FORM “A”
This exam is made up of an answer sheet, two cover sheets and 6 numbered pages. Below are instructions for coding the answer sheet. At the bottom of this sheet are the solubility rules. Cover sheet ii, attached to the back of this exam, contains some useful equations and constants, plus the periodic table.

On the answer sheet:

1. Use #2 pencil. Erase cleanly.
2. Print your NAME in the appropriate designated spaces, then blacken in the letter boxes below each printed letter, last name first, then your first name initial.
3. Fill in your university ID number under STUDENT NUMBER.
4. Under SECTION write the five digit number that corresponds to your section designation, and then blacken in the corresponding number of boxes. For 102A students, the numbers are: AQA = 00011, AQB = 00012, AQC = 00013, AQD = 00014, AQE = 00015, AQF = 00016, AQG = 00017, AQH = 00018, AQI = 00019, AQJ = 00020, AQK = 00021, AQM = 00022. For 102C students, the numbers are: CQ1 = 00031, CQ2 = 00032, CQ3 = 00033, CQ4 = 00034, CQ5 = 00035, CQ6 = 00036, CQ7 = 00037, CQ9 = 00039, CQA = 00041, CQB = 00042, CQC = 00043, CQD = 00044.
5. Under NETWORK ID print your University Network ID beginning on the left hand side with box #1, and then blacken in the corresponding letters, numbers and/or dashes under each character. Do not fill in a character for any unused boxes.
6. Under TEST FORM blacken the letter corresponding to the form designated on the upper left hand corner of the exam booklet.
7. Your TA’s name should be printed for INSTRUCTOR and write your section number for SECTION in the lines provided.
8. Sign your name (do not print) on the line provided. Print your name underneath it.
9. Mark only one answer per question and do not use the answer sheet for scratch paper or make any stray marks on it. Erase cleanly if you wish to change an answer. The exam itself can be used for scratch paper.

Work carefully and efficiently. If your answer differs from one given in the last proper significant figure, mark that answer as correct and not the response “none of these”. All questions are worth the same.

Solubility rules:

1. Most nitrate salts are soluble.
2. Most salts of alkali metals and ammonium cations are soluble.
3. Most chloride, bromide and iodide salts are soluble.
   Exceptions: salts containing Ag⁺, Pb²⁺ and Hg²⁺ ions are insoluble.
4. Most sulfate salts are soluble.
   Exceptions: sulfates containing Ca²⁺, Ba²⁺, Pb²⁺ and Hg²⁺ ions are insoluble.
5. Most hydroxide salts are insoluble.
   Exceptions: hydroxides containing alkali metals, Ba²⁺, Sr²⁺ and Ca²⁺ ions are soluble.
6. Most sulfide, carbonate, chromate and phosphate salts are insoluble.
   Exceptions: salts of alkali metals and ammonium cations are soluble.
1. My answers for this Chemistry 102 exam should be graded with the answer sheet associated with:
   a) Form A  b) Form B  c) Form C  d) Form D  e) Form E

2. A 1.0 L flask is filled initially with 4.0 mol H₂ and 6.0 mol F₂, which then react by the following equation:
   \[
   \text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) \quad K = ?
   \]
   At equilibrium, 3.5 mol of F₂ remains. Calculate the value of \( K \) for the above reaction.
   a) 2.0  b) 1.2  c) 0.95  d) 5.0  e) 4.8

3. A chemist wishes to prepare a buffer at pH = 3.5 and has the following acids available, along with the potassium salts of their conjugate bases. Which acid/salt combination is the best choice for preparing the buffer?
   a) HC₂H₃O₂ (\( K_a = 1.8 \times 10^{-5} \))  b) HOCl (\( K_a = 3.5 \times 10^{-8} \))  c) HNO₂ (\( K_a = 4.0 \times 10^{-4} \))
   d) HCN (\( K_a = 6.2 \times 10^{-10} \))  e) HClO₂ (\( K_a = 1.2 \times 10^{-2} \))

At 10 °C, the equilibrium constant for the autoionization of water (also known as the dissociation constant for water, \( K_w \)), is \( 2.9 \times 10^{-15} \). Use this information to answer the next two questions.

4. Which of the following best explains whether the autoionization of water is an endothermic or an exothermic process?
   a) It is exothermic because as temperature increases, \( K \) decreases.
   b) It is exothermic because as temperature decreases, \( K \) decreases.
   c) It is endothermic because as temperature increases, \( K \) decreases.
   d) It is endothermic because as temperature decreases, \( K \) decreases.

5. What is the pH of neutral water at 10 °C?
   a) 7.00  b) 7.27  c) 6.73  d) 14.53  e) −0.47
6. What is the pH of a 0.50 \textit{M} solution of C_3H_5N (K_b = 1.7 \times 10^{-9})?
   a) 4.54   b) 4.93   c) 9.07   d) 9.46   e) 13.70

7. Calculate the OH^- concentration in a 0.10 \textit{M} solution of H_2NNH_3NO_3. K_b for H_2NNH_2 = 3.0 \times 10^{-6}.
   \[ \text{a) } 1.8 \times 10^{-5} \text{ M} \quad \text{b) } 5.5 \times 10^{-4} \text{ M} \quad \text{c) } 5.5 \times 10^{-10} \text{ M} \]
   \[ \text{d) } 1.8 \times 10^{-11} \text{ M} \quad \text{e) } 3.3 \times 10^{-10} \text{ M} \]

8. Which of the following is \textit{false} concerning a buffer solution of HF and NaF?
   a) If [HF] = [F^-], then the pH of the solution equals the pK_a value of HF.
   b) If HCl is added to the buffer, then the pH of the resulting solution will decrease.
   c) If [F^-] > [HF], then the pH of the solution will be greater than the pK_a value for HF.
   d) If [HF] > [F^-], then [H^+] of the solution will be greater than the K_a value of HF.
   e) If KOH is added to the buffer, then the [HF] of the resulting solution will increase.

9. Rank 0.25 \textit{M} solutions of the following compounds from \textit{highest} to \textit{lowest} [H^+].
   \[ \text{KBr} \quad \text{NH}_4\text{Cl} \quad \text{Sr(OH)}_2 \quad \text{H}_2\text{SO}_4 \quad \text{LiCN} \quad \text{HC}_2\text{H}_3\text{O}_2 \]
   \[ \text{a) } \text{H}_2\text{SO}_4 \quad \text{KBr} \quad \text{HC}_2\text{H}_3\text{O}_2 \quad \text{LiCN} \quad \text{NH}_4\text{Cl} \quad \text{Sr(OH)}_2 \]
   \[ \text{b) } \text{Sr(OH)}_2 \quad \text{LiCN} \quad \text{KBr} \quad \text{NH}_4\text{Cl} \quad \text{HC}_2\text{H}_3\text{O}_2 \quad \text{H}_2\text{SO}_4 \]
   \[ \text{c) } \text{H}_2\text{SO}_4 \quad \text{HC}_2\text{H}_3\text{O}_2 \quad \text{NH}_4\text{Cl} \quad \text{KBr} \quad \text{LiCN} \quad \text{Sr(OH)}_2 \]
   \[ \text{d) } \text{H}_2\text{SO}_4 \quad \text{HC}_2\text{H}_3\text{O}_2 \quad \text{LiCN} \quad \text{KBr} \quad \text{NH}_4\text{Cl} \quad \text{Sr(OH)}_2 \]
   \[ \text{e) } \text{Sr(OH)}_2 \quad \text{NH}_4\text{Cl} \quad \text{LiCN} \quad \text{HC}_2\text{H}_3\text{O}_2 \quad \text{KBr} \quad \text{H}_2\text{SO}_4 \]
10. Calculate the pOH of a solution made by mixing 250.0 mL of 0.150 M NaOH with 50.0 mL of 0.210 M Sr(OH)$_2$.
   a) 0.710    b) 0.796    c) 1.233    d) 13.204    e) 13.290

11. Consider the titration of 100.0 mL of 0.50 M HCl titrated by 0.25 M NaOH. Calculate the pH at the halfway point to equivalence.
   a) 0.50    b) 0.30    c) 0.60    d) 1.00    e) 0.90

12. Which of the following is the correct $K_a$ expression for the acid HOBr?
   a) $\frac{[H_3O^+][H_2OBr^+]}{[HOBr]}$
   b) $\frac{[H_3O^+][HOBr]}{[OBr^-]}$
   c) $\frac{[H_2O][OBr^-]}{[HOBr]}$
   d) $\frac{[OH^-][Br^-]}{[HOBr]}$
   e) $\frac{[OH^-][HOBr]}{[Br^-]}$

13. Which of the following titrations (a-d) will have the **lowest** pH at the equivalence point?
   a) 2.0 M $C_6H_5NH_2$ titrated by 1.0 M HCl
   b) 2.0 M NH$_3$ titrated by 2.0 M HClO$_4$
   c) 2.0 M HBr titrated by 1.0 M KOH
   d) 2.0 M HCl$_2$O$_3$ titrated by 2.0 M RbOH
   e) All of the above solutions will have the same pH at the equivalence point.

14. Which of the following titrations (a-d) will have a pH closest to 5.0 at the **halfway point** to equivalence?
   a) 2.0 M $C_6H_5NH_2$ titrated by 1.0 M HCl
   b) 2.0 M NH$_3$ titrated by 2.0 M HClO$_4$
   c) 2.0 M HBr titrated by 1.0 M KOH
   d) 2.0 M HCl$_2$O$_3$ titrated by 2.0 M RbOH
   e) All of the above solutions will have the same pH at the halfway point to equivalence.

15. What is the pH of a 2.0 $\times$ 10$^{-10}$ M solution of HNO$_3$?
   a) 9.70    b) 7.00    c) 4.30    d) 3.95    e) 0.70
16. What is the pH of a solution that results from adding 0.040 mol RbOH to 1.0 L of a buffer that is 0.20 M HOC₆H₅ and 0.20 M KOC₆H₅? $K_a$ for HOC₆H₅ is $1.6 \times 10^{-10}$.
   a) 9.62   b) 9.71   c) 9.80   d) 9.88   e) 9.97

17. A buffer solution of C₆H₅NH₂ and C₆H₅NH₂Cl has a pH of 4.35. If in this buffer solution $[C₆H₅NH₂] = 1.87 M$, what is $[C₆H₅NH₃⁺]$? $K_b$ for C₆H₅NH₂ = $3.8 \times 10^{-10}$.
   a) 0.31 $M$   b) 3.2 $M$   c) 1.1 $M$   d) 0.44 $M$   e) 8.0 $M$

Consider the titration of 100.0 mL of 0.200 M HOCl ($K_a = 3.5 \times 10^{-8}$) by 0.100 $M$ KOH for the next five questions:

18. Calculate the pH when 0.0 mL of KOH has been added.
   a) 0.70   b) 4.08   c) 7.00   d) 9.92   e) 13.00

19. Calculate the pH after 50.0 mL KOH has been added.
   a) 6.85   b) 6.98   c) 7.46   d) 7.93   e) 12.52

20. Calculate the pH after 100.0 mL KOH has been added.
   a) 1.30   b) 6.54   c) 7.00   d) 7.46   e) 12.70

21. Calculate the pH after 200.0 mL KOH has been added.
   a) 3.86   b) 7.00   c) 9.68   d) 10.14   e) 10.38

22. Calculate the pH after 250.0 mL KOH has been added.
   a) 1.00   b) 1.85   c) 10.15   d) 12.15   e) 13.00
23. Consider the species present in a 0.10 \( M \) solution of \( \text{H}_2\text{SO}_4 \). Which of the following correctly ranks the species present from lowest to highest concentration?

a) \( \text{H}_3\text{O}^+ < \text{SO}_4^{2-} < \text{HSO}_4^- \)
b) \( \text{HSO}_4^- < \text{H}_3\text{O}^+ < \text{H}_2\text{SO}_4 \)
c) \( \text{SO}_4^{2-} < \text{H}_3\text{O}^+ < \text{HSO}_4^- \)
d) \( \text{HSO}_4^- < \text{SO}_4^{2-} < \text{H}_3\text{O}^+ \)
e) \( \text{SO}_4^{2-} < \text{HSO}_4^- < \text{H}_3\text{O}^+ \)

24. Separate 1.0 \( M \) solutions of the following three compounds are prepared. Rank the resulting solutions from lowest to highest pH?

\[
\text{BaO} \quad \text{SO}_2 \quad \text{NH}_4\text{C}_2\text{H}_5\text{O}_2
\]

a) \( \text{BaO} < \text{NH}_4\text{C}_2\text{H}_5\text{O}_2 < \text{SO}_2 \)
b) \( \text{SO}_2 < \text{NH}_4\text{C}_2\text{H}_5\text{O}_2 < \text{BaO} \)
c) \( \text{BaO} < \text{SO}_2 < \text{NH}_4\text{C}_2\text{H}_5\text{O}_2 \)
d) \( \text{NH}_4\text{C}_2\text{H}_5\text{O}_2 < \text{BaO} < \text{SO}_2 \)
e) \( \text{NH}_4\text{C}_2\text{H}_5\text{O}_2 < \text{SO}_2 < \text{BaO} \)

The next two questions refer to the following reaction at 25\(^\circ\)C:

\[
\text{B}_2\text{O}_3(s) + 3 \text{H}_2\text{O}(g) \rightleftharpoons \text{B}_2\text{H}_6(g) + 3 \text{O}_2(g) \quad \Delta H = 2035 \text{ kJ}, \ K = 4.8 \times 10^{-2}
\]

25. Initially, 8.0 mol \( \text{B}_2\text{O}_3 \), 5.0 mol \( \text{H}_2\text{O} \), 6.0 mol \( \text{B}_2\text{H}_6 \), and 2.0 mol \( \text{O}_2 \) are mixed in a 1.0 L container. What will happen to the amount of \( \text{B}_2\text{O}_3 \) present as the reaction reaches equilibrium?

a) It will increase because the reaction will shift to the left to reach equilibrium.
b) It will not change because solids are not involved in the equilibrium.
c) It will not change because the reaction is already at equilibrium.
d) It will decrease because the reaction will shift to the right to reach equilibrium.

26. After the above reaction has reached equilibrium, which of the following statements is true regarding the reaction?

a) Raising the temperature will cause the value of \( K \) to decrease for this reaction.
b) Adding more \( \text{B}_2\text{O}_3 \) will cause the reaction to shift to the right to reestablish equilibrium.
c) If the container volume is cut in half, the reaction will shift to the left to reestablish equilibrium.
d) Removing some \( \text{B}_2\text{H}_6(g) \) will cause the reaction to shift to the left to reestablish equilibrium.
e) Adding more \( \text{O}_2(g) \) will cause the value of \( K \) to decrease for this reaction.
27. Phosphoric acid, $\text{H}_3\text{PO}_4$, is a triprotic acid with three acidic forms and three conjugate base forms. Which of the following correctly pairs an acidic form with its conjugate base?

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<th>Acid</th>
<th>Conjugate Base</th>
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<tbody>
<tr>
<td>a) $\text{H}_3\text{PO}_4$</td>
<td>$\text{PO}_4^{3-}$</td>
</tr>
<tr>
<td>b) $\text{H}_2\text{PO}_4^-$</td>
<td>$\text{PO}_4^{3-}$</td>
</tr>
<tr>
<td>c) $\text{H}_2\text{PO}_4^-$</td>
<td>$\text{HPO}_4^{2-}$</td>
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<tr>
<td>d) $\text{HPO}_4^{2-}$</td>
<td>$\text{H}_2\text{PO}_4^-$</td>
</tr>
<tr>
<td>e) $\text{PO}_4^{3-}$</td>
<td>$\text{H}_2\text{PO}_4^-$</td>
</tr>
</tbody>
</table>

28. At $35^\circ\text{C}$, $K = 1.6 \times 10^{-5}$ for the reaction:

$$2 \text{NO(g)} + \text{Cl}_2(g) \rightleftharpoons 2 \text{NOCl(g)}$$

If 2.0 mol NO and 1.0 mol Cl$_2$ are placed into a 1.0 L evacuated container at $35^\circ\text{C}$, what is the equilibrium concentration of NOCl?

a) $8.0 \times 10^{-3} \text{M}$  b) $6.4 \times 10^{-5} \text{M}$  c) $2.0 \text{M}$

d) $1.6 \times 10^{-5} \text{M}$  e) $4.0 \times 10^{-3} \text{M}$

29. A 75.0 mL solution of HBr is titrated with 0.150 $M$ Ba(OH)$_2$. If it takes 130.0 mL of the base solution to reach the equivalence point, what is the initial concentration of the hydrobromic acid solution?

a) 0.520 $M$  b) 0.260 $M$  c) 0.0951 $M$  d) 0.190 $M$  e) 0.150 $M$

30. A solution of a weak acid, HA, has a pH of 3.30 at $25^\circ\text{C}$. If the acid is 0.31% dissociated to reach equilibrium, what is the $K_a$ value for the acid?

a) $3.1 \times 10^{-3}$  b) $5.0 \times 10^{-4}$  c) $1.6 \times 10^{-4}$  d) $1.6 \times 10^{-6}$  e) $6.0 \times 10^{-9}$

31. A 0.020 mol sample of a weak acid, HX, is dissolved in 400.0 mL of water and titrated with 0.40 $M$ NaOH. After 35.0 mL of the NaOH solution has been added, the overall pH = 5.50. Calculate the $K_a$ value for HX.

a) $1.4 \times 10^{-6}$  b) $3.2 \times 10^{-6}$  c) $1.4 \times 10^{-9}$  d) $3.1 \times 10^{-9}$  e) $7.4 \times 10^{-6}$
USEFUL CONSTANTS/EQUATIONS

\[ K_w = K_a K_b \]
\[ K_w = [H^+] [OH^-] \]
\[ K_w = 1.0 \times 10^{-14} \text{ (at 25°C)} \]
\[ pK_a + pK_b = 14.00 \text{ (at 25°C)} \]
\[ pK_a + pK_b = 14.00 \text{ (at 25°C)} \]
\[ pH = \log [H^+], \ [H^+] = 10^{-pH} \]
\[ pH = pK_a + \log \frac{[\text{base}]}{[\text{acid}]} \]
\[ pOH = -\log [OH^-], \ [OH^-] = 10^{-pOH} \]
\[ pK_a = -\log K_a, \ pK_b = -\log K_b; \ K_a = 10^{-pK_a} \]
\[ MA V_A = MB V_B \]

Acid \hspace{2cm} K_a \hspace{2cm} Base \hspace{2cm} K_b

<table>
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<th>Base</th>
<th>( K_b )</th>
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% dissociation = \( \frac{\text{amount dissociated}}{\text{initial concentration}} \times 100 \)

PERIODIC TABLE OF THE ELEMENTS

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| 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

| K | Ca | Sc | Ti | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | Xe | 39.10 | 40.08 | 44.96 | 47.90 | 50.94 | 52.00 | 54.94 | 55.85 | 58.93 | 58.70 | 63.55 | 65.39 | 69.72 | 72.59 | 74.92 | 78.96 | 79.90 | 83.80 | 85.47 | 87.62 | 88.91 | 91.22 | 92.91 | 95.94 | 98 | 101.1 | 102.9 | 106.4 | 107.9 | 112.4 | 114.8 | 118.7 | 121.8 | 127.6 | 126.9 | 131.3 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn | 132.9 | 137.3 | 138.9 | 178.5 | 180.9 | 183.9 | 186.2 | 190.2 | 192.2 | 195.1 | 197.0 | 200.6 | 204.4 | 207.2 | 209.0 | 209 | 210 | 222 | 87 | 88 | 89 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

| Fr | Ra | Ac | Rf | Db | Sg | Bh | Hs | Mt | Ds | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

'Lanthanides

| Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | 140.1 | 140.9 | 144.2 | 145 | 150.4 | 152.0 | 157.3 | 158.9 | 162.5 | 164.9 | 167.3 | 168.9 | 173.0 | 175.0 |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|

'Actinides

| Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr | 232.0 | 231 | 238 | 244 | 242 | 243 | 247 | 247 | 251 | 252 | 257 | 258 | 259 | 260 |