Answers to Practice Test Questions 10
Nonmetals Part 1 (Hydrogen and Acids)

1.

(a) ^{1}H (protium)

^{2}D or ^{2}H (deuterium)

^{3}T or ^{3}H (tritium)

(b) Being the lightest element, hydrogen is the element which has the largest relative difference in mass between its isotopes. The atomic mass of deuterium is twice as large as that of protium, and the atomic mass of tritium is three times as large as that of protium. This means that many physical properties of deuterium (or tritium) compounds are measurably different than those of the corresponding protium compounds. The differences between the masses of different isotopes of the larger elements (e.g. ^{35}Cl vs. ^{37}Cl) are much smaller.

2. *Only one answer required for each blank; "/" indicates possible choices*

(a) donor

(b) donor

(c) *many possible answers including* BF_3 / $AlCl_3$ / CO_2 / Fe^{3+} *(or most other metal cations)*

(d) Cr^{3+} ; water; less than

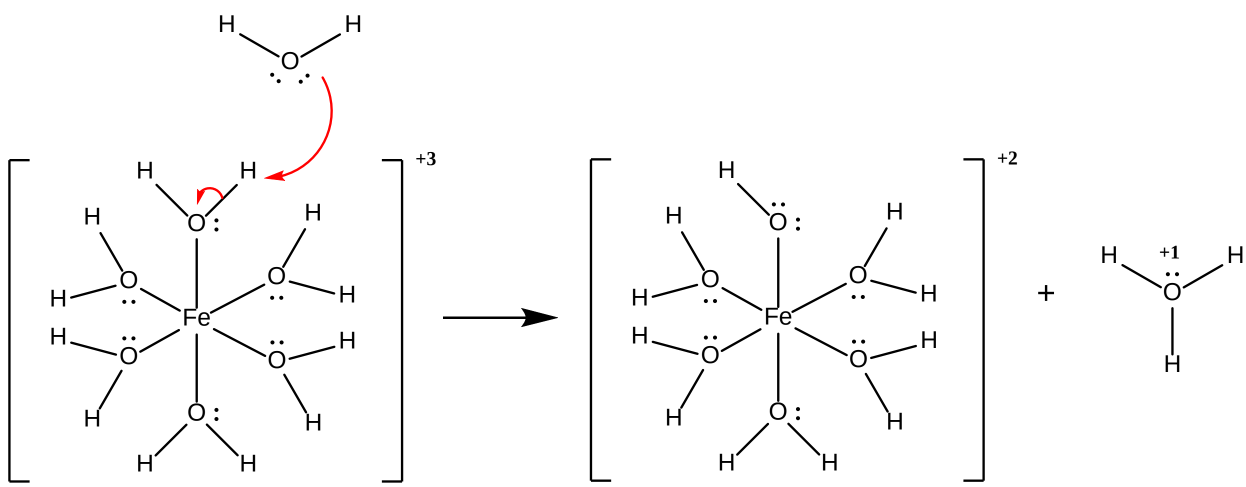
(e) lower

(f) more

3. $H^{-} + H_2O \rightarrow H_2 + OH^{-}$

Hydride is a very strong base. It cannot be a Brønsted acid because if H^{-} *gives up* H^{+}*, we are left with just a pair of electrons!*

4. When $Fe(NO_3)_3$ is dissolved in water, the ions dissociate and the iron cation becomes solvated with water *(see Lewis diagram on left)*. This aqua complex is highly acidic – hence the pH below 7. The main reason that $[Fe(OH_2)_6]^{3+}$ is acidic is the large positive oxidation state of iron(III) , which pulls electron density toward the center of the complex (away from the hydrogen atoms), making it easy for a weak base such as water to remove H^{+} from one of the aqua ligands, *as shown in the reaction equation below*. This generates the H_3O^{+} responsible for the low pH of the solution.



5.

(a) Al^{3+}

The two ions have the same charge, but Al^{3+} has a smaller radius so its charge density is greater. As such, Lewis bases will be more strongly attracted to Al^{3+}, making it the stronger Lewis acid.

(b) Sc^{3+}

The two ions have similar radii, but Sc^{3+} has a greater positive charge so its charge density is greater. As such, Lewis bases will be more strongly attracted to Sc^{3+}, making it the stronger Lewis acid.

(c) Ag^{+}

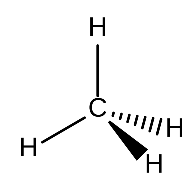
The two ions have the same charge, but Ag is substantially more electronegative than Na. As such, Ag^{+} attracts electron density toward itself more strongly than does Na^{+}.

6.

(a) neither

CH_4 is not a Lewis base because it has no lone pairs* to donate.

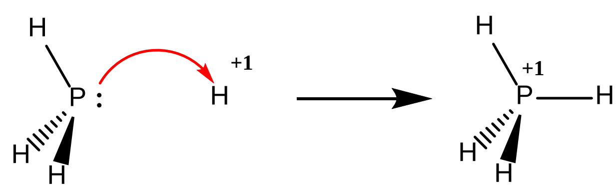
CH_4 is not a Lewis acid because it has no positive or partially positive atoms with the capacity to make an additional bond.



**or π electrons (see CHEM 2000)*

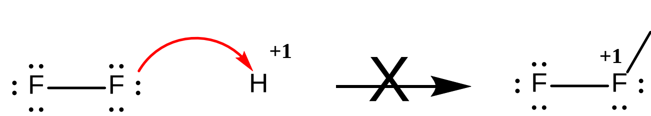
(b) Lewis base

The phosphorus atom of PH_3 has a lone pair and, since phosphorus has a moderate electronegativity, it can take on a + charge in the Lewis acid-base complex formed when that lone pair is donated to a Lewis acid:



(c) neither

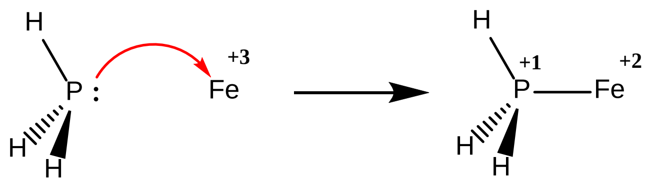
While F_2 has many lone pairs, if it were to donate one to a Lewis acid, that would generate an F^+ atom – which is highly unstable due to the large electronegativity of fluorine:



F_2 is not a Lewis acid because it has no positive or partially positive atoms with the capacity to make an additional bond.

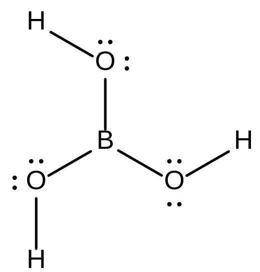
(d) Lewis acid

Fe^{3+} is a good Lewis acid because it is an atom with a positive charge and the capacity to accept electrons by forming an additional bond:



7.

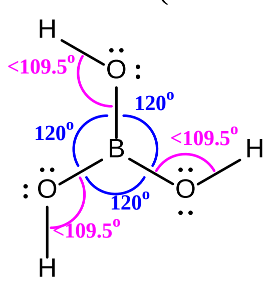
(a)



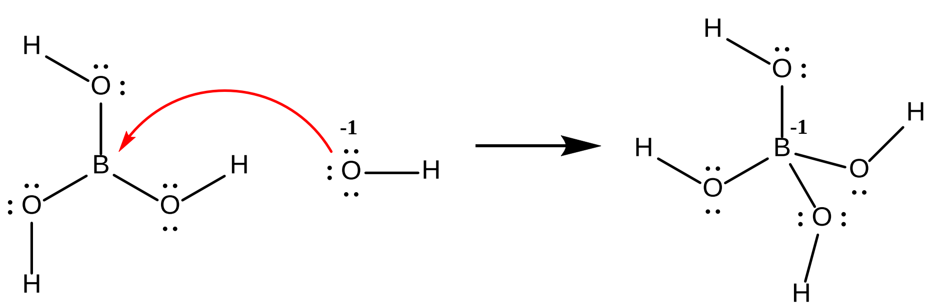
(b) B is trigonal planar

all three O are bent (tetrahedral electron group geometry)

(c)

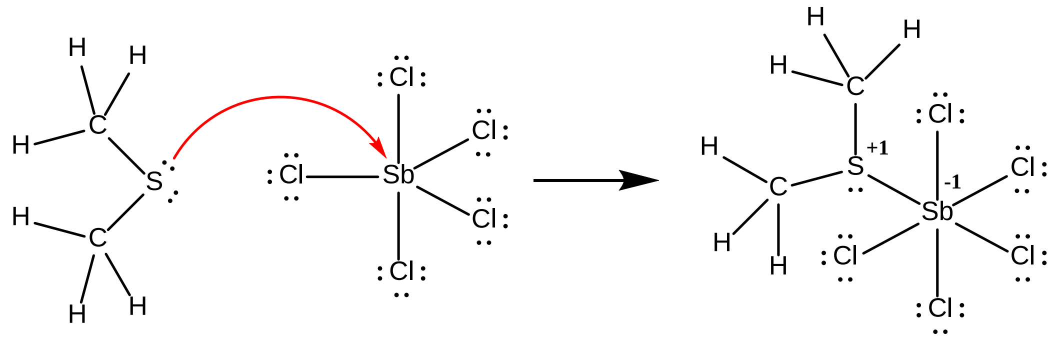


(d)



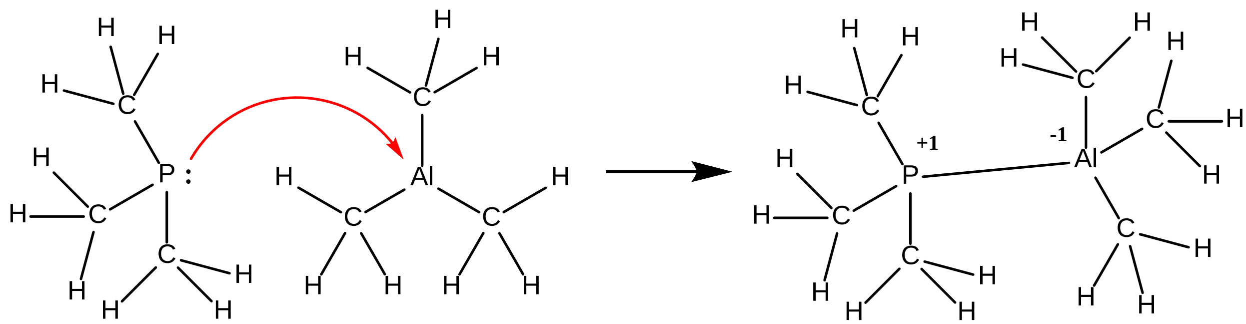
8.

(a)



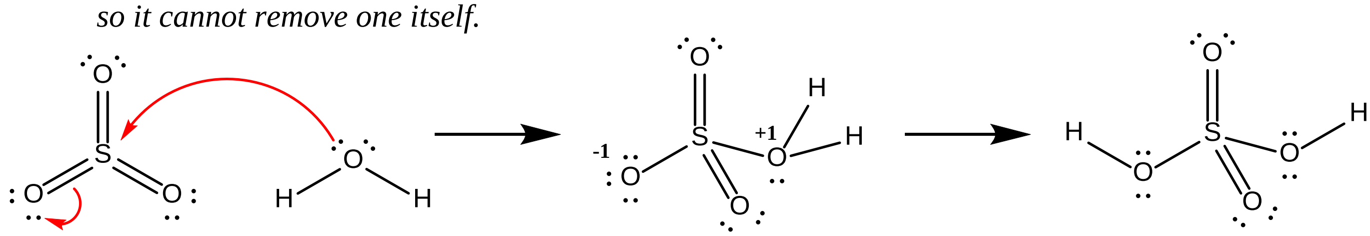
Lewis base Lewis acid

(b)



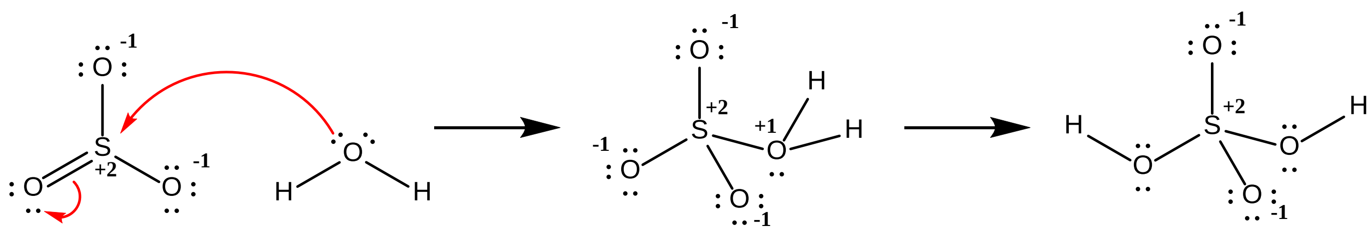
Lewis base Lewis acid

9. *The second step is shown to remind you of the correct Lewis diagram for H_2SO_4. You are only expected to show electron movement using curly arrows for the first step. In the second step, two things must happen: a water molecule must remove one H^+ bonded to the positively charged O, and the negatively charged O must acquire H^+ (most easily shown as removing H^+ from an H_3O^+ ion). The O^- cannot reach either of the H attached to O^+ so it cannot remove one itself.*



Lewis acid Lewis base

or



Lewis acid Lewis base

10. Acid HX has a lower pK_a so it is stronger.

The pK_a is 5 units lower, so acid HX is 10^5 = 100,000 times stronger than acid HY.

Like pH, pK_a is a logarithmic scale, so a difference of 1 pK_a unit corresponds to a tenfold difference in acidity.

11.

(a) The pK_a of a strong acid is negative.

When a strong acid is dissolved in water, it dissociates fully. This means that HCl(aq) does not actually contain HCl. It contains H^+(aq) (which may also be written as H_3O^+(aq)) and Cl^-(aq).

(b)	HCl(aq)	+	NaOH(aq)	→	NaCl(aq)	+	H_2O(l)
$c_{initial}$	0.1234 mol/L		0.1789 mol/L				
V_{inital}	36.25 mL		25.00 mL				
$n_{initial}$	0.004473 mol		0.004473 mol				
n_{change}	-0.004473 mol		-0.004473 mol				
n_{final}	0 mol		0 mol				

Step 1: Write a balanced chemical equation for the reaction

see above

Step 2: Organize all known information

see above

Step 3: Calculate moles of HCl ($n_{initial}$)

$$n_{HCl} = 0.1234\frac{mol}{L} \times 36.25\ mL \times \frac{1L}{1000mL} = 0.004473\ mol$$

Step 4: Use mole ratio to calculate moles of NaOH reacted ($n_{initial}$)

$$n_{NaOH} = 0.004473\ mol\ HCl \times \frac{1\ mol\ NaOH}{1\ mol\ HCl} = 0.004473\ mol\ NaOH$$

Step 5: Calculate concentration of NaOH(aq) ($c_{initial}$)

$$c_{NaOH} = \frac{n_{NaOH}}{V_{NaOH}} = \frac{0.004473\ mol}{25.00\ mL} \times \frac{1000\ mL}{1\ L} = 0.1789\ \frac{mol}{L}$$

Step 6: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

The volume of NaOH was less than the volume of HCl and they react in a 1 : 1 mole ratio, so it makes sense that the concentration of NaOH(aq) is higher than that of HCl(aq) (but is of the same order of magnitude).

While you probably didn't do a titration calculation in lecture, it's just stoichiometry. And you should have done lots of them in lab! ☺

12.

(a) X = Ca   Y = CaH_2

(b) $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

(c) $CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$

(d) Measure the amount of H_2 produced.

The molar masses of Ca and CaH_2 are very similar (40 g/mol and 42 g/mol respectively). So, if the same mass of each reactant was used, the number of moles would be approximately the same.

Since every mole of CaH_2 produces <u>two</u> moles of H_2 while every mole of Ca only produces <u>one</u> mole of H_2, the solid which produces more H_2 per mole (and therefore per gram) will be CaH_2.