MULTIPLE CHOICE. Choose the one alternative that best complet es the statement or answers the question.

1) The first law of thermodynamics can be given as _____.

A) for any spontaneous process, the entropy of the universe increases
B) the entropy of a pure crystalline substance at absolute zero is zero
C) $\Delta H^\circ_{rxn} = \Sigma\, n\Delta H^\circ_f$ (products) - $\Sigma\, m\Delta H^\circ_f$ (reactants)
D) $\Delta S = q_{rev}/T$ at constant temperature
E) $\Delta E = q + w$

2) Which of the following is a reversible process?

A) melting of ice at 0°C and 1 atm
B) melting of ice at 25°C and 1 atm
C) evaporation of water at 25°C and 1 atm
D) freezing of water at –10°C and 1 atm
E) freezing of water at –25°C and 1 atm

3) The second law of thermodynamics can be given as _____.

A) for any spontaneous process, the entropy of the universe increases
B) $\Delta S = q_{rev}/T$ at constant temperature
C) $\Delta H^\circ_{rxn} = \Sigma\, n\Delta H^\circ_f$ (products) - $\Sigma\, m\Delta H^\circ_f$ (reactants)
D) the entropy of a pure crystalline substance is zero at absolute zero
E) $\Delta E = q + w$

4) Which one of the following correctly indicates the relationship between the entropy of a system and the number of different arrangements, W, in the system?

A) $S = kW$ B) $S = k\ \ln W$ C) $S = k/W$ D) $S = Wk$ E) $S = W/k$

5) Cathodic protection of a metal pipe against corrosion usually entails

A) attaching an active metal to make the pipe the cathode in an electrochemical cell.
B) coating the pipe with a fluoropolymer to act as a source of fluoride ion (since the latter is so hard to oxidize).
C) attaching a dry cell to reduce any metal ions which might be formed.
D) coating the pipe with another metal whose standard reduction potential is less

negative than that of the pipe.

E) attaching an active metal to make the pipe the anode in an electrochemical cell.

Use the table below to answer the next question

Thermodynamic Quantities for Selected Substances at 298.15 K (25°C)

Substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S (J/K-mol)
Carbon			
C (s, diamond)	1.88	2.84	2.43
C (s, graphite)	0	0	5.69
C_2H_2 (g)	226.7	209.2	200.8
C_2H_4 (g)	52.30	68.11	219.4
C_2H_4 (g)	-84.68	-32.89	229.5
CO (g)	-110.5	-137.2	197.9
CO_2 (g)	-393.5	-394.4	213.6
Hydrogen			
H_2(g)	0	0	130.58
Oxygen			
O_2 (g)	0	0	205.0
H_2O (l)	-285.83	-237.13	69.91

6) The combustion of acetylene in the presence of excess oxygen yields carbon dioxide and water:

$$2C_2H_2\,(g) + 5O_2\,(g) \rightarrow 4CO_2\,(g) + 2H_2O\,(l)$$

The value of ΔS for this reaction is _____ J/K.

A) +432.4 B) -122.3 C) -432.4 D) +689.3 E) +122.3

7) The standard Gibbs free energy of formation of _____ is zero.

(a) $H_2O(l)$

(b) $O(g)$

(c) $H_2(g)$

A) (a) only
B) (b) only
C) (c) only
D) (b) and (c)
E) (a), (b), and (c)

Use the table below to answer the questions that follow.

Thermodynamic Quantities for Selected Substances at 298.15 K (25°C)

Substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S (J/K-mol)
Calcium			
Ca (s)	0	0	41.4
$CaCl_2$ (s)	-795.8	-748.1	104.6
Ca^{2+} (aq)	226.7	209.2	200.8
Chlorine			
Cl_2 (g)	0	0	222.96
Cl- (aq)	-167.2	-131.2	56.5
Oxygen			
O_2 (g)	0	0	205.0
H_2O (l)	-285.83	-237.13	69.91
Phosphorus			
P_2 (g)	144.3	103.7	218.1
PCl_3 (g)	-288.1	-269.6	311.7
$POCl_3$ (g)	-542.2	-502.5	325
Sulfur			
S (s, rhombic)	0	0	31.88
SO_2(g)	-269.9	-300.4	248.5
SO_3(g)	-395.2	-370.4	256.2

8) The value of ΔG° at 25°C for the formation of $POCl_3$ from its constituent elements,

$$P_2\,(g) + O_2\,(g) + 3Cl_2\,(g) \rightarrow 2POCl_3\,(g)$$

is _____ kJ/mol.

A) -1,005 B) -1,109 C) +606.2 D) -606.2 E) +1,109

9) How many minutes will it take to plate out 2.19 g of chromium metal from a solution of $Cr^{+3}(aq)$ using a current of 35.2 amps in an electrolyte cell?

A) 17.3 B) 115 C) 1.92 D) 346 E) 5.77

10) The standard cell potential E^0_{cell} for the reaction below is +0.63 V. The cell potential for this reaction is _____ V when $[Zn^{+2}] = 1.0M \text{ and } [Pb^{+2}] = 2.0x10^{-4}M$

$$Pb^{+2}(aq) + Zn(s) \rightarrow Zn^{+2}(aq) + Pb(s)$$

A) 0.85 B) 0.52 C) 0.41 D) 0.63 E) 0.74

11) Consider the reaction:

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

Given the following table of thermodynamic data,

Substance	$\Delta H^0_f(kJ/mol)$	$S^0(J/mol\ K)$
$NH_3(g)$	–46.19	192.5
$HCl(g)$	–92.30	186.69
$NH_4Cl(s)$	–314.4	94.6

Determine the temperature (in ^{0}C) above which the reaction is nonspontaneous.

A) This reaction is spontaneous at all temperatures.
B) 618.1
C) 1235
D) 345.1
E) 432.8

12) Consider the reaction:

$$FeO(s) + Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$$

Given the following table of thermodynamic data at 298K:

Substance	$\Delta H_f^0 (kJ/mol)$	$S^0 (J/K\ mol)$
$FeO(s)$	-271.9	60.75
$Fe(s)$	0	27.15
$O_2(g)$	0	205.0
$Fe_2O_3(s)$	-822.16	89.96

The value of K for the reaction at 250C is

A) 3.8×10^{-14} B)370 C)7.1×10^{85} D)8.1×10^{19} E)5.9×10^{4}

13) For a given reaction, $\triangle H = -19.9$ kJ/mol and $\triangle S = -55.5$ J/K-mol. The reaction will have $\triangle G = 0$ at _____ K.

Assume that $\triangle H$ and $\triangle S$ do not vary with temperature.

A) 2.79

B) 359

C) 2789

D) 298

E) 0.359

14) _____ is reduced in the following reaction:

$$Cr_2O_7^{-2} + 6S_2O_3^{-2} + 14H^+ \rightarrow 2Cr^{+3} + 3S_4O_6^{-2} + 7H_2O$$

A)H^+ B)$Cr_2O_7^{-2}$ C)$S_4O_6^{-2}$ D)Cr^{+3} E)$S_2O_3^{-2}$

15) Which substance is the reducing agent in the following reaction?

$Fe_2S_3 + 12HNO_3 \rightarrow 2Fe(NO_3)_3 + 3S + 6NO_2 + 6H_2O$

$A)HNO_3$ $B)H_2O$ $C)S$ $D)NO_2$ $E)Fe_2S_3$

16) _____ electrons appear in the following half–reaction when it is balanced.

$S_4O_6^{-2} \rightarrow 2S_2O_3^{-2}$

A) 1 B) 2 C) 6 D) 3 E) 4

17) The electrode at which oxidation occurs is called the

A) reducing agent
B) anode
C) cathode
D) voltaic cell
E) oxidizing agent

18) The purpose of the salt bridge in an electrochemical cell is to _____.

A) provide a means for electrons to travel from the anode to the cathode.
B) provide oxygen to facilitate oxidation at the anode.
C) provide a source of ions to react at the anode and cathode.
D) maintain electrical neutrality in the half–cells via migration of ions.
E) provide a means for electrons to travel from the cathode to the anode.

19) Which transformation could take place at the anode of an electrochemical cell?

A) $O_2 \rightarrow H_2O_2$
B) $NO \rightarrow NO_3^-$

C) $CO_2 \rightarrow C_2O_4^{-2}$

D) $H_2AsO_4 \rightarrow H_3AsO_3$

E) $VO_2^+ \rightarrow VO^{+2}$

20) 1V = _____.

A) 1 J/C B) 1 J/s C) 1 C/J D) 1 amp x s E) 96485 C

21) Which one of the following types of elements is most likely to be a good oxidizing agent?

A) lanthanides
B) alkaline earth elements
C) alkali metals
D) halogens
E) transition elements

Table 20.1

Half Reaction	E°(V)
$F_2(g) + 2e \rightarrow 2F^-(aq)$	+2.87
$Cl_2(g) + 2e \rightarrow 2Cl^-(aq)$	+1.359
$Br_2(l) + 2e \rightarrow 2Br^-(aq)$	+1.065
$O_2(g) + 4H^+(aq) + 4e \rightarrow 2H_2O(l)$	+1.23
$Ag^+ + e \rightarrow Ag(s)$	+0.799
$Fe^{3+}(aq) + e \rightarrow Fe^{2+}(aq)$	+0.771
$I_2(s) + 2e \rightarrow 2I^-(aq)$	+0.536
$Cu^{+2} + 2e \rightarrow Cu(s)$	+0.34
$2H^+ + 2e \rightarrow H_2(g)$	0
$Pb^{+2} + 2e \rightarrow Pb(s)$	-0.126

Ni^{+2} + 2e → Ni (s) -0.28

Li^{+} + e → Li (s) -3.05

22) Using Table 20.1, which substance can oxidize I^{-}(aq) to I_2 (s) ?

A) Ag (s) B) Br^{-} (aq) C) Cu^{+2}(aq) D) Br_2(l) E) Ni^{+2} (aq)

Table 20.2

Half-reaction	$E^0(V)$
$Cr^{+3}(aq) + 3e \rightarrow Cr(s)$	-0.740
$Fe^{+2}(aq) + 2e \rightarrow Fe(s)$	-0.440
$Fe^{+3}(aq) + e \rightarrow Fe^{+2}(aq)$	+0.771
$Sn^{+4}(aq) + 2e \rightarrow Sn^{+2}(aq)$	+0.154

23) The standard cell potential (E^0_{cell}) for the voltaic cell based on the reaction below is _____ V.

$$Sn^{+2}(aq) + 2Fe^{+3}(aq) \rightarrow 2Fe^{+2}(aq) + Sn^{+4}(aq)$$

A) +0.46 B) +0.617 C) +1.21 D) –0.46 E) +1.39

24) The relationship between the change in Gibbs free energy and the emf of an electrochemical cell is given by _____.

A) $\Delta G = -nF/ERT$
B) $\Delta G = -E/nF$
C) $\Delta G = -nF/E$
D) $\Delta G = -nFE$
E) $\Delta G = -nRTF$

25) The standard cell potential (E^0_{cell}) of the reaction below is +0.126 V. The value of ΔG° for the reaction is _____ kJ/mol.

Pb (s) + 2 H^{+}(aq) → Pb^{+2}(aq) + H_2 (g)

A) –24 B) +24 C) –12 D) +12 E) –50

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) E

2) A

3) A

4) B

5) A

6) C

7) C

8) B

9) E

10) B

11) D

12) C

13) B

14) B

15) E

16) B

17) B

18) D

19) B

20) A

21) D

22) D

23) B

24) D

25) A