1) An object is chiral if it has a non-superimposable mirror image.

2) This molecule has two chiral centers.

3) $S_N2$ reactions are stereospecific (giving 100% inversion) because the nucleophile must attack from directly behind the Carbon – Leaving Group bond.

4) $S_N1$ and E1 reactions always involve a carbocation intermediate.

5) An elimination is a reaction where two atoms or groups are removed to produce a new π bond.

6) Iodide ion is a good leaving group in nucleophilic substitutions.

7) These compounds are related as enantiomers.

8) An electrophilic addition is a reaction where a nucleophilic species replaces another group or atom in a molecule.

9) Single bonds are typically shorter and stronger than double bonds.

10) (R) or (S) stereocenters are assigned according to the Cargo-Into-Treelog convention.
11) (4pts) Assign (R) or (S) to all the chiral centers in the following molecules.

(a) \[
\begin{array}{c}
\text{CO}_2\text{H} \\
\text{Cl} \\
\text{H} \\
\text{H} \\
\text{CF}_3
\end{array}
\]

(b) \[
\begin{array}{c}
\text{F} \\
\text{H} \\
\text{F} \\
\text{Cl} \\
\text{CH}_2
\end{array}
\]

12) The below dibromide has two chiral centers:

\[
\begin{array}{c}
\text{H} \\
\text{CH}_2\text{CH}_3 \\
\text{Br} \\
\text{Br} \\
\text{CH}_2\text{CH}_3
\end{array}
\]

i) (4pts) assign R or S to each chiral center.

ii) (1pt) overall, is this molecule chiral?

iii) (2pts) draw the alkene which would react with Bromine (Br\(_2\)) to generate this product.
13) (6pts) Name these two compounds in IUPAC form.  
*(2 bonus points if you also correctly include the relevant chirality).*

\[ \text{Br} \quad \text{Cl} \quad \text{F} \]

14) (12pts) Give the products formed in the following transformations of the below cyclic alkene, *paying attention to stereo- and regio-chemistry where relevant.*
15) (3pts) i) Write a mechanism (i.e. curly arrows) for this E2 elimination.

\[ \text{Br} \quad \text{K}^+\text{OCH}_3, \text{CH}_3\text{OH} \quad \rightarrow \quad \text{HC} = \text{CH} \]

ii) (1pt) Draw another possible elimination product which could be formed in small amounts in this reaction.

iii) (1pt) Draw a possible product that would be formed in this reaction, if it was substitution (and not an elimination).
16) (4pts) Draw the mechanism (i.e. using curly arrows) for this electrophilic addition of hydrogen chloride to cyclopentene.

17) (2pts) Provide the reagents you could use to achieve this (multi step) transformation.
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1-10 are True / False (10pts)

1) An object is chiral if it has a non-superimposable mirror image. T

2) This molecule has two chiral centers.

3) $S_{N2}$ reactions are stereospecific (giving 100% inversion) because the nucleophile must attack from directly behind the Carbon - Leaving Group bond. T

4) $S_{N1}$ and E1 reactions always involve a carbocation intermediate. T

5) An elimination is a reaction where two atoms or groups are removed to produce a new $\pi$ bond. T

6) Iodide ion is a good leaving group in nucleophilic substitutions. T

7) These compounds are related as enantiomers.

8) An electrophilic addition is a reaction where a nucleophilic species replaces another group or atom in a molecule. F

9) Single bonds are typically shorter and stronger than double bonds. F

10) (R) or (S) stereocenters are assigned according to the Cargo-Into-Treelog convention. F
11) (4pts) Assign (R) or (S) to all the chiral centers in the following molecules.

(a) \[ \text{CO}_2\text{H} \quad \text{H} \quad \text{Cl} \quad \text{H} \quad \text{H} \quad \text{Cl} \quad \text{H} \quad \text{CF}_3 \]

(b) \[ \text{F} \quad \text{H} \quad \text{Cl} \quad \text{CH}_2 \]

12) The below dibromide has two chiral centers:

i) (4pts) assign R or S to each chiral center.

\[ \text{R} \quad \text{S} \]

ii) (1pts) overall, is this molecule chiral?

No (It is MESO)

iii) (2pts) draw the alkene which would react with Bromine (Br\(_2\)) to generate this product.

\[ \text{CH}_3 \quad \text{CH}_2 \quad \text{CH}_2 \quad \text{CH}_2 \text{CH}_3 \]
13) (6pts) Name these two compounds in IUPAC form.
(2 bonus points if you also correctly include the relevant chirality).

(E)-1-BROMOBUTA-1,3-DIENE

Cl5-1-CHLORO-5-FLUOROCYCLOPENTANE
or
(1S,3R)-1-CHLORO-3-FLUOROCYCLOPENTANE

14) (12pts) Give the products formed in the following transformations of the below cyclic alkene, paying attention to stereo- and regio-chemistry where relevant.
15) (3pts) i) Write a mechanism (i.e. curly arrows) for this E2 elimination.

ii) (1pts) Draw another possible elimination product which could be formed in small amounts in this reaction.

iii) (1pts) Draw a possible product that would be formed in this reaction, if it was substitution (and not an elimination).
16) (4pts) Draw the mechanism (i.e. *using curly arrows*) for this electrophilic addition of hydrogen chloride to cyclopentene.

![Mechanism diagram]

17) (2pts) Provide the reagents you could use to achieve this (multi step) transformation.

![Reagents diagram]