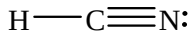
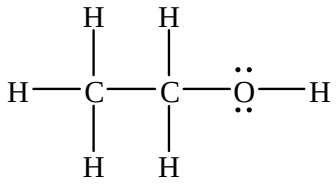
CHEM1001 Answers to Problem Sheet 7

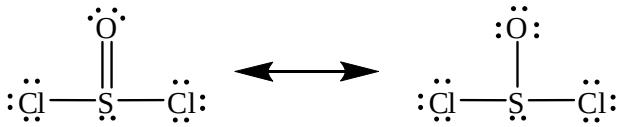
1. (a) hydrogen cyanide, HCN



(b) ethanol, CH_2CH_2OH

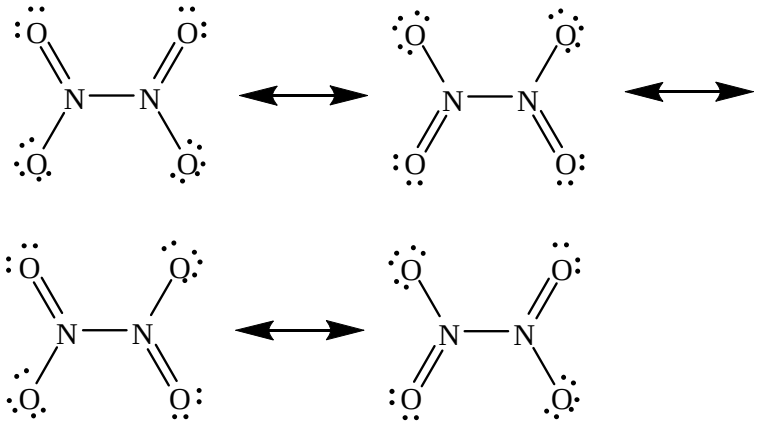


(c) $SOCl_2$



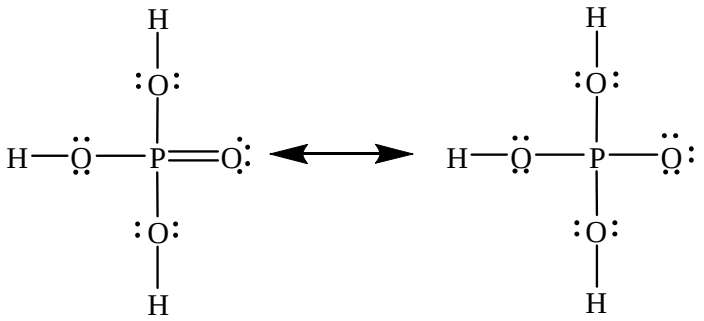
The resonance structure on the left shows the (allowed) expanded valence shell around S with 5 electron pairs (4 bonds for the S(IV) atom and 1 lone pair). The resonance structure on the right shows all atoms obeying the octet rule leading to charges having to be placed on S and O. The resonance forms represent two extremes – the real electron distribution is somewhere between the two.

(d) N_2O_4



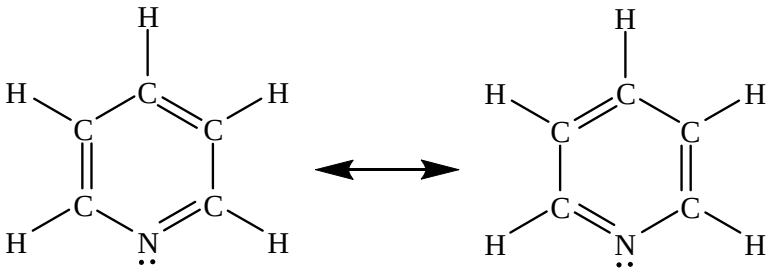
The maximum number of electron pairs around N and O is 4 so no expansion of the octet is allowed. This leads to charges being put on the atoms.
Each resonance form is equivalent – the N-O bonds are intermediate between single and double bonds in character. There is no multiple bond between the nitrogen atoms so there is free rotation about the N-N bond.

(e) phosphoric acid, H_3PO_4 [=$PO(OH)_3$]



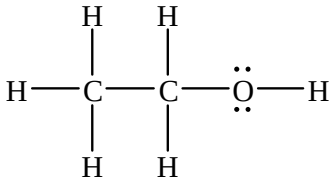
The resonance structure on the left shows the bonding with an expanded valence shell around P (five bonds for the P(V) atom). The resonance structure on the right shows all atoms obeying the octet rule but with charges. As outlined in part (c), the real bonding is somewhere between these two extremes.

(f) pyridine, C_5H_5N [a 6-membered ring]

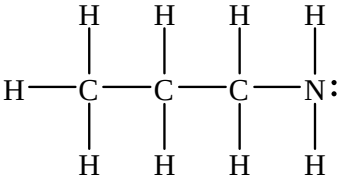


Pyridine has delocalized 'aromatic' electrons like benzene (see Q4(e) on Problem Sheet 6) with a lone pair on nitrogen instead of a C-H bond. Note that this lone pair is pointing away from the ring and is not delocalized.

2. **The Lewis structures of ethanol (C_2H_5OH) and propylamine ($CH_3CH_2CH_2NH_2$) are shown below. There are two lone pairs on the oxygen in ethanol (see Q4 (b)) and one lone pair on the nitrogen in propylamine.**

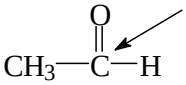
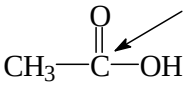
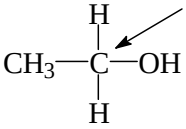


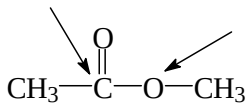
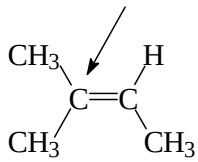
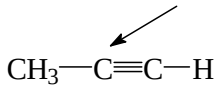
ethanol



propylamine

3.

	Compound	Bond Angle(s)
(a)		**~120°**
(b)		**~120°**
(c)		**~109.5°**

(d)		**~120° and ~109.5°**
(e)		**~120°**
(f)		**180°**

4. **The energy *q* required to heat a substance of mass *m* by a temperature Δ*T* is given by the equation:**

$$q = c \times m \times \Delta T$$

where *c* is the specific heat capacity – a property of the substance involved.

Note that a *change* in temperature of 13.3 °C corresponds to a *change* of 13.3 K. If *q* = 78.2 J, *m* = 45.6 g and Δ*T* = 13.3 K, then

$$c = \frac{q}{m\Delta T} = \frac{78.2\ \text{J}}{(45.6\ \text{g})\times(13.3\ \text{K})} = 0.129\ \text{J K}^{-1}\ \text{g}^{-1}$$

The atomic mass of lead is 207.2 g mol^{-1}. The molar heat capacity, *C*, is therefore:

$$C = (0.129\ \text{J K}^{-1}\ \text{g}^{-1}) \times (207.2\ \text{g mol}^{-1}) = 26.7\ \text{J K}^{-1}\ \text{mol}^{-1}.$$

5. **The neutralization reaction is a 1:1 reaction with chemical equation:**

$$\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$$

After the reactants mix the solution has a volume of 200 mL. The density of water is 1.0 g mol^{-1}, the mass of water is 200 g. The temperature change, Δ*T* = (31.1 – 24.6) K = 6.7 K. The heat capacity of water is 4.184 J K^{-1} g^{-1}. The heat change is therefore:

$$q = c \times m \times \Delta T$$
$$= (4.184\ \text{J K}^{-1}\ \text{g}^{-1}) \times (200\ \text{g}) \times (6.7\ \text{K}) = 5600\ \text{J or } 5.6\ \text{kJ} \qquad \text{(heat released)}$$

100 mL of 1.0 M HCl corresponds to:

$$\text{number of moles} = \text{concentration} \times \text{volume} = (1.0\ \text{mol L}^{-1}) \times (0.100\ \text{L}) = 0.1\ \text{mol}$$

The heat change for a mole would therefore be 10 × 5600 J. The reaction gives out heat (as the temperature rises) so it is an exothermic reaction with a negative enthalpy change:

$$\Delta H = -56\ \text{kJ mol}^{-1}$$