

IMPORTANT: Bubble in **A**, **B** or **C** as the test form code at the top right of your answer sheet AND also bubble in your Section Number and UFID on the left side of your answer sheet.

VERSION 0

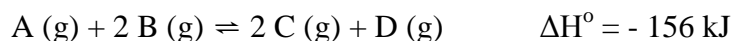
- The reaction $A + 2B \rightleftharpoons 2C$ has $K_c = 200$ at a particular temperature. At a particular moment in time, $[A] = 0.50 \text{ M}$, $[B] = 0.04 \text{ M}$ and $[C] = 0.34 \text{ M}$. Which of the following is true at that moment?
 - The reaction is shifting right-to-left
 - The reaction is shifting left-to-right.
 - The reaction is at equilibrium, so no change in concentrations is occurring.
 - $[B]$ is twice the $[A]$.
 - No conclusion can be made without knowing ΔG° .
- The reaction below has $K_c = 2.0 \times 10^{-3}$ at 400 K. Calculate K_p for this reaction at 400 K.
$$\text{N}_2(\text{g}) + 2 \text{O}_2(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$$

($R = 0.082 \text{ L atm/mol.K}$).
 - 6.1×10^{-5}
 - 2.0×10^{-3}
 - 5.0×10^2
 - 6.6×10^{-2}
 - none of these
- Consider the reaction $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$
2.00 atm CO and 2.00 atm H_2O were placed in a flask and allowed to reach equilibrium at a particular temperature where $K_p = 3.24$. What is p_{CO} at equilibrium?
 - 3.60 atm
 - 1.29 atm
 - 1.80 atm
 - 0.71 atm
 - Impossible to determine without the temperature.
- The reaction below has $K_c = 6.5 \times 10^2$ at 350 K
$$2 \text{NO}(\text{g}) + 2 \text{H}_2(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g})$$

What is K_c at 350 K for
$$2 \text{N}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g}) \rightleftharpoons 4 \text{NO}(\text{g}) + 4 \text{H}_2(\text{g})$$
 - 3.1×10^{-3}
 - 3.9×10^{-2}
 - 2.4×10^{-6}
 - 1.5×10^{-3}
 - 4.2×10^5
- Consider the reaction below
$$\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$$

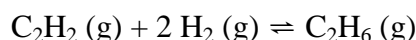
At a particular moment in time, the $[\text{NO}_2]$ is measured and found to be increasing. Which of the following statements must be true at that moment?
 - $Q_c < K_c$
 - Cannot decide without knowing the initial $[\text{N}_2\text{O}_4]$.
 - Cannot decide without knowing K_c
 - $\Delta S_{\text{univ}} < 0$
 - The left-to-right reaction is exothermic.

6. The reaction shown is allowed to reach equilibrium in a 2.00 L vessel at 300 K.



$K_c = 278$ at 300 K. If the temperature is now raised to 310 K, what will happen?

- The reaction will shift left-to-right, and K_c will increase.
 - The reaction will shift left-to-right, and K_c will decrease.
 - The reaction will not shift, and K_c stays unchanged.
 - The reaction will shift right-to-left, and K_c will increase.
 - The reaction will shift right-to-left, and K_c will decrease.
7. Ethane (C_2H_6) can be formed from the reaction of acetylene (C_2H_2) with hydrogen (H_2). $\Delta H^\circ = -311 \text{ kJ}$ for this reaction.



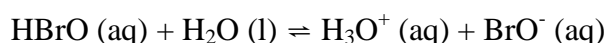
Which of the following conditions will push the equilibrium to the right and thus give the greatest amount of ethane at equilibrium?

- high temperature, high pressure
 - low temperature, high pressure
 - low temperature, low pressure
 - high temperature, low pressure
 - Impossible to predict.
8. What is the pH of a 0.20 M solution of $Ba(OH)_2(aq)$?
- 0.40
 - 13.60
 - 13.30
 - 0.70
 - none of these
9. A solution of HCl of volume 100.0 mL has a pH of 2.00 at 300 K. What is the new pH if the volume of the solution is doubled by addition of 100.0 mL of pure water?
- 3.00
 - 4.00
 - none of these
 - 2.30
 - 2.60
10. Which of the following is not a conjugate acid/base pair?
- HCN / CN^-
 - $H_3PO_4 / H_2PO_4^-$
 - H_2SO_4 / SO_4^{2-}
 - NH_4^+ / NH_3
 - They are all conjugate acid/base pairs.
11. A 0.050 M solution of a weak acid HA has $[H_3O^+] = 3.77 \times 10^{-4} \text{ M}$. What is K_a for this acid?
- 3.7×10^{-5}
 - 7.5×10^{-3}
 - 7.0×10^{-8}
 - 2.6×10^{-11}
 - 2.8×10^{-6}
12. What is the pH of a 0.010 M solution of $NR_3H^+Cl^-$ solution? (K_b for $NR_3 = 5.9 \times 10^{-7}$).
- 7.00
 - 9.11
 - 2.75
 - 11.25
 - 4.89

13. What is the pH of a 3.2×10^{-9} M solution of NaOH (aq)?
- 7.00
 - 8.49
 - 5.51
 - 14.00
 - 10.27
14. Farmers who raise cotton once used arsenic acid, H_3AsO_4 , as a defoliant at harvest time. Arsenic acid is a triprotic acid: $K_{a1} = 2.5 \times 10^{-4}$, $K_{a2} = 5.6 \times 10^{-8}$, and $K_{a3} = 3.0 \times 10^{-13}$. What is the pH of a 0.500 M solution of arsenic acid?
- 1.95
 - 3.90
 - 4.51
 - 2.61
 - 5.14
15. What is the pH of a buffer solution containing equal concentrations of HNO_2 and NaNO_2 ? K_a for HNO_2 is 7.1×10^{-4} .
- 3.36
 - 3.28
 - 3.46
 - 3.15
 - Impossible to determine without the $[\text{HNO}_2]$ and $[\text{NO}_2^-]$.
16. At the equivalence point of a titration of 0.12 M solution of CH_3COOH with 0.12 M NaOH, the pH of the solution will be:
- Less than 7.00
 - Greater than 7.00
 - 7.00
 - None of these.
 - Cannot be predicted.
17. Consider the following reaction at equilibrium at 300 K:
- $$\text{NO}_2^- + \text{HClO}_2 \rightleftharpoons \text{HNO}_2 + \text{ClO}_2^-$$
- What can you predict about this reaction?
- Since it is at equilibrium, $K_c = 1$ and $[\text{HNO}_2] = [\text{HClO}_2]$
 - The equilibrium lies to the left-hand-side ($K_c < 1$)
 - The equilibrium lies to the right-hand-side ($K_c > 1$)
 - Since it is at equilibrium, $[\text{HNO}_2] = [\text{HClO}_2]$
 - No prediction can be made without knowing K_c
18. What is the solubility of BaF_2 (s) in a 0.20 M solution of $\text{Ba}(\text{NO}_3)_2$? ($K_{sp} = 1.5 \times 10^{-6}$).
- 1.9×10^{-3} M
 - 3.8×10^{-6} M
 - 8.7×10^{-3} M
 - 1.4×10^{-3} M
 - none of these
19. What is the K_{sp} of the salt MX_3 (containing M^{3+} and X^- ions) if its molar solubility is 1.2×10^{-2} M?
- 1.9×10^{-7}
 - 6.2×10^{-8}
 - 4.3×10^{-6}
 - 2.1×10^{-8}
 - 5.6×10^{-7}

20. Which of the following will increase the solubility of Ag_2SO_4 in water? K_{sp} for Ag_2SO_4 is 1.5×10^{-5} .
- Lowering the pH by addition of a strong acid.
 - None of these.
 - Adding very soluble Na_2SO_4 to the solution.
 - Adding more Ag_2SO_4 solid to the solution.
 - Adding very soluble AgNO_3 to the solution.

21. At 350 K, the dissociation of HBrO in water has $K_a = 3.8 \times 10^{-9}$. Calculate ΔG when $[\text{H}_3\text{O}^+] = 4.0 \times 10^{-4} \text{ M}$, $[\text{BrO}^-] = 0.20 \text{ M}$ and $[\text{HBrO}] = 0.40 \text{ M}$.



- none of these
 - $\Delta G = 32 \text{ kJ}$
 - $\Delta G = -81 \text{ kJ}$
 - $\Delta G = 81 \text{ kJ}$
 - $\Delta G = -32 \text{ kJ}$
22. Calculate ΔS° for the reaction between Cu (s) and $\text{O}_2 \text{ (g)}$ to give one mole of $\text{Cu}_2\text{O (s)}$. S° values (J/mol.K): $\text{Cu (s)} = 33.1$; $\text{O}_2 \text{ (g)} = 205.0$; $\text{Cu}_2\text{O (s)} = 93.1$
- 178 J/K
 - none of these
 - 151 J/K
 - 145 J/K
 - 75.6 J/K

23. Calculate ΔG° for the following reaction at 400 K, given the ΔH_f° and S° values below.
- $$3 \text{ NO (g)} \rightarrow \text{N}_2\text{O (g)} + \text{NO}_2 \text{ (g)}$$

	$\Delta H_f^\circ \text{ (kJ/mol)}$	$S^\circ \text{ (J/mol.K)}$
$\text{NO}_2 \text{ (g)}$	33.2	239.9
$\text{N}_2\text{O (g)}$	82.1	219.7
NO (g)	90.3	210.7

- 86.6 kJ
 - 74.3 kJ
 - 225 kJ
 - $68.8 \times 10^3 \text{ kJ}$
 - None of these.
24. A particular reaction is non-spontaneous and has $\Delta S_{\text{rxn}}^\circ > 0$ (positive). Which of the following statements is true?
- $\Delta S_{\text{univ}} > 0$
 - None of these
 - $\Delta H_{\text{rxn}}^\circ > 0$
 - $\Delta S_{\text{surr}}^\circ > 0$
 - $\Delta G^\circ < 0$
25. For which of the following changes is ΔS_{sys} negative?
- Bubbles of $\text{CO}_2 \text{ (g)}$ escaping from a carbonated drink.
 - Ice melting to liquid water at 0°C .
 - A liquid warming by 10°C .
 - AgCl (s) precipitating from a solution of $\text{Ag}^+ \text{ (aq)}$ and $\text{Cl}^- \text{ (aq)}$
 - A rock rolling downhill.

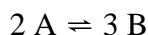
26. The following reaction has $\Delta G^\circ = 326 \text{ kJ}$.
- $$3 \text{ O}_2 (\text{g}) \rightarrow 2 \text{ O}_3 (\text{g})$$
- Calculate ΔG at 309 K for the reaction when $[\text{O}_2] = 1.955 \times 10^{-3} \text{ M}$ and $[\text{O}_3] = 4.505 \times 10^{-3} \text{ M}$.

- 286 kJ
- 306 kJ
- 574 kJ
- 366 kJ
- 346 kJ

27. A reaction has $\Delta H = -300 \text{ kJ}$ and $\Delta S = -50 \text{ J/K}$. Which of the following statements is true?

- The reaction is non-spontaneous at low temperature, and spontaneous at high temperature.
- The reaction is spontaneous at low temperature, and non-spontaneous at high temperature.
- The reaction is spontaneous at all temperatures.
- The reaction is non-spontaneous at all temperatures.
- No conclusion can be made.

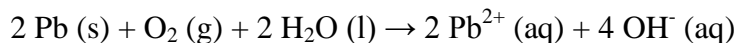
28. The reaction below has $\Delta G^\circ = 0.00 \text{ kJ}$.



When some A was placed in a vessel and allowed to come to equilibrium, the $[\text{B}] = 4.0 \text{ M}$. What is $[\text{A}]$ at equilibrium?

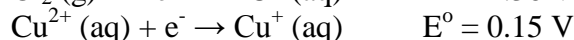
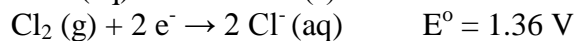
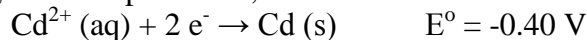
- 32 M
- 8.0 M
- 16 M
- 4.0 M
- 6.0 M

29. What is the cell notation for the voltaic cell driven by the following spontaneous reaction?



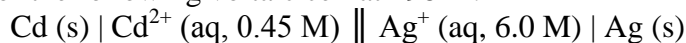
- $\text{Pb} (\text{s}) | \text{Pb}^{2+} (\text{aq}) || \text{O}_2 (\text{g}) | \text{OH}^- (\text{aq}) | \text{graphite}$
- $\text{graphite} | \text{O}_2 (\text{g}) | \text{OH}^- (\text{aq}) || \text{Pb}^{2+} (\text{aq}) | \text{Pb} (\text{s})$
- $\text{Pb} (\text{s}) | \text{O}_2 (\text{g}) || \text{Pb}^{2+} (\text{aq}), \text{OH}^- (\text{aq}) | \text{graphite}$
- $\text{graphite} | \text{O}_2 (\text{g}) || \text{Pb}^{2+} (\text{aq}), \text{OH}^- (\text{aq}) | \text{Pb} (\text{s})$
- $\text{Pb} (\text{s}) | \text{Pb}^{2+} (\text{aq}) || \text{OH}^- (\text{aq}) | \text{O}_2 (\text{g}) | \text{graphite}$

30. Using the following half-cell potentials, determine the order of oxidizing agent strengths.



- None of these.
- $\text{Cd}^{2+} (\text{aq}) > \text{Cu}^{2+} (\text{aq}) > \text{Cl}_2 (\text{g})$
- $\text{Cd} (\text{s}) > \text{Cu}^+ (\text{aq}) > \text{Cl}^- (\text{aq})$
- $\text{Cl}^- (\text{aq}) > \text{Cu}^+ (\text{aq}) > \text{Cd} (\text{s})$
- $\text{Cl}_2 (\text{g}) > \text{Cu}^{2+} (\text{aq}) > \text{Cd}^{2+} (\text{aq})$

31. What is E_{cell} for the following voltaic cell at 298 K?



- 1.23 V
- 1.17 V
- 1.14 V
- 1.26 V
- 1.20 V

32. What is E°_{cell} for the voltaic cell with cell reaction

$$2 \text{Al (s)} + 3 \text{Fe}^{2+} \text{(aq)} \rightarrow 2 \text{Al}^{3+} \text{(aq)} + 3 \text{Fe (s)}$$
 a. -2.10 V
 b. 2.10 V
 c. 1.22 V
 d. -1.22 V
 e. None of these
33. Which of the metals, silver (Ag), copper (Cu), tin (Sn) or cadmium (Cd), could be used to spontaneously produce H_2 (g) from H^+ (aq) solutions?
 a. Cu and Ag only
 b. Cu, Ag and Sn
 c. Cd and Sn only
 d. Cd only
 e. Impossible to determine without ΔG° values
34. Which of the following statements is true about the following reaction?

$$2 \text{NH}_3 \text{(aq)} + 2 \text{CrO}_3 \text{(aq)} + 6 \text{H}^+ \rightarrow \text{N}_2 \text{(g)} + 2 \text{Cr}^{3+} \text{(s)} + 6 \text{H}_2\text{O (l)}$$
 a. The CrO_3 is reduced by H^+ , which is oxidized to H_2O .
 b. The NH_3 is reduced by CrO_3 , which is oxidized to Cr^{3+} .
 c. The NH_3 is oxidized by CrO_3 , which is oxidized to Cr^{3+} .
 d. The CrO_3 is reduced by NH_3 , which is oxidized to N_2 .
 e. The H^+ is oxidized by CrO_3 , which is reduced to Cr^{3+} .
35. Consider the voltaic cell below.

$$\text{Fe (s)} \mid \text{Fe}^{2+} \text{(aq, 0.4 M)} \parallel \text{Fe}^{2+} \text{(aq, 2.6 M)} \mid \text{Fe (s)}$$
 Which of the following statements is true?
 a. None of the statements is true.
 b. The $[\text{Fe}^{2+}]$ in the anode is greater than that in the cathode.
 c. The $[\text{Fe}^{2+}]$ on the left-hand side of the cell will decrease.
 d. $Q > 1$
 e. Since both sides have the same half-cell reaction, no spontaneous reaction is possible and therefore $E_{\text{cell}} = 0.00 \text{ V}$.
36. Consider the voltaic cell below, containing equal volumes of the two solutions:

$$\text{Cr (s)} \mid \text{Cr}^{3+} \text{(aq, 1.0 M)} \parallel \text{Cu}^{2+} \text{(aq, 1.0 M)} \mid \text{Cu (s)}$$
 After current has flowed for 20 minutes, the $[\text{Cr}^{3+}]$ is 1.2 M. Which of the following statements is true?
 a. The $[\text{Cu}^{2+}]$ after 20 minutes is 0.7 M.
 b. The $[\text{Cu}^{2+}]$ after 20 minutes is 0.8 M.
 c. The $[\text{Cu}^{2+}]$ after 20 minutes is 0.9 M.
 d. The $[\text{Cu}^{2+}]$ after 20 minutes is 1.1 M.
 e. The $[\text{Cu}^{2+}]$ after 20 minutes is 1.2 M.
37. The most covalent oxide of manganese (Mn) is:
 a. MnO
 b. Mn_2O_7
 c. MnO_2
 d. Mn_2O_3
 e. MnO_3
38. How many total isomers of any kind are possible for the square planar complex $[\text{PtCl}_2(\text{NO}_2)_2]$?
 a. 3
 b. 8
 c. 2
 d. 4
 e. 6

39. The condensed configuration of the element zirconium (Zr) is
- [Kr] 4s¹ 3d³
 - [Kr] 3d⁴
 - [Kr] 4s² 4d²
 - [Kr] 4d⁴
 - [Kr] 4s² 3d²
40. A metal forms an M³⁺ ion with the condensed electronic configuration [Kr] 4d⁶. The metal is:
- Ru
 - Mo
 - Rh
 - Cd
 - Pd
41. In the following reaction, which has $K_c = 3.1 \times 10^4$ and $\Delta H^\circ = -1376$ kJ, 1.0 mol of each substance is introduced into a 1.0 L vessel in the presence of a catalyst and allowed to reach equilibrium and a constant temperature.
- $$\text{C}_2\text{H}_4 (\text{g}) + 3 \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{CO}_2 (\text{g}) + 2 \text{H}_2\text{O} (\text{l})$$
- If the volume of the vessel is then doubled, what will happen?
- the concentrations will all increase, and the reaction will then shift left-to-right.
 - the concentrations will all decrease, and the reaction will then shift left-to-right.
 - the concentrations will all increase, and the reaction will then shift right-to-left.
 - the concentrations will all decrease, and the reaction will then shift right-to-left.
 - the concentrations will all decrease, but the reaction will then not shift.
42. The compounds *cis*-[Cr(H₂O)₄BrCl]⁺Br⁻ and *cis*-[Cr(H₂O)₄Br₂]⁺Cl⁻ are an example of which type of isomers?
- geometric isomers
 - coordination isomers
 - optical isomers
 - linkage isomers
 - They are not isomers.
43. Which of the following is the most stable in the +7 oxidation state?
- Fe
 - Tc
 - Mn
 - Re
 - W
44. The formulas of tellurous acid and bromic acid are:
- H₂TeO₃ and HBrO₃
 - H₃TeO₄ and HBrO₃
 - H₃TeO₃ and HBrO₂
 - H₂TeO₃ and HBrO₂
 - H₂TeO₃ and HBrO₃
45. Which element has similar properties to Mg as a result of the diagonal relationship?
- Sc
 - K
 - Li
 - B
 - Ga

46. A metal ion in a particular oxidation state has an [Ar] 3d⁵ electronic configuration. The metal ion is:
- Cr²⁺
 - Mo⁺
 - Fe²⁺
 - Re²⁺
 - Mn²⁺
47. For the elements Si, Sr, Nb, and Ga, the order of the electronegativities and the metallic character are
- Si > Ga > Nb > Sr and Sr > Nb > Ga > Si
 - Sr > Nb > Ga > Si and Si > Ga > Nb > Sr
 - Si > Ga > Nb > Sr and Si > Ga > Nb > Sr
 - Sr > Nb > Ga > Si and Sr > Nb > Ga > Si
 - impossible to predict
48. Which is the most basic oxide?
- SeO₃
 - CaO
 - BeO
 - P₄O₆
 - CO₂
49. Which of the following is the ionic hydride?
- HCl
 - B(OH)₃
 - CaH₂
 - H₂
 - CH₃COOH
50. Hydrogen is the only element whose isotopes are given their own name and symbol. For the isotopes ¹H, ²H and ³H, the names and symbols are:
- protium (H), deuterium (D) and tritium (T)
 - proton (H⁺), hydrogen (H) and hydride (H⁻)
 - monodentate (H), bidentate (B) and tridentate (T)
 - hydrium (H), deuterium (D) and trifillium (T)
 - hydrium (H), dihydrium (D) and trihydrium (T)

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

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

$$\Delta S_{\text{rxn}} + \Delta S_{\text{surr}} = \Delta S_{\text{univ}}$$

$$1 \text{ ampere} = 1 \text{ C/s}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - (0.0592/n) \log Q \text{ (at } 25^\circ\text{C)}$$

$$\text{pK}_a = -\log K_a$$

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

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

$$F = 9.65 \times 10^4 \text{ C/mol e}^-$$

$$\text{pH} = \text{pK}_a + \log \left(\frac{[\text{base}]}{[\text{acid}]} \right)$$

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}$$

$$K = k_f/k_r$$

$$\text{rate} = A \exp(-E_a/kT)$$

$$E = mc^2$$

Each student will receive a table of half-cell potentials and a Periodic Table