AP Chemistry
Chapter 19 and 20 Jeopardy

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Round 1 – Chapter 19

Free Response (Must do all 5)	Spontaneous Processes	Entropy	Gibb's Free Energy	Q and K	Surprise
100	100	100	100	100	100
200	200	200	200	200	200
300	300	300	300	300	300
400	400	400	400	400	400
500	500	500	500	500	500

Free Response 100

Consider the reaction represented below, which is spontaneous at 298 K.

$CO_{2(g)} + 2\ NH_{3(g)} \rightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$

$\Delta H^o_{298} = -134$ kJ

For the reaction, indicate whether the standard entropy change, DS^o_{298} is positive, or negative, or zero. Justify your answer.

ΔS^o is negative because there are 3 moles of gases in the reactants and 1 mole of solid and 1 mole of liquid in the products.

Free Response 200

Which factor, the change in enthalpy, ΔH^{o}_{298} or the change in entropy, ΔS^{o}_{298}, provides the principle driving force for the reaction at 298 K? Explain.

$$CO_{2(g)} + 2\ NH_{3(g)} \rightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$$

$$\Delta H^{o}_{298} = -134\ kJ$$

ΔH^{o} is the driving force for the reaction because ΔH^{o} is negative and ΔS^{o} is negative. According to $\Delta G = \Delta H - T\Delta S$, thermodynamically favored reactions have a negative ΔH^{o} and a positive ΔS^{o}.

Free Response 300

For the reaction, how is the value of the standard free energy change, ΔG, affected by an increase in temperature? Explain.

$$CO_{2(g)} + 2\ NH_{3(g)} \rightarrow CO(NH_2)_{2(s)} + H_2O_{(l)}$$

$$\Delta H^{o}_{298} = -134\ kJ$$

$\Delta G = \Delta H - T\Delta S$, and ΔH is negative. Since ΔS is negative, then $-T\Delta S$ will become a larger positive number as temperature increases which means that as temperature increases, then ΔG becomes less negative or more positive.

Free Response 400

Some reactions that are predicted by their sign of ΔG^{o} to be spontaneous at room temperature do not proceed at a measurable rate at room temperature. Account for this apparent contradiction.

Thermodynamically favorable does not mean fast. The speed of the reactions are based on activation energy, not ΔG^{o}.

Free Response 500

A suitable catalyst increases the rate of such a reaction. What effect does the catalyst have on ΔG^{o} for the reaction? Explain.

The catalyst will speed up the reaction by lowering the activation energy, but it has no effect on ΔG^{o}.

Spontaneous Processes 100

Consider the vaporization of liquid water to steam at a pressure of 1atm. In what temperature range is it a spontaneous process?

Temperatures higher than $100^{o}C$.

Spontaneous Processes 200

Does the change in ΔE depend on the particular pathway taken to carry out a change of state?

No, it is a state function.

Spontaneous Processes 300

Which of the following statements about the thermodynamic favorability of the reaction at 298 K is correct?

$2\ Na_2O_{2(s)} + S_{(s)} + 2\ H_2O_{(l)} \rightarrow 4\ NaOH_{(aq)} + SO_{2(aq)}$

$\Delta H^o_{298} = -610\ kJ/mol_{rxn}$, $\Delta S^o_{298} = -7.3\ J/(K \cdot mol_{rxn})$

a. It is thermodynamically unfavorable.

b. It is thermodynamically favorable and is driven by ΔS^o only.

c. It is thermodynamically favorable and is driven by ΔH^o only.

d. It is thermodynamically favorable and is driven by both ΔH^o and ΔS^o.

c

Spontaneous Processes 400

Is the following process spontaneous, nonspontaneous, or at equilibrium?

The formation of CH_4 and O_2 molecules from CO_2 and H_2O.

Nonspontaneous – It would be spontaneous in the reverse direction because it would be combustion.

Spontaneous Processes 500

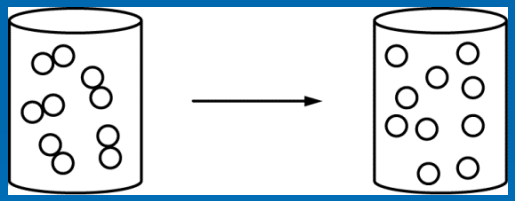
Is the following process spontaneous, nonspontaneous, or at equilibrium?

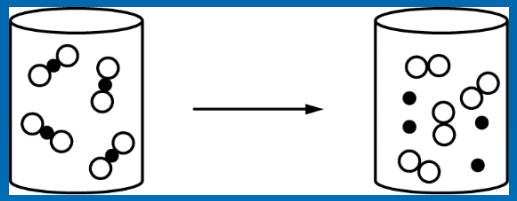
Ice melting at 0^{o}C

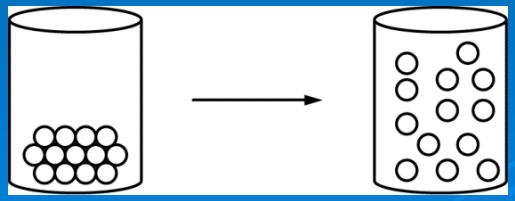
equilibrium

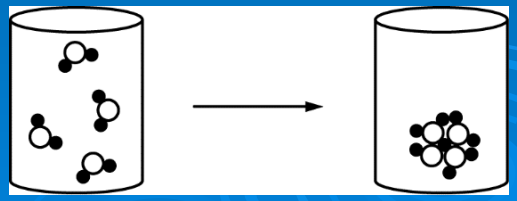
Entropy 100 d

Which of the following particulate representations shows a process during which the entropy of the system decreases?

a. 

c. 

b. 

d. 

Entropy 200

Which of the following reactions would have a $-\Delta S$?

1. $2Fe_2O_{3(s)} \rightarrow 4Fe_{(s)} + 3O_{2(g)}$
2. $Mg^{+2}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg(OH)_{2(s)}$
3. $H_{2(g)} + C_2H_{4(g)} \rightarrow C_2H_{6(g)}$

2 and 3

Entropy 300

Which reaction involves the largest decrease in entropy?

1. $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$
2. $Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$
3. $4La_{(s)} + 3O_{2(g)} \rightarrow 2La_2O_{3(s)}$

3

Entropy 400

Which of the following reactions has the largest $+\Delta S$ value per mole of Cl_2?

1. $2NH_4Cl_{(s)} \rightarrow N_{2(g)} + 4H_{2(g)} + Cl_{2(g)}$
2. $Cl_{2(g)} \rightarrow 2Cl_{(g)}$
3. $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

Entropy 500

For the reaction $Cl_{2(g)} + 3F_{2(g)} \rightarrow 2ClF_{3(g)}$ the ΔH^{o}_{f} is -163.2 kJ/mol and the ΔG^{o}_{f} is -123kJ/mol for ClF_3. Calculate the ΔS^{o} in J/K for the reaction at 298K.

-269.8 J/K

Gibb's Free Energy 100

A cube of ice is added to some hot water in a rigid, insulated container, which is then sealed. There is no heat exchange with the surroundings. What happens to the total energy and the total entropy when the system reaches equilibrium?

Energy stays the same, but entropy increases.

Gibb's Free Energy 200

When solid NH_4SCN is mixed with solid $Ba(OH)_2$ in a closed container, the temperature drops and a gas is produced. What are the signs for ΔG, ΔH, and ΔS?

ΔG = - (spontaneous)
ΔH = + (temp. drops)
ΔS = + (gas is produced)

Gibb's Free Energy 300

The following reaction is spontaneous at 298K, but becomes nonspontaneous at higher temperatures. What are the signs for ΔG, ΔH, and ΔS?

$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

ΔG = - (spontaneous)

ΔH = - (ΔG = ΔH – TΔS)

ΔS = - (less gas)

Gibb's Free Energy 400

The equilibrium constant for a reaction is greater than 1.0 at temperatures above 500K but less than 1.0 at temperatures below 500K. What can be concluded about the values of ΔH^o and ΔS^o for the reaction? (Assume that ΔH^o and ΔS^o are independent of temperature.)

α. $\Delta H^o > 0$ and $\Delta S^o > 0$

β. $\Delta H^o > 0$ and $\Delta S^o < 0$

χ. $\Delta H^o < 0$ and $\Delta S^o > 0$

δ. $\Delta H^o < 0$ and $\Delta S^o < 0$

a

Gibb's Free Energy 500

Classify the following reaction as spontaneous, nonspontaneous, or spontaneous at certain temperatures (specify the temperatures).

$N_2F_{4(g)} \rightarrow 2NF_{2(g)}$

$\Delta H^o = 85kJ$; $\Delta S^o = 198J/K$

Nonspontaneous at low temperatures, but spontaneous at high temperatures.

Q and K 100

What must be true about ΔG^{o} and K_{eq} for a reaction that proceeds spontaneously from initial standard conditions?

ΔG^{o} must be negative and K_{eq} must be larger than 1.

Q and K 200

Explain how ΔG changes for the following reaction as the partial pressure of O_2 is increased:

$$2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$$

ΔG becomes more negative.

Q and K 300

Consider the reaction $2NO_{2(g)} \rightarrow N_2O_{4(g)}$. Calculate ΔG at 298K if the partial pressures of NO_2 and N_2O_4 are 0.40atm and 1.60atm, respectively. $\Delta G^\circ = -5.40kJ$

0.30kJ

Q and K 400

For the reaction $Cl_{2(g)} + 3F_{2(g)} \rightarrow 2ClF_{3(g)}$ the ΔH^o_f is -163.2 kJ/mol and the ΔG^o_f is -123 kJ/mol. Calculate the value of the equilibrium constant for the reaction at 298K.

3.72×10^{21}

Q and K 500

If ΔG^{o} is negative, then K must be _____.

Greater than one.

Surprise 100

b

Shown below are the equation representing the decomposition of $H_2O_{2(l)}$ and a table of bond enthalpies. On the basis of the information, which of the following is the enthalpy of decomposition of 2 mol of $H_2O_{2(l)}$?

$$2\ H_2O_{2(l)} \rightarrow 2\ H_2O_{(l)} + O_{2(g)}$$

a. -349 kJ
b. -203 kJ
c. 203 kJ
d. 349 kJ

Bond	Average Bond Enthalpy (kJ/mol)
O – H	463
O – O	146
O = O	495

Surprise 200

What does it mean if $\Delta G = 0kJ$?

The system is at equilibrium.

Surprise 300

Which substance experiences more entropy when they are at the same temperature and contain the same amount of particles?

$CO_{2(g)}$ or $SO_{3(g)}$

$SO_{3(g)}$ since it has more bonds which means more vibrational energy.

Surprise 400

Can an endothermic process be spontaneous? Explain.

Yes, as long as there is an increase in the entropy that counteracts the decrease in enthalpy.

Surprise 500 b

The oxidation of $PCl_{3(g)}$ is represented by the equation below, and the table provides the approximate values of the absolute molar entropies, S^o, for these substances. Based on the information given, what is the approximate ΔS^o for the reaction?

$$2\ PCl_{3(g)} + O_{2(g)} \rightarrow 2\ POCl_{3(g)}$$

a. +170 J/(mol_{rxn}·K)
b. -170 J/(mol_{rxn}·K)
c. +190 J/(mol_{rxn}·K)
d. -190 J/(mol_{rxn}·K)

Substance	S^o (J/mol·K)
$PCl_{3(g)}$	310
$O_{2(g)}$	210
$POCl_{3(g)}$	330

Redox Reactions	Voltaic Cells	Standard emf	ΔG and redox reactions	Nonstandard emf	Surprise
200	200	200	200	200	200
400	400	400	400	400	400
600	600	600	600	600	600
800	800	800	800	800	800
1000	1000	1000	1000	1000	1000

Redox Reactions 200

Identify the elements that undergo changes in oxidation number.

$3SO_2 + 2HNO_3 + 2H_2O \rightarrow 3H_2SO_4 + 2H_2O$

S = +6 → +4

N = +5 → +2

Redox Reactions 400

Identify the elements that undergo changes in oxidation number.

$2H_2SO_4 + 2NaBr \rightarrow Br_2 + SO_2 + Na_2SO_4 + 2H_2O$

S = +6 → +4

Br = +1 → 0

Redox Reactions 600

Hydrazine (N_2H_4) and dinitrogen tetroxide (N_2O_4) for a self-igniting mixture that has been used as a rocket propellant. The reaction products are N_2 and H_2O. Write a balanced chemical equation, list what is being oxidized and reduced, and list the oxidizing and reducing agent.

$2N_2H_4 + N_2O_4 \rightarrow 3N_2 + 4H_2O$

$N_2H_4 = -2 \rightarrow 0$ oxidizes (reducing agent)

$N_2O_4 = +4 \rightarrow 0$ reduced (oxidizing agent)

Redox Reactions 800

Based on the standard reduction potentials in the table below, what is the value of E^o for a standard galvanic cell made with Ag/Ag^+ and Cr/Cr^{3+} half-cells?

a. 0.39V

b. 1.21V

c. 1.99V

d. 2.81V

Half-Reaction	E° (V)
$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$	0.80
$Cr^{3+}_{(aq)} + 3\ e^- \rightarrow Cr_{(s)}$	-0.41

b

Redox Reactions 1000

Based on the reduction potentials given in the table below, which of the following gives the balance chemical equation and the correct standard cell potential for a galvanic cell involving $Sc^{3+}_{(aq)}$ and $Mn^{2+}_{(aq)}$?

- $2\ Sc^{3+} + 3\ Mn_{(s)} \rightarrow 2\ Sc_{(s)} + 3\ Mn^{2+}$ $E^o = -0.90V$
- $2\ Sc^{3+} + 3\ Mn_{(s)} \rightarrow 2\ Sc_{(s)} + 3\ Mn^{2+}$ $E^o = -0.62V$
- $2\ Sc_{(s)} + 3\ Mn^{3+} \rightarrow 2\ Sc^{3+} + 3\ Mn_{(s)}$ $E^o = +0.62V$
- $2\ Sc_{(s)} + 3\ Mn^{3+} \rightarrow 2\ Sc^{3+} + 3\ Mn_{(s)}$ $E^o = +0.90V$

Half-Reaction	E^o (V)
$Mn^{2+} + 2\ e^- \rightarrow Mn_{(s)}$	-1.18
$Sc^{3+} + 3\ e^- \rightarrow Sc$	-2.08

d

Voltaic Cells 200

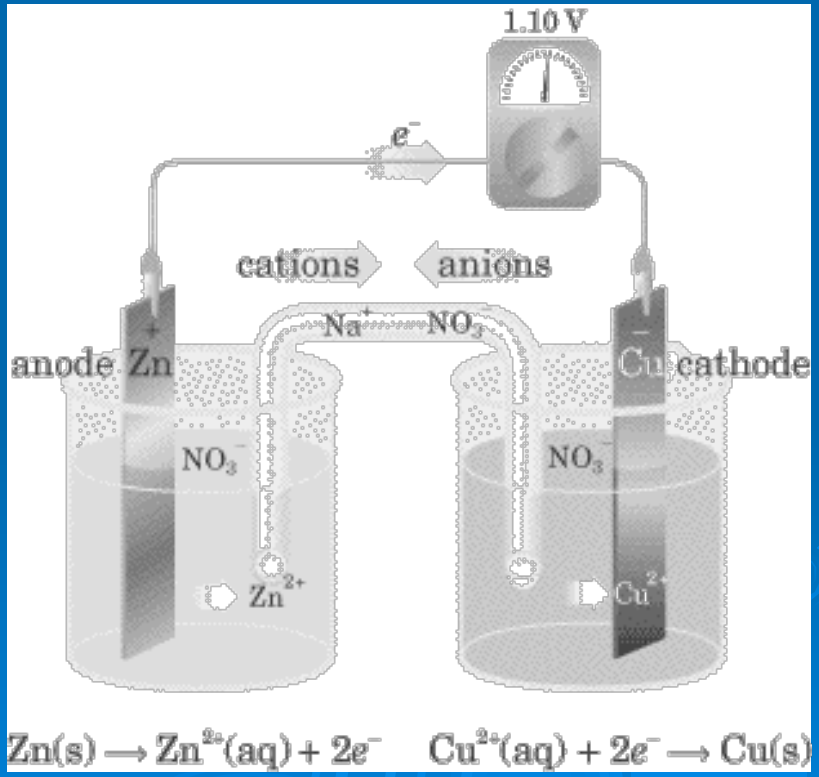
What is the role of a salt bridge?

The salt bridge provides a source of spectator ions that can travel to the cathode or anode which completes the electrical circuit.

Voltaic Cells 400

Why do NO_3^- ions migrate into the anode compartment as the voltaic cell operates?

The reaction at the anode is $Zn_{(s)} \rightarrow Zn^{+2}_{(aq)} + 2e^-$ As more Zn^{+2} is produced, then the half-cell forms a + charge, so the NO_3^- ions travel to the solution to make it neutral.



Voltaic Cells 600

The overall cell reaction is

$2Al_{(s)} + 3Ni^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Ni_{(s)}$

What is being oxidized, and what is being reduced? Write the half-reactions that occur in the two electrode compartments.

Al = 0 → +3 (oxidized)

Ni = +2 → 0 (reduced)

$2Al \rightarrow 2Al^{3+} + 6e^-$

$6e^- + 3Ni^{2+} \rightarrow 3Ni$

Voltaic Cells 800

The overall cell reaction is

$2Al_{(s)} + 3Ni^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Ni_{(s)}$

Which electrode is the anode and which electrode is the cathode? Indicate the signs of each electrode.

Al = anode (-)

Ni = cathode (+)

Voltaic Cells 1000

The overall cell reaction is

$2Al_{(s)} + 3Ni^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Ni_{(s)}$

Do electrons flow from the aluminum electrode to the nickel electrode, or from the nickel to the aluminum? In which direction do the cations and anions migrate through the solution?

Electrons flow from Al to Ni.

Anions travel to Al

Cations travel to Ni

Standard emf 200

A voltaic cell that uses the reaction

$PdCl_4^-{}_{(aq)} + Cd_{(s)} \rightarrow Pd_{(s)} + 4Cl^-{}_{(aq)} + Cd^{+2}{}_{(aq)}$

has a measured the emf of +1.03V.

Write the two half-cell reactions.

Determine the $E^o{}_{red}$ for Pd.

$2e^- + PdCl_4^- \rightarrow Pd + 4Cl^-$

$Cd \rightarrow Cd^{2+} + 2e^-$

$E = 0.627V$

Standard emf 400

A voltaic cell that uses the reaction

$PdCl_4^-{}_{(aq)} + Cd_{(s)} \rightarrow Pd_{(s)} + 4Cl^-{}_{(aq)} + Cd^{+2}{}_{(aq)}$

has a measured the emf of +1.03V. Draw the voltaic cell, label the anode and cathode, and indicate the direction of electrons and ions.

See picture I drew

Standard emf 600

According to the information below, what is the standard reduction potential for the half-reaction $M^{3+}_{(aq)} + 3\ e^- \rightarrow M_{(s)}$?

$M_{(s)} + 3\ Ag^+_{(aq)} \rightarrow 3\ Ag_{(s)} + M^{3+}_{(aq)}$ $E^o = +2.46V$

$Ag^+_{(aq)} + e^- \rightarrow Ag_{(s)}$ $E^o = +0.80V$

- -1.66V
- -0.06V
- 0.06V
- 1.66V
- 3.26V

a

Standard emf 800

According to the standard reduction potentials given below, what is the standard cell potential for the reaction represented below?

$$3\ Ag^{+} + Al_{(s)} \rightarrow 3\ Ag_{(s)} + Al^{3+}$$

$Al^{3+}_{(aq)} + 3\ e^{-} \rightarrow Al_{(s)}$ $E^{o} = -1.66$ V

$Ag^{+}_{(aq)} + e^{-} \rightarrow Ag_{(s)}$ $E^{o} = +0.80$ V

- -1.74 V
- -0.86 V
- +1.74 V
- +2.46 V
- +4.06 V

d

Standard emf 1000

In the electroplating of nickel, 0.200 faraday of electrical charge is passed through a solution of $NiSO_4$. What mass of nickel is deposited?

5.87g

ΔG and Redox 200

Write the balanced chemical equation for the oxidation of Fe^{2+} by $S_2O_6^{2-}$.

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

$$E=0.77V$$

$$S_2O_6^{2-} + 4H^+ + 2e^- \rightarrow 2H_2SO_3$$

$$E = 0.60V$$

$$S_2O_6^{2-} + 2Fe^{2+} + 4H^+ \rightarrow 2Fe^{3+} + 2H_2SO_3$$

ΔG and Redox 400

Calculate the ΔG for the reaction at 298K.

$S_2O_6^{2-} + 2Fe^{2+} + 4H^+ \rightarrow 2Fe^{3+} + 2H_2SO_3$

$Fe^{3+} + e^- \rightarrow Fe^{2+}$

E=0.77V

$S_2O_6^{2-} + 4H^+ + 2e^- \rightarrow 2H_2SO_3$

E = 0.60V

33kJ

ΔG and Redox 600

If the equilibrium constant for a 2 electron redox reaction at 298K is 1.5×10^{-4}, calculate the corresponding ΔG and E_{cell}.

ΔG = 21804.2 J/mol

E_{cell} = -0.11V

ΔG and Redox 800

Using standard reduction potentials, calculate the equilibrium constant for the following reaction at 298K.

$$Fe + Ni^{2+} \rightarrow Fe^{2+} + Ni$$

2.6×10^{5}

ΔG and Redox 1000

Based on the thermodynamic data, which of the following is true at 298 K?

ΔG°_{298}	ΔH°_{298}	ΔS°_{298}
+15 kJ/mol_{rxn}	+12 kJ/mol_{rxn}	-10 J/(K·mol_{rxn})

a. $K_{eq} = 0$

b. $0 < K_{eq} < 1$

c. $K_{eq} = 1$

d. $K_{eq} > 1$

b

Nonstandard emf 200

What happens to the emf of a cell if the concentrations of the reactants are increased?

Equilibrium shifts to the products which makes ΔG more negative, so emf increases.

Nonstandard emf 400

A voltaic cell is constructed that uses the following reaction:

$$Zn + Ni^{2+} \rightarrow Zn^{2+} + Ni$$

A solution of $AgNO_3$ is added to the cathode compartment, increasing the quantity of Ag^+ but not changing its concentration. What is the effect on the cell emf?

No effect

Nonstandard emf 600

A voltaic cell is constructed that uses the following reaction at 298K:

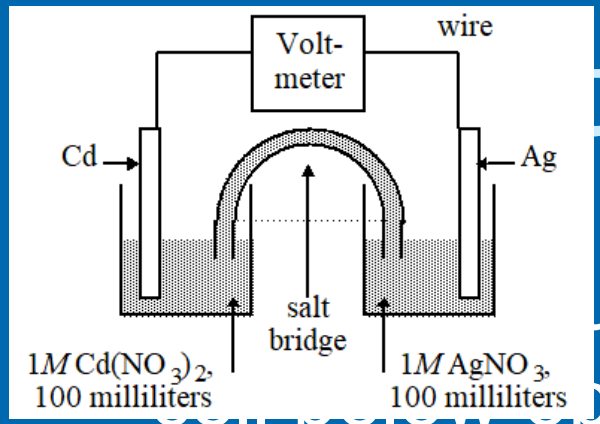
$$Zn + Ni^{2+} \rightarrow Zn^{2+} + Ni$$

What is the emf of this cell when $[Ni^{2+}] = 3.00M$ and $[Zn^{2+}] = 0.100M$?

0.527V

tandard emf 800

b



us reaction that occurs when the
perates is $2\ Ag^{+} + Cd_{(s)} \rightarrow 2\ Ag_{(s)} + Cd^{2+}$. Which of the following occurs when current is allowed to flow for 5 minutes?

a. Voltage increases.
b. Voltage decreases but remains above zero.
c. Voltage becomes zero and remains at zero.
d. No change in voltage occurs.
e. Direction of voltage change cannot be predicted without additional information.

Nonstandard emf 1000 d

A galvanic cell generates a potential of +2.71V when $[Cu^{2+}] = [Mg^{2+}] = 1M$ based on the chemical reaction represented below. Which of the following provides the best justification that the given conditions can be used to decrease the cell potential ($E_{cell} < +2.71V$)?

$$Cu^{2+}_{(aq)} + Mg_{(s)} \rightarrow Cu_{(s)} + Mg^{2+}_{(aq)} \quad E^{o}_{cell} = +2.71\ V$$

a. $[Cu^{2+}] = [Mg^{2+}] = 0.10$ M, because equilibrium is approached at a faster rate, causing a decrease in E_{cell}.

b. $[Cu^{2+}] = [Mg^{2+}] = 2.0$ M, because equilibrium is approached at a slower rate, causing a decrease in E_{cell}.

c. $[Cu^{2+}] = 1.0$ M and $[Mg^{2+}] = 0.10$ M, because Q is smaller than 1, making E_{cell} decrease.

d. $[Cu^{2+}] = 0.10$ M and $[Mg^{2+}] = 1.0$ M, because Q is greater than 1, making E_{cell} decrease.

Surprise 200

A voltaic cell utilizes the following reaction:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

How would the cell emf be affected if the pressure of the H_2 gas is increased in the cathode compartment?

emf decreases

Surprise 400

A voltaic cell utilizes the following reaction:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

How would the cell emf be affected if zinc nitrate is added to the anode compartment?

emf decreases

Surprise 600

A voltaic cell utilizes the following reaction:

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$$

How would the cell emf be affected if sodium hydroxide is added to the cathode compartment, decreasing $[H^+]$?

emf decreases

Surprise 800

A voltaic cell utilizes the following reaction:

$$Zn + 2H^{+} \rightarrow Zn^{2+} + H_2$$

How would the cell emf be affected if the surface areas of the anode is doubled?

No effect

Surprise 1000

c

The decomposition of $NaCl_{(l)}$ into $Na_{(l)}$ and $Cl_{2(g)}$ is thermodynamically unfavorable. The decomposition requires the input of energy from an external source. The diagram represents an electrolytic cell that can be used to drive the decomposition reaction. Which of the following identifies a flaw in the representation?

a. Oxidation is occurring at the anode.
b. Molten Na is shown at the cathode.
c. An external source is not shown.
d. The direction of electron flow in the wires is incorrect.