last name ____________ first name ____________ signature ____________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (290)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

constants

$R = 0.08206$ L atm/mol K

$R = 0.08314$ L bar/mol K

$R = 62.36$ L Torr/mol K

$R = 8.314$ L kPa/mol K

$R = 8.314$ J/mol K

$N_A = 6.022 \times 10^{23}$ /mol

conversions

1 atm = 760 torr

1 atm = 14.7 psi

1 atm = 101325 Pa

1 atm = 1.01325 bar

1 bar = 10^5 Pa

°F = °C(1.8) + 32

K = °C + 273.15

conversions

1 in = 2.54 cm

1 ft = 12 in

1 yd = 3 ft

1 mi = 5280 ft

1 lb = 453.6 g

1 ton = 2000 lbs

1 tonne = 1000 kg

1 gal = 3.785 L

1 gal = 231 in^3

1 gal = 128 fl oz

1 fl oz = 29.57 mL

1 Troy oz = 31.104 g

water data

$C_{s,ice} = 2.09$ J/g °C

$C_{s,water} = 4.184$ J/g °C

$C_{s,steam} = 2.03$ J/g °C

$\rho_{water} = 1.00$ g/mL

$\rho_{ice} = 0.9167$ g/mL

$\rho_{seawater} = 1.024$ g/mL

$\Delta H_{fus} = 334$ J/g

$\Delta H_{vap} = 2260$ J/g

$k_f = 1.86$ °C/m

$k_b = 0.512$ °C/m

$K_w = 1.0 \times 10^{-14}$

This exam should have exactly 25 questions. Each question is equally weighted at 4 points each. You will enter your answer choices on the virtual bubblehseet after you have finished. Your score is based on what you submit on the virtual bubblesheet and not what is circled on the exam.

---

1. What is the conjugate base of trichloroacetic acid (Cl_3CO_2H)?

a. $Cl_3CO_2H_2^+$

b. It is not possible to say.

c. $Cl_3CO_2H_2^-$

d. $Cl_3CO_2^+$

●e. $Cl_3CO_2^-$

Explanation: remove one H+ to get $Cl_3CO_2^-$

---

2. (Part 1 of 2) Hexahydroxybenzene ($C_6H_6O_6$) is a hexaprotic acid whose salts have been considered for use as a battery electrolyte. If we represent the acid in a general way (H_6A), what is the conjugate acid of H_3A^{3-}?

a. H_2A^{4-}

b. H_2A^{2-}

●c. H_4A^{2-}

d. H_4A^{4-}

e. H_3A^{2-}

Explanation: ADD one H+ to get H_4A^{-2}

---

3. (Part 2 of 2) Refering to the last question, which K_a relates to the previously mentioned conjugate pair?

a. K_{a5}

b. K_{a4}

c. K_{a2}

●d. K_{a3}

e. K_{a6}

f. K_{a1}

Explanation: The pairing of H_4A^{-2} and H_3A^{-3} corresponds to the removal of the 3rd proton in the sequence and means that K_{a3} is what relates them.

---

4. We learned in our study of equilibrium that the value of K will change with temperature. K_w is 1.0×10^{-14} at 25 °C. As water gets warmer and warmer the value of K_w increases. How does this affect what we call neutral pH which is normally 7.0 ?

a. will cause it to rise a bit, pH > 7

●b. will cause it to drop a bit, pH < 7

c. will not affect it, it remains pH 7

Explanation: Definition of neutral pH is when [H+] = [OH-] and means that the concentration of each of those is $\sqrt{K_w}$. If K_w increases (say 2.5×10^{-14} for example), then so does $\sqrt{K_w}$, which for this example would be 1.58×10^{-7} M which will be a neutral pH of 6.80 (less than 7).

---

5. A solution of RbOH has a pH of 9.87. What is the concentration of RbOH?

a. 3.3×10^{-3} M

b. 6.1×10^{-4} M

c. 1.4×10^{-10} M

d. 8.1×10^{-2} M

●e. 7.4×10^{-5} M

Explanation: pOH = 14 - 9.87 = 4.13. [OH-] = $10^{-4.13} = 7.4 \times 10^{-5}$ M

---

6. You mix up a 0.01 M weak acid solution. Which of the following is a reasonable guess for the pH of the solution?

a. 12.0

b. 2.0

c. 8.8

●d. 5.4

e. 7.0

Explanation: A weak acid will be acidic and therefore a pH less than 7. However, a pH of 2 would me the acid is strong... therefore, only 5.4 is a logical choice for the pH of this weak acid.

---

7. You have a solution where you know that the $[H^+]$ is exactly 3.5 times that of $[OH^-]$. What is the pH of the solution?

a. 2.23

b. 5.32

c. 7.27

●d. 6.73

e. 8.65

Explanation: [H+][OH-] = Kw, $(3.5x)(x)$ = Kw, $x = \sqrt{Kw/3.5} = 5.35 \times 10^{-8}$. $[H+] = 3.5x = 3.5(5.35 \times 10^{-8}) = 1.87 \times 10^{-7}$ M. Take -log and get pH = 6.73.

---

8. What is the pH of 0.0033 M $Ba(OH)_2$?

a. 8.70

b. 11.96

c. 2.48

d. 2.18

●e. 11.82

f. 11.52

Explanation: This is a double base - two OH-'s, so first double the concentration to get 0.0066 M [OH-]. Now take -log to get pOH = 2.18, subtract from 14 to get pH = 11.82

---

9. A 0.025 M solution of a weak base has a measured pH of 11.65. What is the percent ionization of this base?.

a. 1.2%

b. 15%

c. 12%

●d. 18%

e. 7.5%

Explanation: pOH is 14 - 11.65 = 2.35 which corresponds to a OH- conc of 0.0045 M.
$0.0045/0.025 \times 100\% = 18\%$

---

10. (Part 1 of 2) You decide to titrate a solution of NaH_2PO_4. You add just enough NaOH to achieve an equal ratio of NaH_2PO_4 and Na_2HPO_4. What is the pH of this solution? (for H_3PO_4, $pK_{a1} = 2.12$, $pK_{a2} = 7.21$, $pK_{a3} = 12.32$)

a. 12.32

b. 9.77

c. 2.12

d. 4.67

●e. 7.21

Explanation: Anytime you have equal amounts (a 1-to-1 ratio) of conjugates, your pH will equal pKa. The pKa for this pair is pKa2 which is 7.21.

---

11. (Part 2 of 2) You decide to repeat the experiment from the previous question, but this time you add just enough NaOH to neutralize all of the NaH_2PO_4, leaving you with only Na_2HPO_4. What is the pH of this solution?

a. 7.21

b. 4.67

c. 2.12

●d. 9.77

e. 12.32

Explanation: When you neutralize all of the diprotic, you have a solution of only monoprotic acid (HPO_4^{2-}). This is in between pKa2 and pKa3, so you average them. (7.21+12.32)/2 = 9.77.

---

12. Which of the following is not a strong acid?

a. sulfuric acid

●b. nitrous acid

c. chloric acid

d. hydroiodic acid

e. hydrobromic acid

Explanation: Nitrous acid is NOT on the strong acid list, the others are.

---

13. Consider the triprotic acid H_3A. It possesses $pK_{a1} = 2.30$, $pK_{a2} = 7.03$, $pK_{a3} = 11.52$. What is the main species present in a solution with pH = 5.6?

a. A^{3-}

b. HA^{3-}

c. HA^{2-}

●d. H_2A^-

e. H_3A

Explanation: For any weak acid, if the pH is below the pKa of the acid by more than 1 unit, then the major species is the protonated acid. On the other hand, if you the pH is above the pKa by more than 1 pH unit the major species is the deprotonated acid. Thus, at a pH of 5.6, the protons associated with pKa = 7.03 and 11.52 are still present, where as the proton associated with pKa = 2.30 is deprotonated. Overall, this is H_2A^-.

---

14. According to the Lewis Theory of acids and bases, an acid is:

●a. An electron acceptor.

b. A proton acceptor.

c. A proton donor.

d. A substance which when dissolved in water yields hydroixde ions.

e. An electron donor.

Explanation: Lewis theory deals with e- pair donating and accepting.

---

15. You go into the lab and mix up 100 mL of a buffer which is 0.15 M in HA and 0.10 M in A^-. You then add 150 mL of 0.1 M NaOH. What is the new pH? Assume that K_a for HA = 6.4×10^{-5}.

a. 11.88

b. 5.40

c. 4.19

d. 2.34

●e. 8.60

f. 6.91

Explanation: Initial amounts are 15 mmol HA and 10 mmol A-. You add 15 mmol OH-. This completely converts all of the HA to A-. So you now have 25 mmol of A- in 250 mL of solution which means you have 0.10 M A- (it's all weak base). Kb = Kw/Ka = $10^{-14}/6.4 \times 10^{-5} = 1.56 \times 10^{-10}$. Now use [OH-] = $\sqrt{Kb(C_A)} = 3.95 \times 10^{-6}$. pOH = 5.40 and pH = 8.60

---

16. What is the pH of 0.0045 M $HClO_4$?

●a. 2.35

b. 8.93

c. 3.73

d. 11.65

e. 1.35

Explanation: strong acid. -log(0.0045)) and get pH = 2.35

---

17. Consider these four acids for this question. Each are listed by name and their corresponding K_a values:

benzoic acid 6.4×10^{-5}	hydrazoic acid 2.5×10^{-5}
formic acid 1.8×10^{-4}	chlorous acid 1.2×10^{-2}

Now you mix up equimolar solutions of each acid. Which acid solution has the highest pH?

a. chlorous acid

b. formic acid

●c. hydrazoic acid

d. benzoic acid

e. It is not possible to say.

Explanation: The highest pH will be from the weakest acid in the group. The weakest acid will the one with the smallest value of Ka which is hydrazoic acid.

---

18. Acrylic acid is a feedstock which forms the basis for a number of useful products such as paints, absorbents, and glues. What is the pH of a 0.067 M acrylic acid solution? (For acrylic acid, $K_a = 5.6 \times 10^{-5}$)

a. 9.81

b. 3.55

●c. 2.71

d. 8.42

e. 1.17

Explanation: Use the assumption shortcut: [H+] = $\sqrt{Ka(conc)} = 1.94 \times 10^{-3}$ M which gives a pH of 2.71.

---

19. (Part 1 of 2) How much 0.28 M HCl solution is needed to neutralize 1400 mL of 0.035 NaOH?

a. 1750 mL

b. 1400 mL

c. 225 mL

●d. 175 mL

e. 300 mL

f. 125 mL

Explanation: $M_A V_A = M_B V_B$ solve for V_A.
$V_A = 0.035(1400)/0.28 = 175$ mL

---

20. (Part 2 of 2) Refering to the previous question, which best describes the pH at the equivalence point of the titration?

a. 8.1

b. 9.5

c. It is not possible to say.

●d. 7.0

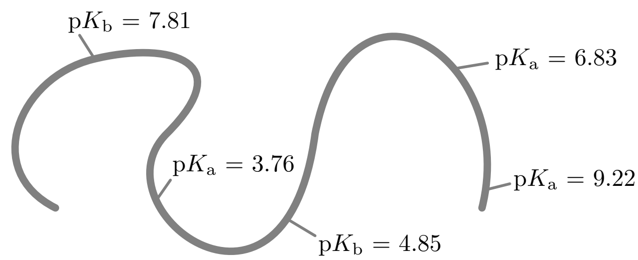
e. 6.3

f. 5.4

Explanation: The equivalence point of any strong acid with strong base is a water solution of a neutral salt (no acid or base is present) and therefore perfectly neutral at pH of 7.

---

21. Consider the following protein chain with five acid/base residues labeled with their corresponing pK_a or pK_b.



What is the overall charge on the this protein chain at a physiological pH of 7.4?

a. 0

b. −2

●c. −1

d. +1

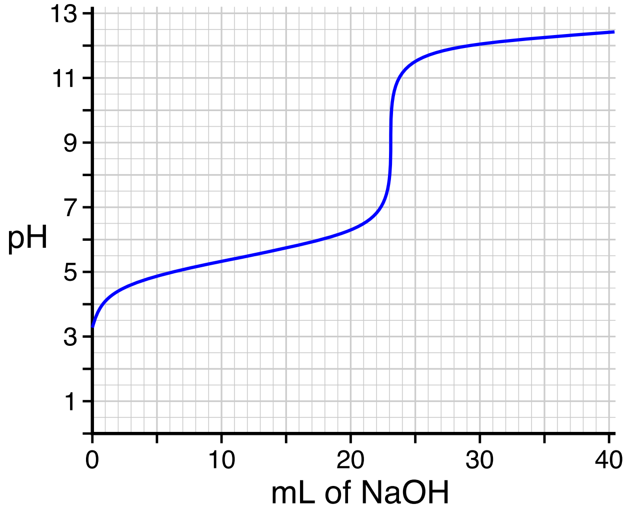
e. +2

Explanation: The two acid residues at 3.76 and 6.83 would both be deprotonated and have −1 charges. The acid at 9.22 would still be protonated and be neutral (0). You have to convert the pKb's to pKa's... you get 6.19 for one and it is not protonated and is still neutral at 0. The other is 9.15 and would be protonated at +1. Summing up you have

$0 - 1 - 1 + 0 + 1 = -1$ overall

---

22. (Part 1 of 4) 50 mL of an unknown monoprotic acid solution is titrated with 0.026 M NaOH. The titration curve for this is shown below. What is the pH at the equivalence point of this titration?



a. 9.1

b. 10.0

c. 8.1

d. 11.2

e. 6.5

Explanation: The endpoint volume is easily seen at 23 mL. The center of the vertical rise is at 9.1 (this is the best number of those listed).

---

23. (Part 2 of 4) Again using the titration curve, what is the K_a of the unknown weak acid?

a. 8.8×10^{-7}

b. 1.8×10^{-6}

c. 1.1×10^{-5}

d. 6.3×10^{-6}

e. 3.2×10^{-6}

Explanation: Go to half titration volume (11.5 mL) and read the pH there of 5.5. Now convert to Ka via $10^{-5.5} = 3.2 \times 10^{-6}$.

---

24. (Part 3 of 4) Again using the titration curve, determine the concentration of the starting acid solution.

a. 0.057 M

b. 0.024 M

c. 0.0082 M

d. 0.015 M

e. 0.012 M

Explanation: 23mL(0.026M) = 0.598 mmol OH-. acid conc = 0.598/50 mL = 0.012 M

---

25. (Part 4 of 4) Finally, refering to the titration curve, which indicator would be best for this titration?

a. phenol red (yellow to red, pH 6.6-8.0)

b. methyl orange (red to yellow, pH 3.2-4.4)

c. propyl red (red to yellow, pH 4.8-6.6)

d. phenolphthalein (colorless to pink, pH 8.2-10.0)

e. bromocresol purple (yellow to purple pH 5.2-6.8)

f. alizarin yellow (yellow to red, pH 10.1-12.0)

Explanation: the phenolphthalein is the only one with the 9.1 equivalence point pH in the transition of its color range.

After you are finished and have all your answers circled, go to the front of the room and then use the QR code show below to pull up the virtual answer page for your exam. Enter the appropriate info plus all your answers - click the SUBMIT button. Double check your choices on the next page. Once your are sure, click the submit button on that page to enter your answers. Make sure you get the confirmation screen (different background color!) and show it to the TA or proctor. After that, turn in your exam and scratch paper. You're free to leave after that.

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