Score_____/72 pts

Team Number: **Answer Key**

Student Names: _____

Team Name: _____

Density Lab Exam

Note: Please show **ALL** work. Units matter towards your score.

1 bar = 100,000 Pa which is approximately atmospheric pressure.

Which 5 are correct density units (1 pt each)

1. G
2. H
3. B
4. C
5. F

a) Kg
b) moles/m^3
c) houses/km^2
d) m/sec^2
e) Kg-m /sec
f) kg/m
g) g/m^3
h) kg/m^3
i) Degrees C
j) people^3/sec

*These answers could be in any order

1. PV = nRT is the Ideal Gas Law. Please define all 5 terms and give exemplary units for each term such that the equation will balance. (5 pts)

P- Pressure (Pa, atm, bar)*

R- Ideal Gas Constant – (J/mol K, L atm/mol K, etc)*

V- Volume (m^3, L, mL)*

T- Temperature – (K)*

n – number of moles of gas (Moles)

Answers have to be consistent with units and the units must be in metric to receive credit. In some cases, this was used as a tie breaker. Proper SI units were given more credit.

2. The following picture has three liquids with different densities. Select which option best describes the liquids relative densities. (2 pts)
   a. Blue>White>Red
   b. Red>White>Blue
   c. All equal
   d. While>Blue>Red

3. The Ideal Molar Volume is the volume of a mole of gas at STP (standard temperature and pressure). What is the value for this volume. (2 pts)

$$PV = nRT$$

$$100{,}000\ Pa * (V) = 1\ mol * \left(8.314 \frac{J}{mol\ K}\right) * 273.15K$$

$$V = 22.4 * 10^{-3} m^3$$

Credit was given for just the answer as well as this is a fairly common constant and it was reasonable to have in your binder

4. Copper is more dense than wood. Which has a larger volume, a 10 g sample of wood or a 10 g sample of copper? (2 pts)
   a. They are the same
   b. Not enough information to solve
   c. Copper
   d. Wood

5. Two cylinders are connected. The first has an unknown volume but is in perfect vacuum. The second is filled with argon, has a volume of 300 ml, and a pressure of 2 bar. If a valve is opened between the two cylinders, the final pressure is 1.4 bar. What is the volume of cylinder 1? (you may assume the temperature is constant) (3 pts)

$$P_1 V_1 = P_2 V_2$$

$$V_1 = \frac{P_2 V_2}{P_1} = \frac{2\ Bar * 300\ mL}{1.4\ Bar} = 428.6\ mL$$

$V_1 = (V_2 + V_3)$ *where* V_3 *is the volume of cylinder 1 and* V_1 *is the volumes of* V_1 *and* V_2 *together*

$$V_1 = 428.6\ mL = V_2 + V_3 = V_3 + 300mL$$

$$V_3 = 129\ mL$$

This exact procedure is used to determine the volume of certain piping systems where I work

6. Which is larger? (1 pt each)
   i. A
   ii. B
   iii. The same
   iv. Not enough information

I.	A. 1%	B. 10,000 ppm	____iii_____
II.	A. 100 ppm	B. 100 ppb	_____i_____
III.	A. 1 microliter	B. 1 liter	_____ii_____

7. In a car engine, gas (a fuel/air mixture) is injected into the cylinder, the valves close and the piston rises, decreasing the volume by a factor of 8. If the initial pressure is 1 bar, what is the final pressure? Please assume ideal gas behavior and no change in temperature. (3 pts)
    i. 8 bar
    ii. 4 bar
    iii. .125 bar
    iv. Cannot be determined
8. When the spark plug sparks, the temperature will go from 50 C to 1050 C, If the piston does not move (and the engine block doesn't blow up, which it almost certainly would) how much would the pressure rise? (3 pts)
    i. x 10
    ii. x1050
    iii. x 21
    iv. x4

    Note to get the correct answer you must convert to Kelvin This is the hardest question on this test and was correctly answered by only 10% of the students (who showed their work, so we know they understood) in Delaware and 1 lucky guess in Colorado (who did not) I gave 1 pt for answer iii, which meant you understood the equation but failed to convert to K)
9. Whose work is not included in the Ideal Gas Law (2 pts)
    a. Boyle
    b. Archimedes
    c. Guy-Lussac
    d. Charles
10. What is Avogadro's Number (2 pts)
    a. 6
    b. 6.02
    c. 8.314×10^{14}
    d. 6.02×10^{23}

True / False (1 pt each)

11. Gases become denser as they cool. ___T__
12. Ice is denser than water ___F__
13. The Ideal Gas law is true for all gases at all conditions ___F__
14. All metal objects will sink in water ___F__
15. If two objects have the same mass but different volumes, the larger volume will have greater density ___F__

16. Buoyancy is an upward force a fluid exerts that oppose the effect of gravity on an immersed object ___T__
17. Archimedes determined the properties of density sitting in a bath tub ___T__
18. Which is not a representation of the Ideal gas law? (2 pts)
    a. PV = nRT
    b. T = VP/nR
    c. R = nT/PV
    d. P = RTn/V
19. A liter of liquid nitrogen weighs 807 g. It has a molecular weight of 28. If I heat the gas to 293 K at atmospheric pressure, what is the final gas volume in liters? (3 pts)

$$n = 807\ g\ N_2/28\ {}^{g}/_{mol} = 28.82\ mol\ N_2$$

$$PV = nRT$$

$$100000\ Pa * V\ ([=]m^3) = 28.82\ mols * 8.314 \frac{J}{molK} * 293K$$

$V = .7\ m^3\ or\ 700\ liters$ *Full credit for any metric unit*

Experimental Section
Experiments were set up in 5 stations, with 5 minutes per station

Experiment 1
Explain the video (6 pts)

Aluminium boat floating on SF6 gas - Stock Video Clip - K004/5561 - Science Photo Library - https://www.sciencephoto.com/media/639545/view/aluminium-boat-floating-on-sf6-gas

A sign was placed by the video stating that no liquids, magnets or wires were used.

This is a stock video showing an experiment we show kids during tours. I decided that it was too difficult to transport a cylinder of gas to the event, so I found this video. The aquarium is partially filled with SF6, a very dense gas (about 5x air). It is supporting an aluminum foil boat. As the boat is filled with SF6, the buoyancy is removed, and it sinks.

A large number of students gave very accurate answers. Several students identified the gas as SF6 in the explanation.

Experiment 2
What is the volume and density of the sample (6 pts)

An iron rod (from an ankle weight, so not easily measured dimensions, a 5in ¾ bolt was used in CO), a 100 ml plastic graduated cylinder, a water bottle, and a wal mart 5 kg scale were provided. (paper towels are also provided)

Using the Archimedes method, the volume of the bar was determined by displacement. The weight was measured using the scale.

Experiment 3
What is the volume and density of the sample? (6 pts)

Ruler and Walmart 5kg scale.
A paper machier H was purchased at Michaels. It was roughly 15 cm tall, 8 cm wide and 2 cm in depth. The volume had to be determined by measuring the 3 rectangles that make the H and adding them together.
Much lower scoring than Exp 2. (also used in the A division in Delaware, but I added dotted lines showing the three rectangles, and gave them the weight. Scoring at the A div was higher than B div)
Most common error was measurement in inches, which was given almost full credit.

Experiment 4
What is the number density of (2 pts each)

1. Blue states
2. Yellow
3. Green

A basic US map was given, with the states in different colors.

Common error was to say 9 blue states, not 9/50 or 0.18 etc

Experiment 5

What is the volume density of pink erasers? (3 pts)

What is the number density of pink erasers? (3 pts)

A graduated cylinder filled with colored erasers and legoes was supplied, filling the graduated cylinder to ~50 ml. (we could not find enough erasers and I don't trust middle school students not to eat Skittles)

There were 9 pink erasers so volume density was 9/50

There were 25 total things in the cup, so number density was 9/25

I prepared this test for the 2019 Delaware Final, and my son then used it in the Colorado Final. He was asked to post this by the other event supervisor, who thought it was better than what was available online. In the two test sessions, no question was not answered correctly, and the high score was 65 in DE and 66 in CO. The low scores were ~10-12. This is almost exactly what I strive for in creating a test. No one gets everything, everyone gets something, and the questions are sufficiently broad that different people get different parts right.