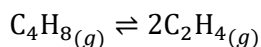**Different professors are covering different material in their classes. Therefore, the questions in this review are separated by chapter.**

Chapter 16: Kinetics, Rate Laws

16.1 Cyclobutane decomposes in a first order reaction shown below.

$$C_4H_{8(g)} \rightleftharpoons 2C_2H_{4(g)}$$

Given that the initial concentration of C_4H_8 is 5M and the final concentration is 0.06M after 0.05 seconds, what is the rate constant and the expected rate law?

    a. 65 s^{-1}; rate = k[C$_2$H$_4$]^2
    b. <u>88 s^{-1}; rate = k[C$_4$H$_8$]</u>
    c. 92 s^{-1}; rate = k[C$_4$H$_8$]
    d. 88 s^{-1}; rate = k[C$_2$H$_4$]^2
    e. 65 s^{-1}; rate = k[C$_4$H$_8$]
    f. 92 s^{-1}; rate = k[C$_2$H$_4$]^2

Integrated Rate Law: First Order $\rightarrow \ln \dfrac{[A]_o}{[A]_t} = kt$, rate = k[A]   k = rate constant

$$C_4H_{8(g)} \rightleftharpoons 2 C_2H_{4(g)} \quad \boxed{rate = k[C_4H_8]} \rightarrow \ln \dfrac{[C_4H_8]_o}{[C_4H_8]_t} = kt \quad ?$$

$$[A]_o = [C_4H_8]_o = 5M \qquad t = 0.05 s$$

$$[A]_t = [C_4H_8]_t = 0.06 M$$

$$\ln \dfrac{[5M]}{[0.06M]} = k(0.05s) \quad \text{Question: What are the units of } k? \rightarrow s^{-1} \text{ (only 1st order k)}$$

$$\downarrow$$

$$k = 88 s^{-1}$$

16.2 The decomposition of hydrogen bromide is shown below.

$$2HBr_{(g)} \rightleftharpoons H_{2\,(g)} + Br_{2\,(g)}$$
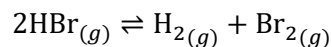
At 600 K, the rate constant is 1.50×10^{-5} L/mol s. At 800 K, the rate constant is 6.80×10^{-3} L/mol s. What is the activation energy for this reaction?

a. 1.82×10^2 kJ/mol
b. 1.39×10^2 kJ/mol
c. 1.58×10^2 kJ/mol
d. 1.22×10^2 kJ/mol
e. 2.02×10^2 kJ/mol

Arrhenius Equation $k = Ae^{-Ea/RT} \rightarrow \ln k = \ln A - \frac{Ea}{R}\left(\frac{1}{T}\right)$

$$\ln \frac{k_2}{k_1} = \frac{Ea}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$T_1 = 600K,\ k_1 = 1.50\times10^{-5}\,L/mol\cdot s$

$T_2 = 800K,\ k_2 = 6.80\times10^{-3}\,L/mol\cdot s$

$$\cfrac{(R)\ \ln\frac{k_2}{k_1} = \cfrac{Ea}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\ (R)}{\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\ \ \ \ \left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$

$$E_a = R\ln\frac{k_2}{k_1}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)^{-1}$$

$R = 8.314\ J/mol\ K$

$$E_a = (8.314\ J/mol\ K)\left[\ln\left(\frac{6.80\times10^{-3}\,L/mol\,s}{1.50\times10^{-5}\,L/mol\,s}\right)\right]\left(\frac{1}{600K} - \frac{1}{800K}\right)^{-1}$$

$$E_a = 1.22\times10^5\ J/mol = 1.22\times10^2\ kJ/mol$$

16.3 Using the information in the previous question (16.2), determine what temperature should be used if you wanted the rate to be three times as fast as it is at 600K?

a. 576 K
b. 582 K
c. <u>626 K</u>
d. 654 K
e. 730 K

What temperature for 3 times as fast?
(T_2)

to $k_1 \times 3 = k_2 \rightarrow 1.50 \times 10^{-5}$ L/mol s $\times 3 = 4.50 \times 10^{-5}$ L/mol s

Ea (from previous part) $= 1.22 \times 10^5$ J/mol

$$\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$
6?

$$\ln \left(\frac{4.50 \times 10^{-5} \text{ L/mol s}}{1.5 \times 10^{-5} \text{ L/mol s}}\right) = \frac{1.22 \times 10^5 \text{ J/mol}}{8.314 \text{ J/mol K}}\left(\frac{1}{600} - \frac{1}{T_2}\right)$$

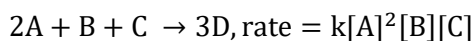$$1.09861 = 14674 \text{ K} \left(\frac{1}{600} - \frac{1}{T_2}\right)$$

$$0.00007 \text{ K}^{-1} = 0.00166 \text{ K}^{-1} - \frac{1}{T_2}$$
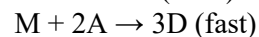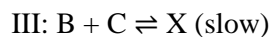
$$\frac{1}{T_2} = 0.00159 \text{ K}^{-1}$$
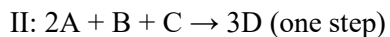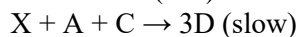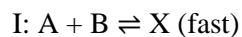
$T_2 = 626 \text{ K}$

(if calculation is done in one step → 628K)

16.4 A fictional reaction is shown below with its rate law.

$$2A + B + C \rightarrow 3D, \text{rate} = k[A]^2[B][C]$$

Which of the following mechanisms can be considered possible mechanisms for this reaction and rate law?

I: $A + B \rightleftharpoons X$ (fast)   II: $2A + B + C \rightarrow 3D$ (one step)   III: $B + C \rightleftharpoons X$ (slow)
 $X + A + C \rightarrow 3D$ (slow) $M + 2A \rightarrow 3D$ (fast)

a. I only

b. II only

c. III only

d. I and II

e. I, and III

f. I, II, and III

I. $A + B \rightleftharpoons X$ (fast)   rate $= [X][A][C] = [A][B][A][C] = [A]^2[B][C]$ ✓
   $X + A + C \rightarrow 3D$ (slow)

II. $2A + B + C \rightarrow 3D$ one step   rate $= [A]^2[B][C]$ ✓

III. $B + C \rightarrow M$ (slow)   rate $= [B][C]$ ✗
   $M + 2A \rightarrow 3D$ (fast)
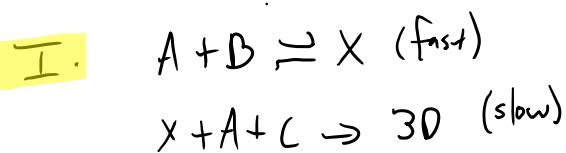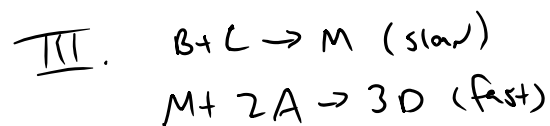
Chapter 17: Chemical Equilibrium, K & Q, Le Chatelier's Principle

17.1 Using Le Chatelier's Principle, match the correct shift for the given change.

Change		Shift	
a)	Increase in Concentration of X	I.	No shift
b)	Decrease in Concentration of X	II.	Away from heat
c)	Increase in Pressure	III.	Away from substance X
d)	Decrease in Pressure	IV.	Toward Heat
e)	Increase in Temperature	V.	Towards fewer moles of gas
f)	Decrease in Temperature	VI.	Towards substance X
g)	Catalyst	VII.	Towards more moles of gas

17.2 Ammonia is created on an industrial scale using the Haber-Bosch process shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4 \text{ kJ} * \text{mol}^{-1}$$
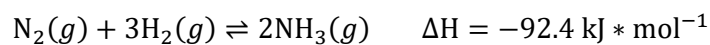
Predict the shift (left, right, or none) for each given change.

$N_2 + 3H_2 \rightarrow 2NH_3 + \Delta H$
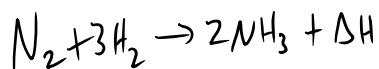
Change	Shift	
Increase [NH₃]	Left	away from NH₃
Decrease [N₂]	Left	toward N₂
Decrease [NH₃]	Right	toward NH₃
Increase Pressure	Right	toward fewer moles of gas
Increase Temperature	Left	exothermic → away from heat
Catalyst	No shift	
Increase [H₂]	Right	away from H₂

17.3 A fictional reaction is shown below.

$$A_{(g)} + B_{(g)} \rightleftharpoons 3C_{(g)} \qquad \Delta H = +36 \text{ kJ mol}^{-1}$$

To favor the production of the product (C), under what conditions should this reaction be carried out?

a. High pressure, Low temperature

b. High pressure, High temperature

c. Low pressure, High temperature

d. Low pressure, Low temperature

2 moles of gas on reactants

3 moles of gas on products

To shift to products, reduce pressure

$A + B + \Delta H \rightleftharpoons 3C$ Reaction is endo thermic (Heat is a reactant)

To shift to products, increase temperature to shift away from heat

17.4 Calculate Kc given the following reaction.

$$PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)} \qquad K_p = 4.07 \times 10^{-1} \text{ (at 226.85°C)}$$
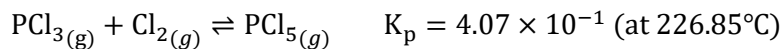
If the Qc was 20.5, is the reaction at equilibrium? Or will it proceed to the left or to the right?

a. <u>Kc=16.7, proceed left until Qc=Kc</u>

b. Kc=38.5, proceed right until Qc=Kc

c. Kc=20.5, the reaction is at equilibrium

d. Kc=30.2, proceed right until Qc=Kc

$226.85 \, C + 273.15 = 500 K$

$1 \, mol \, gas - \left(1 \, mol \, gas + 1 mol \, gas \right) = 1-2 = -1 \quad \Delta n \, gas$
$\qquad PCl_5 \qquad \quad PCl_3 \qquad Cl_2$

$K_p = K_c (RT)^{\Delta n_{gas}}$

$K_p = 4.07 \times 10^{-1}$

$R = 0.0821 \frac{atm L}{mol K}$

$T = 226.85 C + 273.15 = 500 K$

$\Delta n = 1-2 = -1$

$K_p = K_c (RT)^{\Delta n}$

$\dfrac{4.07 \times 10^{-1} = K_c \left(0.0821 \frac{atm L}{mol K} \cdot 500 K \right)^{-1}}{RT^{\Delta n}}$

$\dfrac{}{RT^{\Delta n}}$

$\boxed{K_c = 16.7}$

$Q_c = 20.5 \qquad K_c = 16.7$

$\boxed{Q > K}$

$\boxed{\text{Reaction will shift left}}$

17.5 The decomposition of phosgene is shown in the reaction below.

$$COCl_{2\,(g)} \rightleftharpoons CO_{(g)} + Cl_{2\,(g)} \qquad K_c = 6.3 \times 10^{-4} \text{ (at 500K)}$$

Calculate the equilibrium partial pressures of $COCl_2$, CO, and Cl_2 when the initial partial pressure of $COCl_2$ is 0.28 atm.

a. $COCl_2$=0.5 atm, CO=0.24 atm, Cl_2=0.014 atm

b. $COCl_2$=0.071 atm, CO=Cl_2=0.85 atm

c. $COCl_2$=0.26 atm, CO= Cl_2=0.024 atm

d. $COCl_2$=0.29 atm, CO=0.21 atm, Cl_2=0.79 atm

e. $\underline{COCl_2\text{=0.21 atm, CO= } Cl_2\text{=0.073 atm}}$

$$COCl_2 \rightleftharpoons CO + Cl_2$$
$$1\,mol\,gas \qquad 2\,mol\,gas$$
$$\Delta n = 2-1 = 1$$
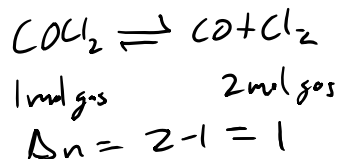
$$K_p = K_c (RT)^{\Delta n\,gas} = (6.3 \times 10^{-4})\left(0.0821\tfrac{atm\,L}{mol\,K}\,500K\right)^{1} \rightarrow K_p = 0.0258615$$

$$Q_p = \frac{P_{CO}\,P_{Cl_2}}{P_{COCl_2}}$$

	$COCl_{2\,(g)}$	$CO_{(g)}$	+ $Cl_2\,(g)$
Initial	0.28	6	0
Change	$-X$	$+X$	$+X$
Equilibrium	$0.28-X$	X	X

$$K_p = 0.0258615 = \frac{P_{CO}\,P_{Cl_2}}{P_{COCl_2}} = \frac{X^2}{0.28-X}$$

$$0.0258615\,(0.28-X) = X^2$$

$$\underset{\underset{a}{\downarrow}}{X^2} + \underset{\underset{b}{\downarrow}}{0.0258615\,X} - \underset{\underset{c}{\downarrow}}{0.007241\,22} = 0$$

$$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$X = 0.07314$$

$$COCl_2 = 0.28 - 0.07314 = 0.20686 \approx \boxed{0.21\ atm}$$

$$CO = Cl_2 = 0.07314 \approx \boxed{0.073\ atm}$$

Chapter 18: Acid-Base Equilibrium (Not all professors are covering Chapter 18)

18.1 Calculate the $[H_3O^+]$, pH, $[OH^-]$, and pOH, of 0.5 M of H_2SO_4.

a. $[H_3O^+]$= 0.5 M, pH=0.30, $[OH^-]$=2×10^{-14} M, pOH=13.70

b. $[H_3O^+]$=0.25M, pH=0.60, $[OH^-]$=5×10^{-10} M, pOH=10.5

c. $[H_3O^+]$=0.15 M, pH=0.90, $[OH^-]$=0.27 M, and pOH=13.2

d. $[H_3O^+]$=0.90 M, pH=3.1, $[OH^-]$=8.1×10^{-5} M, and pOH=10.9

$0.5 \ M \ H_2SO_4 \rightarrow$ Strong acid so completely dissociates

$\hookrightarrow \boxed{[H_3O^+] = 0.5 M}$

$\boxed{pH} = -\log [H_3O^+] = -\lg [0.5] = \boxed{0.30}$

$\boxed{[OH^-]} = \dfrac{k_w}{[H_3O^+]} = \dfrac{1 \times 10^{-14}}{0.5} = \boxed{2 \times 10^{-14} \ M}$

$\boxed{pOH} = -\log [OH^-] = -\log [2 \times 10^{-14}] = \boxed{13.70}$

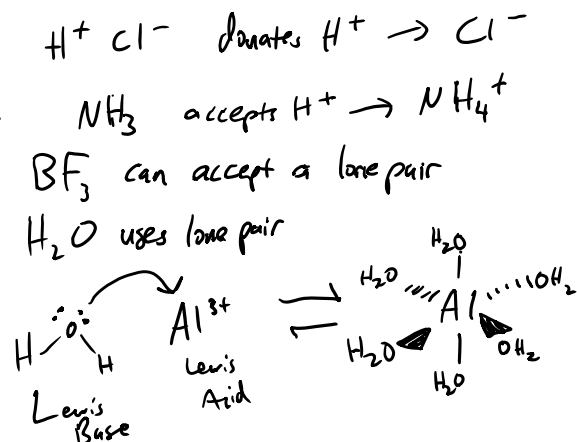$OR \quad pOH = 14 - pH = 14 - 0.3 = 13.70$

18.2 Define each of the following and provide an example.

A Brønsted-Lowry acid is a <u>proton donor</u>. An example is <u>HCl</u>.

A Brønsted-Lowry base is a <u>proton acceptor</u>. An example is <u>NH$_3$</u>.

A Lewis acid is an <u>electron pair acceptor</u>. An example is <u>BF$_3$</u>.

A Lewis base is an <u>electron pair donor</u>. An example is <u>H$_2$O</u>.

$H^+ Cl^-$ donates $H^+ \rightarrow Cl^-$

NH_3 accepts $H^+ \rightarrow NH_4^+$

BF_3 can accept a lone pair

H_2O uses lone pair

$H-\ddot{O}-H$ $Al^{3+} \rightleftharpoons H_2O\cdots Al\cdots OH_2$

Lewis Base   Lewis Acid

18.3 Methylamine (CH_3NH_2) has a K_b of 4.4×10^{-4}. What is the pH of 5 M CH_3NH_2?

a. 10.94

b. 7.62

c. 12.67

d. 13.63

$$K_b = \frac{[BH^+][OH^-]}{[B]} \qquad pK_b = -\log K_b \qquad 10^{-pK_b} = K_b$$

$$CH_3NH_{2\,(aq)} + H_2O_{(l)} \rightleftharpoons CH_3NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$$

Initial	5		0	0
change	-x		+x	+x
Equilibrium	5-x		x	x
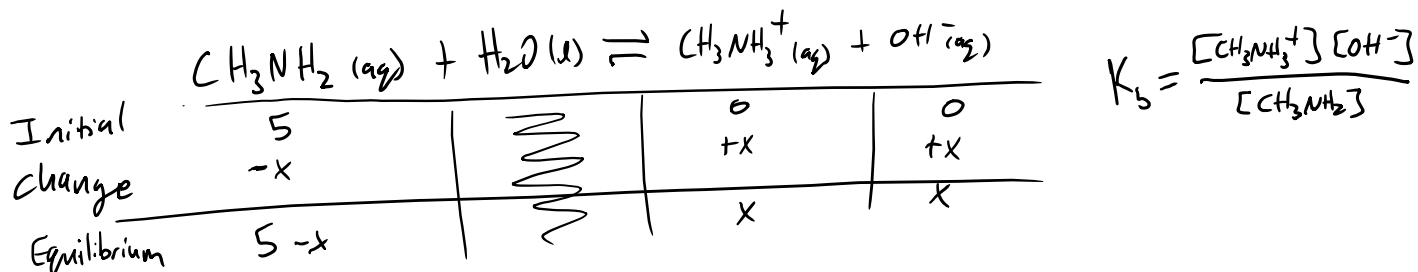
$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

Assume $5M - x \approx 5M$

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = 4.4\times10^{-4} \approx \frac{x^2}{5} \longrightarrow x = [OH^-] \approx 0.04690$$

check assumption: $\frac{0.04690}{5} \times 100\% = 0.94\% < 5\%$ ✓ok

$$pH? \longrightarrow [H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1\times10^{-14}}{0.04690} = 2.13\times10^{-13}M$$

$$pH = -\log(2.13\times10^{-13}) = \boxed{12.67}$$

18.4 Potassium propionate (KCH₃CH₂COO) is a food preservative that is most commonly used as an antimicrobial agent in bread. What is the pH of 0.38 M KCH₃CH₂COO at 298K? The K_a of propionic acid is 1.34×10^{-5}.

a. 10.13

b. 8.34

c. 9.86

d. 9.23

$$CH_3CH_2COO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3CH_2COOH + OH^-$$

	$CH_3CH_2COO^-$		CH_3CH_2COOH	OH^-
Initial	0.38		0	0
Change	$-x$		$+x$	$+x$
Equilibrium	$0.38-x$		x	x

$$K_b = \frac{K_w}{K_a} = \frac{1\times10^{-14}}{1.34\times10^{-5}} = 7.46269 \times 10^{-10}$$

Assume $0.38 - x \approx 0.38$

$$K_b = \frac{[HA][OH^-]}{[A^-]} = 7.46269 \times 10^{-10} \approx \frac{x^2}{0.38} \rightarrow x = 1.68 \times 10^{-5} M \approx 1.7 \times 10^{-5} M$$

check assumption: $\frac{1.7\times10^{-5}}{0.38} = 0.0044\% < 5\%$ ✓

$$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1\times10^{-14}}{1.7\times10^{-5}} = 5.88235 \times 10^{-10}$$

$$pH = -\log[5.88\times10^{-10}] = 9.23$$

18.5 Which of the following is a potential Lewis acid?

a. Cl⁻ → Lewis Base

b. OH⁻ → Lewis Base

Lewis acid : electron pair acceptor

c. BCl₃

d. NH₄⁺ → cannot accept an e⁻
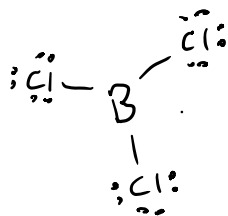
Chapter 15: Organic Chemistry (Not all professors are covering Chapter 15)

15.1 What are the names of these four structures, in order (left to right)?
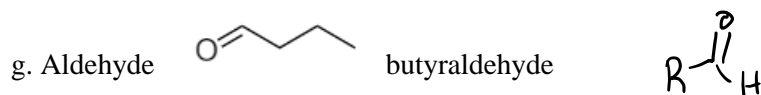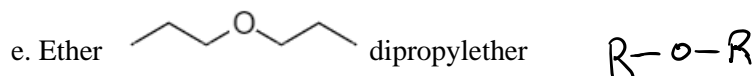
1 = meth-
2 = eth-

3 = prop-

4 = but-

5 = pent-

6 = hex-

7 = hept-

8 = octa-

9 = nona-

10 = deca

3C   4C   5C   6C
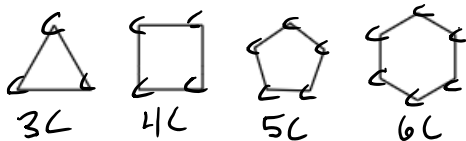
a. Cyclohexane, Cyclobutane, Cycloheptane, Cyclooctane

b. Cyclopropane, Cyclobutane, Cyclopentane, Cyclohexane

c. Cyclopropane, Cyclooctane, Cyclononane, Cyclohexane

d. Cyclobutane, Cyclopropane, Cyclohexane, Cyclononane
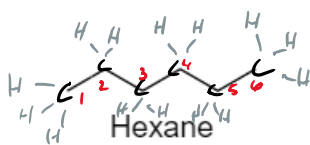
e. Cyclodecane, Cyclononane, Cyclopropane, Cyclohexane

15.2 Draw an example of each functional group.

a. Alkane ⟋⟍⟋⟍⟋ hexane $R-C-C-R$

b. Alkene ⟍⟋⟍⟋ 2-hexene $R-C=C-R$

c. Alkyne ⟍⟋≡ 2-hexyne $R-C\equiv C-R$

d. Alcohol HO⟍⟋ propanol $R-OH$

e. Ether ⟍⟋O⟍⟋ dipropylether $R-O-R$

f. Halide ⟍⟋⟍⟋Br 1-bromohexane $R-X$ $X = F, Cl, Br, I$

g. Aldehyde O⟍⟍⟋ butyraldehyde $R-\overset{O}{\overset{\|}{C}}-H$

h. Ketone ⟍⟋ acetone/2-propanone $R-\overset{O}{\overset{\|}{C}}-R$

i. Carboxylic Acid ⟍⟋⟍OH propionic acid/methyl acetic acid $R-\overset{O}{\overset{\|}{C}}-OH$

j. Ester ⟍⟋⟍O⟍ ethyl propanoate $R-\overset{O}{\overset{\|}{C}}-O-R$ $R \neq H$

k. Amine ⟍N⟍⟋ N-methyl-1-propanamine $R-NH$
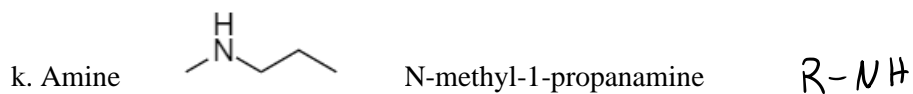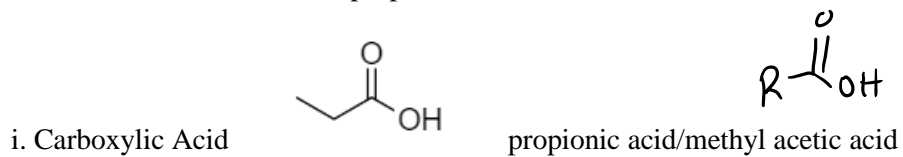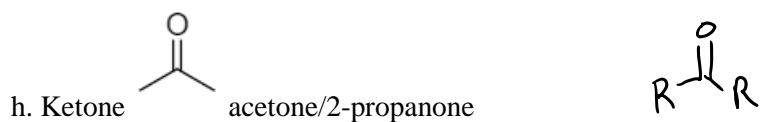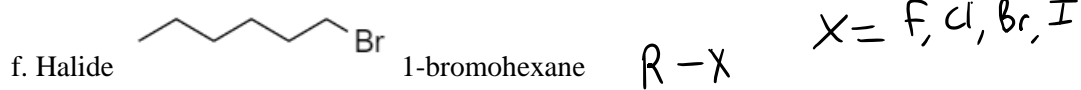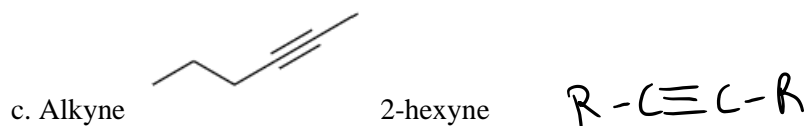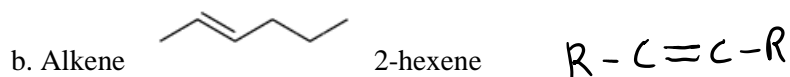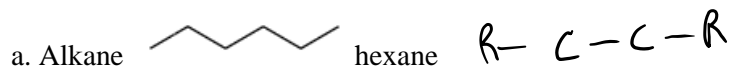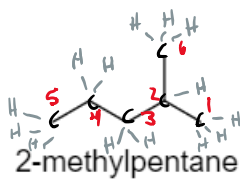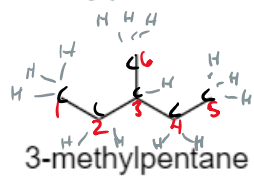
15.3 C₆H₁₄ has 5 different constitutional isomers. Draw each and name according to IUPAC naming rules.

Hexane

a.

2-methylpentane

b.

3-methylpentane

c.

2,2-dimethylbutane

d.

2,3-dimethylbutane

e.