Chem Lab C - Chemistry Lab C - WSO State Tournament Div C - 04-17-2021

Instructions (shown before students start the test)

Chemistry Lab

Exam

2021

WISCONSIN

State Tournament

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Introduction (shown after students start the test)

Greetings Science Olympians,

This Chem Lab C Exam consists of **two** parts. The first is similar to a traditional wet lab experience, but you will be presented with online video data or data sets to interpret. The second part is a set of concept or calculation questions in a traditional online exam format.

The exam is worth a total of **400 points**. The **point value** for **each item** is listed (and some questions are worth **A LOT** more than others). The "lab" questions in general are worth more than the concept questions in the second part. Several of the "lab" questions will be used as tie breaker questions and ties will be broken depending on how accurate your "experimental results" are.

There are likely more questions in this exam than can be completed in the time allowed.

Be strategic and score as many points as possible in the time given!

Notes on video titration data:

In the video, the left hand camera shows a zoomed in view of the meniscus of the titrant in the 50 mL burette, the video follows the meniscus as the titrant is added. The right hand camera shows the bottom of the Erlenmeyer flask receiving the titrant.

(Due to the frame rate of the video the stir bar looks as if it is randomly wobbling, it is in fact spinning smoothly, ignore this video artifact)
(Again due to the frame rate of the video, you may not see the drops of titrant uniformly streaming into the flask, ignore this video artifact)

Video Controls: The video is hosted on YouTube, you should be able to pause and replay as needed to make your observations from the titration experiment. You can slow down the video using the "gear icon" at the bottom left and control the video position using the progress bar. Also you can zoom into the video using Ctrl + and Ctrl - and you can return to normal magnification with Ctrl 0

If you experience trouble loading the video titration data in a question, try using one of the following playlist links: **YouTube** **(https://youtube.com/playlist?list=PLJYULZTSGC_NHTAbLkPNZbDKwk_vbIOT0)**, **Vimeo** **(https://vimeo.com/showcase/8372349)**

Let's Begin . . .

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PART 1 "LAB" QUESTIONS

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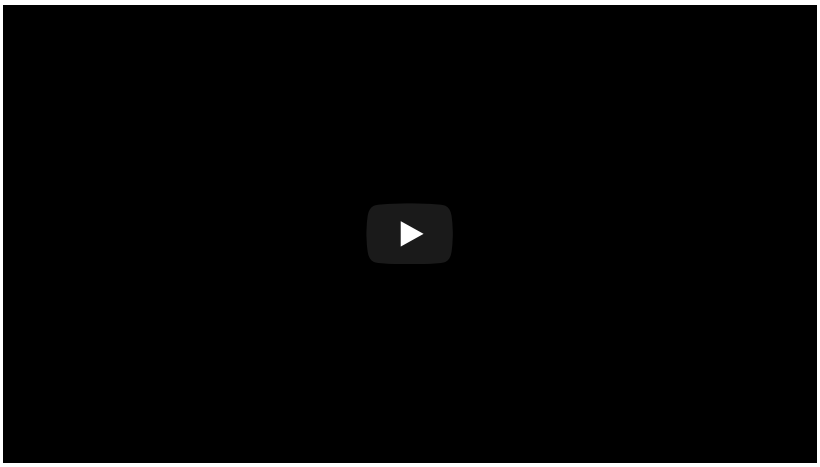
Video Titration 1: Use this video data to answer the next 5 questions

25.00 mL of **hydrochloric acid** of unknown concentration is transferred into a 250 mL Erlenmeyer flask with a volumetric pipette. 75 mL of de-ionized water is added along with 5 drops of phenolphthalein pH indicator solution.

The acid is titrated with **0.1877 M NaOH** solution. The video of the experiment is shown below:

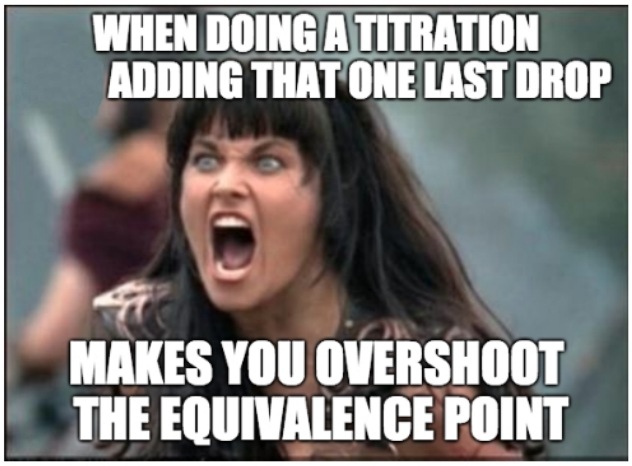


*(**Video Trouble?** Try watching on **YouTube** by clicking this link: **Titration 3356 (https://youtu.be/czOVb955ccA)**)*

1. (2.00 pts) **Video Titration 1:** What is the **initial burette reading**?

2. (5.00 pts) **Video Titration 1:** What is the **final burette reading** at the **equivalence point**?

(and please remember . . .)



3. (5.00 pts) **Video Titration 1:** How many **moles of base** were added to the Erlenmeyer flask to reach the equivalence point?

4. (10.00 pts) **Video Titration 1 (Tie-breaker Question):** Based on the titration data presented, what is the **molarity (M)** of the **unknown hydrochloric acid**?

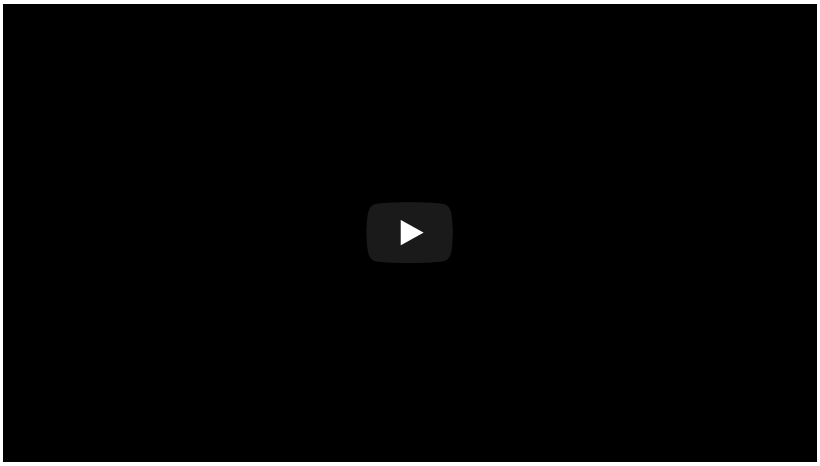
5. (5.00 pts) **Video Titration 1:** What is the approximate **pH** of the solution at the **equivalence point** of this titration?

- A) 4
- B) 5
- C) 6
- D) 7
- E) 8
- F) 9

Video Titration 2: Use this video data to answer the next 6 questions

0.5389 g of a solid **unknown monoprotic acid** was added to a 250 mL Erlenmeyer flask along with 100 mL of deionized water and 5 drops of phenolphthalein indicator solution. The unknown acid was swirled until the solid was fully dissolved.

The unknown acid solution was titrated with **0.1004 M NaOH** solution. The video of the experiment is shown below:



*(**Video Trouble?** Try watching on **YouTube** by clicking this link: **Titration 2750 (https://youtu.be/dvArPRgKAeY)**)*

6. (2.00 pts) **Video Titration 2:** What is the **initial burette reading**?

7. (5.00 pts) **Video Titration 2:** What is the **final burette reading** at the **equivalence point**?

8. (5.00 pts) **Video Titration 2:** How many **moles of base** were added to the Erlenmeyer flask to reach the equivalence point?

9. (10.00 pts)
Video Titration 2 (Tie-breaker Question): Based on the titration data presented, what is the **molecular weight** (or formula weight) of the **unknown monoprotic acid**?

10. (5.00 pts)
Video Titration 2: Based on the titration data presented, which one of the monoprotic acids listed below is the closest match to your calculated molecular weight and the likely identity of the unknown acid?

- ○ A) acetic acid (60 g/mol)

- B) butanoic acid (88 g/mol)
- C) pentanoic acid (102 g/mol)
- D) benzoic acid (122 g/mol)
- E) decanoic acid (172 g/mol)
- F) potassium hydrogen phthalate (204 g/mol)

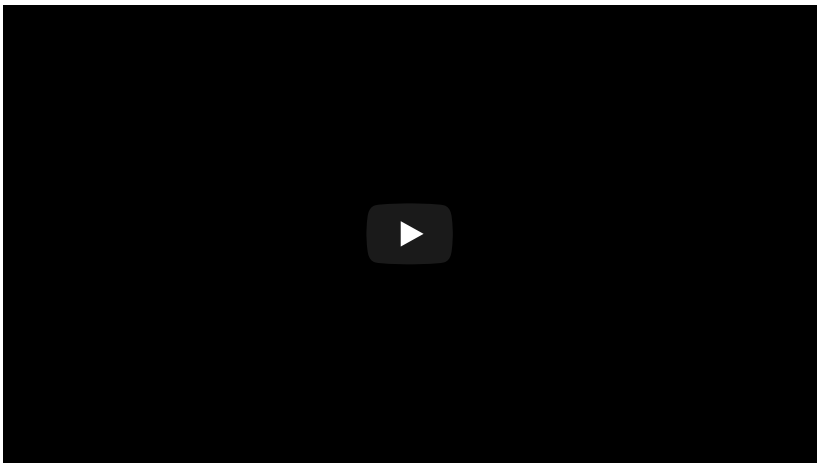
11. (10.00 pts)
Video Titration 2: HYPOTHETICAL SITUATION: If we re-ran the experiment presented in Video Titration 2 with a **different unknown monoprotic acid** by adding **0.2694 g** of solid to the Erlenmeyer flask and did everything else in the experiment the same, and got the exact same initial and final burette results, what would be the likely identity of the unknown acid based on the list of acids below?

- A) acetic acid (60 g/mol)
- B) butanoic acid (88 g/mol)
- C) pentanoic acid (102 g/mol)
- D) benzoic acid (122 g/mol)
- E) decanoic acid (172 g/mol)
- F) potassium hydrogen phthalate (204 g/mol)

Video Titration 3: Use this video data to answer the next 5 questions

10.00 mL of **nitric acid** of unknown concentration is transferred into a 250 mL Erlenmeyer flask with a volumetric pipette. 90 mL of de-ionized water is added along with 5 drops of **bromothymol blue** pH indicator solution**.**

The acid is titrated with **0.1004 M NaOH** solution. The video of the experiment is shown below:



(**Video Trouble?** Try watching on **YouTube** by clicking this link: **Titration 3980 (https://youtu.be/u8P1XMij9iM)**)

12. (2.00 pts) **Video Titration 3:** What is the **initial burette reading**?

13. (5.00 pts) **Video Titration 3:** What is the **final burette reading** at the **equivalence point**?

14. (5.00 pts) **Video Titration 3:** How many **moles of base** were added to the Erlenmeyer flask to reach the equivalence point?

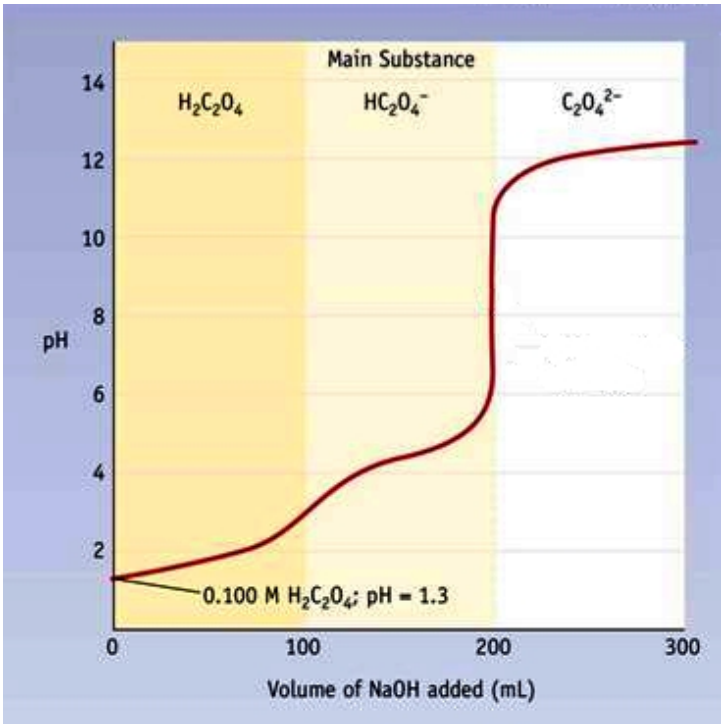
15. (10.00 pts) **Video Titration 3 (Tie-breaker Question):** Based on the titration data presented, what is the **molarity (M)** of the **unknown nitric acid**?

16. (5.00 pts) **Video Titration 3:** What is the approximate **pH** of the solution at the **equivalence point** of this titration?

- A) 4
- B) 5
- C) 6
- D) 7
- E) 8
- F) 9

Titration 4: Use this data to answer the next 6 questions

50.00 mL of **0.100 M oxalic acid** ($H_2C_2O_4$), a diprotic acid, was added to a 250 mL Erlenmeyer flask. The acid was titrated with sodium hydroxide of unknown concentration. The progress of the titration was monitored with a pH meter and the resulting plot of pH as a function of added NaOH solution is shown below:



17. (3.00 pts) **Titration 4:** How many **moles** of **oxalic acid** were added to the flask in this experiment to produce the titration curve shown?

- A) 0.0010 moles
- B) 0.0050 moles
- C) 0.0100 moles
- D) 0.0500 moles
- E) 0.1000 moles
- F) 0.5000 moles

18. (3.00 pts) **Titration 4:** How many **equivalents** of **acidic proton** were added to the flask?

- A) 0.0010 equivalents
- B) 0.0050 equivalents
- C) 0.0100 equivalents
- D) 0.0500 equivalents
- E) 0.1000 equivalents
- F) 0.5000 equivalents

19. (5.00 pts) **Titration 4:** How many **mL** of **NaOH titrant** were added to achieve the **complete neutralization** of the oxalic acid?

- A) 50 mL
- B) 100 mL
- C) 150 mL
- D) 200 mL
- E) 250 mL
- F) 300 mL

20. (5.00 pts) **Titration 4:** What is the **approximate pH** of the solution at the **second equivalence point**?

- A) 4
- B) 5
- C) 6
- D) 7
- E) 8
- F) 9

21. (10.00 pts) **Titration 4:** What is the **molarity (M)** of the **NaOH titrant**?

- A) 0.0010 M
- B) 0.0050 M
- C) 0.0100 M
- D) 0.0500 M
- E) 0.1000 M
- F) 0.5000 M

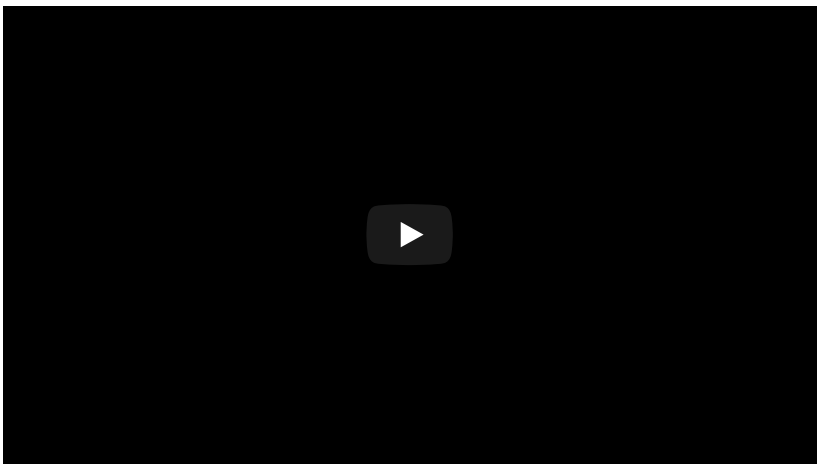
22. (5.00 pts) **Titration 4:** Based on the titration curve, what is the **approximate pKa** of the second proton to be removed from oxalic acid?

- A) 1.5
- B) 2.5
- C) 3.5
- D) 4.5
- E) 5.5
- F) 6.5

Video Titration 5: Use this video data to answer the next 7 questions

An **UNKNOWN** solid mixture of **benzoic acid** (a monoprotic acid, MW = 122 g/mol) and **sodium chloride** was obtained. **0.9782 g** of this solid mixture was added to a 250 mL Erlenmeyer flask and completely dissolved in **100 mL** of deionized water. **5 drops** of **phenolphthalein** indicator solution were added to the flask.

The resulting unknown acid solution was titrated with **0.1872 M NaOH** solution. The video of the experiment is shown below:



*(**Video Trouble?** Try watching on **YouTube** by clicking this link: **Titration 1111 (https://youtu.be/QheeFLeieFY)**)*

23. (2.00 pts) **Video Titration 5:** What is the **initial burette reading**?

24. (5.00 pts) **Video Titration 5:** What is the **final burette reading** at the **equivalence point**?

25. (5.00 pts) **Video Titration 5:** How many **moles of base** were added to the Erlenmeyer flask to reach the equivalence point?

26. (10.00 pts) **Video Titration 5 (Tie-breaker Question):** Based on the titration data presented, **how many grams** of **benzoic acid** were added to the Erlenmeyer flask?

27. (10.00 pts) **Video Titration 5:** Which of the following choices below is closest to the **percent composition by weight** of **benzoic acid** in the unknown solid mixture?

In other words, there is approximately _____ by weight benzoic acid in the unknown solid mixture.

- ○ A) 10 %
- ○ B) 20 %

- C) 30 %
- D) 40 %
- E) 50 %
- F) 60 %

28. (10.00 pts)
Video Titration 5: HYPOTHETICAL SITUATION: If we discovered that the UNKNOWN solid mixture that we titrated was in fact comprised of **pentanoic acid** (a monoprotic acid, MW = 102 g/mol) and **sodium chloride** (instead of benzoic acid and sodium chloride as stated above), which of the following choices below would be closest to the **percent composition by weight of pentanoic acid** in the unknown solid mixture?

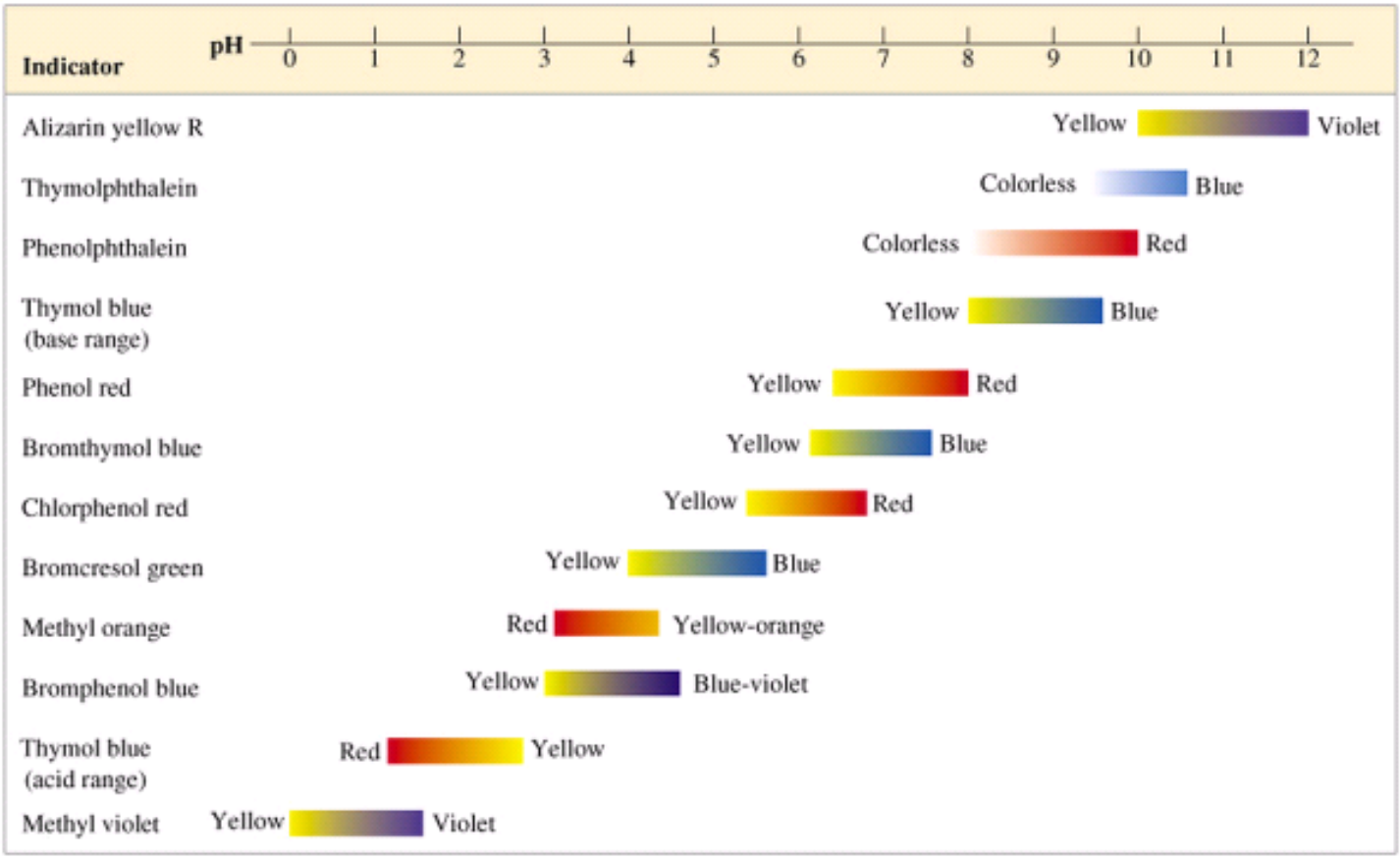
- A) 10 %
- B) 20 %
- C) 30 %
- D) 40 %
- E) 50 %
- F) 60 %

29. (20.00 pts)
Video Titration 5: (Tie-breaker Question) HYPOTHETICAL SITUATION: If it was discovered that the UNKNOWN solid mixture that was titrated was in fact comprised of **potassium hydrogen phthalate** (a monoprotic acid, MW = 204 g/mol) and **sodium chloride** (instead of benzoic acid and sodium chloride as stated above), **what would we conclude about the composition of the unknown solid mixture?**

(please limit your answer to 1000 words or less)

"Here. We promised you a big lab."

pH Indicators



30. (5.00 pts)
An unknown aqueous sample is tested to determine it's approximate pH with pH indicators. The sample is divided into 4 test tubes. Indicator solutions were added with the results summarized below, the resulting **COLOR** is shown after each indicator. What is the approximate pH of the unknown solution?

Tube 1: Bromothymol blue: **YELLOW**

Tube 2: Thymol blue: **YELLOW**

Tube 3: Bromphenol blue: **YELLOW**

Tube 4: Chlorphenol red: **YELLOW**

- A) 2
- B) 4
- C) 6
- D) 8
- E) 10
- F) 12

31. (5.00 pts)
An unknown aqueous sample is tested to determine it's approximate pH with pH indicators. The sample is divided into 4 test tubes. Indicator solutions were added with the results summarized below, the resulting **COLOR** is shown after each indicator. What is the approximate pH of the unknown solution?

Tube 1: Bromothymol blue: **BLUE**

Tube 2: Thymol blue: **BLUE**

Tube 3: Phenolphthalein: **RED**

Tube 4: Alizarin yellow R: **YELLOW**

- A) 2
- B) 4
- C) 6
- D) 8
- E) 10
- F) 12

32. (5.00 pts)
An unknown aqueous sample is tested to determine it's approximate pH with pH indicators. The sample is divided into 4 test tubes. Indicator solutions were added with the results summarized below, the resulting **COLOR** is shown after each indicator. What is the approximate pH of the unknown solution?

Tube 1: Bromothymol blue: **YELLOW**

Tube 2: Thymol blue: **YELLOW**

Tube 3: Bromcresol green: **BLUE**

Tube 4: Bromphenol blue: **BLUE-VIOLET**

- A) 2
- B) 4
- C) 6
- D) 8
- E) 10
- F) 12

33. (5.00 pts)
An unknown aqueous sample is tested to determine it's approximate pH with pH indicators. The sample is divided into 4 test tubes. Indicator solutions were added with the results summarized below, the resulting **COLOR** is shown after each indicator. What is the approximate pH of the unknown solution?

Tube 1: Bromothymol blue: **BLUE**

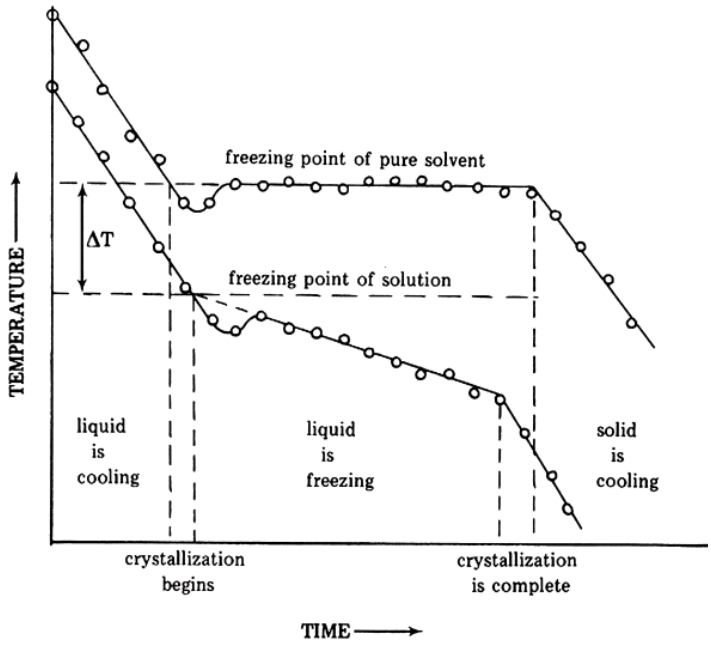
Tube 2: Thymol blue: **YELLOW**

Tube 3: Bromcresol green: **BLUE**

Tube 4: Phenol red: **RED**

- A) 2
- B) 4
- C) 6
- D) 8
- E) 10
- F) 12

Freezing Point Depression



34. (10.00 pts)
Pure camphor has a freezing point of **178.40 degrees Celsius**. The **molal** freezing point depression constant, **Kf,** for camphor is **37.7 degrees Celsius per molal**.

A solution is made by dissolving **0.840 g** of an unknown substance in **25.0 g** of molten (liquid) **camphor**. The resulting **solution** had a **freezing point** of **170.80 degrees Celsius**.

What is the **molecular weight** of the **unknown substance**?

- A) 23 g/mol
- B) 67 g/mol
- C) 100 g/mol
- D) 123 g/mol
- E) 167 g/mol
- F) none of the above

35. (3.00 pts) A salt solution is made by dissolving **31.65 g** of **sodium chloride** in **220.0 mL** of **water**. What is the **freezing point** of this solution in **degrees Celsius**?

NOTE: The **molal freezing point depression constant**, **Kf** , for water is **1.86°C/m**

- A) **0 °C**
- B) **-1.2 °C**
- C) **-2.3 °C**
- D) **-4.2 °C**
- E) **-9.2 °C**
- F) **-18.4 °C**

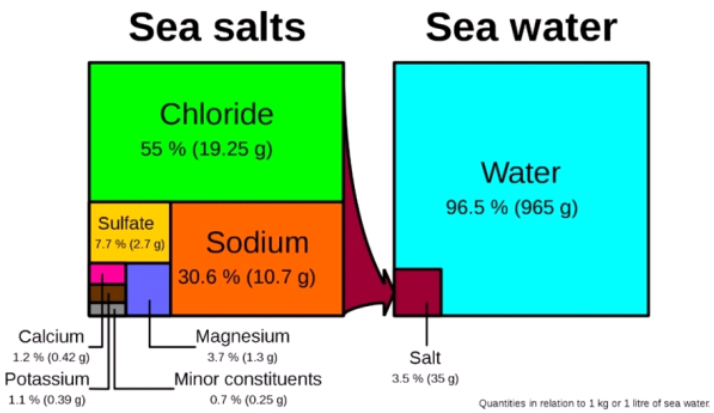
36. (20.00 pts)
(Tie-breaker Question) A 7.00 mile stretch of Wisconsin two lane highway (25.0 ft wide) is covered with a quarter inch (0.25 in) thick layer of ice. The density of ice is 0.9167 g/cm³ and the density of water is 0.9998 g/cm³. The weather forecast predicts an overnight low of **15.0 °F**. Theoretically, how many **kilograms of NaCl(s)** rock salt need to be evenly distributed on the stretch of road to completely melt all of the ice and keep it melted overnight (assuming no water drains off of the road resulting in loss of salt)?

Use this data to answer the next 2 questions

Sea water has an average salinity of 3.5 % by mass (35 g/Kg solution). Based on the data listed below, answer the following two questions:

the molal freezing point depression constant for water, ***K_f = 1.86 °C/m***

the molal boiling point elevation constant for water, ***K_b = 0.512 °C/m***



Component	Concentration (mol/kg)
H_2O	53.6
Cl^-	0.546
Na^+	0.469
Mg^{2+}	0.0528
SO_4^{2-}	0.0282
Ca^{2+}	0.0103
K^+	0.0102
C_T	0.00206
Br^-	0.000844
B_T	0.000416
Sr^{2+}	0.000091
F^-	0.000068

NOTE: $C_T = [CO_2] + [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$

$B_T = [H_3BO_3] + [H_2BO_3^-]$

37. (10.00 pts) **(Tie-breaker Question)** **Based on the data above**, at what temperature does sea water **freeze**? Calculate your answer and enter in the space below:

38. (10.00 pts) **(Tie-breaker Question)** **Based on the data above**, at what temperature does sea water **boil**? Calculate your answer and enter in the space below:

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PART 2 CONCEPT AND CALCULATION QUESTIONS

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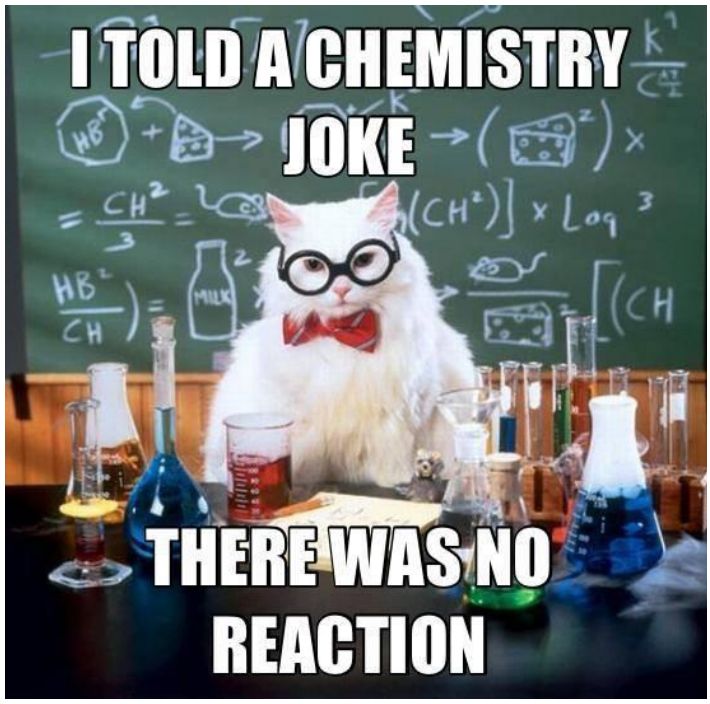


Monatomic and Polyatomic Ions

39. (2.00 pts) What is the correct symbol and charge for the **nitrate** ion?

A) NO_2^- B) NO_3^- C) NO_2^{2-}

D) NO_3^{2-} E) NO_2^{3-} F) NO_3^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

40. (2.00 pts) What is the correct symbol and charge for the **nitrite** ion?

A) NO_2^- B) NO_3^- C) NO_2^{2-}

D) NO_3^{2-} E) NO_2^{3-} F) NO_3^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

41. (2.00 pts) What is the correct symbol and charge for the **sulfate** ion?

A) SO_3^- B) SO_4^- C) SO_3^{2-}

D) SO_4^{2-} E) SO_3^{3-} F) SO_4^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

42. (2.00 pts) What is the correct symbol and charge for the **sulfite** ion?

A) SO_3^- B) SO_4^- C) SO_3^{2-}

D) SO_4^{2-} E) SO_3^{3-} F) SO_4^{3-}

- A) **A**
- B) **B**

- C) **C**
- D) **D**
- E) **E**
- F) **F**

43. (2.00 pts) What is the correct symbol and charge for the **phosphate** ion?

A) PO_3^- **B)** PO_4^- **C)** PO_3^{2-}

D) PO_4^{2-} **E)** PO_3^{3-} **F)** PO_4^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

44. (2.00 pts) What is the correct symbol and charge for the **phosphite** ion?

A) PO_3^- **B)** PO_4^- **C)** PO_3^{2-}

D) PO_4^{2-} **E)** PO_3^{3-} **F)** PO_4^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

45. (2.00 pts) What is the correct symbol and charge for the **acetate** ion?

A) $CH_3CO_2^-$ **B)** $CH_3CO_3^-$ **C)** $CH_3CO_2^{2-}$

D) $CH_3CO_3^{2-}$ **E)** $CH_3CO_2^{3-}$ **F)** $CH_3CO_3^{3-}$

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

46. (2.00 pts) What is the correct symbol and charge for the **ammonium** ion?

A) NH_2^- B) NH_3^- C) NH_4^-

D) NH_2^+ E) NH_3^+ F) NH_4^+

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

47. (2.00 pts) What is the correct symbol and charge for the **carbonate** ion?

A) CO_2^- B) CO_3^- C) CO_2^{2-}

D) CO_3^{2-} E) CO_2^{3-} F) CO_3^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

48. (2.00 pts) What is the correct symbol and charge for the **bicarbonate** ion?

A) HCO_2^- B) HCO_3^- C) HCO_2^{2-}

D) HCO_3^{2-} E) HCO_2^{3-} F) HCO_3^{3-}

- A) **A**
- B) **B**
- C) **C**
- D) **D**
- E) **E**
- F) **F**

49. (2.00 pts) What is the charge for a monatomic **aluminum** ion?

- A) 3+
- B) 2+
- C) 1+
- D) 1-
- E) 2-
- F) 3-

50. (2.00 pts) What is the charge for a monatomic **calcium** ion?

- A) 3+
- B) 2+
- C) 1+
- D) 1-
- E) 2-
- F) 3-

51. (2.00 pts) What is the charge for a monatomic **oxide** ion?

- A) **3+**
- B) **2+**
- C) **1+**
- D) **1-**
- E) **2-**
- F) **3-**

52. (2.00 pts) What is the charge for a monatomic **sulfide** ion?

- A) **3+**
- B) **2+**
- C) **1+**
- D) **1-**
- E) **2-**
- F) **3-**

53. (2.00 pts) What is the charge for a monatomic **fluoride** ion?

- A) **3+**
- B) **2+**
- C) **1+**
- D) **1-**
- E) **2-**
- F) **3-**

54. (2.00 pts) What is the charge for a monatomic **nitride** ion?

- A) **3+**
- B) **2+**
- C) **1+**
- D) **1-**
- E) **2-**
- F) **3-**

Concentration Units

55. (5.00 pts) **10 grams** of **magnesium nitrate** is completely dissolved in **100.0 mL** of deionized H_2O in a 100 mL volumetric flask.

What is the **molarity** of the resulting magnesium nitrate solution?

- A) 0.438 M
- B) 0.674 M
- C) 0.858 M
- D) 0.986 M
- E) 1.046 M
- F) 1.147 M

56. (5.00 pts) A copper solution is prepared with a **Cu^{2+}** ion concentration of **3.0×10^{-4} M**. What is this concentration in **ppm** of **Cu^{2+} ion**?

- A) .0003
- B) .19
- C) 3
- D) 19
- E) 30
- F) 1900

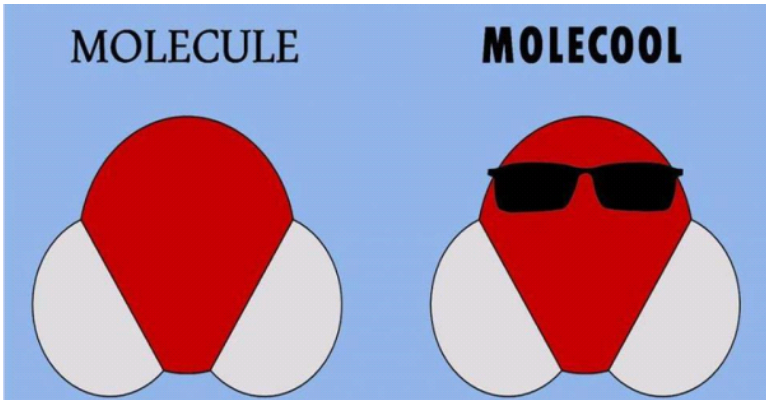
57. (5.00 pts) **15.0 g** of **sucrose** (342.30 g/mol) is added to **2.50 kg** of **water**. What is the concentration of sucrose in **mass percentage**?

- A) 0.0006 %
- B) 0.006 %
- C) 0.06 %
- D) 0.6 %
- E) 6 %
- F) 60 %

58. (5.00 pts) **15.0 g** of **sucrose** (342.30 g/mol) is added to 2.50 kg of water. What is the concentration of sucrose in **molality**?

- A) 0.0438 m
- B) 0.0175 m
- C) 0.109 m
- D) 0.000018 m
- E) 109 m
- F) 0.025 m

Freezing Point Depression, Boiling Point Elevation



59. (5.00 pts) A solution is prepared by dissolving **10.0 g** of an ionic solid in **1.00 kg** of **water**.

Dissolving which ionic solid below would result in the **LOWEST freezing point** for the resulting solution?

- A) aluminum sulfate
- B) lithium fluoride
- C) calcium chloride
- D) potassium bromide
- E) sodium chloride
- F) magnesium nitrate

60. (5.00 pts) A solution is prepared by dissolving **0.100 moles** of an ionic solid in **1.00 kg** of water.

Dissolving which ionic solid below would result in the **LOWEST freezing point** for the resulting solution?

- A) aluminum sulfate
- B) lithium fluoride
- C) calcium chloride
- D) potassium bromide
- E) sodium chloride
- F) magnesium nitrate

61. (5.00 pts) A solution is prepared by dissolving **10.0 g** of an ionic solid in **1.00 kg** of water.

Dissolving which ionic solid below would result in the LOWEST boiling point for the resulting solution?

- A) aluminum sulfate
- B) lithium fluoride
- C) calcium chloride
- D) potassium bromide
- E) sodium chloride
- F) magnesium nitrate

62. (5.00 pts) A solution is prepared by dissolving **0.100 moles** of an ionic solid in **1.00 kg** of water.

Dissolving which ionic solid below would result in the **LOWEST boiling point** for the resulting solution?

- A) aluminum sulfate
- B) lithium fluoride
- C) calcium chloride
- D) aluminum bromide
- E) sodium sulfate
- F) magnesium nitrate

Ions, Concentrations, Yields

63. (1.00 pts) How many **bromide ions** are in **0.55 g** of **iron(III) bromide**?

- A) 1.1 × 10^21 ions
- B) 3.4 × 10^21 ions
- C) 3.3 × 10^23 ions
- D) 9.9 × 10^23 ions
- E) 2.9 × 10^26 ions
- F) 9.9 × 10^26 ions

64. (1.00 pts) A sample of an unknown molecular compound contains **8.35 × 10^21 molecules** and has a **mass** of **1.00 g**

what is the **molar mass** of the unknown compound?

- A) 44.0 g/mol
- B) 66.4 g/mol
- C) 72.1 g/mol
- D) 98.1 g/mol
- E) 132 g/mol
- F) 171 g/mol

65. (2.00 pts)
The reaction of **elemental chlorine** with **potassium iodide** yields **elemental iodine** and **potassium chloride**. Which chemical equation shown below is correct for this reaction?

- A) $Cl2(g) + KI(s) \rightarrow I(s) + KCl2(s)$
- B) $Cl2(g) + 2\ KI(s) \rightarrow I2(s) + 2\ KCl(s)$
- C) $Cl2(g) + KI2(s) \rightarrow I2(s) + KCl2(s)$
- D) $Cl(g) + KI(s) \rightarrow I(s) + KCl(s)$
- E) $Cl2(g) + 2\ K2I(s) \rightarrow I2(s) + 2\ K2Cl(s)$

66. (1.00 pts) Which of the following statements is/are correct?

1. All ionic compounds that are soluble in water are electrolytes.
2. All ionic compounds dissolve in water.
3. Molecular compounds are never soluble in water.

- A) 1 only
- B) 2 only
- C) 3 only
- D) 1 and 2

○ E) 2 and 3

67. (1.00 pts) Which of the following statements is/are correct?

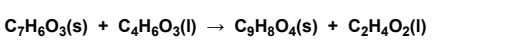
1. Water soluble ionic compounds, such as NaCl, are strong electrolytes.
2. Some molecular compounds, such as HCl, are strong electrolytes.
3. Some molecular compounds, such as acetic acid, are weak electrolytes.

○ A) 1 only
○ B) 2 only
○ C) 3 only
○ D) 1 and 2
○ E) 1, 2, and 3
○ F) none of the statements are correct

68. (1.00 pts) **Hydrogen peroxide** decomposes into oxygen and water. What **mass of oxygen** is formed from the decomposition of **125 g of H_2O_2**?

○ A) 58.8 g
○ B) 66.4 g
○ C) 107 g
○ D) 118 g
○ E) 125 g
○ F) 137 g

69. (2.00 pts) **Aspirin ($C_9H_8O_4$)** is produced by the reaction of **salicylic acid** (MW = 138.1 g/mol) and **acetic anhydride** (MW = 102.1 g/mol).



If you mix **2.00 grams** of each reactant, what **mass of aspirin** (MW = 180.2 g/mol) can theoretically by obtained?

○ A) 2.00 g
○ B) 2.61 g
○ C) 2.71 g
○ D) 3.53 g
○ E) 4.00 g
○ F) 4.50 g

70. (1.00 pts)
Under certain conditions the reaction of **ammonia** with **excess oxygen** will produce a **24.8%** yield of **NO**. What mass of **NH_3** must react with **excess oxygen** to yield **12.5 g NO**?

○ A) 1.76 g
○ B) 7.10 g
○ C) 28.6 g
○ D) 50.4 g
○ E) 88.8 g
○ F) 102 g

71. (1.00 pts) How many **liters** of **0.2805 M $C_6H_{12}O_6$**(aq) contain **10.00 g** of **$C_6H_{12}O_6$**?

- A) 0.198 L
- B) 50.5 L
- C) 3.565 L
- D) 0.2805 L
- E) 0.01979 L
- F) 0.001557 L

72. (1.00 pts) If **1.717 g $Fe(NO_3)_3$** is dissolved in enough water to make exactly **150.0 mL** of solution, what is the molar concentration of nitrate ion?

- A) 0.0218 M
- B) 0.426 M
- C) 0.313 M
- D) 0.142 M
- E) 0.0343 M
- F) 0.00319 M

73. (1.00 pts) If **25.00 mL** of **4.50 M NaOH(aq)** is diluted with water to a volume of **375.0 mL**, what is the **molarity** of the **diluted NaOH(aq)**?

- A) 1.35 × 10^3 M
- B) 6.67 M
- C) 0.300 M
- D) 0.150 M
- E) 0.0333 M
- F) 0.0150 M

pH

74. (3.00 pts) What is the **pH** of **0.51 M HCl (aq)**?

- A) 0.67
- B) 0.51
- C) 0.31
- D) 0.29
- E) -0.29
- F) 1.15

75. (3.00 pts) What is the **pH** of **0.0125 M HNO_3** (aq)?

- A) 0.0125
- B) 0.190
- C) 0.125
- D) 1.25
- E) 1.90
- F) 2.25

76. (3.00 pts) What is the **pH** of **0.00031 M HCl (aq)**?

- A) 1.0
- B) 1.5
- C) 2.0
- D) 2.5
- E) 3.0
- F) 3.5

77. (2.00 pts) The pH of an aqueous NaOH solution is **13.17**. What is the **hydrogen ion concentration** of this solution?

- A) 6.8 × 10^-14 M
- B) 1.9 × 10^-6 M
- C) 0.89 M
- D) 1.1 M
- E) 1.5 × 10^13 M
- F) 1.0 M

78. (2.00 pts) The **pH** of a vinegar solution is **4.15**. What is the **H_3O^+ concentration** of the solution?

- A) 1.4 × 10^4 M
- B) 1.4 M
- C) 0.62 M
- D) 1.6 × 10^-2 M
- E) 7.1 × 10^-5 M
- F) 9.3 × 10^-8 M

K_a, K_b, Buffers

79. (2.00 pts) What is the pH of a solution that results from diluting 0.50 mol formic acid (HCO_2H) and 0.10 mol sodium formate ($NaHCO_2$) with water to a volume of 1.0 L? (K_a of $HCO_2H = 1.8 \times 10^{-4}$)

- A) 4.44
- B) 3.98
- C) 3.74
- D) 3.05
- E) 2.22
- F) 1.75

80. (2.00 pts) What is the pH of a solution that results from adding 50.0 mL of 0.100 M HCl to 50.0 mL of 0.330 M NH_3? (K_b of $NH_3 = 1.8 \times 10^{-5}$)

- A) 13.02
- B) 11.16
- C) 9.62
- D) 4.38
- E) 1.30
- F) 1.00

81. (2.00 pts) What is the pH of a solution that results from adding 25 mL of 0.50 M NaOH to 75 mL of 0.50 M CH_3CO_2H? (K_a of $CH_3CO_2H = 1.8 \times 10^{-5}$)

- A) 13.50
- B) 13.10
- C) 9.26
- D) 5.05
- E) 4.74
- F) 4.44

82. (2.00 pts) What is the pH of an aqueous solution composed of 0.30 M HF and 0.10 M F^-? (K_a of $HF = 7.2 \times 10^{-4}$)

- A) 8.30
- B) 6.99
- C) 3.62
- D) 2.67
- E) 1.83
- F) 0.477

83. (2.00 pts) All of the following statements concerning acid-base buffers are true EXCEPT

- A) buffers are resistant pH changes upon addition of small quantities of strong acids or bases.
- B) buffers are used as colored indicators in acid-base titrations.

- C) the pH of a buffer is close to the pKa of the weak acid from which it is made.
- D) buffers contain appreciable quantities of a weak acid and its conjugate base.
- E) buffers are resistant to changes in pH when diluted with water.

84. (2.00 pts) Which of the following mathematical expressions is the Henderson-Hasselbalch equation?

a) $pK_a = pH + \log\left(\frac{[\text{conjugate base}]}{[\text{acid}]}\right)$

b) $pH = pK_a + \log\left(\frac{[OH^-]}{[H_3O^+]}\right)$

c) $pH = pK_a + \log\left(\frac{[\text{acid}]}{[\text{conjugate base}]}\right)$

d) $pK_a = pH + \log\left(\frac{[OH^-]}{[H_3O^+]}\right)$

e) $pH = pK_a + \log\left(\frac{[\text{conjugate base}]}{[\text{acid}]}\right)$

- A) a
- B) b
- C) c
- D) d
- E) e

85. (2.00 pts) What is the pH of a buffer composed of 0.50 M $H_2PO_4^-$(aq) and 0.30 M HPO_4^{2-}(aq)? (K_a of $H_2PO_4^-$ is 6.2×10^{-8})

- A) 7.43
- B) 7.20
- C) 6.99
- D) 6.81
- E) 4.32
- F) 3.69

86. (2.00 pts) What is the pH of the buffer that results when 15.0 g of NaH_2PO_4 and 15.0 g of Na_2HPO_4 are diluted with water to a volume of 0.50 L? (K_a of $H_2PO_4^-$ = 6.2×10^{-8}, the molar masses of NaH_2PO_4 and Na_2HPO_4 are 120.0 g/mol and 142.0 mol, respectively)

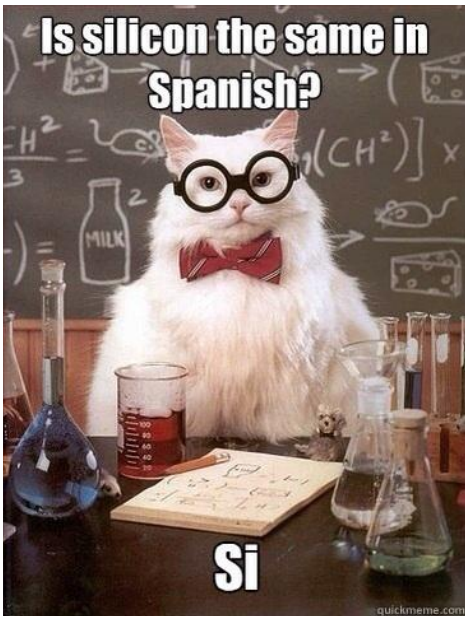
- A) 8.30
- B) 8.03
- C) 7.29
- D) 7.24
- E) 7.13
- F) 6.89

87. (2.00 pts) What is the pH of the buffer that results when 12 g sodium formate ($NaHCO_2$) is mixed with 250 mL of 0.50 M formic acid (HCO_2H) and diluted with water to 1.0 L? (K_a of HCO_2H = 1.8×10^{-4})

- A) 3.20
- B) 3.55
- C) 3.71
- D) 3.89
- E) 5.10
- F) 4.76

88. (2.00 pts) What is the pH of a buffer that results when 0.50 mole of H_3PO_4 is mixed with 0.25 mole of NaOH and diluted with water to 1.00 L? (The acid dissociation constants of phosphoric acid are $K_{a1} = 7.5 \times 10^{-3}$, $K_{a2} = 6.2 \times 10^{-8}$, and $K_{a3} = 3.6 \times 10^{-13}$)

- A) 1.80
- B) 2.12
- C) 6.87
- D) 7.30
- E) 9.95
- F) 12.42



General Questions

89. (1.00 pts) Which of the following **balanced chemical equations** is correct for the complete **neutralization of H_2SO_4 by KOH** in aqueous solution?

- A) 2H+ (aq) + 2OH- (aq) → 2 H2O (l)
- B) 2H+ (aq) + 2KOH (aq) → 2 H2O (l) + 2K+ (aq)
- C) H2SO4 (aq) + 2OH- (aq) → 2 H2O (l) + SO42- (aq)
- D) H2SO4 (aq) + 2KOH (aq) → 2 H2O (l) + K2SO4 (s)
- E) H2SO4 (aq) + 2KOH (aq) → 2 H2O (l) + K2SO4 (aq)

90. (1.00 pts) For a **0.193 M** solution of **barium iodide**, what is the concentration of **iodide ions**?

- A) 0.193 M
- B) 0.386 M
- C) 0.0965 M
- D) 0.579 M
- E) 0.0643 M

91. (1.00 pts)
In a solution that has a concentration of **2.104 M sodium sulfate**, the concentration of **sodium ion** is **_____ M**, and the concentration of **sulfate ion** is **_____ M**

- A) 2.104, 1.052
- B) 2.104, 2.104
- C) 2.104, 4.208
- D) 1.052, 1.052
- E) 4.208, 2.104

92. (1.00 pts) A solution is prepared by combining **0.500 moles** of **$HC_2H_3O_2$** with enough water to make a **300.0 mL** solution.

What is the concentration of $HC_2H_3O_2$ in the resulting solution?

- A) 3.33 M
- B) 1.67 M
- C) 0.835 M
- D) 0.00167 M
- E) 0.150 M

93. (1.00 pts) How many **mL** of **0.827 M KOH** solution are required to completely neutralize **35.00 mL** of **0.737 M H_2SO_4** ?

- A) 35.0
- B) 1.10
- C) 25.2
- D) 62.4
- E) 39.3
- F) 57.9

94. (1.00 pts)
Determine the percent of **oxalic acid** ($H_2C_2O_4$) in an **unknown solid mixture** given that a **0.7984-g** sample of that solid required **37.98 mL** of **0.2283 M NaOH** for neutralization.

(Remember, oxalic acid is a diprotic acid)

- A) 48.89
- B) 96.72
- C) 29.09
- D) 2.22
- E) 22.80
- F) 14.90

95. (1.00 pts) The concentration of **sulfate ions** in a **0.233 M** solution of **sulfuric acid** is _____.

- A) 0.699 M
- B) 0.233 M
- C) 0.466 M
- D) 0.0777 M
- E) 0.155 M

96. (1.00 pts)
If a solid material contains **53.66 percent of oxalic acid** ($H_2C_2O_4$), by mass, then a **0.3272 g** sample of that solid will require _____ mL of **0.3483 M NaOH** for neutralization.

- A) 11.19
- B) 97.78
- C) 28.59
- D) 1.119
- E) 22.39
- F) 11.20

97. (1.00 pts) The concentration of **chloride ions** in a **0.0193 M** solution of **potassium chloride** is _____.

- A) 0.0643 M
- B) 0.386 M
- C) 0.0965 M
- D) 0.579 M
- E) 0.193 M
- F) 0.0193 M

98. (1.00 pts) The **molarity** of a solution prepared by diluting **87.44 mL** of **5.005 M** aqueous **$K_2Cr_2O_7$** to **500.0 mL** is _____.

- A) 57.2
- B) 0.0044
- C) 0.438
- D) 0.0879
- E) 0.875
- F) 0.998

99. (1.00 pts)
A **17.5 mL** sample of an **acetic acid** (CH_3CO_2H) solution required **29.6 mL** of **0.500 M NaOH** for neutralization. The concentration of **acetic acid** was **_____ M**.

- A) 0.158
- B) 0.423
- C) 0.846
- D) 6.88
- E) 0.214
- F) 134

100. (1.00 pts)
A **25.5 mL** aliquot of **HCl (aq)** of unknown concentration was titrated with **0.05650 M NaOH (aq)**. It took **51.2 mL** of the base to reach the endpoint of the titration. The **concentration (M)** of the acid was _____.

- A) 1.02
- B) 0.113
- C) 0.454
- D) 0.124
- E) 0.227
- F) 0.356

101. (1.00 pts)
A **31.5 mL** aliquot of **HNO_3 (aq)** of unknown concentration was titrated with **0.0268 M NaOH (aq)**. It took **23.9 mL** of the base to reach the endpoint of the titration. The **concentration (M)** of the **acid** was _____.

- A) 0.0102
- B) 0.0051
- C) 0.0203
- D) 0.227
- E) 1.02
- F) 2.06

102. (1.00 pts)
A **31.5 mL** aliquot of H_2SO_4 (aq) of **unknown concentration** was titrated with **0.0134 M NaOH** (aq). It took **23.9 mL** of the base to reach the endpoint of the titration. What was the concentration (M) of the acid?

- A) 0.0102 M
- B) 0.00508 M
- C) 0.0204 M
- D) 0.102 M
- E) 0.227 M

103. (1.00 pts) The total concentration of **ions** in a **0.625 M** solution of **HCl** is _____.

- A) 0 M
- B) 0.500 M
- C) 0.625 M
- D) 1.25 M
- E) 1.50 M

104. (1.00 pts) What is the **molarity** of a **NaOH** solution if **28.2 mL** of a **0.355 M H_2SO_4** solution is required to neutralize a **25.0-mL sample** of the NaOH solution?

- A) 0.801
- B) 0.315
- C) 0.629
- D) 125
- E) 0.400

105. (1.00 pts) Calculate the number of **grams of solute** in **500.0 mL** of **0.189 M KOH**.

- A) 148
- B) 1.68
- C) 5.30 × 10^3
- D) 5.30
- E) 1.68 × 10^-3

106. (1.00 pts) How many **milliliters** of **0.132 M $HClO_4$** solution are needed to neutralize **50.00 mL** of **0.0789 M NaOH**?

- A) 0.521
- B) 0.0120
- C) 83.7
- D) 0.0335
- E) 29.9

107. (1.00 pts) A solution contains **28% phosphoric acid by mass**. This means that _____.

- A) 1 mL of this solution contains 28 g of phosphoric acid
- B) 1 L of this solution has a mass of 28 g
- C) 100 g of this solution contains 28 g of phosphoric acid
- D) 1 L of this solution contains 28 mL of phosphoric acid
- E) the density of this solution is 2.8 g/mL

108. (1.00 pts) Calculate the **molality** of a **10.0% (by mass)** aqueous solution of **hydrochloric acid**.

- A) 0.274 m
- B) 2.74 m
- C) 3.05 m

D) 4.33 m

E) The density of the solution is needed to solve the problem.

109. (1.00 pts) Calculate the **mole fraction** of **HCl** in a **10.0% (by mass)** aqueous solution.

A) 0.00111

B) 0.0344

C) 0.0520

D) 0.0548

E) 0.122

110. (1.00 pts) **Molality** is defined as the _____.

A) moles solute/moles solvent

B) moles solute/liters solution

C) moles solute/kg solution

D) moles solute/kg solvent

E) none (dimensionless)

111. (1.00 pts) A solution contains **11% by mass of sodium chloride**. This means that _____.

A) there are 11 g of sodium chloride in in 1.0 mL of this solution

B) 100 g of the solution contains 11 g of sodium chloride

C) 100 mL of the solution contains 11 g of sodium chloride

D) the density of the solution is 11 g/mL

E) the molality of the solution is 11

112. (1.00 pts)
A solution is prepared by dissolving **15.0 g** of **NH_3** in **250.0 g** of **water**. The density of the resulting solution is **0.974 g/mL**. The **molarity** of NH_3 in the solution is _____.

A) 0.00353

B) 0.882

C) 60.0

D) 3.24

E) 3.53

113. (1.00 pts) What is the **molality** of **sodium chloride** in solution that is **13.0% by mass** sodium chloride and that has a density of **1.10 g/mL**?

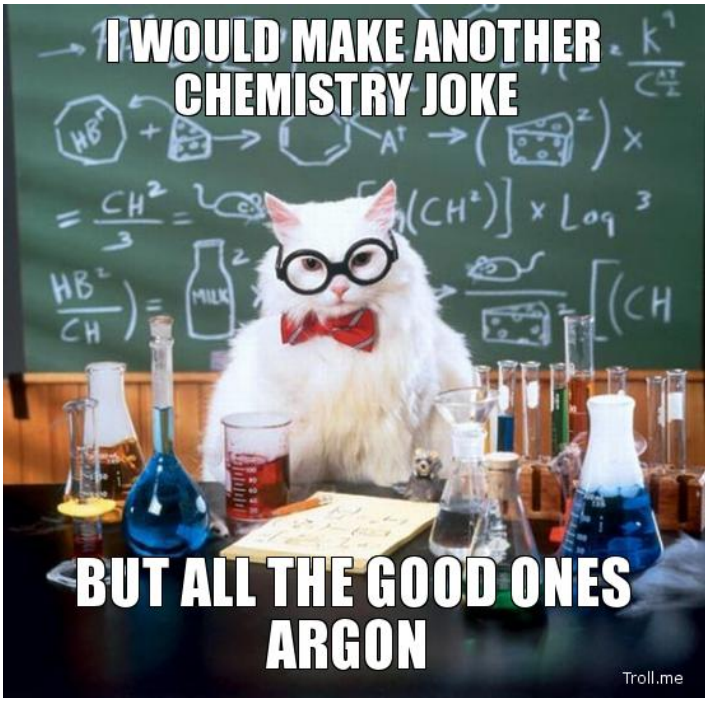
A) 2.23

B) 1.30

C) 2.56

D) 2.03

E) 1.10



Congratulations! You just completed the 2021 Wisconsin State Science Olympiad Chemistry Lab C EXAM