## Periodic Table of the Elements

| 1A 1 | | | | | | | | | | | | 3A 13 | 4A 14 | 5A 15 | 6A 16 | 7A 17 | 8A 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H 1.008 | 2A 2 | | | | | | 8B | | | 1B 11 | 2B 12 | | | | | | 2 He 4.00 |
| 3 Li 6.94 | 4 Be 9.01 | | | | | | | | | | | 5 B 10.81 | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 11 Na 22.99 | 12 Mg 24.31 | 3B 3 | 4B 4 | 5B 5 | 6B 6 | 7B 7 | 8 | 9 | 10 | | | 13 Al 26.98 | 14 Si 28.09 | 15 P 30.97 | 16 S 32.07 | 17 Cl 35.45 | 18 Ar 39.95 |
| 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.87 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.38 | 31 Ga 69.72 | 32 Ge 72.64 | 33 As 74.92 | 34 Se 78.96 | 35 Br 79.90 | 36 Kr 83.80 |
| 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.96 | 43 Tc (98) | 44 Ru 101.1 | 45 Rh 102.9 | 46 Pd 106.4 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.8 | 52 Te 127.6 | 53 I 126.9 | 54 Xe 131.3 |
| 55 Cs 132.9 | 56 Ba 137.3 | 57 La 138.9 | 72 Hf 178.5 | 73 Ta 180.9 | 74 W 183.8 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 192.2 | 78 Pt 195.1 | 79 Au 197.0 | 80 Hg 200.6 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po (209) | 85 At (210) | 86 Rn (222) |
| 87 Fr (223) | 88 Ra (226) | 89 Ac (227) | 104 Rf (261) | 105 Db (262) | 106 Sg (266) | 107 Bh (264) | 108 Hs (277) | 109 Mt (268) | 110 Ds (281) | 111 Rg (281) | 112 Cn (285) | 113 Nh (286) | 114 Fl (289) | 115 Mc (289) | 116 Lv (293) | 117 Ts (293) | 118 Og (294) |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 58 Ce 140.1 | 59 Pr 140.9 | 60 Nd 144.2 | 61 Pm (145) | 62 Sm 150.4 | 63 Eu 152.0 | 64 Gd 157.3 | 65 Tb 158.9 | 66 Dy 162.5 | 67 Ho 164.9 | 68 Er 167.3 | 69 Tm 168.9 | 70 Yb 173.0 | 71 Lu 175.0 |
| 90 Th 232.0 | 91 Pa 231.0 | 92 U 238.0 | 93 Np (237) | 94 Pu (244) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (252) | 100 Fm (257) | 101 Md (258) | 102 No (259) | 103 Lr (262) |

### constants

$R = 0.08206$ L atm/mol K

$R = 8.314$ J/mol K

$N_A = 6.022 \times 10^{23}$ /mol

$h = 6.626 \times 10^{-34}$ J·s

$c = 3.00 \times 10^{8}$ m/s

$g = 9.81$ m/s$^2$

### conversions

1 atm = 760 torr

1 atm = 101325 Pa

1 atm = 1.01325 bar

1 bar = $10^5$ Pa

°F = °C(1.8) + 32

K = °C + 273.15

### conversions

1 in = 2.54 cm

1 ft = 12 in

1 yd = 3 ft

1 mi = 5280 ft

1 lb = 453.6 g

1 ton = 2000 lbs

1 tonne = 1000 kg

1 gal = 3.785 L

1 gal = 231 in$^3$

1 gal = 128 fl oz

1 fl oz = 29.57 mL

### water data

$C_{s,ice} = 2.09$ J/g °C

$C_{s,water} = 4.184$ J/g °C

$C_{s,steam} = 2.03$ J/g °C

$\rho_{water} = 1.00$ g/mL

$\rho_{ice} = 0.9167$ g/mL

$\rho_{seawater} = 1.024$ g/mL

$\Delta H_{fus} = 334$ J/g

$\Delta H_{vap} = 2260$ J/g

$K_w = 1.0 \times 10^{-14}$

This exam should have 20 questions. The questions are equally weighted at 5 points each. Bubble in your answer choices on the bubblesheet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam. Double check all information on the bubblesheet before you turn it in.

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1. In an experimental set up, a scientist places two equal masses of gold and silver into separate beakers with identical starting volumes of water. The density of gold is 19.3 g/cm$^3$ and the density of silver is 10.5 g/cm$^3$. Which beaker will have the greater final volume?

a. Gold

● b. Silver

c. Both beakers will have equal final volumes

**Explanation:** The less dense metal (silver) will require more volume to have a mass equal to the more dense metal (gold). Therefore, the beaker with water and silver will have the greatest final volume.

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2. How many nitrogen atoms are present in a sample of 1.87 moles of nitrogen gas?

a. $6.21 \times 10^{-24}$

b. $5.63 \times 10^{23}$

c. $1.13 \times 10^{24}$

● d. $2.25 \times 10^{24}$

**Explanation:** Convert from the number of moles to number of molecules and then multiply by 2 to account for the 2 nitrogen atoms in each diatomic $N_2$:
$(1.87\,\text{mol}\,N_2)\left(\frac{6.022\times10^{23}\,N_2\,\text{molecules}}{\text{mol}\,N_2}\right)\left(\frac{2\,N\,\text{atoms}}{N_2\,\text{molecule}}\right)$
$= 2.25 \times 10^{24}$ atoms

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3. Carl was hot and decided to whip up a batch of Kool-Aid. He followed the instructions pouring the packet of Cherry Kool-Aid and a cup of sugar into two quarts of water. A perfect batch - nice and cherry red, everything dissolved nicely. Which of the following is the best description of Carl's cherry Kool-Aid?

a. It's a heterogeneous mixture.

● b. It's a homogeneous mixture

c. It's a compound.

d. It's an element.

e. It's a pure substance.

**Explanation:** Once "everything dissolved", Carl's Kool-Aid was definitely a homogeneous mixture. A tasty one at that.

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4. Which of the following best describes the purpose of the mole in chemistry?

a. A mole is an arbitrary quantity, but it is easy to use for calculations.

b. A molecule is a packet of $6.022 \times 10^{23}$ moles.

c. A molecule is an Avogadro's number worth of moles, which allows scientists to conveniently use amu to measure mass in the lab.

● d. The mole is an Avogadro's number worth of elementary entities, which allows scientists to use macroscopic units (g/mol) with the atomic mass values on the periodic table.

**Explanation:** A mole is a packet of $6.022 \times 10^{23}$ elementary entities. This is the conversion factor between amu and g/mol, allowing us to use macroscopic units with the periodic table values.

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5. Approximately 14.78 moles of an unknown metal weighs 398.76 g. What is the identity of this metal?

a. Fe

b. Cu

c. Zn

● d. Al

e. Mg

**Explanation:** This is a composition stoichiometry problem. Solve directly for the molar mass and use the periodic table to identify the metal.

$$\frac{398.76\,\text{g}}{14.78\,\text{mol}} = 26.98\,\text{g/mol}$$

Refer to the periodic table to see that this best matches Al.

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6. Nitrogen gas reacts with hydrogen gas to produce ammonia ($NH_3$). Write the balanced reaction for this process.

a. $N_2(g) + H_2(g) \rightarrow NH_3(g)$

b. $2N(g) + 3H_2(g) \rightarrow 2NH_3(g)$

● c. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

d. $3N_2(g) + 6H_2(g) \rightarrow 4NH_3(g)$

e. $N(g) + 3H(g) \rightarrow NH_3(g)$

**Explanation:** First you must remember that both nitrogen gas and hydrogen gas are diatomic molecules. Therefore, you are reacting $N_2$ and $H_2$ to form ammonia. The unbalanced reaction is:

$$N_2(g) + H_2(g) \rightarrow NH_3(g)$$

Then balance:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

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7. Refer to the following balanced chemical reaction for the aqueous extraction of benzocaine, the active ingredient in cough drops and other mild topical anesthetics:

$$C_9H_{11}NO_2(aq) + HNO_3(aq) \rightarrow C_9H_{11}NO_2(aq)$$

A pharmaceutical company attempts to mass produce cough drops by reacting 5.7 kg benzoate ($C_9H_{11}NO_2$, molar mass = 122 g/mol) with 5.7 kg nitric acid ($HNO_3$, molar mass = 63 g/mol). Nitric acid is a very dangerous chemical that should be used with extreme caution. Is this recipe a good idea for mass producing cough drops? Why or why not?

● a. No, there is a dangerous chemical left in the cough drops.

b. Yes, the reactants were added in equal mole amounts so there is no excess reagent.

c. Yes, there is excess nitric acid but that does not matter.

d. No, there is excess benzoate left over.

**Explanation:** The limiting reagent is what the question calls "benzoate" (it's not really benzoate), meaning there is nitric acid left over. This should be a serious concern if you are hoping to manufacture consumable products. Although the answer is correct based on the information given, the reaction and the synthesis of benzocaine is totally bogus. We will do better next time.

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8. Consider the balanced chemical reaction shown below:

$$2Al_2O_3(s) \longrightarrow 4Al(s) + 3O_2(g)$$

What is the mass of $Al_2O_3$ necessary to form 6.00 moles of aluminum solid? The molar mass of $Al_2O_3$ is 101.96 g/mol.

● a. 306 g

b. 459 g

c. 204 g

d. 408 g

e. 556 g

**Explanation:** First solve for the number of moles of $Al_2O_3$ using the mole ratio:

$$6\,\text{mol Al} \times \frac{2\,\text{mol } Al_2O_3}{4\,\text{mol Al}} = 3\,\text{mol } Al_2O_3$$

Then multiply by the molar mass:

$$3\,\text{mol } Al_2O_3 \times 101.96\,\text{g/mol} = 305.88\,\text{g}$$

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9. Calculate the number of moles of carbon dioxide that are produced when 6.4 moles of methanol ($CH_3OH$) are burned with 7.8 moles of oxygen gas. You will need to write out the chemical equation and balance it on your own.

- a. 5.2 mol
- b. 7.8 mol
- c. 6.4 mol
- d. 7.2 mol
- e. 11.7 mol

**Explanation:** First, write out the equation for the combustion of methanol:

$$2CH_3OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(\ell)$$

The oxygen to methanol ratio is 3:2 which means you need at least 9.6 moles of oxygen (1.5× more)to match up stoichiometrically with 6 moles of methanol. 7.8 moles is too few which means that oxygen will be the limiting reagent. Now calculate carbon dioxide from the oxygen:

$$7.8\,\text{mol}\,O_2 \times \frac{2\,\text{mol}\,CO_2}{3\,\text{mol}\,O_2} = 5.2\,\text{mol}\,CO_2$$

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10. Which of the following alkanes do you expect to have the largest molecular weight?

- a. butane
- b. ethane
- c. heptane
- d. pentane
- e. hexane

**Explanation:** All of these alkanes will have the formula: $C_nH_{2n+2}$. Therefore, you are looking for the highest n-value, which is the most carbons. This corresponds to heptane in this case: 7 carbons. All the others are less than 7.

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11. Which of the following substances do you expect to have the lowest density at room temperature?

- a. $CH_4(g)$
- b. $H_2O(\ell)$
- c. Fe(s)
- d. $CH_3OH(\ell)$
- e. $CH_3CH_2OH(\ell)$

**Explanation:** A gas will have the lowest density out of solids, liquids, and gases. Methane, $CH_4(g)$, will have the lowest density of the answer choices provided.

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12. Consider the following data for the elevations of four different cities:

Moab, UT: 4,026 ft

Flagstaff, AZ: 6,909 ft

New Orleans, LA: -1.500 ft

Estes Park, CO: 7,522 ft

Which city will have the lowest predicted atmospheric pressure?

- a. Estes Park
- b. Moab
- c. Flagstaff
- d. New Orleans($\ell$)

**Explanation:** You can predict that the lowest atmospheric pressure will be the highest elevation. This corresponds to Estes Park.

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13. What is a reasonable estimation for the percent of carbon dioxide in the troposphere?

- a. 0.04%
- b. 12%
- c. 3%
- d. 40%
- e. 66%

**Explanation:** Carbon dioxide makes up 0.04% of the atmosphere. This can be reasonably estimated because it is a trace gas and none of the other choices would reasonably represent a trace gas.

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14. The gas known as the silent killer is the primary culprit in fatalities caused by the unsafe use of personal generators. This gas is produced by the incomplete combustion of a fuel. What gas is this?

●a. CO

b. $CO_2$

c. $H_2O_2$

d. $NO_x$

e. $O_3$

**Explanation:** Carbon monoxide is a product of incomplete combustion and is known as the silent killer.

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15. A sampling of air is taken in Houston on a typical warm humid day. Although there are many different gases in the sample, which of the following four gases are the top four in terms of percentage in the sample?

●a. $H_2O$, Ar, $N_2$, and $O_2$

b. $H_2O$, Ar, $N_2$, and $O_3$

c. $H_2O$, Ar, $N_2$, and $CO_2$

d. $H_2O$, $CO_2$, $N_2$, and $O_2$

e. $H_2O$, $NO_2$, $N_2$, and $O_2$

**Explanation:** Typical air consists of Ar, $N_2$, and $O_2$. On a particularly humid day, $H_2O$ can be added to the mix as the fourth major gas. $CO_2$ is around 0.04

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16. Which of the following is a pollutant that is not directly produced by combustion?

●a. $O_3$

b. $CO_2$

c. CO

d. $NO_x$

e. $H_2O$

**Explanation:** $CO_2$, CO, and $NO_x$ are all produced by combustion. $CO_2$ is not really a pollutant and $H_2O$ definitely is not. $O_3$ is a pollutant that is not formed by combustion.

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17. A 40 L flexible container has a pressure of 32 psi. What is the pressure when the container is compressed to 23 L?

●a. 56 psi

b. 18 psi

c. 63 psi

d. 29 psi

e. 68 psi

**Explanation:** This is a Boyle's Law problem:

$$P_1V_1 = P_2V_2$$

$$56 = \frac{(40)(32)}{(23)}$$

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18. What best describes the temperature of our atmosphere as altitude increases from sea level to the thermosphere?

a. The atmospheric temperature steadily increases.

b. The atmospheric temperature steadily decreases.

c. The atmospheric temperature initially increases, then reverses in the middle of each atmospheric layer.

●d. The atmospheric temperature initially decreases, but reverses trend several times in the pauses between atmospheric layers.

**Explanation:** Temperature initially decreases, but reverses trend several times in the pauses between atmospheric layers

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19. A hot air balloon must be expanded to a volume of 2800 $m^3$ in order to sustain flight. If a deflated hot air balloon at 298 K occupies 2118 $m^3$, what temperature is necessary to inflate the balloon enough to fly?

●a. 394 K

b. 225 K

c. 309 K

d. 591 K

e. 273 K

**Explanation:** Use Charles' Law:

$$V_1/T_1 = V_2/T_2$$

$$2118\,m^3/298\,K = 2800\,m^3/T_2$$

$$T_2 = 394\,K$$

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20. Calculate the volume that 3.96 moles of an ideal gas occupies at 2.94 atm and 37 °C.

a. 4.09 L

● b. 34.3 L

c. 3110 L

d. 45.9 L

e. 311 L

f. 35.6 L

**Explanation:** Use $PV = nRT$, solve for $V$... $V = \frac{(3.96\,\text{mol})(0.08206\,\text{L atm/mol K})(310.15\,\text{K})}{2.94\,\text{atm}} = 34.3\,\text{L}$

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Remember to bubble in ALL your answers BEFORE time is called. Sign your bubblesheet AND your exam. Then turn in BOTH your exam copy and you bubblesheet.