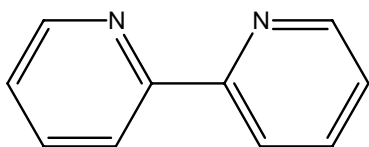


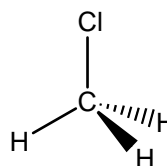
**Quiz 3**  
**CHEM 325**  
**Spring 2009**

Name: \_\_\_\_\_

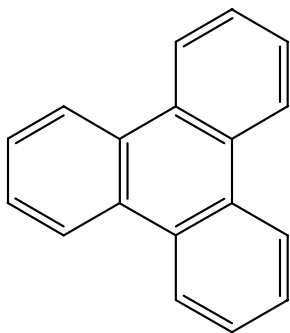
1. (7 Points) Assign the following molecules to the proper point group. Ignore the disposition of the H on the NH<sub>2</sub> in the cobalt complex and the positions of double bonds in aromatic rings.



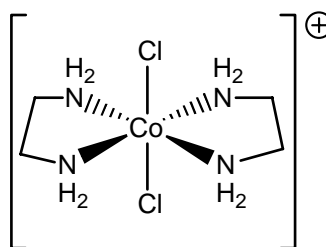
C<sub>2v</sub>



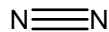
C<sub>3v</sub>



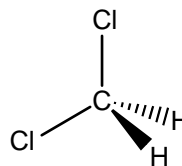
D<sub>3h</sub>



D<sub>2h</sub>



D<sub>∞h</sub>



C<sub>2v</sub>

2. (5 Points) Determine the commutator of the operators  $\frac{d}{dx}$  and  $\frac{1}{x}$ .

The commutator is  $\left[ \frac{d}{dx}, \frac{1}{x} \right] = \frac{d}{dx} \frac{1}{x} - \frac{1}{x} \frac{d}{dx}$ . To determine its value, apply it to  $\psi$  an arbitrary function of  $x$ .

$$\left[ \frac{d}{dx}, \frac{1}{x} \right] \psi = \frac{d}{dx} \left( \frac{1}{x} \psi \right) - \frac{1}{x} \left( \frac{d\psi}{dx} \right) = \left[ \left( \frac{1}{x} \right) \left( \frac{d\psi}{dx} \right) + (\psi) (-x^{-2}) \right] - \frac{1}{x} \left( \frac{d\psi}{dx} \right)$$

$$\left[ \frac{d}{dx}, \frac{1}{x} \right] \psi = -x^{-2} \psi$$

Now divide both sides by  $\psi$  to give  $\left[ \frac{d}{dx}, \frac{1}{x} \right] = -x^{-2}$ .

The commutator's value is  $-x^{-2}$ .

3. (10 Points) Which of these functions is an eigenfunction of the operator  $-i \frac{d}{dx}$ ? If a function is an eigenfunction, give the eigenvalue. No work = no credit!

a.  $e^{ikx} : -i \frac{d e^{ikx}}{dx} = (-i)(ik)e^{ikx} = k e^{ikx}$

**The operator returns the original function times a constant, so it is an eigenfunction of the operator and the eigenvalue is  $k$ .**

b.  $\cos(ikx) : -i \frac{d \cos(ikx)}{dx} = (-i)(-ik)\sin(ikx) = -k \sin(ikx)$

**Since the operator does not return the original function times a constant, this function is not an eigenfunction of the operator.**

c.  $e^{-i\alpha x^2} : -i \frac{d e^{-i\alpha x^2}}{dx} = (-i)(-2i\alpha x)e^{-i\alpha x^2} = -2\alpha x e^{-i\alpha x^2}$

**The operator gives the same function back, but not times a constant. Therefore, this function is not an eigenfunction of the operator.**

4. (6 Points) The work function for metallic rubidium is 2.09 eV. Calculate the kinetic energy of the electron ejected by light with a wavelength of 650.0 nm.

**Starting from the Einstein equation for the photoelectric effect  $\frac{1}{2}mv^2 = h\nu - \Phi$ , and**

**noting that  $E_K = \frac{1}{2}mv^2$ , gives us  $E_K = h\nu - \Phi$ . Combining this with  $\lambda\nu = c$  gives**

$$E_K = \frac{hc}{\lambda} - \Phi.$$

$$E_K = \frac{hc}{\lambda} - \Phi = \left( \frac{(6.62608 \times 10^{-34} \text{ J} \cdot \text{s})(2.99792458 \times 10^8 \text{ m} \cdot \text{s}^{-1})}{650.0 \times 10^{-9} \text{ m}} \right) \left( \frac{1 \text{ eV}}{1.60218 \times 10^{-19} \text{ J}} \right) - 2.09 \text{ eV}$$

$$E_K = 1.907_4 \text{ eV} - 2.09 \text{ eV} = -0.18 \text{ eV}$$

**The negative value of the kinetic energy is physically unreasonable. Therefore, light with this wavelength has insufficient energy to eject an electron from rubidium.**