CHEMISTRY 102B/C
Hour Exam III
December 4, 2019
T. Hummel

NAME _____

SIGNATURE _____

SECTION _____

**FORM "A"**

This exam is made up of an answer sheet, two cover sheets and 7 numbered pages. Below are instructions for coding the answer sheet. The last page 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 102B students,** the numbers are: BQ1 = 00011, BQ2 = 00012, BQ4 = 00014, BQ6 = 00016, BQ7 = 00017, BQ8 = 00018, BQA = 00021, BQB = 00022, BQD = 00024, BQG = 00027, BQH = 00028, BQI = 00029. **For 102C students**, the numbers are: CQ1 = 00031, CQ2 = 00032, CQ3 = 00033, CQ5 = 00035, CQ6 = 00036, CQ7 = 00037, CQ8 = 00038, CQ9 = 00039, CQA = 00041, CQB = 00042, CQC = 00043, CQE = 00045.
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. 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 $Ag^+$, $Pb^{2+}$, and $Hg_2^{2+}$ ions are insoluble.
4. Most sulfate salts are soluble.
   Exceptions: sulfates containing $Ca^{2+}$, $Ba^{2+}$, $Pb^{2+}$, and $Hg_2^{2+}$ ions are insoluble.
5. Most hydroxide salts are insoluble.
   Exceptions: hydroxides containing alkali metals, $Ba^{2+}$, $Sr^{2+}$, and $Ca^{2+}$ ions are soluble.
6. Most sulfide, carbonate, chromate, and phosphate salts are insoluble.
   Exceptions: salts of alkali metals and ammonium cations are soluble.

1. Consider the following reaction at some constant temperature:

$$2\ HCl(g) \rightleftharpoons H_2(g) + Cl_2(g) \qquad K_p = 1.00$$

If 1.00 atm of HCl is initially reacted in a rigid container, calculate the equilibrium partial pressure of HCl.

a) 0.67 atm b) 1.33 atm c) 0.75 atm d) 0.50 atm e) 0.33 atm

2. Consider the following reaction at 960 K:

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$

An initial mixture contains the following concentrations of reactants and products: $[CO_2] = 0.040\ M$, $[H_2] = 0.022\ M$, $[CO] = 0.024\ M$, and $[H_2O] = 0.019\ M$. Once equilibrium is established, the equilibrium concentration of $CO_2$ is $0.030\ M$. Calculate the value of K for this reaction?

a) 0.52 b) 1.5 c) 0.69 d) 0.37 e) 2.7

3. When 385 kJ of energy is added to some water of unknown mass, the temperature increases from 50.0°C to 150.0°C. Calculate the mass of the water sample. For $H_2O$: boiling point = 100.0°C, specific heat capacity of $H_2O(l) = 4.18$ J/g•°C, specific heat capacity of $H_2O(g) = 2.02$ J/g•°C, $\Delta H_{vap} = 2.26$ kJ/g.

a) 31.5 g b) 150. g c) 320. g d) 540. g e) 1370 g

4. Consider a solution which contains $1 \times 10^{-4}\ M$ NaF, $1 \times 10^{-4}\ M$ $Na_2S$, and $1 \times 10^{-4}\ M$ $Na_3PO_4$. $Pb(NO_3)_2(aq)$ is gradually added to this solution. What is the order of precipitation as $Pb(NO_3)_2$ is added? $K_{sp}$ for $PbF_2 = 4 \times 10^{-8}$, $K_{sp}$ for $PbS = 7 \times 10^{-29}$, and $K_{sp}$ for $Pb_3(PO_4)_2 = 1 \times 10^{-54}$.

a) PbS precipitates first, then $PbF_2$ precipitates, and $Pb_3(PO_4)_2$ precipitates last.
b) PbS precipitates first, then $Pb_3(PO_4)_2$ precipitates, and $PbF_2$ precipitates last.
c) $PbF_2$ precipitates first, then $Pb_3(PO_4)_2$ precipitates, and PbS precipitates last.
d) $PbF_2$ precipitates first, then PbS precipitates, and $Pb_3(PO_4)_2$ precipitates last.
e) $Pb_3(PO_4)_2$ precipitates first, then PbS precipitates, and $PbF_2$ precipitates last.

5. Let $s$ = molar solubility (mol/L) of $Al_2(CO_3)_3(s)$. Which of the following is the correct mathematical expression relating $s$ to the $K_{sp}$ value for $Al_2(CO_3)_3(s)$?

a) $6s^2 = K_{sp}$ b) $4s^3 = K_{sp}$ c) $6s^4 = K_{sp}$ d) $108s^5 = K_{sp}$ e) $27s^6 = K_{sp}$

6. When xenon (Xe) gas and fluorine ($F_2$) gas are reacted at a certain temperature, solid $XeF_4$ is produced. Which of the following is a correct equilibrium constant expression for this reaction?

a) $\frac{1}{[Xe][F_2]^2}$ b) $\frac{[Xe][F_2]}{[XeF_4]}$ c) $\frac{[XeF_4]}{[Xe][F_2]}$

d) $\frac{[XeF_4]}{[Xe][F_2]^2}$ e) $\frac{1}{[Xe][F_2]}$

7. Consider the following reaction:

$$H_2(g) + F_2(g) \rightarrow 2\ HF(g)$$

Given that the HF bond is a stronger bond than either the $H_2$ bond or the $F_2$ bond, which of the following conclusions (a-d) can be drawn?

a) The reaction must be exothermic.
b) The reaction may be exothermic.
c) The reaction may be endothermic.
d) The reaction must be endothermic.
e) Answers b and c could both be correct.

8. Given the following data:

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ $\Delta H = -11$ kJ

$3\ Fe_2O_3(s) + CO(g) \rightarrow 2\ Fe_3O_4(s) + CO_2(g)$ $\Delta H = -39$ kJ

$3\ FeO(s) + CO_2(g) \rightarrow Fe_3O_4(s) + CO(g)$ $\Delta H = -18$ kJ

calculate $\Delta H$ for:

$Fe_2O_3(s) + 3\ CO\ (g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta H = ?$

a) −68 kJ b) 68 kJ c) −32 kJ d) 32 kJ e) −23 kJ

9. At 25°C, an equilibrium mixture for the reaction:

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g)$$

contains 0.120 mol of $NO_2$, 0.080 mol of NO, and 0.640 mol of $O_2$ in a 4.00 L bulb. What is the value of K at 25°C for this reaction?

a) 0.071 b) 14 c) 9.4 d) 3.5 e) 2.3

10. Two salts, $PbX_2$ and $PbY_2$, have similar solubilities in water. Experiments reveal that $PbX_2$ is more soluble in acidic solution than in water. However, this is not the case for the solubility of $PbY_2$. Which of the following statements is **true**?

a) The $K_{sp}$ value for $PbX_2$ must be smaller than the $K_{sp}$ value for $PbY_2$.
b) The $K_{sp}$ value for $PbY_2$ must be smaller than the $K_{sp}$ value for $PbX_2$.
c) $Pb^{2+}$ is a base.
d) The $X^-$ anion could be $F^-$.
e) The $Y^-$ anion could be $C_2H_3O_2^-$.

11. Consider the following reaction at 25°C and 1 atm:

$$2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g) \qquad \Delta H° = ?$$

If the standard enthalpies of formation for $N_2O_5(g)$ and $NO_2(g)$ are 11.3 kJ/mol 33.2 kJ/mol, respectively, calculate the enthalpy change for the above reaction.

a) −77.5 kJ b) 21.2 kJ c) −21.2 kJ d) 43.8 kJ e) 110.2 kJ

12. If the internal energy of a thermodynamic system increases by 300. J while 75 J of expansion work is done, what is the value of q for this system?

a) 375 J b) −375 J c) 225 J d) −225 J e) 0 J

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

$$2\ NO(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$$

If 2.0 mol NO and 1.0 mol $Cl_2$ are placed into a 1.0 L evacuated container at 35°C, what is the equilibrium concentration of NOCl?

a) $1.6 \times 10^{-5}\ M$ b) $6.4 \times 10^{-5}\ M$ c) $2.0\ M$

d) $8.0 \times 10^{-3}\ M$ e) $4.0 \times 10^{-3}\ M$

14. Consider the following precipitation reaction:

$$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq) \qquad \Delta H = ?$$

When 100.0 mL of 0.200 *M* $AgNO_3$ is mixed with a 100.0 mL of 0.100 *M* NaCl in a coffee-cup calorimeter, the temperature increases from 24.60°C to 25.30°C. Determine ΔH for the above reaction. Assume the density of the solution is 1.00 g/mL and assume the heat capacity of the solution is 4.18 J/g•°C.

a) −29 kJ b) −59 kJ c) 59 kJ d) −590 J e) 290 J

15. Consider the following reaction at 25°C:

$$B_2O_3(s) + 3\ H_2O(g) \rightleftharpoons B_2H_6(g) + 3\ O_2(g) \qquad \Delta H = 2035\ kJ,\ K = 4.8 \times 10^{-2}$$

Initially, 8.0 mol $B_2O_3$, 5.0 mol $H_2O$, 6.0 mol $B_2H_6$, and 2.0 mol $O_2$ are mixed in a 1.0 L container. What will happen to the amount of $B_2O_3$ 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.

16. Excess $Ag_3PO_4(s)$ is added to some water. At equilibrium, the concentration of $Ag^+$ is $4.8 \times 10^{-5}$ *M*. Calculate the $K_{sp}$ value for $Ag_3PO_4(s)$.

a) $1.4 \times 10^{-16}$ b) $2.3 \times 10^{-9}$ c) $4.4 \times 10^{-13}$ d) $6.7 \times 10^{-10}$ e) $1.8 \times 10^{-18}$

17. Consider the following reaction which is utilized for propulsion in space shuttles:

$$4\ N_2H_3CH_3(l) + 5\ N_2O_4(l) \rightarrow 12\ H_2O(g) + 9\ N_2(g) + 4\ CO_2(g) \qquad \Delta H = ?$$

At 1.00 atm and 110.°C, $\Delta E = -4674$ kJ for the above reaction. Determine $\Delta H$ for this reaction at 1.00 atm and 110.°C.

a) −4754 kJ b) −4623 kJ c) −4725 kJ d) −4594 kJ e) −4674 kJ

18. Which of the following statements (a-d) is **true** if $\Delta E$ for a system equals −95 J ($\Delta E = -95$ J)?

a) The system is gaining 95 J of energy, while the surroundings are losing 95 J of energy.
b) The system is losing 95 J of energy, while the surroundings are gaining 95 J of energy.
c) Both the system and the surroundings are gaining 95 J of energy.
d) Both the system and the surroundings are losing 95 J of energy.
e) None of the above (a-d) are true.

19. How many moles of $CaF_2(s)$ will dissolve in 3.0 liters of a 0.050 *M* NaF solution? Assume no volume change on addition of $CaF_2(s)$. $K_{sp}$ for $CaF_2 = 4.0 \times 10^{-11}$.

a) $8.9 \times 10^{-9}$ mol b) $8.0 \times 10^{-8}$ mol c) $4.8 \times 10^{-8}$ mol

d) $2.7 \times 10^{-8}$ mol e) 0.15 mol

20. For how many of the following (I-IV) does the enthalpy change for the reaction equal the standard enthalpy of formation for the product in the reaction, i.e., for how many does $\Delta H_{reaction} = \Delta H°_f$?

I. $2\ H(g) \rightarrow H_2(g)$

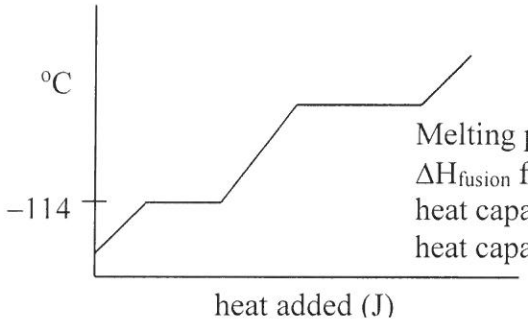
II. $H_2(g) + SO_4(l) \rightarrow H_2SO_4(l)$

III. $C(g) + 4\ H(g) + O(g) \rightarrow CH_3OH(g)$

IV. $Ba^{2+}(aq) + 2\ Cl^-(aq) \rightarrow BaCl_2(s)$

a) 0 (none) b) 1 c) 2 d) 3 e) 4 (all)

21. Consider the following heating curve for ethanol, $C_2H_5OH$:




Melting point = −114°C, b.p. = 78°C
$\Delta H_{fusion}$ for ethanol = 5.02 kJ/mol
heat capacity of ethanol(l) = 2.46 J/g•°C
heat capacity of ethanol(s) = 0.97 J/g•°C

How much energy is required to convert 23.0 g of solid ethanol at −114°C to liquid ethanol at 25°C? The molar mass of ethanol is 46.0 g/mol.

a) 5.35 kJ b) 2.51 kJ c) 7.86 kJ d) 10.37 kJ e) 5.04 kJ

22. Which of the following four salts when dissolved in water will produce the **largest** concentration of $Pb^{2+}$ at equilibrium?

| | |
|---|---|
| $PbCO_3$ | $K_{sp} = 1.5 \times 10^{-15}$ |
| $PbS$ | $K_{sp} = 7.0 \times 10^{-29}$ |
| $Pb(OH)_2$ | $K_{sp} = 1.2 \times 10^{-15}$ |
| $PbCrO_4$ | $K_{sp} = 2.0 \times 10^{-16}$ |

a) $PbCO_3$ b) $PbS$ c) $Pb(OH)_2$ d) $PbCrO_4$

23. An initial chemical reaction is reversed and then the coefficients are all multiplied by a factor of 2. The K value for this final reaction is 0.01. What is the value of K for the initial reaction?

a) 0.01 b) 100 c) 0.1 d) 10 e) 10,000

24. Consider the reaction:

$$2\ F_2(g) + 2\ H_2O(g) \rightarrow 4\ HF(g) + O_2(g) \qquad \Delta H = -579\ kJ$$

Calculate the H–F bond energy (in kJ/mol) given the following bond energies:

| **bond** | **bond energy** |
|---|---|
| H–H | 432 kJ/mol |
| O–H | 467 kJ/mol |
| F–F | 154 kJ/mol |
| O–O | 146 kJ/mol |
| O=O | 495 kJ/mol |

a) 314 kJ/mol b) 159 kJ/mol c) 565 kJ/mol d) 515 kJ/mol e) 2149 kJ/mol

25. Some $Cu(NO_3)_2(aq)$ and KOH(aq) are added together and a precipitate of $Cu(OH)_2(s)$ forms. How many of the following (I-IV) will cause the precipitate to dissolve?

I. Excess $Cu(NO_3)_2(aq)$ is added.
II. Excess KOH(aq) is added.
III. Excess $NH_3(aq)$ is added.
IV. Excess $HNO_3(aq)$ is added.

a) 0 (none) b) 1 c) 2 d) 3

e) 4 [All will cause the $Cu(OH)_2(s)$ to dissolve.]

26. A bomb calorimeter has a heat capacity of 5.02 kJ/°C and an initial temperature of 24.62°C. What is the final temperature in the bomb calorimeter if 1.785 g of benzoic acid ($HC_7H_5O_2$) is combusted in the calorimeter? The energy of combustion of benzoic acid is –26.42 kJ/g.

a) 51.07°C b) 29.88°C c) 19.36°C d) 15.23°C e) 34.01°C

27. A reaction at equilibrium shifts left to reestablish equilibrium when the volume of the container is increased. For the same reaction, the value of the equilibrium constant increases as temperature increases. Which of the following could be this reaction?

a) $2\ H_2O_2(l) \rightarrow 2\ H_2O(l) + O_2(g)$ This reaction is exothermic.

b) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ This reaction is endothermic.

c) $3\ O_2(g) \rightarrow 2\ O_3(g)$ This reaction is endothermic.

d) $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$ This reaction is exothermic.

28. When 100.0 mL of 2.0 *M* $Ce(NO_3)_3$ is added to 100.0 mL of 3.0 *M* $KIO_3$, a precipitate of $Ce(IO_3)_3(s)$ forms. Calculate the equilibrium concentration of $IO_3^-$ in this solution. $K_{sp}$ for $Ce(IO_3)_3$ is $3.0 \times 10^{-10}$.

a) $8.4 \times 10^{-4}$ *M* b) $5.5 \times 10^{-3}$ *M* c) $1.8 \times 10^{-3}$ *M*

d) $1.1 \times 10^{-10}$ *M* e) 1.5 *M*

29. Consider the following four reactions at constant pressure:

I. $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$

II. $2\ PBr_3(g) + 3\ Cl_2(g) \rightarrow 2\ PCl_3(g) + 3\ Br_2(l)$

III. $3\ Fe(s) + 4\ H_2O(g) \rightarrow Fe_3O_4(s) + 4\ H_2(g)$

IV. $2\ H_2O(l) \rightarrow 2\ H_2(g) + O_2(g)$

For how many of these reactions is the PV work a positive value ($w > 0$)?

a) 0 (none) b) 1 c) 2 d) 3

e) 4 (All of these reactions have a positive value for the PV work.)

30. Consider the following reaction at some temperature:

$$2\ H_2O(g) \rightleftharpoons 2\ H_2(g) + O_2(g)$$

Initially, 1.0 mol of $H_2$, 1.0 mol of $O_2$, and 1.0 mol of $H_2O$ are placed in a 2.0 L container. At these conditions, the rate of the reverse reaction is greater than the rate of the forward reaction. Which of the following statements (a-d) regarding this reaction is **true** once it reaches equilibrium?

a) $K > 1$.
b) At equilibrium, $[H_2O] = [H_2]$.
c) At equilibrium, $[H_2O] > 0.50$ *M*.
d) At equilibrium, $[H_2] = [O_2]$.
e) None of these statements (a-d) are true.

31. 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

## USEFUL CONSTANTS/EQUATIONS

$K = °C + 273$

$PV = nRT$

$R = 0.08206$ L atm/K mol

1 L = 1000 mL

Avogadro's number, $N = 6.022 \times 10^{23}$

kinetic energy = $(1/2)\,mv^2$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

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

1 J = 1 kg $m^2/sec^2$

$R = 8.3145$ J/K mol

$\Delta E = q + w$

101.3 J = 1 L • atm

$\Delta H = \Delta E + \Delta(PV)$

$w = -P\Delta V = -RT\Delta n$ (at constant P and T)

$\Delta E_{univ} = \Delta E_{surr} + \Delta E_{sys}$

$$\Delta H^\circ_{rxn} = \Sigma\Delta H^\circ_{f,\,products} - \Sigma\Delta H^\circ_{f,\,reactants}$$

$q = s \times mass \times \Delta T$, s = specific heat capacity

## PERIODIC TABLE OF THE ELEMENTS

| 1 1A | | | | | | | | | | | | 13 3A | 14 4A | 15 5A | 16 6A | 17 7A | 18 8A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.008 | 2 2A | | | | | | | | | | | | | | | | 2 He 4.003 |
| 3 Li 6.941 | 4 Be 9.012 | | | | | 26 Fe 55.85 | ←Atomic number<br>←Atomic mass | | | | | 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 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 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 47.90 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.70 | 29 Cu 63.55 | 30 Zn 65.39 | 31 Ga 69.72 | 32 Ge 72.59 | 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 101.1 | 45 Rh 102.9 | 46 Pd 106.4 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.8 | 52 Te 127.6 | 53 I 126.9 | 54 Xe 131.3 |
| 55 Cs 132.9 | 56 Ba 137.3 | 57 La* 138.9 | 72 Hf 178.5 | 73 Ta 180.9 | 74 W 183.9 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 192.2 | 78 Pt 195.1 | 79 Au 197.0 | 80 Hg 200.6 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po 209 | 85 At 210 | 86 Rn 222 |
| 87 Fr 223 | 88 Ra 226 | 89 Ac† 227 | 104 Rf 261 | 105 Db 262 | 106 Sg 266 | 107 Bh 262 | 108 Hs 265 | 109 Mt 266 | 110 Ds 271 | 111 | 112 | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lanthanides | 58 Ce 140.1 | 59 Pr 140.9 | 60 Nd 144.2 | 61 Pm 145 | 62 Sm 150.4 | 63 Eu 152.0 | 64 Gd 157.3 | 65 Tb 158.9 | 66 Dy 162.5 | 67 Ho 164.9 | 68 Er 167.3 | 69 Tm 168.9 | 70 Yb 173.0 | 71 Lu 175.0 |
| †Actinides | 90 Th 232.0 | 91 Pa 231 | 92 U 238 | 93 Np 244 | 94 Pu 242 | 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 260 |