**MULTIPLE CHOICE**

1. How many of the molecules below are able to participate in intermolecular hydrogen bonding?

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |

(A) 1

(B) 2

(C) 3

(D) 4

2. Which collection of glassware is the best choice for diluting a stock solution of 1.0 M solution of cobalt(II) chloride to 250 mL of 0.8 M solution for use in a Beer-Lambert law experiment?

(A) 250 mL graduated cylinder and a beaker

(B) 250 mL graduated cylinder and a buret

(C) 250 mL beaker and a 250 mL graduated cylinder

(D) 250 mL volumetric flask and a buret

3. The following data were collected during a paper chromatography experiment that was designed to separate a mixture of A, B, C and D (not the chemical formula of any component).

|  |  |
| --- | --- |
|  | **Distance moved from source** |
| Solvent | 12.0 cm |
| Component A | 2.00 cm |
| Component B | 7.00 cm |
| Component C | 1.00 cm |
| Component D | 11.5 cm |

In a second experiment the chromatogram was developed for a shorter period of time, where the solvent only traveled a total distance of 8.00 cm. Given that all other conditions were identical, how far would component A travel in the second experiment?

(A) 0.25 cm

(B) 1.33 cm

(C) 2.00 cm

(D) 8.00 cm

**Questions 4 – 6**

Consider the REDOX equation shown below that summarizes the reaction between permanganate ions

(MnO4-) and Fe(II) ions (Fe2+).

MnO4- + 5Fe2+ + 8H+ → 5Fe3+ + Mn2+ + 4H2O

4. What is the oxidation number of Mn in MnO4-?

(A) +1

(B) -1

(C) +4

(D) +7

5. Which species is oxidized in the reaction?

(A) MnO4-

(B) Fe2+

(C) Fe3+

(D) H+

6. In a titration to investigate the reaction, iron(II) sulfate solution of known concentration was pipetted into an Erlenmeyer flask using a volumetric pipet. That solution was acidified using sulfuric acid, and then titrated with KMnO4(aq) solution delivered from a buret. The following data were collected.

|  |  |
| --- | --- |
| **Volume of 0.0200 M FeSO4(aq)** | 20.00 mL |
| **Initial buret reading** | 12.30 mL |
| **Final buret reading** | 34.35 mL |
| **Volume of 1.0 M sulfuric acid used** | 1.00 mL |

What is the molarity of the KMnO4(aq) solution?

(A) 0.01814 M

(B) 0.002329 M

(C) 0.003628 M

(D) 0.004000 M

7. Which of the following processes involves the breaking of covalent bonds?

(A) Melting solid potassium chloride

(B) Melting an alloy made of copper and tin metals

(C) Solid carbon dioxide turning directly into a gas via sublimation

(D) Electricity passing through water to create hydrogen gas and oxygen gas

8. On passing from left to right through period 3 of the periodic table (elements 11 – 17), which of the following generally increases?

(A) Atomic radii

(B) 1st ionization energy

(C) Metallic character

(D) Number of occupied quantum shells

9. Which of the following best describes the particulate level explanation for the fact that a reaction is observed to proceed at a faster rate when a homogeneous catalyst is present in a reaction between two aqueous solutions.

(A) The catalyst increases the kinetic energy of the particles resulting in higher energy collisions and a greater rate

(B) The catalyst increases the concentration of the particles resulting in more collisions and a greater rate

(C) The catalyst allows more collisions with the walls of the container, increasing pressure, and producing a greater rate

(D) The activation energy is lowered by a catalyst, meaning that a greater number of particles meet or exceed the activation energy, and can therefore be involved in successful collisions

**Questions 10 -11**

10. Consider the diagram below that shows several possible transitions of an electron in the

hydrogen atom, and where **n** represents the principal quantum number (shell number).

|  |  |
| --- | --- |
| A black line with a white background  Description automatically generated | A diagram of a series of lines  Description automatically generated with medium confidence |

??In which of the following electron transitions would the atom **release** the greatest amount of energy?

(A) n = 1 to n = 2

(B) n = 4 to n = 3

(C) n = 2 to n = 1

(D) n = 6 to n = 5

11. Considering *only the Balmer series*, which of the energy transitions listed would produce a photon with the longest wavelength?

(A) n = 6 to n = 2

(B) n = 5 to n = 2

(C) n = 4 to n = 2

(D) n = 3 to n = 2

**Questions 12 - 13**

Questions 12 and 13 concern the molecule XeO3, formed with a Xe atom at the center, and three oxygen

atoms connected individually to that central, Xe atom.

12. The oxygen atoms can be connected to the Xe atom with all single bonds, OR all double bonds, OR a combination of single and double bonds. Which combination leads to the molecule with the most favorable formal charge?

(A) All single

(B) All double

(C) Two single and one double

(D) Two double and one single

13. What is the atom geometry of the molecule that contains only singly bonded oxygen atoms?

(A) Tetrahedral

(B) Trigonal planar

(C) Trigonal pyramidal

(D) Square planar

14. The photoelectron spectrum (PES) for Al is shown below with the binding energy plotted on the x-axis in units of MJ/mol.

A graph of energy

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What is the best estimate of the approximate first ionization energy of Al in kJ/mol?

(A) 150 kJ/mol

(B) 1500 kJ/mol

(C) 600 kJ/mol

(D) 6000 kJ/mol

15. The four gases listed below are contained in a single vessel. As the volume of the vessel is slowly reduced over time, the gases begin to condense into liquids. Which gas will remain in the gaseous for the longest period?

(A) CH4

(B) C2H6

(C) C3H8

(D) C4H10

16. The following is a list of alloys that shows the metals that they are made from, and the atomic radii (in pm) of those metals. Which is an interstital alloy?

(A) Brass: Copper (Cu) and Zinc (Zn). Cu: 128, Zn: 134

(B) Bronze: Copper (Cu) and Tin (Sn). Cu: 128, Sn: 140

(C) Steel: Iron (Fe) and Carbon (C). Fe: 126, C: 77

(D) Stainless Steel: Iron (Fe) and Chromium (Cr) and Nickel (Ni). Fe: 126, Cr: 125, Ni: 125

17. When diluting a concentrated, strong acid, the correct procedure involves adding the acid to a

relatively large volume of distilled water in a volumetric flask. What is the purpose of adding the acid

to a large volume of water rather than adding water to a relatively large volume of the acid?

(A) Since it is strong, the large amount of water allows for the complete ionization of the acid

(B) To allow the solutions to form a completely homogenous mixture

(C) To allow the water to absorb the large amount of energy released as the solution is diluted

(D) To ensure that the acid does not react with the glass surface of the volumetric flask

18. Which of the following liquids would you expect to have the lowest vapor pressure at 298 K?

(A) CS2

(B) CCl4

(C) C2H5OH

(D) C6H14

19. The diagram below represents what happens when a stress is applied to an ionic crystal lattice.

A diagram of a stress applied

Description automatically generated

What is the consequence of applying this stress?

(A) The solid ionic crystal will break apart since like charges attract

(B) The solid ionic crystal will break apart since like charges repel

(C) The solid ionic crystal will now be able to conduct since like charges attract

(D) The solid ionic crystal will now be able to conduct since like charges repel

20. Which of the following will exhibit a bond length between the central atom and the terminal (outside) atoms that is intermediate between a double and a single bond?

(A) CO32-

(B) CCl4

(C) H2O

(D) CO2

21. Titanium (element with atomic number 22) can exhibit more than one oxidation state. One compound of titanium (Ti), carbon (C) and oxygen (O) is found to have a percentage by mass as follows;

**Ti 44.4 %**

**C 11.1%**

**O 44.5 %**

What is the empirical formula of the compound?

(A) Ti(CO)6

(B) Ti(CO)3

(C) TiCO3

(D) TiCO

22. Assuming the electron orbital diagrams below to be the ground state configurations of elements

that all start with 1s, which configuration shows an element with exactly six valence electrons?

(A)

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(B)

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(C)

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(D)

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23.

**CH4 + 2O2 🡺 CO2 + 2H2O**

In the reaction above, if 1.20 mols of CH4 are completely burned in 3.00 mols of O2, what is the

maximum number of moles of H2O that can be formed?

(A) 1.20

(B) 2.40

(C) 3.00

(D) 4.20

24. Which answer correctly evaluates the following statement?

***An increase in activation energy causes the rate of a chemical reaction to increase***

(A) True, because when particles have greater energies more of them will possess the minimum required energy to result in successful collisions

(B) True, because particles with higher energies will collide more often

(C) False, because with a higher activation energy fewer particles will possess the minimum required energy to result in successful collisions

(D) False, because the rate of a chemical reaction does not depend upon the activation energy

25. A 1.0 M solution of aqueous Na2CO3 is found to be a better conductor of electricity than a 1.0 M

solution of NaBr. Which statement correctly explains this observation?

(A) Both salts are soluble, but Na2CO3 is more soluble than NaBr

(B) NaBr is insoluble

(C) Na2CO3 produces Na, C and O ions in solution, whereas NaBr only produces Na and Br ions

(D) Both salts are soluble, but Na2CO3 produces a greater number of ions than does NaBr

**ANSWERS**

**1. C**

**2. D**

**3. B**

**4. D**

**5. B**

**6. C**

**7. D**

**8. B**

**9. D**

**10. C**

**11. D**

**12. B**

**13. C**

**14. C**

**15. A**

**16. C**

**17. C**

**18. C**

**19. B**

**20. A**

**21. C**

**22. A**

**23. B**

**24. C**

**25. D**

**FREE RESPONSE**

**Question 1**

A silver alloy with a mass of 15.33 g, is dissolved in acid to create an aqueous solution containing aqueous silver ions. A large excess of aqueous sodium bromide is added to the solution containing the silver ions, and a precipitate forms. The precipitate that now contains the silver ions is filtered, dried thoroughly, and weighed, and is found to have a mass of 8.22 g

(a) Write a balanced net ionic chemical equation to show the reaction of aqueous silver ions with aqueous bromide ions that produces the solid precipitate. Include state symbols. (2)

**Ag+(aq) + Br-(aq) 🡺 AgBr(s)**

(b) What is the purpose of adding a ‘large excess’ of aqueous sodium bromide? (1)

**To ensure that all of the silver ions were precipitated**

(c) Use the data to calculate the percentage of silver in the original alloy. (4)

**Moles of AgBr = (8.22 g/187.77 g mol-1) = 4.378 x 10-2 mols = Moles of Ag+ = Moles of Ag**

**Mass of Ag = (4.378 x 10-2 moles of Ag)(107.87 g mol-1) = 4.722 g**

**% by mass in the alloy = (4.722 g/15.33 g)\*100 = 30.8 %**

(d) If the precipitate were not dried completely, what effect would this have on the calculated % of silver metal in the alloy? Explain. (2)

**It would be calculated as being too high. The mass of the precipitate would include water and**

**so would be too large, making the moles of the precipitate too large, making the moles of the silver too large, and the mass of the silver too large.**

**Question 2**

Samples of four different gases are separately placed into four identical containers, each with the same

pressure, the same volume and the same temperature. The four gases are helium (He), nitrogen (N2),

methane (CH4) and carbon dioxide (CO2). You may assume that they act as ideal gases.

(a) Which gas would have the smallest value for ‘b’ in the van der Waals equation for *real* gases? (The equation is shown below). Explain your answer. (2)

**He. The magnitude of the value for b reflects the volume that the particles themselves occupy. Helium atoms have the smallest volume of the gases listed**

(b) Which container has the greatest number of moles of gas? Explain your answer, but there is no need to perform any calculations. (2)

**All have the same. The values for P, V, T and R are all identical, and if the gases behave ideally then n must have the same value in each case**

(c) In which container to the particles have,

(i) the smallest kinetic energy. Explain your answer. (2)

**All have the same. Kinetic energy is dependent upon temperature, and in each case the temperature is identical**

(ii) the greatest average velocity? Explain your answer. (2)

**He. Since kinetic energy is the same for all of the gases, and KE = ½ mv2, as mass decreases, velocity increases. He atoms have the smallest mass.**

(d) Draw a Lewis structure for the carbon dioxide molecule and identify the geometry of the atoms. (2)

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**Linear**

**Question 3**

The first ten ionization energies in units of kJ/mol for the element magnesium, are given below.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **1st** | **2nd** | **3rd** | **4th** | **5th** | **6th** | **7th** | **8th** | **9th** | **10th** |
| 738 | 1451 | 7733 | 10543 | 13630 | 18020 | 21711 | 25661 | 31653 | 35458 |

(a) Account for the large increase in ionization energy between the 2nd and 3rd values. (2)

**The first and second electrons are removed from the 3s energy level, but the 3rd electron is removed from an inner shell (n = 2), that is closer to the nucleus, experiences a much greater Coulombic attraction, meaning a much larger amount of energy is required to overcome the greater attraction**

(b) Calculate the minimum wavelength of a photon that could be used to convert a single, neutral magnesium atom (Mg) to a magnesium ion with a charge of +1 (Mg+). (2)

**(738 kJ mol-1)/(6.022 x 1023 mol-1) = 1.226 x10-21 kJ per atom = 1.226 x10-18 J per atom**

**E = h u = 1.226 x10-18 J = (6.626 x 10-34 J s) (u)**

**u = 1.85 x 1015 s-1**

**c = l u = 2.998 x 108 ms-1 = (l) (u)**

**l = 1.62 x 10-7 m**

**Question 4**

One of the particles in solid potassium chloride, KCl, is shown below being hydrated by water

molecules.

A diagram of red and white circles

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(a) Identify which species is being hydrated in the diagram above. Explain your answer. (2)

**K+. The d- end of the water molecules dipoles are pointing towards the positve ion.**

(b) Explain why KCl will conduct electricity when it is hydrated in aqueous solution, but not when it is a solid. (1)

**In the solid state the ions are held in a rigid lattice and are not free to move, but when hydrated the lattice breaks down, and the ions become free to move, acting as charge carriers in solution**

(c) Choosing from the list below, identify the best description of the interaction between the water molecules and the particle from potassium chloride shown in the diagram above. (1)

*ion to dipole, dipole to dipole, ion to induced dipole, ion to ion*

**Ion to dipole**