Exam 2

# Part 1: Multiple Choice (2 points each)

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

1. Assuming ideal behavior, which of these gas samples will have the greatest volume at STP?
2. 1 g of H2
3. 1 g of Ar
4. 1 g of O2
5. all of the above
6. not enough information
7. Which of the following is true of the internal energy of a system and its surroundings during an energy exchange with a negative ∆Esys?
8. The internal energy of both the system and the surroundings increases.
9. The internal energy of the system increases and the internal energy of the surroundings decreases.
10. The internal energy of both the system and the surroundings decreases.
11. The internal energy of the system decreases and the internal energy of the surroundings increases.
12. none of the above
13. What is a photon?
	1. A packet of light.
	2. A packet of force.
	3. The smallest particle.
	4. The way of any interaction.
	5. Charge transporting particle.
14. Which one of the following is not used to describe the condition of a gas?
	1. polarity
	2. number of moles
	3. temperature
	4. volume
	5. pressure
15. Which statement is true about kinetic molecular theory?
	1. A single particle does not move in a straight line.
	2. The size of the particle is large compared to the volume.
	3. The collisions of particles with one another is completely elastic.
	4. The average kinetic energy of a particle is not proportional to the temperature.
	5. none of the above
16. A sun burn is caused by overexpose to \_\_\_\_\_\_\_\_\_\_\_\_\_\_ radiation.
	1. ultraviolet
	2. gamma
	3. microwave
	4. x-ray
	5. radio
17. What value of the angular momentum quantum number, l, is represented by a d orbital?
	1. 0
	2. 1
	3. 2
	4. 3
	5. 4
18. How many electrons does an f orbital contain?
	1. 2
	2. 6
	3. 7
	4. 10
	5. 14
19. Two aqueous solutions are both at room temperature and are then mixed in a coffee cup calorimeter. The reaction causes the temperature of the resulting solution to fall below room temperature. Which of the following statements is true?
	1. The products have a lower potential energy than the reactants.
	2. This type of experiment will provide data to calculate ∆Erxn.
	3. The reaction is exothermic.
	4. Energy is leaving the system during the reaction.
	5. none of the above; all statements are true.
20. Which rule(s) about lab safety is true?
	1. If a small piece of matter is lodged in the tip of a pipet, buret, or eye dropper, it is acceptable to blow the piece out with your mouth.
	2. If a chemical smells good, it must taste good and therefore it can be eaten.
	3. Eye protect is needed while you are reading or writing in the lab if other students are still performing their experiments.
	4. If a glass drops and shatters, you should immediately pick up all large pieces with unprotected hands.
	5. You should deeply inhale all chemicals at the opening of the reagent bottle to smell it.

# 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. In constructing a barometer, what advantage is there in choosing a dense liquid (3 points)?

A more dense liquid has a shorter column of liquid in a barometer and therefore we do not need to have a very tall barometer to measure atmospheric pressure.

1. Determine the total volume of all gases (at STP) formed when 50.0 mL of TNT, C3H5(NO3)3, density = 1.60 g/mL and molar mass = 227.10 g/mol, react according to the following reaction (10 points):

4 C3H5(NO3)3 (l) 🡪 6 N2 (g) + O2 (g) + 12 CO2 (g) + 10 H2O (g)

$$50.0 mL TNT×\frac{1.60 g TNT}{1 mol TNT}×\frac{1 mol TNT}{227.10 g TNT}=0.352 mol TNT $$

$$0.352 mol TNT×\frac{6 mol N\_{2}}{4 mol TNT}×\frac{22.4 L}{1 mol }=11.9 L$$

$$0.352 mol TNT×\frac{1 mol O\_{2}}{4 mol TNT}×\frac{22.4 L}{1 mol }=1.97 L$$

$$0.352 mol TNT×\frac{12 mol CO\_{2}}{4 mol TNT}×\frac{22.4 L}{1 mol }=23.7 L$$

$$0.352 mol TNT×\frac{10 mol H\_{2}O}{4 mol TNT}×\frac{22.4 L}{1 mol }=19.7 L$$

$$V\_{total }=V\_{N\_{2}}+V\_{O\_{2}}+V\_{CO\_{2}}+V\_{H\_{2}O}=11.9 L+1.97 L+23.7 L+19.7 L=57.3 L$$

Or

$50.0 mL TNT×\frac{1.60 g TNT}{1 mol TNT}×\frac{1 mol TNT}{227.10 g TNT}×\frac{\left(6 mol+1 mol+12 mol+ 10 mol\right)gas }{4 mol TNT}×\frac{22.4 L gas}{1 mol gas}=57.2 L$

You either get question 3 or 4

1. A gas bottle contains 0.250 mol of gas at 730 mm Hg pressure. If the final pressure is 1.15 atm, how many moles of gas were added to the bottle (6 points)?

$$PV=nRT⇒\frac{n\_{1}}{P\_{1}}=\frac{n\_{2}}{P\_{2}}⇒n\_{2}=n\_{1}\frac{P\_{2}}{P\_{1}}$$

$$n\_{2}=\left(0.250 mol \right)\left(\frac{1.15 atm}{730 mm Hg}×\frac{760 mm Hg}{1 atm}\right)=0.299 mol $$

$$n=n\_{2}-n\_{1}=0.299 mol-0.250 mol=0.049 moles added$$

1. A gas bottle contains 0.1571 mol of gas at 727.1 torr pressure. If the final pressure is 0.9754 atm, how many moles of gas were added to the bottle (6 points)?

$$PV=nRT⇒\frac{n\_{1}}{P\_{1}}=\frac{n\_{2}}{P\_{2}}⇒n\_{2}=n\_{1}\frac{P\_{2}}{P\_{1}}$$

$$n\_{2}=\left(0.1571 mol \right)\left(\frac{0.9754 atm}{727.1 torr}×\frac{760 torr}{1 atm}\right)=0.1602 mol $$

$$n=n\_{2}-n\_{1}=0.1602 mol-0.1571 mol=0.0031 moles added$$

You either get question 5 or 6

1. What is the volume of 9.783 x 1023 atoms of kypton at 9.25 atm and 239 °C (5 points)?

$$PV=nRT⇒V=\frac{nRT}{P}$$

$V=\frac{\left(9.783×10^{23} atoms\right)\left(0.08206 \frac{L atm}{mol K}\right)\left(239+273\right)K}{9.25 atm}×\frac{1 mol }{6.022×10^{23} atoms}=7.38 L$

1. What is the volume of 3.711 x 1023 atoms of argon at 5.741 atm and 133.2 °C (5 points)?

$$PV=nRT⇒V=\frac{nRT}{P}$$

$V=\frac{\left(3.711×10^{23} atoms\right)\left(0.08206 \frac{L atm}{mol K}\right)\left(133.2+273.15\right)K}{5.741 atm}×\frac{1 mol }{6.022×10^{23} atoms}=3.579 L$

You either get question 7 or 8

1. A system releases 673 kJ of heat and does 115 kJ of work on the surroundings. What is the change in internal energy of the system (3 points)?

$$∆E=q+w=-673 kJ+\left(-115 kJ\right)= -788 kJ $$

1. A system absorbs 673 kJ of heat and does 115 kJ of work on the surroundings. What is the change in internal energy of the system (3 points)?

$$∆E=q+w=673 kJ+\left(-115 kJ\right)=558 kJ $$

1. How is Hess’ Law consistent with the law of conservation of energy (3 points)?

When we apply Hess’ law all the heat is accounted for in the reaction; energy is neither created nor destroyed when using Hess’ law.

1. A sample of an unknown metal was reacted with 150.0 g of hydrochloric acid in a calorimeter (16 points).
	1. If a 2.744 g sample of the metal caused the temperature of the calorimeter and its contents to rise from 22.4oC to 61.2oC, calculate the heat of reaction per g for the metal. (The acid solution has a specific heat of 4.168 J/g K, and the calorimeter has a heat capacity of 39.2J/K.)

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

$$-q\_{metal}=q\_{acid}+q\_{calorimeter}$$

$$-q\_{metal}=m\_{acid}c\_{acid}∆T\_{acid}+C\_{calorimter}∆T$$

$$-q\_{metal}=\left(150.0 g\right)\left(4.168 \frac{J}{g K}\right)\left(61.2 ℃-22.4℃\right)+(39.2\frac{J}{K})\left(61.2 ℃-22.4℃\right)$$

$$-q\_{metal}=\left(150.0 g\right)\left(4.168 \frac{J}{g K}\right)\left(38.8℃\right)+(39.2\frac{J}{K})\left(38.8℃\right)$$

$$-q\_{metal}=24257.76 J+1520.96 J$$

$$-q\_{metal}=25778.72 J$$

$$\frac{q\_{metal}}{m\_{metal}}=-\frac{2.58×10^{4} J}{2.744 g}=-9.39×10^{3}\frac{J}{g}$$

* 1. The hydrogen gas from the experiment above was collected in a 397 mL at 30.0oC and 731 torr pressure, how many moles of hydrogen were collected?

V = 397 mL

T = 30.0 °C

P = 731 torr

n = ?

$$PV=nRT⟹n=\frac{PV}{RT}$$

$$n=\frac{\left(731 torr\right)(397 mL)}{\left(0.0821 \frac{L atm}{mol K}\right)(30.0 ℃+273.15)}×\frac{1 atm}{760 torr}×\frac{1 L}{1000 mL}=0.0153 mol H\_{2}$$

* 1. What is the molar mass of the metal? (Previous experiments have shown the metal to form a chloride of the formula MCl3. Write a balanced chemical reaction and determine how many moles of the metal reacted.)

2 M (s)  + 6 HCl (aq) 🡪 3 H2 (g) + 2 MCl3 (aq)

$$0.0153 mol H\_{2}×\frac{2 mol M}{3 mol H\_{2}}=0.0102 mol M$$

$$MM=\frac{m}{n}=\frac{2.744 g}{0.0102 mol}=269\frac{g}{mol}$$

* 1. Calculate the molar heat of reaction of the metal.

$$\frac{q\_{metal}}{n\_{metal}}=-\frac{2.58×10^{4} J}{0.0102 mol}=-2.48×10^{6}\frac{J}{mol}$$

|  |  |
| --- | --- |
| Substance | ∆H°f (kJ/mol) |
| CH4 (g) | -75 |
| CHCl3 (g) | -134 |
| Cl2 (g) | 0 |
| HCl (g) | -92 |

1. Use the information provided to determine ∆H°rxn for the following reaction (5 points):

CH4 (g) + 3 Cl2 (g) 🡪 CHCl3 (g) + 3 HCl (g) ∆H°rxn = ?

$$∆H\_{rxn}^{°}=\sum\_{}^{}n∆H\_{f}^{o}\_{products}-\sum\_{}^{}n∆H\_{f}^{o}\_{reactants}$$

$$∆H\_{rxn}^{°}=\left(n\_{CHCl\_{3}}∆H\_{f}^{o}\_{CHCl\_{3}}+n\_{HCl}∆H\_{f}^{o}\_{HCl}\right)-\left(n\_{CH\_{4}}∆H\_{f}^{o}\_{CH\_{4}}+n\_{Cl\_{2}}∆H\_{f}^{o}\_{Cl\_{2}}\right)$$

$$∆H\_{rxn}^{°}=\left(\left(1 mol\right)\left(-134\frac{kJ}{mol}\right)+\left(3 mol \right)\left(-92\frac{kJ}{mol}\right) \right)-\left(\left(1 mol\right)\left(-75\frac{kJ}{mol}\right)+\left(3 mol\right)\left(0\frac{kJ}{mol}\right)\right)$$

$$∆H\_{rxn}^{°}=-335 kJ$$

You either get question 12 or 13

1. A laser pulse has a wavelength of 505 nm (10 points).
	1. What is the frequency of the laser pulse?

$$ν=\frac{c}{λ}=\frac{3.00×10^{8}\frac{m}{s}}{505×10^{-9} m}=5.94×10^{14}\frac{1}{s}$$

* 1. What is the energy of the photon?

$$E\_{photon}=\frac{hc}{λ}=\frac{\left(6.626×10^{-34} J s\right)\left(3.00×10^{8}\frac{m}{s}\right)}{(505×10^{-9} m)}=3.94×10^{-19}\frac{J}{photon}$$

* 1. It contains 4.40 mJ of energy. How many photons are in the laser pulse?

$$number of photons=\frac{E\_{total}}{E\_{photon}}=\frac{4.40×10^{-3} J}{3.94×10^{-19}\frac{J}{photon}}=1.12×10^{16} photons$$

1. An x-ray has a wavelength of 1.5 × 10-2 nm (8 points).
2. 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. An electron in the n = 7 level of the hydrogen atom relaxes to a lower energy level, emitting light of 1005 nm. What is the value of n for the level to which the electron relaxed? RH = 1.097 x 10-2 nm-1 (4 points).

$$\frac{1}{λ}=R\_{H}\left(\frac{1}{n\_{f}^{2}}-\frac{1}{n\_{i}^{2}}\right)$$

$$\frac{1}{1005 nm}=\left(1.097×10^{-2}\frac{1}{nm}\right)\left(\frac{1}{n\_{f}^{2}}-\frac{1}{7^{2}}\right)$$

$$n\_{f}=3$$

1. Why are the various forms of radiant energy called electromagnetic radiation (3 points)?

All these forms of light have perpendicular, oscillating electric and magnetic fields that travel together through space.

1. Why don’t we observe the wavelength of everyday macroscopic objects (3 points)?

Due to the large mass of macroscopic objects, the deBroglie wavelength is extremely small. The wavelength is so small that it is impossible to detect compared to the size of the object.

1. How does the concept of an orbit in the Bohr model of the hydrogen atom differ from the concept of an orbital in quantum theory (4 points)?

The Bohr model orbit showed the quantized nature of the electron in the atom as a particle moving around the nucleus in concentric orbits, much like planets moving around the sun.

In quantum theory, an orbital is a region of space where the probability of finding the electron is high. The electron is not viewed as a particle, but as a wave, and it is not confined to a clearly defined orbit; rather, we refer to the probability of the electron being at various locations around the nucleus.

1. What is the photoelectric effect (2 points)?

Many metals emit electrons when light of high enough energy is shone on them. (This observation brought the classical view of light into question.)

1. Complete the following statements (4 points):
2. The quantum number, n, describes the \_\_size and energy\_\_\_\_\_\_\_\_\_ of an atomic orbital.
3. The shape of an atomic orbital is given by the \_angular momentum quantum number, l .
4. When n = 5, the possible values of l are \_\_\_\_\_\_0, 1, 2, 3, 4,\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
5. When ℓ is 2, what are the possible values of mℓ? \_\_\_\_ mℓ = -2, -1, 0, 1, 2