General Chemistry I Test Bank

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This document contains 256 test questions and answers that I have used during the past decade. Some of the equations were created using MathType equation editor 5.1. This is an upgrade to the equation editor that comes with Word. I got it so that the equations could be displayed in a blue font (I show answers in blue on my web pages). To modify the equations, you will need to get the MathType free upgrade (<http://www.dessci.com/en/>). If you don’t purchase the upgrade, you can only change colors for the first 30 days.

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You must show your work to get credit (or partial credit). Watch significant figures and show units.

Some constants: *c* = 3.00 × 108 m/s *h* = 6.63 × 10-34 J s *RH* = 3.29 × 1015 Hz

*N*A = 6.022 × 1023

### Scientific Method

(2 pts) Complete the following sentence. A *scientific theory* is (select one)

1. a tentative explanation for a set of observations that can be tested by further experimentation.
2. an explanation of the general cause of a phenomena, in which the explanation is supported by considerable evidence.

c) a statement describing a relationship between phenomena that is always the same under the same conditions.

d) a unifying principle that explains a body of facts and relations.

e) a model used to visualize the invisible.

f) all of the above.

(2 pts) Complete the following sentence. A *scientific hypothesis* is (select one)

a) a tentative explanation for a set of observations that can be tested by further experimentation.

b) a statement describing a relationship between phenomena that is always the same under the same conditions.

c) a unifying principle that explains a body of facts and relations.

d) a model used to visualize the invisible.

e) all of the above.

(2 pts) Complete the following sentence. A *scientific law* is (select one)

a. a tentative explanation for a set of observations that can be tested by further experimentation.

b. a statement describing a relationship between phenomena that is always the same under the same conditions.

c. a unifying principle that explains a body of facts and relations.

d. a model used to visualize the invisible.

(3 pts) Which one of the following is not a characteristic of science?

1. Reproducible
2. Testable
3. Can be challenged
4. Disagreements are settled by a recognized authority.

(5 pts) Give an example of a “pseudoscience”: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Give one way in which your example does not qualify as “science”.

Something like astrology (not astronomy) or mind reading would be an example. These don’t follow the scientific method, so any aspect of the scientific method could be given as an example of how they don’t qualify as science.

### States of Matter

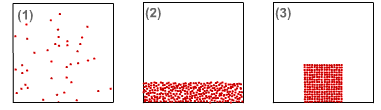
(3 pts) The molecules in a solid are

1. attracted to each other so strongly that the molecules can’t slide past each other.
2. somewhat attracted to each other, allowing the molecules to slide past each other.
3. hardly attracted to each other at all, allowing the molecules to freely move around.

(3 pts) What is the name of the state of matter in which the matter takes the same shape and volume as whatever container the matter is in?

1. gas

(2 pts) Which of the following figures represents a gas?

1. a. 1
2. b. 2
3. c. 3
4. d. They all do
5. e. None of them do

### Components of Atoms

(2 pts) Atoms of the same element, regardless of charge, all have the same number of \_\_\_protons\_\_\_\_\_\_.

(2 pts) Comparing the mass of an electron to the mass of a proton, one could say that the electron is \_\_\_\_\_much less\_\_\_\_\_\_\_\_ massive than the proton.

(2 pts) Comparing the mass of a neutron to the mass of a proton, one could say that the neutron

1. is much less massive than the proton.
2. is less massive than the proton.
3. has nearly the same mass as the proton.
4. is more massive than the proton.
5. is much more massive than the proton.

(2 pts) How large is the nucleus compared to the size of an atom? Very small.

(4 pts) What two kinds of atomic particles are found in the nucleus of an atom?

\_\_\_\_protons\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_neutrons\_\_\_\_\_\_\_\_\_

(2 pts) Atoms of the same element that have different masses are called isotopes\_\_\_\_\_\_\_\_.

(2 pts) What is the charge of the particle in cathode rays? -1

(5 pts) Draw a sketch of an atom. Label the nucleus, protons, neutrons.



(6 pts) Draw a sketch of an atom. Label the nucleus, protons, neutrons and electrons.



(4 pts) Rutherford bombarded gold foil with alpha particles. Explain how the results of this experiment lead to the nuclear model of the atom.

Some of the alpha particles bounced back from the foil. The only way that this could happen is if most of the mass of the atoms is in one region of space, called the nucleus.

### Symbols of Isotopes

(6 pts) Give the symbol that identifies the following species. Include the charge if they are not neutral (for example, 1H+)

8 protons, 8 neutrons, 8 electrons: 16O

43 protons, 55 neutrons, 39 electrons: 98Tc4+

(2 pts) One of the following is an isotope of hydrogen. Circle it.

a. 2D b. 4He c. 9Li d. 9Be e. 165Ho f. 201Hg

(4 pts) Write the name of the isotope that has 108 neutrons, 73 protons, and 73 electrons. (The name should indicate which isotope this is.)

181Ta or tantalum-181

Recognize that element must be given, select correct element, and include isotope identifier that is correct.

(6 pts) Give the symbol that identifies the following isotope. Include the charge if the isotope is not neutral (for example, 1H+)

53 protons, 76 neutrons, 54 electrons: 129I–

(12 pts) Give the symbol that identifies the following species. Include the charge if the species is not neutral (for example, 1H+)

9 protons, 10 neutrons, 10 electrons: 19F–

94 protons, 150 neutrons, 91 electrons: 244Pu3+

(6 pts) Give the symbol that identifies the following isotope, and the charge, if any. (For example, 1H+)

8 protons, 9 neutrons, 10 electrons: \_\_\_\_\_\_\_ 17O2-

(6 pts) Give the symbol that identifies the following species, and the charge, if any. (For example, 1H+)

16 protons, 16 neutrons, 16 electrons: \_\_\_\_\_\_\_ 32S

92 protons, 146 neutrons, 88 electrons: \_\_\_\_\_\_\_ 238U4+

(6 pts) Give the number of subatomic particles in .

protons \_\_\_\_\_ 6 neutrons \_\_\_\_\_ 7 electrons \_\_\_\_\_ 6

(6 pts) How many protons are in the ion ? \_\_\_\_\_\_\_ 15

How many neutrons are in that ion? \_\_\_\_\_\_\_ 16

How many electrons are in that ion? \_\_\_\_\_\_\_ 12 (the ion has a 3+ charge)

(6 pts) How many protons are in the ion ? \_\_\_\_\_\_\_ 26

How many neutrons are in that ion? \_\_\_\_\_\_\_ 30

How many electrons are in that ion? \_\_\_\_\_\_\_ 23 (the ion has a 3+ charge)

(2 pts) An atom containing which one of the following is an isotope of carbon?

a) 6 neutrons and 7 protons

b) 7 neutrons and 6 protons

c) 12 neutrons and 12 protons

d) 13 neutrons and 13 protons

e) 14 neutrons and 14 protons

(2 pts) The current scientific theory is that the elements heavier than hydrogen (this includes the elements from which we are made) are formed from/in \_\_\_\_\_stars or supernova\_\_\_.

### Using the Periodic Table

(2 pts) The atomic symbol for sodium is

a. S b. Si c. Sn d. Ni e. Na

(6 pts) Classify the following as metal, nonmetal, or metalloid:

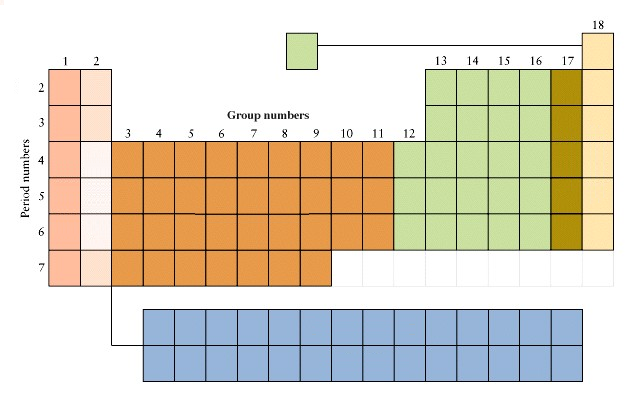
chlorine: nonmetal metal metalloid

sodium: nonmetal metal metalloid

boron: nonmetal metal metalloid

(2 pts) The formula of the ion of sulfur that would be expected to form based on sulfur’s position in the periodic table is \_\_\_\_\_\_\_\_\_. S2- Element symbol must have correct charge.

(10 pts) Fill in the boxes to identify the five parts of the periodic table that are circled.



noble gases

actinides

halogens

alkali metals

transition metals (or elements)

### Mixtures

(3 pts) A sample of tap water consists of water, fluoride ions, calcium ions, and several other dissolved ions. The ions are evenly distributed throughout the water. Which of the following best describes this sample of tap water?

1. an element
2. a heterogeneous mixture
3. a homogeneous mixture
4. a pure chemical substance

(2 pts) Suppose that a gold ring is composed completely of gold, absolutely free of impurities. Which of the following best describes the gold ring?

1. a heterogeneous mixture
2. a homogeneous mixture
3. a solution
4. a pure chemical substance
5. a compound

(8 pts) Classify each of the following as a pure substance, a heterogeneous mixture, or a homogeneous mixture.

(a) chocolate-chip cookie \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ heterogeneous mixture

(b) distilled water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pure substance

(c) vodka \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ homogeneous mixture

(d) a pure gold coin \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pure substance

(6 pts) Classify each of the following as a pure substance, a heterogeneous mixture, or a homogeneous mixture.

an ear of corn \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ heterogeneous mixture

sodium chloride \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pure substance

sugar water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ homogeneous mixture

(8 pts) Classify each of the following as an element, compound, or mixture.

(a) the air we breath \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mixture

(b) the gas in a tank of chlorine used to disinfect water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ element

(c) table salt \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compound

(d) a mosquito \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mixture

(8 pts) Classify each of the following as an element, compound, or mixture.

(a) aluminum metal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ element

(b) the gas in a tank of propane, C3H8 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compound

(c) pure water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ compound

(d) soil \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ mixture

(12 pts) Part of the universe can be classified into the following categories: compounds, elements, heterogeneous, homogeneous, matter, mixtures, and pure substances. Organize these in the boxes of the following hierarchy chart.

matter

mixtures

homogeneous

heterogeneous

pure substances

elements

compounds

### Solution Terminology

(2 pts) In the process of dissolving 1 g of sodium perchlorate in water, the sodium perchlorate is referred to as the

A) solute. B) solvent. C) solution. D) precipitate E) solid solution.

(2 pts) If 1 g of sodium perchlorate is dissolved in water, the water is referred to as the

A) solute. B) solvent. C) solution. D) precipitate E) solid solution.

### Physical & Chemical Properties

(3 pts) At 25°C, chlorine is a green-yellow gas with a density of 3 × 10–3 g/cm3. Chlorine has a melting point of –101°C and a boiling point of –35°C, and the energy required to melt and boil chlorine is 6.4 and 20.4 kJ/mol, respectively. Chlorine burns in hydrogen to form hydrogen chloride. Underline the chemical property/properties of chlorine.

(6 pts) Describe how to separate a mixture of dirt, salt, and water into three components.

Filter the mixture to separate the dirt from the salt water. Distill the salt water to separate the salt from the water. (The solid left behind is the salt; the liquid that distills is the water.)

(2 pts) A **physical** property of a substance is being described in which statement listed below?

a. Its boiling point is 720°C.

b. It dissolves in acid to give off hydrogen.

c. It reacts violently with chlorine gas.

d. It is very flammable in air.

e. It reacts with water with the evolution of hydrogen.

(2 pts) Which one of the processes listed below describes a **chemical** (rather than physical) change?

a. Water evaporates from the surface of the skin.

b. Frozen lemonade is reconstituted by adding water to it.

c. Fat is metabolized by the body to make energy.

d. Kool Aid is made by adding a dry powder to water.

e. A deposit of salt on a car or windshield is washed away with water.

(2 pts) Which one of the processes given below describes a **physical** (rather than a chemical) change?

a. Lard is melted in a frying pan.

b. Carbohydrates are digested in the stomach.

c. Hair protein is formed by the follicle cells of the head.

d. Proteins are synthesized or formed in plants.

e. Proteins are digested in the intestines.

(1 pts) Paper chromatography separations are based on the fact that

A) the components to be separated are volatile.

B) The components to be separated have different tendencies to stick to the paper.

C) liquids are adsorbed on calcium carbonate.

D) a carrier gas is unreactive.

E) the components can be distilled.

(2 pts) Which of the following statements describes a physical property of a substance?

a. Its boiling point is 720°C.

b. It dissolves in acid to give off hydrogen.

c. It reacts violently with chlorine gas.

d. It is very flammable in air.

e. It reacts with water with the evolution of hydrogen.

(3 pts) Which of the following describe a chemical change, and which a physical change? (Circle the correct answer.)

|  |  |
| --- | --- |
| a. Sheep are sheared, and the wool is spun into yarn. | Physical or chemical? |
| b. Frozen lemonade is reconstituted by adding water to it. | Physical or chemical? |
| c. Milk turns sour when left out of the refrigerator for many hours | Physical or chemical? |

### Diatomic Elements

(5 pts) Name five elements that are diatomic.

hydrogen 5 pts for correct elements

oxygen (Wanted to charge 5 pts for spelling, but too many people

nitrogen just gave symbols instead of names)

fluorine

chlorine

bromine

iodine

(2 pts) “So,” your great-uncle asks you, “is chlorine an element or a molecule?” What would be the best answer?

It is both. Recognize that it is both an element and a molecule. –1 for just element.

(5 pt) Give the formulas of 4 diatomic elements: N2, O2, H2, F2, Cl2, Br2, I2 1 pt for the subscripts

### Anion and Cation Terms

(2 pt) When an atom loses an electron, it becomes an ion. What is an ion with a positive charge called? A cation

(2 pt) When an atom loses an electron, it becomes an ion. What is an ion with a negative charge called? An anion

### Naming Compounds

(24 pts) Name the following compounds (Ni, nickel, is element number 28).

NiCl4 nickel(IV)chloride 4 pts

Ca(CN)2 calcium cyanide 3 pts

P2S5 diphosphorus pentasulfide 4 pts

The common name used for NH3 ammonia 2 pts

HBr(aq) hydrobromic acid 4 pts

H2SO4(aq) sulfuric acid 3 pts

NaClO4 sodium perchlorate 4 pts

(29 pts) Name the following compounds.

CuNO3·6H2O copper(I)nitrate hexahydrate 5 pts

KCN potassium cyanide 2 pts

SiC (commonly called carborundum) silicon carbide 3 pts

N2O5 dinitrogen pentaoxide 4 pts

The common name used for NH3 ammonia 2 pts

HCl(g) hydrogen chloride 3 pts

HCl(aq) hydrochloric acid 4 pts

H2SO4(aq) sulfuric acid 3 pts

HClO3(aq) chloric acid 3 pts

(30 pts) Name the following compounds. (Co is cobalt, Z = 27)

Na2CO3·10H2O sodium carbonate decahydrate 4 pts

Co(CN)2·3H2O cobalt(II)cyanide trihydrate 4 pts

SiC (commonly called carborundum) silicon carbide 3 pts

P4O10 tetraphosphorus decaoxide 4 pts

The common name used for NH3 ammonia 2 pts

HCl(g) hydrogen chloride 3 pts

HCl(aq) hydrochloric acid 4 pts

HNO3(aq) nitric acid 3 pts

HIO3(aq) iodic acid 3 pts

(33 pts) Name the following compounds. (Co is cobalt, Z = 27)

Na2CO3 sodium carbonate 3 pts

Co(CN)2 cobalt(II)cyanide 4 pts

SiC (commonly called carborundum) silicon carbide 3 pts

P4O10 tetraphosphorus decaoxide 4 pts

The common name used for NH3 ammonia 2 pts

(NH4)2SO4 ammonium sulfate 4 pts

This molecular compound: HCl(g) hydrogen chloride 3 pts

This aqueous acid: HCl(aq) hydrochloric acid 4 pts

HNO3(aq) nitric acid 3 pts

HIO3(aq) iodic acid 3 pts

(25 pts) Name the following compounds (Fe is iron).

FeSO4·7H2O iron(II)sulfate heptahydrate 5 pts

NH4CN ammonium cyanide 4 pts

ClO2 chlorine dioxide 3 pts

IF5 iodine pentafluoride 3 pts

HI(g) hydrogen iodide 3 pts

HI(aq) hydroiodic acid 4 pts

LiNO2 lithium nitrite 3 pts

(20 pts) Name the following compounds (Ni, nickel, is element number 28).

NiCl4·8H2O nickel (IV)chloride octahydrate 5 pts

Ca(CN)2 calcium cyanide 3 pts

CS2 carbon disulfide 3 pts

P2S5 diphosphorus pentasulfide 4 pts

NaClO4 sodium perchlorate 4 pts

(14 pts) Name the following compounds.

NiSO4·6H2O nickel(II) sulfate hexahydrate 5 pts

SF6 sulfur hexafluoride 3 pts

HBr(g) hydrogen bromide 3 pts

HNO3(aq) nitric acid 3 pts

(17 pts) Name the following compounds.

Al(ClO3)3 aluminum chlorate 4 pts

Cu(NO3)2·6H2O copper(II) nitrate hexahydrate 5 pts

N2O5 dinitrogen pentoxide 4 pts

HBr(aq) hydrobromic acid 4 pts

(15 pts) Name the following compounds.

Fe(CN)3 iron(III) cyanide (or ferric cyanide) 4 pts

K2SO3 potassium sulfite 4 pts

CaCO3 calcium carbonate 3 pts

LiIO4 lithium periodate 4 pts

(5 pts) The name of Na2CO3•10H2O is

sodium carbonate decahydrate

2 pts for sodium without numbers, 1 for carbonate (1 for spelling), 1 for deca, 1 for hydrate

(6 pts) Name these common laboratory compounds:

a) HCl(aq) hydrochloric acid

hydro chlor ic acid (acid should be present or absent in both names)

1 1 1 1

b) H2SO4(aq) sulfuric acid

sulfur ic

1 1

(45 pts) Name the following compounds.

NO2 nitrogen dioxide 4 pts

XeO3 xenon trioxide 4 pts

IF5 iodine pentafluoride 4 pts

SiS2 silicon disulfide 4 pts

K2SO3 potassium sulfite 3 pts

Cr(NO3)2·9H2O chromium(II) nitrate nonahydrate 7 pts

Mn(CN)2 manganese(II) cyanide 3 pts

AgNO3 silver(I) nitrate 3 pts

HClO2 chlorous acid 3 pts

Ba(OH)2 barium hydroxide 3 pts

H2CO3 carbonic acid 3 pts

H3PO4 phosphoric acid 3 pts

The common name used for NH3 is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ammonia 2 pts; -1 for ammonium

### Formulas of Compounds

(22 pts) Give formulas for the following compounds. (Chromium has Z = 24)

chromium(II) sulfate CrSO4 4 pts

sodium carbonate monohydrate Na2CO3·H2O 7 pts

dibromine heptoxide Br2O7 4 pts

perchloric acid HClO4 4 pts

sodium hypochlorite NaClO 3 pts

(21 pts) Give formulas for the following compounds. (Vanadium has Z = 23)

vanadium(III) iodide VI3 3 pts

calcium perchlorate hexahydrate Ca(ClO4)2·6H2O 7 pts

dichlorine heptoxide Cl2O7 4 pts

perchloric acid HClO4 4 pts

sodium hypochlorite NaClO 3 pts

(18 pts) Give formulas for the following compounds.

iron(II) phosphate Fe3(PO4)2 6 pts

sodium sulfate dihydrate Na2SO4·2H2O 8 pts

dichlorine dioxide Cl2O2 4 pts

(27 pts) Give formulas for the following compounds.

lead(II) phosphate Pb3(PO4)2 8 pts

sodium carbonate Na2CO3 6 pts

dichlorine heptaoxide Cl2O7 4 pts

phosphoric acid H3PO4 5 pts

perbromic acid HBrO4 4 pts

(8 pts) Give formulas for the following compounds.

sulfuric acid H2SO4 4 pts

phosphoric acid H3PO4 4 pts

(21 pts) Give formulas for the following compounds. (manganese, Mn, is element number 25)

manganese(IV) oxide MnO2 3 pts

sodium carbonate hexahydrate Na2CO3·6H2O 9 pts

phosphoric acid H3PO4 5 pts

perbromic acid HBrO4 4 pts

(20 pts) Give formulas for the following compounds.

iron(III) oxide Fe2O3 4 pts

potassium sulfite dihydrate K2SO3·2H2O 8 pts

diphosphorus trisulfide P2S3 4 pts

periodic acid HIO4 4 pts

(17 pts) Give formulas for the following compounds.

perchloric acid HClO4 4 pts

potassium hypochlorite KClO 3 pts

iron(II) phosphate Fe3(PO4)2 6 pts

dichlorine dioxide Cl2O2 4 pts

(48 pts) Give formulas for the following compounds.

phosphorus trichloride PCl3 3 pts

sulfur dioxide SO2 3 pts

dichlorine heptoxide Cl2O7 4 pts

tetraphosphorus decoxide P4O10 4 pts

magnesium dihydrogen phosphate Mg(H2PO4)2 7 pts

cobalt(III) oxide Co2O3 4 pts

calcium permanganate Ca(MnO4)2 5 pts

Iron(III) chloride hexahydrate FeCl3·6H2O 6 pts

periodic acid HIO4 4 pts

bromic acid HBrO3 4 pts

potassium hydroxide KOH 3 pts

(15 pts) Give formulas for the following compounds.

magnesium phosphate Mg3(PO4)2 7 pts

ammonium hypochlorite NH4ClO 5pts

mercury(II) bromide HgBr2 3 pts

(4 pts) The formula of dinitrogen tetraoxide is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. N2O4

(4 pts) The formula for aqueous perchloric acid is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. HClO4(aq)

The (aq) is optional

(9 pts) Give the formula of the compound that is apt to be formed from the following:

a) calcium ions and nitrate ions \_\_\_\_\_\_\_\_\_\_ Ca(NO3)2 -2 for Ca3N2

b) aluminum and sulfur \_\_\_\_\_\_\_\_\_\_ Al2S3

(8 pts) Give the formula of the compound that is apt to be formed from the following:

a) beryllium and chlorine \_\_\_\_\_\_\_\_\_\_ BeCl2

b) boron and oxygen \_\_\_\_\_\_\_\_\_\_ B2O3

### Understanding Chemical Formulas

(2 pts) What is the empirical formula of P4O10? P2O5

(2 pts) What is the empirical formula of hydrogen peroxide, H2O2? HO

(2 pts) How many atoms are in one molecule of (NH4)3PO4? \_\_\_\_ 20

(2 pts) How many atoms are in one “formula unit” of Al2(SO4)3? \_\_\_\_ 17

### Units of Volume

(3 pts) Which of the following is equal to one one thousandth of a liter?

1. 1 mL
2. 1 cm3
3. 1 cubic centimeter
4. All of the above

### Metric Prefixes

(6 pts) The distances below use metric prefixes. Give the number that the prefix represents (for example, mm: 10-3 meter).

a. pm \_\_\_\_\_\_\_\_\_ 10-12 meter.

b. nm \_\_\_\_\_\_\_\_\_ 10-9 meter.

c. cm \_\_\_\_\_\_\_\_\_ 10-2 meter.

(12 pts) The distances below use metric prefixes. Give the number that the prefix represents (for example, 10-7)

a. µm \_\_\_\_\_\_\_\_\_ 10-6

b. mm \_\_\_\_\_\_\_\_\_ 10-3

c. Mm \_\_\_\_\_\_\_\_\_ 106

d. pm \_\_\_\_\_\_\_\_\_ 10-12

e. nm \_\_\_\_\_\_\_\_\_ 10-9

f. cm \_\_\_\_\_\_\_\_\_ 10-2

(8 pts) Change the unit used to report each of the following measurements by replacing the power of ten by an appropriate SI prefix.

1. 8.01 × 10-6 g becomes 8.01 \_\_\_g µg
2. 1.05 × 10-9 m becomes 1.05 \_\_\_m nm
3. 7.9 × 10-3 L becomes 7.9 \_\_\_L mL
4. 1.48 × 10-12 m becomes 1.48 \_\_\_m pm

### Significant Figures

(2 pts) How many significant figures should be given in the result of ?

(Note: no calculation is necessary.) 2 (0.0019 only has 2 significant figures)

(2 pts) How many significant figures should be given in the result of ?

(Note: no calculation is necessary.) 3 (0.00186 only has 3 significant figures)

(1 pts) Do the following measurement calculation.

11.0

-4.00

7.0

(Just counting number of significant figures.)

(2 pts) How many significant figures are there in the measured number 0.0020340?

5

(2 pts) How many significant figures are in the measured number 0.000001830100?

7

Perform the indicated operation, and give answers with the proper number of significant figures. Assume all numbers are measurement (none are exact numbers).

1. (2pts) 0.0983
2. (3 pts) 33.62 + 12.2 – 48.36 = -2.54 = 2.5 (just 2 significant figures)

### Dimensional Analysis

(2 pts) A bottle of cola purchased in Europe gave the volume as 50 cL. What is this volume in mL?

a) 0.005 L

b) 5000 mL

c) 500 mL

d) 50 mL

e) 0.05 L

(8 pts) If a little old lady is doing 98.3 kilometers/hour, will she get a speeding ticket if the speed limit is 55 miles / hour? [USE: 5280 feet = 1 mile and 2.54 cm = 1.00 inch] (Show how to convert to miles / hour, even if your calculator does it for you.)



Would get a speeding ticket.

(5 pts) A supersonic transport (SST) airplane consumes about 18,000 L of kerosene per hour of flight. Kerosene has a density of 0.965 kg/L. What mass of kerosene is consumed on a flight lasting 3.0 hours?



1 1 1 1 1 for sig. figs.

(8 pts) Santa visits about 95,000 chimneys a minute on a certain night of the year (ask Einstein how he does it). How many sleigh loads per hour is this? [USE: 12 presents = 1 chimney, and 27,000 presents = 1 sleigh load]



(12 pts) A particular brand of gasoline has a density of 0.737 g/mL at 25 °C. How many grams of this gasoline would fill a 12.2 gal tank? (1 gal = 3.7854 L). Use the correct number of significant figures in your answer.



2 pt, sig. figs.; 1 pt m = d × v; 2 pts for (1L / 1000 mL)

(**7** pts) You have been told that a certain house is 164 m2 in area. How much is this in square feet? (1 ft = 0.3048 m)



2 pt, sig. figs.

(6 pts) Convert 5.750 gal/hr to L/s. (1 gal = 3.7854 L)

(6 pts) Convert 1.30 kg/m3 to g/L. (1 L is a cube 0.1 m on a side.)

### Temperature

(3 pts) What is the Celsius temperature that corresponds to 0 K?

-273°C

(4 pts) What Celsius temperature is equivalent to 5°F?

-15°C

Formula is on the top of the front page

(4 pts) What Fahrenheit temperature is equivalent to 84°C?

Formula is on the top of the front page: 

### Density

(5 pts) The density of carbon tetrachloride is 1.59 g/mL. What is the mass of 3.65 mL of carbon tetrachloride?



(8 pts) The density of diamond is 3.51 g/cm3. The international (but non-SI) unit for reporting the masses of diamonds is the “carat”, with 1 carat = 200. mg. What is the volume of a diamond of mass 0.300 carat?



(8 pts) What volume (in cm3) of lead (of density 11.3 g/cm3) has the same mass as 100. cm3 of a piece of redwood (of density 0.38 g/cm3)?

First, find the mass of the redwood:



Second, find the volume of the same mass of lead:



(5 pts) The average Christmas present has a density of 2.15 kg/L. What would you expect the mass to be of a present having a volume of 3.65 L?



(7 pts) One of Santa’s elves determined that the average Christmas present has a density of 2.15 kg/L. What would you expect the mass to be of a present having a volume of 364 mL?



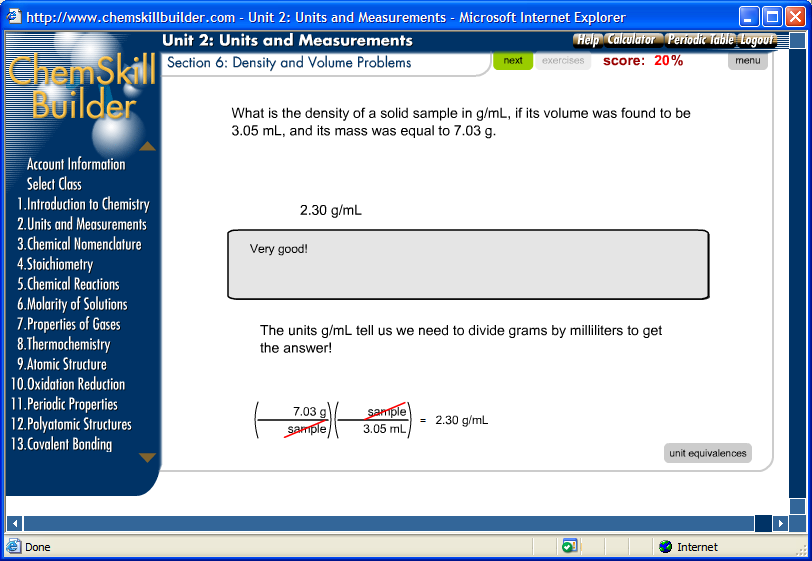
1 pt, sig. figs.; 1 pt m = dv; 2 pts for (1L / 1000 mL)

-2 pts for 783 kg (NOTE: This density is unrealistically high, and should be changed.)

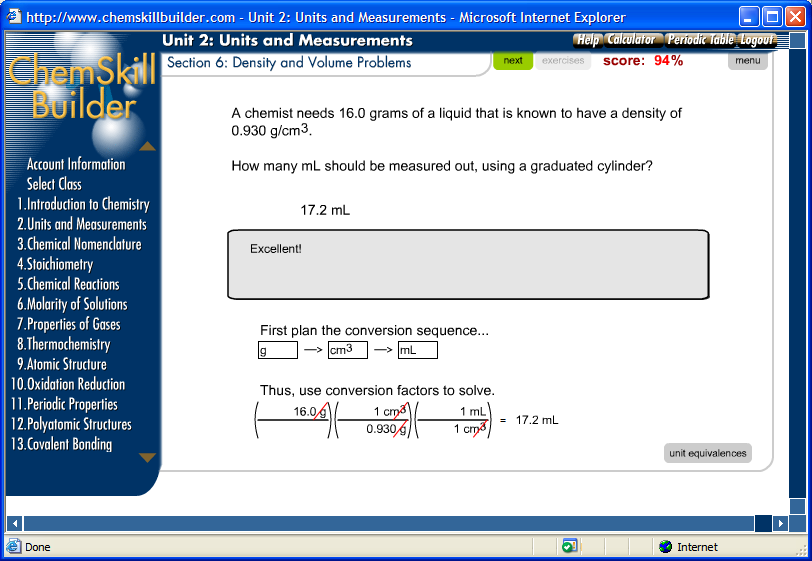
(2 pts) 8.0 grams of granite has a density of 2.7 g/mL. What is the density of 16.0 g of granite? 2.7 g/mL

(5 pts) What is the density of a solid sample in g/mL if its volume was found to be 3.05 mL and its mass was 7.03 g?

The units g/mL indicates that grams needs to be divided by milliliters to get the answer.



(6 pts) A chemist needs 16.0 grams of a liquid that has a density of 0.930 g/cm3. How many mL should be measured out, using a graduated cylinder?



(9 pts) A certain silvery metal had a density of 12.5 g/cm3. What would be the mass, in grams, of a solid block that has a volume of 50 in3? (1 inch = 2.54 cm exactly) (Tip: clearly show significant figures in the answer.)



Accepted either 1 or 2 significant figures, since the 50 is ambiguous.

(5 pts) What is the mass in grams of 477 mL of blood plasma? The density of blood plasma is 1.027 g/mL.



### Avogadro’s Number

(6 pts) How many moles of hydrogen *atoms* are in 5 × 1022 hydrogen *molecules*?



-2 pts for 0.08 moles

(6 pts) A glass of water contains 4.22 mol of water **molecules**. How many hydrogen **atoms** are in the water?



-2 pts for 2.54 × 1024 (didn’t multiply by 2)

(6 pts) How many moles of chlorine **atoms** are in 4 × 1021 chlorine **molecules**?



-2 pts for 0.006 moles; -1 for 0.003 moles

(6 pts) How many moles of bromine **atoms** are in 8 × 1020 bromine **molecules,** Br2?



-2 pts for 0.0013 moles; -1 for 0.00066 moles

### Molar Mass from % Abundance

(5 pts) A certain element consists of two stable isotopes with the masses and percent abundances given below. Determine the molar mass AND identify this element. (*N*A = 6.022 × 1023/mol)

|  |  |  |
| --- | --- | --- |
|  | Mass of an atom | % abundance |
|  | 1.663×10-23 | 19.9 |
|  | 1.828×10-23 | 80.1 |



Identity of element: \_\_\_B

### Molar Mass; grams 🡨🡪 moles

(4 pts) Determine the molar mass of Ca3(PO4)2.

|  |  |
| --- | --- |
| 3Ca | 3 × 40.08 g/mol |
| 2P | 2 × 30.97 g/mol |
| 8O | 8 × 16,00 g/mol |
|  | 310.18 g/mol |

(6 pts) How many moles are in 8.0 g of Ca3(PO4)2?



(5 pts) How many moles are in 2.0 g of Ca3(PO4)2?



(4 pts) Determine the molar mass of Pb3(PO4)2.

|  |  |
| --- | --- |
| 3Pb | 3 × 207.2 g/mol |
| 2P | 2 × 30.97 g/mol |
| 8O | 8 × 16,00 g/mol |
|  | 811.5 g/mol |

-2 pts for 101 mol (upside down calculation)

(5 pts) How many moles are in 8.0 g of Pb3(PO4)2?



### Understanding Molar Mass

(4 pts) The molar mass of krypton is 83.80 g/mol. What is the average mass of one atom of Kr?



1 using NA, 1 for dividing, 1 for getting right answer, 1 for sig. figs.

(2 pts) The last problem called for calculating the average mass of one atom of krypton. Actually, no atoms of krypton have exactly that mass. This could be because the element Kr

consists of several \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. isotopes

(4 pts) How many moles of CuBr2•4H2O are in 5.50 g of CuBr2•4H2O?



(2 pts) How many moles of water molecules are in the above amount of CuBr2•4H2O?

4 × 0.0186 mol = 0.0744 mol

### Percent Composition from Formula

(4 pts) What is the percent of hydrogen in H2O?



(4 pts) What is the mass percent chlorine in NaCl?



(4 pts) What is the mass percent of silver in AgCl?

3 for setup, 1 for right answer

(5 pts) What is the mass percent of nitrogen in N2O (laughing gas)?



-2 pts for 31.83% (from not using 2 nitrogens)

### Formulas from Percent Composition Data

(4 pts) 4.69 g of sulfur combined with 11.12 g fluorine to produce a gas. What is the empirical formula of the gas? (Must show work to get credit.)

S + F  an SF compound

4.69 g 11.12 g

0.146 mol 0.585 mol

Divide by smallest, get 1 S to 4.00 F, so formula is SF4.

1 each for moles, 1 for 4.00, 1 for formula

(13 pts) The percentage composition of fructose, a sugar, is 40.0% carbon, 6.72% hydrogen, and 53.28% oxygen. The molar mass of fructose is 180.2 g/mol. What is the molecular formula of fructose?

|  |  |  |
| --- | --- | --- |
| 40.0% C |  | 40.0 g C |
| 6.72% H |  | 6.72 g H |
| 53.28% O |  | 53.28 g O |





1 pt, convert to g; 6 pts, convert to mol; 2 pts, divide by smallest; 1 pt, empirical formula; 3 pts, molecular formula.

(13 pts) Cacodyl, which has an intolerable garlicky odor and is used in the manufacture of cacodylic acid, a cotton herbicide, has a molar mass of 209.96 g/mol. Its mass composition is 22.88% C, 5.76% H, and 71.36% As. (Yes, it contains arsenic). What is the molecular formula of cacodyl?

|  |  |  |
| --- | --- | --- |
| 22.88% C |  | 22.88 g C |
| 5.76% H |  | 5.76 g H |
| 71.36% As |  | 71.36 g As |





1 pt, convert to g; 6 pts, convert to mol; 2 pts, divide by smallest; 1 pt, empirical formula; 3 pts, molecular formula. -7 pts for C4Has better

(13 pts) One of the components of frankincense is boswellic acid, which is 78.90% carbon, 10.59% hydrogen, and 10.51% oxygen. The molar mass of boswellic acid is 456.71 g/mol. What is the molecular formula of boswellic acid?

|  |  |  |
| --- | --- | --- |
| 78.90% C |  | 78.90 g C |
| 10.59% H |  | 10.59 g H |
| 10.51% O |  | 10.51 g O |





1 pt, convert to g; 6 pts, convert to mol; 2 pts, divide by smallest; 1 pt, empirical formula; 3 pts, molecular formula.

(13 pts) Cyclopropane, when combined with oxygen, has been used as an anesthetic. Its mass percent composition is 85.63% C and 14.37% H. The compound has a molar mass of 42.08 g/mol. What is the molecular formula of cyclopropane?

|  |  |  |  |
| --- | --- | --- | --- |
| 85.63% C |  | 85.63 g C | 2 pts. |
| 14.37% H | 14.37 g H |  |

4 pts.



1 pt, convert to g; 4 pts, convert to mol; 2 pts, divide by smallest; 1 pt, empirical formula; 3 pts, molecular formula.

(10 pts) A red compound composed of lead and oxygen contains 90.66% Pb. What is the empirical formula of the compound?

|  |  |  |
| --- | --- | --- |
| 90.66% Pb | → | 90.66 g Pb |
| 9.34% O | 9.34 g O |





1 pt, convert to g; 4 pts, convert to mol; 2 pts, divide by smallest; 3 pts, convert to Pb3O4.

(10 pts) A white compound that is used to absorb water contains 43.64% P and 56.36% oxygen. What is the empirical formula of the compound?

|  |  |  |
| --- | --- | --- |
| 43.64% P | → | 43.64 g P |
| 56.36% O | 56.36 g O |





1 pt, convert to g; 4 pts, convert to mol; 2 pts, divide by smallest; 3 pts, convert to P2O5.

(4 pts) The molar mass of pyrazine is 80.1 g/mol and its empirical formula is C2H2N. What is its molecular formula?

The molar mass of C2H2N is 40 g/mol. The molar mass of pyrazine is twice that, so its molecular formula is C4H4N2.

(4 pts) A certain edible compound has a molar mass of 180.1 g/mol. Its empirical formula is CH2O. What is its molecular formula?

The molar mass of CH2O is 30 g/mol. Dividing 180 by 30 gives 6, indicating the molecule consists of 6 empirical formula “units”, so its molecular formula is C6H12O6.

### Combination and Decomposition Reactions

(4 pts) Bromine and aluminum react to form a white solid. Give the formula of the solid.

AlBr3

(4 pts) Magnesium and nitrogen react to form a gray solid. Give the formula of the solid.

Mg3N2 (-1 for Mg2N3)

(3 pts) Complete the following combination reaction.

CaO(s) + H2O(l) → \_\_\_\_\_\_\_\_\_\_ Ca(OH)2(s) (-1 for CaOH)

(2 pts) Complete the following decomposition reaction.

PbCO3(s) PbO(s) + \_\_\_\_\_\_\_\_\_\_ CO2(g)

### Balanced Reaction of Sodium or Potassium with Water

(8 pts) Write a balanced equation describing the reaction of sodium metal with water to produce hydrogen gas and sodium hydroxide. (-1 pt if not include states.)

2Na(s) + 2H2O(l)  H2(g) + 2NaOH(aq) 1 pt for states -1 for H instead of H2

2 pts for balancing

(7 pts) Write a balanced equation for the reaction of potassium metal with water to produce hydrogen gas and potassium hydroxide. Include states.

2K(s) + 2H2O(l)  H2(g) + 2KOH(aq) 1 pt for states, 2 for balancing, 4 for each species

### Oxidation Numbers

(17 pts) a) Give the oxidation number of each element in the following chemical reaction:

3HNO3(aq) + Al(s) 🡪 Al3+ + 3NO2(g) + 3OH-

H: +1 N: +5 O: -2 Al: 0 Al: +3 N: +4 O: -2 O: -2 H: +1

For N in HNO3: x + 3(-2) = -1; x – 6 = -1; so x = -1 + 6 = +5 11 pts (2 each for the N’s)

b) Which element got oxidized (give a reason for your answer)? Al: lost electrons going from Al to Al3+. 3 pts

c) Which element got reduced (give a reason for your answer)? N: gained electrons going from NO3- to NO 3 pts

(10 pts) Give the oxidation number of each element in the following chemical reaction:

3H2S(g) + SO2(g) → 3S + 2H2O(l)

H: +1 S: -2 S: +4 O: -2 S: 0

For S in SO2: x + 2(-2) = 0; x – 4 = 0; so x = 4 10 pts

(4 pts) The following reaction destroys ozone in the stratosphere. What are the oxidation numbers of the indicated elements?

***NO***(g) + O3(g)  ***NO*2**(g) + ***O***2(g)

***O***: \_\_\_-2 ***O***: \_\_\_0

***N***: \_\_\_+2 ***N***: \_\_\_+4

(1 pts) Is the N oxidized or reduced in the above reaction? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

oxidized

(6 pts) Give the oxidation number of the following:

a) S in SO42- 6+ x + 4(-2) = -2, so x = +6

b) O in O2 0

c) Fe in Fe2O3 3+

(5 pts) Give the oxidation number of the following:

a) P in PO43- +5 x + 4(-2) = -3; x – 8 = -3; so x = -3 + 8 = +5 3 pts

b) H in H2 0 2 pts

(5 pt) In the following reaction give the oxidation number of Fe in the reactant and product.

2*Fe*(s) + 3H2O(g)  *Fe*2O3(s) + 3H2(g)

+3

0

oxidation numbers: 2 pts each

Does the iron get oxidized or reduced? 1 pt

Fe(s) has oxidation number 0. Fe in Fe2O3 has oxidation number +3. The Fe therefore has been oxidized.

(3 pts) What is the oxidation number of chlorine in ClO4–? +7

For Cl in ClO4–: x + 4(-2) = -1; x – 8 = -1; so x = -1 + 8 = +7

(3 pts) Circle the species that gets oxidized in the following reaction.

Cu(s) + 2H2SO4(aq, conc.)  Cu2+(aq) + SO42-(aq) + SO2(g) + 2H2O(l)

3 pts (-2 pt for Cu2+)

Which species is the reducing agent? \_\_\_\_\_\_\_\_ Cu(s) 1 pt (must be same as part a)

### Balance Simple Redox Equations

a) (3 pts) Balance the following redox reaction.

2Ag+(aq) + Cu(s)  2Ag(s) + Cu+2(aq) -2 pts if just have 2Ag+

b) (1 pts) Is the silver oxidized or reduced? Reduced

(4 pts) a) Balance the following equation.

Fe2+(aq) + Cu(s)  Fe(s) + Cu+(aq)

Fe2+(aq) + 2Cu(s)  Fe(s) + 2Cu+(aq) -2 pts if just have 2Cu+

b) Is the copper oxidized or reduced? Oxidized 1 pt

(3 pts) Balance the following redox reaction.

2 Fe2+(aq) + Sn4+(aq)  2 Fe3+(aq) + Sn2+(aq)

(4 pts) Balance the following reaction (this one’s a bit challenging):

3F2(g) + 3H2O(l)  1O3(g) + 6HF(g)

(4 pts) Balance the following reaction:

2Al(s) + 6HCl(aq)  3H2(g) + 2AlCl3(aq)

(6 pts) For each reaction below, indicate if the reaction will occur, or if no reaction will occur, or if not enough data is provided to determine if a reaction will occur.

Zn2+(aq) + Co(s) → Zn(s) + Co2+(aq) occurs no reaction insufficient data

Zn2+(aq) + Mg(s) → Zn(s) + Mg2+(aq) occurs no reaction insufficient data

Ba2+(aq) + Co2+(aq) → Ba(s) + Co(s) occurs no reaction insufficient data

potassium K+(aq) + e–  → K(s)

ease of reduction increases

barium Ba2+(aq) + 2e–  → Ba(s)

sodium Na+(aq) + e–  → Na(s)

magnesium Mg2+(aq) + 2e–  → Mg(s)

aluminum Al3+(aq) + 3e–  → Al(s)

zinc Zn2+(aq) + 2e–  → Zn(s)

iron Fe2+(aq) + 2e–  → Fe(s)

cobalt Co2+(aq) + 2e–  → Co(s)

tin Sn2+(aq) + 2e–  → Sn(s)

### Combustion Reactions

(7 pts) Give a balanced equation for the combustion of ethane, C2H6, in air.

2C2H6 + 7O2(g)  4CO2(g) + 6H2O(g) 2 pts for balancing, 5 pts for O2, CO2, & H2O

(7 pts) Give the balanced equation for the combustion of butane, C4H10, in air.

2 C4H10 + 13 O2(g)  8 CO2(g) + 10 H2O(g)

(6 pts) Give the balanced equation for the combustion of heptane, C7H16, in air.

C7H16 + 11 O2(g)  7 CO2(g) + 8 H2O(g)

(3 pts) Give the balanced equation for the combustion of C5H12.

C5H12 + 8 O2(g)  5 CO2(g) + 6 H2O(g)

(7 pts) Give the balanced equation for the combustion of C6H14.

2 C6H14 + 19 O2(g)  12 CO2(g) + 14 H2O(g)

(9 pts) Give a balanced chemical equation for the reaction of hydrogen and oxygen to produce water. (Show the states in your equation.)

2H2(g) + O2(g)  2H2O(g) 4 pts ( -2 pts for 2H(g) + O(g)  H2O(g) )

### Apply Solubility Rules

|  |  |
| --- | --- |
| *Solubility rules for inorganic compounds* | |
| **Soluble compounds** | **Insoluble compounds** |
| compounds of group 1 elements  ammonium compounds  chlorides, bromides, and iodides, **except** those of Ag+, Hg22+, and Pb2+  nitrates, acetates, chlorates, and perchlorates  sulfates, **except** those of Ca2+, Sr2+, Ba2+, Pb2+, Hg22+, and Ag+ | carbonates, chromates, oxalates, and phosphates, **except** those of the group 1 elements and NH4+  sulfides, **except** those of the group 1 elements and NH4+  hydroxides and oxides, **except** those of the group 1 and 2 elements |

(6 pts) You are asked to analyze a solution for the cations Hg22+, Ca2+, and Cu2+. You add potassium chloride and a precipitate forms. You filter out the solid and add potassium sulfate to the solution. Nothing appears to happen. Then you add potassium sulfide. A precipitate forms. Which of the three cations ions were present in the original solution? (Hint: use the solubility rules.) Hg22+ and Cu2+

Adding KCl adds chloride to the solution. According to the solubility rules, Hg2Cl2 is insoluble; CaCl2 and CuCl2 are both soluble. Since a precipitate formed, Hg22+ was present.

The precipitate was filtered out, so the mercurous ion has been removed from the solution. Ca2+ and Cu2+ may still be present in the solution. Potassium sulfate was then added to the solution, which adds sulfate to the solution. CaSO4 is insoluble; CuSO4 is soluble. Since no precipitate formed, Ca2+ was not present.

The solution may still contain Cu2+. Potassium sulfide is added to the solution. CuS is insoluble. A precipitate forms, indicating that Cu2+ was present.

(6 pts) You are asked to analyze a solution for the cations Ag+, Ba2+, and Zn2+. You add potassium chloride and a precipitate forms. You filter out the solid and add potassium sulfate to the solution. Nothing appears to happen. Then you add potassium sulfide. A precipitate forms. Which ions were originally present in the solution? (Hint: use the solubility rules.)

Adding KCl adds chloride to the solution. According to the solubility rules, AgCl is insoluble; BaCl2 and ZnCl2 are both soluble. Since a precipitate formed, Ag+ was present.

The precipitate was filtered out, so the silver ion has been removed from the solution. Ba2+ and Zn2+ may still be present in the solution. Potassium sulftae was then added to the solution, which adds sulfate to the solution. BaSO4 is insoluble; ZnSO4 is soluble. Since no precipitate formed, Ba2+ was not present.

The solution may still contain Zn2+. Potassium sulfide is added to the solution. ZnS is insoluble. A precipitate forms, indicating that Zn2+ was present.

(6 pts) You are asked to analyze a solution for the cations Zn2+, Ag+, and Ba2+. You add hydrochloric acid. A precipitate forms. You filter out this solid and add sulfuric acid to the solution. A white precipitate forms. You filter out this solid also, and then add hydrogen sulfide to the solution. Nothing appears to happen. Which cations were present in the original solution?

Adding HCl adds chloride to the solution. According to the solubility rules, AgCl is insoluble; BaCl2 and ZnCl2 are both soluble. Since a precipitate formed, Ag+ was present.

The precipitate was filtered out, so the silver ion has been removed from the solution. Ba2+ and Zn2+ may still be present in the solution. Sulfuric acid was then added to the solution, which adds sulfate to the solution. BaSO4 is insoluble; ZnSO4 is soluble. Since a precipitate formed, Ba2+ was present.

The calcium sulfate precipitate was filtered out, so now both the Ag+ and Ba2+ have been removed. The solution may still contain Zn2+. Hydrogen sulfide is added to the solution. ZnS is insoluble, but no precipitate forms, indicating that Zn2+ was not present.

(3 pts) You are asked to analyze a solution for the cations Ag+, Ca2+, and Hg2+. You add hydrochloric acid. Nothing appears to happen. You then add sulfuric acid to the solution and a white precipitate forms. You filter out the solid and add hydrogen sulfide to the solution. A black precipitate forms. Which ions were present in the original solution?

Ca2+, Hg2+

Adding HCl adds chloride to the solution. According to the solubility rules, AgCl is insoluble; CaCl2 and HgCl2 are both soluble. Since no precipitate formed, Ag+ was absent.

Ca2+ and Hg2+ may still be present in the solution. Sulfuric acid was then added to the solution, which adds sulfate to the solution. CaSO4 is insoluble; HgSO4 is soluble. (The compound Hg2SO4 is insoluble, but Hg22+ isn’t present here.) Since a precipitate formed, Ca2+ was present.

The solution may still contain Hg2+. Hydrogen sulfide is added to the solution. HgS is insoluble. A precipitate forms, indicating that Hg2+ was present.

(5 pts) Circle the correct description of the solubility in water of the following salts.

a) silver(I) chloride soluble insoluble

b) silver(I) sulfide soluble insoluble

c) silver(I) acetate soluble insoluble

d) silver(I) carbonate soluble insoluble

e) silver(I) sulfate soluble insoluble

(5 pts) Circle the correct description of the solubility in water of the following salts.

a) lead(II) sulfide soluble insoluble

b) lead(II) acetate soluble insoluble

c) Hg2Cl2 soluble insoluble

d) lead(II) carbonate soluble insoluble

e) lead(II) sulfate soluble insoluble

(10 pts) Write the balanced equation for the reaction that occurs when aqueous solutions of ammonium chromate and lead(II) nitrate are mixed. (Tip: chromate is CrO42-)

(NH4)2CrO4(aq) + Pb(NO3)2(aq)  2NH4NO3(aq) + PbCrO4(s)

### Examples of Strong Acids & Bases

(6 pts) a) Give an example of a strong acid. HNO3, HCl, H2SO4, H3PO4 are common examples

b) Give an example of a weak base. NH3 -1 pt for NH4+

c) Give the formula of the hydronium ion. H3O+

(6 pts) a) Give an example of a weak acid. HF, HCN, or CH3CO2H

b) Give an example of a weak base. NH3 -1 pt for NH4+

c) Give the formula of the hydronium ion. H3O+

(4 pts) Complete the following reaction, which shows how ammonia acts as a base, even though it doesn’t contain hydroxide.

NH3(aq) + H2O(l) → NH4+(aq) + OH-(aq)

### Complete the Reaction; Net Ionic Equations

(25 pts) Complete and balance the following chemical equations, then write the net ionic equation for each. (You may find it helpful to first write the ionic equation.) Include the state (aq, s, l, or g) and charges in the net ionic equation.

Pb(NO3)2(aq) + K2SO4(aq)  PbSO4(s) + 2KNO3(aq)

Pb SO4 (s) 3 K NO3 (aq) 7 pts

net ionic equation:

Pb2+(aq) + SO42–(aq)  PbSO4(s)

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions,

1 pts for balancing correctly. 6 pts

\_\_\_\_\_\_\_\_\_\_\_\_

H2SO4(aq) + 2KOH(aq)  K2SO4(aq) + 2H2O(l) -2 pts for KSO4 + H3O+

2 K 2 SO4 (aq) 2 H2O 7 pts

net ionic equation:

2H+(aq)+ SO4–(aq) + 2K+(aq) + 2OH–(aq)  2K+(aq) + SO42-(aq) + 2H2O(l)

2H+(aq) + 2OH–(aq)  2H2O(l)

or

H+(aq) + OH–(aq)  H2O(l) 5 pts

(41 pts) Complete and balance the following chemical equations, then write the net ionic equation for each. Include the state (aq, s, l, or g).

Fe2(SO4)3(aq) + 3BaOH(aq)  2Fe(OH)3(s) + 3BaSO4(s)

3 2 Fe OH 3 (s) 3 Ba SO4 (s) 10 pts

net ionic equation:

2Fe3+(aq) + 3SO42–(aq) + 3Ba2+(aq) + 3OH–(aq)  2Fe(OH)3(s) + 3BaSO4(s)

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions,

2 pts for balancing correctly. 7 pts

\_\_\_\_\_\_\_\_\_\_\_\_

AgNO3(aq) + KBr(aq)  AgCl(s) + KNO3(aq)

Ag Cl (s) K NO3 (aq) 1 pt for balancing 7 pts

net ionic equation:

Ag+(aq) + NO3–(aq) + K+(aq) + Br–(aq)  AgCl(s) + K+(aq) + NO3–(aq)

Ag+(aq) + Br–(aq)  AgCl(s)

1 pt for (aq)’s, 2 pt for separating ions, 2 pts for showing charges 5 pts

\_\_\_\_\_\_\_\_\_\_\_\_

H3PO4(aq) + 3NaOH(aq)  Na3PO4(aq) + 3H2O(l)

3 Na 3 PO4 (aq) 3 H2O 7 pts

net ionic equation:

3H+(aq)+ PO4–(aq) + 3Na+(aq) + 3OH–(aq)  3Na+(aq) + PO43-(aq) + 3H2O(l)

3H+(aq) + 3OH–(aq)  3H2O(l)

or

H+(aq) + OH–(aq)  H2O(l) 5 pts

Complete and balance the following chemical equations, then write the net ionic equation for each. Include the state (aq, s, l, or g).

FeCl3(aq) + 3NaOH(aq)  Fe(OH)3(s) + 3NaCl(aq) 7 pts.

net ionic equation: Fe3+(aq) + 3OH-(aq)  Fe(OH)3(s) 7 pts.

Pb(NO3)2(aq) + K2SO4(aq)  PbSO4(s) + 2KNO3(aq) 7 pts.

net ionic equation: Pb2+(aq) + SO42-(aq)  PbSO4(s) 2 pts.

H2SO4(aq) + 2KOH(aq)  K2SO4(aq) + 2H2O(l) 4 pts.

net ionic equation: 2H+(aq) + 2OH-(aq)  2H2O(l)

or H+(aq) + OH-(aq)  H2O(l) 3 pts.

(25 pts) Complete and balance the following chemical equations, then write the net ionic equation for each. Include the state (aq, s, or g).

Na2SO4(aq) + Pb(NO3)2(aq)  PbSO4(s) + 2NaNO3(aq) 7 pts

net ionic equation: Pb2+(aq) + SO42-(aq)  PbSO4(s) 6 pts

(1 for separating ions, 1 for aq, 2 for charges, 1 for balancing, 1 for product)

2 NaOH(aq) + H2SO4(aq)  Na2SO4(aq) + 2H2O(l) 7 pts

net ionic equation: 2H+(aq) + 2OH-(aq)  2H2O(l)

or H+(aq) + OH-(aq)  H2O(l) 5 pts

(26 pts) Complete and balance the following chemical equations, then write the net ionic equation for each. Include the state (aq, s, l, or g).

2K3PO4(aq) + 3Ca(OH)2(aq)  Ca3(PO4)2(s) + 6KOH(aq) 10 pts

2 3 Ca 3 PO4 2 (s) 6 KOH (aq)

net ionic equation:

3Ca2+(aq) + 2PO43–(aq)  Ca3(PO4)2(s) 7 pts

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions,

2 pts for balancing correctly.

\_\_\_\_\_\_\_\_\_\_\_\_

HCl(aq) + NaOH(aq)  NaCl(aq) + H2O(l) 4 pts

net ionic equation:

H+(aq) + OH–(aq)  H2O(l) 5 pts

(14 pts) Complete and balance the following chemical equation, then write a net ionic equation for it. (You may find it helpful to first write the ionic equation.) Include the state (aq, s, l, or g) and charges in the net ionic equation.

Pb(NO3)2(aq) + 2 KI(aq)  PbI2(s) + 2KNO3(aq)

2 Pb I 2 (s) 2 K NO3 8 pts

net ionic equation:

Pb2+(aq) + 2I–(aq)  PbI2(s)

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions,

1 pt for balancing correctly. 6 pts

(25 pts) Complete and balance the following chemical equations, then write the net ionic equation for each. (You may find it helpful to first write the complete ionic equation.) Include the states (aq, s, l, or g) and charges in the net ionic equation.

K2SO4(aq) + Ba(NO3)2(aq)  BaSO4(s) + 2KNO3(aq)

Ba SO4 (s) 2 K NO3 6 pts

net ionic equation:

Ba2+(aq) + SO42–(aq)  BaSO4(s)

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions,

1 pt for balancing correctly, 1 pt for (s). 7 pts

\_\_\_\_\_\_\_\_\_\_\_\_

K2CO3(aq) + H2SO4(aq)  K2SO4(aq) + CO2(g) + H2O(l)

K 2 SO4 CO2 H2O 5 pts

net ionic equation:

2K+(aq)+ CO32-(aq) + 2H+(aq) + 2SO42-(aq)  2K+(aq) + 2SO42-(aq) + CO2(g) + H2O(l)

CO32-(aq) + 2H+(aq)  CO2(g) + H2O(l) 7 pts

(12 pts) Complete and balance the following chemical reactions. Include the states (aq, s, l, or g) in your reactions.

Na2CO3(aq) + 2HCl(aq)  2NaCl(aq) + CO2(g) + H2O(l)

2 Na Cl CO2 H2O 5 pts

net ionic equation:

2Na+(aq)+ CO32-(aq) + 2H+(aq) + 2Cl-(aq)  2Na+(aq) + 2Cl-(aq) + CO2(g) + H2O(l)

CO32-(aq) + 2H+(aq)  CO2(g) + H2O(l) 7 pts

(16 pts) Complete and balance the following chemical reactions. Include the states (aq, s, l, or g) in your reactions.

2Na3PO4(aq) + 3FeCl2(aq)  6NaCl(aq) + Fe3(PO4)2(s)

2 3 6 Na Cl (aq) Fe 3 (PO4 )2 10 pts

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

K2CO3(aq) + H2SO4(aq)  K2SO4(aq) + CO2(g) + H2O(l) (or H2CO3(aq) )

K 2 SO4 CO2 (g) H2O 6 pts

(6 pts) Write the net ionic equation for the following reaction. (You may find it helpful to first write the ionic equation.) Include the state (aq, s, l, or g) and charges in the net ionic equation.

Pb(NO3)2(aq) + 2 KI(aq)  PbI2(s) + 2KNO3(aq)

Pb2+(aq) + 2I–(aq)  PbI2(s)

1 pt for the (aq)’s; 2 pts for showing charges, 2 pts for separating ions, 6 pts

(12 pts) Complete and balance the following chemical reaction, then write the net ionic equation. Include the states (aq, s, l, or g) and charges of ions.

2 NaOH(aq) + H2SO4(aq)  Na2SO4(aq) + 2H2O(l) 7 pts

net ionic equation: 2H+(aq) + 2OH-(aq)  2H2O(l)

or H+(aq) + OH-(aq)  H2O(l) 5 pts

### Molarity

(6 pts) An aqueous solution was prepared by dissolving 2.11 g of NaCl in enough water to make 1500. mL of solution. What is the **molarity** of NaCl in the solution?

(molar mass of NaCl: 58.44 g/mol)

1 1 1 1 1, + 1 for sig. figs



(6 pts) An aqueous solution was prepared by dissolving 4.93 g of KBr in enough water to make 750**.** mL of solution. What is the **molarity** of KBr in the solution?

(molar mass of KBr: 119.00 g/mol)



1 1 1 1 1, + 1 for sig. figs

(6 pts) An aqueous solution was prepared by dissolving 4.93 g of KI in enough water to make 500.0 mL of solution. What is the **molarity** of KI in the solution?

(molar mass of KI: 166.00 g/mol)



1 1 1 1 1, + 1 for sig. figs

(6 pts) An aqueous solution was prepared by dissolving 1.567 g of AgNO3 in enough water to make 250.0 mL of solution. What is the **molarity** of silver nitrate in the solution?

(molar mass of AgNO3: 169.87 g/mol)

### Dilution

(5 pts) Suppose you need to prepare 1000. mL of 0.100 m HCl(aq), and all you have on hand is 0.500 m HCl(aq). What volume of the 0.500 m solution should be diluted to 1000. mL to give the desired 0.100 m HCl(aq) solution?



(5 pts) Suppose you need to prepare 1.00 L of 0.100 m HCl(aq), and all you have on hand is 0.250 m HCl(aq). What volume of the 0.250 m solution should be diluted to 1.00 L to give the desired 0.100 m HCl(aq) solution?



(5 pts) What **volume** of a 0.0155 *M* HCl(aq) solution should be used to prepare 100. mL of a 5.23 × 10-4 *M* HCl(aq) solution?



(5 pts) What **volume** of a 0.204 *M* HCl(aq) solution should be used to prepare 100. mL of a 0.0204 *M* HCl(aq) solution?



-2 for 1000 mL

(5 pts) What volume of a 0.778 m Na2CO3(aq) solution should be diluted to 150.0 mL with water to reduce its concentration to 0.0234 m Na2CO3(aq)?



### Titration

(12 pts) One method used commercially to peel potatoes is to soak them in a solution of NaOH for a short time, remove them from the NaOH, and spray off the peel. The concentration of NaOH is normally in the range 3 to 6 m. The NaOH is analyzed periodically. In one such analysis, 45.7 mL of 0.500 m H2SO4 is required to react completely with a 20.0 mL sample of the NaOH solution. What is the molar concentration of the NaOH solution?

First, figure out what is given.

|  |  |  |  |
| --- | --- | --- | --- |
| 2NaOH(aq) | + | H2SO4 |  Na2SO4(aq) + 2H2O(l) |
| ? m |  | 0.500 m |  |
| 20.00 mL |  | 45.7 mL |  |
| 0.02000 L |  | 0.0457 L |  |

m 🡪 moles 🡪 moles 🡪 m

4 pts Molarity to moles:



3 pts Convert from moles KOH to moles phosphoric acid:

2KOH ≏ 1H2SO4



5 pts Moles to molarity:



-2 for 0.438 m (switched volumes)

-3 for 1.14 m (didn’t do mol-to-mol conversion)

-2 for 0.571 m (multiplied by 2 instead of divided by 2 in mol-to-mol conversion)

(12 pts) Many abandoned mines have exposed nearby communities to the problem of acid mine drainage. Certain minerals, such as pyrite (FeS2), decompose when exposed to air, forming solutions of sulfuric acid. The acidic mine water then drains into lakes and creeks, killing fish and other animals. Anyway, at a mine in Colorado, a sample of mine water of volume 25.00 mL was neutralized with 16.34 mL of 0.255 *M* KOH(aq). What is the molar concentration of H2SO4 in the water?

First, figure out what is given.

|  |  |  |  |
| --- | --- | --- | --- |
| 2KOH(aq) | + | H2SO4 |  K2SO4(aq) + 2H2O(l) |
| 0.255 *M* |  | ? *M* |  |
| 16.34 mL |  | 25.00 mL |  |
| 0.01634 L |  | 0.02500 L |  |

*M* 🡪 moles 🡪 moles 🡪 *M*

4 pts Molarity to moles:



3 pts Convert from moles KOH to moles phosphoric acid:

2KOH ≏ 1H2SO4



5 pts Moles to molarity:



-2 for 0.195 *M* (switched volumes)

-3 for 0.167 *M* (didn’t do mol to mol conversion)

(8 pts) 25.00 mL of a solution of oxalic acid, H2C2O4, are titrated with 0.2586 m NaOH(aq). The stoichiometric end point is reached when 43.42 mL of the solution of base is added. What is the molarity of the oxalic acid solution? Oxalic acid reacts with sodium hydroxide as shown below:

H2C2O4(aq) + 2 NaOH(aq)  Na2C2O4(aq) + 2 H2O(l)

First, figure out what is given.

|  |  |  |  |
| --- | --- | --- | --- |
| H2C2O4(aq) | + | 2 NaOH(aq) |  Na2C2O4(aq) + 2 H2O(l) |
| ? *M* |  | 0.2586 *M* |  |
| 25.00 mL |  | 43.42 mL |  |
| 0.02500 L |  | 0.04342 L |  |

**Molarity to moles:** 3 pts

**Convert from moles NaOH to moles oxalic acid:**

2NaOH ≏ 1H2C2O4

 2 pts

**Moles to molarity:**  3 pts

-3 for 0.298 *M* (switched volumes, and switched 2:1 conversion)

-1 for 0.896 *M* (switched 2:1 conversion)

(12 pts) 38.5 mL of a 0.120 m KOH(aq) solution were needed to reach the stoichiometric point in a titration of 10.0 mL of a phosphoric acid solution, according to the reaction below. What is the molarity of the phosphoric acid solution?

First, figure out what is given.

|  |  |  |  |
| --- | --- | --- | --- |
| 3KOH(aq) | + | H3PO4(aq) |  K3PO4(aq) + 3H2O(l) |
| 0.120 m |  | ? m |  |
| 38.5 mL |  | 10.0 mL |  |
| 0.0385 L |  | 0.0100 L |  |

molarity 🡪 moles 🡪 moles 🡪 molarity

4 pts Molarity to moles:



3 pts Convert from moles KOH to moles H3PO4:

3KOH ≏ 1H3PO4



5 pts Moles to molarity:



-2 for 0.0104 m (switched volumes)

-3 for 0.462 m (didn’t do mol to mol conversion)

-5 for 0.0312 m (didn’t do both of above)

### Limiting Reactant, Theoretical Yield, % Yield

(20 pts) One of the steps in the commercial process for converting ammonia to nitric acid involves the conversion of NH3 to NO:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 4NH3(g) | + | 5O2(g) |  | 4NO(g) | + | 6H2O(s) |
| molar masses, in g/mol: | 17.03 |  | 32.00 |  |  |  |  |

a) (9 pts) If 1.00 g of NH3 and 1.50 g of O2 are mixed, which is the **limiting reactant**? (1 pt for right answer, 9 pts for showing the calculation)

There are several ways to do this. One is to calculate how much NO could be produced from each of the reactants.

4 pts for each mol calculation

(or 0.0881 mol H2O and 0.0563 mol H2O)

The 1.50 g of O2 forms the least amount of NO, so O2 is the limiting reactant. 1 pt

b) (4 pts) What is the **theoretical yield** (in grams) of NO that can be produced when the quantities in part a are mixed?

The theoretical yield is determined by the limiting reactant, which is O2. The mass of NO that can be formed from the O2 is:

 3 pts, + 1 for sig. figs.

c) (7 pts) If 1.05 g of NO are actually obtained from the reaction, what is the **percent yield**?



(20 pts) Manganese metal can be prepared by the thermite process:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 4Al(s) | + | 3MnO2(s) |  | 3Mn(l) | + | 2Al2O3(s) |
| molar masses, in g/mol: | 26.98 |  | 86.94 |  |  |  |  |

1. (9 pts) If 203 g of Al and 472 g of MnO2 are mixed, which is the **limiting reactant**? (1 pt for right answer, 9 pts for showing the calculation)

There are several ways to do this. One is to calculate how much Mn could be produced from each of the reactants.

4 pts for each mol calculation

(or 3.76 mol Al2O3 and 3.62 mol Al2O3)

The 472 g of MnO2 forms the least amount of Mn, so

MnO2 is the limiting reactant. 1 pt

1. (4 pts) What is the **theoretical yield** (in grams) of Mn that can be produced when the quantities in (a) are mixed?

The theoretical yield is determined by the limiting reactant, which is MnO2. The mass of Mn that can be formed from the MnO2 is:

 3 pts, + 1 for sig. figs.

c) (7 pts) If 254 g of Mn are actually obtained from the reaction, what is the **percent yield**?



(20 pts) A fuel mixture used in the early days of rocketry is composed of two liquids, hydrazine (N2H4) and dinitrogen tetraoxide (N2O4), which ignite on contact to form nitrogen gas and water vapor.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2N2H4(l) | + | N2O4(l) |  | 3N2(g) | + | 4H2O(g) |
| molar masses, in g/mol: | 32.05 |  | 92.01 |  |  |  |  |

a) (9 pts) If 1.50 × 102 g of N2H4 and 2.00 × 102 g of N2O4 are mixed, which is the **limiting reactant**? (1 pt for right answer, 8 pts for showing the calculation)

There are several ways to do this. One is to calculate how much N2 could be produced from each of the reactants.

4 pts for each mol calculation

(or 14.0 mol H2O and 13.0 mol H2O)

The 150. g of N2O4 forms the least amount of N2, so N2O4 is the limiting reactant. 1 pt

b) (4 pts) What is the **theoretical yield** (in grams) of N2 that can be produced when the quantities in part a) are mixed?

The theoretical yield is determined by the limiting reactant, which is N2O4. The mass of N2 that can be formed from the N2O4 is:

 3 pts, + 1 for sig. figs.

c) (7 pts) If 155 g of N­2 are actually obtained from the reaction, what is the **percent yield**?



(18 pts) Lithium metal is the only member of Group 1 that reacts directly with nitrogen to produce a nitride, Li3N:

6Li(s) + N2(g)  2Li3N(s)

(molar masses, in g/mol: Li 6.941, N2 28.01, Li3N 34.83)

a) If 124.0 g of Li and 98.2 g of N2 are mixed, which is the **limiting reactant**? (1 pt for right answer, 8 pts for showing the calculation) 9 pts.

There are several ways to do this. One is to calculate how much Li3N could be produced from each of the reactants.



The 124.0 g of Li forms the least amount of Li3N, so Li is the limiting reactant.

b) What is the **theoretical yield** (in grams) of Li3N that can be produced when the quantities in (a) are mixed? 4 pts.

The theoretical yield is determined by the limiting reactant, which is Li. The mass of Li3N that can be formed from the Li is:



c) If 195 g of Li3N are actually obtained from the reaction, what is the **percent yield**?



5 pts.

(9 pts) Which is the limiting reactant when 100. g of CaC2 reacts with 100. g of H2O according to the following reaction?

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | CaC2(s) | + | 2H2O(l) |  | Ca(OH)2(aq) | + | C2H2(g) |
| molar masses, in g/mol: | 64.10 |  | 18.02 |  |  |  |  |

There are several ways to do this. One is to calculate how much C2H2 could be produced from each of the reactants.

4 pts for each mol calculation

(or 1.56 and 2.78 mol Ca(OH)2)

The 100. g of CaC2 forms the least amount of C2H2, so

CaC2 is the limiting reactant. 1 pt

Aluminum chloride, an important reagent used in many industrial chemical processes, is made by treating scrap aluminum with chlorine according to the following equation.

2Al(s) + 3Cl2(g)  2AlCl3(s)

(molar masses, in g/mol: Al 26.98, Cl2 70.91, AlCl3 133.34)

a) If 98.0 g of Al and 345 g of Cl2 are mixed, which is the **limiting reactant**? (1 pt for right answer, 8 pts for showing the calculation)

There are several ways to do this. One is to calculate how much AlCl3 could be produced from each of the reactants.



The 345 g of Cl2 forms the least amount of AlCl3, so Cl2 is the limiting reactant. 9 pts.

b) What is the **theoretical yield** (in grams) of AlCl3 that can be produced when the quantities in (a) are mixed?

The theoretical yield is determined by the limiting reactant, which is Cl2. The mass of AlCl3 that can be formed from the Cl2 is:

 4 pts.

c) If 412 g of AlCl3 are actually obtained from the reaction, what is the **percent yield**?

 7 pts.

### Energy 🡨🡪 Wavelength 🡨🡪 Frequency

(8 pts) Human vision cuts off on the red side of the spectrum at about 675 nm. What is the energy of a photon of this wavelength?

*E* = h and c = , so

 1 pt., sig. figs.

(6 pts) One of the visible lines in the spectrum of hydrogen occurs at 486 nm. What is the energy of a photon of this wavelength?

*E* = h and c = , so

 1 pt., sig. figs.

(8 pts) The solar spectrum contains light having a wavelength of 517 nm; this light results from emission from magnesium atoms. What is the energy of a photon of this wavelength?

*E* = h and c = , so

 1 pt., sig. figs.

(5 pts) One of the visible lines in the spectrum of hydrogen has an energy of 3.03 × 10-19 J. What is the frequency in Hz of a photon of this energy?

*E* = h, so

 1 pt., sig. figs.

(6 pts) Sodium vapor lamps, used for public lighting, emit at 589 nm. What is the energy of a photon of this energy?

*E* = h and c = , so



(6 pts) Mercury vapor lamps, used for public lighting, emit at 254 nm. What is the energy of a photon of this energy?

*E* = h and c = , so



### Quantum Numbers

(2 pt) Which one of the following is an allowable set of quantum numbers for an electron?

a) n = 3, l = 2, ml = -1, ms = -1/2

b) n = 2, l = -2, ml = 1, ms = +1/2 l too small

c) n = 2, l = 3, ml = -2, ms = +1/2 l too large

d) n = 3, l = 2, ml = -1, ms = 0 ms can’t be 0

e) n = 3, l = 3, ml = 3, ms = +1/2 l too large

f) n = 4, l = 2, ml = -3, ms = -1/2 ml too small

(2 pt) Which one of the following is an allowable set of quantum numbers for an electron?

a) n = 1, l = 1, ml = 1, ms = +1/2 l too large

b) n = 2, l = 3, ml = -2, ms = +1/2 l too large

c) n = 3, l = 2, ml = -1, ms = 0 ms can’t be 0

d) n = 4, l = 4, ml = 3, ms = +1/2 l too large

e) n = 2, l = 1, ml = -1, ms = -1/2

f) n = 4, l = 2, ml = 3, ms = -1/2 ml too large

(1 pt) Which one of the following is an allowable set of quantum numbers for an electron?

a) n = 1, l = 1, ml = 1, ms = +1/2 l too large

b) n = 2, l = 1, ml = -1, ms = -1/2

c) n = 2, l = 3, ml = -2, ms = +1/2 l too large

d) n = 3, l = 2, ml = -1, ms = 0 ms can’t be 0

e) n = 4, l = 4, ml = 3, ms = +1/2 l too large

f) n = 4, l = 2, ml = 3, ms = -1/2 ml too large

(2 pt) Give a possible set of four quantum numbers {*n, l, ml*, *ms*} for the starred electron in the following diagram. Select the values of *ml* by numbering from –*l* to +*l* from left to right.

2*p* ↑↓ ↑↓\* ↑

*n* = \_\_\_, *l* = \_\_\_, *ml* = \_\_\_, *ms* = \_\_\_

*n* = 2, *l* = 2, *ml* = 0, *ms* = +½ or –½

### Orbitals

(4 pts) Draw an s and a p orbital. 2 pts for each one.

s orbital p orbital (could be drawn in any orientation)

(2 pts) In an outline drawing (a “balloon” picture) of an orbital, the boundary surface

a) encloses a volume of space in which where is a high probability of finding an electron.

b) encloses the region where electron density is zero.

c) describes the path in which an electron travels as it revolves around the nucleus.

d) encloses a volume of space which an electron never leaves.

e) is the distance from the nucleus where the electron is most likely to be found.

### Electron Configurations of Elements

(8 pts) Astatine, having atomic number 85 on the periodic table, is a radioactive member of the halogens. Give the full electron configuration of At. Arrange the orbitals in order of increasing energy. (Do not use noble gas abbreviations, such as [Xe], for this problem.)

1s22s22p63s23p64s23d104p65s24d105p66s24f145d106p5

(8 pts) Give the full electron configuration of bismuth (element 83). Arrange the orbitals in order of increasing energy. (Do not use noble gas abbreviations, such as [Xe], for this problem.)

1s22s22p63s23p64s23d104p65s24d105p66s24f145d106p3

(8 pts) Radon, having atomic number 86 on the periodic table, is a radioactive noble gas. Give the full electron configuration of Rn. Arrange the orbitals in order of increasing energy. (Do not use noble gas abbreviations, such as [Xe], for this problem.)

1s22s22p63s23p64s23d104p65s24d105p66s24f145d106p6

(5 pts) Give the full electron configuration of lead. Arrange the orbitals in order of increasing energy. (Do not use noble gas abbreviations, such as [Xe], for this problem.)

1s22s22p63s23p64s23d104p65s24d105p66s24f145d106p2

### Electron Configurations of Ions

(6 pts) Give the electron configurations of the following ions. (No boxes; noble gas abbreviations are ok.) –2 pts. for wrong # of electrons; -1 for wrong configuration.

V2+ [Ar]3d3

Ge2+ [Ar]4s23d10

F– 1s22s23p6 (or [Ne])

(6 pts) Give the electron configurations of the following ions. (No boxes; noble gas abbreviations are ok.) –2 pts. for wrong # of electrons; -1 for wrong configuration.

Co2+ [Ar]3d7 -2 for [Ar]4s23d5

Ga+ [Ar]4s23d10

S2- [Ne]3s23p6 (or [Ar])

(3 pts) Give the electron configurations of the following ion. (No boxes; noble gas abbreviations are ok.) –2 pts. for wrong # of electrons; -1 for wrong configuration.

Ti2+ [Ar]3d2 (some thought this was Tl2+; gave credit for [Xe]6s14f145d10.)

(3 pts) Give the electron configurations of the following ion. (No boxes; noble gas abbreviations are ok.) –3 pts. for wrong # of electrons; -2 for wrong configuration.

Ni2+ [Ar]3d8

(6 pts) Give the electron configuration of the following:

(without using noble gas abbreviations) Ni: 1s22s22p63s23p64s23d8 4 pts

(**using** noble gas abbreviations) Ni2+: [Ar]3d8 2 pts

(6 pts) Give the electron configurations of the following ions. (No boxes; noble gas abbreviations are ok.)

Fe2+ [Ar]3d6

In+ [Kr]5s24d10

Cl- [Ne]3s23p6 (or [Ar])

(6 pts) Give the electron configurations of the following ions. (noble gas abbreviations are ok.)

Cu2+ [Ar]3d9

Sn2+ [Kr]5s24d10

Br– [Ar]4s23d34p6 (or just [Kr])

### Hund’s Rule

(4 pts) Place electrons in the boxes below to show the lowest energy electron configuration of an oxygen atom. (Use all electrons, not just valence electrons.) 1 for 8 e-, 1 for 4 e- in 2p orbitals, 2 for 2 unpaired e-.



(4 pts) Place electrons in the boxes below to show the lowest energy electron configuration of a carbon atom. (Use all electrons, not just valence electrons.) 1 for 6 e-, 1 for 2 e- in 2p orbitals, 2 for 2 unpaired e-.



(4 pts) Place electrons in the boxes below to show the lowest energy electron configuration of a silicon atom. (Use all electrons, not just valence electrons.) 1 for 14 e-, 1 for 2 e- in 2p orbitals, 2 for 2 unpaired e-.

2s

2p

1s

3s

3p

2p

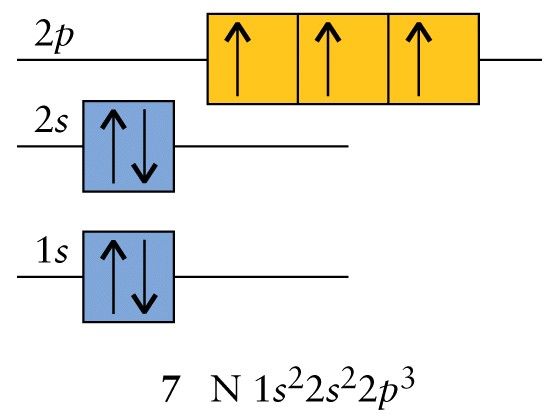
3p

2s

1s

2s

(4 pts) Place electrons in the boxes below to show the lowest energy electron configuration of a nitrogen atom. (Use all electrons, not just valence electrons.) 1 for 7 e-, 1 for 3 e- in 2p orbitals, 2 for 3 unpaired e-.

### Periodic Trends

(3 pts) One property of atoms is their ionization energies, which vary according to position in the periodic table. The trend in ionization energy is exactly opposite the trend in what other property? \_size\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. (Bad question)

(3 pts) Arrange in order of increasing atomic radii:

As, F, N smallest \_F\_ \_N\_ \_As\_ largest

(3 pts) Arrange in order of increasing atomic radii:

C, F, Si smallest F \_C\_ \_Si\_ largest

(3 pt) Arrange in order of increasing electron affinity:

C, F, Si smallest \_Si\_ \_C\_ F largest

(4 pts) Arrange in order of increasing atomic radii: (Bad question)

C, Si, F, Al smallest \_F\_ \_C\_ \_Si\_ \_Al\_ largest

(3 pt) Arrange in order of increasing ionization energy:

As, F, N smallest As\_ \_ N\_ \_ F\_ largest

(3 pt) Arrange in order of increasing ionization energy:

F, O, P smallest \_P\_ \_O\_ \_F\_ largest

(2 pt) Arrange in order of increasing ionization energy: (Bad question)

C, Si, F, Al smallest \_ Al \_ \_ Si\_ \_C\_ \_ F\_ largest

(3 pts) Arrange in order of increasing electronegativity: (Bad question)

S, Si, Ge, Ga smallest \_Ga\_ \_Ge\_ \_Si\_ \_S\_ largest -2 if backwards

(3 pt) Arrange in order of increasing electronegativity:

N, F, P smallest \_\_\_ \_\_\_ \_\_\_ largest P, N, F

(6 pts) Arrange in order of increasing electronegativity: (Bad question)

a) N, F, O smallest \_N\_ \_O\_ \_F\_ largest

b) Li, Cs, K smallest \_Cs\_ \_K\_ \_Li\_ largest

(3 pt) Arrange in order of increasing electronegativity:

Sb, Cl, P smallest \_Sb\_ \_P\_ \_Cl\_ largest

(5 pts) Circle the best of the three choices:

a) highest first ionization energy: O S F

b) lowest second ionization energy: Ar K Ca

c) largest radius: S2- Cl- Cl

d) smallest atomic radius: Sb I Bi

e) impossible subshell designation: 4g 5d 4p

(1 pt) Which one of the following elements has the highest first ionization energy?

a) lithium b) sodium c) boron d) aluminum e) nitrogen f) phosphorus

(2 pt) In which of the lists below are the atoms arranged in order of increasing size (increasing atomic radius)? (not a good problem)

a) Si In Ge N b) N In Ge Si c) In Si Ge N

d) In Ge N Si e) N Si Ge In f) N Ge Si In

### Valence Electrons

(2 pts) How many valence electrons does a phosphorus atom have? 5

### Ionic or Covalent from Electronegativity

(8 pts) Determine whether the bonds in the following compounds are ionic or covalent. Show your reasoning. Electronegativities: Mg, 1.3; I, 2.7; Na, 0.9; Br, 3.0. 4 pts for difference, 2 for giving 1.5 and 2.0, and 2 pts for ionic & covalent.

|  |  |  |
| --- | --- | --- |
|  | NaBr | MgI |
| Electronegativity difference: | 3.0 – 0.9 = 2.1 | 2.7 – 1.3 = 1.4 |
|  | > 2.0, so mainly ionic | < 1.5, so mainly covalent |

(8 pts) Use electronegativities to determine whether the bonds in the following compounds are ionic or covalent. Show your reasoning. Electronegativities: Ca, 1.3; O, 3.4; C, 2.6. 4 pts for difference, 2 for giving 1.5 and 2.0, and 2 pts for ionic & covalent.

|  |  |  |
| --- | --- | --- |
|  | CO2 | CaO |
| Electronegativity difference: | 3.4 – 2.6 = 0.8 | 3.4 – 1.3 = 2.1 |
|  | < 1.5, so mainly covalent | > 2.0, so mainly ionic |

(8 pts) Determine whether the bonds in the following compounds are ionic or covalent. Show your reasoning. Electronegativities: Mg, 1.3; S, 2.6; O, 3.4; F, 4.0. 4 pts for difference, 2 for giving 1.5 and 1.0, and 2 pts for ionic & covalent.

|  |  |  |
| --- | --- | --- |
|  | MgO | SO2 |
| Electronegativity difference: | 1.3 - 3.4 = 2.1 | 2.6 – 3.4 = 0.8 |
|  | > 2.0, so ionic | < 1.5, so covalent |

(8 pts) Determine whether the bonds in the following compounds are ionic or covalent. **Show your reasoning.** Electronegativities: N, 3.0; Mg, 1.3; I, 2.7; O, 3.4. 4 pts for difference, 2 for giving 0.3 and 2.1, and 2 pts for ionic & covalent.

|  |  |  |
| --- | --- | --- |
|  | NI3 | MgO |
| Electronegativity difference: | 3.0 – 2.7 = 0.3 | 3.4 – 1.3 = 2.1 |
|  | < 1.5, so mainly covalent | > 2, so mainly ionic |

### Formal Charges

(8 pts) In the atmosphere, many chlorine atoms end up in ClO. Two possible Lewis structures for ClO are shown. Calculate the formal charges on each of the four atoms.





(1 pt) Circle the most favorable structure for ClO. Must be the structure with the lowest formal charges.

(5 pts) Two possible structures for BF3 are shown. Calculate the formal charges on each of the eight atoms.





(1 pt) Circle the most favorable structure for BF3. Must be the structure with the lowest formal charges.

(6 pts) Three possible structures of the cyanate anion are shown. Calculate the formal charges on each of the nine atoms.

N=C=O C=N=O N=O=C



(1 pt) Circle the most favorable structure for cyanate.

(7 pts) Here is the Lewis structure for NO3-. Calculate the formal charges on each of the four atoms.



(8 pts) Two possible Lewis structures for ClO2– are shown. Calculate the formal charges on each of the six atoms.

-1

+1

-1

0

-1

0

O

Cl

O

**-**

O

Cl

O

**-**

(1 pt) Circle the most favorable structure for ClO2–. Must be the structure with the lowest formal charges.

(2 pts) If the shape of the ClO2– molecule shown above were drawn correctly, the O—Cl—O angle would best be described as …

|  |  |  |
| --- | --- | --- |
| a. Greater than 90°  b. Equal to 90°  c. Less than 90°  d. Greater than 109½°  e. Equal to 109½°  f. Less than 109½° | g. Greater than 120°  h. Equal to 120°  i. Less than 120°  j. Greater than 180°  k. Equal to 180°  l. Less than 180° | m. Cannot be predicted |

### Resonance Structures

(5 pts) Draw the three resonance structures of nitrate ion, NO3-.

1 pt for 1st, 2 pts. for others.

(5 pts) Draw the three resonance structures of carbonate ion, CO32-. (Remember the double-headed arrow.)

(6 pts) Draw the Lewis structures that contribute to the resonance hybrid of NO2– (N is the central atom).

 18 e-, since NO2- has a charge

3 pt for 1st, 3 pts. for other.

(4 pts) Draw the resonance structures of SO2.

18 e‑. 1 pt for 1st, 3 pts. for other.

### Deviations from Idea Geometry (and some mixed questions)

(1 pt) In the SO2 molecule shown above, the O—S—O angle would be…

|  |  |
| --- | --- |
| a. Greater than 120°  b. Equal to 120°  c. Less than 120°  d. Cannot be predicted |  |

(1 pt) In an actual SO2 molecule, the indicated angle would be…

|  |  |
| --- | --- |
| a. Greater than 120°  b. Equal to 120°  c. Less than 120°  d. Cannot be predicted |  |

(3 pts) Calculate the formal charge on S in the above molecule.

f.c. = 6 – 2 – ½(6) = +1

(2 pts) The hybridization of that sulfur atom is \_\_\_\_ sp2\_\_\_\_\_.

(1 pt) In an actual SF4 molecule, the indicated angle would be…

|  |  |
| --- | --- |
| a. Greater than 90°  b. Equal to 90°  c. Less than 90°  d. Cannot be predicted |  |

(1 pt) In an actual NH3 molecule, the indicated angle would be…

|  |  |
| --- | --- |
| a. Greater than 109.5°  b. Equal to 109.5°  c. Less than 109.5°  d. Cannot be predicted |  |

(9 pts) Draw the **resonance** Lewis structures for NO2-. For one of the structures, include **formal charges** on all atoms and the bond **angle,** using < and > to indicate any distortion from an idealized geometry.

1 for resonance structures, 3 for Lewis structure, 3 for formal charges, 2 for angle with distortion.

(2 pt) In an actual SO2 molecule, the indicated angle would best be described as…

|  |  |  |
| --- | --- | --- |
| a. Greater than 90°  b. Equal to 90°  c. Less than 90°  d. Greater than 109½°  e. Equal to 109½°  f. Less than 109½° | g. Greater than 120°  h. Equal to 120°  i. Less than 120°  j. Greater than 180°  k. Equal to 180°  l. Less than 180° | m. Cannot be predicted |

(3 pts) Calculate the formal charge on S in the above molecule.

f.c. = 6 – 2 – ½(6) = +1

### Lewis Acids, Bases, and Adducts

(5 pt) Identify the Lewis acid, Lewis base, and the complex in the following reaction:

NH3(g) + BF3(g) → NH3BF3(s)

base acid complex -3 pts if switch acid and base

(3 pts) In the following reaction, identify the Lewis acid, Lewis base, and the complex.

PF5 + F-  PF6

Lewis acid \_\_\_\_\_\_ PF5

Lewis base \_\_\_\_\_\_ F-

the complex \_\_\_\_\_\_ PF6

(5 pt) Identify the Lewis acid, Lewis base, and the complex in the following reaction:

NH3(g) + BBr3(g) → NH3BBr3(s)

base acid complex

### Lewis Structures, Shapes, and Polarities

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not the electron arrangement) and state whether the molecule is polar or non-polar. Resonance structures may be ignored.

|  |  |  |  |
| --- | --- | --- | --- |
|  | HCCH | BrF2– | NO2 |
| 1 pt. for correct number of electrons. –2 for each atom without octet. | 10 e- | 22 e- | 17 e- |
| Shape: | linear | linear | bent or angular |
| Polar or non-polar: | nonpolar | nonpolar | polar |

|  |  |  |  |
| --- | --- | --- | --- |
|  | PF3 | Cl2CO | IF5 |
| Shape must agree with Lewis structure.  Polarity must agree with shape. | 26 e- | 24 e- | 42 e- |
| Shape: | trigonal pyramidal | trigonal planar | square pyramidal |
| Polar or non-polar: | polar | polar | polar |

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not the electron arrangement) and state whether the molecule is polar or non-polar. Resonance structures may be ignored.

|  |  |  |  |
| --- | --- | --- | --- |
|  | HCN | BrF5 | NO2 |
| 1 pt. for correct number of electrons. –2 for each atom without octet. |  |  |  |
| Shape: | linear | square pyramidal | bent or angular |
| Polar or non-polar: | polar | polar | polar |

|  |  |  |  |
| --- | --- | --- | --- |
|  | SiH2Cl2 | H2O | IF3 |
| Shape must agree with Lewis structure.  Polarity must agree with shape. |  |  |  |
| Shape: | Tetrahedral | bent or angular | T-shaped |
| Polar or non-polar: | Polar | polar | polar |

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not the electron arrangement) and state whether the molecule is polar or non-polar. Resonance structures may be ignored.

|  |  |  |  |
| --- | --- | --- | --- |
|  | SCN– | PCl3O  (P is central atom) | IF4+ |
| 1 pt. for correct number of electrons. –2 for each atom with less than an octet. | 16 e- | 32 e- | 36 e- |
| Shape: | linear | tetrahedral | See-saw |
| Polar or non-polar: | polar | polar | polar |

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not the electron arrangement) and state whether the molecule is polar or non-polar. Resonance structures may be ignored.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ICl2– | NH3 | NO3– |
| 1 pt. for correct number of electrons. 1 pt for correct connectivity. Shape must agree with Lewis structure. Polarity must agree with shape. |  |  |  |
|  | 22 e- | 8 e- | 24 e- |
| Shape: | linear | trigonal pyramidal | trigonal planar |
| Polar or nonpolar: | nonpolar | polar | nonpolar |

(20 pts) For the following molecules, draw the Lewis structure, give the molecular shape, polarity, and bond angles.

|  |  |  |
| --- | --- | --- |
|  | SOCl2 | NO (a radical) |
| 3 Lewis, 1 shape, 1 polarity |  |  |
| Shape: | trigonal pyramidal | linear |
| Polar or non-polar: | polar | polar |
|  |  |  |
|  | H2O | BeCl2 |
|  |  |  |
| Shape: | bent or angular | linear |
| Polar or non-polar: | polar | non-polar |

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not of the electrons) and state whether the molecule is polar or non-polar.

|  |  |  |  |
| --- | --- | --- | --- |
|  | AlCl3 | XeF4 | SO2 |
|  |  |  |  |
| Shape: | trigonal planar | square planar | bent or angular |
| Polar or non-polar: | non-polar | non-polar | polar |

|  |  |  |  |
| --- | --- | --- | --- |
|  | CH2Cl2 | NH3 | PF5 |
|  |  |  |  |
| Shape: | tetrahedral | trigonal pyramidal | trigonal bipyramidal |
| Polar or non-polar: | polar | polar | non-polar |

(7 pts each) Draw the Lewis structures of the following molecules; name the shape of the molecule (not the electron arrangement) and state whether the molecule is polar or non-polar. Resonance structures may be ignored.

|  |  |  |
| --- | --- | --- |
|  | ClO (a radical) | ClF3 |
| 1 pt. for correct number of electrons. –2 for each atom without octet. | or    13 e- | 28 e- |
| Molecular shape: | linear | T-shaped |
| Polar or non-polar: | polar | polar |

### Hybridization; sigma and pi bonds

(6 pts) Fill in the boxes below with the requested information for describing the acetic acid molecule in terms of hybridization and  and  components.



(6 pts) Fill in the boxes below with the requested information for describing the formaldehyde molecule in terms of hybridization and  and  components.



(3 pt) The nitrogen atom in NO3- is \_\_sp2\_\_\_ hybridized.



### Molecular Orbitals

(4 pts) Draw the Lewis structure of the O2 molecule.



(10 pts) Construct a diagram showing the molecular orbitals in O2. Label the molecular orbitals (, \*, etc.). Put electrons in the orbitals.

 2 pts for 12 e-; 4 pts for 8 orbitals; 4 pts for labels.

(5 pts) What is the bond order of O2, according to your MO diagram? (Show the calculation.)

b.o. = ½ × (bonding electrons – antibonding electrons = ½ × (8 – 4) = 2 1 pt. for 2; 4 pts. for showing work.

(1 pt) Is the molecule paramagnetic or diagmagnetic, according to your MO diagram?

Paramagnetic: it has unpaired electrons.

(4 pts) Draw the Lewis structure of the N2 molecule.



(10 pts) Construct a diagram showing the molecular orbitals in N2. Label the molecular orbitals (, \*, etc.). Put electrons in the molecular orbitals.



2 pts for 10 e-; 4 pts for 8 orbitals; 4 pts for labels. (Figure has too many electrons in it.)

Here are some figures that could be used for F2.



### Energy from Enthalpy and amounts

(6 pts) Calcium oxide (lime) reacts with carbon dioxide to form calcium carbonate (chalk).

CaO(s) + CO2(g) → CaCO3(s) *H* = –178.4 kJ

How many kilojoules of heat are evolved in the reaction of 0.500 kg CaO(s) (molar mass 56.08 g/mol) with an excess of carbon dioxide?

-3 pts for 89,000 kJ (didn’t convert to moles)

(4 pts) The oxidation of nitrogen in the hot exhaust of jet engines and automobiles occurs by the reaction

N2(g) + O2(g)  2NO(g) *H°* = +180.5 kJ

How much heat is absorbed in the formation of 0.70 mol NO?

-2 pt for 126 kJ (didn’t divide by 2); -1 pt for significant figures

### Calorimetry

(8 pts) A piece of metal of mass 20.0 g at 100.0°C is placed in a Styrofoam cup calorimeter containing 50.7 g of water at 22.0°C. The final temperature of the mixture is 25.7°C. What is the specific heat capacity of the metal? Assume that all the energy lost by the metal is gained by the water. (The specific heat capacity of water is 4.184 J/(g°C).

1. Heat gained by the water: *q* = *C*s *m* *T* = 4.184 J/(g °C) × 50.7 g × (25.7°C – 22.0°C)

*q* = 784.9 J

(Temperature difference is 3.7°C, so round final result to 2 significant figures.)

1. Heat lost by metal: *q* = 784.9 J
2. Heat capacity of metal: *C*s = *q* / *m* *T* = 784.9 J / 20.0 g / (100.0°C – 25.7°C)

= 0.528 J/g/°C = 0.53 J/g/°C

(7 pts) 50.0 mL of 1 *M* NaOH(aq) and 50.0 mL of 1 *M* HNO3(aq), both initially at 18.6°C, were mixed in a calorimeter. The temperature of the solution rose to 25.4°C. How much heat was released? Assume that the heat capacity of the solution is 4.184 J / (g °C), and the density of the solution is 1.00 g/ml.

Since the density is 1.00, and there are 100.0 mL of solution, the mass of the solution is 100. g.

q = –Ccal × *T* × mass = –4.184 J / (g °C) × (25.4°C – 18.6°C) × 100 g

= –4.184 J / (g °C) × 6.8°C × 100 g

= –2845 J

= –2.8 × 103 J

(7 pts) 50.0 mL of NaOH(aq) and 50.0 mL of HNO3(aq), both initially at 18.6°C, were mixed and stirred in a calorimeter having a heat capacity equal to 525.0 J/°C when containing 100.0 mL water. The temperature of the mixture rose to 21.3°C.

1. What is the enthalpy change for this neutralization reaction?

*H*reaction = –Ccal × *T* = –525.0 J / °C × (21.3°C – 18.6°C)

= –525.0 J / °C × 2.7°C

= –1.4 × 103 J 6 pts

1. Is this reaction endothermic or exothermic? exothermic 1 pt.

(9 pts) A calorimeter has a measured heat capacity of 6.27 kJ/°C. The combustion of 1.84 g of magnesium caused the temperature to rise from 21.30°C to 28.56°C.

1. Is this reaction endothermic or exothermic? exothermic 1 pt.
2. Calculate the enthalpy change of the reaction.

*H*reaction = Ccal × *T* = 6.27 kJ / °C × (28.56°C – 21.30°C) = +45.5 kJ 4 pts

-2 pts for –83.8 kJ (multiplied by mass) (results in –111- kJ/mol in part c)

1. What is the enthalpy change for this combustion in kilojoules per mole of magnesium atoms? (Make sure the sign of your answer is consistent with part a.) 1 pt

Number of moles of Mg = 1.84 g Mg × (1 mol Mg / 24.31 g Mg) = 0.0757 mol

*H* = *H*reaction / moles Mg = +45.5 kJ / 0.0757 mol

= –601 kJ/mol 3 pts

-1 pt for 3.45 (divided by molar mass)

### Hess’s Law

(7 pts) Two successive stages in the industrial manufacture of sulfuric acid are the combustion of sulfur and the oxidation of sulfur dioxde to sulfur trioxide. From the standard reaction enthalpies

S(s) + O2(g)  SO2(g) *H°* = –296.83 kJ

2S(s) + 3 O2(g)  2SO3(g) *H°* = –791.44 kJ

calculate the reaction enthalpy for the oxidation of sulfur dioxide to sulfur trioxide in the reaction 2SO2(g) + O2(g)  2SO3(g).

2SO2(g)  2S(s) + 2O2(g) *H°* = 2 × +296.83 kJ = +593.66 kJ

2S(s) + 3O2(g) 2SO3 *H°* = –791.44 kJ

2SO2(g) + O2(g)  2SO3(g) *H°* = –197.78 kJ

-2 pts for -1385.10 kJ (didn’t reverse the equation)

-3 pts for -494.61 kJ (didn’t multiply by 2)

-5 pts for -1088.27 kJ (just added the equations)

(12 pts) Calculate the standard reaction enthalpy for the synthesis of hydrogen chloride gas

H2(g) + Cl2(g) → 2HCl(g)

from the following data:

NH3(g) + HCl(g) → NH4Cl(s) *H°* = -176.0 kJ

N2(g) + 3H2(g) → 2NH3(g) *H°* = -92.22 kJ

N2(g) + 4H2(g) + Cl2(g) → 2NH4Cl(s) *H*° = -628.86 kJ

These can be made to add up to the desired reaction:

2NH4Cl(s)  NH3(g) + 2HCl(g) *H°* = +352.0 kJ reverse,2 pt,× 2, 2 pt

2NH3(g)  N2(g) + 3H2(g) *H°* = +92.22 kJ reverse, 2 pt

N2(g) + 4H2(g) + Cl2(g)  2NH4Cl(s) *H°* = -628.86 kJ divide by two, 2 pt

H2(g) + Cl2(g) → 2HCl(g) *H°* = -184.7 kJ 2 pts for answer

(6 pts) An important reaction that occurs in the atmosphere is NO2(g)  NO(g) + O(g), which is brought about by sunlight. Calculate the standard enthalpy of the reaction from the following data. (You may want to use a fraction of one of these.)

O2(g)  2O(g) *H°* = +498.4 kJ

NO(g) + O3(g)  NO2(g) + O2(g) *H°* = –200 kJ

3/2 O2(g) O3(g) H° = +142.7 kJ

These can be made to add up to the desired reaction:

NO2(g) + O2(g)  NO(g) + O3(g) *H°* = +200 kJ reverse, 1 pt

O3(g)  3/2 O2(g) *H°* = –142.7 kJ reverse, 1 pt

½ O2(g)  O(g) *H°* = +498.4 kJ / 2 = +249.2 kJ divide by two, 1 pt

NO2(g)  NO(g) + O(g) *H°* = +306 kJ 2 pts for right answer

### Enthalpy of Formation

(10 pts) Use data in the following table to calculate the standard enthalpy of combustion of butane, C4H10(g). (Yes, all the necessary data is provided.)

C4H10(g) + O2(g) → 4CO2(g) + 5H2O(l) *H°* = ?

|  |  |
| --- | --- |
| Using *H°* = ∑ν(*H°*f)products - ∑ν(*H°*f)products gives  +4 × *H°f* (CO2)  +5 × *H°f* (H2O, l)  –1 × *H°f* (C4H10)  × *H°f* (O2)  *H°f* (O2) = 0, because O2 is an element  Putting in numbers gives  +4 × –393.5 = –1574.0  +5 × –285.8 = –1429  –1 × –125.7 = +125.7  –13/2 × 0 = 0  **–2877.3 kJ, or –2877 kJ**  -1 pt for -2657.3 kJ; used H2O(g) instead of (l)  -2 pts for -3129 kJ; wrong sign for 125.7 | **Substance , kJ/mol**  CO2(g) –393.5  C4H10(g) –125.7  H2O(g) –241.8  H2O(l) –285.8 |

(2 pts) The enthalpy change that you determined in the previous problem is (circle one):

1. exothermic b) endothermic c) neither (heat neutral)

Must be consistent with answer above

(10 pts) Use data in the following table to calculate the standard enthalpy of combustion of octane, C8H18:

2C8H18(l) + 25O2(g) → 16CO2(g) + 18H2O(l) *H°* = ?

|  |  |
| --- | --- |
| Using *H°* = ∑ν(*H°*f)products - ∑ν(*H°*f)products gives  +16 × *H°f* (CO2)  +18 × *H°f* (H2O)  –2 × *H°f* (C8H18)  –25 × *H°f* (O2)  *H°f* (O2) = 0, because O2 is an element  Putting in numbers gives  +16 × –393.5 = -6296  +18 × –285.8 = -5144.4  -11440.4  –2 × –249.9 = +499.8  –25 × 0 = 0  **–10940.6 kJ**  -1 pt for 10156.5 kJ; used H2O(g) instead of (l) | **Substance , kJ/mol**  CO(g) –110.5  CO2(g) –393.5  CH4(g) –74.81  C2H2(g) +226.7  C2H4(g) +52.26  C2H6(g) –84.68  C3H8(g) –103.8  C4H10(g) –125.7  C6H6(l) +48.99  C8H18(l) –249.9  CH3OH(l) –238.7  CH3CH2OH(l) –277.7  H2O(g) –241.8  H2O(l) –285.8 |

(2 pts) The enthalpy change that you determined in the previous problem is (circle one):

1. exothermic b) endothermic c) neither (heat neutral)

Must be consistent with answer above

(8 pts) Determine the enthalpy of reaction of

2H2S(g) + SO2(g) → 3S(s) + 2H2O(l)

using the following standard enthalpies of formation:

H2S(g) *H°*f*­* = -20.63 kJ/mol

SO2(g) *H°*f*­* = -296.83 kJ/mol

H2O(g) *H°*f*­* = -241.82 kJ/mol

H2O(l) *H°*f*­* = -285.83 kJ/mol

*H°* = 2 mol × (-285.83 kJ/mol) – 2 mol × (-20.63 kJ/mol) – 1 mol × (-296.83 kJ/mol)

= -233.57 kJ -2 pts for -145 kJ; used H2O(g) instead of H2O(l)