Chemistry 30
Equilibrium, Acids & Bases
Unit Review

Use the following information to answer the next four questions.

Prairie Chem Inc. in Edmonton is a bulk manufacturer of concentrated bleach ($NaOCl_{(aq)}$). The bleach reacts with water to form a solution with a pH of 10.87.

$$OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$$

b a ca cb

1. In this reaction, the substances that act as Brønsted-Lowry acids are

A. $OCl^-_{(aq)}$ and $H_2O_{(l)}$ H_2O / $HOCl$

B. $OCl^-_{(aq)}$ and $HOCl_{(aq)}$

C. $OCl^-_{(aq)}$ and $OH^-_{(aq)}$

D. $H_2O_{(l)}$ and $HOCl_{(aq)}$

2. The substance in the equation above that may act as an amphiprotic species is

A. $OCl^-_{(aq)}$

B. $H_2O_{(l)}$ $OH^- \leftarrow H_2O \rightarrow H_3O^+$

C. $HOCl_{(aq)}$

D. $OH^-_{(aq)}$

3. The two species in equimolar amounts that could act as a buffer in this bleach solution are

A. $OCl^-_{(aq)}$ and $HOCl_{(aq)}$ buffer: weak acid/base conjugate pair

B. $HOCl_{(aq)}$ and $OH^-_{(aq)}$

C. $OCl^-_{(aq)}$ and $H_2O_{(l)}$

D. $H_2O_{(l)}$ and $OH^-_{(aq)}$

4. In this bleach solution, the acid-base indicator

A. phenolphthalein would be colourless ✗

B. alizarin yellow R would be orange ✓

C. indigo carmine would be green ✗

D. methyl orange would be red ✗

10.87

10.1 —— 12.0

yellow orange red

Use the following information to answer the next question.

A source of hydrogen for the Haber process is "syngas", which is produced by a reaction of methane and water at 1 000°C.

$$CH_{4(g)} + H_2O_{(g)} \overset{\text{nickel catalyst}}{\rightleftharpoons} CO_{(g)} + 3\,H_{2(g)}$$

$K_{eq} = \frac{[CO_{(g)}][H_{2(g)}]^3}{[CH_{4(g)}][H_2O_{(g)}]}$

$= \frac{(5.45)(2.10)^3}{(2.97)(7.94)} = 2.14$

Numerical Response

1. If, at equilibrium, the $[CH_{4(g)}] = 2.97$ mol/L, $[H_2O_{(g)}] = 7.94$ mol/L, $[CO_{(g)}] = 5.45$ mol/L, and $[H_{2(g)}] = 2.10$ mol/L, then the K_{eq} is 2.14.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.

Some of the $SO_{2(g)}$ produced from the burning of coal and natural gas can react with $NO_{2(g)}$ in the atmosphere according to the equation

$$SO_{2(g)} + NO_{2(g)} \rightleftharpoons NO_{(g)} + SO_{3(g)} + \text{heat} \quad \Delta H = -41.9 \text{ kJ}$$

5. The equilibrium concentration of $SO_{3(g)}$ in the reaction could be increased by

A. raising the temperature ✗

B. adding a catalyst ✗

C. removing $SO_{2(g)}$ ✗

D. adding $NO_{2(g)}$ ✓

---

6. Which of the following acid solutions has the lowest pH?

A. 300 mL of 1.00×10^{-2} mol/L $H_2S_{(aq)}$ wA

B. 100 mL of 1.00×10^{-1} mol/L $H_2CO_{3(aq)}$ wA

C. 100 mL of 1.00×10^{-3} mol/L $H_2SO_{4(aq)}$ SA

D. 10.0 mL of 1.00×10^{-4} mol/L $H_2SO_{4(aq)}$ SA

don't affect

$[H_2SO_4] = [H_3O^+]$

$\uparrow [H_3O^+] = \downarrow$ lowest pH

Use the following information to answer the next question.

Antibiotics formed by different species of the genus of bacteria *Penicillium* are among the most widely prescribed drugs in the world today.

One of these antibiotics is penicillin G (benzylpenicillinic acid), which is represented as $HPn_{(s)}$. This acid is only slightly soluble in water. The saturated aqueous solution is represented by the equilibrium

$$H_2O_{(l)} + HPn_{(s)} \rightleftharpoons H_3O^+_{(aq)} + Pn^-_{(aq)}$$

definition of

7. This system is at equilibrium when the rate of formation of $Pn^-_{(aq)}$ in the forward reaction is

A. favoured over the rate of the formation of $HPn_{(s)}$ in the reverse reaction

B. slower than the rate of the formation of $HPn_{(s)}$ in the reverse reaction

C. faster than the rate of the formation of $HPn_{(s)}$ in the reverse reaction

D. equal to the rate of the formation of $HPn_{(s)}$ in the reverse reaction

---

Numerical Response

2. The concentration of $H_3O^+_{(aq)}$ ions in a particular bottle of wine is 3.2×10^{-4} mol/L. The pH of this wine is 3.49.

$pH = -\log[H_3O^+] = -\log(3.2 \times 10^{-4})$

$= 3.4948$

$= 3.49$

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.

Rainwater is acidic because it contains dissolved atmospheric $CO_{2(g)}$ that occurs naturally. It may also contain air pollutants, $NO_{x(g)}$, and $SO_{x(g)}$ from industrial sources.

8. If each of the following components of acid rain is of equal concentration, then which of them would have the lowest pH?

highest Ka

A. $HNO_{3(aq)}$ SA

B. $HNO_{2(aq)}$ WA

C. $H_2SO_{3(aq)}$ WA

D. $H_2SO_{4(aq)}$ SA

H_2SO_4 above HNO_3 in table of relative strengths

Use the following information to answer the next two questions.

If $H_2S_{(g)}$ is released into the atmosphere, it dissolves in atmosphere water to form hydrosulphuric acid. The ionization of $H_2S_{(aq)}$ can be represented by the equilibrium

$$H_2S_{(aq)} + H_2O_{(l)} \rightleftharpoons HS^-_{(aq)} + H_3O^+_{(aq)}$$

9. The K_a expression for this ionization is

A. $K_a = \dfrac{[H_2S_{(aq)}]}{[HS^-_{(aq)}][H_3O^+_{(aq)}]}$

B. $K_a = \dfrac{[H_2S_{(aq)}][H_2O_{(l)}]}{[HS^-_{(aq)}][H_3O^+_{(aq)}]}$

C. $K_a = \dfrac{[HS^-_{(aq)}][H_3O^+_{(aq)}]}{[H_2S_{(aq)}][H_2O_{(l)}]}$

D. $K_a = \dfrac{[HS^-_{(aq)}][H_3O^+_{(aq)}]}{[H_2S_{(aq)}]}$

10. The $[H_3O^+_{(aq)}]$ in a 0.050 mol/L $H_2S_{(aq)}$ solution is

A. 4.5×10^{-9} mol/L

B. 6.7×10^{-5} mol/L

C. 1.3×10^{-4} mol/L

D. 0.10 mol/L

$K_a = \dfrac{[HS^-][H_3O^+]}{[H_2S]}$ $\quad 8.9 \times 10^{-8} = \dfrac{x^2}{0.050}$ $\quad x = 6.7 \times 10^{-5}$

approx rule ✓

---

11. An equilibrium that would favour the products is

SA above = favours products

A. $NH_4^+_{(aq)} + H_2PO_4^-_{(aq)} \rightleftharpoons NH_{3(aq)} + H_3PO_{4(aq)}$ ✗

B. $HCN_{(aq)} + HS^-_{(aq)} \rightleftharpoons CN^-_{(aq)} + H_2S_{(aq)}$ ✗

C. $HCO_3^-_{(aq)} + PO_4^{3-}_{(aq)} \rightleftharpoons HPO_4^{2-}_{(aq)} + CO_3^{2-}_{(aq)}$ ✓

D. $HSO_4^-_{(aq)} + HSO_3^-_{(aq)} \rightleftharpoons H_2SO_{3(aq)} + SO_4^{2-}_{(aq)}$ ✗

$K_w = K_a K_b$ $K_b = \frac{K_w}{K_a} = \frac{1.00\times10^{-14}}{5.6\times10^{-10}}$

Numerical Response

3. The K_b for the conjugate base of the ammonium ion, expressed in scientific notation, is ___1.79___ $\times 10^{-5}$.

$= 1.7857\times10^{-5}$
$= 1.79\times10^{-5}$

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$[H_3O^+]$

12. If the $[H^+_{(aq)}]$ in a reaction is 0.020 mol/L, then the pH and pOH are, respectively,

A. 1.05 and 12.95
B. 1.40 and 12.60
C. 1.70 and 12.30
D. 2.00 and 12.00

$pH = -\log[H_3O^+]$
$= -\log(0.020)$
$= 1.70$

$pOH = 14 - pH$
$= 14 - 1.70$
$= 12.30$

13. When ammonium nitrate dissolves in water, the resulting solution will be

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$
(WA)

A. basic
B. acidic
C. neutral
D. a non-electrolyte

Use the following information to answer the next question.

Blood pH is influenced by the concentration of buffers and gas solutes, such as carbon dioxide, which is formed during cellular respiration. In red blood cells, the enzyme carbonic anhydrase catalyzes the equilibrium

$$CO_{2(g)} + H_2O_{(l)} \xrightleftharpoons{\text{carbonic anhydrase}} HCO_3^-{}_{(g)} + H^+_{(g)}$$

14. In this equilibrium, carbonic anhydrase

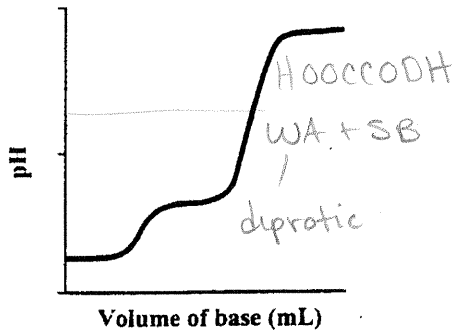
A. increases the concentration of $HCO_3^-{}_{(aq)}$ formed at equilibrium
B. decreases the concentration of $HCO_3^-{}_{(aq)}$ formed at equilibrium
C. increases the concentration of $CO_{2(g)}$ formed at equilibrium
D. increases the speed at which equilibrium is reached

catalysts don't affect K
only speed up rxn by
decreasing Ea

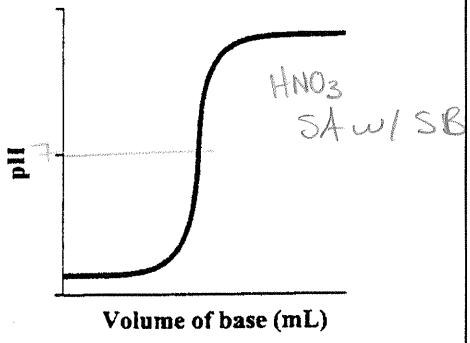
Use the following information to answer the next question.

When equally concentrated solutions of $HNO_{3(aq)}$, $CH_3COOH_{(aq)}$, $HOOCCOOH_{(aq)}$, and $Na_2S_{(aq)}$ were titrated with either a strong acid or strong base, the following curves were obtained.

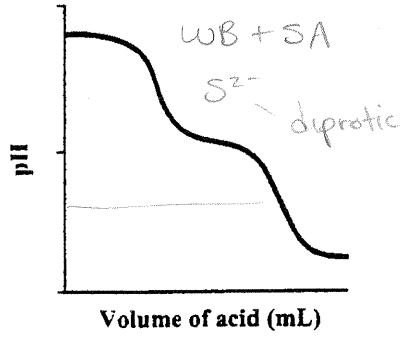
Graph 1



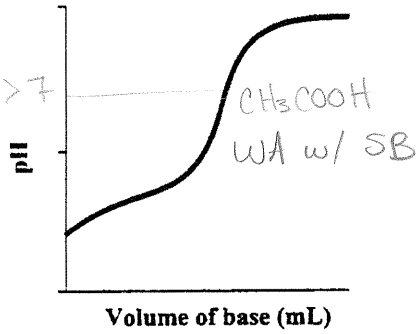
Graph 2



Graph 3



Graph 4



Numerical Response

4. Match each of the graphs, as numbered above, with the corresponding titration species listed below.

$HNO_{3(aq)}$	2	(Record in the **first** column)
$CH_3COOH_{(aq)}$	4	(Record in the **second** column)
$HOOCCOOH_{(aq)}$	1	(Record in the **third** column)
$Na_2S_{(aq)}$	3	(Record in the **fourth** column)

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.

Oxoacids of Chlorine

Acid	K_a
$HClO_{4(aq)}$	very large SA
$HClO_{3(aq)}$	5.1×10^{2} ✱ sometimes considered strong
$HClO_{2(aq)}$	1.1×10^{-2} WA
$HClO_{(aq)}$	2.9×10^{-8} WA

OMIT

15. Acids are classified as either strong or weak. Of the acids listed above, only

A. $HClO_{(aq)}$ is a strong acid

B. $HClO_{4(aq)}$ is a strong acid

C. $HClO_{4(aq)}$ and $HClO_{3(aq)}$ are strong acids

D. $HClO_{4(aq)}$, $HClO_{3(aq)}$, and $HClO_{2(aq)}$ are strong acids

---

16. In the equation $HNO_{3(aq)} + N_2H_{4(aq)} \rightleftharpoons NO_3^-{}_{(aq)} + N_2H_5^+{}_{(aq)}$, one conjugate acid-base pair is

A. $HNO_{3(aq)}$ and $N_2H_5^+{}_{(aq)}$

B. $HNO_{3(aq)}$ and $N_2H_{4(aq)}$

C. $N_2H_{4(aq)}$ and $N_2H_5^+{}_{(aq)}$ ~ conjugate pairs differ by only one H^+

D. $N_2H_{4(aq)}$ and $NO_3^-{}_{(aq)}$

Use the following information to answer the next question.

0.10 mol/L Solutions

NO_3^-
NO_2^-
HCO_3^-
OH^- ↓ SB

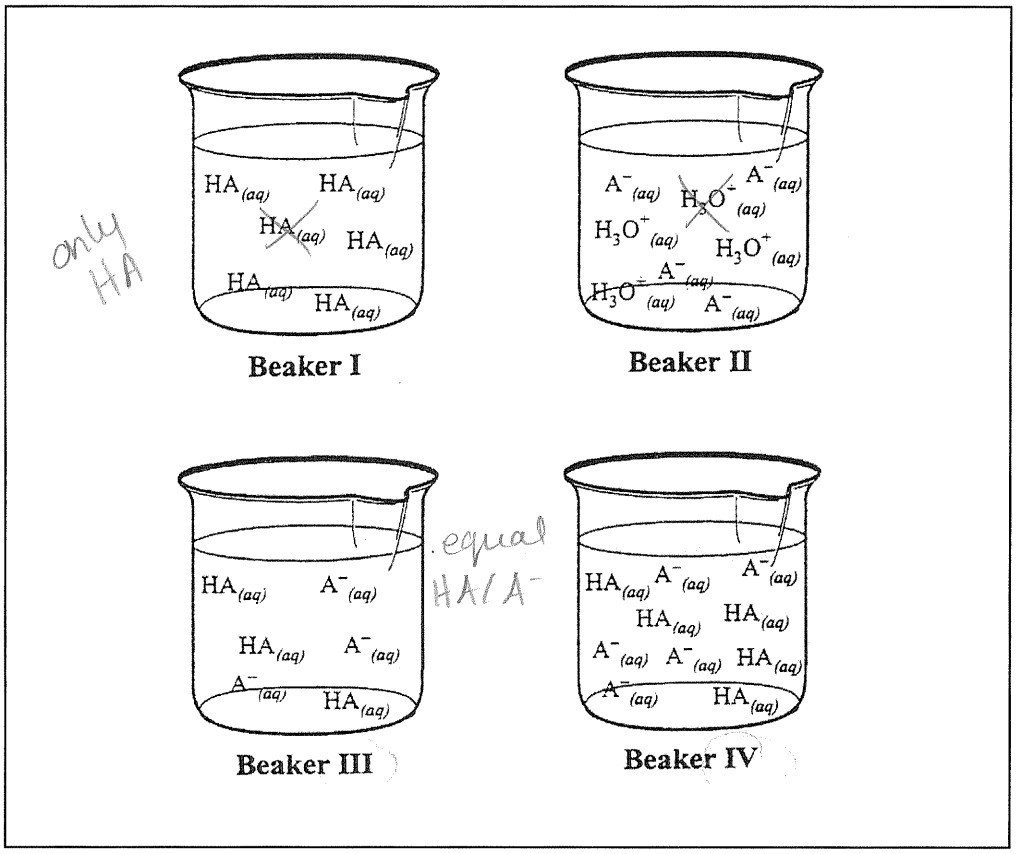
WB	SA ~ least basic
1 $NaNO_{2(aq)}$	**3** $HNO_{3(aq)}$
2 $NaHCO_{3(aq)}$ WB	**4** $Ba(OH)_{2(aq)}$ ~ most basic $Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

Numerical Response

5. When the solutions above are ordered from most basic to least basic, the order is 4, 2, 1, and 3.

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.



17. The beakers that best represent a buffer solution in which $HA_{(aq)}$ is a weak acid are those labelled

A. I and II

B. I and III

C. II and III

D. III and IV

buffer: equal amounts of weak acid/weak base conjugate pairs

---

18. Which of the following mixtures could act as a buffer solution?

A. $HF_{(aq)}$ and $H_2S_{(aq)}$ X not cony. pairs

B. $NaOH_{(aq)}$ and $HCl_{(aq)}$ X SA + SB

C. $Na_2CO_{3(aq)}$ and $NH_{3(aq)}$ X not cony. pairs

D. $NaH_2BO_{3(aq)}$ and $Na_2HBO_{3(aq)}$ $H_2BO_3^-$ / HBO_3^{2-}

$N_2H_{4(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + N_2H_5^+{}_{(aq)}$

$K_b = \frac{[OH^-][N_2H_5^+]}{[N_2H_4]} = \frac{(2.14\times10^{-3})^2}{0.498} = 9.195\times10^{-6}$

$= 9.20\times10^{-6}$

9206

Use the following information to answer the next question.

A 0.500 mol/L solution of hydrazine ($N_2H_{4(aq)}$) contains the following equilibrium concentrations.

$[N_2H_{4(aq)}] = 0.498$ mol/L

$[OH^-_{(aq)}] = 2.14 \times 10^{-3}$ mol/L

$[N_2H_5^+{}_{(aq)}] = 2.14 \times 10^{-3}$ mol/L

Numerical Response

6. The K_b for hydrazine, in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$. The values of ***a***, ***b***, ***c***, and ***d*** are, respectively, 9, 2, 0, and 6.

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

---

19. Acid rain is linked to the leaching of heavy metals and their ions in lakes and rivers. Biomagnification of these metals and ions increases levels of disease in fish and wildlife. Based on this information, a decision to reduce sulphur dioxide emissions would be

A. political

B. scientific

C. technological

D. environmental

20. A drop of thymol blue indicator in its blue form (Tb^{2-}) added to 10.0 mL of 0.10 mol/L $H_2SO_{4(aq)}$ would become

A. yellow because the indicator would gain one proton

B. yellow because the indicator would lose one proton

C. red because the indicator would gain two protons

D. red because the indicator would lose two protons

$H_2SO_4 + H_2O \xrightarrow{>99\%} H_3O^+ + HSO_4^-$

$0.10\text{mol/L} = [H_3O^+]$

$-\log[0.10) = 1$

H_2Tb red 1.2 – 2.8 HTb^- yellow

yellow 8.0 – 9.6 blue Tb^{2-}

HTb^-

$Tb^{2-} + 2H^+ \rightarrow H_2Tb$

blue red

Use the following information to answer the next question.

The labels came off four cleaning solution containers found under a kitchen sink. Each of the cleaning solutions was tested with two available indicators, and the following results ere recorded.

Cleaning Solution	Bromothymol Blue	Phenolphthalein
1	blue >7.6	pink >10
2	blue >7.6	colourless <8.2
3	green 6.0-7.6	colourless <8.2
4	blue >7.6	light pink 8.2-10

Overall pH
>10
7.6-8.2
6.0-7.6
8.2-10

Numerical Response

7. Listed in order from lowest to highest pH, the cleaning solutions are, respectively, 3, 2, 4, and 1.

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.

Apple growers in British Columbia's Okanagan Valley are coping with trees that are stunted and have blistered bark as a result of a dramatic increase in the acidity of the region's soil. Nitrogen fertilizers are one of the main causes of the high acidity level of the soil.

21. To solve this problem, Agriculture Canada has suggested that apple growers work lime into the soil in their orchards because lime is

A. a base

B. an acid

C. a neutral ionic compound

D. a neutral molecular compound

acid + base = neutralize

lime (calcium hydroxide)

↳ not the fruit!

Use the following information to answer the next three questions.

Methanoic (formic) acid is the irritant secreted during an ant bite. The irritation is partially due to the ionization of methanoic acid. The equilibrium equation for the ionization can be represented as

$$HCOOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HCOO^-_{(aq)}$$

22. Which of the substances in the equation above could function as an amphiprotic species?

A. $H_2O_{(l)}$ and $H_3O^+_{(aq)}$

B. $H_2O_{(l)}$

C. $H_3O^+_{(aq)}$ and $HCOO^-_{(aq)}$

D. $H_2O_{(l)}$, $H_3O^+_{(aq)}$, and $HCOO^-_{(aq)}$

23. In a comparison of the species present in $HCOOH_{(aq)}$, the

A. $[H_3O^+_{(aq)}]$ is greater than $[HCOOH_{(aq)}]$

B. $[H_3O^+_{(aq)}]$ is equal to $[HCOOH_{(aq)}]$

C. $[HCOOH_{(aq)}]$ is greater than $[HCOO^-_{(aq)}]$

D. $[HCOOH_{(aq)}]$ is equal to $[HCOO^-_{(aq)}]$

$K_a = 1.8 \times 10^{-4}$ (less than 1)

$\therefore$ [products] < [reactants]

24. When a 0.100 mol/L $HCOOH_{(aq)}$ (WA) is titrated with 0.100 mol/L $NaOH_{(aq)}$ (SB), an appropriate choice of indicator for this titration is

A. orange IV ✗ too low

B. cresol red ✓

C. methyl red ✗ too low

D. indigo carmine ✗ too high

WA + SB → equivalence > 7

7.0 – 8.8
yellow red

Use the following information to answer the next three questions.

Sodium hydrogen carbonate, $NaHCO_{3(s)}$ (baking soda), is used in baking. When lactic acid, $HC_3H_5O_{3(aq)}$, and baking soda are present, they cause doughs and batters to rise. Lactic acid, a component of buttermilk, has a $K_a = 1.4 \times 10^{-4}$.

$HCO_3^- + HC_3H_5O_3 \rightleftharpoons H_2CO_3 + C_3H_5O_3^-$

b a

$H_2CO_3 \rightarrow CO_{2(g)} + H_2O_{(l)}$

25. The net ionic equation that best illustrates the reaction responsible for the dough rising is

A. $H_3O^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow CO_{2(g)} + 2\,H_2O_{(l)}$

B. $HCO_3^-{}_{(aq)} + C_3H_5O_3^-{}_{(aq)} \rightarrow HC_3H_5O_{3(aq)} + CO_3^{2-}{}_{(aq)}$

C. $NaHCO_{3(aq)} + H_3O^+_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)} + Na^+_{(aq)}$

D. $HCO_3^-{}_{(aq)} + HC_3H_5O_{3(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)} + C_3H_5O_3^-{}_{(aq)}$

* carbonic acid

$H_2CO_3 \rightarrow CO_{2(g)} + H_2O_{(l)}$

(in data booklet

26. The $[H_3O^+_{(aq)}]$ in 0.20 mol/L $HC_3H_5O_{3(aq)}$ is

A. 2.8×10^{-3} mol/L

B. 5.3×10^{-3} mol/L

C. 2.6×10^{-2} mol/L

D. 7.0×10^{-4} mol/L

$HC_3H_5O_3 + H_2O \rightleftharpoons H_3O^+ + C_3H_5O_3^-$

$K_a = \dfrac{[H_3O^+][C_3H_5O_3^-]}{[HC_3H_5O_3]}$ $\quad 1.4 \times 10^{-4} = \dfrac{x^2}{0.20}$

approx rule $(0.20 - x = 0.20)$

Use your recorded answer from ***Multiple choice 26*** *to answer* ***Numerical Response 8****.

Numerical Response

8. The pH of the $HC_3H_5O_{3(aq)}$ is __2.28__.

$pH = -\log[H_3O^+]$

$= 2.2757$

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

***You can receive marks for this question even if the previous question was answered incorrectly.**

---

27. To completely react 50 mL of 0.10 mol/L acid, 150 mL of 0.10 mol/L $KOH_{(aq)}$ was required. The number of protons donated by each acid molecule was

x 3

1 : 3 ratio

A. 1

B. 2

C. 3

D. 4

K^+, MnO_4^-, H^+, $H_2O_{2(l)}$, $H_2O_{(l)}$

SRA

Use the following information to answer the next three questions.

Titration of 20.0 mL Samples of Acidified $H_2O_{2(l)}$ with 0.15 mol/L $KMnO_{4(aq)}$

Trial	I	II	III	IV
Final Buret Volume (mL)	18.3	34.6	17.4	33.8
Initial Buret Volume (mL)	0.4	18.3	0.9	17.4
	17.9	16.3	16.5	16.4
Colour at endpoint	purple	pink	pink	pink

Unit B

avg = 16.4mL

$2(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O)$

$5(H_2O_{2(l)} \rightarrow O_{2(g)} + 2H^+ + 2e^-)$

28. The balanced equation for the titration is

A. $2\ MnO_4^-{}_{(aq)} + 16\ H^+{}_{(aq)} + 5\ H_2O_{2(l)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 8\ H_2O_{(l)} + 5\ O_{2(g)}$

B. $2\ MnO_4^-{}_{(aq)} + 6\ H^+{}_{(aq)} + 5\ H_2O_{2(l)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 4\ H_2O_{(l)} + O_{2(g)}$

C. $2\ MnO_4^-{}_{(aq)} + 6\ H^+{}_{(aq)} + 5\ H_2O_{2(l)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 3\ H_2O_{(l)} + 5\ O_{2(g)}$

D. $2\ MnO_4^-{}_{(aq)} + 6\ H^+{}_{(aq)} + 5\ H_2O_{2(l)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 8\ H_2O_{(l)} + 5\ O_{2(g)}$

V = 16.4mL, c = 0.15mol/L — V = 20.0mL, c = ?

$16.4\text{mL} \times \frac{0.15\text{mol}}{1\text{L}} \times \frac{5\text{mol } H_2O_2}{2\text{mol } MnO_4^-} \times \frac{1}{20.0\text{mL}} = 0.3075\text{ mol/L} = 0.31\text{mol/L}$

Numerical Response

9. The volume of potassium permanganate that should be used in subsequent calculations is 16.4 mL.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

*Use your recorded answer from **Numerical Response 9** to answer **Numerical Response 10*.***

Numerical Response

10. The hydrogen peroxide concentration is 0.31 mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next four questions.

Sodium azide, $NaN_{3(s)}$, which is found in automobile air bags, reacts readily with acids to form the highly toxic and explosive hydroazoic acid $HN_{3(aq)}$. The K_a for hydroazoic acid is 1.9×10^{-5}.

29. The K_a expression for hydroazoic acid is

A. $K_a = \dfrac{[HN_{3(aq)}]}{[N_3^-{}_{(aq)}][H_3O^+_{(aq)}]}$

B. $K_a = \dfrac{[H_3O^+_{(aq)}][N_3^-{}_{(aq)}]}{[HN_{3(aq)}]}$

C. $K_a = \dfrac{[HN_{3(aq)}]^3}{[N_3^-{}_{(aq)}][H_3O^+_{(aq)}]}$

D. $K_a = \dfrac{[N_3^-{}_{(aq)}]^3[H_3O^+_{(aq)}]}{[HN_{3(aq)}]^3}$

30. In a solution of hydroazoic acid, the

$HN_3 + H_2O_{(l)} \rightleftharpoons H_3O^+ + N_3^-$

A. $[HN_{3(aq)}] < [N_3^-{}_{(aq)}]$

B. $[HN_{3(aq)}] > [H_3O^+_{(aq)}]$

C. $[HN_{3(aq)}] > [H_2O_{(l)}]$

D. $[HN_{3(aq)}] = [H_3O^+_{(aq)}]$

$K_a < 1 \therefore [\text{products}] < [\text{reactants}]$

$1.9 \times 10^{-5} = \dfrac{x^2}{(0.28)}$ $[H_3O^+]$

$x = 0.002306\ mol/L$

$pH = -\log[H_3O^+]$

$= 2.637$

Numerical Response

11. The pH of a 0.28 mol/L $HN_{3(aq)}$ solution is 2.64.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$HN_3 + OH^- \rightarrow H_2O + N_3^-$

2.20kg 6.00mol/L

V = ?

Numerical Response

12. The volume of 6.00 mol/L $NaOH_{(aq)}$ required to neutralize 2.20 kg of $HN_{3(aq)}$ is 8.52 L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$2.20kg \times \dfrac{mol}{43.04g} \times \dfrac{1\ mol\ OH^-}{1\ mol\ HN_3} \times \dfrac{1L}{6.00mol} = 0.008519kL$

$= 8.52L$

Use the following information to answer the next two questions.

Body chemistry involves a number of chemical systems that are critically dependent of pH, buffering action, and concentration of gas solutes such as $CO_{2(g)}$ and $O_{2(g)}$.

31. The function of chemical buffers in the blood is to

A. control all reactions

B. act as catalysts to increase the rate of reaction

C. withstand the continual addition of acid or base

D. maintain a constant pH when a small amount of acid or base is added best defn

32. One of the buffers present in blood is

A. $HSO_3^-{}_{(aq)} - H_2SO_{3(aq)}$

B. $HCO_3^-{}_{(aq)} - H_2CO_{3(aq)}$

carbonic acid H_2CO_3/HCO_3^-

phosphate $H_2PO_4^-/HPO_4^{2-}$

C. $NO_3^-{}_{(aq)} - HNO_{3(aq)}$

D. $Cl^-{}_{(aq)} - HCl_{(aq)}$

Use the following information to answer the next question.

$$HSO_4^-{}_{(aq)} + HCOO^-{}_{(aq)} \rightleftharpoons HCOOH_{(aq)} + SO_4^{2-}{}_{(aq)}$$

1 acid **2** base **3** ca **4** cb

Numerical Response

13. Match each acid or base in the forward reaction, as numbered above, with the corresponding term below.

acid	1	(Record in the **first** column)
conjugate base	4	(Record in the **second** column)
base	2	(Record in the **third** column)
conjugate acid	3	(Record in the **fourth** column)

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next two questions.

$$HNO_{2(aq)} + H_2BO_3^-{}_{(aq)} \rightleftharpoons NO_2^-{}_{(aq)} + H_3BO_{3(aq)}$$

33. A conjugate acid-base pair in the reaction is

A. $H_2BO_3^-{}_{(aq)}$ and $NO_2^-{}_{(aq)}$

B. $H_3BO_{3(aq)}$ and $H_2BO_3^-{}_{(aq)}$ ~ conjugate pairs ~ differ by one proton

C. $HNO_{2(aq)}$ and $H_2BO_3^-{}_{(aq)}$

D. $H_3BO_{3(aq)}$ and $NO_2^-{}_{(aq)}$

34. The amphiprotic species in the reaction is

A. $H_2BO_3^-{}_{(aq)}$

B. $HNO_{2(aq)}$

C. $NO_2^-{}_{(aq)}$

D. $H_3BO_{3(aq)}$

Use the following information to answer the next question.

A sample of rainwater is poured into five test tubes. A different indicator is added to each test tube. Four of the observations are recorded in the table below.

Indicator	**Colour**	
methyl red	yellow	>6.0
phenol red	yellow	<6.6
bromocresol green	blue	>5.4
phenolphthalein	colourless	<8.2
bromothymol blue	?	

6.0 – 6.6

35. The pH of the rainwater and the predicted colour of the sample containing bromothymol blue are

A. ~~6.0 and blue~~

B. 7.6 and blue phenol red = orange

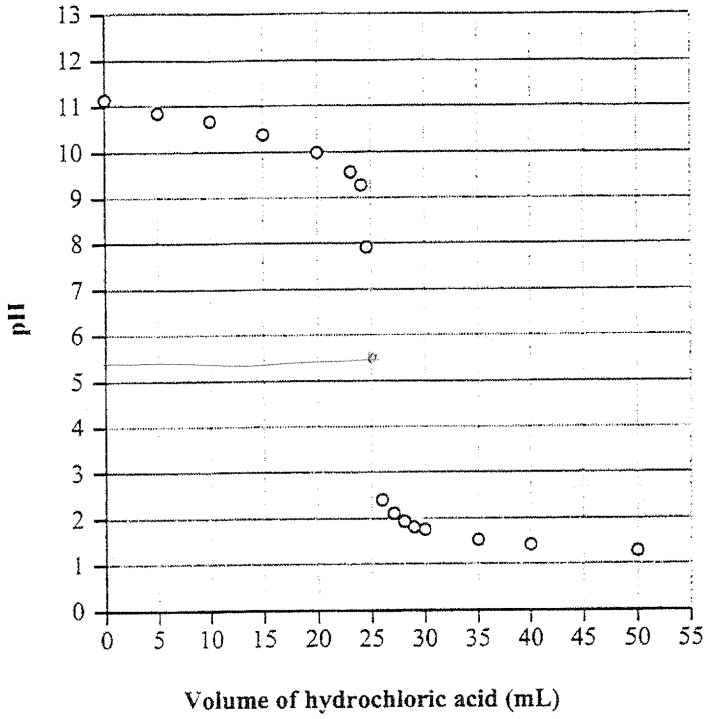
C. 6.0 and yellow

6.0 – 7.6 bromothymol blue
yellow blue

D. 7.6 and yellow

Use the following information to answer the next question.

Titration Plot for 25.0 mL of 0.100 mol/L $NH_{3(aq)}$ with 0.100 mol/L $HCl_{(aq)}$



36. The most suitable indicator for the titration is

A. phenolphthalein X

B. methyl violet X

C. chlorophenol red

D. methyl orange X

---

37. A solution was tested and found to have a pOH of 3.2. This solution would most likely

pH = 10.8

A. be a proton donor X

B. react violently with zinc X

C. cause thymolphthalein to be blue 9.4 - 10.6 blue

D. cause bromocresol green to be yellow

Use the following information to answer the next two questions.

The Stelco Plant in Camrose, Alberta, uses phosphoric acid to remove rust from steel pipes before they are welded. A technician is responsible for ensuring that the proper concentration of phosphoric acid is used. The technician titrated 10.00 mL of the $H_3PO_{4(aq)}$ with 0.125 mol/L $NaOH_{(aq)}$ to the second equivalence point. The technician obtained the following data.

Volume of $NaOH_{(aq)}$ used

Trial	**I**	**II**	**III**	**IV**
Final Buret Volume (mL)	12.8	24.1	35.5	46.7
Initial Buret Volume (mL)	0.7	12.8	24.1	35.5
	12.1	11.3	11.4	11.2

avg = 11.3mL

Numerical Response

14. The average volume of sodium hydroxide required to determine the $[H_3PO_{4(aq)}]$ is __11.3__ mL.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

38. Based on the data gathered at the second equivalence point, the concentration of the phosphoric acid was

$H_3PO_4 \rightarrow H_2PO_4^- \rightarrow HPO_4^{2-}$

$H_3PO_4 + 2OH^- \rightarrow HPO_4^{2-} + 2H_2O$

10.0mL 0.125mol/L 11.3mL

A. 47.1 mmol/L

B. 70.6 mmol/L

C. 141 mmol/L

D. 283 mmol/L

$$11.3mL \times \frac{0.125mol}{L} \times \frac{1mol\ H_3PO_4}{2mol\ OH^-} \times \frac{1}{10.0mL} = 0.0706mol/L = 70.6mmol/L$$

---

39. A glass of orange juice contains enough hydronium ions to kill you if your blood is not buffered to a pH of about 7.35. One of the several buffer systems that your blood contains is $H_2PO_4^-{}_{(aq)} - HPO_4^{2-}{}_{(aq)}$. This system initially buffers the addition of hydronium ions from orange juice by the reaction

(Ca) (Cb)

A. $H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)} \rightleftharpoons H_3PO_{4(aq)} + H_2O_{(l)}$

B. $H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftharpoons H_2PO_4^-{}_{(aq)} + H_2O_{(l)}$

C. $2\,H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)} \rightleftharpoons H_2PO_4^-{}_{(aq)} + H_2O_{(l)}$

D. $2\,H_3O^+_{(aq)} + 2\,H_2PO_4^-{}_{(aq)} \rightleftharpoons PO_4^{3-}{}_{(aq)} + 2\,H_2O_{(l)}$

Use the following information to answer the next two questions.

After the ethene is separated from the byproducts of the cracking process, it is washed with a caustic soda solution ($NaOH_{(aq)}$).

$H_3O^+ + OH^- \rightarrow H_2O + H_2O$

$HCl + NaOH \rightarrow H_2O + NaCl$

0.860 mol/L, 10.0 mL, 2.57 mol/L, v = ?

Numerical Response

15. A lab technician titrated 10.0 mL of a 2.57 mol/L caustic soda solution with a 0.860 mol/L standardized $HCl_{(aq)}$ solution. The volume of $HCl_{(aq)}$ needed to completely neutralize the caustic soda solution is 29.9 mL.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$10.0\,\text{mL} \times \frac{2.57\,\text{mol}}{\text{L}} \times \frac{1\,\text{mol HCl}}{1\,\text{mol NaOH}} \times \frac{\text{L}}{0.860\,\text{mol}} = 29.8837\,\text{mL} = 29.9\,\text{mL}$

40. The indicator that would best identify the equivalence point of this titration is

A. methyl violet

B. bromocresol green

C. bromothymol blue

D. 1,3,5–trinitrobenzene

SA + SB = equivalence point = 7

Use the following information to answer the next question.

A student was asked to determine the concentration of an aqueous $HCl_{(aq)}$ solution by titrating it with 1.13 mol/L $NaOH_{(aq)}$ in the presence of bromothymol blue indicator. Since burets were not available, the student used droppers for each solution and assumed that each drop was of equal volume. It took 26 drops of $NaOH_{(aq)}$ to neutralize 20 drops of the $HCl_{(aq)}$ solution and to reach the bromothymol blue endpoint.

Numerical Response

16. The concentration of the $HCl_{(aq)}$ solution was 1.47 mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$H_3O^+ + OH^- \rightarrow H_2O + H_2O$

20 drops, c = ?, 1.13 mol/L, 26 drops

$26\,\text{drops} \times \frac{1.13\,\text{mol}}{\text{L}} \times \frac{1\,\text{mol}}{1\,\text{mol}} \times \frac{1}{20\,\text{drops}} = \frac{1.469\,\text{mol}}{\text{L}} = 1.47\,\text{mol/L}$

Use the following information to answer the next question.

At the Wascana Gas Plant in Balzac, Alberta, environmental and economic concerns have resulted in the development of an efficient process for the removal of sulphur from sour gas, which is a mixture of hydrocarbons and $H_2S_{(g)}$. In the first step of the process, one-third of the $H_2S_{(g)}$ reacts with $O_{2(g)}$ to produce $SO_{2(g)}$. In the second step of the process, the $SO_{2(g)}$ produced reacts with the remaining $H_2S_{(g)}$ to form elemental sulphur and water.

Step I $\quad 2\ H_2S_{(g)} + 3\ O_{2(g)} \rightleftharpoons 2\ H_2O_{(g)} + 2\ SO_{2(g)}$

Step II $\quad 2\ H_2S_{(g)} + SO_{2(g)} \rightleftharpoons 2\ H_2O_{(g)} + 3\ S_{(s)}$

Overall Equation $\quad 2\ H_2S_{(g)} + O_{2(g)} \rightleftharpoons 2\ H_2O_{(g)} + 2\ S_{(s)}$ + heat

To maximize the amount of sulphur removed from the sour gas, the gas plant engineers apply Le Chatelier's Principle.

41. According to the overall equilibrium equation above, the amount of sulphur removed may be increased by

shift products

A. adding a catalyst ✗

B. removing water vapour ✓

C. increasing the volume of the system ↓P = ↑P (system) shift step 1 towards reactants

D. increasing the temperature of the system ✗ ↑heat = ←

$\Delta H = 2\text{mol}\left(-241.8\frac{\text{kJ}}{\text{mol}}\right) - 2\text{mol}\left(-20.6\frac{\text{kJ}}{\text{mol}}\right)$

$= -442.4\text{kJ}$

42. The indicator that would most accurately identify a solution with a pH between 4.00 and 4.30 is

yellow orange

A. thymol blue

B. methyl orange

C. litmus

D. methyl red

3.2 — 4.4
red ↑ yellow
4.0

Use the following information to answer the next two questions.

A student titrated a 10.0 mL sample of nitric acid with sodium hydroxide solution in the presence of an indicator.

Volume of 5.00 mmol/L $NaOH_{(aq)}$ Used

Trial	**I**	**II**	**III**	**IV**
Final Buret Volume (mL)	7.99	14.51	21.02	27.53
Initial Buret Volume (mL)	1.00	7.99	14.51	21.02
	6.99	6.52	6.51	6.51

Numerical Response $= 6.5133\,mL$

17. The average volume of titrant used is 6.51 mL.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$HNO_3 + NaOH \rightarrow HOH + NaNO_3$

*Use your recorded answer from **Numerical Response 17** to answer **Numerical Response 18*.***

Numerical Response

18. The concentration of the nitric acid is 3.26 mmol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

°You can receive marks for this question even if the previous question was answered incorrectly.

$H_3O^+ + OH^- \rightarrow H_2O + H_2O$

$V = 10.0mL$ $5.0mmol/L$

$V = 6.5133mL$

$6.5133\,mL \times \frac{5.0mmol}{L} \times \frac{1mol}{1mol} \times \frac{1}{10.0mL} = \frac{3.2566mmol}{L} = \frac{3.26mmol}{L}$

43. The addition of $NaOH_{(aq)}$ would cause the equilibrium system

$HBb_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Bb^-_{(aq)}$ to turn

yellow → ↓ blue

A. blue and the pH to decrease

B. blue and the pH to increase

C. yellow and the pH to decrease

D. yellow and the pH to increase

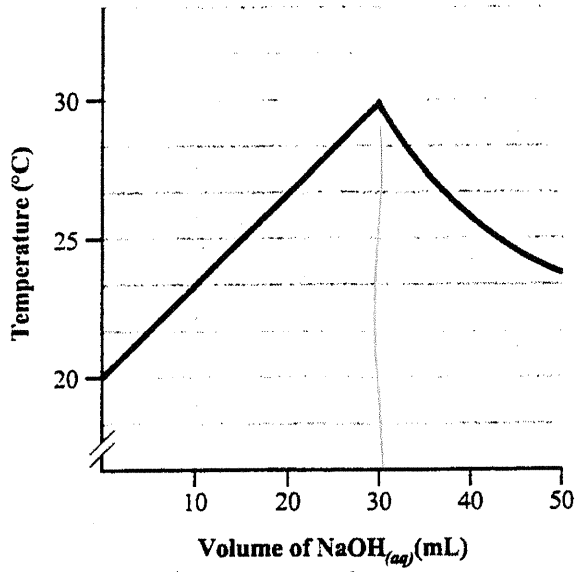
$HBb + OH^- \rightleftharpoons H_2O + Bb^-$ (blue)

↑ shift →

$H_3O^+ + OH^- \rightarrow 2H_2O$

Use the following information to answer the next question.

Thermometric Titration of 20.0 mL of 0.20 mol/L $HCl_{(aq)}$ with $NaOH_{(aq)}$



Numerical Response

19. This experiment is an example of a thermometric titration in which a change in temperature occurs as the reagents react. The $[NaOH_{(aq)}]$ for this titration is 0.13 mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$HCl + NaOH \longrightarrow HOH + NaCl$

20.0mL 30mL
0.20mol/L c=?

$20mL \times \frac{0.20mol}{L} \times \frac{1mol}{1mol} \times \frac{1}{30mL} = 0.133\,mol/L$

44. The main buffer solution of plasma and tissue fluid found in our bodies is $H_2CO_{3(aq)} - HCO_3^-{}_{(aq)}$. When excess hydronium ions enter our blood, the equation that represents the reaction that occurs is

A. $H_3O^+_{(aq)} + OH^-_{(aq)} \rightarrow 2\,H_2O_{(l)}$

B. $H_2CO_{3(aq)} + OH^-_{(aq)} \rightarrow HCO_3^-{}_{(aq)} + H_2O_{(l)}$

C. $H_2CO_{3(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$

D. $H_3O^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)}$

Use the following information to answer the next question.

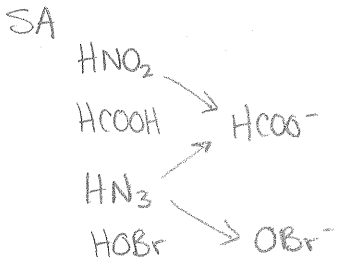
A student was asked to rank the relative strength of the following four acids.

1 Formic acid ($HCOOH_{(aq)}$)

2 Hydroazoic acid ($HN_{3(aq)}$)

3 Hypobromous acid ($HOBr_{(aq)}$)

4 Nitrous acid ($HNO_{2(aq)}$)



The student was given the following information.

$HNO_{2(aq)} + HCOO^-_{(aq)} \rightleftharpoons NO_2^-{}_{(aq)} + HCOOH_{(aq)}$ (Products favoured)

$HN_{3(aq)} + OBr^-_{(aq)} \rightleftharpoons N_3^-{}_{(aq)} + HOBr_{(aq)}$ (Products favoured)

$HN_{3(aq)} + HCOO^-_{(aq)} \rightleftharpoons N_3^-{}_{(aq)} + HCOOH_{(aq)}$ (Reactants favoured)

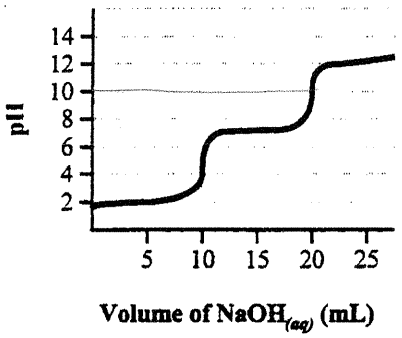
Numerical Response

20. Based on the reaction evidence, the four acids, ranked from strongest to weakest, are 4, 1, 2, and 3.

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

Use the following information to answer the next question.

A student sketched a titration curve based on data collected during a reaction between 0.050 mol/L $NaOH_{(aq)}$ and a 25.0 mL sample of a soft drink.



45. The most suitable indicator to identify the equivalence point of the second reaction is

A. phenolphthalein

B. bromothymol blue

C. methyl red

D. methyl orange

Equilibrium, Acids & Bases Review

Multiple Choice Key

1. **D**
2. **B**
3. **A**
4. **B**
5. **D**
6. **C**
7. **D**
8. **D**
9. **D**
10. **B**
11. **C**
12. **C**
13. **B**
14. **D**
15. **C**
16. **C**
17. **D**
18. **D**
19. **D**
20. **C**
21. **A**
22. **B**
23. **C**
24. **B**
25. **D**
26. **B**
27. **C**
28. **D**
29. **B**
30. **B**
31. **D**
32. **B**
33. **B**
34. **A**
35. **C**
36. **C**
37. **C**
38. **B**
39. **B**
40. **C**
41. **B**
42. **B**
43. **B**
44. **D**
45. **A**

Numerical Response Key

1. 2.14
2. 3.49
3. 1.79
4. 2413
5. 4213
6. 9206
7. 3241
8. 2.28
9. 16.4
10. 0.31
11. 2.64
12. 8.52
13. 1423
14. 11.3
15. 29.9
16. 1.47
17. 6.51 or 6.63
18. 3.26
19. 0.13
20. 4123