Section D

Question 19

(*a*) Bromine and xenon have seven and eight outer electrons, respectively. In BrF_5, five of the seven outer electrons are used to form bonds with fluorine, leaving one non-bonded pair. In XeO_3, six of the eight outer electrons form bonds with oxygen, leaving one non-bonded pair. The shapes of BrF_5 and XeO_3 are therefore based on an octahedral and tetrahedral disposition of repulsion axes, respectively. BrF_5 is therefore square pyramidal, with the non-bonded pair occupying the sixth position in the octahedron (Structure **20**). XeO_3 is pyramidal, the xenon atom occupying the apex, with the non-bonded pair above (Structure **21**).

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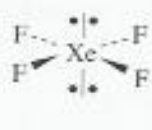
The angles ∠F—Br—F are less than 90° in BrF_5. This is consistent with the idea that the repulsion between the non-bonded pair and the Br—F bond pairs in the horizontal plane of Structure **20** will be especially strong. In XeO_3, the angle ∠O—Xe—O should be close to tetrahedral. It is, in fact, 103°, marking again the strong repulsion exerted by the non-bonded pair.

(*Note that the general arguments used above are systematically presented in Book 2, Section 7.2*).

(*b*) Application of the same procedure to SiF_4, SF_4 and XeF_4 shows that, although the three compounds have similar formulae, their shapes are dictated by four, five and six repulsion axes, respectively. Thus, SiF_4 is tetrahedral, and XeF_4 is square planar, with the two non-bonded pairs minimizing their repulsion by occupying axial positions in the octahedron (Structure **22**). In SF_4, the disposition of repulsion axes is trigonal bipyramidal, a situation in which non-bonded pairs invariably occupy equatorial positions. The molecule therefore has the shape shown in Structure **23**.



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In SF_4, the fluorines are pushed a little towards each other by the strong repulsion of the non-bonded pair.

Question 20

(*a*) (i) In the industrial electrolysis of concentrated sodium chloride solution, the positive electrode (the anode) is usually metallic titanium. The negative electrode (the cathode) is often woven steel wire.

At the positive electrode, chloride ions are oxidized to chlorine gas:

$$Cl^-(aq) = \tfrac{1}{2}Cl_2(g) + e^- \qquad (15)$$

At the negative electrode, water is reduced to hydrogen and aqueous hydroxide ions:

$$H_2O(l) + e^-(g) = \tfrac{1}{2}H_2(g) + OH^-(aq) \qquad (16)$$

Here, the most important product is the aqueous hydroxide ions, which must ultimately be converted to solid sodium hydroxide.

(ii) Chlorine and aqueous hydroxide react together, so unless steps are taken to separate the positive and negative electrode compartments, the desired products of the cell will destroy each other. The compartments are separated by a cation exchange membrane, which allows the passage of cations (positive ions) but not anions (negative ions). *Book 4 Figure 24.3 shows how this is done*. Concentrated brine is added to the positive electrode