Dawson COLLEGE

Department of Chemistry & Chemical Technology
CHEMISTRY OF SOLUTIONS (202-SN2-RE)

PRACTICE FINAL EXAMINATION

This practice examination is intended to reflect the structure and timing of the upcoming Chemistry of Solutions (202-SN2-RE) Final Examination; however, the question style, difficulty level, and exact formatting on the actual exam may differ.

Furthermore, while this practice test contains no laboratory questions, *the actual final exam may include one question dedicated to laboratory work*. Students are advised to review all in-semester laboratory exercises and lab reports as part of their final preparation.

Recommended Preparation Guidelines

- **Simulate Authentic Test Conditions:** Complete this practice exam in a quiet room without distractions. Strictly enforce the **2-hour** time limit to gauge your pacing.
- **Work Closed-Book:** To get the maximum learning benefit, treat this sample exam as a true practice. Attempt all questions without checking textbooks, instructors' notes or solutions mid-exam. Once completed, grade your exam using the answer key attached at the end.

General Examination Instructions

- Non-programmable calculators are permitted.
- A periodic table and important constants are attached to the back of the exam booklet.
- Show all work for calculation questions, ensuring all numerical answers are expressed with the correct number of significant figures and appropriate units.

Question 1

The electrolyte of an automobile lead storage battery is a 3.75 M sulfuric acid (H_2SO_4) solution in water. It has a density of 1.23 g/mL. Calculate for the sulfuric acid:

a. the mass percent

b. the molality

c. the mole fraction

d. What volume of 3.75 M sulfuric acid must be used to prepare 1.5 L of a 0.10 M H_2SO_4(aq) solution?

Answers

a. mass percent:	*b. molality:*	*c. mole fraction:*	*d. volume:*

Question 2

At a high altitude camp in the Rockies, water boils at 95.4°C instead of 100.0°C. A visitor has requested a soft-boiled egg (usually boiled for 3.00 minutes at 100.0°C). The activation energy for the reaction in question is 453 kJ/mol.

$$\text{egg protein (l)} \longrightarrow \text{egg protein (s)}$$

How long will it take to cook his egg at 95.4°C?

Answer

time :

Question 3

The following data were obtained for the reaction:

$$2ClO_2(aq) + 2OH^-(aq) \longrightarrow ClO_3^-(aq) + ClO_2(aq) + H_2O(l)$$

Where Rate = $-\frac{\Delta[ClO_2]}{2\Delta t}$

Experiment no.	$[ClO_2]_o$ ($mol \cdot L^{-1}$)	$[OH^-]_o$ ($mol \cdot L^{-1}$)	Initial rate ($mol \cdot L^{-1} \cdot s^{-1}$)
1	0.0500	0.100	5.75×10^{-2}
2	0.100	0.100	2.30×10^{-1}
3	0.200	0.0250	2.30×10^{-1}

a. Determine the rate law

b. Calculate the value of the rate constant (with units).

c. What is the overall order of this reaction?

Answers

a. rate law :	*b. rate constant :*	*c. overall order :*

Question 4

Consider the following chemical reaction at 10°C with $[NOBr]_o$ = 0.080 M:

$$2NOBr(g) \longrightarrow 2NO(g) + Br_2(g) \qquad \text{Rate} = 0.80\ M^{-1}s^{-1}[NOBr]^2$$

a. Calculate the time required for 85% of the initial NOBr to react.

Answer

time :

b. What is the half-life of this reaction?

Answer

b. half-life :

c. Indicate whether the following statements are true of false for the chemical reaction described above.

	True	False
i. The rate of the reaction doubles if the concentration of NOBr is doubled	☐	☐
ii. The rate of the reaction decreases as time goes on	☐	☐
iii. If $[NOBr]_o$ = 0.080 mol/L, then after 100 s all the reactant is consumed	☐	☐
iv. The half-life of the reaction is 5.0 s when $[NOBr]_o$ = 0.040 mol/L	☐	☐
v. The plot of [NOBr] vs. time is a straight line	☐	☐
vi. Changing the temperature will affect the order of the reaction	☐	☐

Question 5

Consider the following reaction

$$H_2S(g) + I_2(s) \rightleftharpoons 2HI(g) + S(s) \qquad K_p = 1.34 \times 10^{-5} \text{ at } 60°C$$

A 5.00 L reactor contains the following initial mixture at 60°C

- 2.00 g solid iodine (I_2)
- 1.07 g sulfur powder
- 10.1 kPa of hydrogen sulfide (H_2S)

a. What will be the pressure of HI at equilibrium?

b. What is the *K* value for this equilibrium at 60°C?

c. What will be the value of K_p for the following reaction at the same temperature?

$$4HI(g) + 2S(s) \rightleftharpoons 2H_2S(g) + 2I_2(s)$$

Answers

a. HI pressure :	*b. K :*	*c. K_p :*

Question 6

a. Indicate whether the following statements are true of false

	True	False
i. Colligative properties are based on the number of particles in solution, whatever the "size" of the particle.	☐	☐
ii. The addition of an ionic compound to any solvent will cause a boiling point depression.	☐	☐

b. The gas Arsine, AsH_3 decomposes as follows:

$$2AsH_3(g) \rightleftharpoons 2As(s) + 3H_2(g) \qquad \Delta H = +122.8 \text{ kJ}$$

For each of the following cases, in which direction will the position of the equilibrium be shifted if:

(to the reactant = left, to the products = right, no effect = no change)

	left	no change	right
i. $As(s)$ is added	☐	☐	☐
ii. the pressure is increased by adding argon gas	☐	☐	☐
iii. the volume of the reaction container is decreased	☐	☐	☐
iv. the temperature is decreased	☐	☐	☐
v. hydrogen is removed	☐	☐	☐
vi. a catalyst is added	☐	☐	☐

Question 7

The percent dissociation of chlorous acid $HClO_2$ in water is 8.0% when its concentration is 1.58 M.

a. What is the pH of this solution?

b. What is the K_a of this acid?

c. What will be the percent dissociation if the concentration increases to 4.5 M?

Answers

a. pH :	*b. K_a :*	*c. percent dissociation :*

Question 8

a. Order the following from the strongest to the weakest base

i. H_2O
ii. CH_3NH_2
iii. ClO_4^-

_____ _____ _____
strongest base *weakest base*

b. Arrange the following aqueous solutions in order from most acidic to most basic.

i. $0.1M\ KF$
ii. $0.1M\ KNO_3$
iii. $0.1M\ NH_4Cl$

_____ _____ _____
most acidic *most basic*

c. What will be the pH of an aqueous solution made up of 0.514 g potassium cyanide KCN in 125 mL water. K_a $HCN = 6.2 \times 10^{-10}$.

Answer

pH :

Question 9

Calculate the mass of KNO_2 that must be added to 500. mL of 0.20 M nitrous acid (HNO_2, K_a = 4.6x10^{-4}) to get a solution of pH = 4.00. Assume no change of the volume of the solution with the addition of KNO_2.

Answer

Mass of KNO_2 :

Question 10

A 20.0 mL sample of 0.10 M formic acid ($HCOOH$) was titrated with 5.0×10^{-2} M $Ba(OH)_2$.

K_a for $HCOOH$ is 1.8×10^{-4}.

a. Calculate the pH of the solution upon the addition of 15.0 mL of $Ba(OH)_2$ to the sample.

Answer

a. pH :

b. What volume of $Ba(OH)_2$ is needed to reach the equivalence point?

c. Calculate the pH of the solution at the equivalence point.

Answers

b. volume at equivalence point :	*c. pH at equivalence point :*

Question 11

Solid NaI is slowly added to a solution that contains both $Pb(NO_3)_2$ (0.100 *M*) and $AgNO_3$ (2.0×10^{-4} *M*).

a. Which begins to precipitate first: the lead iodide or the silver iodide? Show your work

b. The concentration of the first cation species to precipitate, either the lead or the silver, decreases as the precipitate forms. What is the concentration in solution of the first species when the second begins to precipitate? Assume no change of volume of the solution with the addition of NaI.

Note: K_{sp} $PbI_2 = 1.4 \times 10^{-8}$, K_{sp} $AgI = 1.5 \times 10^{-16}$

Answers

a. :	*b. :*

Question 12

a. Predict the sign of ΔS of the system for each of the following processes

	$\Delta S < 0$	$\Delta S > 0$
i. A liquid that boils	☐	☐
ii. Sugar that crystallized out from a supersaturated sugar solution	☐	☐
iii. Iron rusts (formation of Fe_2O_3 from pure Fe and O_2)	☐	☐
iv. $A\text{-}B(g) + C\text{-}D(s) \longrightarrow A\text{-}B\text{-}C(g) + D(s)$	☐	☐
v. $N_2O_4(g) \longrightarrow 2NO_2(g)$	☐	☐
vi. $NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$ ΔH_{sol} = +4.0 kJ/mol	☐	☐

b. For mercury (Hg), the enthalpy of vaporization is 58.51 kJ/mol and the entropy of vaporization is 92.92 J/K.mol. What is the normal boiling point of mercury?

Answer

b. T_b :

Question 13

Consider the following reaction

$$N_2O_4(g) \longrightarrow 2NO_2(g)$$

Will the reaction be spontaneous at each of the following temperatures? Show your work.
(assume that ΔH° and ΔS° do not change very much within the given temperature range)

a. 25.0°C
b. 60.0°C

Answers

a. spontaneous at 25°C? :	*b. spontaneous at 60°C? :*

Useful data	$N_2O_4(g)$	$NO_2(g)$
ΔH°_f in kJ/mol	+9.67	+33.8
S° in J/(mol·K)	+304	+240.5

Periodic Table of the Elements

	1A												3A	4A	5A	6A	7A	8A
1	1 H 1.008	2A																2 He 4.003
2	3 Li 6.941	4 Be 9.012											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	3B	4B	5B	6B	7B	8B	9B	10B	1B	2B	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 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	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 98.00	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac[a] (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

6 C 12.01 — Atomic number / symbol / mass (amu or g/mol)

metalloid

*Lanthanides	58 Ce 140	59 Pr 141	60 Nd 144	61 Pm 145	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175
[a]Actinides	90 Th 232	91 Pa 231	92 U 238	93 Np 237.1	94 Pu 244	95 Am 243	96 Cm 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 260

constants
R = 8.31451 J.K^{-1}.mol^{-1}
R = 8.31451 L.kPa.K^{-1}.mol^{-1}
R = 0.08206 L.atm.K^{-1}.mol^{-1}
Avogadro (N_A) = 6.022 x 10^{23} mole^{-1}

p = 10^{-12}	k = 10^{3}
n = 10^{-9}	M = 10^{6}
μ = 10^{-6}	G = 10^{9}
m = 10^{-3}	T = 10^{12}

conversions
Cal ≡ 4.184 J
Pa = N.m^{-2}
J = kg.m^{2}.s^{-2}
Å = 10^{-10} m
273.15 K = 0°C
101.325 kPa = 1 atm
101.325 kPa = 760 mm Hg
101.325 kPa = 760 torr
101.325 kPa = 1.01325 bar

PRACTICE FINAL EXAMINATION 202-SN2-RE — ANSWER KEY

Question 1

a. Mass percent H_2SO_4	29.9%
b. Molality	4.35 m (or mol/kg)
c. Mole fraction (X)	0.0727
d. Volume of 3.75 M H_2SO_4 required	0.040 L (or 40. mL)

Question 2

Time required to cook egg at 95.4 °C: 18.6 min

Question 3

a. Rate law	Rate = $k\,[ClO_2]^2\,[OH^-]$
b. Rate constant (k)	230 $L^2 \cdot mol^{-2} \cdot s^{-1}$ (or $M^{-2} \cdot s^{-1}$)
c. Overall reaction order	3 (Third order)

Question 4

a. Time for 85% of initial NOBr to react: 89 s

b. Half-life ($t_{1/2}$): 16 s

c. True / False Statements:

i. The rate of the reaction doubles if the concentration of NOBr is doubled	False
ii. The rate of the reaction decreases as time goes on	True
iii. If $[NOBr]_0$ = 0.080 mol/L, then after 100 s all the reactant is consumed	False
iv. The half-life of the reaction is 5.0 s when $[NOBr]_0$ = 0.040 mol/L	False
v. The plot of [NOBr] vs. time is a straight line	False
vi. Changing the temperature will affect the order of the reaction	False

Question 5

a. Pressure of HI at equilibrium (P_{HI})	1.16×10^{-3} atm
b. Value of K (or Kc)	4.90×10^{-7}
c. Value of Kp for the modified reaction	5.57×10^{9}

Question 6

a. True / False Statements:

i. Colligative properties are based on the number of particles in solution, whatever the "size" of the particle.	True
ii. The addition of an ionic compound to any solvent will cause a boiling point depression.	False

b. Equilibrium Shifts for $2\ AsH_3(g) \rightleftharpoons 2\ As(s) + 3\ H_2(g)$ ($\Delta H = +122.8$ kJ):

i. As(s) is added	No change
ii. Pressure is increased by adding argon gas	No change
iii. Volume of the reaction container is decreased	Left (to reactants)
iv. Temperature is decreased	Left (to reactants)
v. Hydrogen is removed	Right (to products)
vi. A catalyst is added	No change

Question 7

a. pH of 1.58 M $HClO_2$ solution	0.89
b. Acid dissociation constant (Ka)	1.1×10^{-2}
c. Percent dissociation at 4.5 M	4.9%

Question 8 — Acid-Base Strengths & Salt pH

a. Base strength ranking (strongest to weakest)	$CH_3NH_2 > H_2O > ClO_4^-$
b. Solution acidity ranking (most acidic to most basic)	0.1 M NH_4Cl > 0.1 M KNO_3 > 0.1 M KF
c. pH of KCN solution	11.00

Question 9

Mass of KNO_2 required: 39 g

Question 10

a. pH after adding 15.0 mL of $Ba(OH)_2$	4.19
b. Volume of $Ba(OH)_2$ to reach equivalence point	0.020 L (or 20. mL)
c. pH at the equivalence point	8.23

Question 11

a. First species to precipitate	Silver iodide (AgI) precipitates first (requires $[I^-] = 7.5 \times 10^{-13}$ M, vs. 3.7×10^{-4} M for PbI_2)
b. $[Ag^+]$ when PbI_2 begins to precipitate	4.0×10^{-13} M

Question 12

a. Sign of ΔS for given processes:

i. A liquid that boils	$\Delta S > 0$
ii. Sugar that crystallized out from a supersaturated sugar solution	$\Delta S < 0$
iii. Iron rusts (formation of Fe_2O_3 from pure Fe and O_2)	$\Delta S < 0$
iv. A-B(g) + C-D(s) → A-B-C(g) + D(s)	$\Delta S > 0$
v. $N_2O_4(g) \rightarrow 2\ NO_2(g)$	$\Delta S > 0$
vi. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$	$\Delta S > 0$

b. Normal boiling point of mercury (T_b): 629.7 K (or 365.5 °C)

Question 13

a. Spontaneous at 25.0 °C?	No (Not spontaneous, $\Delta G° = +5.1$ kJ)
b. Spontaneous at 60.0 °C?	Yes (Spontaneous, $\Delta G° = -1.1$ kJ)