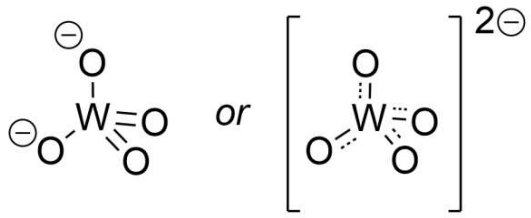
**2. This question is about the chemistry of tungsten**

(a)



½

Bond Angle: 109.5°

½

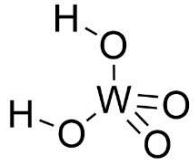
*Must have attempted to draw a tetrahedral shape to be given credit, i.e. do not credit square planar structures.*

(b) (i) $CaWO_{4\,(s)} + Na_2CO_{3\,(aq)} \rightarrow CaCO_{3\,(s)} + Na_2WO_{4\,(aq)}$ **1**

*State symbols not required.*

(ii) $Na_2WO_{4\,(aq)} + 2HCl_{\,(aq)} \rightarrow H_2WO_{4\,(aq)} + 2NaCl_{\,(aq)}$ **1**

*State symbols not required.*



**1**

*Correct 3D tetrahedral structure not required as long as connectivity and bonding are correct.*

(iii) $H_2WO_{4\,(aq)} \rightarrow WO_{3\,(s)} + H_2O_{\,(g)}$ **1**

*State symbols not required.*

(iv) $WO_{3\,(s)} + 3H_{2\,(g)} \rightarrow W_{\,(s)} + 3H_2O_{\,(l)}$ **1**

*State symbols not required.*

(c) (i) x = 1
3 × O = −6
1 × Li = +1
Therefore W = **+5** **1**

*Accept if 5 is written rather than +5.*

(ii) x = 0.3
3 × O = −6
1 × Li = +0.3
Therefore W = **+5.7** **1**

*Accept if 5.7 is written rather than +5.7.*

(d) Assuming air to be made only of nitrogen ($N_2$)
Density of $SF_6$ relative to air = 32.06 + (6 × 19.00) / (2 × 14.01)
= 146.06 / 28.02
= 5.21

**1**

Density of $WF_6$ relative to air = 183.85 + (6 × 19.00) / (2 × 14.01)
= 297.85 / 28.02
= 10.63

**1**

(e) $pV = nRT$
1 mol of gas occupies: $V/n = RT/p$
$= (8.314\ J\ K\ mol^{-1} \times 298\ K) / 100000\ N\ m^{-2}$
$= 0.02476\ m^3\ mol^{-1}$
$= 2.476 \times 10^4\ cm^3\ mol^{-1}$
Density of $WF_6 = 297.85\ g\ mol^{-1} / 2.476 \times 10^4\ cm^3\ mol^{-1}$
$= 0.0120\ g\ cm^{-3}$ **2**
*Give credit if they use 24 $dm^3$ for 1 mol of gas as a known value at STP.*

(f) $WF_{6\ (g)} + 4H_2O_{\ (l)} \rightarrow H_2WO_{4\ (aq)} + 6HF_{\ (aq)}$ **1**

$WF_{6\ (g)} + 3H_2O_{\ (l)} \rightarrow WO_{3\ (s)} + 6HF_{\ (aq)}$
*Accept either. State symbols not required.*

(g) (i) Positive **1**
*This is because there are more moles of gas on the right than the left.*

(ii) $\Delta_r H^o = \Delta_f H^o (H_2SO_{4\ (g)}) + 6 \times \Delta_f H^o (HF_{\ (g)}) - \Delta_f H^o (SF_6) - 4 \times \Delta_f H^o (H_2O)$ **1**
$= -735 + (6 \times -273) - (-1210 + 4 \times -242)\ kJ\ mol^{-1}$
$= -195\ kJ\ mol^{-1}$ **1**
*1 mark for correct expression if numerical calculation is done incorrectly.Correct answer scores full marks.*

(iii) **B** $SF_6$ is kinetically stable but thermodynamically unstable **1**

(h) Tungsten = 1 atom inside unit cell + 4 × atoms on face + 8 × atoms on corner
$= 1 + (4 \times ½) + (8 \times ⅛) =$ **4 atoms** **1**

Calcium = 6 × atoms on face + 4 × atoms on edge
$= (6 \times ½) + (4 \times ¼) =$ **4 atoms** **1**

Oxygen = 16 × atoms inside unit cell
**= 16 atoms** **1**

(i) Volume of Unit Cell = 0.524 nm × 0.524 nm × 1.137 nm
$= 3.122 \times 10^{-28}\ m^3 \quad = 3.122 \times 10^{-22}\ cm^3$

Molar mass of $CaWO_4 = (40.08 + 183.85 + 4 \times 16.00)\ g\ mol^{-1}$
$= 287.93\ g\ mol^{-1}$

Mass of one formula unit $= 287.93\ g\ mol^{-1} / 6.02 \times 10^{23}\ mol^{-1}$
$= 4.783 \times 10^{-22}\ g$ **1**

Mass of one unit cell
$= 4 \times 4.783 \times 10^{-22}\ g \quad = 1.913 \times 10^{-21}\ g$ **1**

Density $= 1.913 \times 10^{-21}\ g / 3.122 \times 10^{-22}\ cm^3$
$= 6.13\ g\ cm^{-3}$ **1**

*1 mark for calculation of mass of formula unit, 1 mark for four formula units per unit cell and 1 mark for answer. Correct answer scores full marks.*

**Question Total 23**