Exam 2

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

1. The pressure exerted on a sample of a fixed amount of gas is doubled at constant temperature, and then the temperature of the gas in kelvins in double at constant pressure. What is the final volume of the gas?
	1. The final volume of the gas is four times the initial volume.
	2. The final volume of the gas is one-fourth the initial volume.
	3. The final volume of the gas is one-half the initial volume.
	4. The final volume is twice the initial volume.
	5. The final volume of the gas is the same as the initial volume.
2. \_\_\_\_\_\_\_\_\_\_\_\_\_ states that the volume of a gas varies inversely to the pressure on the gas, when temperature and number of moles are kept constant (PV = constant).
	1. Avogadro’s law
	2. Boyle’s law
	3. Charles’ law
	4. Gay-Lussac’s law
	5. Dalton’s law
3. Assuming ideal behavior, which of these gas samples has the greatest volume at STP?
	1. 1 g H2
	2. 1 g O2
	3. 1 g Ar
	4. 1 g CH4
	5. all of the above have the same volume



1. What is the measurement shown by the calipers?
	1. 24 mm
	2. 27.4 cm
	3. 28.4 cm
	4. 29 cm
	5. 30.4 cm
2. For which should the standard heat of formation, ∆Hf°, be zero at 25 °C?
	1. oxygen gas, O2 (g)
	2. ozone gas, O3 (g)
	3. atomic oxygen gas, O (g)
	4. all of the above
	5. none of the above
3. For a process at constant volume:
	1. q = 0, w = 0, ∆E = 0
	2. w = 0 and ∆E = q
	3. w = 0 and ∆H = q
	4. w = 0 and ∆E = ∆H
	5. none of the above
4. For the reaction I2 (g) 🡪 I2 (s), ∆H°  = -62.4 kJ at 25 °C then
	1. ∆H°vap = -62.4 kJ/mol
	2. ∆H°vap = 62.4 kJ/mol
	3. ∆H°sub = -62.4 kJ/mol
	4. ∆H°sub = 62.4 kJ/mol
	5. b and c
5. A quantized variable
	1. can be continuously varied.
	2. can only assume certain values.
	3. consists of photons.
	4. is extremely small.
	5. is a state function.
6. Which subshell letter corresponds to an 8 lobed pattern?
	1. s
	2. p
	3. d
	4. f
	5. more than one answer
7. How many electrons does an f orbital contain?
	1. 2
	2. 6
	3. 7
	4. 10
	5. 14

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. State whether each of the following samples of matter is a gas. If there is not enough information for you to decide, write “insufficient information.” (5 points)
	1. A material is in a steel tank at 100 atm pressure. When the tank is opened to the atmosphere, the material suddenly expands, increases its volume by 1%.

Not a gas. A gas would expand to an infinite volume.

* 1. A 1.0 mL sample of material weighs 8.2 g.

Not a gas. A density of 8.2 g/mL is typical of a solid.

* 1. The material is transparent and pale green in color.

Insufficient information

* 1. Nitrogen, oxygen, and helium at room temperature and pressure.

Gas

* 1. One cubic meter of material contains as many molecules as 1.0 m3 of air at the same temperature and pressure.

Gas

1. At an underwater depth of 250. ft, the pressure is 8.38 atm. What should the mole percent of oxygen in the diving gas be for the partial pressure of oxygen in the gas to be 0.21 atm, the same as it is in air at 1.0 atm (6 points)?

$$P\_{O\_{2}}=P\_{total}χ\_{O\_{2}}⟹χ\_{O\_{2}}=\frac{P\_{O\_{2}}}{P\_{total}}=\frac{0.21 atm}{8.38 atm}=0.025$$

$$\%O\_{2}=0.025×100\%=2.5\% O\_{2}$$

1. You have a gas, one of the three known phosphorus-fluorine compounds (PF3, PF5, and P2F4). To find out which, you decide to measure its molar mass (12 points).
	1. First you determine that the density of the gas is 5.60 g/L at a pressure of 0.971 atm and a temperature of 18.2 °C. Calculate the molar mass and identify the compound.

$$MM=\frac{DRT}{P}$$

$$MM=\frac{\left(5.60\frac{g}{L}\right)\left(0.08206 \frac{L atm}{mol K}\right)\left(18.2+273.15\right)K }{0.971 atm}$$

$$MM=\frac{DRT}{P}=\frac{\left(5.60\frac{g}{L}\right)\left(0.08206 \frac{L atm}{mol K}\right)\left(291.35 K\right) }{0.971 atm}=137.884463\frac{g}{mol}≈138\frac{g}{mol}$$

The molar mass is closest to that of P2F4, which has a molar mass of 137.94 g/mol.

* 1. To check the results from part (a), you decide to measure the molar mass based on the relative rates of effusion of the unknown gas and CO2. You find that CO2 effuses at a rate of 0.050 mol/min, whereas the unknown phosphorus fluoride effuses at a rate of 0.028 mol/min. Calculate the molar mass of the unknown gas based on these results.

$$\frac{rate 1}{rate 2}=\sqrt{\frac{MM 2}{MM 1}}⟹MM2=\left(\frac{rate 1}{rate 2}\right)^{2}MM1=\left(\frac{0.050 \frac{mol}{min}}{0.028 \frac{mol }{min}}\right)^{2}\left(44.009\frac{g}{mol}\right)=140.3348214\frac{g}{mol}≈140\frac{g}{mol}$$

This is consistent with the results from part a.

1. A 13.8 g piece of zinc is heated to 98.8 °C in boiling water and then dropped into a beaker containing 45.0 g of water at 25.0 °C. When the water and metal come to thermal equilibrium, the temperature is 27.1 °C (15 points).
	1. What is the specific heat capacity of zinc?

$$q\_{in}=-q\_{out}$$

$$q\_{water}=-q\_{zinc}$$

$$m\_{water}c\_{water}∆T\_{water}=-m\_{zinc}c\_{zinc}∆T\_{zinc}⇒c\_{zinc}=\frac{m\_{water}c\_{water}∆T\_{water}}{-m\_{zinc}∆T\_{zinc}}$$

$$c\_{zinc}=\frac{\left(45.0 g\right)\left(4.184\frac{J}{g ℃}\right)(27.1℃-25.0℃)}{-(13.8 g)(27.1℃-98.8℃)}=\frac{\left(45.0 g\right)\left(4.184\frac{J}{g ℃}\right)(2.1℃)}{-(13.8 g)(-71.7℃)}=0.399599782\frac{J}{g ℃}≈0.40 \frac{J}{g ℃} $$

* 1. If the molar heat capacity of zinc at 300 K is 25.45 J/mol K, what is the percent error?

$$25.45\frac{J}{mol K}×\frac{1 mol Zn}{65.382 g Zn}×\frac{1 K}{1 ℃}=0.389250864\frac{J}{ g ℃}≈0.3893\frac{J}{g ℃}$$

$$\%error=\frac{observed value-accepted value}{accepted value}×100$$

$$\%error=\frac{0.40 \frac{J}{g ℃}-0.3893\frac{J}{g ℃}}{0.3893\frac{J}{g ℃}}×100=\frac{0.0107\frac{J}{g ℃}}{0.3893\frac{J}{g ℃}}×100=2.7\%$$

1. If the same amount of heat is supplied to samples of 10.0 g each of aluminum (specific heat 0.897 J/g °C), iron (specific heat 0.450 J/g °C) and copper (specific heat 0.385 J/g °C) all at 15.0 °C, which sample would reach the highest temperature (3 points)?

Recall that q = mc∆T, since all of the samples are the same mass and have the same temperature, so the lower the specific heat the greater the temperature rise. Therefore, the copper sample would reach the highest temperature.

1. The bombardier beetle uses an explosive discharge as a defense mechanism. The chemistry of the reaction involved is the oxidation of hydroquinone by H2O2 to produce quinone and water (9 points).

C6H4(OH)2(aq) + H2O2(aq) → C6H4O2(aq) + 2 H2O(l)

Given the following reactions, calculate ΔH:

C6H4(OH)2(aq) → C6H4O2(aq)  + H2(g)  ΔH = + 177.4 kJ

H2(g) + 1/2O2(g)  → H2O(g)  ΔH = − 241.8 kJ

H2(g) + O2(g)  → H2O2(aq)  ΔH = −191.2 kJ

H2O(g)  → H2O(l )  ΔH = − 43.8 kJ

C6H4(OH)2(aq) → C6H4O2(aq)  + H2(g)  ΔH = + 177.4 kJ

**[**H2(g) + 1/2O2(g)  → H2O(g)  ΔH = − 241.8 kJ**]x2**

**[**H2(g) + O2(g)  → H2O2(aq)  ΔH = −191.2 kJ**]** $↬$**flip over**

**[**H2O(g)  → H2O(l )  ΔH = − 43.8 kJ**]x2**

C6H4(OH)2(aq) → C6H4O2(aq)  + ~~H~~~~2(g)~~  ΔH = + 177.4 kJ

~~2 H~~~~2(g)~~ + ~~O~~~~2(g)~~  → ~~2 H~~~~2~~~~O~~~~(g)~~  ΔH = − 483.6 kJ

H2O2(aq)  → ~~H~~~~2(g)~~ + ~~O~~~~2(g)~~  ΔH = 191.2 kJ

~~2 H~~~~2~~~~O~~~~(g)~~  → 2 H2O(l )  ΔH = − 87.6 kJ

C6H4(OH)2(aq) + H2O2(aq) → C6H4O2(aq) + 2 H2O(l )  ΔH = -202.6 kJ

How much heat is produced by a bombardier beetle that produces 15.0 mg of quinine?

$$15.0 mg C\_{6}H\_{4}O\_{4}×\frac{1 g}{1000 mg}×\frac{1 mol C\_{6}H\_{4}O\_{4}}{108.096 g C\_{6}H\_{4}O\_{4}}×\frac{1 mol C\_{6}H\_{4}(OH)\_{2}}{1 mol C\_{6}H\_{4}O\_{4}}×\frac{-202.6 kJ}{mol C\_{6}H\_{4}(OH)\_{2}}=$$

$$=-0.028113899 kJ ≈-0.0281 kJ=28.1 J$$

1. Which of the following are applicable when explaining the photoelectric effect? Correct any statements that are wrong (4 points).
	1. Light is electromagnetic radiation.

Correct

* 1. The intensity of a light beam is related to its frequency.

Incorrect, the intensity of a light beam is independent of frequency and is related to the number of photons of light with a certain energy.

* 1. Light can be thought of as consisting of massless particles whose energy is given by Planck’s equation, E = hν.

Correct

1. An x-ray has a wavelength of 1.5 × 10-2 nm (8 points).
	1. What is the frequency?

$$ν=\frac{c}{λ}=\frac{3.00×10^{8} \frac{m}{s}}{1.5×10^{-2} nm}×\frac{10^{9} nm}{1 m}=2.0×10^{19}\frac{1}{s}$$

* 1. What is the energy, in joules, associated with a photon of this frequency?

$$E=\frac{hc}{λ}=\frac{\left(6.626×10^{-34} J s\right)\left(3.00×10^{8} \frac{m}{s}\right)}{1.5×10^{-2} nm}×\frac{10^{9} nm}{1 m}=1.3×10^{-14}J$$

* 1. What would be the energy of a mole of such photons?

$$1.3×10^{-14}\frac{J}{photon}×\frac{6.022 ×10^{23} photons}{1 mol photons}=7.98×10^{9}\frac{J}{mol}≈8.0×10^{6}\frac{kJ}{mol} $$

1. Complete the following statements (12 points):
	1. The quantum number, n, describes the \_\_size and energy\_\_\_\_\_\_\_\_\_ of an atomic orbital.
	2. The shape of an atomic orbital is given by the \_angular momentum quantum number, l .
	3. A photon of green light has (less or more) energy that a photon of orange light.
	4. The maximum number of orbitals that may be associated with the set of quantum numbers n = 4 and l = 3 is \_\_\_7, l = 3 these are f orbitals\_\_\_\_\_\_\_\_\_\_.
	5. When n = 5, the possible values of l are \_\_\_\_\_\_0, 1, 2, 3, 4,\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
	6. The maximum number of orbitals that may be associated with the quantum number set n = 3, l = 2, and ml = -2 is \_\_\_\_one\_\_\_\_\_\_\_\_\_\_\_\_\_.
	7. The number of orbitals in the n = 4 shell is \_\_16, l = 3, 2, 1, 0, or f sublevel (7 orbitals), d sublevel (5 orbitals), p sublevel (3 orbitals), s sublevel (1 orbital) \_\_\_\_\_\_\_\_\_\_\_.

1. Calculate the wavelength of the green line (ni = 4) in the visible spectrum of excited H atoms in nm, where Rydberg’s constant is 1.097 × 107 m-1 (6 points).

$\frac{1}{λ}=R\_{H}\left(\frac{1}{n\_{f}^{2}}-\frac{1}{n\_{1}^{2}}\right)=\left(1.097×10^{7}\frac{1}{m}\right)\left(\frac{1}{2^{2}}-\frac{1}{4^{2}}\right)=\left(1.097×10^{7}\frac{1}{m}\right)\left(\frac{1}{4}-\frac{1}{16}\right)=2056875\frac{1}{m}$

$λ=\frac{1}{2056875\frac{1}{m}}=4.86144151×10^{-7} m×\frac{10^{9} nm}{1 m}≈486.1 nm$