Exam 2 solutions

1. Hard water is due to Ca^{2+} and Mg^{2+} ions in water. These ions come from water running over or sitting in a reservoir over limestone ($CaCO_3$, $K_{sp} = 3.8x10^{-9}$ = 3.8E-9) and dolomite ($MgCO_3$, $K_{sp} = 4.0x10^{-5}$ = 4.0E-5) minerals.

a. 1 mole of $CaCO_3$ and 1 mole of $MgCO_3$ are dumped into 1 liter of water. The concentration of Ca^{2+} = 6.2E-5 M.

The concentration of Ca^{2+} will be ___ than the concentration of Mg^{2+}. To support my answer, I use the equation ____ and calculate the concentration of Mg^{2+} = ___ M.

greater than (blank 1)

equal to (blank 1)

less than (blank 1)

Blank 2: Write the equation that involves the numerical value of K and x, where x = concentration of reactant/product in “Other”. E.g., 1.0E-1 = (x)/(x-1).

4.0E-5 = (x) (x)

Blank 3: Write a number in scientific notation as _._E_ _ in “Other”. E.g., 1.1E11. Use 2 significant figures. Do not include text.

6.3E-3

4.0E-5 = (x) (x)

Solve for x = 6.3E-3 = [Mg^{2+}]

b. To remove unsightly hard water stains from by cups and glasses, this reaction

$$Ca(OH)_2\ (s) \rightleftharpoons Ca^{2+}\ (aq) + 2\ OH^-\ (aq)$$

tells me I would use a ___ because this substance reacts with ___ and shifts the reaction to the ___ side.

acid (blank 1)

base (blank 1)

soap (blank 1)

$Ca(OH)_2$ (s) (blank 2)

Ca^{2+} (aq) (blank 2)

OH^- (aq) (blank 2)

reactant (blank 3)

product (blank 3)

either (blank 3)

2. When a fuel, such as ethanol (C_2H_5OH), is burned, energy, water, and carbon dioxide are produced:

$C_2H_5OH + O_2 \rightarrow H_2O + CO_2$ (not balanced).

Carbon dioxide is a greenhouse gas. CO_2 (g) in the earth’s atmosphere is absorbed by the the oceans in an equilibrium reaction:

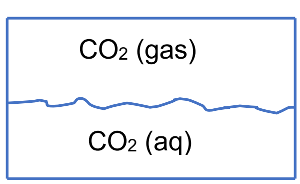
$$CO_2\ (g) \rightleftharpoons CO_2\ (aq) \qquad K = 3.36x10^{-2} = 3.36E\text{-}2 \text{ at } T = 25^oC.$$

CO_2 also reacts with water to produce H^+ and HCO_3^-:

$$CO_2\ (aq) + H_2O\ (l) \rightleftharpoons H^+ + HCO_3^- \qquad K = 4.3x10^{-7} = 4.3E\text{-}7 \text{ at } T = 25^oC.$$

a. The K for the ethanol burning reaction is ___ 1 because ethanol burns and ___. In the picture, there is ___ CO_2 in gas phase than the liquid phase because ___.

Blank 4: give reasons in “Other”.



greater than (blank 1)

equal to (blank 1)

less than (blank 1)
makes a lot of products (blank 2)
makes few products (blank 2)
more (blank 3)
same (blank 3)
less (blank 3)
Other
K is less than 1

b. I support my answer to part a because when 1 mole of CO_2 (g) is bubbled into 1 liter of water at 25°C, I use the equation ____ and calculate [CO_2 (aq)] = ___ M.
Blank 1: Write the equation that involves the numerical value of K and x, where x = concentration of reactant/product. E.g., 1.0E-1 = (x)/(x-1).
3.36E-2 = x/(1-x)
or
3.36E-2 = x/(1)
Blank 2: Write a number in scientific notation as _._E_ _ in "Other". E.g., 1.1E11. Use 2 significant figures. Do not include text.
0.033
0.0325 to 0.0336
Calculate [CO_2 (aq)] = ___ M.
$K = 3.36\times10^{-2} = x/(1-x)$
Solve for x = 0.0325.
Assume 1-x = 1 (since $K = 3.36\times10^{-2}$ is very small compared to initial concentration of 1 M, solve for x = 0.0336.

c. Earlier in Chem 1B, we learned that gases are ____ soluble in hot water than cold water. This means the CO_2 (g) $\rightleftharpoons$ CO_2 (aq) reaction is ___ because heat is a ___ and as temperature increases, the reaction shifts to the __ side. This also tells us as the earth's temperature rises, ____ CO_2 gas dissolves in the ocean.
more (blank 1)
same (blank 1)
less (blank 1)
exothermic (blank 2)
endothermic (blank 2)
reactant (blank 3)
product (blank 3)
reactant (blank 4)
product (blank 4)
more (blank 5)
same (blank 5)
less (blank 5)

3. CO_2 is also involved in our blood buffer:

$$CO_2\ (aq) + H_2O\ (l) \rightleftharpoons H^+\ (aq) + HCO_3^-\ (aq) \qquad K = 7.9\times10^{-7} = 7.9E\text{-}7 \text{ at } 37^\circ C$$

a. CO_2 (aq) behaves like an acid in this reaction. In a titration curve of this acid, the pH at the half-way point is __. This means at blood pH of 7.4, [CO_2 (aq)] is ___ [HCO_3^- (aq)] and the ratio of [HCO_3^- (aq)] / [CO_2 (aq)] is ___.
Blank 1: give a number with 2 significant figures in "Other". Do not include text. Blank 3: give a number with 2 significant figures in "Other". Do not include text. Separate each answer with a comma.
Greater than (blank 2)
Equal to (blank 2)
less than (blank 2)
Other
6.1, 20

pKa = -log Ka = -log (7.9E-7) = 6.1

Use H-H equation: 7.4 = 6.1 + log [HCO_3^- (aq)] / [CO_2 (aq)]

Solve for [HCO_3^- (aq)] / [CO_2 (aq)] = 20.

b. When a person starts to hyperventilate, the person breathes rapidly and rapidly exhales CO_2. This causes pH to ___ because ___ is ___ and shifts the reaction to the ___ side.

increase (blank 1)
decrease (blank 1)
does not change (blank 1)
reactant (blank 2)
product (blank 2)
neither (blank 2)
added (blank 3)
removed (blank 3)
neither (blank 3)
reactant (blank 4)
product (blank 4)
neither (blank 4)

4. Hemoglobin is the oxygen carrier in blood that transports oxygen from our lungs to tissues. Hemoglobin is a protein and exists as deoxygenated hemoglobin (H Hgb, pK_a = 7.7) and its conjugate base (Hgb) and oxygenated hemoglobin (H Hgb O_2, pK_a = 6.2) and its conjugate base (Hgb O_2).

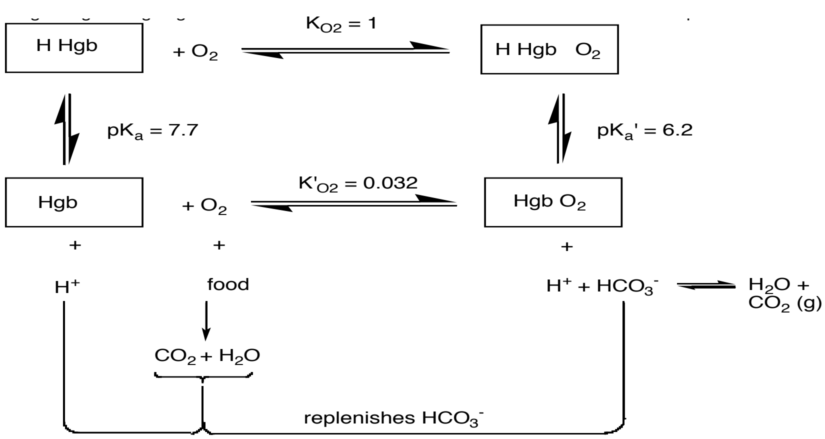
Reaction 1: H Hgb $\rightleftharpoons$ H^+ + Hgb pK_a = 7.7

Reaction 2: H Hgb O_2 $\rightleftharpoons$ H^+ + Hgb O_2 pK_a = 6.2

These two reactions show how well O_2 binds to the acid and base forms of hemoglobin:

Reaction 3: H Hgb O_2 $\rightleftharpoons$ H Hgb + O_2 K_{O2} = 1

Reaction 4: Hgb O_2 $\rightleftharpoons$ Hgb + O_2 K'_{O2} = 0.032

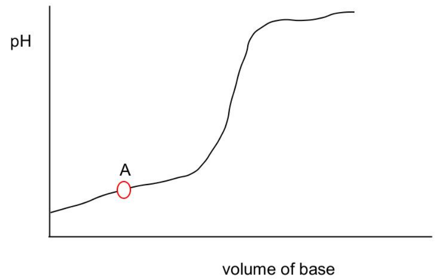


a. The form of hemoglobin that is the strongest acid is ___. The form of hemoglobin that binds to oxygen better is ___ because ___.

Blank 3: give reasons in "Other".

H Hgb (blank 1)
Hgb (blank 1)
H Hgb O_2 (blank 1)
Hgb O_2 (blank 1)
H Hgb (blank 2)
Hgb (blank 2)
Other
Lower K'_{O2} means more reactant (Hgb O_2).

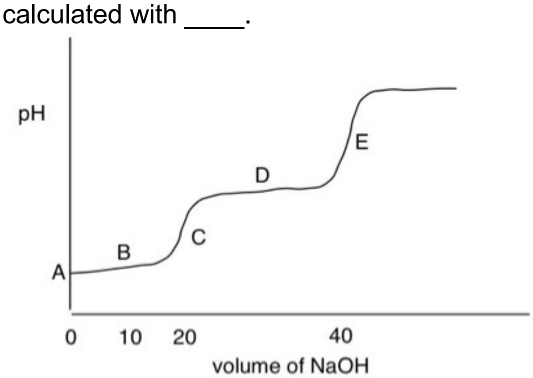
b. The pH of blood is 7.4. When hemoglobin is oxygenated to form H Hgb O_2, there is ____ Hbg O_2 than H Hgb O_2 because the pH of blood is ___ the half-way point (Point A) in the titration curve of this acid with a base. In the tissues where the O_2 concentration is low, Reaction 4 shifts to the ___ side and Hbg O_2 releases O_2.



more (blank 1)
less (blank 1)
same (blank 1)
before (blank 2)
at (blank 2)
after (blank 2)
reactant (blank 3)
product (blank 3)

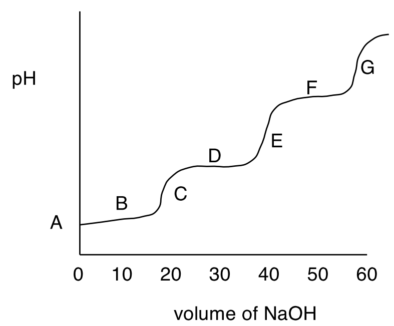
c. When hemoglobin is oxygenated, this reaction shifts to the products: H Hgb $O_2 \rightleftharpoons H^+$ + Hgb O_2. The blood pH ___ because $[H^+]$ ___ and affects a second reaction: $H^+ + HCO_3^- \rightleftharpoons H_2O + CO_2$ (g) and makes this reaction shift to the product side. Our body ___ the excess CO_2 (g) because our body is an ___ system.
Blank 3: give a 1 or 2 word answer in "Other". Blank 4: give a 1 word answer in "Other". Separate each answer with a comma.
increases (blank 1)
decreases (blank 1)
stays the same (blank 1)
increases (blank 2)
decreases (blank 2)
stays the same (blank 2)
Other
Exhale, open
We exhale excess CO_2 out of our lungs into the atmosphere. The CO_2/HCO_3^- blood buffer system is an open system that helps keep the pH of our blood between 7 and 7.5.

Quiz 8 solutions
1. This titration curve could represent 20 ml of 0.1 M ____ with 0.1 M NaOH. The pH at Point C is calculated with ____.



CH3COOH (blank 1)
H2CO3 (blank 1)
H3PO4 (blank 1)
pH = pKa1 (blank 2)
pH = pKa2 (blank 2)
pH = pKa3 (blank 2)
pH = 0.5(pK_{a1} + pK_{a2}) (blank 2)
pH = 0.5(pK_{a2} + pK_{a3}) (blank 2)
K_{a1} and doing an equlibrium calculation (blank 2)
K_b and doing an equlibrium calculation (blank 2)

2. Soda has a pH between 3 and 4. Soda makers often add phosphoric acid to give a tart taste to soda. 20 ml of 0.1 M phosphoric acid (H_3PO_4, pK_{a1} = 2.1, pK_{a2} = 7.2, pK_{a3} = 12.3) is titrated with 0.1 M NaOH.

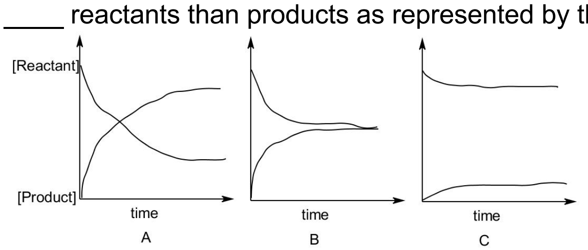


a. In the phosphoric acid titration curve, pH 4.65 is the pH at the _____. pH 7.2 is the pH at the ____.
starting point (blank 1)
1st ½ way point (blank 1)
1st endpoint (blank 1)
2nd ½ way point (blank 1)
2nd endpoint (blank 1)
3rd ½ way point (blank 1)
3rd endpoint (blank 1)
4th ½ way point (blank 1)
4th endpoint (blank 1)
starting point (blank 2)
1st ½ way point (blank 2)
1st endpoint (blank 2)
2nd ½ way point (blank 2)
2nd endpoint (blank 2)
3rd ½ way point (blank 2)
3rd endpoint (blank 2)
4th ½ way point (blank 2)
4th endpoint (blank 2)
b. To calculate the pH at the 3rd endpoint in the phosphoric acid titration curve, I would need to know K_b and set up an equilibrium calculation using the _____ reaction. The numerical value of K_b is _____.
1st blank: give a one or two word answer. 2nd blank: Write a number in scientific notation as _._E_ _ . E.g., 1.1E11. Use 2 significant figures. Separate each answer with a comma.
Base hydrolysis, $K_b = K_w/K_{a3} = 1E\text{-}14/10^{-12.3} = 2.0E\text{-}02$
c. I could use phosphate (PO_4^{-3}) and ____ to make a pH ___ buffer.
H_3PO_4 (blank 1)
$H_2PO_4^-$ (blank 1)
HPO_4^{-2} (blank 1)
PO_4^{-3} (blank 1)
2 (blank 2)

5 (blank 2)
7 (blank 2)
12 (blank 2)
d. To make soda with a pH of 3.5, I would use ___ as the acid and ___ as the base. The ratio of [base] to [acid] is __.
Blank 3: give a number with 3 significant figures only in "Other". Do not include text.
H_3PO_4 (blank 1)
$H_2PO_4^-$ (blank 1)
HPO_4^{-2} (blank 1)
PO_4^{-3} (blank 1)
H_3PO_4 (blank 2)
$H_2PO_4^-$ (blank 2)
HPO_4^{-2} (blank 2)
PO_4^{-3} (blank 2)
Other
25.1
Use Henderson-Hasselbach equation: pH = pKa + log ([base]/[acid]).
$3.5 = 2.1 + \log([H_2PO_4^-]/[H_3PO_4])$
$\log([H_2PO_4^-]/[H_3PO_4]) = 1.4$
$([H_2PO_4^-]/[H_3PO_4]) = 10^{1.4} = 25.1$

Quiz 7 solutions
1. Consider the acid dissociation reaction: HA <==> $H^+ + A^-$.
For a weak acid at equilibrium, there is ____ HA than $H^+ + A^-$. This means K_a for this reaction is ___ and pKa should be ___.
more (blank 1)
same (blank 1)
less (blank 1)
Equal to 1 (blank 2)
Greater than 1 (blank 2)
Less than 1 (blank 2)
Larger than 1 (blank 3)
small or negative (blank 3)

2. NH_3 (ammonia) is a weak base. Graph __ represents the hydrolysis of ammonia because there are ____ reactants than products as represented by the chemical equation ___.



A (blank 1)
B (blank 1)
C (blank 1)
More (blank 2)
Same amount of (blank 2)
Less (blank 2)
$NH_3 + H_2O$ <==> $NH_2^- + H_3O^+$ (blank 3)
$NH_3 + H_3O^+$ <==> $NH_4^+ + H_2O$ (blank 3)
$NH_3 + H_2O$ <==> $NH_4^+ + OH^-$ (blank 3)

3. 0.05 M acetic acid has a __ $[H^+]$ than 0.2 M acetic acid because higher concentration means ____ pH.

higher (blank 1)
same (blank 1)
lower (blank 1)
higher (blank 2)
same (blank 2)
lower (blank 2)

4. You have a 0.1 M solution of an acid, HA. This acid has a Ka = 1.2E-5.
a. The chemical equation for this reaction is __.
$HA + H_2O \Longleftrightarrow A^- + H_3O^+$ (blank 1)
$A^- + H_3O^+ \Longleftrightarrow H_2A + H_2O$ (blank 1)
$A^- + H_2O \Longleftrightarrow HA + OH^-$ (blank 1)
b. The $[H^+]$ = __ M at equilibrium.
Give a number with 2 significant figures in scientific notation as x.xE-x, e.g., 1.1E-4.
1.1E-3
c. The pH of this acid is ___.
Give a number with 2 significant figures.
3.0
$HA \Longleftrightarrow H^+ + A^-$

0.1	0	0
x	x	x
0.1-x	x	x

1.2E-5 = (x)(x)/(0.1-x) = (x)(x)/(0.1)
solve for x = $[H^+]$ = 1.1E-3
pH = - log (1.1E-3) = 3.0

5. You have a 0.1 M solution of a base, A^-. This base has a Kb = 4.3E-11.
a. The equation I would use to calculate $[OH^-]$ is __. C = concentration of A^-.
Kb = (C)/(x)(x)
Kb = x/C-x
Kb = (C-x)(C-x)/(x)
Kb = (x)(x)/(C)
b. The $[OH^-]$ = __ M at equilibrium.
Give a number with 2 significant figures in scientific notation as x.xE-x, e.g., 1.1E-4.
2.1E-6
c. The pH of this base is ___.
Give a number with 2 significant figures in “Other”. Separate each answer with a comma.
8.3
$A^- + H_2O \Longleftrightarrow HA + OH^-$

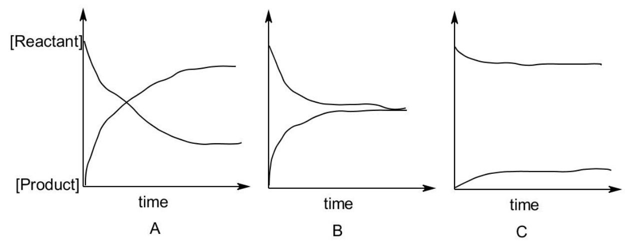
0.1	0	0
x	x	x
0.1-x	x	x

4.3E-11 = (x)(x)/(0.1-x) = (x)(x)/(0.1)
solve for x = $[OH^-]$ = 2.1E-6
pOH = - log (2.1E-6) = 5.7
pH = 14- pOH = 14 – 5.7 = 8.3

Quiz 6 solutions
1. A beverage is carbonated by dissolving CO_2 (g) into the drink:

$$CO_2\ (g) \rightleftharpoons CO_2\ (aq) \qquad K_{eq} = 0.036 \text{ at } 25^oC$$

a. Graph __ represents this reaction because there are ___ reactants and ___ products.



A (blank 1)
B (blank 1)
C (blank 1)
More (blank 2)
Same (blank 2)
Less (blank 2)
More (blank 3)
Same (blank 3)
Less (blank 3)

b. 1 mole of CO_2 (g) is bubbled into 1 liter of water: CO_2 (g) $\rightleftharpoons$ CO_2 (aq).
The equilibrium constant equation for this reaction is Keq = ___. The equilibrium concentration of CO_2 (aq) = ___ M.
An equilibrium constant equation for A + B <==> C is Keq = [C]/[A][B]. Blank 1: give the right side of the equation only in "Other". Blank 2: give a number with 2 significant figures only in "Other". Do not include text. Separate each answer with a comma.
[CO_2 (aq)]/[CO_2 (g)], 0.035

	CO_2 (g) $\rightleftharpoons$	CO_2 (aq).	K_{eq} = [CO_2 (aq)]/[CO_2 (g)]
Initial	1	0	
Reacts	x	x	
Equilibrium	1-x	x	

K_{eq} = [CO_2 (aq)]/[CO_2 (g)] = x/(1-x) = 0.036
Solve for x: x = 0.036 (1-x) = 0.036 – 0.036x
1.036 x = 0.036
x = 0.036/1.036 = 0.035 = [CO_2 (aq)] at equilibrium

c. Bubbling more CO_2 (g) into 1 liter of water ___ the [CO_2 (aq)]/[CO_2 (g)] ratio. To get the system back to ___, the reaction shifts to make more ___.
Blank 2: give a one word answer in "Other".
increases (blank 1)
decreases (blank 1)
does not change (blank 1)
CO_2 (g) (blank 3)
CO_2 (aq) (blank 3)
Other
Equilibrium

2 points d. You can keep the soda from going flat by keeping the soda cold.
This means Keq at a temperature lower than 25°C is ___ Keq at 25°C. This means ΔH for this reaction is ___ because heat is a ___ and lowering the temperature is like ___ heat and shifts the reaction toward the ___ side.
Greater than (blank 1)
Equal to (blank 1)
Less than (blank 1)
exothermic (blank 2)
endothermic (blank 2)
reactant (blank 3)
product (blank 3)

adding (blank 4)
removing (blank 4)
reactant (blank 5)
product (blank 5)
neither (blank 5)