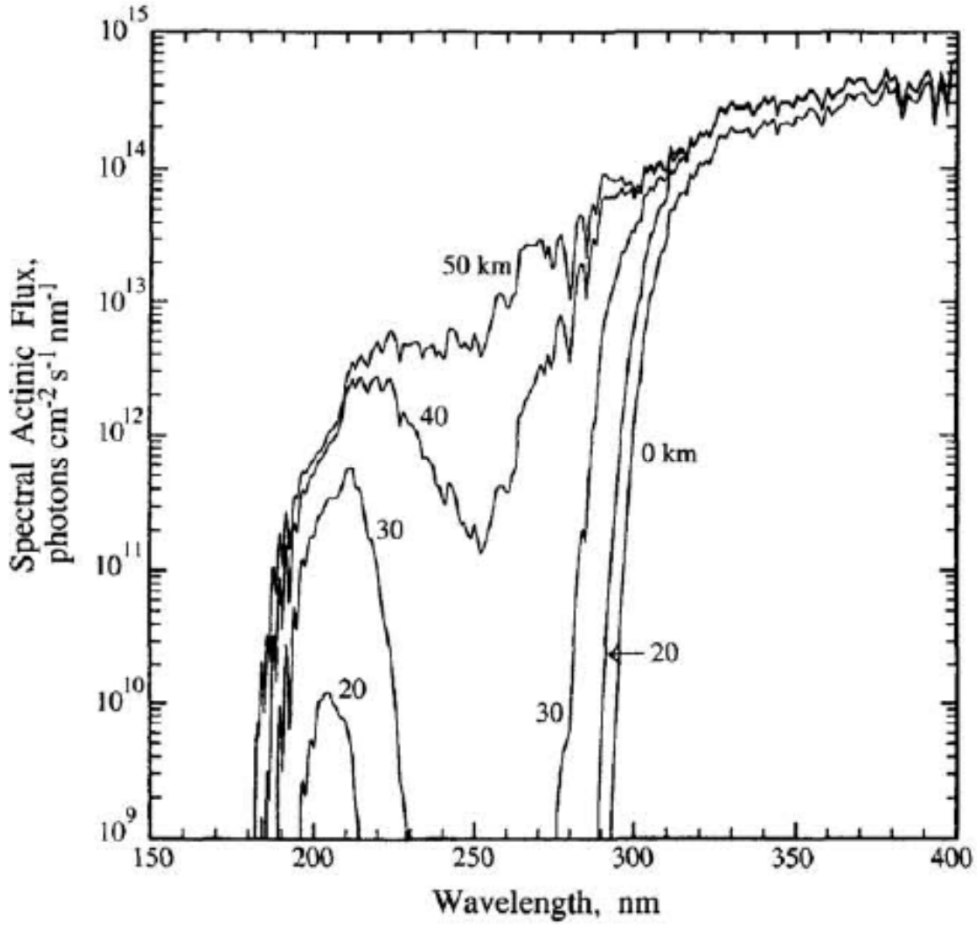
Air pollution II

Today's lecture

- Ozone depletion
- Global warming
- Air pollution control for gaseous pollutants
- Air pollution control for particulates

Ozone depletion

- Ozone protects life if it is in the stratosphere
- Ozone layer (20-40 km or up above the ground): absorbs UV light



Ozone depletion

- Photoreactions of ozone to absorb UV light

$$O_2 + UV \rightarrow 2O$$

$$O + O_2 + M \rightarrow O_3 + M$$ (*M*: a third molecule)

$$O_3 + UV \rightarrow O_2 + O$$

- CFCs (chlorofluorocarbons)
  - Good for refrigerants, propellants, and solvents
  - Stable in the troposphere → can reach the stratosphere without break-down
  - Causes ozone depletion

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Ozone depletion

- Ozone destruction mechanism by CFCs

$$CCl_3F + UV \rightarrow CCl_2F + Cl$$

$$Cl + O_3 \rightarrow ClO + O_2$$

$$ClO + O \rightarrow Cl + O_2$$

$$O_3 + O \rightarrow 2O_2$$

  - Cl atom acts as a catalyst
  - One CFC molecule can destroy uncountable number of ozone molecules

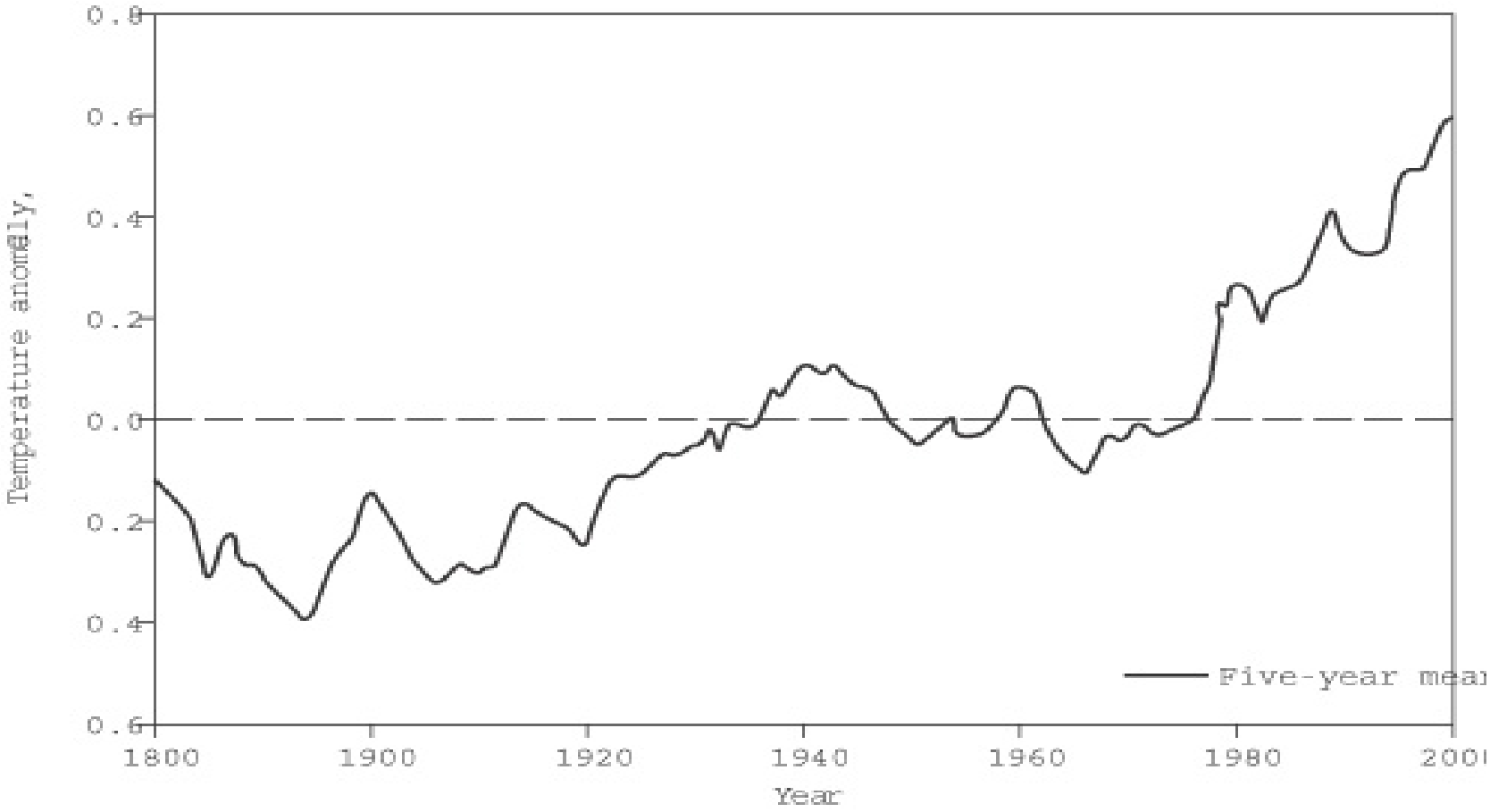
Ozone depletion

- Efforts to stop ozone depletion
  - **Montreal Protocol** on Substances That Deplete the Ozone Layer
    - An international treaty agreed on September 16, 1987
    - Became effective in January 1989
    - Eight revisions: 1990, 1991, 1992, 1993, 1995, 1997, 1999, and 2007
    - Complete phase-out of CFCs

Ozone depletion

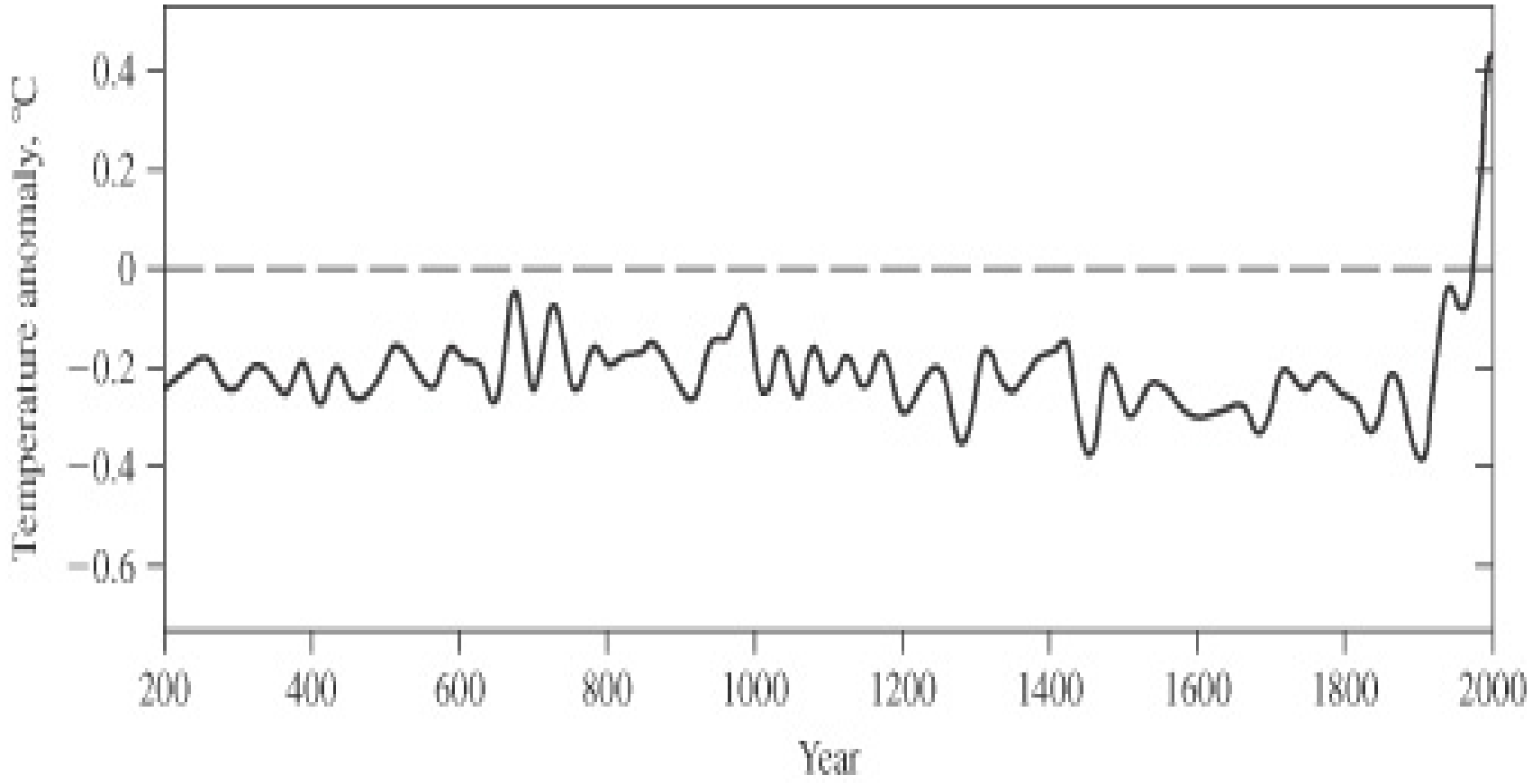
- Efforts to stop ozone depletion
  - Substitutes: hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs)
    - HCFCs are more reactive than CFCs in the troposphere → only small amount reaches the stratosphere (but still has some ozone depletion potential)
    - HFCs do not contain chlorine atoms → no ozone depletion potential
    - Problem: HFCs and HCFCs are greenhouse gases

Global warming

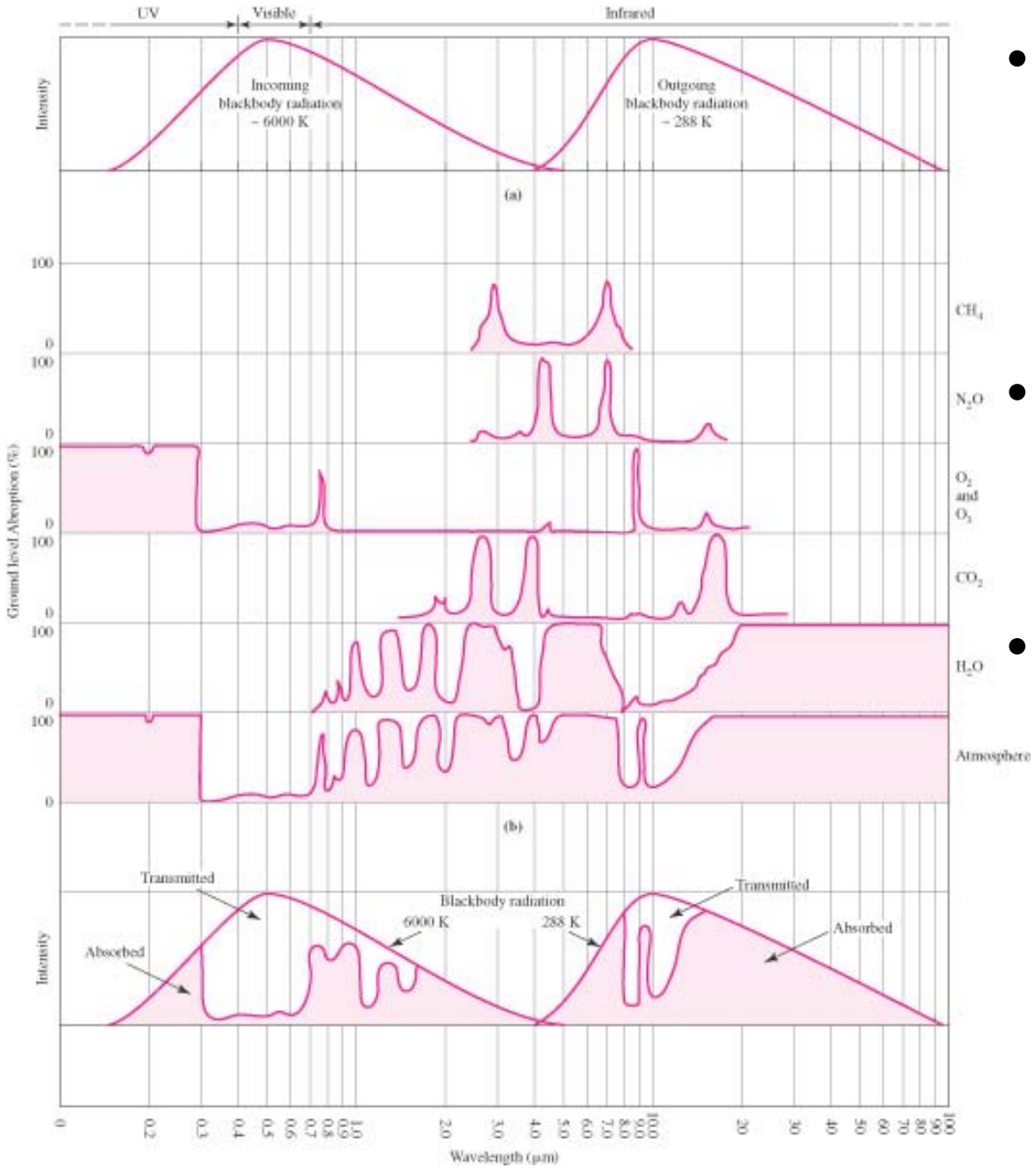


The temperature of the globe is really increasing!

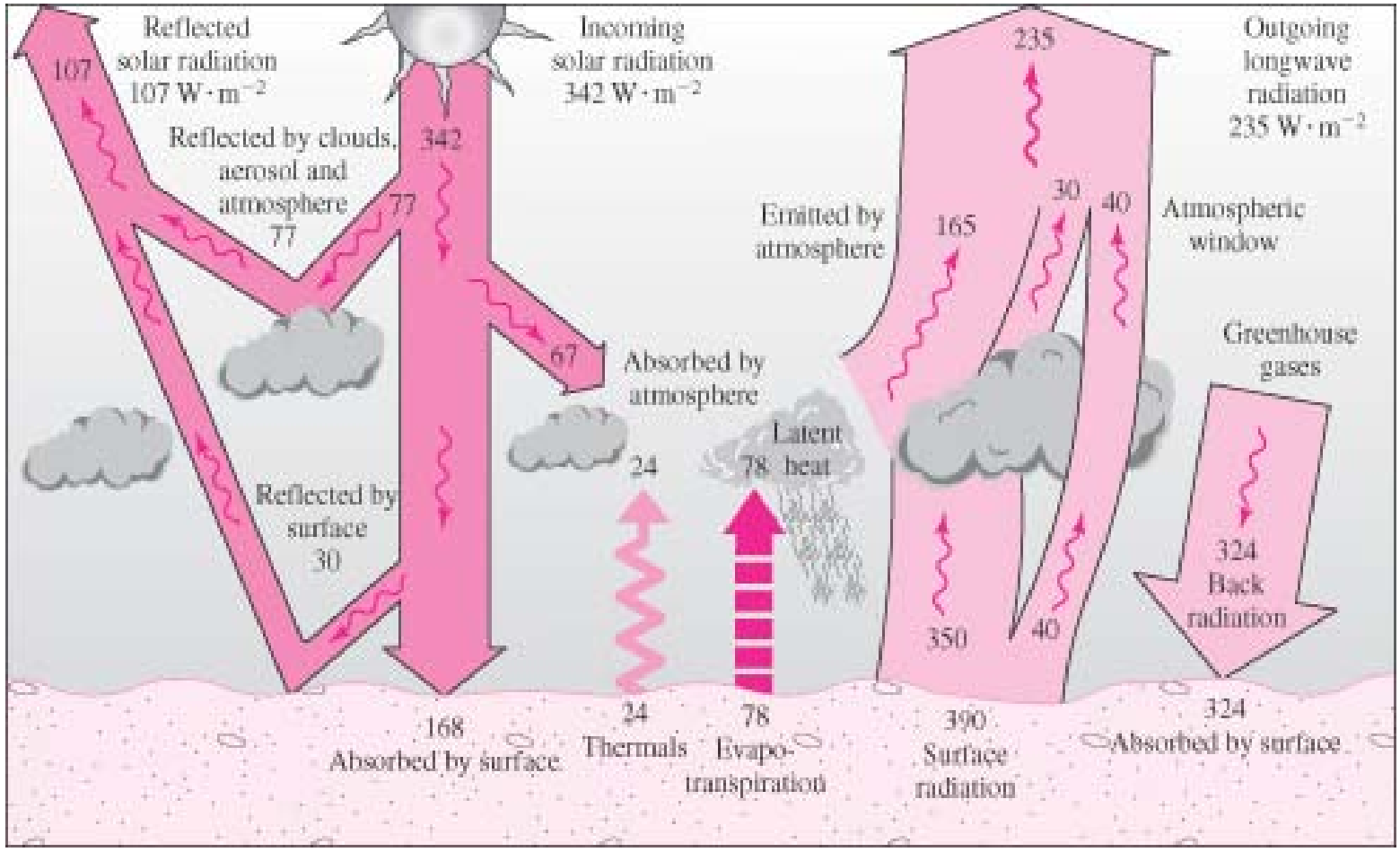
Global warming



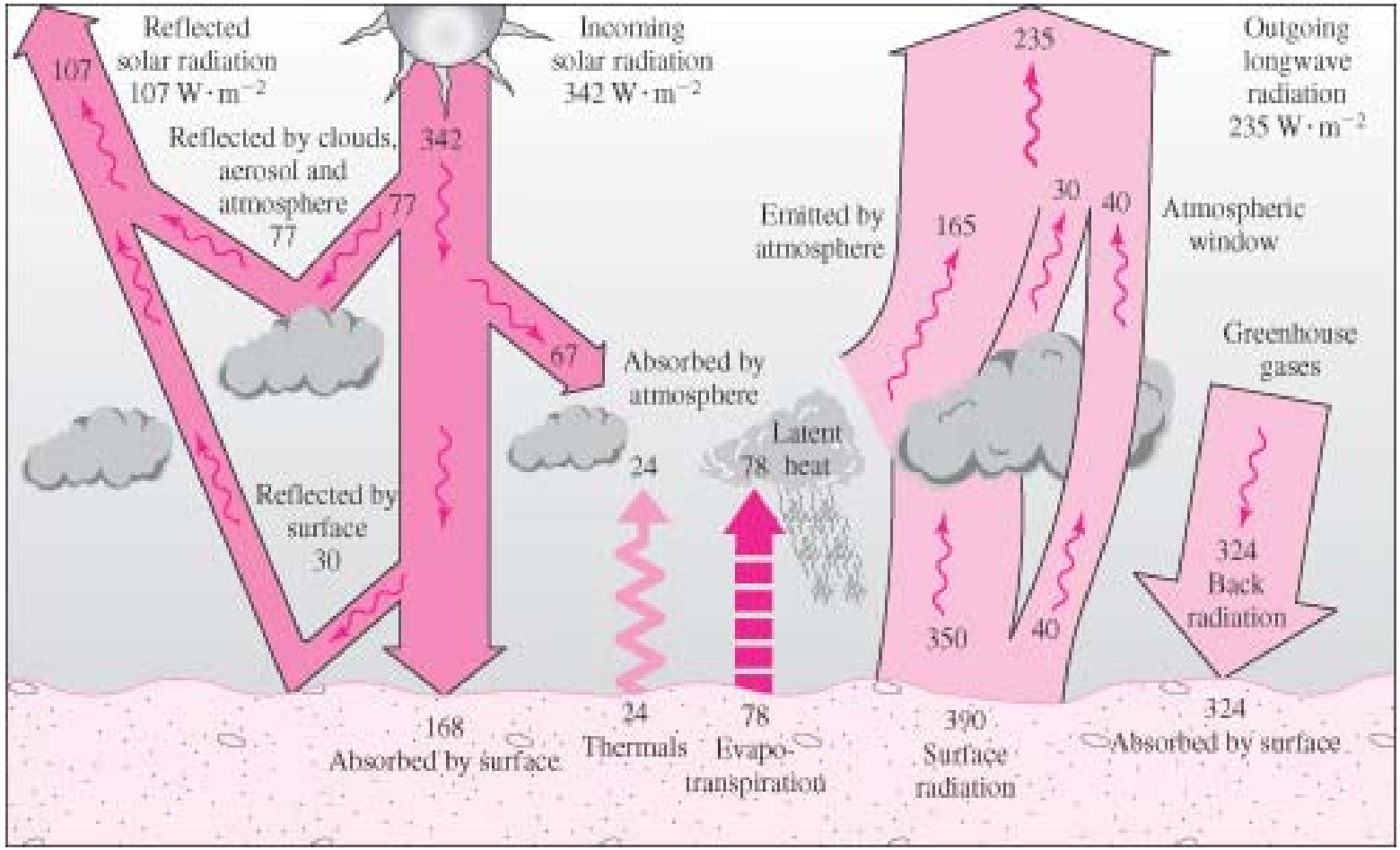
The “hockey stick” graph



- The earth receives short-wave radiation from the Sun
- The Earth's surface emits long-wave radiation
- Some molecules absorb the long-wave radiation → prevent energy to be released out of the Earth



- The greenhouse gases (GHGs) work like the glass on a greenhouse or a blanket
- Maintain the Earth's temperature good for life (without GHGs, the Earth's temperature will be around -17°C)



- 30% increase in the atmospheric CO_2 concentration since 1750
- The increased levels of greenhouse gases changes the radiation balance: greater back radiation → higher surface temperature

Greenhouse gases (GHGs)

- CO_2 is major, but others can also be significant
- Overall greenhouse effect depends on concentration, global warming potential, and lifetime

Chemicals	**Lifetime (year)**	**Global warming potential (kg CO_2/kg chemical)**
Carbon dioxide (CO_2)	30-200	1
Methane (CH_4)	12	62
Nitrous oxide (N_2O)	114	275
CFC-12 (CF_2Cl_2)	100	10200
HCFC-22 (CHF_2Cl)	12	4800
Tetrafluoromethane (CF_4)	50000	3900
Sulfur hexafluoride (SF_6)	3200	15100

Global warming

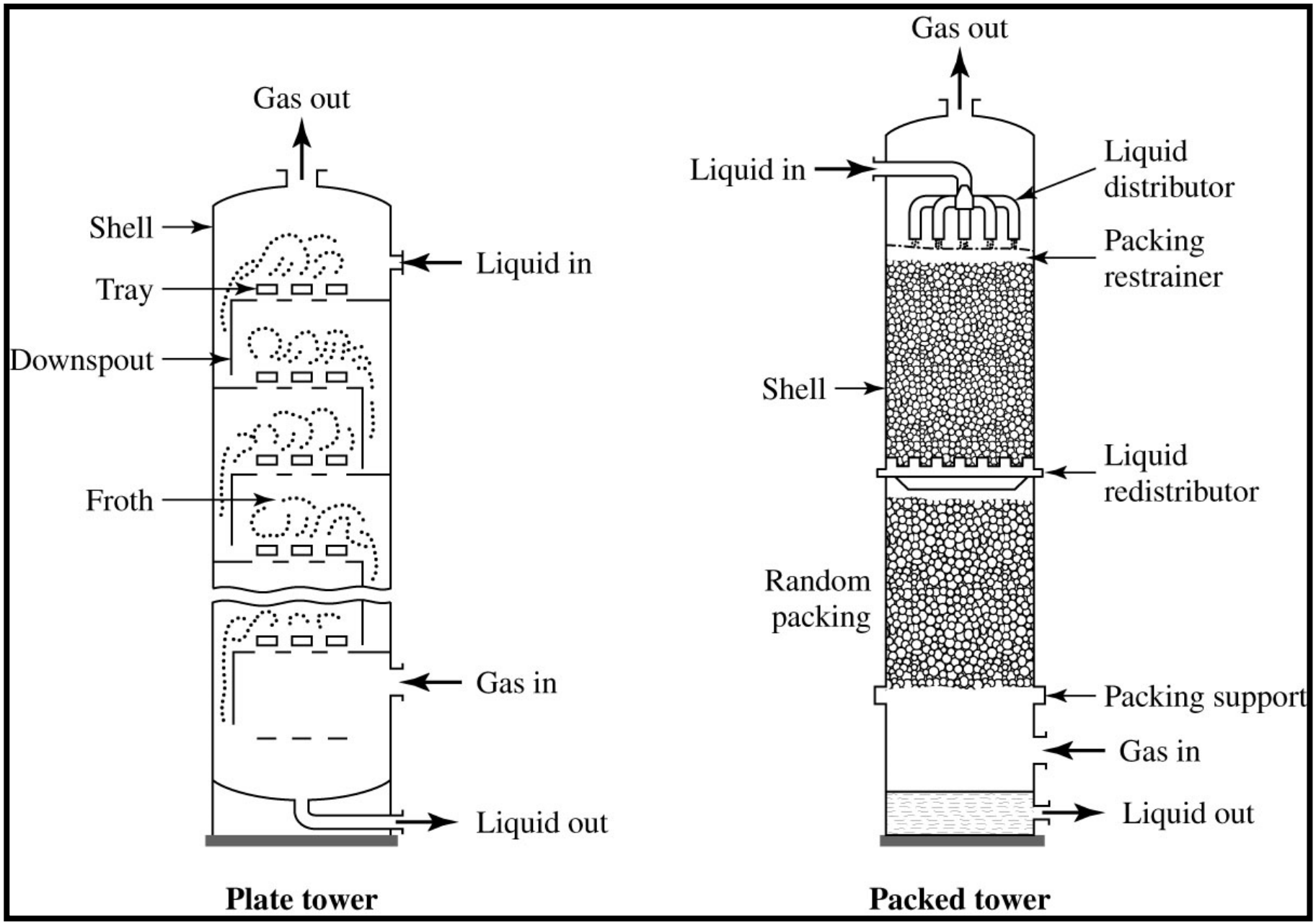
- Efforts to reduce GHG emissions
  - Kyoto Protocol
    - Adopted on December 11, 1997
    - Became effective in 2005
    - Targets to reduce GHG emissions in developed countries by 5% compared to 1990 levels during the first commitment period (2008-2012)
    - U.S. did not ratify the protocol

Global warming

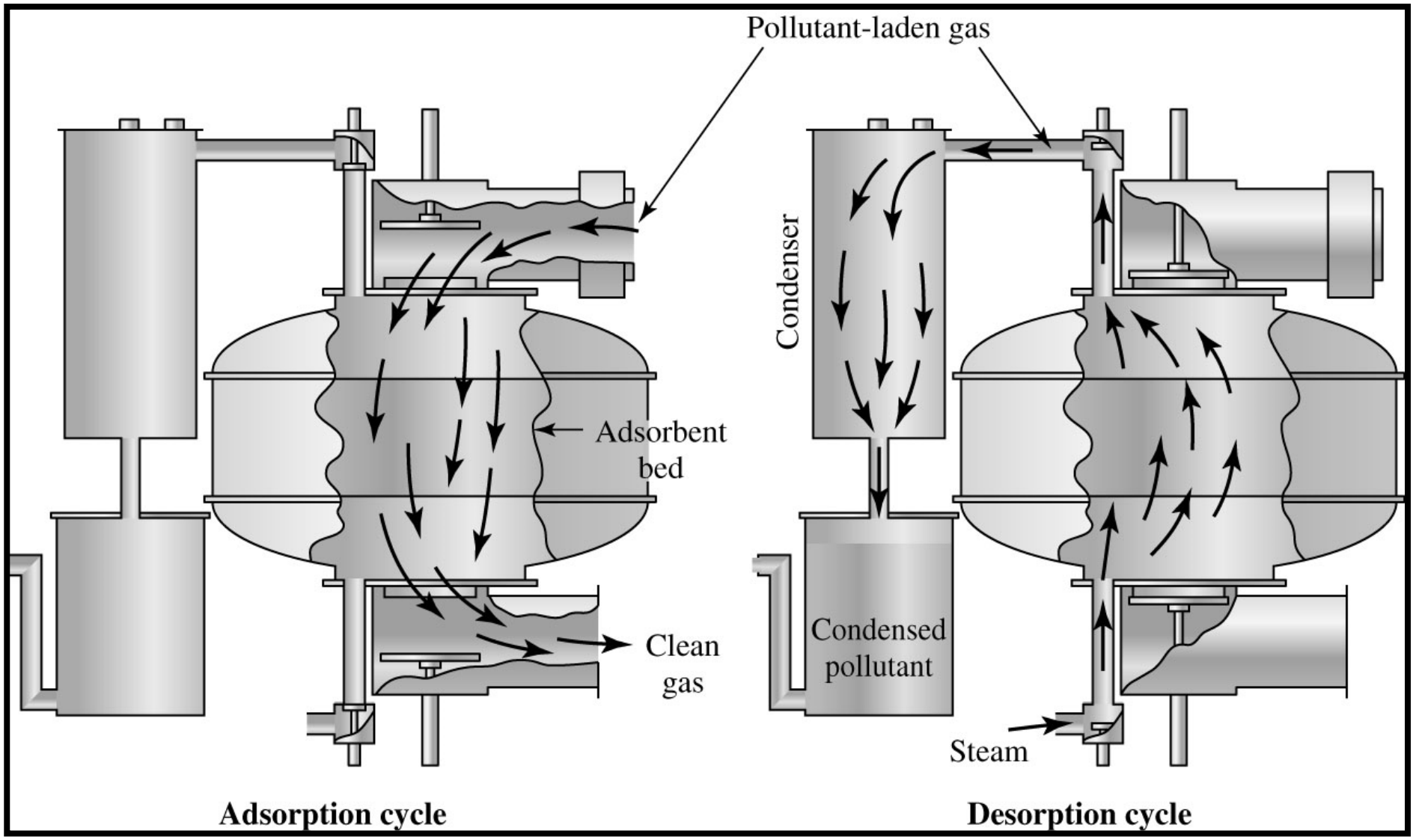
- Efforts to reduce GHG emissions
  - Kyoto Protocol
    - Doha amendment (2012)
      - Reduce GHG emissions by 25-40% compared to 1990 levels during the second commitment period (2013-2020)
      - Major CO_2-producing countries (U.S., China, and India) denied to ratify
      - Only 37 countries including EU, Australia, and the Switzerland participated
      - EU has not ratified the amendment yet
  - Korea was not included in Kyoto protocol, but "voluntarily" promised to reduce the GHG emissions

Air pollution control – gaseous pollutants

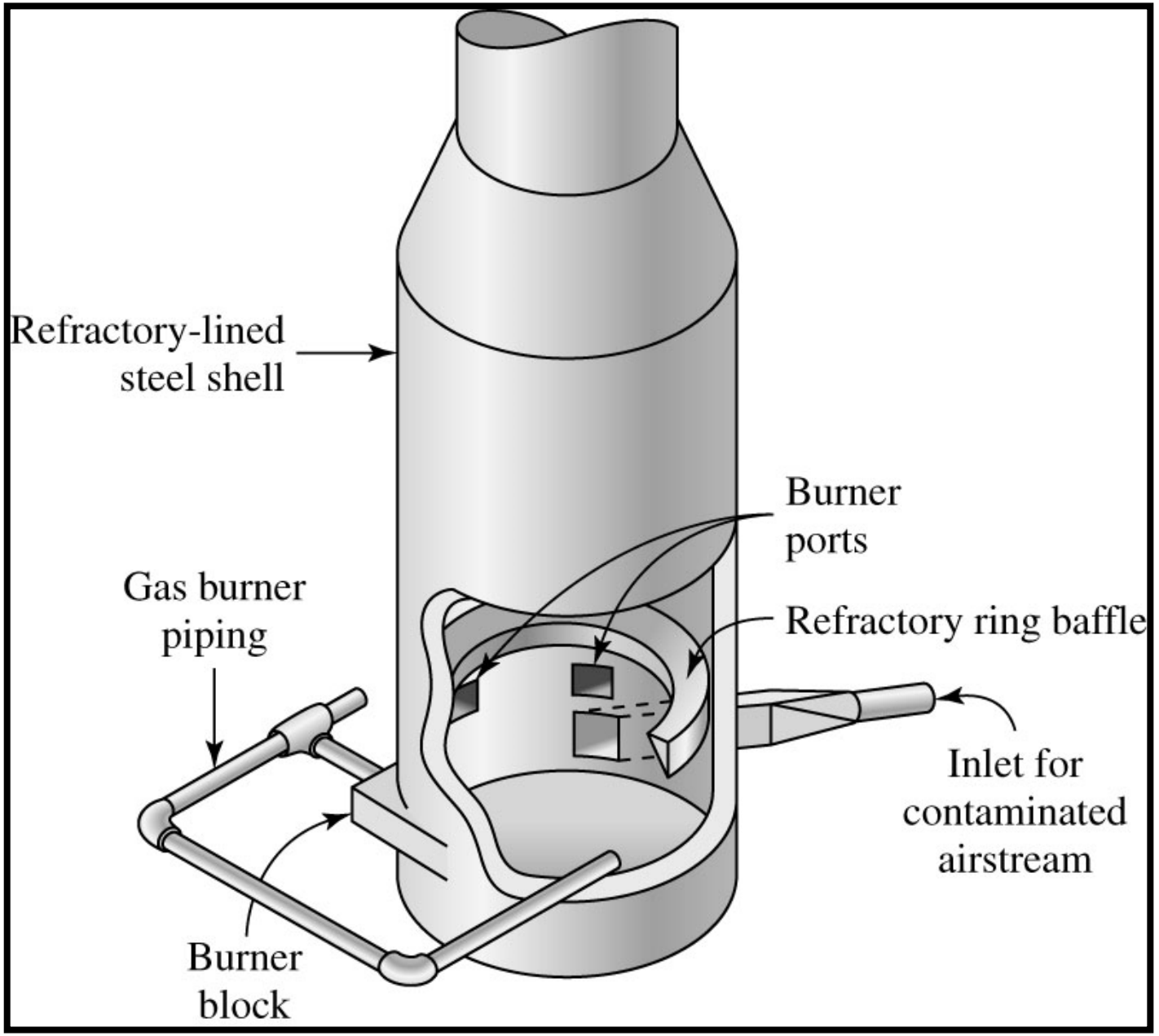
- Absorption
  - Dissolution of pollutant gas into a liquid
  - If water is used, only applicable to gases having high water solubility such as NH_3, Cl_2, and SO_2
- Adsorption
  - Binding of pollutant gas to a solid
  - Common adsorbents: activated carbon, zeolites, silica gel, and activated aluminum oxide
- Combustion
  - Applicable when the pollutant gas can be oxidized to inert gas such as CO_2
  - Can be applied to CO and organic pollutants



Absorption processes



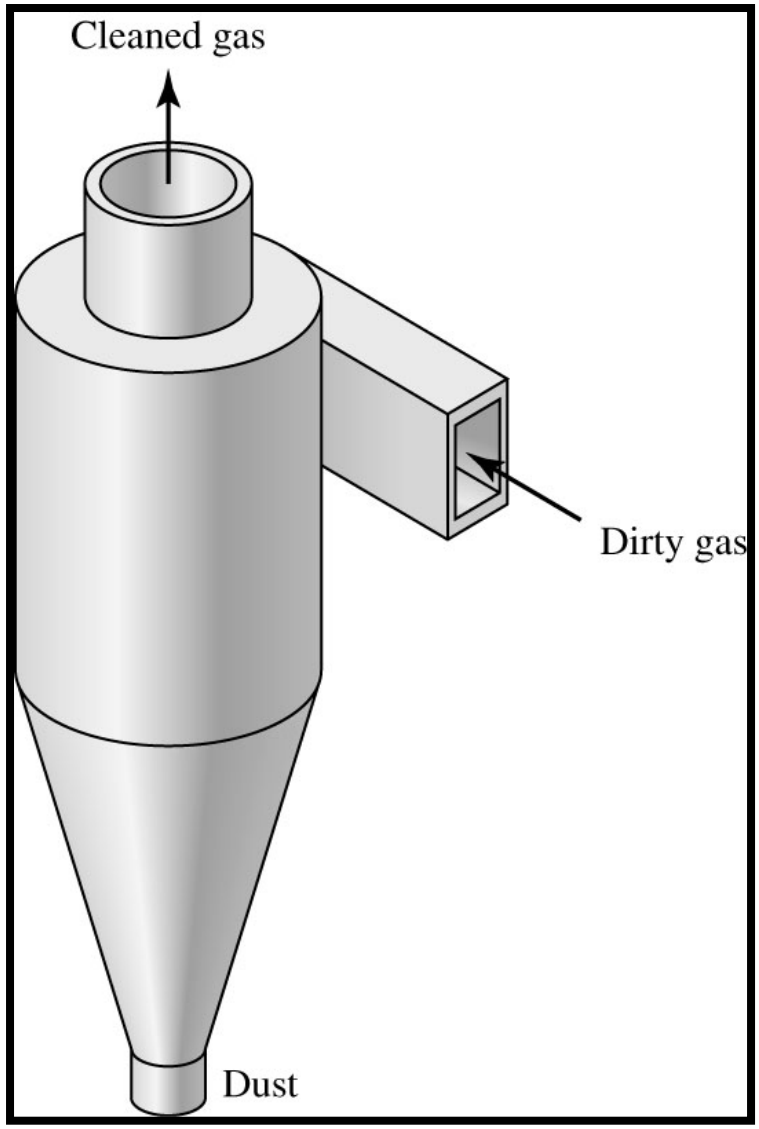
Adsorption processes



Combustion process: direct incinerator

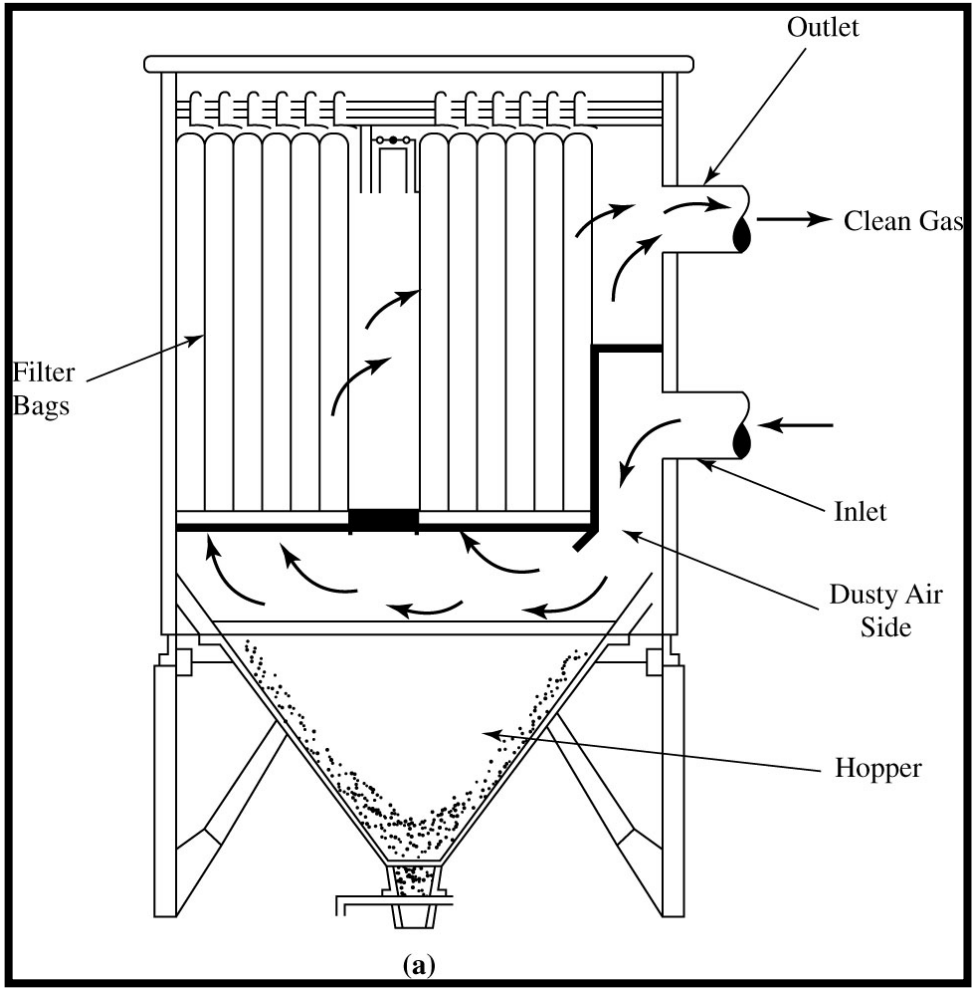
Air pollution control – particulates

- Cyclones: good for large particles (>10 µm)



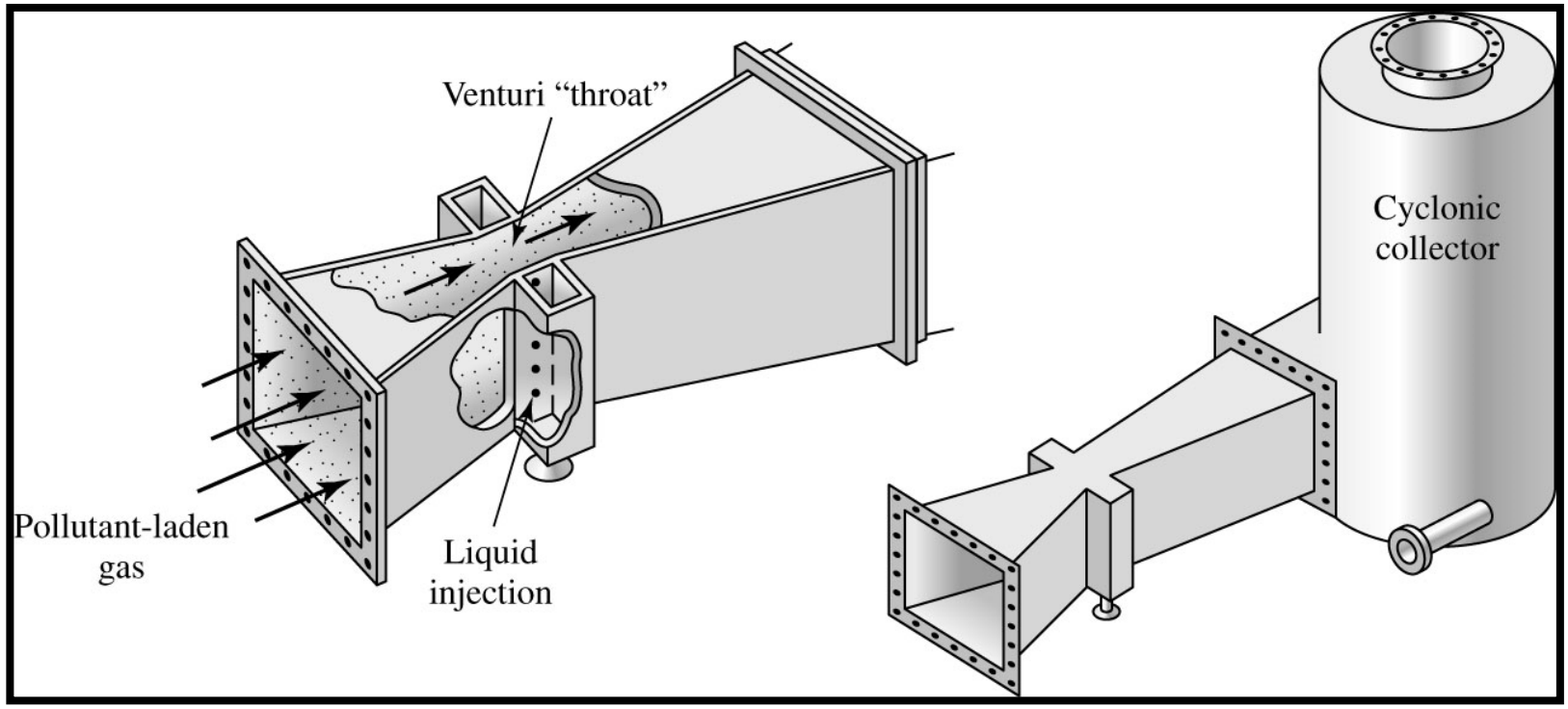
Air pollution control – particulates

- Filter: good for small particles (<5 µm)



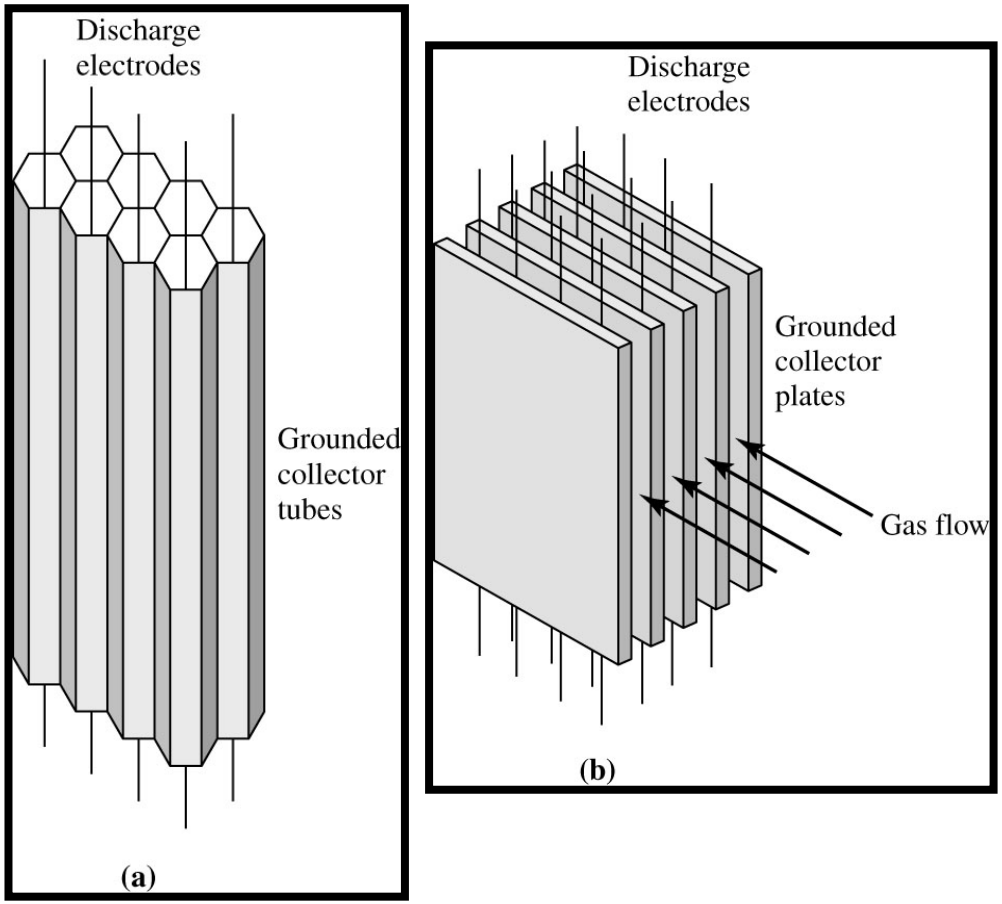
Air pollution control – particulates

- Liquid scrubbing: good for wet, corrosive, or very hot particulates



Air pollution control – particulates

- Electrostatic precipitation: high-efficiency, dry collection of particles from hot gas streams



Air pollution control – particulates

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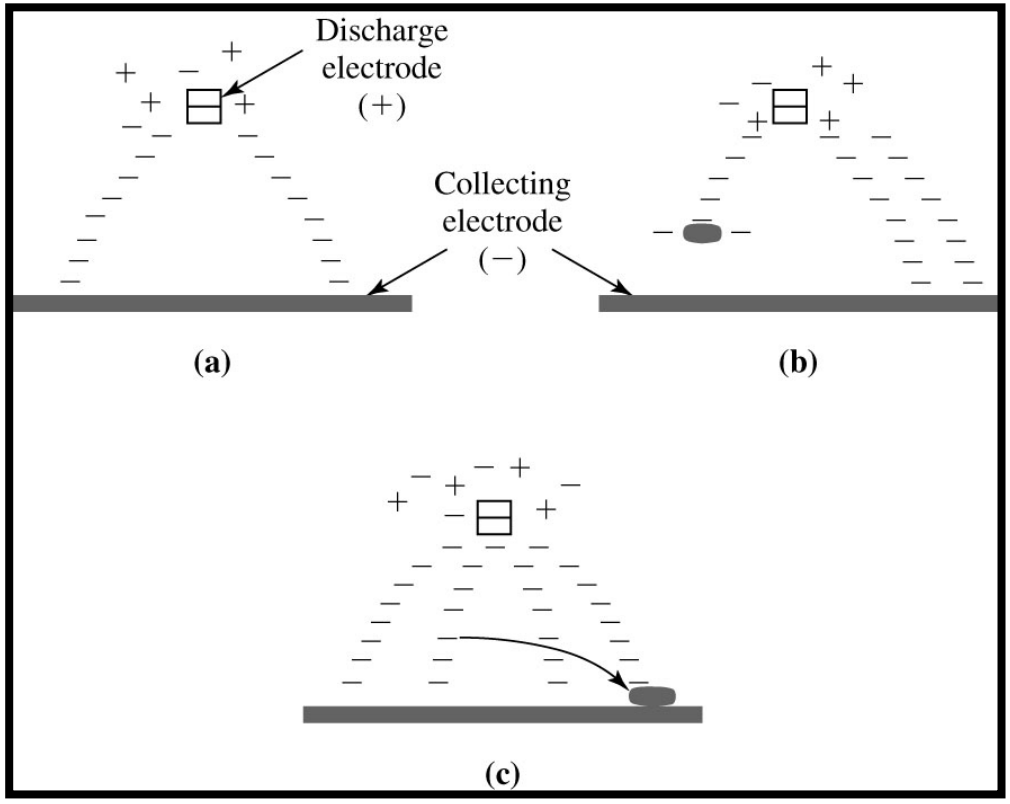

Reading assignment

Textbook Ch 12 p. 631-644