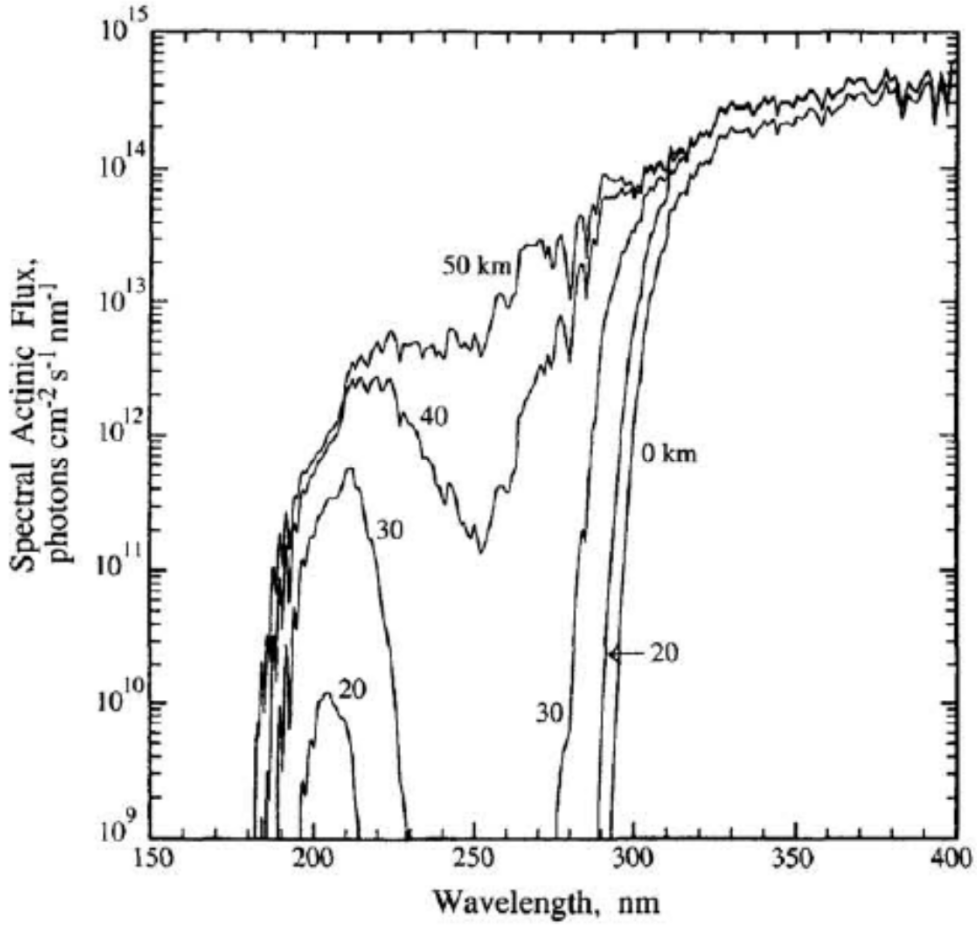
Air pollution II

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

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

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

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

$$\Big\} \quad O_3 + O \rightarrow 2O_2$$

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

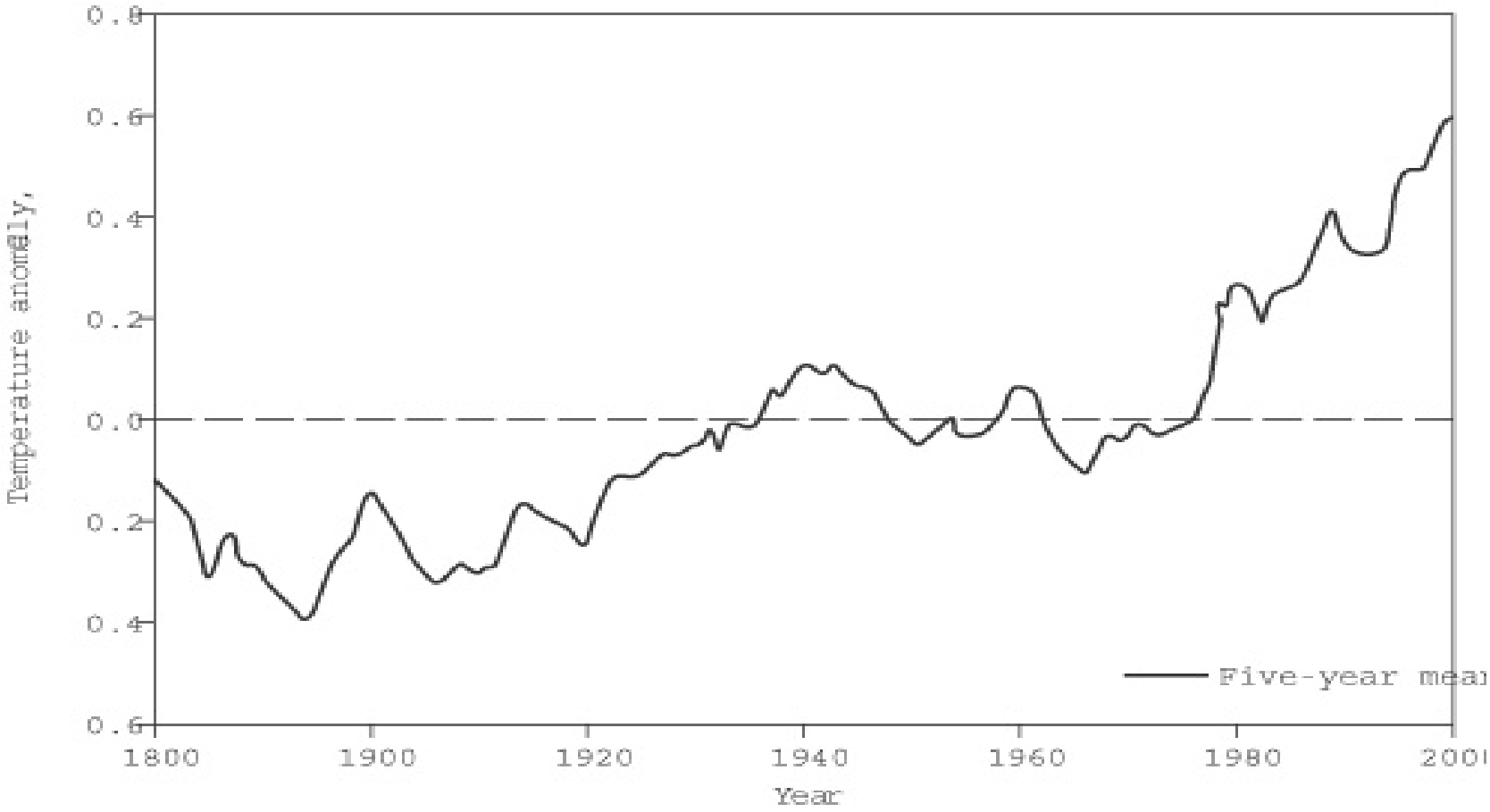
Ozone depletion

- 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

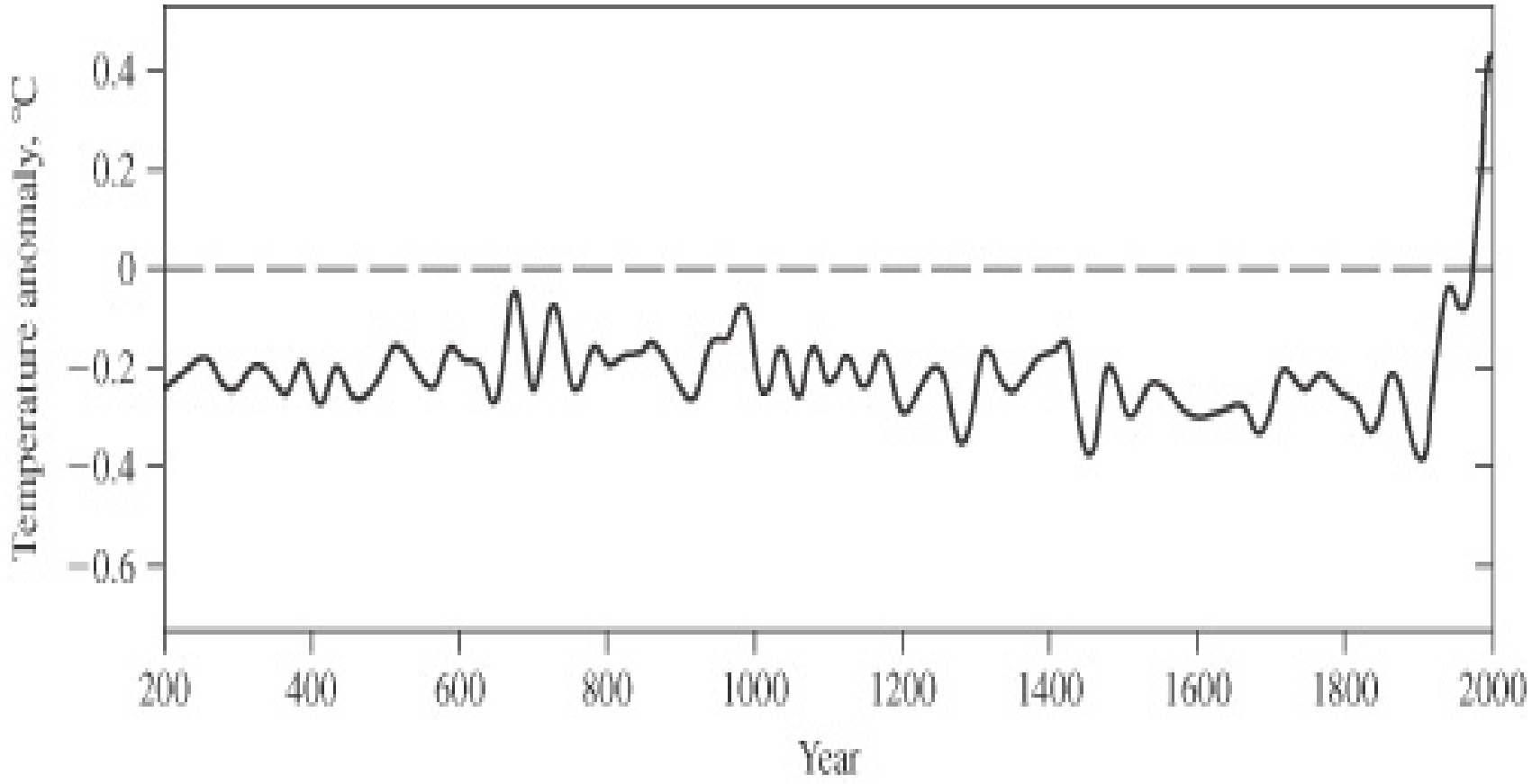
- Efforts to stop ozone depletion
  - Substitutes: hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs)
    - HCFCs are more reactive than CFCs in the troposphere → only small amount reaches the stratosphere (but still has some ozone depletion potential)
    - HFCs do not contain chlorine atoms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

Global warming

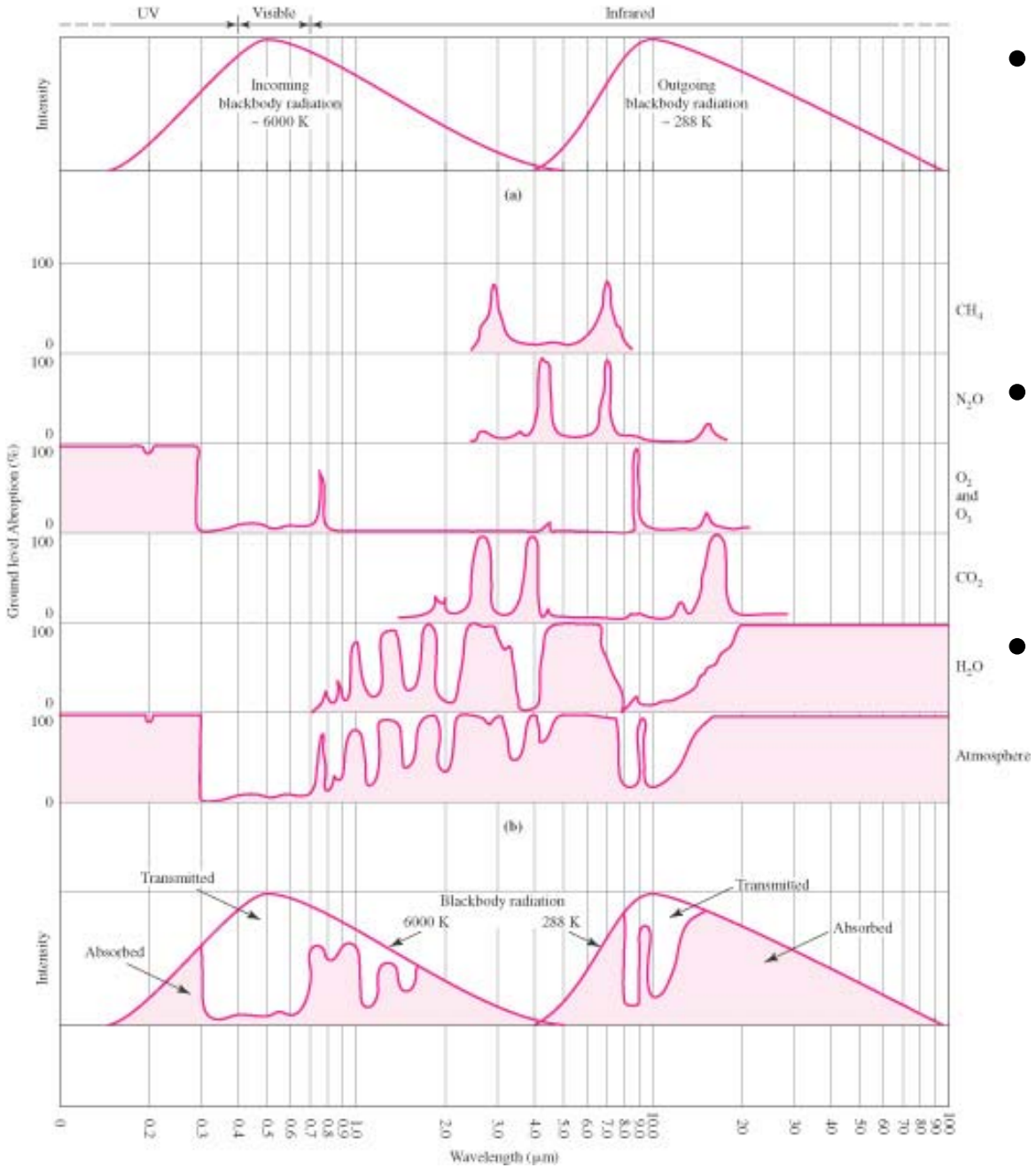


The temperature of the globe is really increasing!

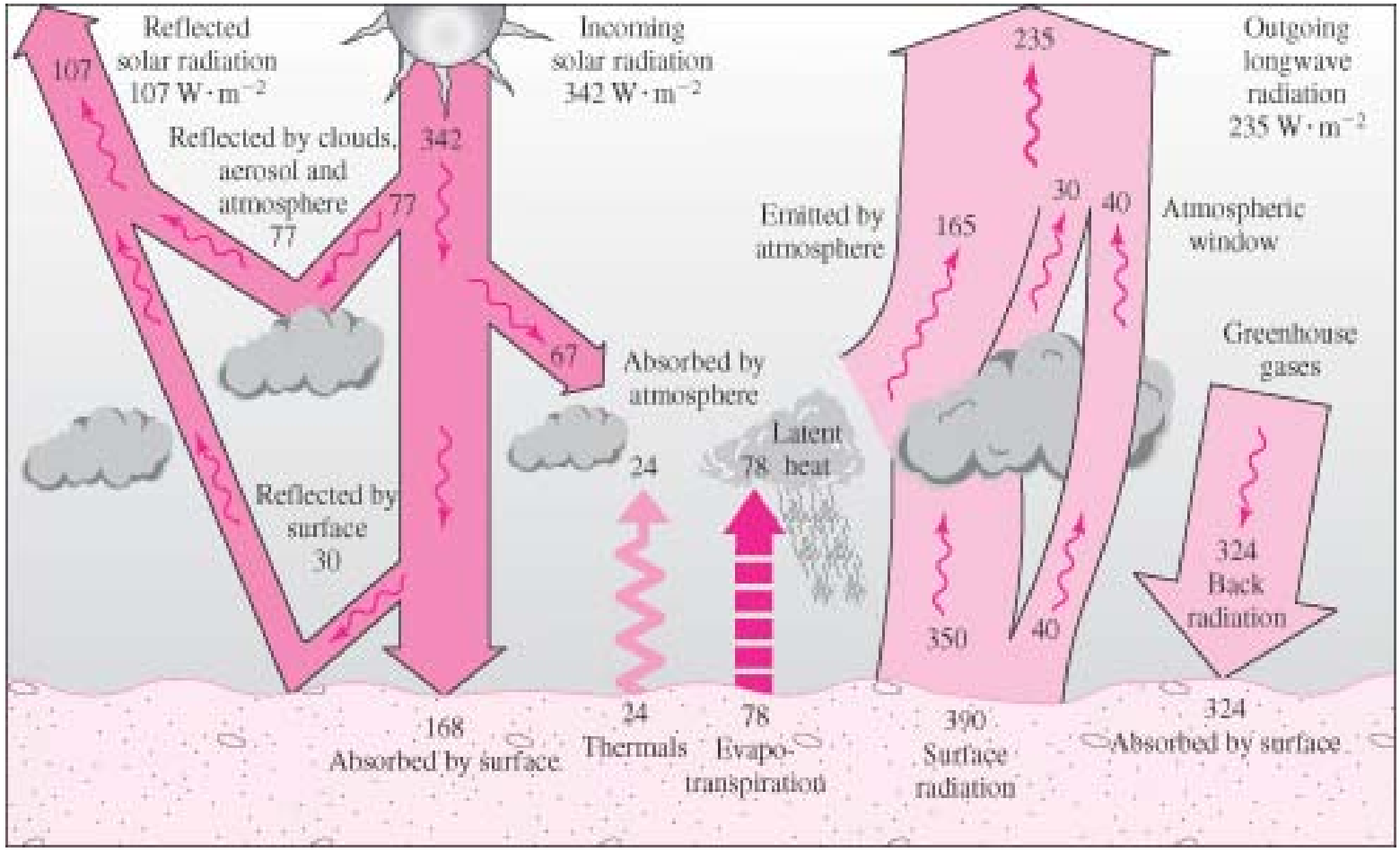
Global warming



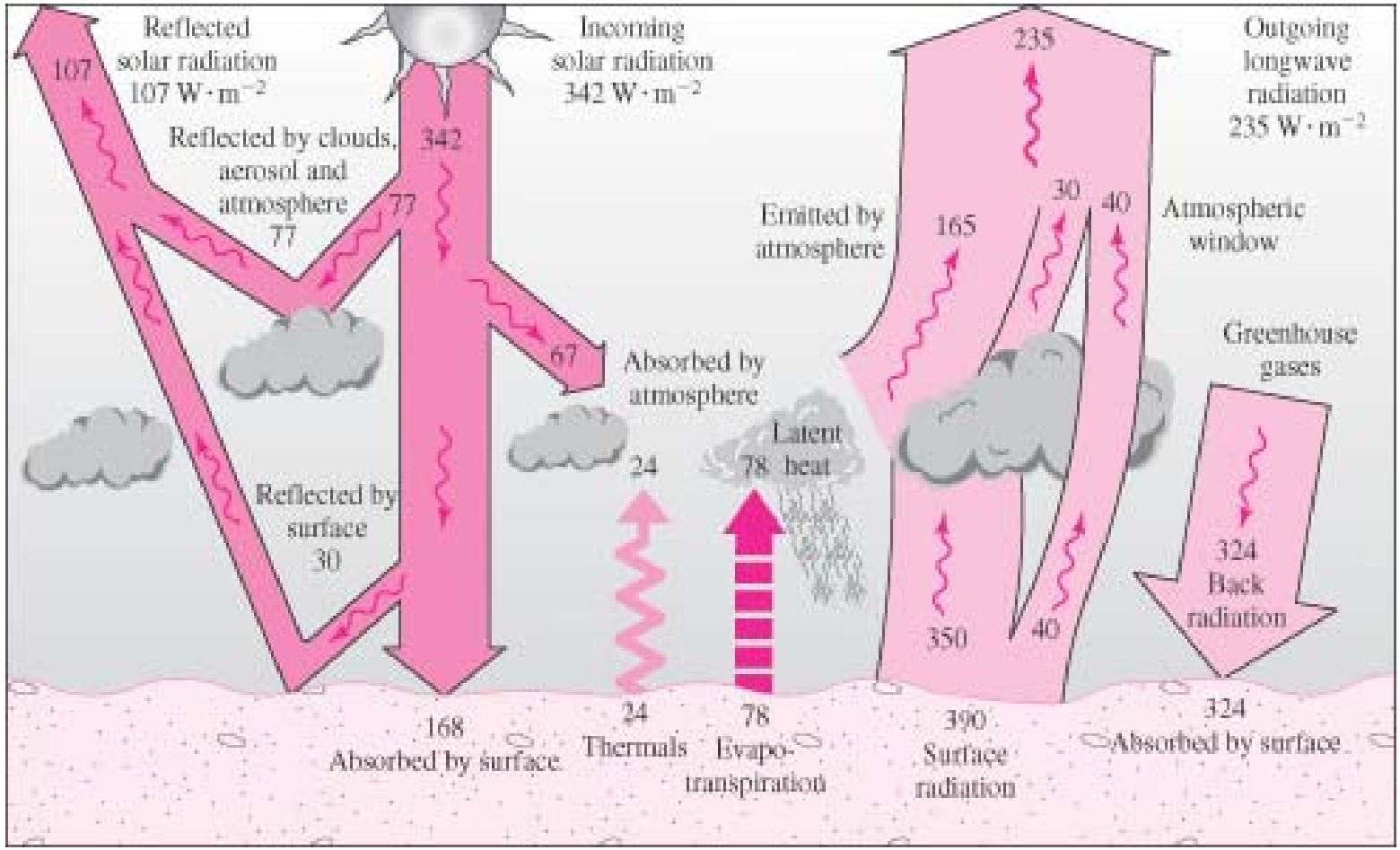
The “hockey stick” graph



- 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

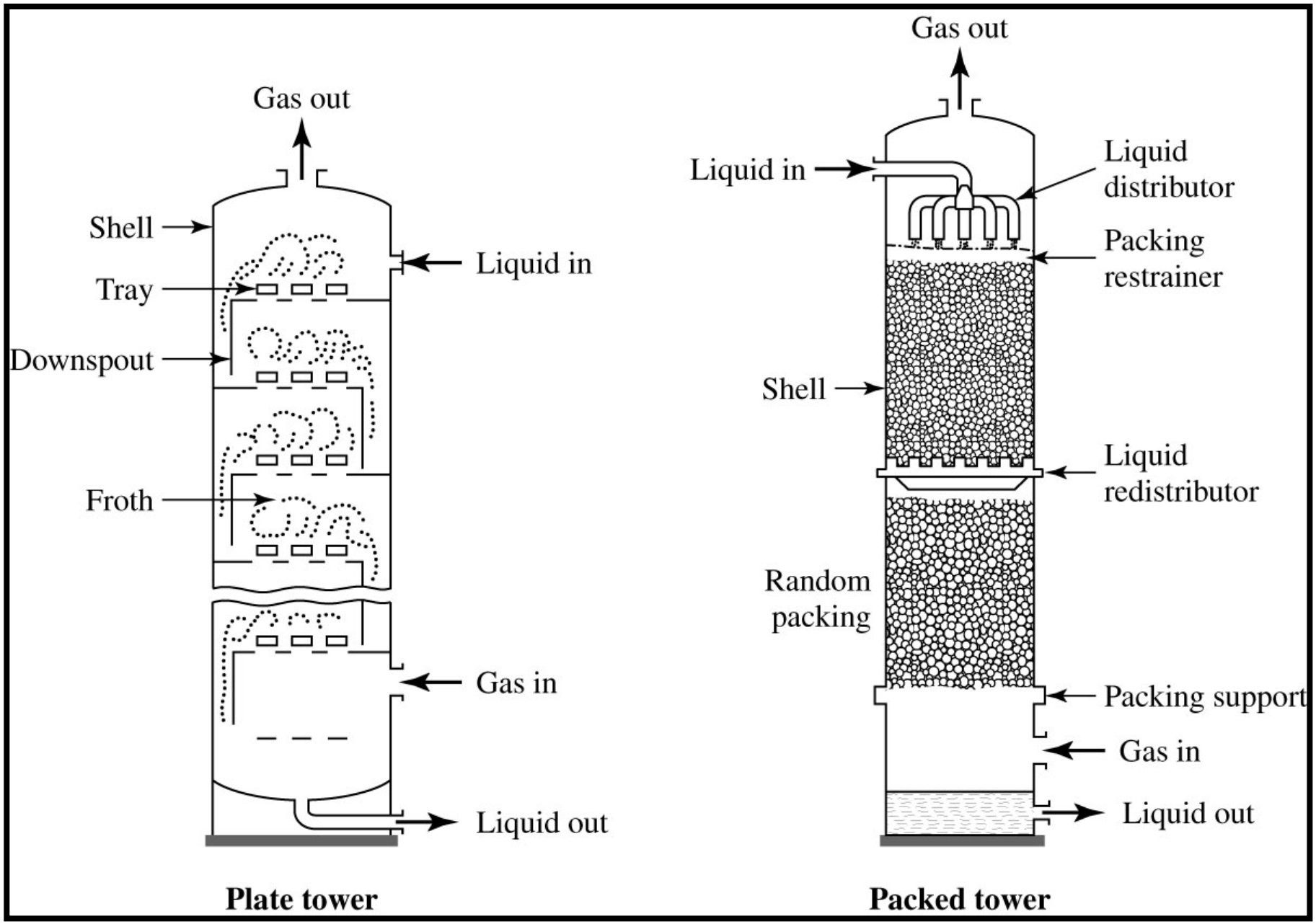
- Efforts to reduce GHG emissions
  - Kyoto Protocol
    - Adopted on December 11, 1997
    - Became effective in 2005
    - Targets to reduce GHG emissions in developed countries by 5% compared to 1990 levels during the first commitment period (2008-2012)
    - U.S. did not ratify the protocol

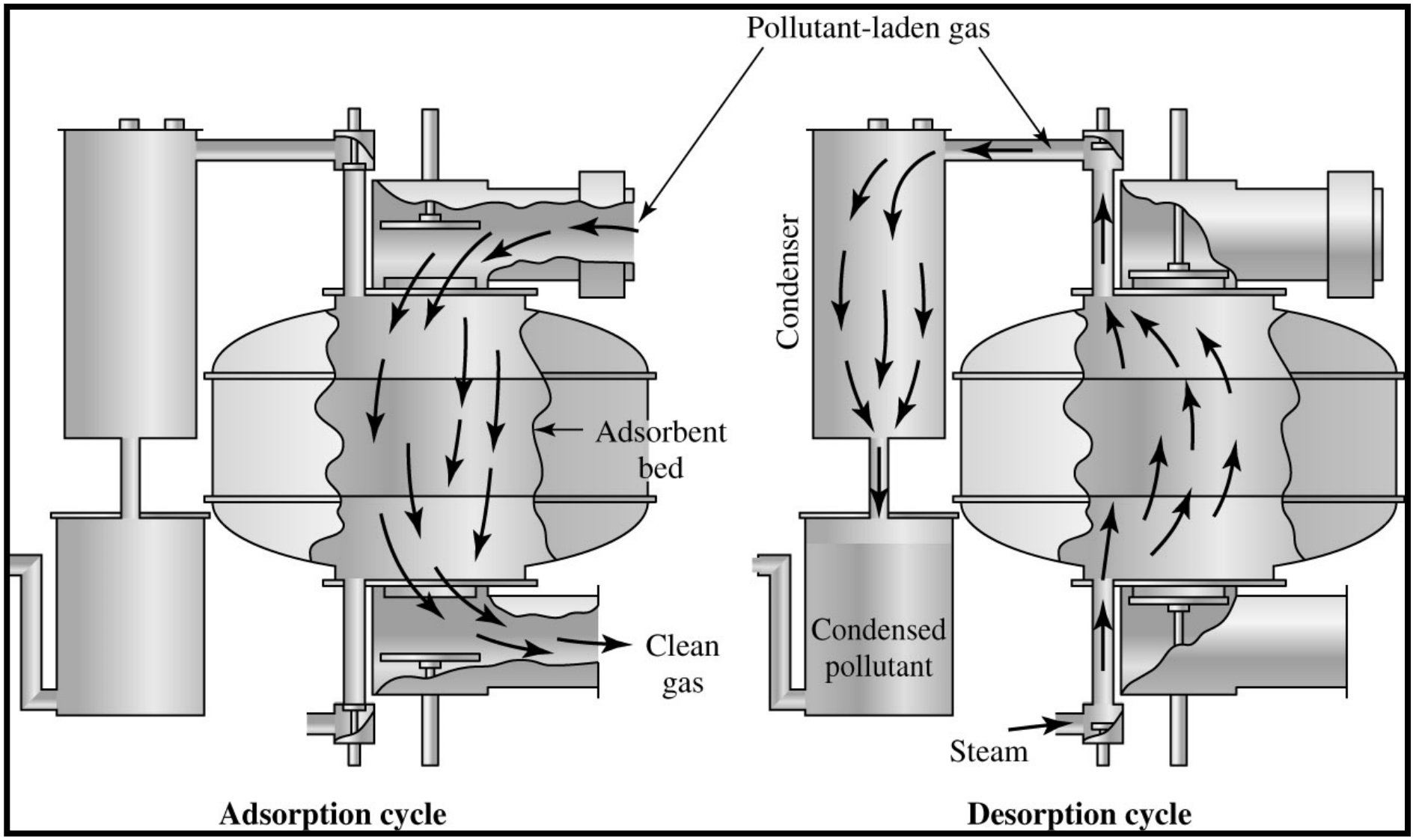
Global warming

- 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

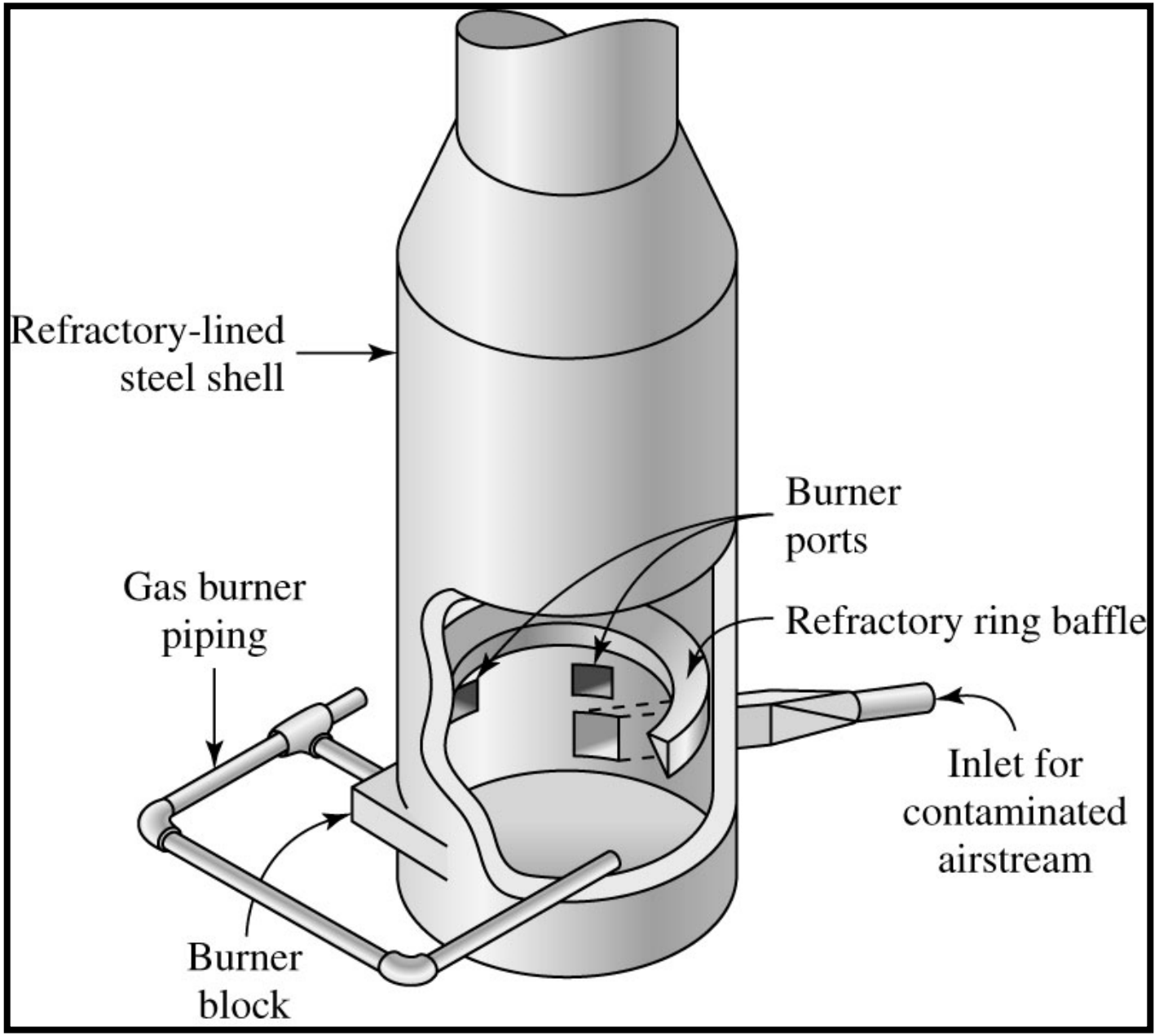
Air pollution control – gaseous pollutants

- 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


Gas out
Shell
Tray
Downspout
Froth
Liquid in
Gas in
Liquid out
Plate tower
Gas out
Liquid in
Liquid distributor
Packing restrainer
Shell
Liquid redistributor
Random packing
Packing support
Gas in
Liquid out
Packed tower



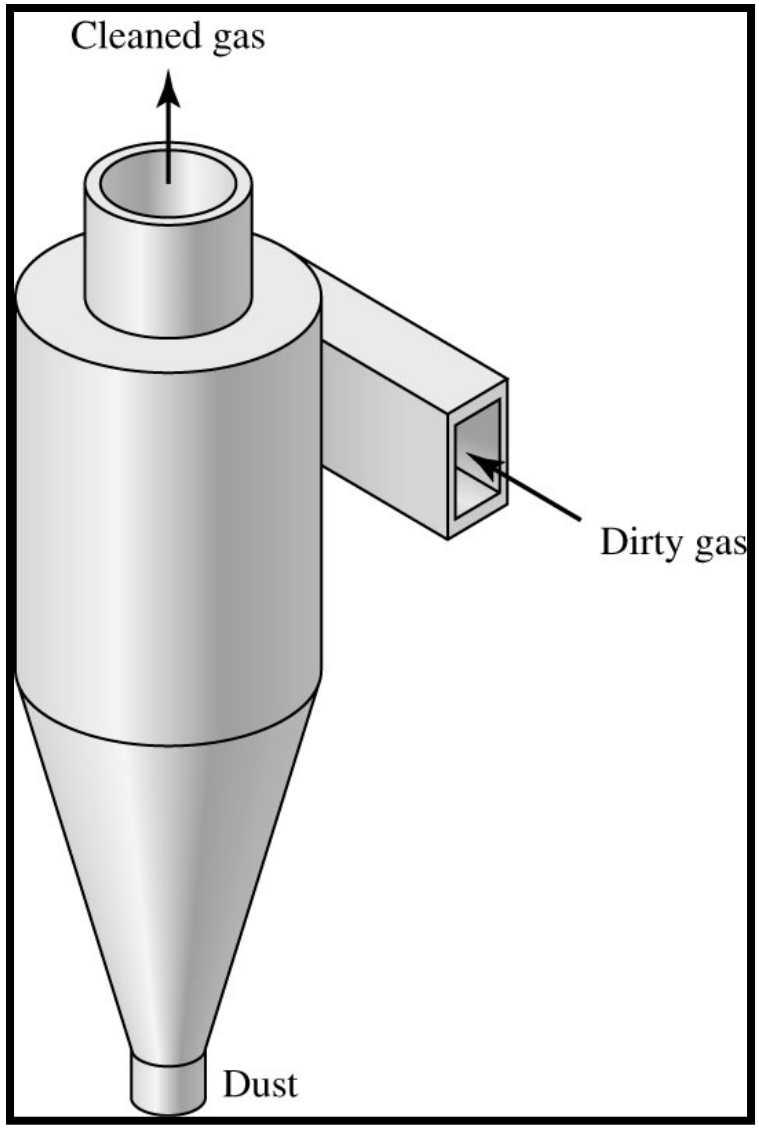
Adsorption processes



Combustion process: direct incinerator

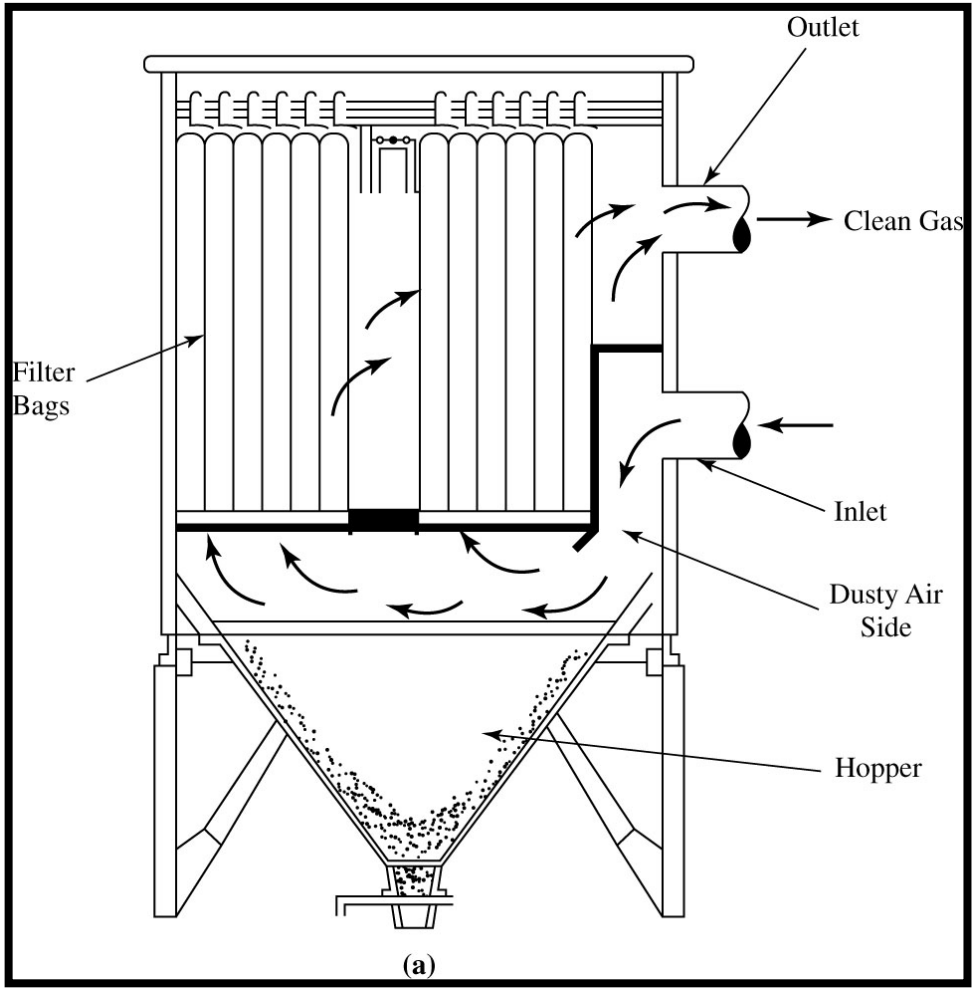
Air pollution control – particulates

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



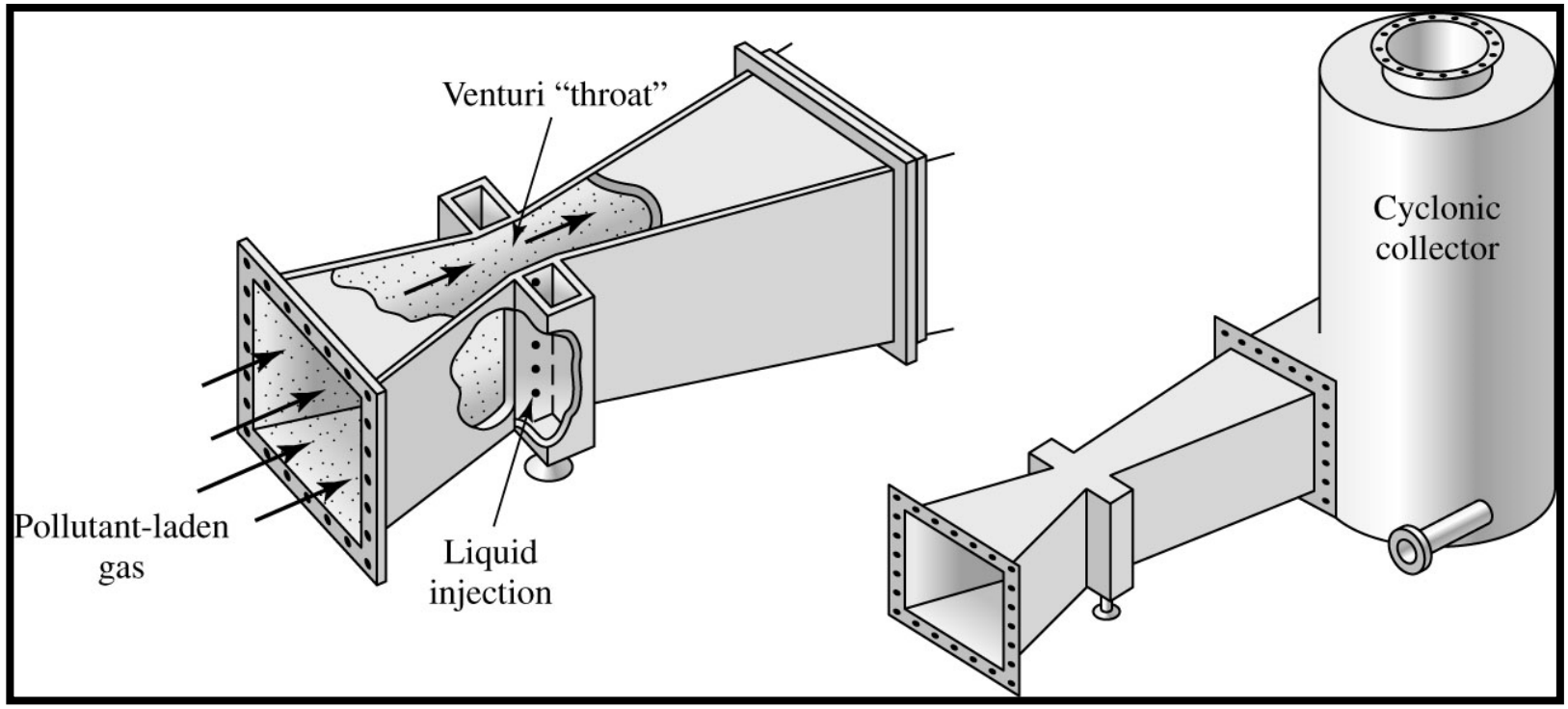
Air pollution control – particulates

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



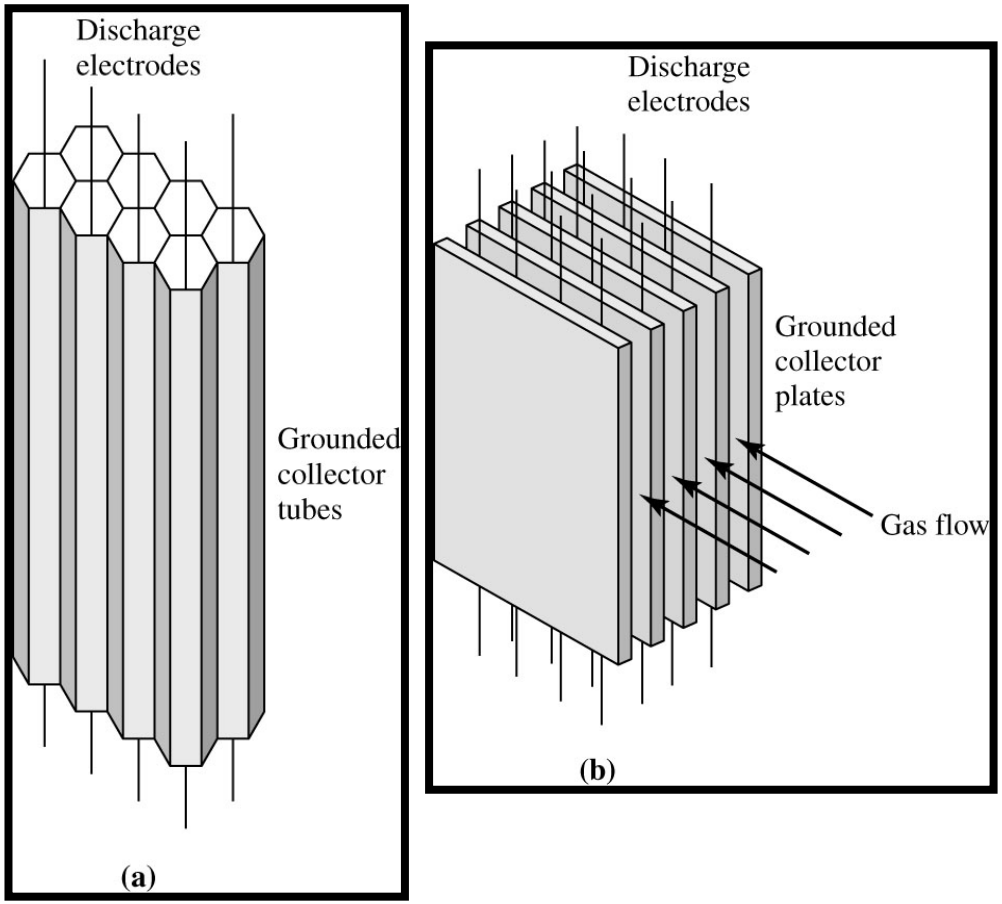
Air pollution control – particulates

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



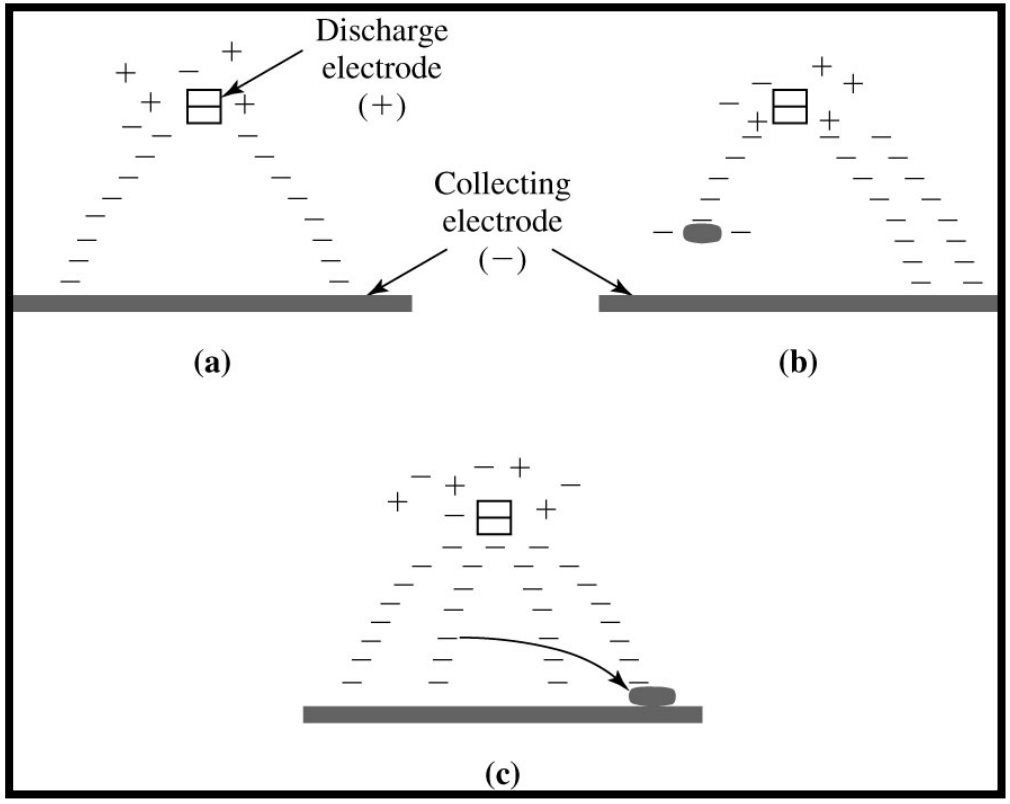
Air pollution control – particulates

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



Air pollution control – particulates

- Electrostatic precipitation



Reading assignment

Textbook Ch 12 p. 631-644