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

$R = 8.314$ J/mol K

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

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^{8}$ m/s

$g = 9.81$ m/s^2

conversions

1 atm = 760 torr

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

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

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

This exam should have exactly 20 questions. Each question is equally weighted at 5 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. Which pH represents a solution with 1000 times higher hydroxide ion concentration than a solution with a pH of 8?

a. pH = 12

b. pH = 6

c. pH = 10

●d. pH = 11

e. pH = 5

f. pH = 7

Explanation: By using a logarithmic scale, a 1000 times difference indicates a difference of 3 orders of magnitude (pH units). Given this, a solution with 1000 times higher $[OH^-]$ concentration means that the solution is more basic by 3 pH units, so 8 + 3 = pH 11.

---

2. A sample of 100 mL of a weak acid (HA) solution was completely neutralized in a titration experiment with 27.4 mL of 0.0555 M KOH. What is the concentration of the original HA solution?

a. 0.203 M

b. 0.0215 M

c. 0.0175 M

●d. 0.0152 M

e. 0.0555 M

Explanation: Complete neutralization occurs at the equivalence point of a titration and this is where

$M_A \cdot V_A = M_B \cdot V_B$

$M_A \cdot 100\,\text{mL} = 0.0555\,\text{M} \cdot 27.4\,\text{mL}$

$M_A = 0.0152$ M

---

3. A titration experiment is set up to fully neutralize a 50 mL weak acid solution using the strong base, NaOH. After adding 15.1 mL 0.0463 M NaOH, the solution turns from clear to pink and you know that your titration is complete. How many **moles** of acid were present in the initial weak acid solution?

a. 0.0200 moles

●b. 6.99×10^{-4} moles

c. 7.55×10^{-3} moles

d. 1.51×10^{-8} moles

e. 0.151 moles

Explanation: The number of moles of both the acid and the base at the equivalence point is the concentration of the titrant times the volume added in liters.

$0.0463(0.151) = 6.99 \times 10^{-4}$

---

4. Which of the following compounds would be the least likely to dissolve in water?

a. KNO_3

b. CH_3OH

c. RbOH

●d. $CH_3CH_2CH_3$

Explanation: Polar/ionic solvents dissolve polar/ionic solutes and non-polar solvents dissolve non-polar solutes. Water is a polar solvent, KNO_3 and RbOH are ionic compounds and CH_3OH (methanol) is polar (note the OH group). $CH_3CH_2CH_3$ is propane and is very non-polar which prevents it from having any substantial solubility in water. A simple rule of thumb is "likes dissolves likes".

---

5. Which two strong acids are the most likely candidates to be found in acid rain?

a. H_2SO_3 and HNO_2

b. HNO_3 and H_2CO_3

c. H_2SO_4 and H_3PO_4

●d. H_2SO_4 and HNO_3

e. H_2S and NH_2

Explanation: Sulfur and nitrogen oxides react with water droplets and make sulfuric acid and nitric acid, H_2SO_4 and HNO_3.

---

6. What is the conjugate base of hydrogen carbonate (bicarbonate), HCO_3^- ?

●a. CO_3^{2-}

b. HCO_2^-

c. $H_2CO_3^+$

d. H_2CO_3

e. H_3O^+

f. OH^-

Explanation: Remove ONE proton and get CO_3^{-2} which is carbonate.

---

7. A weak acid, HX, ionizes 7.8% at a 0.077 M concentration. What is the pH of this solution?

a. 3.33

●b. 2.22

c. 1.22

d. 1.11

e. 2.33

Explanation: Percent ionization gives you the dissociation of a weak electrolyte at a particular concentration:

$[H^+] = 0.077 \times 0.078$ M

$[H^+] = 0.006006$ M

pH = -log(0.006006) = 2.2214 = 2.22 (2 sig fig)

---

8. Calculate the molarity of $[OH^-]$ when 56.0 grams of NaOH (40.0 g/mol) are fully dissolved in a 16.0 L solution.

a. 3.50 M

b. 0.0446 M

c. 0.0722 M

●d. 0.0875 M

e. 0.0667 M

f. 0.875 M

Explanation: Convert grams to moles and then divide to solve for molarity.

56 g / (40 g/mol) =1.4 mol

1.4 mol / 16.0 L = 0.0875 M

---

9. Which of the following species has the smallest value for K_a?

●a. HF

b. $HClO_4$

c. $HClO_3$

d. HI

e. HCl

Explanation: Everything listed *except* HF is a strong acid... So the HF will definitely have the smallest value of K_a because it is the only weak acid listed.

---

10. Each of the following acids are mixed at the same concentration of 0.072 mol/L. Which one will give the most acidic solution?

name	K_a
butanoic acid	1.5×10^{-5}
hydrofluoric acid	6.3×10^{-4}
hypochlorous acid	3.5×10^{-8}
propanoic acid	1.3×10^{-5}
lactic acid	1.4×10^{-4}

a. butanoic acid

b. lactic acid

●c. hydrofluoric acid

d. hypochlorous acid

e. propanoic acid

Explanation: The larger the value of K, the more products are formed and the stronger the acid. The highest K_a is hydrofluoric acid, which is $K_a = 6.3\times10^{-4}$. This will yield the most acid solution because more hydronium ion will beformed as a product.

---

11. A weak base, B, undergoes a 13% ionization when mixed at a concentration of 0.31 M. What is the value of K_b for this weak base?

a. 6.5×10^{-4}

b. 2.8×10^{-4}

c. 7.2×10^{-5}

●d. 6.0×10^{-3}

e. 5.1×10^{-3}

Explanation: For weak base B, :

$K_b = \frac{[OH^-][BH^+]}{[B]}$

Amount ionized is 13% of 0.31 = 0.0403 M which is equal to the $[OH^-]$ and the $[BH^+]$ concentrations. The B concentration just drops by that amount which makes it 0.2697 M. Now just plug them all in...

$K_b = \frac{0.0403^2}{0.2697}$

$K_b = 6.0218 \times 10^{-3}$

with 2 sig figs this is 6.0×10^{-3}

---

12. Below is a list of just three indicators and the pH transition range in which they change from one color to another. Which indicator would be the best one to use for the titration of a strong acid and strong base?

a. thymolphthalein, 9.3 to 10.5

b. bromocresol green, 3.8 to 5.4

●c. bromothymol blue, 6.1 to 7.6

Explanation: For a titration of a strong acid and strong base, the equivalence point will be at a pH of approximately 7. Bromothymol blue in this listing covers that pH during the color transition. The other two are well out of range.

---

13. According to the Lowry-Bronsted Theory of acids and bases, an acid is:

a. a substance which when dossolved in water yields hydroxide ions.

b. a proton acceptor.

c. an electron acceptor.

●d. a proton donor.

e. an electron donor.

Explanation: All Lowry-Bronsted acids are proton donors.

---

14. A 0.024 M solution of HNO_3 is diluted 100:1 with water (to be clear, that is 1 part acid to 99 parts water). What is the pH of the diluted acid solution?

●a. 3.62

b. 4.26

c. 2.62

d. 1.62

e. 1.26

f. 3.26

Explanation: The 100:1 dilution makes the concentration 100× less concentrated or 0.00024 M. HNO_3 is a strong acid that dissociates completely, resulting in a 0.00024 M hydrogen ion concentration. Now do the pH math

pH = -log(0.00024) = 3.62

---

15. What is a role of limestone (calcium carbonate, $CaCO_3$) in lakes that is beneficial for aquatic life?

a. dissolved limestone will lower the pH to make lakes acidic

●b. dissolved limestone can resist large changes in pH from artificial sources, such as chemical leaks and acid rain

c. dissolved limestone can increase the pH of lakes by acting like a strong acid

d. limestone can increase the pH of lakes by acting like a strong base

Explanation: Calcium carbonate protects from large pH changes by creating a buffer system.

---

16. The pH of a solution is measured to be 9.15. What is the concentration of hydroxide in this solution?

a. 7.1×10^{-10} M

b. 3.2×10^{-5} M

c. 4.2×10^{-6} M

●d. 1.4×10^{-5} M

e. 3.1×10^{-10} M

Explanation: Convert to pOH and then to the concentration of hydroxide.

$\text{pOH} = 14 - 9.15 = 3.85$

$[\text{OH}^-] = 10^{-3.85} = 1.4125 \times 10^{-5}$ M

---

17. A 6.00 gram sample of KNO_3 is dissolved into 34.0 grams of water. What is the percent concentration (by mass) of this solution?

a. 17.6%

b. 18.6%

●c. 15.0%

d. 20.0%

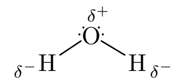
e. 12.5%

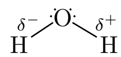
Explanation: Total mass is 40 grams.

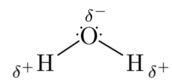
$\%\text{conc} = 6/40 \times 100 = 15\%$

---

18. Which of the three structures for water is correctly showing the partial charges?

a. 

b. 

●c. 

Explanation: The partial positives go on the H's because it has a lower electronegativity value than O. Oxygen is very electronegative.

---

19. Strontium hydroxide is typically used to extract sugar molecules from concentrated solutions such as molasses. What is the pH of a 0.00038 M $Ba(OH)_2$ aqueous solution?

a. 11.58

b. 3.12

c. 10.58

●d. 10.88

e. 3.42

Explanation: 0.00038 M barium hydroxide is a strong base that dissociates completely, resulting in a 0.00076 M hydroxide ion concentration.

$\text{pOH} = -\log(0.0076) = 3.12$

$\text{pH} = 14 - \text{pOH} = 14 - 3.12 = 10.88$

---

20. Consider the following reaction:

$$C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$$

Which of the following pairs are conjugate pairs?

I. H_3O^+ and H_2O
II. C_6H_5COOH and H_3O^+
III. C_6H_5COOH and H_2O
IV. C_6H_5COOH and $C_6H_5COO^-$
V. H_2O and $C_6H_5COO^-$

a. V only

b. III and V

c. IV only

d. I only

●e. I and IV

f. II and V

Explanation: C_6H_5COOH is a weak acid, so its conjugate is the base $C_6H_5COO^-$ and thus it is a pair (IV). Plus, water H_2O, acts as a weak base accepting a proton to form hydronium ion, H_3O^+ which is the other conjugate pair (I).

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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