Name: _____ **Class:** _____ **Date:** _____ **ID: Z**

CHEM 220 - Final Exam - Spring 2006-Z

Multiple Choice
Identify the choice that best completes the statement or answers the question.

1. Consider the reaction

   $Ni(OH)_2(s) + 4\ CN^-(aq) \rightleftharpoons Ni(CN)_4^{2-}(aq) + 2\ OH^-(aq)$ $K = 2.8 \times 10^{14}$

   If K_{sp} for $Ni(OH)_2$ is 2.8×10^{-16}, what is the value of the formation constant, K_{form}, for the reaction below?

   $Ni^{2+}(aq) + 4\ CN^-(aq) \rightleftharpoons Ni(CN)_4^{2-}(aq)$

   A) 1.0×10^{-30}
   B) 1.0×10^{30}
   C) 1.3×10^{1}
   D) 7.8×10^{-2}
   E) 2.8×10^{2}

2. Complete the following fusion reaction.

   ${}^{4}_{2}He + _____ \rightarrow {}^{1}_{0}n + {}^{12}_{6}C$

   A) ${}^{9}_{4}Be$
   B) ${}^{6}_{3}Li$
   C) ${}^{0}_{+1}\beta$
   D) ${}^{4}_{2}He$
   E) ${}^{7}_{4}Be$

3. Above what temperature would you expect a reaction to become spontaneous if $\Delta H = +322$ kJ and $\Delta S = +531$ J/K?
   A) 209 K
   B) The reaction will be spontaneous at any temperature.
   C) The reaction will NOT be spontaneous at any temperature.
   D) 606 K
   E) 171 K

4. Based on inductive and resonance effects, which of the following will have the smallest Ka value?
   A) $HBrO_2$
   B) $HClO_2$
   C) $HBrO_3$
   D) $HClO_3$
   E) All are the same

5. The conjugate base of NH_3 is
   A) H_3O^+
   B) H_2O
   C) OH^-
   D) NH_2^-
   E) NH_4^+

6. A flask contains the following chemical system in equilibrium.

   $Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2\ OH^-(aq)$

   Addition of which of the following reagents would increase the solubility of $Cu(OH)_2$?
   A) NaCl
   B) HCl
   C) NaOH
   D) $Cu(NO_3)_2$
   E) $Cu(OH)_2$

7. A solution is prepared by diluting 0.25 mol HNO_3 to a volume of 750 mL. What is the pH of this solution?
   A) 0.33
   B) 0.60
   C) 0.48
   D) 4.2
   E) 3.5

8. Write the expression for K_p for the reaction below.

   $CO_2(g) + CaO(s) \rightleftharpoons CaCO_3(s)$

   A) $K_p = [CO_2]$
   B) $K_p = \dfrac{[CaCO_3]}{[CaO][CO_2]}$
   C) $K_p = \dfrac{P_{CaO}P_{CO_2}}{P_{CaCO_3}}$
   D) $K_p = \dfrac{P_{CaCO_3}}{P_{CaO}P_{CO_2}}$
   E) $K_p = \dfrac{1}{P_{CO_2}}$

9. Predict the signs of ΔH, ΔS, and ΔG for the combustion of hydrogen gas at 25ºC.

   $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(\ell)$

   A) $\Delta H < 0$, $\Delta S < 0$, $\Delta G < 0$
   B) $\Delta H > 0$, $\Delta S < 0$, $\Delta G > 0$
   C) $\Delta H > 0$, $\Delta S < 0$, $\Delta G < 0$
   D) $\Delta H < 0$, $\Delta S > 0$, $\Delta G < 0$
   E) $\Delta H < 0$, $\Delta S > 0$, $\Delta G < 0$

10. A solution with a pH of 3.00 is _____ times more _____ than a solution with a pH of 1.00? Fill in the blanks by choosing the correct response.
    A) 300, acidic
    B) 300, basic
    C) 3, acidic
    D) 100, acidic
    E) 100, basic

11. The oxidation of sulfur dioxide produces sulfur trioxide.

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

Calculate the value of K_p, given that K_c for the reaction is 2.3×10^4 at 999 K.

A) 2.3×10^4
B) 1.9×10^6
C) 2.8×10^2
D) 3.42
E) 2.9×10^3

12. Which of the following involves a decrease in entropy?
A) the freezing of liquid water into ice
B) the evaporation of ethanol
C) the decomposition of $N_2O_4(g)$ to $NO_2(g)$
D) the dissolution of NaCl in water
E) the sublimation of carbon dioxide

13. Consider the reversible reaction: A ↔ B, for which $\Delta G° = +25$ kJ. Which of the following is true
A) The lowest energy state for the reaction is an equal mixture of A & B.
B) The lowest energy state for the reaction is a mixture of A & B with more reactant, A.
C) The lowest energy state for the reaction is all reactant, A.
D) The lowest energy state for the reaction is a mixture of A & B with more product, B.
E) The lowest energy state for the reaction is all product, B.

14. Consider the general reaction: $2\ A_{(g)} + B_{(g)} \leftrightarrow C_{(g)} + D_{(g)}$
If the volume of a mixture of reactants and products at equilibrium is tripled, what will be the effect on the reaction system?
A) K will decrease.
B) It will produce more products.
C) It will produce more products and more reactants.
D) It will produce more reactants.
E) No change will occur.

15. The elementary steps for the catalyzed decomposition of dinitrogen monoxide are shown below. Identify the catalyst in the reaction.

$N_2O(g) + NO(g) \rightarrow N_2(g) + NO_2(g)$
$2\ NO_2(g) \rightarrow 2\ NO(g) + O_2(g)$

A) NO_2
B) NO
C) N_2O
D) N_2
E) O_2

16. What is the OH^- concentration of a solution with a pH of 12.81?
    A) 1.2×10^0 M
    B) 2.7×10^{-8} M
    C) 1.6×10^{-13} M
    D) 6.5×10^{-2} M
    E) 1.3×10^1 M

17. Complete the following fission reaction.

    $^{1}_{0}n + ^{235}_{92}U \rightarrow ^{146}_{57}La + _____ + 3\ ^{1}_{0}n$

    A) $^{93}_{36}Kr$
    B) $^{87}_{36}Kr$
    C) $^{87}_{37}Rb$
    D) $^{87}_{35}Br$
    E) $^{85}_{35}Br$

18. Plutonium-244 decays by successive α, β, β, α, emissions. What nucleus is produced?
    A) $^{236}_{88}Ra$
    B) $^{240}_{92}U$
    C) $^{236}_{90}Th$
    D) $^{236}_{92}U$
    E) $^{234}_{90}Th$

19. At 2010 K, the equilibrium constant, K_c, for the following reaction is 4.0×10^{-4}.

    $N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g)$

    If the equilibrium concentrations of N_2 and O_2 are 0.25 mol/L and 0.33 mol/L, what is the equilibrium concentration of NO?

    A) 3.3×10^{-5} M
    B) 6.8×10^{-3} M
    C) 1.7×10^{-5} M
    D) 5.7×10^{-3} M
    E) 7.0×10^{-2} M

20. For a second-order decomposition reaction,

    $2A \rightarrow B$ rate = $k[A]^2$

    which of the following can be plotted versus time to give a straight line?
    A) $\frac{1}{[A]}$
    B) $\ln[A]$
    C) $\ln\frac{1}{[A]}$
    D) $\frac{1}{[A]^2}$
    E) $[A]$

FREE RESPONSE: *Please answer the following questions in the spaces provided.*
You must show all work and units! Unless otherwise noted, assume all systems are at 25°C. No problems require a quadratic solution. You may NOT use a calculator program to solve quadratic or higher-order expressions – apply appropriate approximations when needed.

Answer ALL of the following 9 questions (1-9).

1. (15 points) The reaction $2\ NOCl \rightarrow 2\ NO + Cl_2$ exhibits the differential rate law: rate = k[NOCl]. In an experiment, 0.100 *M* NOCl is present initially. After 8 minutes, 0.077 *M* remains.

   A) Determine $t_{1/2}$ for this reaction.

   B) What would be the initial rate observed for the experiment described?

2. (10 points) Consider the ***gas phase*** reaction of nitric oxide and hydrogen gas: $2\ NO + 2H_2 \Leftrightarrow N_2 + H_2O$.

$2\ NO \Leftrightarrow N_2O_2$	fast
$N_2O_2 + H_2 \Leftrightarrow N_2O + H_2O$	fast
$N_2O + H_2 \rightarrow N_2 + H_2O$	slow

The above overall reaction is exergonic (release of energy). *Draw a reaction energy diagram for this mechanism.*

Clearly indicate:
- Relative energies of ***R***eactants, ***P***roducts, ***I***ntermediates, and the ***T***ransition ***S***tates.
- $\mathbf{E_a}$ for the ***overall*** reaction
- $\mathbf{\Delta E}$ for the reaction

3. (25 points) Consider the overall reaction: $H_2O_2 + 3\ I^- + 2\ H^+ \rightarrow I_3^- + 2\ H_2O$

A) The following mechanism is *proposed* for this reaction:

Step 1.	$H_2O_2 + H^+ \rightleftharpoons H_3O_2^+$	(fast equilibrium, rate constants: k_1 and k_{-1})
Step 2.	$H_3O_2^+ + I^- \rightarrow H_2O + HOI$	(slow, rate constant k_2)
Step 3.	$HOI + I^- \rightarrow OH^- + I_2$	(fast, rate constant k_3)
Step 4.	$OH^- + H^+ \rightarrow H_2O$	(fast, rate constant k_4)
Step 5.	$I_2 + I^- \rightarrow I_3^-$	(fast, rate constant k_5)

What would be the predicted differential rate law expression for this mechanism?

B) What is the role of HOI in this mechanism?

C) The following initial rates data are collected experimentally:

	$[H_2O_2]$	$[I^-]$	$[H^+]$	rate
I	0.100 *M*	5.00×10^{-4} *M*	1.00×10^{-2} *M*	0.067 *M*/sec
II.	0.100 *M*	1.00×10^{-3} *M*	1.00×10^{-2} *M*	0.268 *M*/sec
III.	0.200 *M*	1.00×10^{-3} *M*	1.00×10^{-2} *M*	0.542 *M*/sec
IV.	0.200 *M*	1.00×10^{-3} *M*	2.00×10^{-2} *M*	0.540 *M*/sec

Based on these data, what is the differential rate law expression for the reaction?

D) Could the mechanism proposed in part A be the correct mechanism? Explain.

E) Calculate the initial rate of this reaction when $[H_2O_2] = 0.150$ *M*, $[I^-] = 0.0025$ and the pH = 2.75.

4. (25 points) Consider the titration of a 30.0 mL sample of 0.40 *M* solution benzoic acid, $C_6H_5CO_2H$, with a 0.25 *M* KOH solution. The K_a of benzoic acid is 6.3×10^{-5}.

A) What is the $[H^+]$ in the 0.25 *M* KOH solution?

B) What will be the pH of the benzoic solution before the addition of any potassium hydroxide?

C) What will be the pH of the solution after the addition of 40.0 mL of the KOH solution?

D) Calculate the pH of the solution at the equivalence point.

5. (15 points) Consider the voltaic cell with cell notation: $\{ Cd^{2+}_{(aq)} \mid Cd_{(s)} \mid\mid V^{3+}_{(aq)}, V^{2+}_{(aq)} \mid Au \}$

A) The measured $E°_{cell}$ is 0.14 V. What is the reduction potential for $V^{3+}_{(aq)}$ (to $V^{2+}_{(aq)}$) ?

B) What is ΔG° for this reaction?

C) What is E_{cell} (at 25°C) for this reaction when $[Cd^{2+}] = 0.00020\ M$, $[V^{3+}] = 0.00020\ M$, and $[V^{2+}] = 0.10\ M$?

6. (20 points) Consider the reaction: $\mathbf{ZnSO_{4(aq)} + Fe_{(s)} \Leftrightarrow FeSO_{4(aq)} + Zn_{(s)}}$

A) Using information provided on the exam, calculate K for the above reaction:

B) Calcluate ΔG for a reaction system where $[FeSO_4] = 1.0 \times 10^{-8}\ M$ and $[ZnSO_4] = 0.10\ M$.

C) What effect would diluting an equilibrium mixture of the above reaction have on the equilibrium position of the reaction – will the reaction shift left, right, or remain unchanged?

Ammonia (NH_3) complexes to zinc ions with a large K_f values, but ***not*** *to iron (II) ions.*

D) If concentrated ammonia is added to an equilibrium mixture of the above reaction, will the reaction shift left, right, or remain unchanged?

7. (15 points) An aqueous solution of tin (II) fluoride, $SnF_{2(aq)}$ is subjected to electrolysis.

A) What half-reaction will occur at the anode?

B) What half-reaction will occur at the cathode?

8. (15 points) An electrolytic process is used to purify copper industrially. What current must be applied to produce 500 kg of copper from Cu^{2+} ions in solution in 3.0 hours?

9. (25 points) Nickel (II) carbonate, $NiCO_3$ has a K_{sp} of 1.4×10^{-7}.

A) What is the solubility (in mol/L) of nickel (II) carbonate in a 0.50 *M* HCl solution?

B) What is the solubility (in mol/L) of nickel (II) carbonate in a 0.50 *M* $NiCl_2$ solution?

Nickel (II) complexes with aqueous ammonia, $NH_{3(aq)}$ to make the linear complex ion, $[Ni(NH_3)_2]^{2+}$.
This reaction has a K_f of 5.6×10^8.

C) Write the balanced overall equation for dissolving solid nickel (II) carbonate in an aqueous ammonia solution and calculate K for the reaction.

Reaction:

$K_{overall}$:

D) What is the solubility of nickel (II) carbonate (in mol/L) in a 0.100 *M* aqueous solution of ammonia?

Answer 3 of the following 4 questions (10-13). Cross out the question you do not want graded or the first 3 questions answered will be graded. (15 points each)

10. A 0.100 M solution of selenous acid, H_2SeO_3,is found to have a pH of 1.821. What is K_{a1} for selenous acid?

11. Consider the reaction system: $2\ N_2O_{(g)} + O_{2(g)} \Leftrightarrow 4\ NO_{(g)}$

When the reactants are mixed in a sealed container at 750 Kwith the initial P_{N2O} = 1.6 atm and the initial P_{O2} = 2.1 atm with no product present and they are allowed to equilibrate, the gases reach a total pressure of 4.5 atm. What is K_P at 750 K?

12. Consider the equilibrium reaction below with a $K_C = 4.0 \times 10^{-7}$ at 375 K
A chemist injects all three gases at a concentration of 0.33 *M* into an evacuated flask at 375 K.

What will be the equilibrium concentrations of all reactants and products?

$$2\ NCl_{3(g)} \Leftrightarrow N_{2\ (g)} + 3\ Cl_{2(g)}$$

13. Consider the polyprotic base, ethylenediamine: $H_2NCH_2CH_2NH_2$, for which $K_{b1} = 8.5 \times 10^{-5}$ and $K_{b2} = 2.7 \times 10^{-8}$. Determine the pH and the equilibrium concentrations for the following species in a solution that is 0.20 *M* in ethylenediamine. Show all work.

pH =

$[H_2NCH_2CH_2NH_3^+]$ =

$[H_2NCH_2CH_2NH_2]$ =

$[H_3NCH_2CH_2NH_3^{2+}]$ =

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Integrated Rate Equations

Zero-order reaction:

$[A] = -kt + [A]_0$

$$t_{1/2} = \frac{[A]_0}{2k}$$

First-order reaction:

$\ln[A] = -kt + \ln[A]_0$

or $\ln([A] / [A]_0) = -kt$

$$t_{1/2} = \frac{0.693}{k}$$

Second-order reaction:

$1/[A] = kt + 1/[A]_0$

$$t_{1/2} = \frac{1}{k[A]_0}$$

Order of Reaction

$$n = \frac{\log\left(\frac{rate_2}{rate_1}\right)}{\log\left(\frac{[A]_2}{[A]_1}\right)}$$

Arrhenius Equation

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

Quadratic equation

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

Dalton's Law of Partial Pressures

$P_{Total} = P_1 + P_2 + \ldots + P_n$

Autoionization of water

$K_w = 1.00 \times 10^{-14}$

K_a relationships

$$K_{overall} = \frac{K_{a,forward}}{K_{a,reverse}}$$

Henderson–Hasselbalch

$$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$$

Other Constants and Formulas

$K_P = K_C(RT)^{\Delta n}$

Temp (K) = Temp (C) + 273.15

$D_{liquid\ water}$ = 1.0 g/mL

D_{ice} = 0.92 g/mL

Heat Constants & Equations

– $q_{system} = q_{surroundings}$

– $q_{lost} = q_{gained}$

$q = mC_p\Delta T$

$q = Hc\Delta T$

$q = n\Delta H_x$ (with enthalpy units of kJ/mole)

$q = m\Delta H_x$ (with enthalpy units of J/g)

Specific Heat Capacity (H_2O)	$^{J}/_{g \cdot C}$
Solid	2.1
Liquid	4.184
Gas	2.0

Phase Changes (H_2O)	$^{kJ}/_{mol}$	$^{J}/_{g}$
ΔH_{fusion}	6.01	334
$\Delta H_{vaporization}$	40.7	2260

Thermodynamics and Electrochemistry

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

$$\Delta S_{surr} = -\frac{\Delta H_{sys}}{T}$$

$$\Delta G = -T\Delta S_{univ}$$

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

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

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

$$\Delta G^\circ = -RT\ln K$$

$$\ln K = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R}$$

$$\ln\frac{K_2}{K_1} = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$E^o_{cell} = E^o_{red} + E^o_{oxid}$$

$$E_{cell} = E_{red} + E_{oxid}$$

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

$$\Delta G = -nFE$$

$$E^\circ = \frac{RT}{nF}\ln K$$

$$E^\circ = \frac{0.0257}{n}\ln K$$

$$E = E^\circ - \frac{RT}{nF}\ln Q$$

$$E = E^\circ - \frac{0.0257}{n}\ln Q$$

$$current\ (A) = \frac{charge\ (C)}{time\ (s)}$$

$$R = 8.314\ \frac{J}{K \bullet mol} = 0.008314\ \frac{kJ}{K \bullet mol} = 0.08206\ \frac{L \bullet atm}{K \bullet mol}$$

$$F = 96{,}485\ \frac{J}{V \bullet mol\,(electron)} = 96{,}485\ \frac{C}{mol\,(electron)}$$

TABLE 19.1 Standard Reduction Potentials at 25°C*

Half-Reaction	$E°$(V)
$F_2(g) + 2e^- \longrightarrow 2F^-(aq)$	+2.87
$O_3(g) + 2H^+(aq) + 2e^- \longrightarrow O_2(g) + H_2O$	+2.07
$Co^{3+}(aq) + e^- \longrightarrow Co^{2+}(aq)$	+1.82
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O$	+1.77
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow PbSO_4(s) + 2H_2O$	+1.70
$Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$	+1.61
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O$	+1.51
$Au^{3+}(aq) + 3e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O$	+1.33
$MnO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Mn^{2+}(aq) + 2H_2O$	+1.23
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O$	+1.23
$Br_2(l) + 2e^- \longrightarrow 2Br^-(aq)$	+1.07
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O$	+0.96
$2Hg^{2+}(aq) + 2e^- \longrightarrow Hg_2^{2+}(aq)$	+0.92
$Hg_2^{2+}(aq) + 2e^- \longrightarrow 2Hg(l)$	+0.85
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	+0.68
$MnO_4^-(aq) + 2H_2O + 3e^- \longrightarrow MnO_2(s) + 4OH^-(aq)$	+0.59
$I_2(s) + 2e^- \longrightarrow 2I^-(aq)$	+0.53
$O_2(g) + 2H_2O + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	+0.34
$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	+0.22
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO_2(g) + 2H_2O$	+0.20
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	+0.15
$Sn^{4+}(aq) + 2e^- \longrightarrow Sn^{2+}(aq)$	+0.13
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \longrightarrow Pb(s)$	−0.13
$Sn^{2+}(aq) + 2e^- \longrightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$	−0.25
$Co^{2+}(aq) + 2e^- \longrightarrow Co(s)$	−0.28
$PbSO_4(s) + 2e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.31
$Cd^{2+}(aq) + 2e^- \longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	−0.74
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	−0.76
$2H_2O + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Mn^{2+}(aq) + 2e^- \longrightarrow Mn(s)$	−1.18
$Al^{3+}(aq) + 3e^- \longrightarrow Al(s)$	−1.66
$Be^{2+}(aq) + 2e^- \longrightarrow Be(s)$	−1.85
$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$	−2.37
$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
$Ca^{2+}(aq) + 2e^- \longrightarrow Ca(s)$	−2.87
$Sr^{2+}(aq) + 2e^- \longrightarrow Sr(s)$	−2.89
$Ba^{2+}(aq) + 2e^- \longrightarrow Ba(s)$	−2.90
$K^+(aq) + e^- \longrightarrow K(s)$	−2.93
$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.05

*For all half-reactions the concentration is 1 *M* for dissolved species and the pressure is 1 atm for gases. These are the standard-state values.

A Periodic Table was also provided.

Thermodynamic Data

Substance or Ion	ΔH_f^0 (kJ/mol)	ΔG_f^0 (kJ/mol)	S^0 (J/mol·K)
Nitrogen			
$N_2(g)$	0	0	191.5
$N(g)$	473	456	153.2
$N_2O(g)$	82.05	104.2	219.7
$NO(g)$	90.29	86.60	210.65
$NO_2(g)$	33.2	51	239.9
$N_2O_4(g)$	9.16	97.7	304.3
$N_2O_5(g)$	11	118	346
$N_2O_5(s)$	−43.1	114	178
$NH_3(g)$	−45.9	−16	193
$NH_3(aq)$	−80.83	26.7	110
$N_2H_4(l)$	50.63	149.2	121.2
$NO_3^-(aq)$	−206.57	−110.5	146
$HNO_3(l)$	−173.23	−79.914	155.6
$HNO_3(aq)$	−206.57	−110.5	146
$NF_3(g)$	−125	−83.3	260.6
$NOCl(g)$	51.71	66.07	261.6
$NH_4Cl(s)$	−314.4	−203.0	94.6
Oxygen			
$O_2(g)$	0	0	205.0
Chlorine			
$Cl_2(g)$	0	0	223.0