Name: _____ Date: _____

1. Hydrogen cyanide, HCN, is a poisonous gas that is also important in industrial chemical synthesis. It is produced from methane, ammonia and oxygen according to

   $2\ CH_4(g) + 2\ NH_3(g) + 3\ O_2(g) \rightarrow 2\ HCN(g) + 6\ H_2O(g)$

   What mass of **oxygen** (in kg) is required to produce 200. kg of hydrogen cyanide?

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   A) 149
   B) 423
   C) 257
   D) 317
   E) 355

2. What is the **chemical formula** of sodium carbonate?

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   A) $NaCO_3$
   B) $NaClO_3$
   C) $Na(CO_3)_2$
   D) Na_2CO_3
   E) Na_2CO_2

3. Suppose 25.0 mL of a 0.610 M NaOH solution reacts with 20.0 mL of a 0.245 M H_2SO_4 solution. Which one of the following statements is **TRUE**?

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   A) The limiting reagent is H_2SO_4 and the resulting solution is basic
   B) The limiting reagent is NaOH and the resulting solution is basic.
   C) The limiting reagent is H_2SO_4 and the resulting solution is acidic.
   D) The resulting solution is pH neutral.
   E) The limiting reagent is NaOH and the resulting solution is acidic.

4. What is the **empirical formula** of the compound formed by gallium and oxygen?

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   A) GaO_3
   B) Ga_2O
   C) Ga_3O_2
   D) GaO
   E) Ga_2O_3

5. Which **one** of the following statements is **FALSE** regarding a gas initially at 300. K, 1.00 atm pressure, and 1.00 L volume?

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A) Increasing the temperature to 900. K, at constant volume, increases the pressure to 3.00 atm.
B) Increasing the pressure to 2.00 atm, and volume to 3.00 L, leaves the gas at 1500. K.
C) Increasing the temperature to 1200. K, at constant pressure, increases the volume to 4.00 L.
D) Decreasing the pressure to 0.500 atm, while increasing the volume to 4.00 L, leaves the gas at 600. K.
E) There are 0.0406 moles of gas.

6. The density of a **noble gas** is 2.71 g L^{-1} at 3.00 atm and 0 °C. What is the gas?

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A) Xe
B) Kr
C) He
D) Ar
E) Ne

7. Ammonium nitrate decomposes according to

$NH_4NO_3(s) \rightarrow N_2(g) + 2\ H_2O(l) + ½\ O_2(g)$

What **total volume** of gas (in L) is produced when 10.0 g of ammonium nitrate decomposes, and the product gas is at 1.00 atm pressure and 25°C?

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A) 3.71
B) 6.12
C) 4.11
D) 5.23
E) 4.58

8. Which **one** of the following sets of reactants does **not** produce a **visible change** (gas evolved or precipitate) when combined?

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A) $Na_2CO_3(aq) + Ba(ClO_3)_2(aq)$
B) $Li(s) + H_2O(l)$
C) $LiCl(aq) + AgCH_3COO(aq)$
D) $LiClO_3(aq) + AgNO_3(aq)$
E) $Zn(s) + HCl(aq)$

9. Classify the reaction $KH(s) + H_2O(l) \rightarrow KOH(aq) + H_2(g)$ according to the following three **reaction types** (choose all that apply):

(i) acid-base
(ii) oxidation-reduction
(iii) precipitation

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A) ii
B) iii
C) i, ii
D) ii, iii
E) i, iii

10. Label the following substances as **strong**, **weak** or **non**, according to whether they are strong or weak electrolytes, or nonelectrolytes, respectively:

HCl HOCl CH_4 $BaCl_2$

In the order they are listed here, the labels are as follows:

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A) strong non non weak
B) strong non weak strong
C) weak strong non strong
D) strong strong non strong
E) strong weak non strong

11. Which of the following statements is **FALSE** regarding the given reaction?

$3\ HOCl(aq) + 2\ NO(g) + H_2O(l) \rightarrow 3\ Cl^-(aq) + 2\ NO_3^-(aq) + 5\ H^+(aq)$

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A) NO(g) is the reducing agent.
B) Each nitrogen atom loses 3 electrons.
C) HOCl(aq) is a stronger oxidizing agent than NO_3^- (aq).
D) Cl^-(aq) is a stronger reducing agent than NO(g).
E) Each chlorine atom gains 2 electrons.

12. **Balance** the reaction (unbalanced as written),

$OCl^-(aq) + H_2CO(aq) \rightarrow Cl^-(aq) + HCOO^-(aq)$

under basic conditions. If 1 mol of H_2CO is consumed, how much OH^-(aq) is consumed/produced?

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A) 1 mol of OH^-(aq) is consumed
B) 3 mol of OH^-(aq) is produced
C) 1 mol of OH^-(aq) is produced
D) 2 mol of OH^-(aq) is produced
E) 2 mol of OH^-(aq) is consumed

13. Which one of the following reactions is an **oxidation-reduction reaction**?

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A) $NH_4NO_3(s) \rightarrow N_2O(g) + 2\ H_2O(g)$
B) $LiNH_2(aq) + 2\ HBr(aq) \rightarrow LiBr(aq) + NH_4Br(aq)$
C) $CuCl_2(aq) + K_2S(aq) \rightarrow CuS(s) + 2\ KCl(aq)$
D) $Be(OH)_2(s) + 2\ HClO_4(aq) \rightarrow 4\ Be(ClO_4)_2(aq) + 2\ H_2O(l)$
E) $SO_2(g) + H_2O(l) \rightarrow 2\ H_2SO_3(aq)$

14. Given the enthalpy of reaction for the decomposition of ammonium nitrate,

$NH_4NO_3(s) \rightarrow N_2(g) + 2\ H_2O(l) + ½\ O_2(g)$,

is $\Delta H° = -206.0$ kJ mol^{-1} and the enthalpy of formation of liquid water is $\Delta H_f° = -285.8$ kJ mol^{-1}, determine the **enthalpy of formation** of ammonium nitrate (in kJ mol^{-1})?

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A) −405.7
B) −254.9
C) −211.8
D) −317.1
E) −356.6

15. A system undergoes an **exothermic** reaction for which work is done **by** the system (i.e. $w < 0$). Which **one** of the following could be the reaction?

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A) $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$
B) $NaCl(l) \rightarrow NaCl(s)$
C) $2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$
D) $CO_2(aq) \rightarrow CO_2(g)$
E) $CCl_4(l) \rightarrow CCl_4(g)$

16. A coffee cup calorimeter, including the water it contains, has a heat capacity of 425 J K^{-1}, and is initially at a temperature of 23.07°C. A 16.9 gram piece of nickel metal, initially at a temperature of 4.0°C is placed in the calorimeter. The final temperature of the calorimeter and the metal is 22.74°C. What is the **specific heat of nickel metal (in J g^{-1} K^{-1})** ?

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A) 0.17
B) 0.44
C) 1.4
D) 145
E) 25

17. Choose the one **FALSE** statement from among the following:

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A) All diatomic molecules have molar heat capacities that are larger than their specific heat capacities.
B) The process, $CO_2(g) \rightarrow CO_2(s)$, releases energy.
C) For all processes of a closed system, $q = 0$.
D) If two samples absorb the same quantity of heat, the sample with the lower heat capacity has the larger increase in temperature.
E) The process, $O_2(g) \rightarrow 2\ O(g)$, requires an input of energy.

18. Identify the **TRUE** statement(s) from among the following:

(i) $\Delta H° < 0$ for the reaction $2\ K(s) + 2\ H_2O \rightarrow 2\ KOH(aq) + H_2(g)$
(ii) The vaporization of liquid HCl at –85°C is exothermic.
(iii) For $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$, $\Delta H°(\text{reaction}) = \Delta H_f°[CaCO_3(s)]$

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A) all
B) i, iii
C) ii, iii
D) i
E) i, ii

19. Which **one** of the following statements is **FALSE** regarding the changes in enthalpy, ΔH, and energy, ΔU accompanying a process?

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A) A "coffee cup" calorimeter operates at constant pressure.
B) ΔH is always larger than ΔU.
C) $\Delta H = \Delta U + \Delta n_{gas} RT$, where Δn_{gas} is the change in the number of moles of gas.
D) $\Delta H = q$, if the pressure is constant.
E) $\Delta U = q$, if the volume is constant.

20. An arsenic atom (Z = 33) is in its ground state. Which one of the following sets of quantum numbers (n, ℓ, m_ℓ, m_s) could **not** possibly describe one of its electrons?

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A) 4, 2, 2, -1/2
B) 2, 1, -1, ½
C) 4, 1, 0, ½
D) 3, 0, 0, -1/2
E) 3, 2, -2, ½

21. Which **one** of the following is an **excited state** electron configuration for S?

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A) [Ne] $3s^2\ 3d^1$
B) [Ne] $3s^2\ 3p^4\ 3d^1$
C) [Ne] $3s^2\ 3p^4$
D) [Ne] $3s^2\ 3p^3\ 3d^1$
E) [Ne] $3s^2\ 3p^3$

22. If light with a wavelength of 400. nm falls on the surface of sodium metal, electrons with a kinetic energy of 1.31×10^{-19} J are ejected. What is the **minimum frequency** (in THz) of light required to eject an electron from sodium?

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A) 663
B) 366
C) 750
D) 300
E) 552

23. Electrons in an orbital with $\ell = 1$ are in a

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A) p orbital
B) f orbital
C) d orbital
D) g orbital
E) s orbital

24. Which **one** of the following atoms has two **unpaired** electrons in its ground state electronic configuration?

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A) B
B) He
C) N
D) C
E) Be

25. Calculate the **longest wavelength (in mm)** of light **emitted** by an excited hydrogen atom in which the electron occupies the energy level $n = 6$.

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A) 21.6
B) 93.9
C) 2.28
D) 3.21
E) 7.46