Instructions (shown before students start the test)

Per Texas Science Olympiad rules, you must have printed notes for this event. If you are communicating with your partner through a voice or video call, please start it before you begin the test itself.

Significant time spent outside of the browser window is grounds for a penalty or disqualification per TSO policies.

Introduction (shown after students start the test)

Welcome to Chem Lab at the UT Regional. Best of luck!

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For questions 1-7, match the acids to an industrial / commercial / environmental detail according to the table below. In the provided blank, put only the single letter representing your answer choice (ex. "A"). (3.5 points total)

Acids	**Industrial / Commercial / Environmental Detail**
1.1. HCl	A. Disrupts shell formation in the ocean. Its concentration is tied to dissolved CO2.
1.2. HNO_3	B. Dilute form produced from fermentation then oxidation of ethanol can be used for cooking and cleaning.
1.3. H_2SO_4	C. Can be bought over-the-counter as Vitamin C.
1.4. H_3PO_4	D. Primarily used in fertilizers (90% of production).
1.5. H_2CO_3	E. Used in manufacturing of PVC (Poly Vinyl Chloride).
1.6. Acetic acid	F. Often neutralized with ammonia to yield ammonium nitrate.
1.7. Ascorbic acid	G. Often used as a catalyst in the production of nylon. Also used in the oil and gas industry to raise octane rating.

1. (0.50 pts) HCl

2. (0.50 pts) HNO_3

3. (0.50 pts) H_2SO_4

4. (0.50 pts) H_3PO_4

5. (0.50 pts) H_2CO_3

6. (0.50 pts) Acetic acid

7. (0.50 pts) Ascorbic acid

For questions 8-12, match the bases to an industrial / commercial / environmental detail according to the table below. In the provided blank, put only the single letter representing your answer choice (ex. "A"). (2.5 points total)

Bases	**Industrial / Commercial / Environmental Detail**
2.1. NaOH 2.2. KOH 2.3. $Ca(OH)_2$ 2.4. $Mg(OH)_2$ 2.5. NH_3	A. The product produced by the Haber process. B. A strong base with a molar mass around 40 g/mol. C. The saturated version of this compound is called limewater. D. A common component of antacids. Splitting this compound through electrolysis is part of making Air Krete, a recent insulation innovation. E. Also known as lye.

8. (0.50 pts) NaOH

9. (0.50 pts) KOH

10. (0.50 pts) $Ca(OH)_2$

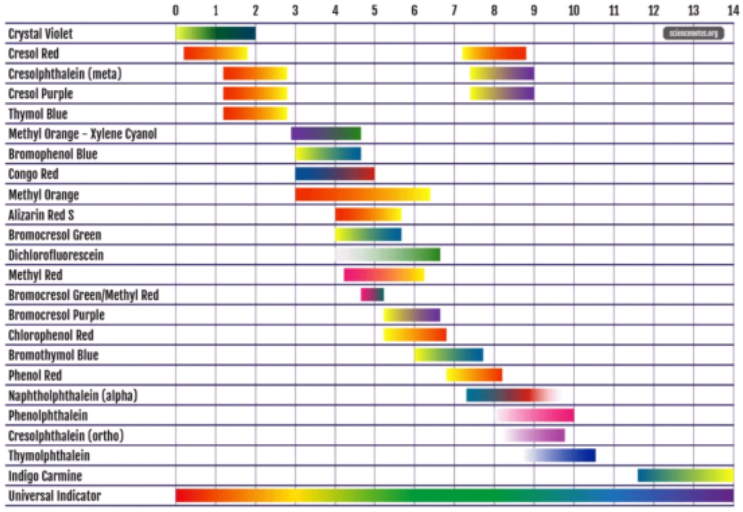
11. (0.50 pts) $Mg(OH)_2$

12. (0.50 pts) NH_3

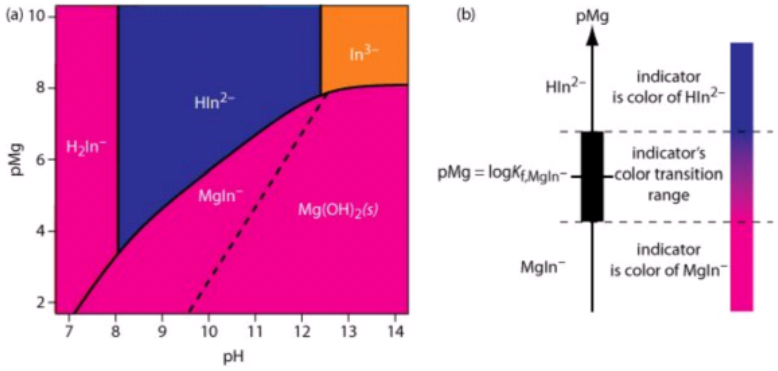
These images may be useful for the next set of questions.

Litmus paper: See below.
Red: acidic
Blue: alkaline

Universal indicator / phenolphthalein / bromocresol green: See below.



Calmagite: Specialty indicator which forms a ligand complex. See below.



For questions 13-17, match each scenario to an indicator according to the table below. In the provided blank, put only the single letter representing your answer choice (ex. "A"). (2.5 points total)

Scenario	**Indicator**
3.1. Standardizing NaOH (titrant) using a known mass of KHP dissolved in a volumetric flask (titrate). 3.2. Using the Kjeldahl method to find the ammonium salt content. A brief summary of this method: $NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$ $H_2BO_3^- + HCl \rightarrow H_3BO_3 + Cl^-$ dihydrogen borate, (pKb = 4.76) 3.3. Titrating MgO with standard EDTA. 3.4. Quickly identifying a beaker of HCl and a beaker of NaOH which are missing labels. 3.5. Measuring the pH as an indicator of water quality in the field.	A. Litmus paper B. Universal indicator C. Phenolphthalein D. Bromocresol green E. Calmagite indicator

13. (0.50 pts) Standardizing NaOH (titrant) using a known mass of KHP dissolved in a volumetric flask (titrate).

14. (0.50 pts) Using the Kjeldahl method to find the ammonium salt content. A brief summary of this method:

$NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$
$H_2BO_3^- + HCl \rightarrow H_3BO_3 + Cl^-$
dihydrogen borate, (pKb = 4.76)

15. (0.50 pts) Titrating MgO with standard EDTA.

16. (0.50 pts) Quickly identifying a beaker of HCl and a beaker of NaOH which are missing labels.

17. (0.50 pts) Measuring the pH as an indicator of water quality in the field.

This section will cover acid-base reactions. Reactions include metals, carbonates, bicarbonates, sulfites, bisulfites, oxides, and neutralizations.

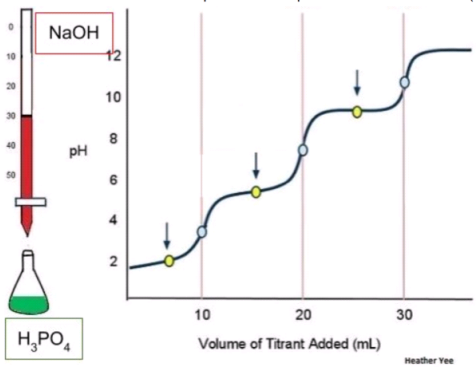
18. (2.00 pts) Is $CaCl_2$ an acidic, neutral, or basic salt? Justify your answer with a chemical equation showing the formation of the salt.

19. (2.00 pts) Is KCN an acidic, neutral, or basic salt? Justify your answer with a chemical equation showing the formation of the salt.

20. (2.00 pts) Is NH_4Cl an acidic, neutral, or basic salt? Justify your answer with a chemical equation showing the formation of the salt.

21. (1.00 pts) Give a net ionic equation for a neutralization reaction.

22. (3.00 pts) Write a series of chemical equations that represent this titration curve.



This section consists of a multi-part titration problem to answer a series of questions. This section might be more time-intensive.

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Use the following information to answer questions 23-29:

A new solid, monoprotic weak acid, HY, is synthesized. A titration of 0.4206 g of HY dissolved in 50.00 mL of water requires 30.00 mL of 0.10 M KOH solution to reach the equivalence point.

23. (1.00 pts) Write the dissociation equation for HY in water and its equilibrium expression (Ka).

24. (1.00 pts) Write the net ionic equation for the titration reaction.

25. (3.00 pts) Calculate the molar mass of HY in g/mol. Report your answer to the ones place and do not write units in the blank.

26. (3.00 pts) After 6.00 mL of the base is added, the pH of solution is 5.00. What is the value for the Ka of HY?

27. (1.00 pts) What is the value of Kb for the Y- ion?

28. (2.00 pts) At the equivalence point of the reaction, will the solution be acidic, basic, or neutral? Use an equation to support your conclusion.

29. (2.00 pts) Calculate the pH of the solution at the equivalence point. Report your answer to 2 decimal places.

This section consists of calculations based on supplied data and analysis of an observed trend. This section might be more time-intensive.

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For questions 30-35, fill in the following spots in the table marked "ANSWER 3#" with a numerical value.

Table 6. Temperature Dependence of the pH of Pure Water

T (Celsius)	Kw (mol2 dm-6)	pH	pOH
0	0.114e-14	7.47	7.47
10	0.293e-14	ANSWER #30	ANSWER #31
20	ANSWER #32	7.08	7.08
25	1.008e-14	ANSWER #33	ANSWER #34
30	1.471e-14	6.92	6.92
50	ANSWER #35	6.63	6.63
100	51.3e-14	6.14	6.14

30. (0.50 pts) Report answer to 2 decimal places.

31. (0.50 pts) Report answer to 2 decimal places.

32. (1.00 pts) Provide the answer for the corresponding blank in the table.

33. (0.50 pts) Report answer to 2 decimal places.

34. (0.50 pts) Report answer to 2 decimal places.

35. (1.00 pts) Provide the answer for the corresponding blank in the table.

36. (1.00 pts) Given pH + pOH = 14 at STP, which value on the chart corresponds to standard temperature (C)?

37. (1.00 pts) Is the formation of hydrogen ions and hydroxide ions from liquid water ($H2O(l) \rightleftharpoons H+(aq)+OH-(aq)$) endothermic or exothermic?

- A) endothermic
- B) exothermic

38. (1.00 pts) TRUE or FALSE. Water is becoming more acidic at higher temperatures.

- True
- False

This section consists of multiple choice questions that cover concepts and less involved calculations.

39. (0.50 pts) The pH of 0.0001 M HNO3 solution is

- A) 4
- B) 3
- C) 2
- D) 1

40. (0.50 pts) Which property is not typically associated with basic solutions?

- A) Feel slippery
- B) React with metals to produce hydrogen gas
- C) Have a pH above 7.0
- D) React with solutions containing HCO_3^-

41. (0.50 pts) The pH of a 1.0 M solution of HI

- A) 0.0
- B) 1.0
- C) 2.0
- D) 12

42. (0.50 pts) The pH of a 0.01 M solution of KOH

- A) 0.0
- B) 1.0
- C) 2.0
- D) 12

43. (0.50 pts) TRUE or FALSE. It is acceptable to use a weak acid or base as a titrant.

○ True ○ False

This section (44-53) requires you to sort definitions using three acid-base models. Some questions will have more than one correct answer. All must be correct for credit. Mark these definitions as:

A. Arrhenius

B. Bronsted-Lowry

C. Lewis

Put only the letter for your answer choice in the blank (ex. "A"). If there are multiple answers, put your answers in alphabetical order separated by a comma (ex. "A,B").

44. (0.50 pts) Acids are an electron pair acceptor.

45. (0.50 pts) Acids release H+ ions in aqueous solutions.

46. (0.50 pts) Acids are described as proton donors

47. (0.50 pts) Water seen as neither an acid nor base.

48. (0.50 pts) Water is seen as amphoteric.

49. (0.50 pts) KOH is a base.

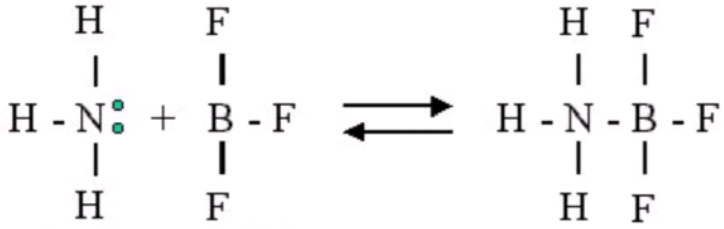
50. (0.50 pts) Neutralization is the reaction of an acid and a base to form a conjugate acid and a conjugate base.

51. (0.50 pts) Neutralization is the reaction of an acid and a base to produce salt and water.

52. (0.50 pts) Neutralization is the reaction of an acid and a base to produce a new substance with a new covalent bond.

53. (0.50 pts)

Classify the reaction below.



Uh oh...buffers! This section will help you get some practice with a State/Nationals topic. (4 pts total).

54. (2.00 pts) Calculate the pH of a solution that's 0.65M in NaF and 0.75M in HF. (HF, Ka=7.2e-4).

Report answer to 2 decimal places.

55. (2.00 pts) Calculate the pH of a solution that's 0.65M in $NaNO_2$ and 0.40M in HNO_2. (HNO_2, Ka=4e-4).

Report answer to 2 decimal places.

Aqueous Solutions

Question types vary and are listed in order of increasing difficulty. These sections will test basic concepts and calculations.

A student adds 32.2 g of table salt (MM = 58.44 g/mol) to 2 L of water while cooking pasta.

56. (0.50 pts) What effect will the salt have on the vapor pressure of the water?

57. (1.00 pts) What is the molarity of the Na^+ ion in the solution?

Report answer to 3 decimal places.

58. (1.00 pts) What is the pH of the resulting solution, explain your answer.

59. (0.50 pts)
How many moles of Nitric Acid must be added to the 2L of water in order to give a solution with a pH = 4.00? Assume that the Nitric Acid does not react with the dissolved NaCl ions.

Urea, $H_2NC(O)NH_2$ (MM = 60.0) is very soluble in water (up to 27 g in 25 mL of solution) but methoxyethane, $CH_3CH_2OCH_3$, (MM = 60.1) is only sparingly soluble.

60. (0.50 pts) Calculate the molarity of urea in a 25.0 mL solution that contains 27.0 g of Urea.

Report answer as a whole number.

61. (0.50 pts) Account for the differences in solubility of urea and methoxyethane in terms of the forces between the solute and solvent molecules.

This section will test your knowledge of experimental procedures.

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A student is asked to determine the molarity of H_2SO_4 by titrating it with a NaOH solution of known molarity.

62. (2.00 pts) List the pieces of equipment needed to determine the H2SO4 molarity and describe briefly the purpose of each item.

63. (0.50 pts) List the measurements that must be made to determine the molarity.

64. (1.00 pts) Describe briefly how the student can tell when the reaction is complete.

65. (1.00 pts)

Four successive titrations of the same volume of H_2SO_4 require 23.55, 22.66, 23.46, and 23.48 ml. State the average volume that should be reported. Explain your reasoning.

This section covers identifying and balancing reactions.

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Consider the following unbalanced equations that occur in aqueous solutions.

(A) $Na_3PO_4 + Ca(NO_3)^2 \rightarrow Ca_3(PO_4)^2 + NaNO_3$

(B) $H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4 + H_2O$

(C) $K_2Cr_2O_7 + SnCl_2 + HCl \rightarrow SnCl_4 + H_2O + KCl$

66. (3.00 pts) Identify each equation as an acid-base, oxidation-reduction, and/or precipitation reaction.

67. (0.50 pts) Balance each equation.

68. (3.00 pts) For each

(i) acid-base reaction, give the formula of the base.

(ii) oxidation-reduction reaction, identify the oxidizer, and state the number of electrons gained by one unit of the oxidizer

(iii) precipitation reaction, give the formula of the insoluble substance

We hope you enjoyed this exam! If you have any feedback about any of the exams at this tournament, please let us know through this form: https://tinyurl.com/utreg21feedback (https://tinyurl.com/utreg21feedback)