an open-end manometer filled with a nonvolatile liquid of density 0.993 g/mL as shown below.



The difference in heights of the liquid in the two sides of the manometer is 32.3 mm when the atmospheric pressure is 765 mm Hg. Given that the density of mercury is 13.6 g/mL, the pressure of the enclosed gas is __________ atm.

A) 1.05
B) 1.01
C) 0.976
D) 0.993
E) 1.08

23) A sample of a gas (5.0 mol) at 1.0 atm is expanded at constant temperature from 10 L to 15 L. The final pressure is __________ atm.

A) 1.5
B) 7.5
C) 0.67
D) 3.3
E) 15

24) A sample of a gas (1.50 mol) is contained in a 15.0 L cylinder. The temperature is increased from 100°C to 150°C. The ratio of final pressure to initial pressure $\left[\frac{P_2}{P_1}\right]$ is __________.

A) 1.50
B) 0.667
C) 0.882
D) 1.13
E) 1.00

DO NOT MARK ON THIS QUESTION BOOKLET

25) A sample of a gas originally at 25°C and 1.00 atm pressure in a 2.5 L container is subject to a pressure of 0.85 atm and a temperature of 15°C. The final volume of the gas is __________ L.
A) 3.0
B) 2.8
C) 2.6
D) 2.1
E) 0.38

26) The reaction of 50 mL of N_2 gas with 150 mL of H_2 gas to form ammonia via the equation:

$$N_2\ (g) + 3H_2\ (g) \rightarrow 2NH_3\ (g)$$

will produce __________ mL of ammonia if pressure and temperature are kept constant.
A) 250
B) 50
C) 200
D) 150
E) 100

27) The reaction of 50 mL of Cl_2 gas with 50 mL of C_2H_4 gas via the equation:

$$Cl_2\ (g) + C_2H_4\ (g) \rightarrow C_2H_4Cl_2\ (g)$$

will produce a total of __________ mL of products if pressure and temperature are kept constant.
A) 100
B) 50
C) 25
D) 125
E) 150

28) The amount of gas that occupies 60.82 L at 31.0°C and 367 mm Hg is __________ mol.
A) 1.18
B) 0.850
C) 894
D) 11.6
E) 0.120

29) A gas in a 325 mL container has a pressure of 695 torr at 19°C. There are __________ mol of gas in the flask.
A) 1.24×10^{-2}
B) 1.48×10^{-2}
C) 9.42
D) 12.4
E) 80.6

DO NOT MARK ON THIS QUESTION BOOKLET

30) The mass of nitrogen dioxide contained in a 4.32 L vessel at 48°C and 141600 Pa is __________ g.

A) 5.35×10^{4}
B) 53.5
C) 10.5
D) 70.5
E) 9.46×10^{-2}

31) The density of ammonia gas in a 4.32 L container at 837 torr and 45.0°C is __________ g/L.

A) 3.86
B) 0.719
C) 0.432
D) 0.194
E) 4.22×10^{-2}

32) The molecular weight of a gas is __________ g/mol if 3.5 g of the gas occupies 2.1 L at STP.

A) 41
B) 5.5×10^{3}
C) 37
D) 4.6×10^{2}
E) 2.7×10^{-2}
Answer: C
Diff: 3 Page Ref: Sec. 10.5

33) The volume of fluorine gas required to react with 4.26 g of calcium bromide to form calcium fluoride and bromine at 25.0°C and 4195 torr is __________ L.

A) 0.0943
B) 0.241
C) 241
D) 1.24×10^{-4}
E) 0.124

DO NOT MARK ON THIS QUESTION BOOKLET

34) The Mond process produces pure nickel metal via the thermal decomposition of nickel tetracarbonyl:

$Ni(CO)_4$ (l) → Ni (s) + 4CO (g).

What volume (L) of CO is formed from the complete decomposition of 444 g of $Ni(CO)_4$ at 752 torr and 22.0°C?
A) 0.356
B) 63.7
C) 255
D) 20.2
E) 11.0

35) The thermal decomposition of potassium chlorate can be used to produce oxygen in the laboratory.

$2KClO_3$ (s) → 2KCl (s) + $3O_2$ (g)

What volume (L) of O_2 gas at 25°C and 1.00 atm pressure is produced by the decomposition of 7.5 g of $KClO_3$ (s)?
A) 4.5
B) 7.5
C) 2.0
D) 3.7
E) 11

36) Since air is a mixture, it does not have a "molar mass." However, for calculation purposes, it is possible to speak of its "effective molar mass." (An effective molar mass is a weighted average of the molar masses of a mixture's components.) If air at STP has a density of 1.285 g/L, its effective molar mass is __________ g/mol.
A) 26.94
B) 31.49
C) 30.00
D) 34.42
E) 28.80

DO NOT MARK ON THIS QUESTION BOOKLET

37) Zinc reacts with aqueous sulfuric acid to form hydrogen gas:

$$Zn\ (s) + H_2SO_4\ (aq) \rightarrow ZnSO_4\ (aq) + H_2\ (g)$$

In an experiment, 225 mL of wet H_2 is collected over water at 27°C and a barometric pressure of 748 torr. How many grams of Zn have been consumed? The vapor pressure of water at 27°C is 26.74 torr.

A) 4.79×10^6
B) 0.567
C) 567
D) 431
E) 4.31×10^5

38) A vessel contained N_2, Ar, He, and Ne. The total pressure in the vessel was 987 torr. The partial pressures of nitrogen, argon, and helium were 44.0, 486, and 218 torr, respectively. The partial pressure of neon in the vessel was __________ torr.

A) 42.4
B) 521
C) 19.4
D) 239
E) 760

39) The pressure in a 12.2 L vessel that contains 2.34 g of carbon dioxide, 1.73 g of sulfur dioxide, and 3.33 g of argon, all at 42 °C is __________ mm Hg.

A) 263
B) 134
C) 395
D) 116
E) 0.347

40) A sample of O_2 gas (2.0 mmol) effused through a pinhole in 5.0 s. It will take __________ s for the same amount of CO_2 to effuse under the same conditions.

A) 4.3
B) 0.23
C) 3.6
D) 5.9
E) 6.9

DO NOT MARK ON THIS QUESTION BOOKLET

41) If 3.21 mol of a gas occupies 56.2 L at 44°C and 793 torr, 5.21 mol of this gas occupies __________ L under these conditions.
A) 14.7
B) 61.7
C) 30.9
D) 91.2
E) 478

42) At 0.967 atm, the height of mercury in a barometer is 0.735 m. If the mercury were replaced with water, what height of water (in meters) would be supported at this pressure? The densities of Hg and H_2O are 13.5 g/cm^3 and 0.997 g/cm^3, respectively.
a) 0.0546 m b) 0.735 m c) 0.760 m d) 9.95 m e) 13.1 m

43) At constant temperature, 12.5 L of N_2 at 262 mm Hg is compressed to 4.15 L. What is the final pressure of N_2?
a) 5.05 mm Hg b) 87.0 mm Hg c) 262 mm Hg d) 789 mm Hg e) 873 mm Hg

44) If the volume of a confined gas is reduced to ½ the original volume while its temperature remains constant, what change will be observed?
a) The pressure of the gas will increase to twice its original value.
b) The pressure of the gas will remain unchanged.
c) The density of the gas will decrease to ½ its original value.
d) The pressure of the gas will decrease to ½ its original value.
e) The average velocity of the molecules will double.

45) The lid is tightly sealed on a rigid flask containing 4.20 L O_2 at 27 °C and 0.969 atm. If the flask is heated to 81 °C, what is the pressure in the flask?
a) 0.821 atm b) 1.14 atm c) 1.18 atm d) 2.91 atm e) 3.45 atm

46) A 0.225-L flask contains CO_2 at 22 °C and 451 mm Hg. What is the pressure of the CO_2 if the volume is increased to 0.600 L and the temperature increased to 85 °C?
a) 43.8 mm Hg b) 139 mm Hg c) 205 mm Hg d) 653mm Hg e) 991 mm Hg

47) Avogadro's hypothesis states that equal volumes of gases under the same conditions of temperature and pressure have equal ________.
a) numbers of particles
b) particle velocities
c) molar masses
d) densities
e) masses

DO NOT MARK ON THIS QUESTION BOOKLET

48) Sodium azide decomposes rapidly to produce nitrogen gas.

$$2\ NaN_3(s) \rightarrow 2\ Na(s) + 3\ N_2(g)$$

What mass of sodium azide will inflate a 56.6 L airbag for a car to a pressure of 811 mm Hg at 25 °C? (*R* = 0.08206 L·atm/mol·K)

a) 17.6 g b) 39.5 g c) 107 g d) 161 g e) 241 g

49) What volume of O_2, measured at 82.1 °C and 713 mm Hg, will be produced by the decomposition of 5.71 g $KClO_3$? (*R* = 0.08206 L·atm/mol·K)

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

a) 0.335 L b) 1.44 L c) 2.17 L d) 2.24 L e) 5.55 L

50) Propane, C_3H_8, reacts with excess oxygen to produce carbon dioxide gas and water. What volume of CO_2, measured at 27.2 °C and 0.918 atm is produced from the reaction of 10.1 g C_3H_8 with excess oxygen? (*R* = 0.08206 L·atm/mol·K)

a) 0.557 L b) 0.687 L c) 1.67 L d) 6.15 L e) 18.5 L

DO NOT MARK ON THIS QUESTION BOOKLET

KINETICS

51) A burning splint will burn more vigorously in pure oxygen than in air because
A) oxygen is a reactant in combustion and concentration of oxygen is higher in pure oxygen than is in air.
B) oxygen is a catalyst for combustion.
C) oxygen is a product of combustion.
D) nitrogen is a product of combustion and the system reaches equilibrium at a lower temperature.
E) nitrogen is a reactant in combustion and its low concentration in pure oxygen catalyzes the combustion.

52) Of the following, all are valid units for a reaction rate except __________.
A) mol/L
B) M/s
C) mol/hr
D) g/s
E) mol/L-hr

53) Nitrogen dioxide decomposes to nitric oxide and oxygen via the reaction:

$$2NO_2 \rightarrow 2NO + O_2$$

In a particular experiment at 300 °C, $[NO_2]$ drops from 0.0100 to 0.00650 M in 100 s. The rate of disappearance of NO_2 for this period is __________ M/s.
A) 0.35
B) 3.5×10^{-3}
C) 3.5×10^{-5}
D) 7.0×10^{-3}
E) 1.8×10^{-3}

54) At elevated temperatures, dinitrogen pentoxide decomposes to nitrogen dioxide and oxygen:

$$2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$$

When the rate of formation of O_2 is 2.2×10^{-4} M/s, the rate of decomposition of N_2O_5 is __________ M/s.
A) 1.1×10^{-4}
B) 2.2×10^{-4}
C) 2.8×10^{-4}
D) 4.4×10^{-4}
E) 5.5×10^{-4}

DO NOT MARK ON THIS QUESTION BOOKLET

55) The rate law for a reaction is

rate = k [A][B]^2

Which one of the following statements is <u>false</u>?
A) The reaction is first order in A.
B) The reaction is second order in B.
C) The reaction is second order overall.
D) k is the reaction rate constant
E) If [B] is doubled, the reaction rate will increase by a factor of 4.

56) Under constant conditions, the half-life of a first-order reaction __________.
A) is the time necessary for the reactant concentration to drop to half its original value
B) is constant
C) can be calculated from the reaction rate constant
D) does not depend on the initial reactant concentration
E) All of the above are correct.

57) The reaction

$2NO_2 \rightarrow 2NO + O_2$

follows second-order kinetics. At 300°C, [NO_2] drops from 0.0100 M to 0.00650 M in 100.0 s. The rate constant for the reaction is __________ $M^{-1}s^{-1}$.
A) 0.096
B) 0.65
C) 0.81
D) 1.2
E) 0.54

58) The reaction

$CH_3\text{-}N{\equiv}C \rightarrow CH_3\text{-}C{\equiv}N$

is a first-order reaction. At 230.3 °C, k = $6.29 \times 10^{-4} s^{-1}$. If [$CH_3$-N≡C] is 1.00×10^{-3} initially, [CH_3-N≡C] is __________ after 1.000×10^3 s.
A) 5.33×10^{-4}
B) 2.34×10^{-4}
C) 1.88×10^{-3}
D) 4.27×10^{-3}
E) 1.00×10^{-6}

DO NOT MARK ON THIS QUESTION BOOKLET

59) The following reaction is second order in [A] and the rate constant is 0.025 $M^{-1}s^{-1}$:

A $\rightarrow$ B

The concentration of A was 0.65 M at 33 s. The initial concentration of A was __________ M.
A) 2.4
B) 0.27
C) 0.24
D) 1.4
E) 1.2×10^{-2}

The reaction A $\rightarrow$ B *is first order in* [A]. *Consider the following data.*

time (s)	[A] (M)
0.0	1.60
10.0	0.40
20.0	0.10

60) The rate constant for this reaction is __________ s^{-1}.
A) 0.013
B) 0.030
C) 0.14
D) 3.0
E) 3.1×10^{-3}

61) The half-life of this reaction is __________ s.
A) 0.97
B) 7.1
C) 5.0
D) 3.0
E) 0.14

DO NOT MARK ON THIS QUESTION BOOKLET

The reaction A $\rightarrow$ B *is first order in* [A]. *Consider the following data.*

Time (s)	0.0	5.0	10.0	15.0	20.0
[A] (M)	0.20	0.14	0.10	0.071	0.050

62) The rate constant for this reaction is __________ s^{-1}.
A) 6.9×10^{-2}
B) 3.0×10^{-2}
C) 14
D) 0.46
E) 4.0×10^{2}

63) The concentration of A is __________ M after 40.0 s.
A) 1.3×10^{-2}
B) 1.2
C) 0.17
D) 3.5×10^{-4}
E) 0.025

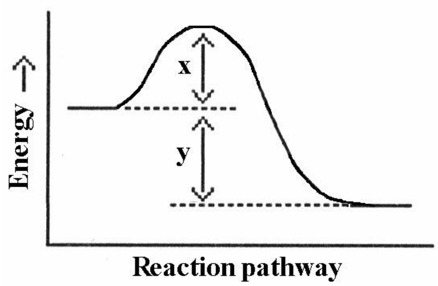
64) The rate constant of a first-order process that has a half-life of 225 s is __________ s^{-1}.
A) 0.693
B) 3.08×10^{-3}
C) 1.25
D) 12.5
E) 4.44×10^{-3}

65) One difference between first- and second-order reactions is that __________.
A) the half-life of a first-order reaction does not depend on $[A]_0$; the half-life of a second-order reaction does depend on $[A]_0$
B) the rate of both first-order and second-order reactions do not depend on reactant concentrations
C) the rate of a first-order reaction depends on reactant concentrations; the rate of a second-order reaction does not depend on reactant concentrations
D) a first-order reaction can be catalyzed; a second-order reaction cannot be catalyzed
E) None of the above are true.

DO NOT MARK ON THIS QUESTION BOOKLET

66) The rate of a reaction depends on __________.
A) collision frequency
B) collision energy
C) collision orientation
D) all of the above
E) none of the above

67) Which energy difference in the energy profile below corresponds to the activation energy for the forward reaction?



A) x
B) y
C) x + y
D) x - y
E) y - x

68) In the energy profile of a reaction, the species that exists at the maximum on the curve is called the __________.
A) product
B) activated complex
C) activation energy
D) enthalpy of reaction
E) atomic state

69) In general, as temperature goes up, reaction rate __________.
A) goes up if the reaction is exothermic
B) goes up if the reaction is endothermic
C) goes up regardless of whether the reaction is exothermic or endothermic
D) stays the same regardless of whether the reaction is exothermic or endothermic
E) stays the same if the reaction is first order

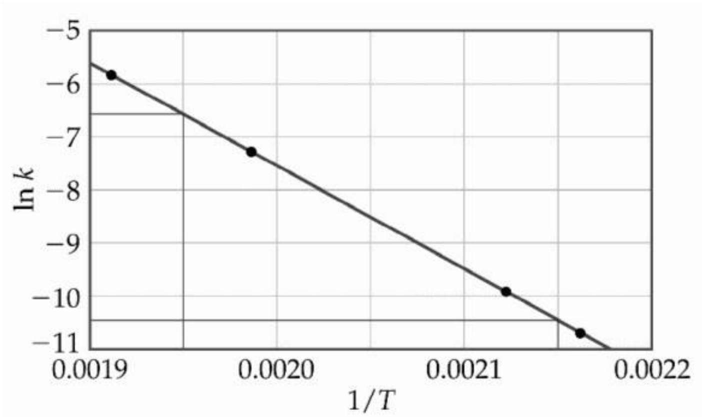
DO NOT MARK ON THIS QUESTION BOOKLET

70) In general, as temperature goes down, reaction rate __________.
A) goes down if the reaction is exothermic
B) goes down if the reaction is endothermic
C) stays the same regardless of whether the reaction is exothermic or endothermic
D) goes down regardless of whether the reaction is exothermic or endothermic
E) none of the above

71) At elevated temperatures, methylisonitrile (CH_3NC) isomerizes to acetonitrile (CH_3CN):

$$CH_3NC\ (g) \rightarrow CH_3CN\ (g)$$

The dependence of the rate constant on temperature is studied and the graph below is prepared from the results.



The energy of activation of this reaction is __________ kJ/mol.
A) 160
B) 1.6×10^5
C) 4.4×10^{-7}
D) 4.4×10^{-4}
E) 1.9×10^4

72) The mechanism for formation of the product X is:

$$A + B \rightarrow C + D \quad \text{(slow)}$$
$$B + D \rightarrow X \quad \text{(fast)}$$

The intermediate reactant in the reaction is __________.
A) A
B) B
C) C
D) D
E) X

DO NOT MARK ON THIS QUESTION BOOKLET

73) For the elementary reaction

$$NO_3 + CO \rightarrow NO_2 + CO_2$$

the molecularity of the reaction is __________, and the rate law is rate = __________.
A) 2, $k[NO_3][CO]$
B) 4, $k[NO_3][CO][NO_2][CO_2]$
C) 2, $k[NO_2][CO_2]$
D) 2, $k[NO_3][CO]/[NO_2][CO_2]$
E) 4, $k[NO_2][CO_2]/[NO_3][CO]$

74) Of the following, __________ will lower the activation energy for a reaction.
A) increasing the concentrations of reactants
B) raising the temperature of the reaction
C) adding a catalyst for the reaction
D) removing products as the reaction proceeds
E) increasing the pressure

75) The rate law of the overall reaction

$$A + B \rightarrow C$$

is rate = $k[A]^2$. Which of the following will not increase the rate of the reaction?
A) increasing the concentration of reactant A
B) increasing the concentration of reactant B
C) increasing the temperature of the reaction
D) adding a catalyst for the reaction
E) All of these will increase the rate.

76) A catalyst can increase the rate of a reaction __________.
A) by changing the value of the frequency factor (A)
B) by increasing the overall activation energy (E_a) of the reaction
C) by lowering the activation energy of the reverse reaction
D) by providing an alternative pathway with a lower activation energy
E) All of these are ways that a catalyst might act to increase the rate of reaction.

DO NOT MARK ON THIS QUESTION BOOKLET

77) Consider the following reaction:

$$3A \rightarrow 2B$$

The average rate of appearance of B is given by Δ[B]/Δt. Comparing the rate of appearance of B and the rate of disappearance of A, we get Δ[B]/Δt = __________ × (-Δ[A]/Δt).
A) -2/3
B) +2/3
C) -3/2
D) +1
E) +3/2

78) Which substance in the reaction below either appears or disappears the fastest?

$$4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$$

A) NH_3
B) O_2
C) NO_2
D) H_2O
E) The rates of appearance/disappearance are the same for all of these.

79) If the rate law for the reaction

$$2A + 3B \rightarrow \text{products}$$

is first order in A and second order in B, then the rate law is rate = __________.
A) k[A][B]
B) $k[A]^2[B]^3$
C) $k[A][B]^2$
D) $k[A]^2[B]$
E) $k[A]^2[B]^2$

80) A reaction was found to be zero order in A. Increasing the concentration of A by a factor of 3 will cause the reaction rate to __________.
A) remain constant
B) increase by a factor of 27
C) increase by a factor of 9
D) triple
E) decrease by a factor of the cube root of 3

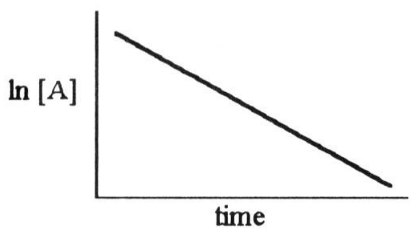
DO NOT MARK ON THIS QUESTION BOOKLET

81) The half-life of a first-order reaction is 13 min. If the initial concentration of reactant is 0.085 M, it takes __________ min for it to decrease to 0.055 M.
A) 8.2
B) 11
C) 3.6
D) 0.048
E) 8.4

82) The half-life of a first-order reaction is 13 min. If the initial concentration of reactant is 0.13 M, it takes __________ min for it to decrease to 0.085 M.
A) 12
B) 10
C) 8.0
D) 11
E) 7.0

83) The graph shown below depicts the relationship between concentration and time for the following chemical reaction.

$$2A \longrightarrow C$$



The slope of this line is equal to __________.
A) k
B) -1/k
C) $\ln[A]_o$
D) -k
E) 1/k

DO NOT MARK ON THIS QUESTION BOOKLET

84) The reaction below is first order in [H_2O_2]:

$$2H_2O_2\ (l) \rightarrow 2H_2O\ (l) + O_2\ (g)$$

A solution originally at 0.600 M H_2O_2 is found to be 0.075 M after 54 min. The half-life for this reaction is __________ min.

A) 6.8
B) 18
C) 14
D) 28
E) 54

85) A second-order reaction has a half-life of 18 s when the initial concentration of reactant is 0.71 M. The rate constant for this reaction is __________ $M^{-1}s^{-1}$.

A) 7.8×10^{-2}
B) 3.8×10^{-2}
C) 2.0×10^{-2}
D) 1.3
E) 18

86) The decomposition of N_2O_5 in solution in carbon tetrachloride proceeds via the reaction

$$2N_2O_5\ (soln) \rightarrow 4NO_2\ (soln) + O_2\ (soln)$$

The reaction is first order and has a rate constant of $4.82 \times 10^{-3} s^{-1}$ at 64°C. If the reaction is initiated with 0.058 mol in a 1.00-L vessel, how many moles remain after 151 s?

A) 0.055
B) 0.060
C) 0.028
D) 12
E) 2.0×10^{3}

87) The reaction $2NOBr\ (g) \rightarrow 2\ NO\ (g) + Br_2\ (g)$
is a second-order reaction with a rate constant of 0.80 $M^{-1}s^{-1}$ at 11°C. If the initial concentration of NOBr is 0.0440 M, the concentration of NOBr after 7.0 seconds is __________.

A) 0.0276 M
B) 0.0324 M
C) 0.0353 M
D) 0.0480 M
E) 0.0402 M

DO NOT MARK ON THIS QUESTION BOOKLET

88) Which statement concerning relative rates of reaction is correct for the chemical equation given below?

$$2\ NOBr(g) \rightarrow 2\ NO(g) + Br_2(g)$$

a) The rate of disappearance of NOBr is equal to the rate of appearance of Br_2.
b) The rate of disappearance of NOBr is two times the rate of appearance of NO.
c) The rate of disappearance of NOBr is half the rate of appearance of Br_2.
d) The rate of appearance of NO is equal to the rate of appearance of Br_2.
e) The rate of appearance of NO is two times the rate of appearance of Br_2.

89) Which relationship correctly compares the rates of the following reactants and products?

$$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$$

a) $\frac{\Delta[C_3H_8]}{\Delta t} = \frac{\Delta[O_2]}{\Delta t} = \frac{\Delta[CO_2]}{\Delta t} = \frac{\Delta[H_2O]}{\Delta t}$

b) $\frac{\Delta[C_3H_8]}{\Delta t} = \frac{\Delta[O_2]}{\Delta t} = -\frac{\Delta[CO_2]}{\Delta t} = -\frac{\Delta[H_2O]}{\Delta t}$

c) $-\frac{\Delta[C_3H_8]}{\Delta t} = -\frac{1}{5}\frac{\Delta[O_2]}{\Delta t} = \frac{1}{3}\frac{\Delta[CO_2]}{\Delta t} = \frac{1}{4}\frac{\Delta[H_2O]}{\Delta t}$

d) $\frac{\Delta[C_3H_8]}{\Delta t} = \frac{5\ \Delta[O_2]}{\Delta t} = -\frac{3\ \Delta[CO_2]}{\Delta t} = -\frac{4\ \Delta[H_2O]}{\Delta t}$

e) $\frac{\Delta[C_3H_8]}{\Delta t} = \frac{5\ \Delta[O_2]}{\Delta t} = \frac{3\ \Delta[CO_2]}{\Delta t} = \frac{4\ \Delta[H_2O]}{\Delta t}$

90) Which of the following factors are likely to affect the rate of a chemical reaction?

1. the presence of a catalyst
2. the temperature of the reactants
3. the physical state (solid, liquid, or gas) of the reactants

a) 1 only b) 2 only c) 3 only d) 1 and 3 e) 1, 2, and 3

91) What is the overall order of the reaction below

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$

if it proceeds via the following rate expression?

$$-\frac{\Delta[NO]}{\Delta t} = k[NO]^2[O_2]$$

a) zero-order b) first-order c) second-order d) third-order e) fourth-order

DO NOT MARK ON THIS QUESTION BOOKLET

92) What is the overall order of the reaction below

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$

if it proceeds via the following rate expression?

$$-\frac{\Delta[NO]}{\Delta t} = k[NO][O_3]$$

a) zero-order b) first-order c) second-order d) third-order e) fourth-order

93) Given the initial rate data for the decomposition reaction,

$$A \rightarrow B + C$$

determine the rate expression for the reaction.

[A], M	$-\Delta[A]/\Delta t$ M/s
0.0625	5.44×10^{-7}
0.0938	8.16×10^{-7}
0.125	1.09×10^{-6}

a) $\frac{-\Delta[A]}{\Delta t} = 8.71 \times 10^{-6}\ s^{-1}[A]$

b) $\frac{-\Delta[A]}{\Delta t} = 1.39 \times 10^{-4}\ M^{-1}s^{-1}[A]^2$

c) $\frac{-\Delta[A]}{\Delta t} = 6.98 \times 10^{-5}\ M^{-1}s^{-1}[A]^2$

d) $\frac{-\Delta[A]}{\Delta t} = 5.44 \times 10^{-7}\ M\ s^{-1}$

e) $\frac{-\Delta[A]}{\Delta t} = 5.44 \times 10^{-7}\ s^{-1}[A]$

94) Given the initial rate data for the reaction $2A + B \rightarrow C$, determine the rate expression for the reaction.

[A], M	[B], M	$\Delta[C]/\Delta t$ (initial) M/s
0.180	0.250	1.36×10^{-3}
0.180	0.500	2.72×10^{-3}
0.720	0.500	1.09×10^{-2}

a) $\frac{\Delta[C]}{\Delta t} = 1.21 \times 10^{-1}\ M^{-2}s^{-1}[A][B]^2$

b) $\frac{\Delta[C]}{\Delta t} = 3.02 \times 10^{-2}\ M^{-2}s^{-1}[A]^2[B]$

c) $\frac{\Delta[C]}{\Delta t} = 1.68 \times 10^{-1}\ M^{-2}s^{-1}[A]^2[B]$

d) $\frac{\Delta[C]}{\Delta t} = 1.36 \times 10^{-3}\ M^{-1}s^{-1}[A][B]$

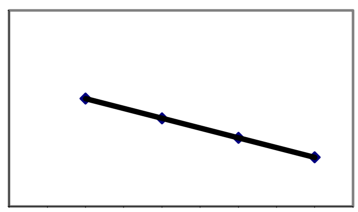
e) $\frac{\Delta[C]}{\Delta t} = 3.02 \times 10^{-2}\ M^{-1}s^{-1}[A][B]$

DO NOT MARK ON THIS QUESTION BOOKLET

95) Which of the following statements is correct for the first-order reaction: $A \rightarrow 2B$?
  a) The concentration of A decreases linearly with respect to time.
  b) The concentration of A is constant with respect to time.
  c) The natural logarithm of the concentration of A decreases linearly with respect to time.
  d) The rate of reaction is constant with respect to time.
  e) The rate constant, *k*, of the reaction decreases linearly with respect to time.

96) For a second-order decomposition reaction,
  $2A \rightarrow B$ rate = $k[A]^2$
  which of the following functions can be plotted versus time to give a straight line?
  a) [A] b) $\frac{k}{[A]^2}$ c) $\ln\frac{1}{[A]}$ d) ln[A] e) $\frac{1}{[A]}$

97) A student analyzed a second-order reaction and obtained the graph below. Unfortunately, the student forgot to label the axes. What are the correct labels for the x and y axes?
  a) x axis = time, y axis = ln[A]
  b) x axis = ln[time], y axis = [A]
  c) x axis = ln[time], y axis = [A]
  d) x axis = time, y axis = 1/[A]
  e) x axis = 1/time, y axis = 1/[A]



98) For a reaction, $A \rightarrow B + C$, which of the following equations corresponds to the integrated expression for a first-order decomposition reaction?
  a) $[A]_t = -kt + [A]_0$
  b) $\ln\frac{[A]_t}{[A]_0} = -kt$
  c) $\ln[A]_t = \ln\left[-kt\right] + \ln[A]_0$
  d) $\frac{[A]_t}{[A]_0} = -kt$
  e) $\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$

DO NOT MARK ON THIS QUESTION BOOKLET

99) In general, as temperature increases, the rate of a chemical reaction
a) decreases due to fewer collisions with proper molecular orientation.
b) increases for exothermic reactions, but decreases for endothermic reactions.
c) increases due to a greater number of effective collisions.
d) remains unchanged.
e) decreases due to an increase in the activation energy.

100) For the overall reaction

$$A + 2B \rightarrow C$$

which of the following mechanisms yields the correct overall chemical equation and is consistent with the rate equation below?

$$\text{rate} = k[A]^2[B]$$

a) $A + B \rightleftharpoons I$ (fast)
$I + A \rightarrow C$ (slow)

b) $A + B \rightarrow I$ (slow)
$I + B \rightarrow C$ (fast)

c) $2B \rightarrow I$ (slow)
$A + I \rightarrow C$ (fast)

d) $2B \rightleftharpoons I$ (fast)
$I + A \rightarrow C$ (slow)

e) $A + 2B \rightleftharpoons I$ (fast)
$I + B \rightarrow C + B$ (slow)