



# DO NOT OPEN

## UNTIL INSTRUCTED TO DO SO

*CHEM 111 – Dr. McCorkle – Exam #2 **KEY***

While you wait, please complete the following information:

**Name:** \_\_\_\_\_

**Student ID:** \_\_\_\_\_

*Turn off cellphones and stow them away. No headphones, mp3 players, hats, sunglasses, food, drinks, restroom breaks, graphing calculators, programmable calculators, or sharing calculators. Grade corrections for incorrectly marked or incompletely erased answers will not be made.*

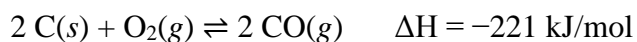
# Periodic Table of the Elements

PERIOD	GROUP 1 IA	GROUP 2 IIA	GROUP 3 IIIB	GROUP 4 IVB	GROUP 5 VB	GROUP 6 VIB	GROUP 7 VIIB	GROUP 8 VIII	GROUP 9 VIII	GROUP 10 VIII	GROUP 11 IB	GROUP 12 IIB	GROUP 13 IIIA	GROUP 14 IVA	GROUP 15 VA	GROUP 16 VIA	GROUP 17 VIIA	GROUP 18 VIIIA
1	1 H 1.01	2 He 4.00											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
2	3 Li 6.94	4 Be 9.01											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
3	11 Na 22.99	12 Mg 24.31	3 III	4 IV	5 V	6 VI	7 VII	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	3 III	4 IV	5 V	6 VI	7 VII	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
5	37 Rb 85.47	38 Sr 87.62	3 III	4 IV	5 V	6 VI	7 VII	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
6	55 Cs 132.91	56 Ba 137.33	3 III	4 IV	5 V	6 VI	7 VII	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
7	87 Fr (223)	88 Ra (226)	3 III	4 IV	5 V	6 VI	7 VII	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95

GROUP 13 IIIA	GROUP 14 IVA	GROUP 15 VA	GROUP 16 VIA	GROUP 17 VIIA	GROUP 18 VIIIA
59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)
89 Ac** (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)
87 Fr (223)	88 Ra (226)	89 Ac** (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03
85 At (210)	86 Rn (222)	87 Fr (223)	88 Ra (226)	89 Ac** (227)	90 Th 232.04
83 Bi (209)	84 Po (209)	85 At (210)	86 Rn (222)	87 Fr (223)	88 Ra (226)
81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)
77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2
76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38
74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97
72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22
70 Zr 91.22	71 Nb 92.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21
68 Y 88.91	69 Zr 91.22	70 Nb 92.91	71 Mo 95.95	72 Tc (98)	73 Ru 101.07
66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93
62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93
60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96
103 Lr (262)	104 No (259)	105 Md (258)	106 Lr (262)	107 Uuo (294)	108 Uus (294)
101 Ml (257)	102 No (259)	103 Lr (262)	104 No (259)	105 Md (258)	106 Lr (262)
99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)	104 No (259)
97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)
95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)
93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)
91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)
89 Ac** (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)
87 Fr (223)	88 Ra (226)	89 Ac** (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03

**Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]**

For #1-5, predict how the following reaction will respond to the indicated stress.



- CO is added  
A) **shifts left**                      B) shifts right                      C) no effect
- Reaction is cooled  
A) shifts left                      B) **shifts right**                      C) no effect
- Volume of the container is doubled  
A) shifts left                      B) **shifts right**                      C) no effect
- C is removed  
A) shifts left                      B) shifts right                      C) **no effect**
- Ne is added  
A) shifts left                      B) shifts right                      C) **no effect**

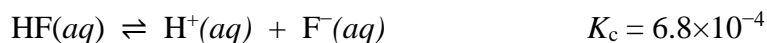
For #6-9, when the compound listed is dissolved in water, predict if the resulting solution will be acidic, basic, or neutral.

- $\text{NH}_4\text{ClO}_4$   
A) **acidic**                      B) basic                      C) neutral
- $\text{Cu}(\text{NO}_3)_2$   
A) **acidic**                      B) basic                      C) neutral
- $\text{CaI}_2$   
A) acidic                      B) basic                      C) **neutral**
- $\text{NaCN}$   
A) acidic                      B) **basic**                      C) neutral
- What is the conjugate acid of  $\text{HCO}_3^-$ ?  
A)  $\text{CO}_3^{2-}$                       B)  $\text{H}_3\text{O}^+$                       C)  $\text{H}_2\text{O}$                       D)  $\text{OH}^-$                       E)  **$\text{H}_2\text{CO}_3$**

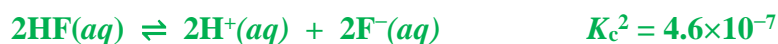
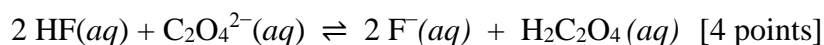
11. A substance that accepts  $\text{H}^+$  (proton acceptor) in solution is a(n):  
A) Arrhenius acid                      B) Arrhenius base                      C) Lewis acid  
D) Lewis base                              E) **Brønsted-Lowry base**
12. A substance that donates an electron pair in solution is a(n):  
A) Brønsted-Lowry acid                      B) Brønsted-Lowry base                      C) Lewis acid  
D) **Lewis base**                              E) Arrhenius acid
13. Calculate the pOH of a solution that contains  $3.9 \times 10^{-4} \text{ M } \text{H}_3\text{O}^+$  at  $25^\circ\text{C}$ .  
A) 4.39                      B) 3.41                      C) **10.59**                      D) 6.15                      E) 7.85
14. Based on its molecular structure, which of the following is the strongest acid?  
A)  **$\text{HClO}_2$**                               B)  $\text{HBrO}_2$                               C)  $\text{HIO}_2$
15. Based on its molecular structure, which of the following is the strongest acid?  
A)  $\text{HF}$                       B)  $\text{HCl}$                       C)  $\text{HBr}$                       D)  **$\text{HI}$**                       E)  $\text{H}_2\text{S}$

**Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. Refer to the table of  $K_a$  values at the end as necessary. Place a box around your final answer.**

16. Given the following information,

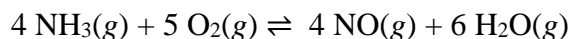


determine the value of  $K_c$  for the reaction:

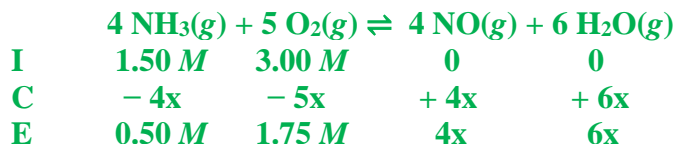


$$K = 0.12$$

17. At a certain temperature, 3.00 mol of  $\text{NH}_3$  and 6.00 mol of  $\text{O}_2$  were introduced into a 2.00-L container and reacted by the following equation:



At equilibrium, 1.00 mol of  $\text{NH}_3$  and 3.50 mol of  $\text{O}_2$  remain. What is the value of  $K$  for this reaction? [5]



$$4x = 1.00 \quad 5x = 1.25$$

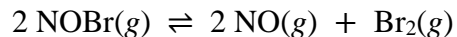
$$x = 0.25 \text{ M} \quad x = 0.250 \text{ M}$$

$$[\text{NO}] = 4x = 4(0.25) = 1.0 \text{ M}$$

$$[\text{H}_2\text{O}] = 6x = 6(0.25) = 1.5 \text{ M}$$

$$K = \frac{[\text{NO}]^4 [\text{H}_2\text{O}]^6}{[\text{NH}_3]^4 [\text{O}_2]^5} = \frac{(1.0)^4 (1.5)^6}{(0.50)^4 (1.75)^5} = \mathbf{11}$$

18. The equilibrium constant,  $K$ , is  $3.9 \times 10^{-4}$  at a certain temperature for the reaction:



A 3.00-L flask contains 0.165 g NOBr, 0.102 g NO, and 5.39 g Br<sub>2</sub>. Determine if the reaction is at equilibrium. If not, what direction will the system shift? [7]

$$[\text{NOBr}] = 0.165 \text{ g} \times \frac{1 \text{ mol NOBr}}{109.91 \text{ g}} \div 3.00 \text{ L} = 5.00 \times 10^{-4} \text{ M}$$

$$[\text{NO}] = 0.102 \text{ g} \times \frac{1 \text{ mol NO}}{30.01 \text{ g}} \div 3.00 \text{ L} = 1.13 \times 10^{-3} \text{ M}$$

$$[\text{Br}_2] = 5.39 \text{ g} \times \frac{1 \text{ mol Br}_2}{159.80 \text{ g}} \div 3.00 \text{ L} = 1.12 \times 10^{-2} \text{ M}$$

$$Q = \frac{[\text{NO}]^2 [\text{Br}_2]}{[\text{NOBr}]^2} = \frac{(1.13 \times 10^{-3})^2 (1.12 \times 10^{-2})}{(5.00 \times 10^{-4})^2} = 5.72 \times 10^{-2}$$

**Q > K so reaction shifts left**

19. Nitrogen and oxygen gases react to form nitrous oxide according to the following reaction:



If 70.0 g of  $\text{N}_2$  and 110.0 g of  $\text{O}_2$  are mixed in a 1.50-L flask at  $25^\circ\text{C}$ , calculate the concentration of all species at equilibrium. (Enter results in the blanks provided.) [10]

$$[\text{N}_2] = 70.0 \text{ g} \times \frac{1 \text{ mol N}_2}{28.02 \text{ g}} \div 1.50 \text{ L} = 1.67 \text{ M}$$

$$[\text{O}_2] = 110.0 \text{ g} \times \frac{1 \text{ mol O}_2}{32.00 \text{ g}} \div 1.50 \text{ L} = 2.29 \text{ M}$$



<b>I</b>	<b>1.67 M</b>	<b>2.29 M</b>	<b>0 M</b>
<b>C</b>	<b>- x</b>	<b>- x</b>	<b>+ 2x</b>
<b>E</b>	<b>1.67-x</b>	<b>2.29-x</b>	<b>2x</b>
	<b>≈1.67</b>	<b>≈2.29</b>	

$$K = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}$$

$$4.6 \times 10^{-31} = \frac{(2x)^2}{(1.67)(2.29)} = \frac{4x^2}{(1.67)(2.29)}$$

$$x = 6.6 \times 10^{-16}$$

$$[\text{N}_2]_{\text{equil}} = 1.67 \text{ M}$$

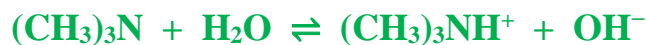
$$[\text{O}_2]_{\text{equil}} = 2.29 \text{ M}$$

$$[\text{NO}]_{\text{equil}} = 2x = 1.3 \times 10^{-15} \text{ M}$$

20. Trimethylamine,  $(\text{CH}_3)_3\text{N}$ , is a gas with a fishy, ammonia-like odor. An aqueous solution that is  $0.25\text{ M}$  trimethylamine has a pH of 11.63. What is  $K_b$  for trimethylamine? *Hint: Do amines typically behave like acids or bases?* [7]

$$\text{pOH} = 14 - \text{pH} = 14 - 11.63 = 2.37$$

$$[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-2.37} = 4.3 \times 10^{-3}\text{ M}$$



I	0.25 M	0	0
C	-x	+x	+x
E	0.25 - x	$4.3 \times 10^{-3}$	$4.3 \times 10^{-3}$

$$x = 4.3 \times 10^{-3}$$

$$[(\text{CH}_3)_3\text{N}] = 0.25 - 4.3 \times 10^{-3} = 0.25\text{ M}$$

$$[(\text{CH}_3)_3\text{NH}^+] = 4.3 \times 10^{-3}\text{ M}$$

$$[\text{OH}^-] = 4.3 \times 10^{-3}$$

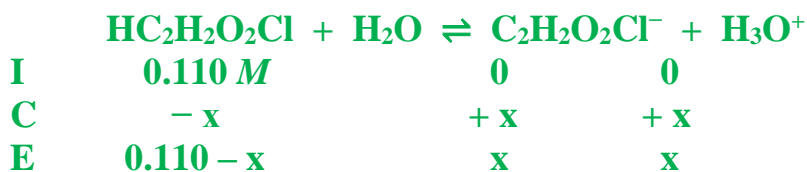
$$K_b = \frac{(4.3 \times 10^{-3})(4.3 \times 10^{-3})}{0.25} = 7.4 \times 10^{-5}$$



21. Calculate the pH of a mixture of 0.145 M HC<sub>6</sub>H<sub>5</sub>O and 0.110 M HC<sub>2</sub>H<sub>2</sub>O<sub>2</sub>Cl. [7]



$K_a$  for HC<sub>2</sub>H<sub>2</sub>O<sub>2</sub>Cl is much larger than the  $K_a$  for HC<sub>6</sub>H<sub>5</sub>O so ignore HC<sub>6</sub>H<sub>5</sub>O.



$$K_a = \frac{[\text{C}_2\text{H}_2\text{O}_2\text{Cl}^-][\text{H}_3\text{O}^+]}{[\text{HC}_2\text{H}_2\text{O}_2\text{Cl}]}$$

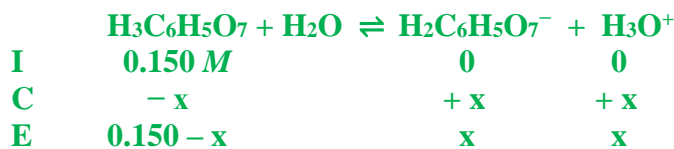
$$1.4 \times 10^{-3} = \frac{x^2}{0.110 - x}$$

$$0 = x^2 + 1.4 \times 10^{-3}x - 1.54 \times 10^{-4}$$

$$x = 0.012 = [\text{H}_3\text{O}^+]$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+] = -\log(0.012) = 1.92$$

22. **Challenge Question:** Calculate the mass in milligrams of  $\text{C}_6\text{H}_5\text{O}_7^{3-}$  in 1.75 L of a 0.150 M citric acid ( $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$ ) solution. ( $K_{a1} = 7.4 \times 10^{-4}$ ,  $K_{a2} = 1.7 \times 10^{-5}$ ,  $K_{a3} = 4.0 \times 10^{-10}$ ) [10]

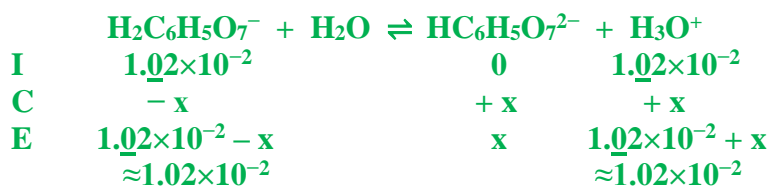


$$K_a = \frac{[\text{H}_2\text{C}_6\text{H}_5\text{O}_7^-][\text{H}_3\text{O}^+]}{[\text{H}_3\text{C}_6\text{H}_5\text{O}_7]}$$

$$7.4 \times 10^{-4} = \frac{(x)(x)}{(0.150 - x)}$$

$$0 = x^2 + 7.4 \times 10^{-4}x - 1.11 \times 10^{-4}$$

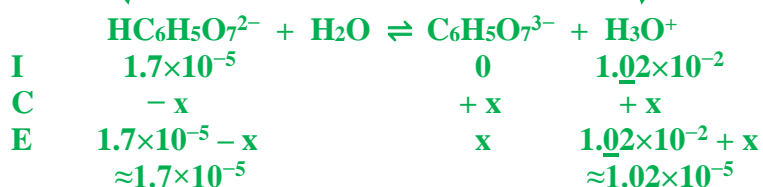
$$x = 1.02 \times 10^{-2} = [\text{H}_2\text{C}_6\text{H}_5\text{O}_7^-] = [\text{H}_3\text{O}^+]$$



$$K_a = \frac{[\text{HC}_6\text{H}_5\text{O}_7^{2-}][\text{H}_3\text{O}^+]}{[\text{H}_2\text{C}_6\text{H}_5\text{O}_7^-]}$$

$$1.7 \times 10^{-5} = \frac{(x)(1.02 \times 10^{-2})}{(1.02 \times 10^{-2})}$$

$$x = 1.7 \times 10^{-5} = [\text{HC}_6\text{H}_5\text{O}_7^{2-}]$$



$$K_a = \frac{[\text{C}_6\text{H}_5\text{O}_7^{3-}][\text{H}_3\text{O}^+]}{[\text{HC}_6\text{H}_5\text{O}_7^{2-}]}$$

$$4.0 \times 10^{-10} = \frac{(x)(1.02 \times 10^{-2})}{(1.7 \times 10^{-5})}$$

$$x = [\text{C}_6\text{H}_5\text{O}_7^{3-}] = 6.7 \times 10^{-13} \text{ M}$$

$$1.75 \text{ L} \times \frac{6.7 \times 10^{-13} \text{ mol}}{1 \text{ L}} \times \frac{189.11 \text{ g}}{\text{mol}} \times \frac{1 \text{ mg}}{10^{-3} \text{ g}} = 2.2 \times 10^{-7} \text{ mg}$$

**Extra Credit:** Explain why boron-containing compounds such as  $\text{BF}_3$  typically make good Lewis acids. [2] **B compounds are often electron deficient so they can accept an  $e^-$  pair.**

**Formulas & Constants**

$$M = \frac{\text{mol solute}}{\text{liters solution}}$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}}$$

$$\chi_A = \frac{\text{mol A}}{\text{total moles}}$$

$$P_A = \chi_A \cdot P_A^\circ$$

$$R = 0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$$

$$R = 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

$$\Delta T_f = \underline{m} \cdot K_f$$

$$\Delta T_b = \underline{m} \cdot K_b$$

$$\Pi = \underline{M}RT$$

$$\Delta T_f = i \cdot \underline{m} \cdot K_f$$

$$\Delta T_b = i \cdot \underline{m} \cdot K_b$$

$$\Pi = i \cdot \underline{M}RT$$

$$K = ^\circ\text{C} + 273.15$$

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mmHg}$$

$$S_{\text{gas}} = k_H \cdot P_{\text{gas}}$$

$$\Delta H_{\text{sol'n}} = \Delta H_{\text{hydration}} - \Delta H_{\text{lattice}}$$

$$f = e^{-E_a/RT}$$

$$k = Ae^{-E_a/RT}$$

$$\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln k = -\frac{E_a}{R} \left( \frac{1}{T} \right) + \ln A$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$K_p = K_c(RT)^{\Delta n}$$

$$K_w = 1.0 \times 10^{-14} \text{ @ } 25^\circ\text{C}$$

$$K_a \times K_b = K_w$$

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$K = e^{-\Delta G^\circ/RT}$$

$$\Delta G^\circ = -nFE^\circ$$

$$F = 96,485 \text{ J/V}\cdot\text{mol}$$

$$E^\circ_{\text{cell}} = E^\circ(\text{cathode}) - E^\circ(\text{anode}) \quad E = E^\circ - (0.0592/n) \log Q$$

$$E = E^\circ - (RT/nF) \ln Q$$

$$1 \text{ V} = 1 \text{ J/C}$$

*Acid Dissociation Constants at 25°C*

Name	Formula	$K_a$
Benzoic	HC <sub>7</sub> H <sub>5</sub> O <sub>2</sub>	$6.5 \times 10^{-5}$
Chloroacetic	HC <sub>2</sub> H <sub>2</sub> O <sub>2</sub> Cl	$1.4 \times 10^{-3}$
Phenol	HC <sub>6</sub> H <sub>5</sub> O	$1.3 \times 10^{-10}$

**Scratch Page**  
(to be handed in)