

Exc.1
$$M = \frac{SRT}{(1 - \rho v_s)D} \quad [11.2]$$

$$= \frac{(3.2 \text{ Sv}) \times (10^{-13} \text{ s Sv}^{-1}) \times (8.3145 \text{ J mol}^{-1} \text{ K}^{-1}) \times (293.15 \text{ K})}{\{1 - (1.06 \text{ g cm}^{-3}) \times (0.656 \text{ cm}^3 \text{ g}^{-1})\} \times (8.3 \times 10^{-11} \text{ m}^2 \text{ s}^{-1})}$$

$$= \boxed{31 \text{ kg mol}^{-1}}$$

Exc.2
$$M = \frac{2RT}{(r_2^2 - r_1^2)b\omega^2} \ln \frac{c_2}{c_1} \quad [11.3a] = \frac{2RT}{(r_2^2 - r_1^2)b(2\pi\nu)^2} \ln \frac{c_2}{c_1} \quad [\omega = 2\pi\nu]$$

Solving for the squared rotational frequency ν and substitution of $b = 1 - \rho v_s$ gives

$$\nu^2 = \frac{RT \ln(c_2/c_1)}{2\pi^2 M \times (1 - \rho v_s) \times (r_2^2 - r_1^2)}$$

$$= \frac{(8.3145 \text{ J K}^{-1} \text{ mol}^{-1}) \times (298 \text{ K}) \times \ln 5}{2\pi^2 \times (1 \times 10^2 \text{ kg mol}^{-1}) \times (1 - 0.75) \times (7.0^2 - 5.0^2) \times 10^{-4} \text{ m}^2}$$

$$= 3367 \text{ s}^{-2}$$

$$\nu = (58 \text{ s}^{-1}) \times (60 \text{ s min}^{-1}) = \boxed{3500 \text{ r.p.m.}}$$

Exc.3 Draw up the following table, using the procedure set out in Section 11.4(c).

Original	Reciprocal	Clear fractions	Miller indices
$(2a, 3b, c)$ or $(2, 3, 1)$	$(\frac{1}{2}, \frac{1}{3}, 1)$	$(3, 2, 6)$	(326)
(a, b, c) or $(1, 1, 1)$	$(1, 1, 1)$	$(1, 1, 1)$	(111)
$(6a, 3b, 3c)$ or $(6, 3, 3)$	$(\frac{1}{6}, \frac{1}{3}, \frac{1}{3})$	$(1, 2, 2)$	(122)
$(2a, -3b, -3c)$ or $(2, -3, -3)$	$(\frac{1}{2}, -\frac{1}{3}, -\frac{1}{3})$	$(3, -2, -2)$	$(\overline{3}\overline{2}\overline{2})$

Exc.4
$$\lambda = 2d \sin \theta \quad [11.11a] = 2 \times (97.3 \text{ pm}) \times (\sin 19.85^\circ) = \boxed{66.1 \text{ pm}}$$

Exc.5 From Table 10.2: $\chi(\text{H}) = 2.1$, $\chi(\text{Cl}) = 3.0$, and $\Delta\chi_{\text{HCl}} = 0.9$. Thus,

$$\mu_{\text{HCl}} \approx \Delta\chi_{\text{HCl}} D [11.14] = \boxed{0.9 \text{ D}}$$

$$\mu_{\text{HCl}} \approx (0.9 \text{ D}) \times (3.33564 \times 10^{-30} \text{ C m D}^{-1}) = \boxed{3 \times 10^{-30} \text{ C m}}$$

The chlorine atom has the greater electronegativity and a partial negative charge. Consequently, the dipole moment points toward the hydrogen atom. The experimental dipole moment of $\text{HCl}(\text{g})$ is 1.08 D so the estimate based on electronegativity differences is low by 17%.

Exc.6 (a) $\mu_{\text{res}} = (\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2 \cos \theta)^{1/2}$

$$= \{(1.50)^2 + (0.80)^2 + 2 \times 1.50 \times 0.80 \times \cos 109.5^\circ\}^{1/2} \text{ D} = \boxed{1.45 \text{ D}}$$

(b) The *ortho* disubstituted benzene orients two identical dipoles μ at 60° .

$$\mu_{\text{ortho}} = \{1 + 1 + 2 \times \cos 60^\circ\}^{1/2} \mu = \sqrt{3} \mu$$

The *meta* disubstituted benzene orients two identical dipoles μ at 120° .

$$\mu_{\text{meta}} = \{1 + 1 + 2 \times \cos 120^\circ\}^{1/2} \mu = \mu$$

Thus, $\boxed{\mu_{\text{ortho}}/\mu_{\text{meta}} = \sqrt{3}}$

Exc.7 We assume that the dipole of the water molecule and the Li^+ ion are collinear and that the separation of charges in the dipole is smaller than the distance to the ion. With these assumptions we can use eqn 11.16a of the text. To flip the water molecule over requires twice the energy of interaction given by eqn 11.16a.

$$\begin{aligned} E &= \left(-\frac{Q_2(-\mu_1)}{4\pi\epsilon_0 r^2} \right) - \left(-\frac{Q_2(+\mu_1)}{4\pi\epsilon_0 r^2} \right) = \frac{2Q_2\mu_1}{4\pi\epsilon_0 r^2} \quad Q_2 = e = 1.602 \times 10^{-19} \text{ C} \\ &= \frac{2 \times (1.602 \times 10^{-19} \text{ C}) \times (1.85 \text{ D}) \times (3.336 \times 10^{-30} \text{ C m D}^{-1})}{(4\pi \times 8.854 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}) \times r^2} \\ &= \frac{1.777 \times 10^{-38} \text{ J m}^2}{r^2} \end{aligned}$$

(a) $E = \frac{1.777 \times 10^{-38} \text{ J m}^2}{(100 \times 10^{-12} \text{ m})^2} = 1.78 \times 10^{-18} \text{ J}$

molar energy = $N_A \times E = \boxed{1.07 \times 10^3 \text{ kJ mol}^{-1}}$

(b) $E = \frac{1.777 \times 10^{-38} \text{ J m}^2}{(300 \times 10^{-12} \text{ m})^2} = 1.97 \times 10^{-19} \text{ J}$

molar energy = $N_A \times E = \boxed{119 \text{ kJ mol}^{-1}}$

Exc.8 (a) Polarizability, $\alpha = \mu^*/\mathcal{E}$ [11.19], where μ^* , the induced dipole moment has the SI unit “C m”. The electric field strength, \mathcal{E} , is the force per unit charge experienced by a charge. It has the unit “N C⁻¹” or “J C⁻¹ m⁻¹”. Consequently, polarizability has the SI unit

$$(\text{C m})/(\text{J C}^{-1} \text{ m}^{-1}) = \text{C}^2 \text{ m}^2 \text{ J}^{-1}.$$

(b) Polarizability volume, $\alpha' = \alpha/4\pi\epsilon_0$ [11.20], where α has the SI unit “C² m² J⁻¹” and ϵ_0 has the “C² J⁻¹ m⁻¹” unit. Consequently, the polarizability volume has the SI unit

$$(\text{C}^2 \text{ m}^2 \text{ J}^{-1})/(\text{C}^2 \text{ J}^{-1} \text{ m}^{-1}) = \text{m}^3.$$

Exc.9 $\mu^* = \alpha\mathcal{E}$ [11.19] = $4\pi\epsilon_0\alpha'\mathcal{E}$ [11.20] = $4\pi\epsilon_0\alpha' \left(\frac{e}{4\pi\epsilon_0 r^2} \right) = 1.85 \text{ D}$ [$Q = e$ for a proton]

$$\frac{\alpha'e}{r^2} = 1.85 \text{ D}$$

Solve for r ,

$$r = \left(\frac{\alpha'e}{1.85 \text{ D}} \right)^{1/2} = \left(\frac{(1.48 \times 10^{-30} \text{ m}^3) \times (1.602 \times 10^{-19} \text{ C})}{(1.85 \text{ D}) \times (3.336 \times 10^{-30} \text{ C m D}^{-1})} \right)^{1/2}$$

$$= 1.96 \times 10^{-10} \text{ m} = \boxed{196 \text{ pm}}$$

Exc.10 $F = -\frac{dV}{dr} = -4\epsilon \frac{d}{dr} \left\{ \left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^6 \right\} = -4\epsilon \left\{ \frac{12\sigma^{12}}{r^{13}} - \frac{6\sigma^6}{r^7} \right\} = -\frac{24\epsilon\sigma^6}{r^7} \left\{ \frac{2\sigma^6}{r^6} - 1 \right\}$

The minimum occurs when

$$\frac{2\sigma^6}{r^6} - 1 = 0, \text{ which solves to } \boxed{r = 2^{1/6}\sigma}.$$