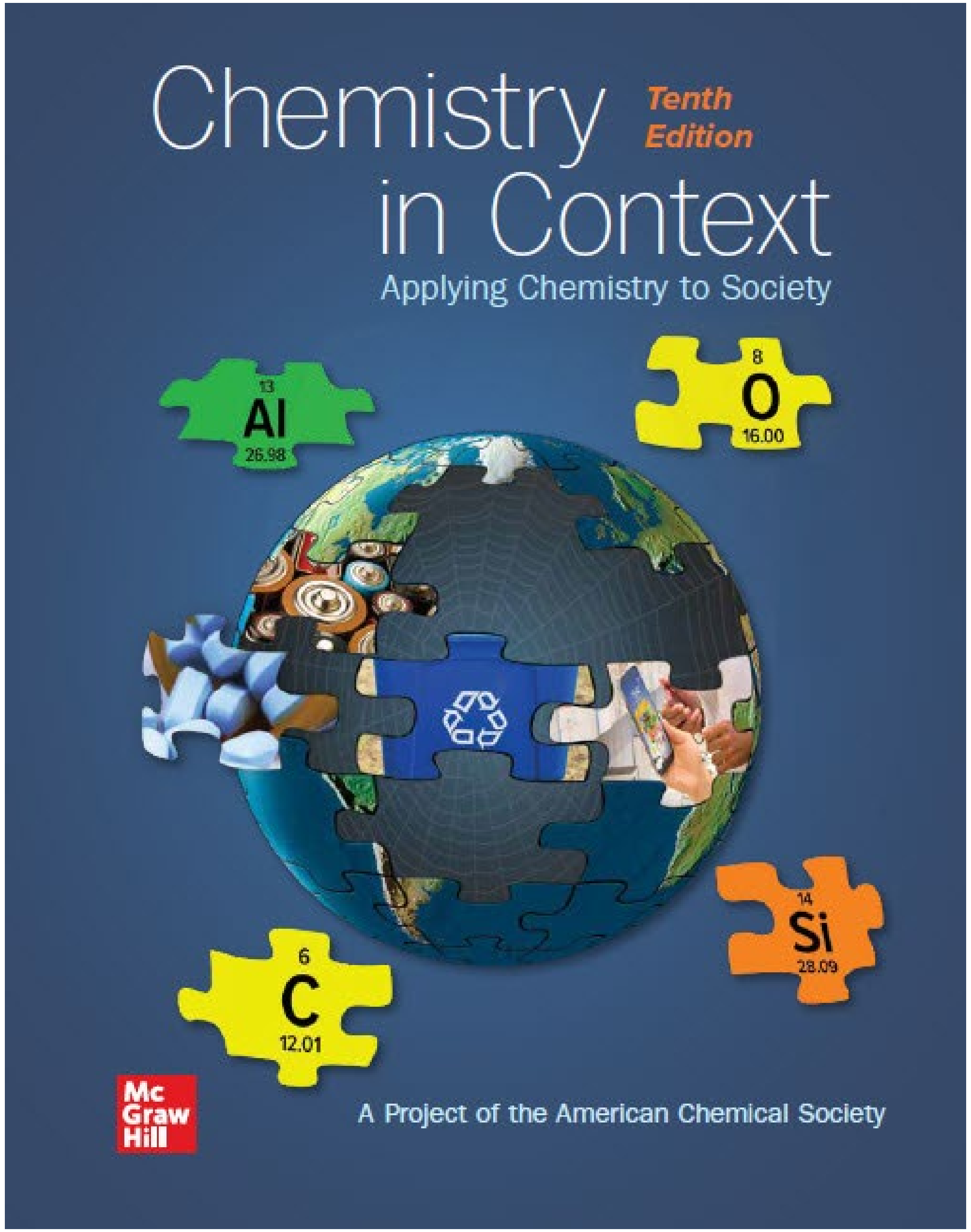
General Chemistry (CH101): Chemistry around Us

Department of Chemistry

KAIST

Chapter 04

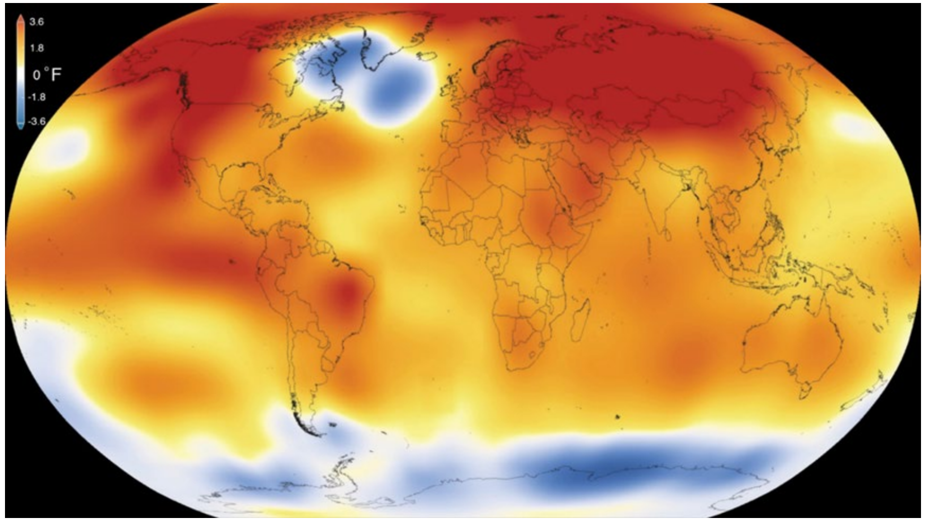
Climate Change



Chapter 4
Climate Change

- What are the sources of carbon on Earth?
- How does carbon move between reservoirs, and how do scientists measure this?
- What are “greenhouse gases,” and what are their positive and negative effects?
- What are the global consequences of climate change?
- How do our current climate trends differ from the past?
- How can my daily actions affect the global environment?

Reflect



Climate Change

Watch the chapter opening video (www.acs.org/cic). The controversial topic of climate change has been widely portrayed in the media. Answer these questions based on your current knowledge.

a. Do you think the warming effect of greenhouse gases is beneficial or harmful? Why?

b. Where does the carbon dioxide in the air come from?

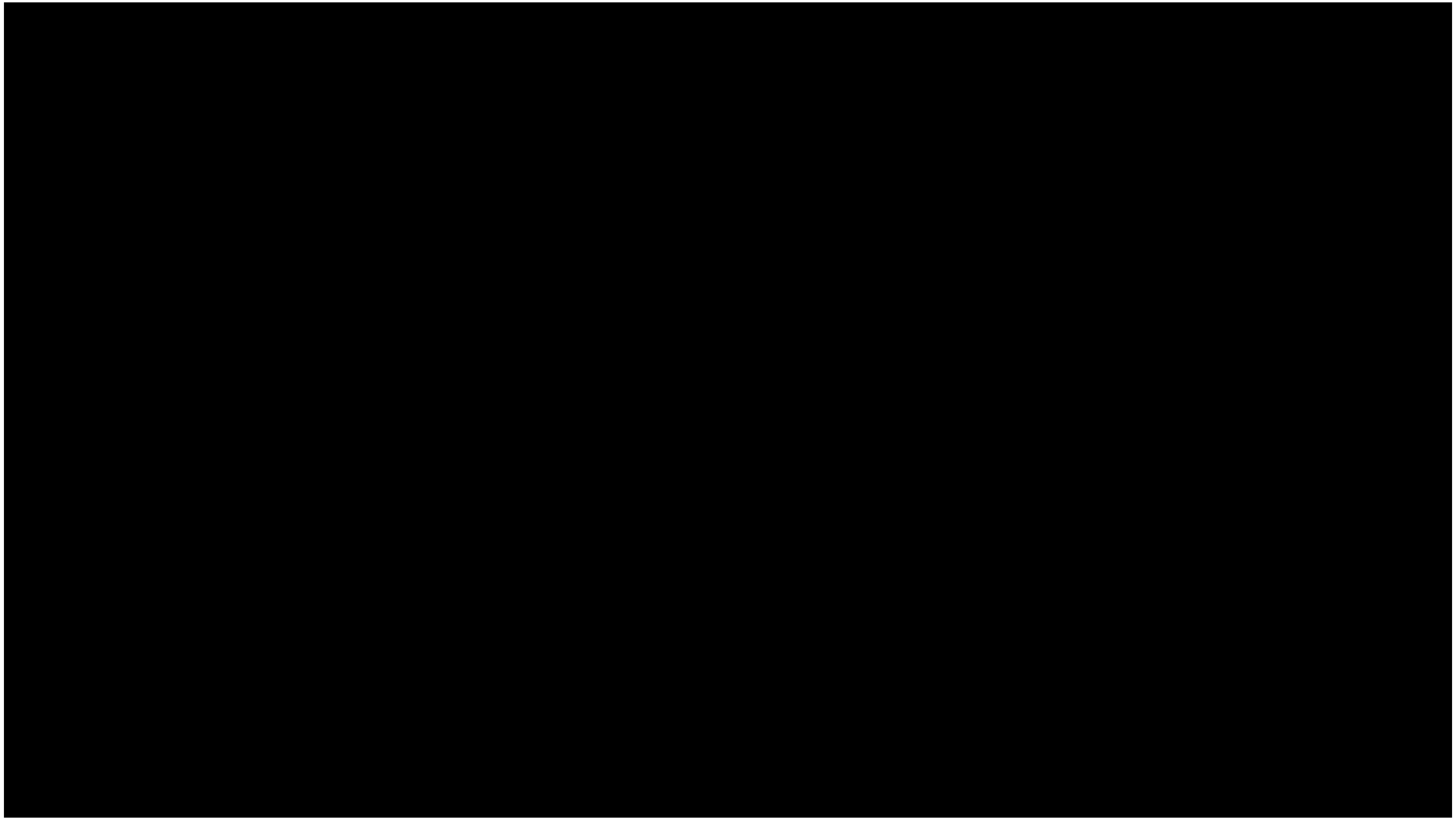
c. What is climate change?

d. Is there evidence that climate change is occurring now? Explain.

Chapter 4 video

https://www.acs.org/education/resources/undergraduate/chemistryincontext/interactives/climate-change/chapter-opening.html

Source:Scientific Visualization Studio/Goddard Space Flight CenterNASA

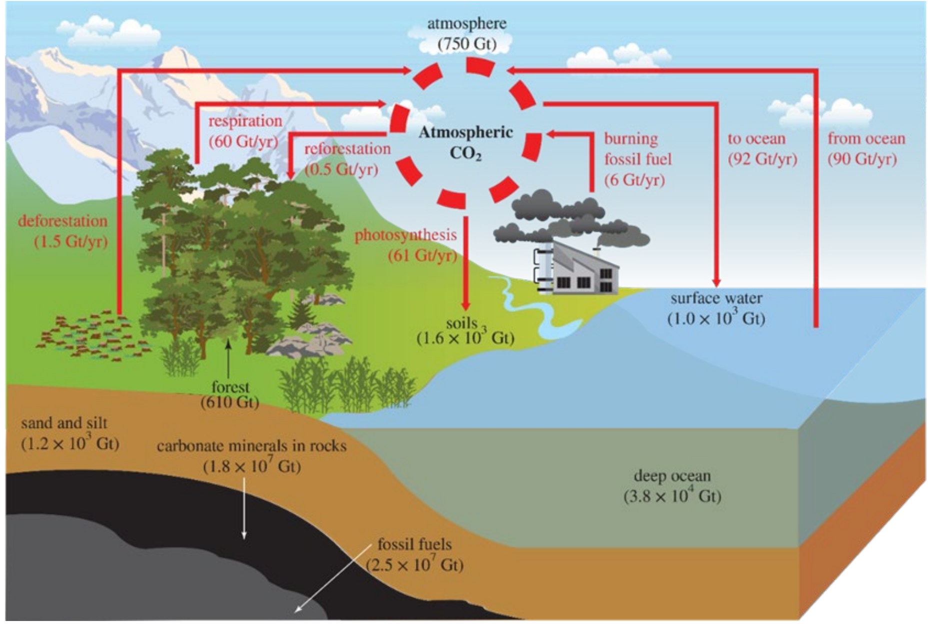


https://youtu.be/E8Y6L5TI_94?si=vIcPZfwFFe9lLBIW

The Carbon Cycle

There are four main reservoirs for carbon:

1. Atmosphere, in the form of carbon dioxide (400 ppm), methane (1.8 ppm), and carbon monoxide (trace amounts).
2. Carbonate-containing rocks, fossil fuels, and soils.
3. Plants and animals, where carbon atoms are combined with hydrogen, oxygen, and nitrogen.
4. Dissolved in surface and ocean water.



How much additional carbon accumulates in the atmosphere in a year?

Source:Purves, Orians, Heller, and Savada, The Science of Biology, 5th ed., 1998, p. 1186.

Ions

- Carbon found in rocks are part of **ionic compounds**, typically carbonates.
- **Ions** are an atom or group of atoms that have gained or lost one or more electrons and have become charged.
- Atoms that lose an electron become positively charged and are called **cations.**
- Atoms that gain an electron become negatively charged and are called **anions.**

$$\mathrm{Na} \rightarrow \mathrm{Na}^{+} + e^{-}$$

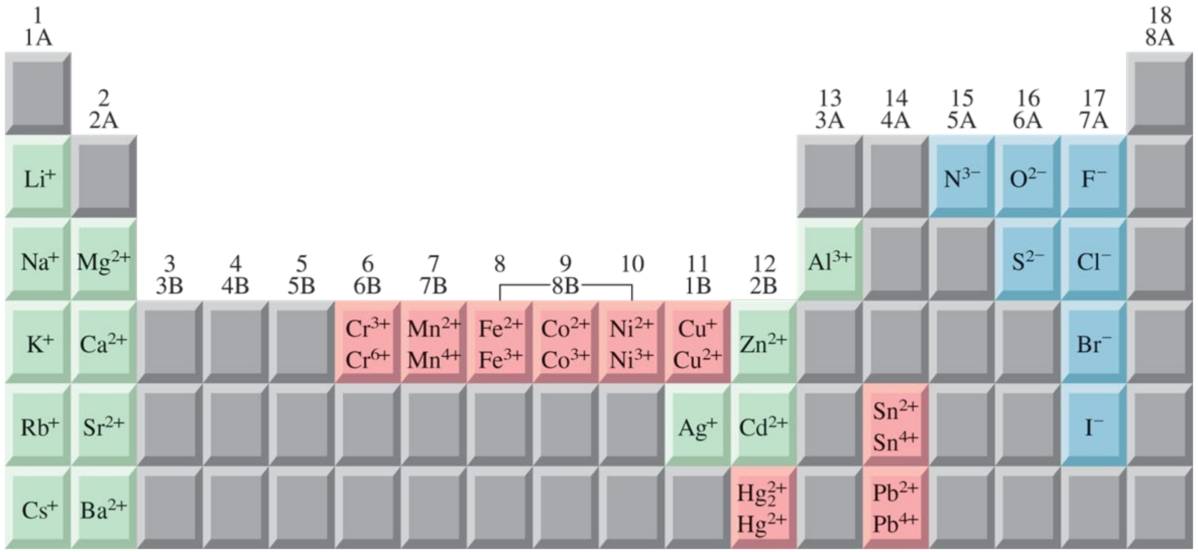
e^{-} are electrons

$$\mathrm{Cl} + e^{-} \rightarrow \mathrm{Cl}^{-}$$

Ion Charges

Ionic compounds generally contain both a metal and a nonmetal

Common ion charges:



The preferred ionic charge for a particular element is based on their group number:

Elements from Groups 1 and 2 form cations with +1 and +2 charges

Elements from Groups 16 and 17 form anions with −2 and −1 charges

Naming Ionic Compounds

Naming ionic compounds is slightly different than naming molecular compounds

- Cation is listed first, then anion.
- Suffix of the second element is changed to –*ide* (oxygen → oxide).
- Prefixes are not used.

MgO	**NaBr**
magnesium oxide	**sodium bromide**

- Use Roman numerals for transition metals with multiple possible charges – numeral refers to the charge of the metal.

FeO	**Fe_2O_3**
Iron (II) oxide	**Iron (III) oxide**

Your Turn [1]

Your Turn 4.3 Forming Ionic Compounds

Each pair of elements forms one or more ionic compounds. For each, write all of the possible chemical formulas and names.

a. Ca and S

b. F and K

c. Mn and O

d. Cl and Al

e. Co and Br

Polyatomic Ions

Ions that are made of more than one atom bonded together are called polyatomic ions

- Polyatomic ions are fairly stable and often stay together in a reaction.
- Most are negatively charged.

Table 4.3 Common Polyatomic Ions

Name	Formula	Name	Formula
acetate	$C_2H_3O_2^-$	nitrite	NO_2^-
bicarbonate*	HCO_3^-	phosphate	PO_4^{3-}
carbonate	CO_3^{2-}	sulfate	SO_4^{2-}
hydroxide	OH^-	sulfite	SO_3^{2-}
hypochlorite	ClO^-	ammonium	NH_4^+
nitrate	NO_3^-		

*Also called hydrogen carbonate

More Naming Ionic Compounds

Ionic compounds with polyatomic ions use the name of the polyatomic ion as- is (do not change the suffix)

K_2CO_3	NH_4Br
potassium carbonate	**ammonium bromide**

Your Turn 2

Your Turn 4.5 Polyatomic Ions II

Name each of these compounds.

a. KNO_3 **b.** $(NH_4)_2SO_4$

c. $FeSO_4$ **d.** $NaHCO_3$

e. $Mg_3(PO_4)_2$

Your Turn 4.6 Polyatomic Ions III

Write the chemical formula for each of these compounds.

a. sodium hypochlorite (an ingredient found in common household bleach)

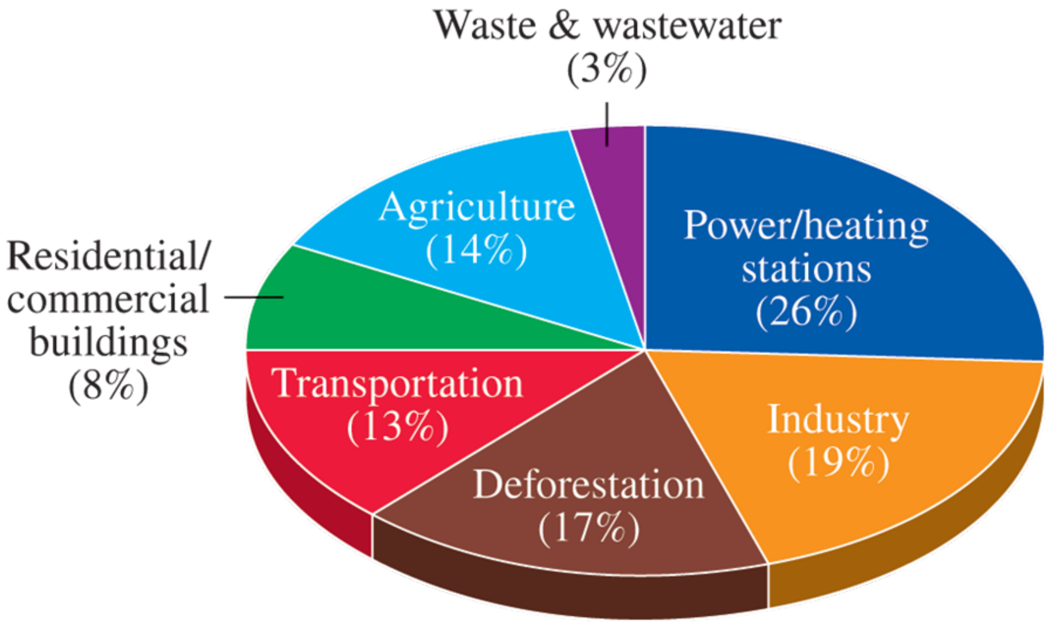
b. magnesium carbonate (found in limestone rocks)

c. ammonium nitrate (an active ingredient in some fertilizers)

d. calcium hydroxide (an agent used in water purification)

Global Carbon Dioxide Emissions

- Burning fuel for electricity, transportation, and heating are major contributors to carbon dioxide emissions.
- Every second, enough rain forest is cut down or burned to cover two football fields.



Source: EPA

Quantifying Carbon: Atomic Mass

- The atomic mass on the periodic table is the weighted average of the naturally occurring isotopes of the element.
- **Isotopes** have equal numbers of protons, but different amounts of neutrons.
- Mass number: number of neutrons + number of protons.

Table 4.4 Isotopes of Carbon

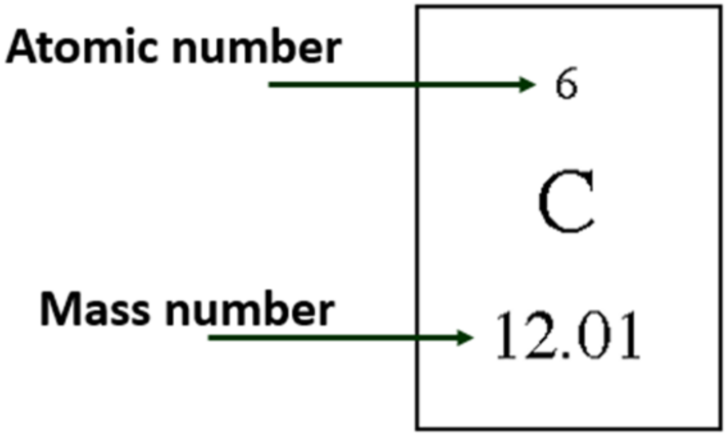
Isotope	Mass Number	Relative Percent	Contribution to Relative Atomic Mass*
C-12	12	98.90%	11.868
C-13	13	1.10%	0.143
C-14	14	~0.001%	0.0001
			Avg. atomic mass of C = 11.868 + 0.143 + 0.0001 = 12.011

* Calculated as the relative percent × mass number. For instance, 98.90% of the C-12 isotope is 0.9890 × 12 = 11.868.

Isotopes and Atomic Mass

Using the Atomic Mass: The Mole

- A **mole** is defined as the number of carbon atoms in exactly 12 g of pure carbon-12.
- This number is known as Avogadro's number $1\,\text{mole} = 6.022 \times 10^{23}$



- One mole of atoms of any element has a mass in grams equal to the atomic mass of the element.

[Mole Day – Avogadro & The Mole]

What is a mole in chemistry?

COMPOUND INTEREST

What is a mole?

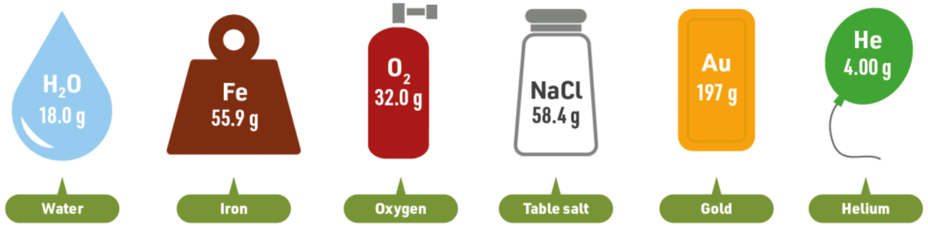
One mole is the amount of substance that contains exactly 6.02214076 × 10^{23} atoms, molecules or ions. This number is also known as 'Avogadro's number'. It's named after Italian scientist Amedeo Avogadro (left), a suggestion put forward by French scientist Jean Perrin to recognise Avogadro's work. 'Mole' derives from molecule – it's not related to the animal.

602,214,076,000,000,000,000,000

The number of atoms, molecules or ions in one mole of a substance

Atoms, molecules and ions are very small and impossible for chemists to count. Using the mole makes it easier to talk about amounts of substances involved in reactions, by relating the mass of a substance to its atomic or molecular mass.

Amount of substance = mass (g) ÷ mass of 1 mole (g mol^{-1})



One mole contains a different mass for different substances

This makes sense if you think about it. Different substances will have atoms, molecules or ions which have different masses. Gold atoms have a greater mass than iron atoms, so the mass contained in one mole of gold atoms is greater.

Coins and moles: A useful analogy

Using moles to express amount of substance is analogous to weighing coin rolls to estimate the number of coins. In this analogy, the value of the coins is like mass (different for different coins), the number of coins is like number of atoms, and the rolls of coins are like moles of atoms.

Counting Atoms: Avogadro's Number

The same number of objects will have a different mass.

Avogadro's number is the number of atoms in a mole of atoms:

- Like 12 is a dozen, or 20 is a score, or 100 is a century, etc.
- 1 mole of anything equals 6.022×10^{23} of that substance.

Your Turn 3

Your Turn 4.10 Marshmallows and Pennies

Avogadro's number is so large that the only way to visualize it is through analogies. For example, an Avogadro's number of regular-sized marshmallows, 6.02×10^{23} of them, would cover the surface of the United States to a depth of 650 miles. Or, if you are more impressed by money than marshmallows, assume 6.02×10^{23} pennies were distributed evenly among the approximately 7.5 billion inhabitants of Earth. Every man, woman, and child could spend $1 million every hour, day and night, and half of those pennies would still be left unspent by the time each person passes away. Can these fantastic claims be correct? Check one or both, showing your reasoning. Come up with an analogy of your own.

Molar Mass

- The atomic mass listed for each element are for 1 mole.
- The molar mass of a compound is calculated by simply adding up the atomic masses for the different types of atoms.

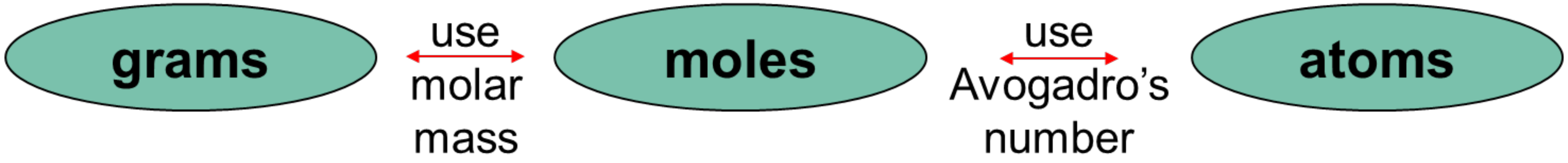
1 mole of NaCl = 22.99 g/mol Na + 35.45 g/mol Cl = 58.44 g/mol

1 mole of $LiNO_3$ = 6.941 g/mol Li + 14.01 g/mol N + (3 × 15.999 g/mol O)

= 68.95 g/mol

Mole Calculations

- Be aware of what units you are starting from and where you are going.
- Use these relationships:



If you have 36.0 grams of carbon, how many atoms do you have?

$$36.0\ \cancel{\text{g C}} \times \frac{1\ \text{mole C}}{12.01\ \cancel{\text{g C}}} = 3.00\ \text{moles C}$$

$$3.00\ \cancel{\text{moles C}} \times \frac{6.022\times10^{23}}{1\ \cancel{\text{mole C}}} = 1.81\times10^{24}\ \text{atoms C}$$

Your Turn

Your Turn 4.11 Calculating the Mass of Atoms

Follow these instructions for the three examples:

i. Predict whether the value will be large or small.

ii. Calculate the value.

iii. Do your calculations match your predictions? Think about whether your predictions were reasonable.

a. The average mass in grams of an individual atom of carbon.

b. The mass in grams of 5 trillion carbon atoms.

c. The mass in grams of 6×10^{15} carbon atoms.

Carbon Dioxide Emissions: Calculations

With a knowledge of atomic and molar mass, let's calculate how much carbon dioxide is produced from burning 3.3 gigatonnes (Gt) of coal (carbon)

- The molar mass of carbon dioxide is 44.0 g/mol (12.01 + (2 × 16)).
- The atomic mass of carbon is 12.01 g/mol.
- Therefore, the mass ratio of CO_2 / C = 44.0 g / 12.01 g (or 44.0 Gt carbon dioxide for every 12.01 Gt of carbon):

$$3.3\ \cancel{\text{Gt C}} \times \frac{44.0\ \text{Gt CO}_2}{12.01\ \cancel{\text{Gt C}}} = 12\ \text{Gt CO}_2$$

Carbon Dioxide Emissions: More Calculations

How many molecules of carbon dioxide are in 12 Gt? We need to use our knowledge of Avogadro's number and moles.

The molar mass of carbon dioxide is 44.0 g/mol (12.0 + (2 × 16.0))

We must first convert 12 gigatonnes to grams $(\text{note: } 1\ \text{Gt} = 1\times10^{15}\ \text{g})$:

$$12\ \text{Gt CO}_2 \times \frac{1\times10^{15}\ \text{g CO}_2}{1\ \text{Gt CO}_2} = 1.2\times10^{16}\ \text{g CO}_2$$

Next, convert grams to moles:

$$1.2\times10^{16}\ \text{g CO}_2 \times \frac{1\ \text{mole CO}_2}{44.0\ \text{g CO}_2} = 2.7\times10^{14}\ \text{moles CO}_2$$

Finally, use Avogadro's number to calculate the number of molecules:

$$2.7\times10^{14}\ \text{moles CO}_2 \times \frac{6.02\times10^{23}\ \text{molecules CO}_2}{1\ \text{mole CO}_2} = 1.6\times10^{38}\ \text{molecules!!}$$

Your Turn

Your Turn 4.17 Checking Carbon from Cars

A clean-burning automobile engine emits about 5 lb of C atoms in the form of CO_2 molecules for every gallon of gasoline it consumes. The average American car is driven about 12,000 miles per year. Using this information, check the statement that the average American car releases its own weight in carbon into the atmosphere each year. List the assumptions you make to solve this problem. Compare your list and your answer with those of your classmates.

Counting Significant Figures

All non-zero digits are significant

- 1.55 g has 3 sig. figs.

All zeroes embedded between non-zero digits are significant

- 1.003 mL has 4 sig. figs.

Trailing zeros in a number with a decimal place are significant

- 1.000 g has 4 sig. figs.
- 1000 g has 1 sig. fig.

Leading zeroes are not significant

- 0.00305 mL has 3 sig. figs.

Your Turn 4.14 Significant Figures, Part 1

For each of the values below, determine the number of significant figures.

a. 100.0 mL **b.** 60.1 g **c.** 0.0001 L **d.** 1.003 g

Calculating with Significant Figures

Addition & subtraction: Answer based on the smallest number of **decimal places**.

- 1.003 g + 0.2 g + 0.001 g = 1.2 g

Multiplication & division: Answer based on the smallest number of **significant figures**.

- $1.002\ \text{cm} \times 0.005\ \text{cm} = 0.005\ \text{cm}^2$

Your Turn 4.15 Significant Figures, Part 2

For each of the following, report the answer to the correct number of significant figures. Remember to also include the correct unit for each of the calculations.

a. 5.0 g ÷ 0.31 mL **b.** 15.0 m × 0.003 m

c. 1.003 g + 0.01 g **d.** 1.000 mL − 0.1 mL

Based on the distance between the Sun and earth and the amount of solar radiation that reaches the earth

➔ The average temperature on earth should be -18 ºC

➔ But real avg. temp. is 15 ºC.

Based on the distance between the Sun and Venus and the amount of solar radiation that reaches Venus

➔ The average temperature on earth should be 100 ºC

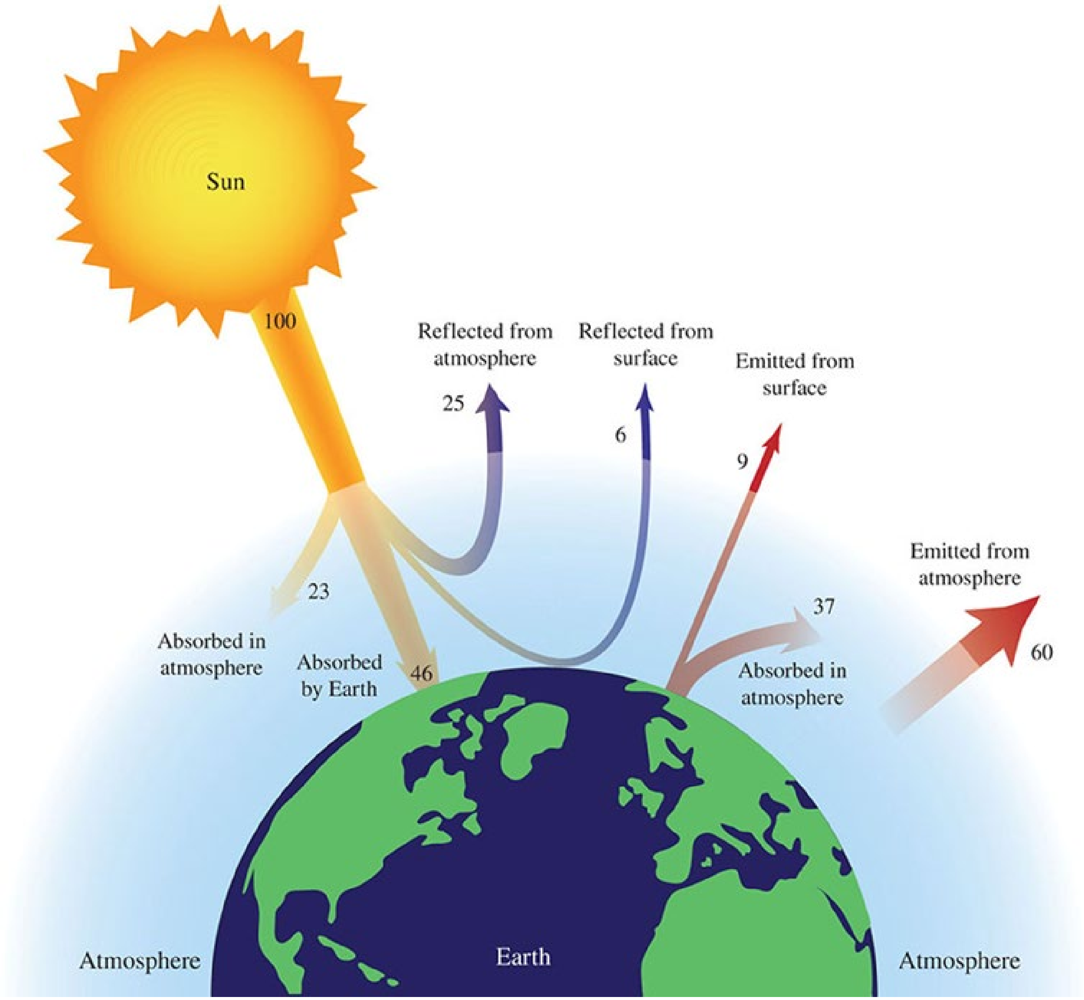
➔ But real avg. temp. is 450 ºC.

Why?

https://youtu.be/zE3x2wjslt0?si=5dW2GZZB1VjVhw2v

Earth’s Energy Balance

- 46% of the Sun’s radiation is absorbed by Earth.
- Of that 46% absorbed, 37% is reemitted in the form of infrared (IR) radiation that is absorbed by the atmosphere.
- This results in a **greenhouse effect**, with an average temperature on Earth of 15 °C.
- Without this natural balance, the average temperature of Earth would be −18 °C.



Greenhouse Gases: Molecular Shapes Matter

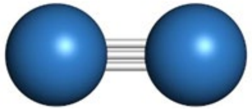
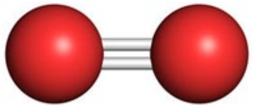
About 80% of infrared radiation emitted by Earth is absorbed by atmospheric gases.

- Absorption of IR radiation causes molecular vibrations such as bending and stretching.

Why do carbon dioxide and water vapor absorb IR, but nitrogen and oxygen do not?

Vibrations are related to the shape of the molecule.



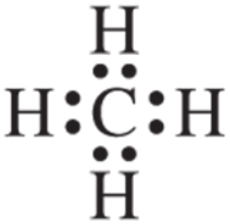



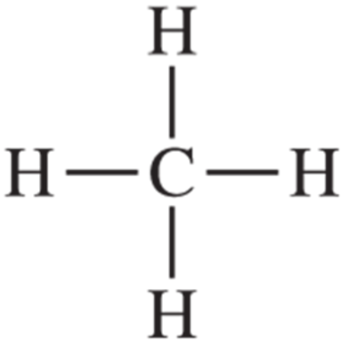
https://acswebcontent.acs.org/ChemistryInContextSuite/applets/ozone/ozone.html

Representations of Methane

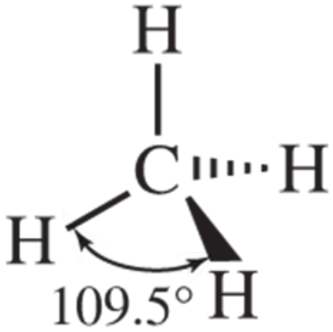
The molecular formula does not express connectivity (CH_4)

Structural formulas show how atoms are connected:

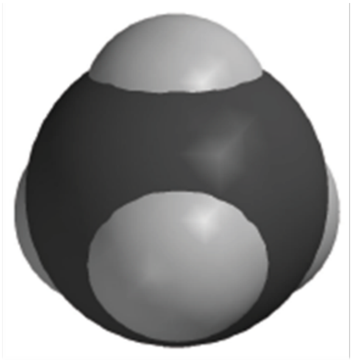




Lewis structures show connectivity



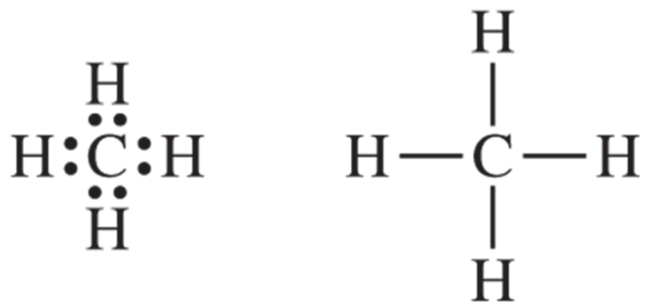
This Lewis structure is drawn in 3-D



Space-filling model

Valence Shell Electron Pair Repulsion Theory

- VSEPR assumes that the most stable molecular shape has the electron pairs surrounding a central atom as far away from one another as possible.



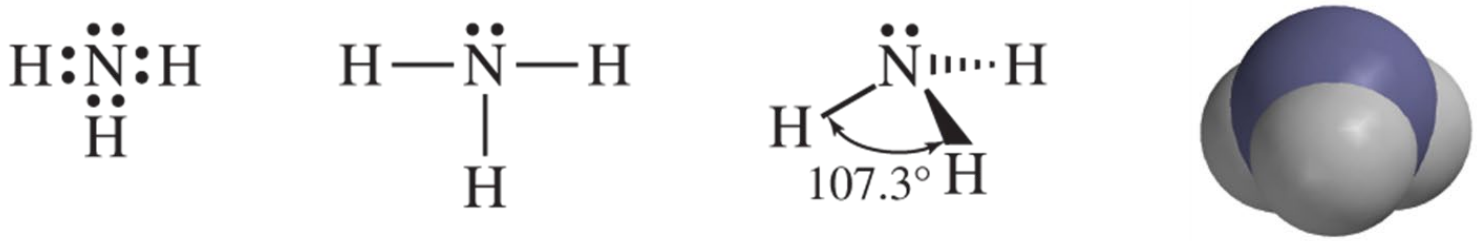
- Four electron pairs as far from each other as possible indicates a tetrahedral arrangement.
- A tetrahedral-shaped molecule has bond angles of 109.5°.

Rotatable model of methane in MolView

Lone Pairs of Electrons

The central atom in a molecule must have non-bonding electron pairs known as **lone pairs**.

- A lone pair of electrons occupies a greater space than a bonding electron pair.



The electron pairs are tetrahedrally arranged, but the shape of the molecule is described only in terms of the atoms present.

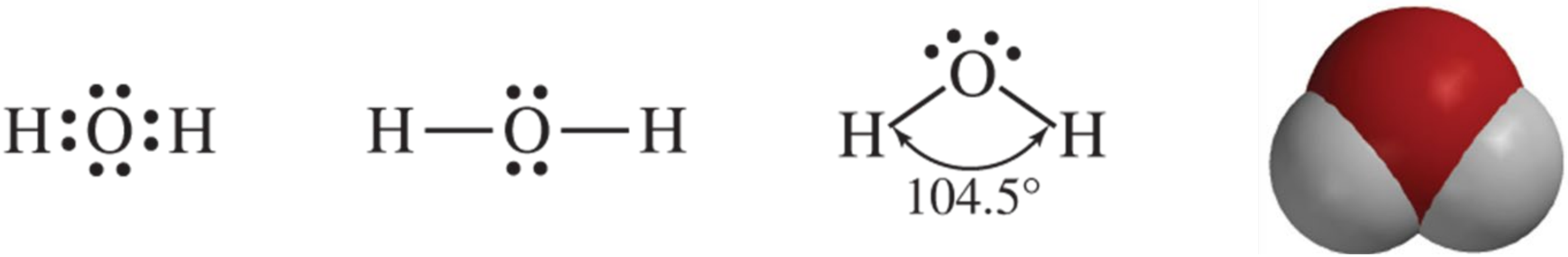
A molecule of ammonia has a “trigonal pyramid” shape.

[Rotatable model of ammonia in MolView]

The Shape of Water

Water has two electron pairs that are bonding and two that are nonbonding.

- The bond angle is even smaller than NH_3 and CH_4.



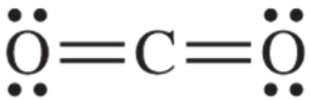
- The electron pairs are tetrahedrally arranged, but the shape of the molecule is described only in terms of the atoms present.
- A molecule of water has a “bent” shape.

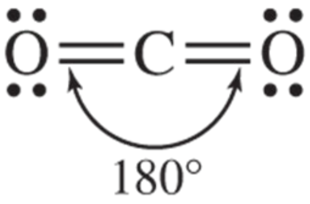
[Rotatable model of water in MolView]

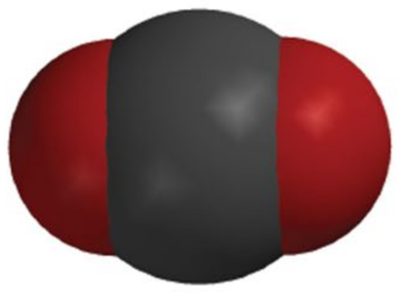
The Shape of Carbon Dioxide

For molecules with two atoms bonded to the central atom, the shape will be “linear” if there are no lone pairs on the central atom.

- Carbon dioxide has two atoms connected to the central carbon, but no lone pairs.
- Electrons in the two bonds push apart as far as possible: 180 degrees from each other.

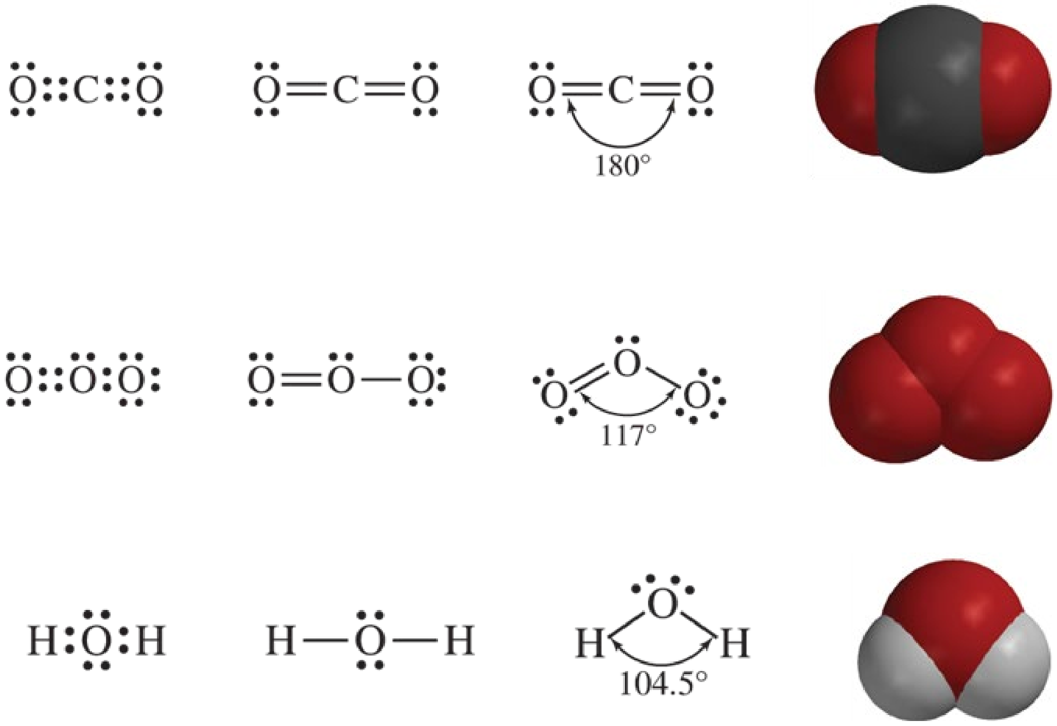






Rotatable model of water in MolView

Linear versus Bent Geometries



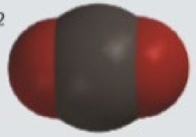
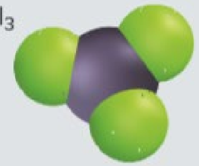
For 3-atom molecules, if there is at least one lone pair on the central atom, the geometry is bent.

- Minimizes the repulsion between the lone pair(s) and bonding electrons.

Molecular shape governs physical and chemical properties.

Common Molecular Geometries

Table 4.6 Common Molecular Geometries

# of Bonded Atoms to the Central Atom	# of Nonbonding Electron Pairs on Central Atom	Geometry	Space-Filling Model
2	0	linear	CO_2 
2	2	bent	H_2O 
3	0	trigonal planar	BCl_3 
3	1	trigonal pyramid	NH_3 
4	0	tetrahedral	CH_4 

[Molecule Shapes]

Your Turn 6

Your Turn 4.23 Predicting Molecular Shapes, Part 1

Using Table 4.6 and the strategies just described, sketch the shape for each of these molecules.

a. CCl_4 (carbon tetrachloride)

b. CCl_2F_2 (Freon-12, dichlorodifluoromethane)

c. H_2S (hydrogen sulfide)

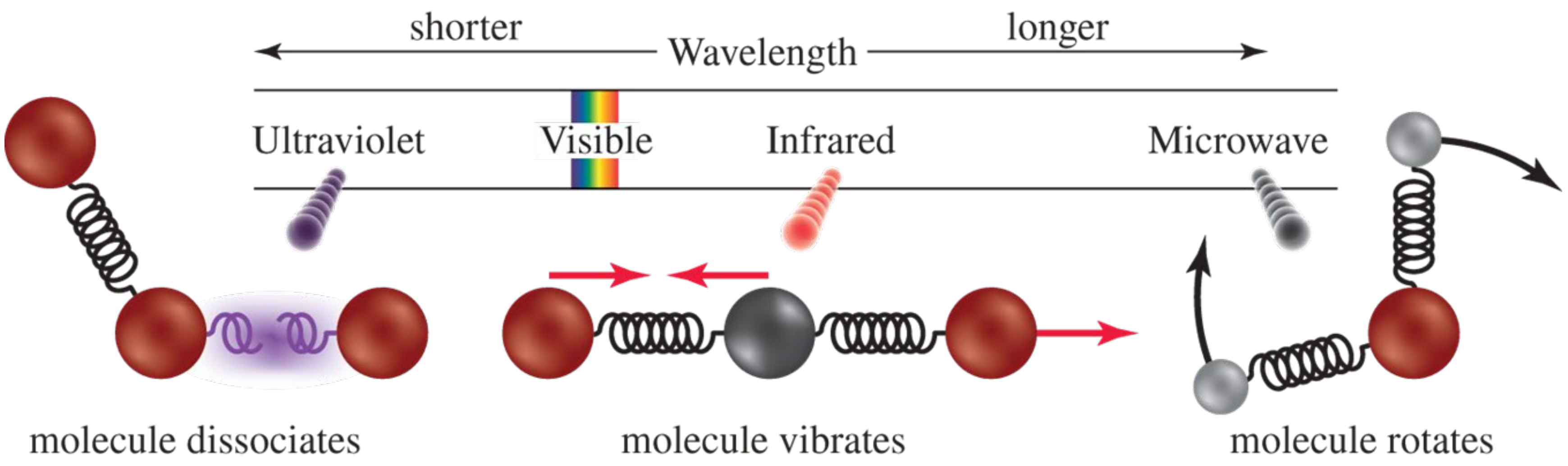
Your Turn 4.24 Predicting Molecular Shapes, Part 2

Using Table 4.6 and the strategies just described, predict and sketch the shape of molecules of SO_2 (sulfur dioxide) and SO_3 (sulfur trioxide).

Interactions of Light and Matter

Molecules behave differently when exposed to different types of electromagnetic radiation

- UV breaks bonds.
- Infrared cause vibrations of stretching and bending.
- Microwave radiation causes molecular rotations.



Interaction between
light $\leftrightarrow$ matter

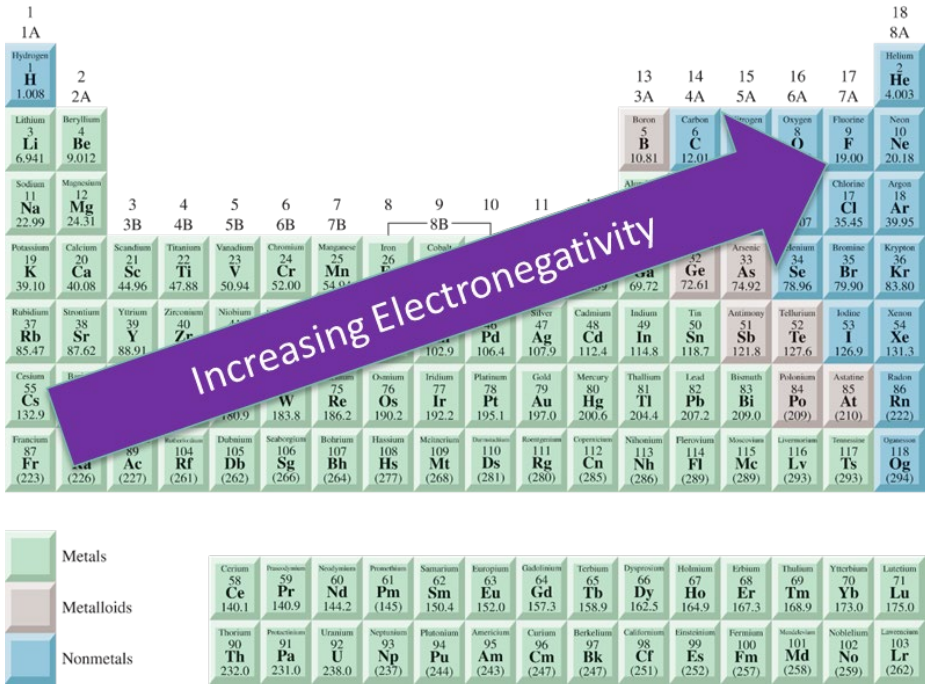
= Interaction between
electric field of light
$\leftrightarrow$ electrons (electron distribution)
of matter

Electronegativity [1]

Electronegativity refers to the measure of an atom’s ability to attract bonded electrons

- Like a “tug-of-war” for electrons between the two atoms in a bond.
- The “stronger” atom has a higher electronegativity.

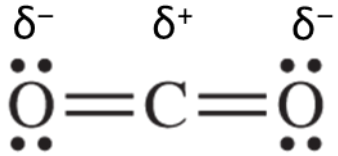
Electronegativity increases from the bottom-top of a group and left-right across a period



Electronegativity 2

In a bond, the more electronegative atom will carry a partial negative charge

(δ^-), and the other atom will have a partial positive charge (δ^+)

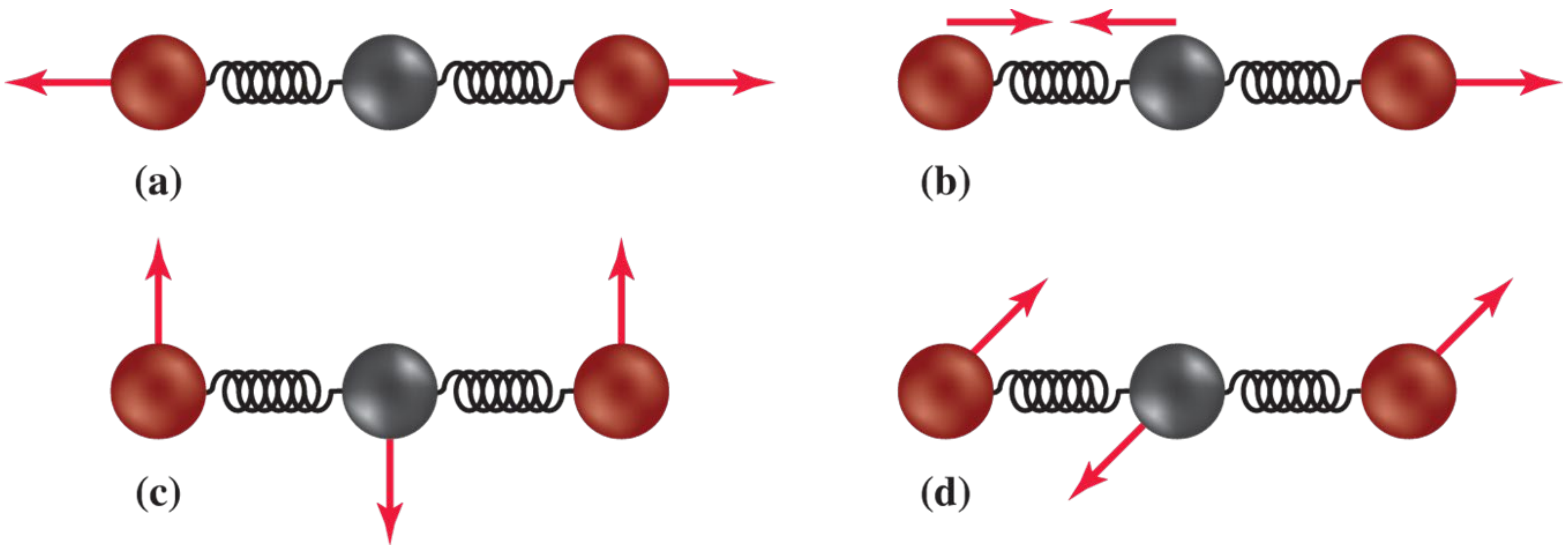


- Oxygen is to the right of carbon on the periodic table.
- Oxygen is therefore more electronegative than carbon.
- The electrons in each oxygen-carbon bond are pulled towards the oxygen atom, giving that side of the bond a partial negative charge.

As bonds are stretched or bent in a molecule, the charge distribution of the molecule will be affected

- If the geometry and direction of stretching/bending cancel this charge redistribution, then infrared radiation will not be absorbed.

Molecular Geometry and IR Absorption

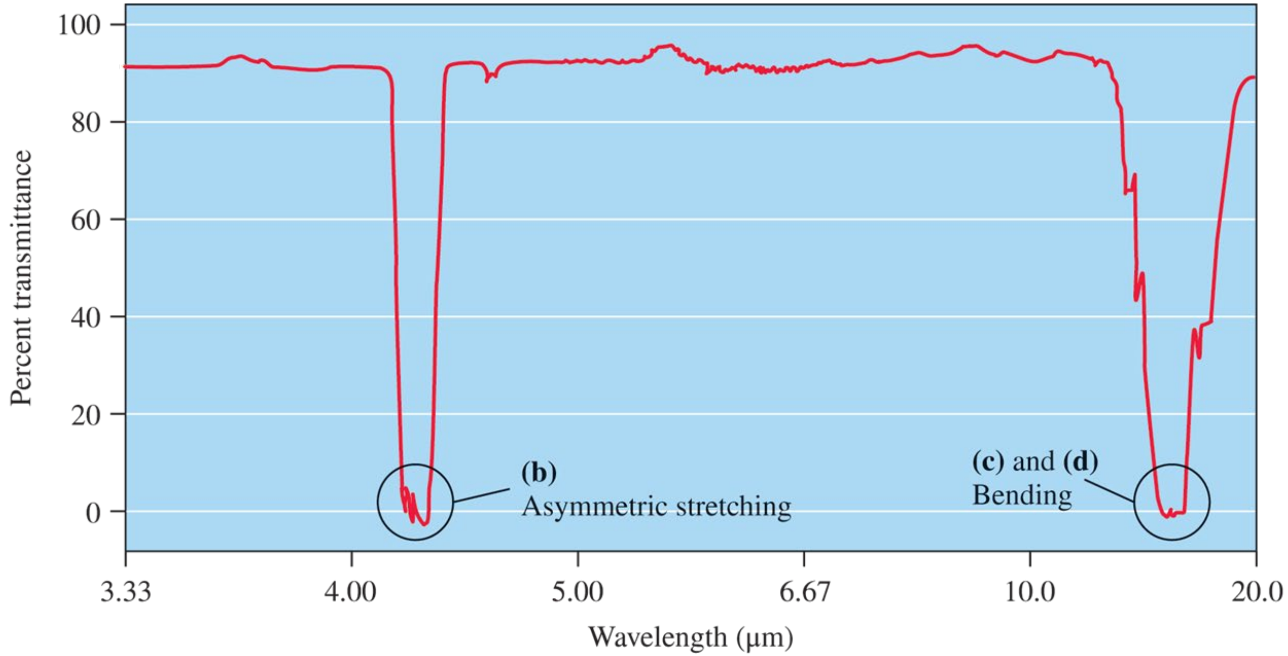


- Above are molecular vibrations of CO_2.
- Each spring represents a C=O bond.

  (a) = No net change in electron distribution (dipole) – no IR absorption

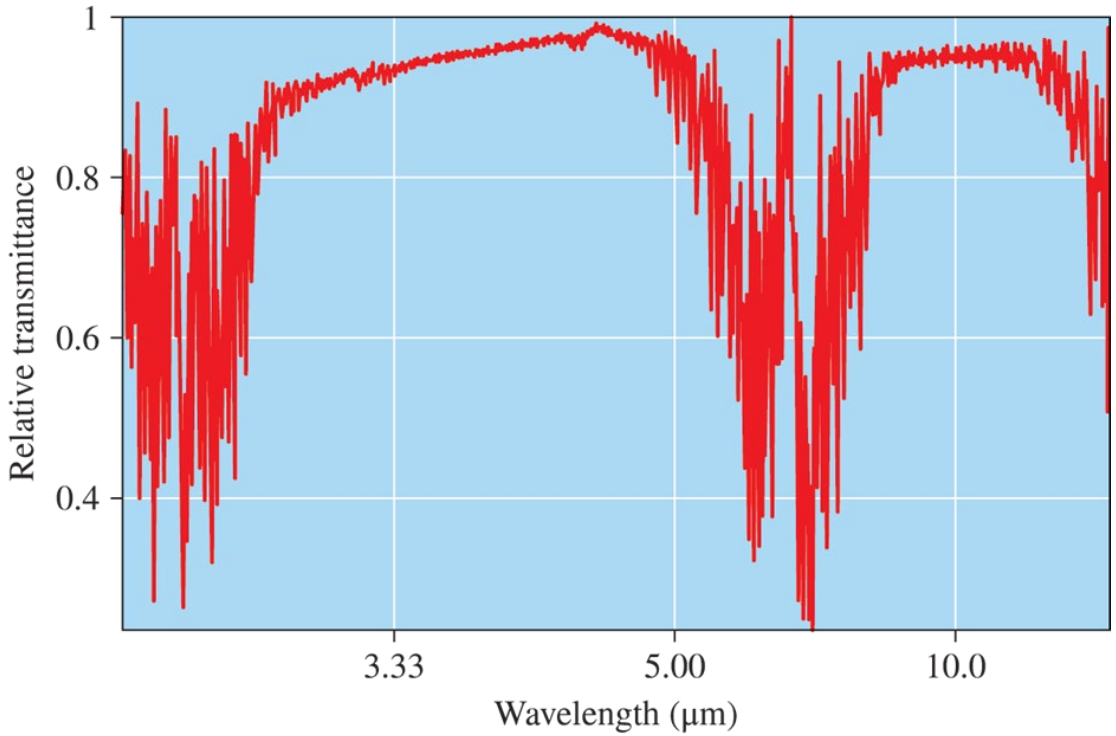
  (b, c, d) = Net change in dipole – absorb IR radiation

Infrared Absorption Spectrum of CO_2



As infrared radiation is absorbed, the amount of radiation that makes it through the sample is reduced

Infrared Absorption Spectrum of H_2O



- Any molecule of three or more atoms can absorb IR light and act as a greenhouse gas.
- Water is the most important gas in maintaining Earth's temperature, with carbon dioxide second.

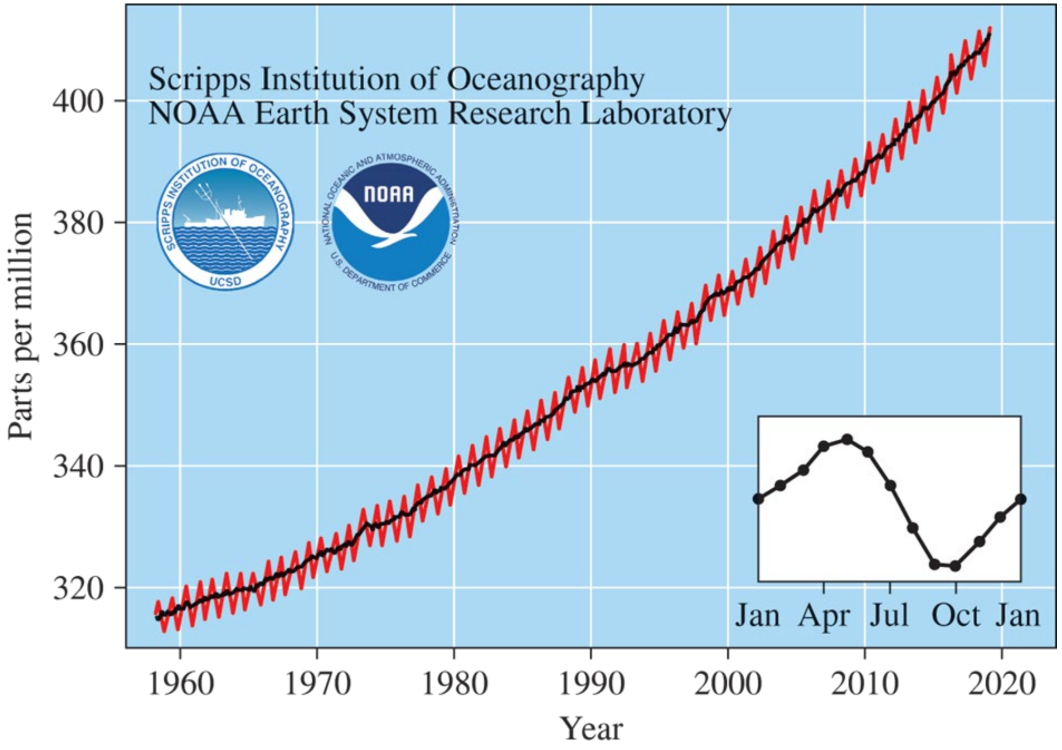
Source: NIST Chemistry WebBook

60-year CO_2 Concentrations

According to data taken at Mauna Loa, Hawaii since 1958

- CO_2 levels are on the rise.

Isolated place



Source: NOAA

Your Turn

Your Turn 4.30 What Is Causing CO_2 to Increase?

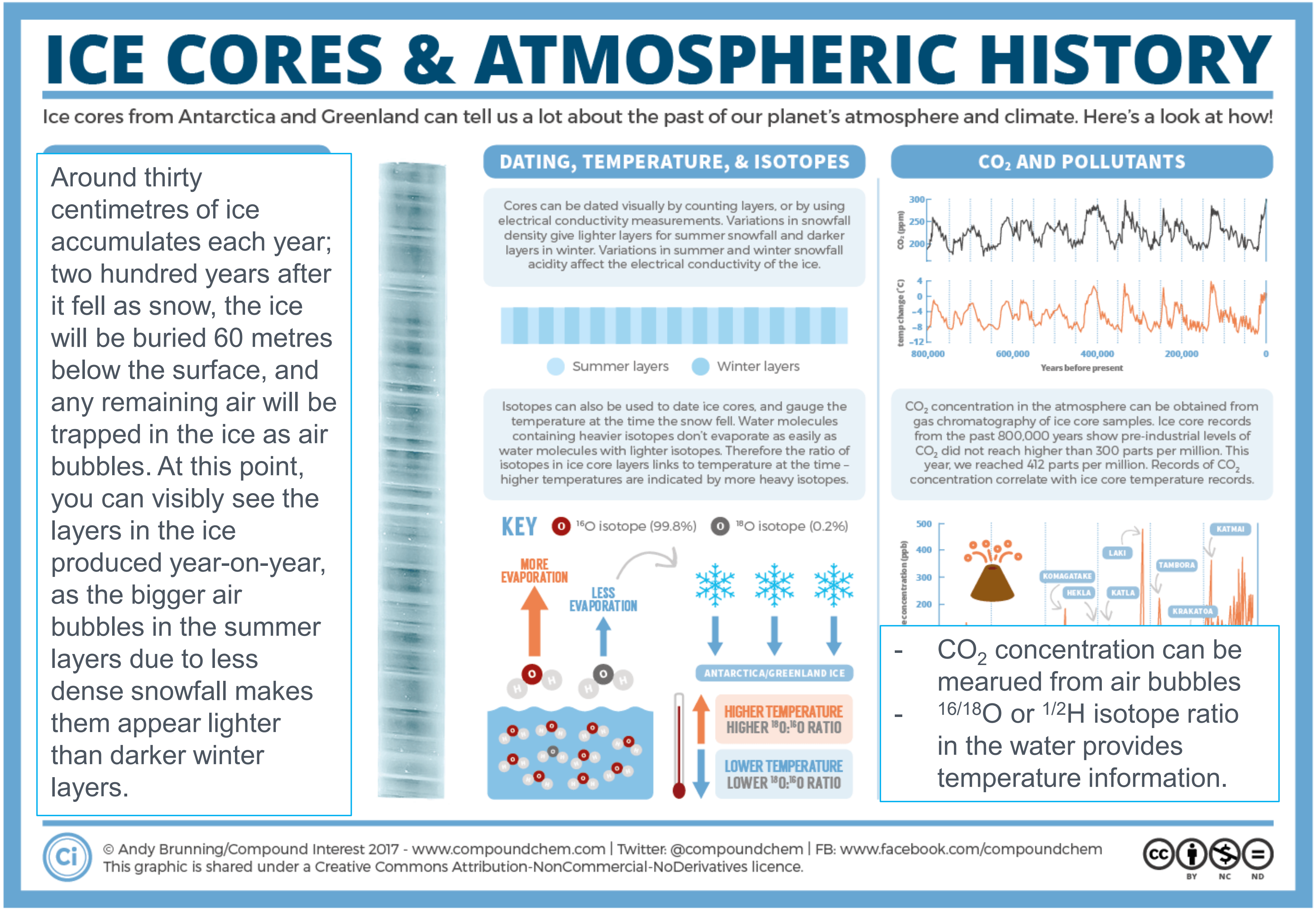
Figure 4.20 shows that the amount of carbon dioxide in Earth's atmosphere is increasing. Make a list of the reasons why this could be occurring over this time frame.

Learning from Our Past: Ice Core Sampling

- Microscopic air bubbles in ice core samples from glaciers can be used to determine changes in greenhouse gas concentrations over time.

[The science of ice cores]

Mike Waszkiewicz/NOAA



Around thirty centimetres of ice accumulates each year; two hundred years after it fell as snow, the ice will be buried 60 metres below the surface, and any remaining air will be trapped in the ice as air bubbles. At this point, you can visibly see the layers in the ice produced year-on-year, as the bigger air bubbles in the summer layers due to less dense snowfall makes them appear lighter than darker winter layers.

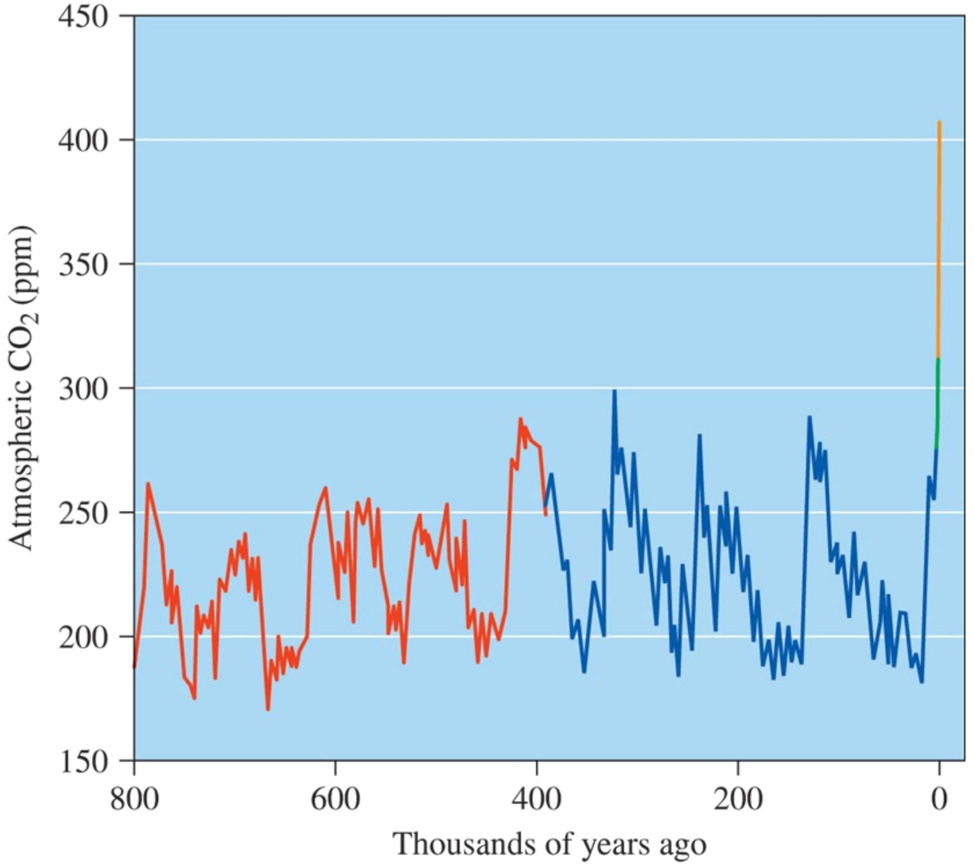
- CO_2 concentration can be meaured from air bubbles
- $^{16/18}O$ or $^{1/2}H$ isotope ratio in the water provides temperature information.

https://www.compoundchem.com/2017/08/15/ice-cores/

800,000-year CO_2 Concentrations

- The concentration of carbon dioxide appears to be increasing over time.
- Current concentration of CO_2 is 100 ppm higher than any time in the last million years.

Data from ice cores in Antarctica EPICA Dome C (red), Vostok (blue), Law Dome (green), and atmospheric data from Mauna Loa (orange)



Learning from Our Past: Temperatures

Temperature from ice cores are found by measuring relative amounts of ^{2}H and ^{1}H

- Water with more ^{2}H condense to form snow at higher temperatures.

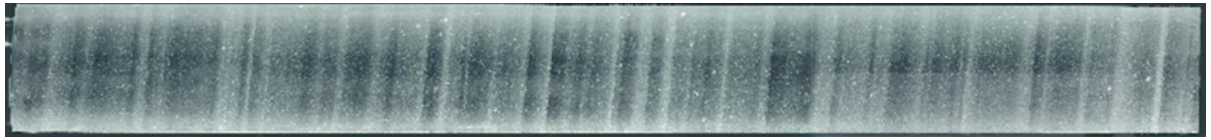
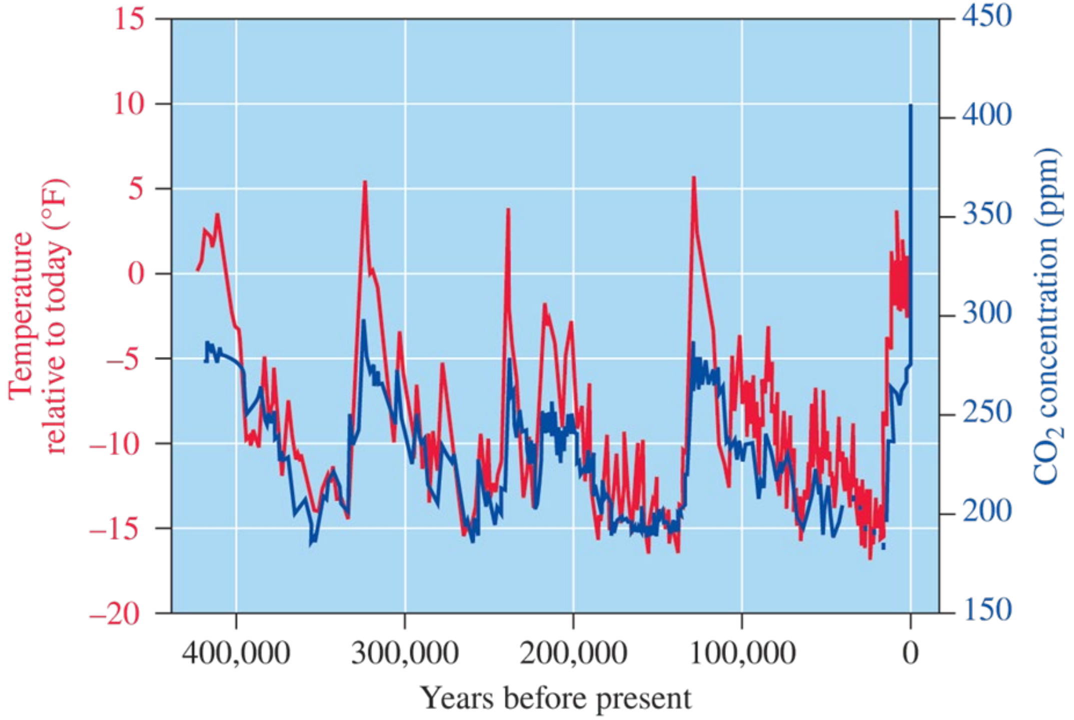


Photo from National Ice Core Laboratory, National Science Foundation and U.S. Geological Survey

400,000-year CO_2 and Temperature

The concentration of carbon dioxide (blue) and global temperature (red) are well correlated over the past 400,000 years.



[Historic Climate Trends]

Source: Environmental Defense Fund

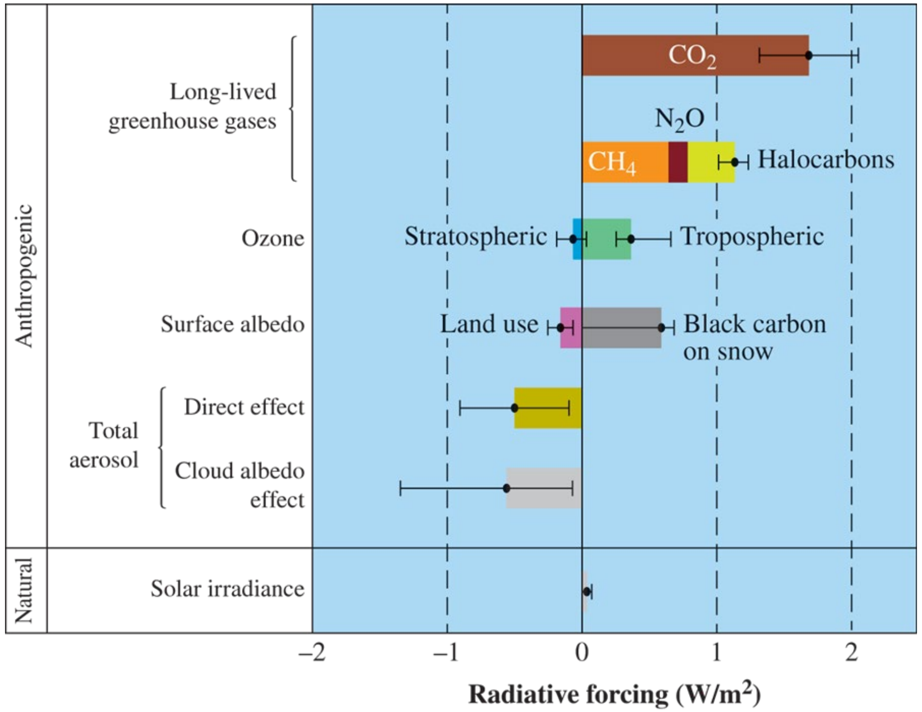
Climate Modeling

Radiative forcings are factors that affect the baseline of Earth's incoming and outgoing radiation.

Greatest warming effects are found for greenhouse gases of CO_2, water, methane, halocarbons, and N_2O

Greatest cooling effects are found for aerosols such as mineral dust and other particulate matter

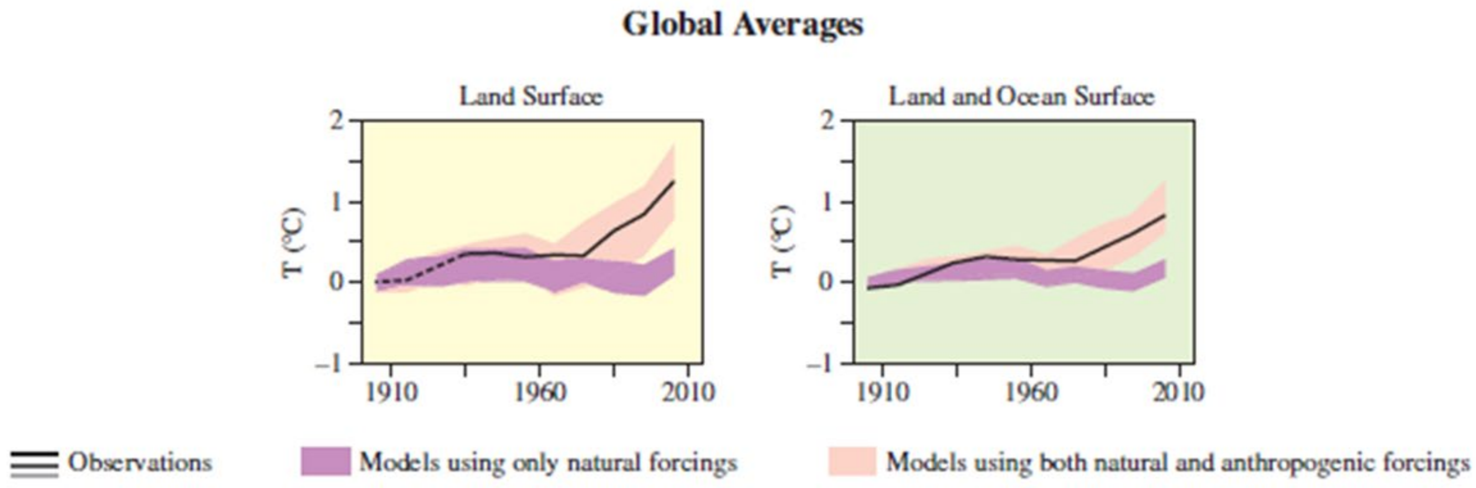
[Build a Planet]



Source: Adapted from Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Climate Modeling: Simulated Climate Change

Climate models used to explain the temperature increases over the last 50 years show that both natural and anthropogenic factors play important roles, but anthropogenic factors contribute most strongly in recent years.



Source: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change (IPCC)

Recognizing the problem of potential climate change, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) established the IPCC in 1988

- IPCC releases a report every six to eight years on climate change.

IPCC 2014 Report [1]

Table 4.8 IPCC Conclusions, 2014
Virtually Certain (99 to 100% probability) • The upper ocean (0 to 700 m) warmed from 1971 to 2010. • There will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales. • The extent of near-surface permafrost at high northern latitudes will be reduced. • Global mean sea level rise will continue for many centuries beyond 2100.
Extremely Likely (95 to 100% probability) • Human-caused emissions are the main factor causing warming since 1951.
Very Likely (90 to 100% probability) • Anthropogenic influences, particularly GHGs and stratospheric ozone depletion, have led to a detectable observed pattern of tropospheric warming and a corresponding cooling in the lower stratosphere since 1961. These influences also have contributed to Arctic sea ice loss since 1979. • Since the mid-20th century, the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. • Heat waves will occur with a higher frequency and longer duration. • Extreme precipitation events over most midlatitude landmasses and over wet tropical regions will become more intense and more frequent.

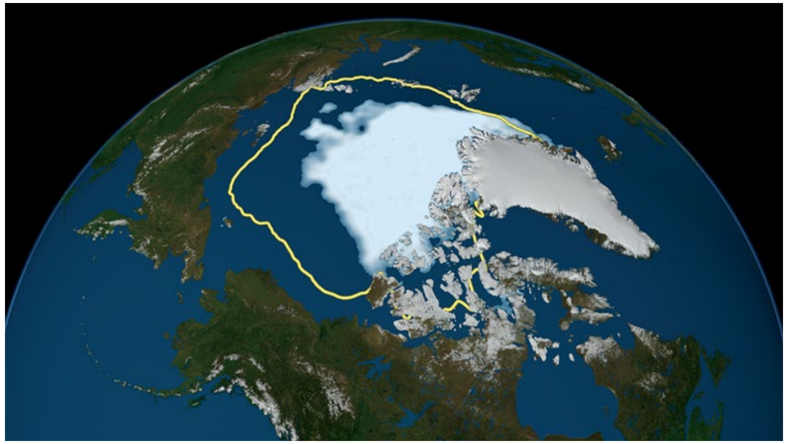
IPCC 2014 Report [2]

Table 4.8 IPCC Conclusions, 2014
Likely (66 to 100% probability) • Anthropogenic forcings have made a substantial contribution to surface temperature increases since the mid-20th century. • Anthropogenic influences have affected the global water cycle and the retreat of glaciers since 1960. • Over the second half of the 20th century, there were more land regions where the number of heavy precipitation events had increased than where it had decreased. • The ocean warmed at depths of 700 to 2000 m from 1957 to 2009, and depths of 3000 m to the bottom for the period 1992 to 2005. • Tropical oxygen-minimum zones have expanded in recent decades. • The global mean surface warming is in the range of 0.5 to 1.3°C over the period 1951 to 2010.
Unlikely (0 to 33% probability) • Relative to 1850 to 1900, the global surface temperature change for the end of the 21st century (2081 to 2100) will exceed 2°C.

Our Future?

Perennial, or year-round, sea ice in the Arctic is declining at a rate of 9% per decade

- As the oceans warm and ice thins, more solar energy is absorbed by the water, creating positive feedbacks that lead to further melting.
- Such dynamics can change the temperature of ocean layers, impact ocean circulation and salinity, change marine habitats, and widen shipping lanes.



The extent of Arctic ice in September 2012 in comparison to the 30-year average sea ice minimum (yellow line)

Source: NASA GSFC Scientific Visualization Studio

Other Impacts

Sea level rise.

- Coastal areas in danger.

More extreme weather.

- Severe storms, drought, flooding, etc.

Changes in ocean chemistry.

Loss of biodiversity.

- Change in range, habits, or extinction.

Vulnerability of freshwater resources.

Human health.

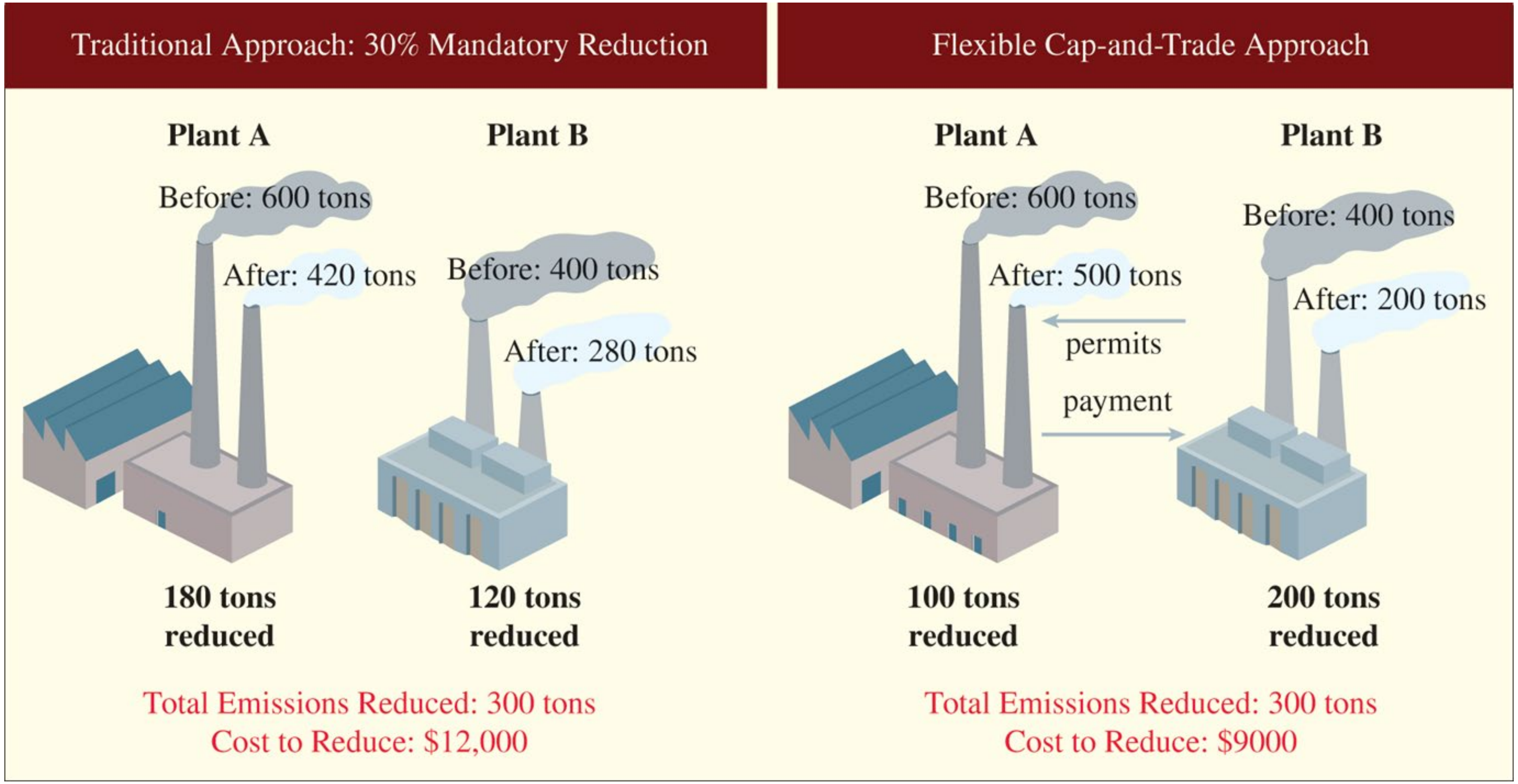
- Spread of diseases like malaria, cholera.

Action Plans: Legislation

- The Intergovernmental Panel on Climate Change (IPCC) certified the scientific basis of the greenhouse effect.
- The Kyoto Protocol (1997) established goals to stabilize and reduce atmospheric greenhouse gases.
- Emission targets set to reduce emissions of six greenhouse gases from 1990 levels (CO_2, CH_4, NO, HFCs, PFCs, and SF_6).

Economic Incentivization

Cap-and-trade to economically incentivize CO_2 emission reductions



Source: EPA, Cleaning the Air, The Facts About Capping and Trading Emissions, 2002, p3.

What Do You Think?

Your Turn 4.54 Group Activity: The "Big Question" Revisited

Form a group and answer these questions based on your current knowledge.

a. Do you feel the greenhouse effect and warming of the atmosphere is good or bad? Why or why not?

b. Where does the carbon dioxide in the air come from?

c. What is climate change?

d. Is climate change occurring? Why or why not?

Compare your answers to those from the start of the chapter. How have your answers changed?

Example topics that you can delve into further...

1. What's your carbon footprint? Use apps that allow you to measure the carbon emission of your daily action. Calculate your footprint and show what actions you can take to reduce it.
2. Think about your future major or career and check how your future work will be related to carbon emission. What can you do to reduce it? What efforts have been made by related companies and researches?
3. Check what type of analytic methods are out there to measure the temperature of earth or the CO_2 level of earth? How consistent are the results from different analyses? What are the pros and cons of the methods and which methods seem to be more accurate?
4. To predict the exact temperature of earth, people from different expertise and majors work together. Check collaborative examples and present.

Etc…