Energy Storage

D. Forms of Energy Storage

1. Mechanical Storage

a) Gravitational Storage

USES POTENTIAL ENERGY ASSOCIATED WITH GRAVITY FOR STORAGE

NATURAL H_2O CYCLE

ELECTRICAL ENERGY

SOLAR ENERGY → POTENTIAL ENERGY

EVAPORATED WATER FALLS AS RAIN & ENDS UP IN RESERVOIR

PUMPED STORAGE

ELECTRICAL ENERGY ⇄ POTENTIAL ENERGY

WHEN EXCESS EXISTS, PUMP WATER TO ELEVATION. WHEN DEMAND INCREASES, RELEASE WATER THROUGH A TURBINE

ENERGY IS STORED AS $\rho g h$

SHORT TERM
PUMPED
SMALL RESERVOIR

LONG-TERM
NATURAL
LARGE RESERVOIR

Energy Storage

D. Forms of Energy Storage

1. Mechanical Storage

b) Elastic Storage

USES POTENTIAL ENERGY ASSOCIATED WITH ELASTICITY OR COMPRESSIBILITY

SPRINGS – WATCH

RUBBER – MODEL AIRPLANE

COMPRESSED AIR

$$\int_{V_1}^{V_2} p \, dV$$

LARGE STORAGE VOLUMES
- SALT DOMES
- SOLID ROCK CAVES
- AQUIFERS

ELECTRICITY → COMPRESSOR → COMPRESSED AIR → NATURAL GAS → TURBINE → ELECTRICITY

c) Kinetic Energy Storage

USES LINETIC ENERGY TO STORE ENERGY

FOR PRACTICAL REASONS, ROTATIONAL SYSTEMS – FLYWHEEL

ENERGY STORED $\frac{1}{2} I \omega^2$

Energy Storage

D. Forms of Energy Storage

2. Electro-Magnetic Storage

a) Electric Fields

USES ELECTRICAL POTENTIAL ASSOCIATED WITH E FIELD

CAPACITOR IS TYPICAL IMPLEMENTATION

ENERGY STORED $\frac{1}{2} C V^2$

STORE ENERGY STATICALLY OR IN A TRANSIENT WAY

TOTAL ENERGY STORED IS SMALL

RATE OF STORAGE & DELIVERY OF ENERGY IS VERY HIGH

} GOOD SHORT TERM STORAGE SOLUTION

b) Magnetic Fields

USE MAGNETIC POTENTIAL ASSOCIATED WITH B FIELD

INDUCTOR IS TYPICAL IMPLEMENTATION

ENERGY STORED $\frac{1}{2} L I^2$

ENERGY ONLY STORED IN A TRANSIENT MANNER

A LARGE AMOUNT OF ENERGY MAY BE STORED

SOME PROBLEMS → HIGH LOSSES WITH HIGH CURRENT

→ SUPERCONDUCTORS

Energy Storage

D. Forms of Energy Storage

2. Electro-Magnetic Storage

c) Electro-Magnetic Radiation

USES ENERGY ASSOCIATED WITH "LIGHT"

ALL TYPES OF E-M RADIATION CAN BE USED

- VISIBLE
- INFRARED
- ULTRA-VIOLET
- MICRO WAVES

ENERGY STORED IS LOW

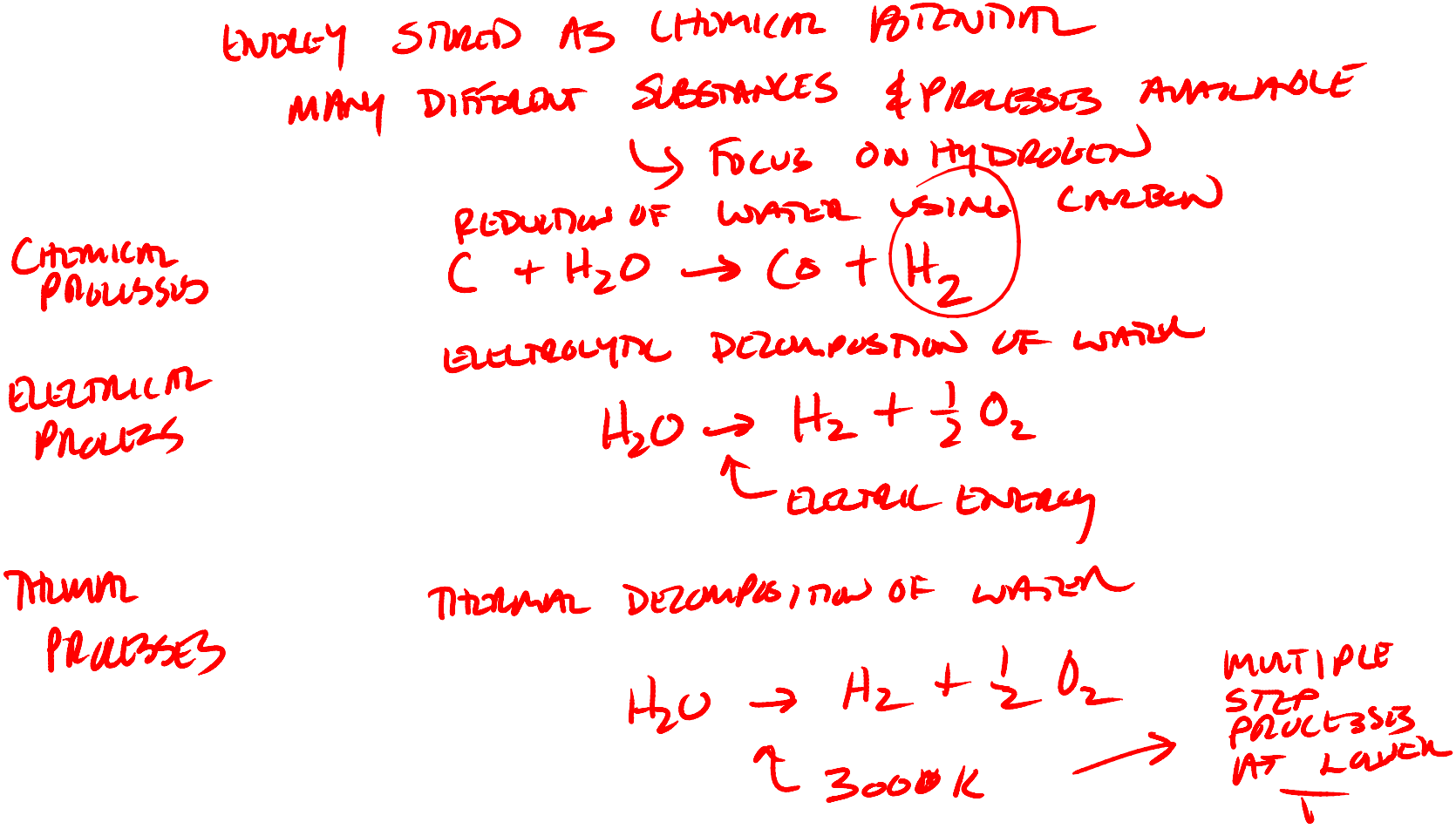
TEMPORARY STORAGE

PRIMARILY USED FOR TRANSPORT OF ENERGY

Energy Storage

D. Forms of Energy Storage

3. Chemical Storage



Energy Storage

D. Forms of Energy Storage

3. Chemical Storage

PHOTOSYNTHESIS

NATURAL PHOTOSYNTHESIS

SOLAR EM ENERGY → CARBOHYDRATES

BIOMASS

PHOTOSYNTHESIS

MODIFIED PHOTOSYNTHESIS

SOLAR EM ENERGY → HYDROGEN

PHOTOSYNTHESIS

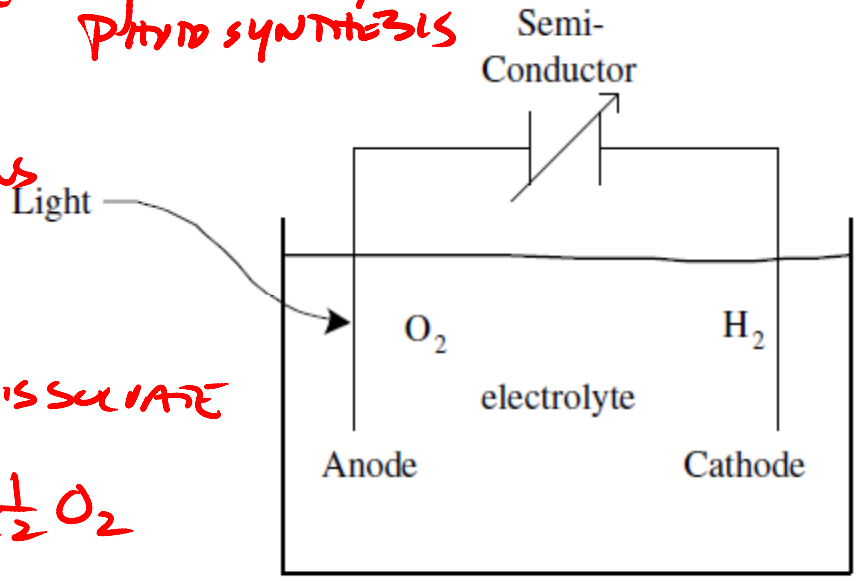
PHOTOELECTROCHEMICAL

PHOTON PRODUCES ELECTRONS

PHOTON → e^-

ELECTRONS IS USED TO DISSOCIATE H_2O

$H_2O \xrightarrow[e^-]{} H_2 + \frac{1}{2} O_2$



Energy Storage

D. Forms of Energy Storage

4. Electro-Chemical Storage

a) Battery

ENERGY IS STORED AS CHEMICAL POTENTIAL → ELECTRICITY AS SOURCE/FINAL PRODUCT

ELECTRICITY ⇄ CHEMICAL

EXAMPLE: LEAD-ACID BATTERY

$$Pb + H_2O + PbSO_4 \rightarrow Pb + 2H_2SO_4 + PbO_2$$

↑ CHARGING

BATTERY ISSUES

HEAVY

LIMITED CHARGE/DISCHARGE CYCLES

TO RETRIEVE ELECTRICITY, PROCESS IS REVERSED

$$Pb + 2\,H_2SO_4 + PbO_2 \underbrace{\rightarrow}_{\text{discharging}} PbSO_4 + 2\,H_2O + PbSO_4$$

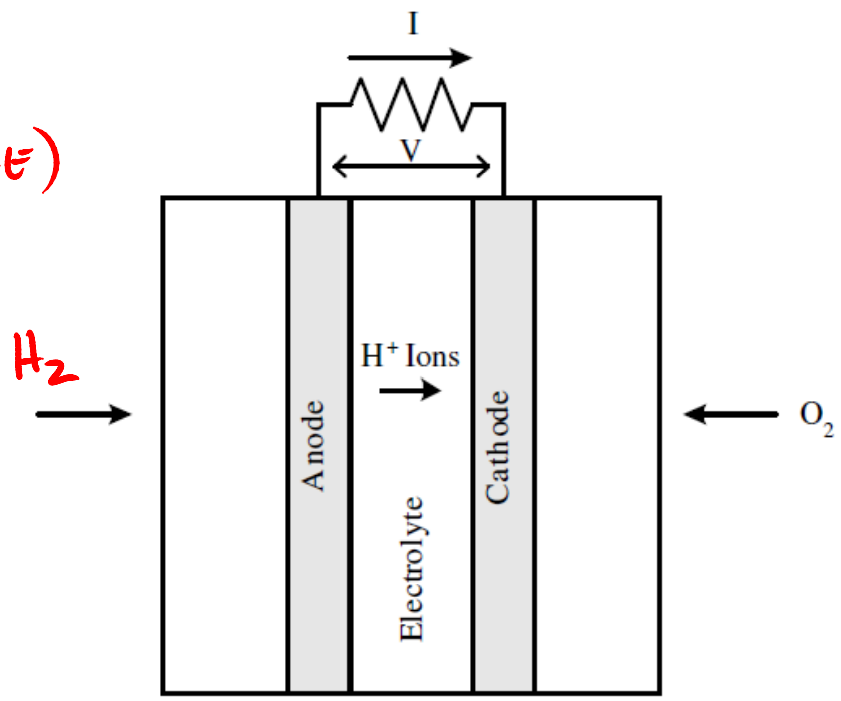
Energy Storage

D. Forms of Energy Storage

4. Electro-Chemical Storage

b) Fuel Cell (CONVERSION DEVICE)

CHEMICAL → ELECTRICAL



CONCEPT IS SOMEWHAT CLOSE TO A BATTERY EXCEPT THERE ARE REACTANTS & PRODUCTS CONTINUOUSLY SUPPLIED

PROCESS

AT ANODE $2H_2 \rightarrow 4H^+ + 4e^-$

ELECTRONS FLOW THROUGH CIRCUIT & RETURN TO CATHODE → H_2O

H^+ IONS DIFFUSE THROUGH THE ELECTROLYTE

AT CATHODE, THE ELECTRONS & H^+ IONS COMBINE WITH O_2

$4e^- + 4H^+ + O_2 \rightarrow 2H_2O$ ← WATER IS PRODUCT

ELECTRICITY + HEAT

Energy Storage

DISADVANTAGES
HIGH COST
CONTROL OF REACTANT FLOW

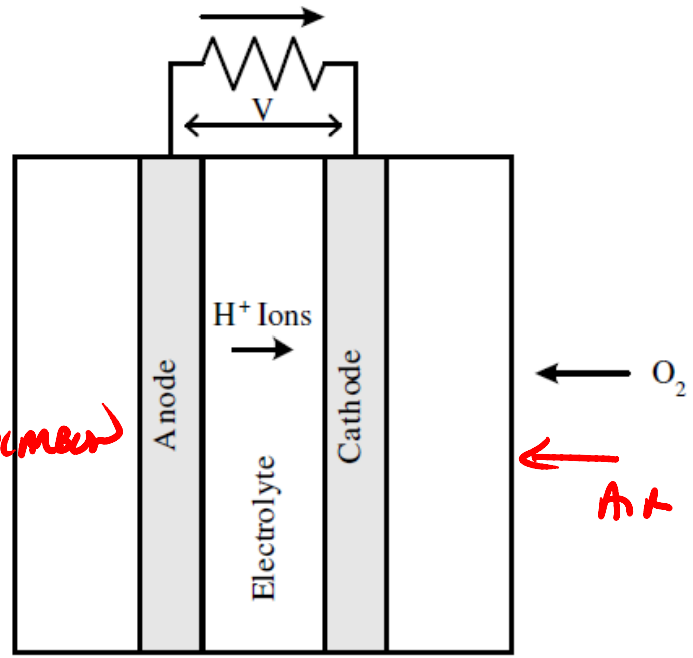
REACTANT/MATERIAL INTERACTIONS
SHORT LIFE

ADVANTAGES
SIMPLE DEVICE
LIGHT WEIGHT
HIGH POWER TO WEIGHT
BENIGN PRODUCTS

D. Forms of Energy Storage

4. Electro-Chemical Storage

b) Fuel Cell



(-) MOLAR BASIS

EFFICIENCY

FIRST LAW

$$\bar{w} = \bar{h}_r - \bar{h}_p + \bar{q}$$

FOR A REVERSIBLE PROCESS

$$\bar{q} = T(\bar{s}_p - \bar{s}_r)$$

THUS, THE MAXIMUM WORK POSSIBLE

$$\bar{w}_{max} = \bar{h}_r - \bar{h}_p + T(\bar{s}_p + \bar{s}_r) = \bar{g}_r - \bar{g}_p$$

$\bar{g}$ - GIBBS FUNCTION

$$\bar{g} = \bar{h} - T\bar{s}$$

THUS

$$\eta = \frac{\bar{w}_{max}}{\bar{h}_r - \bar{h}_p} = \frac{\bar{g}_r - \bar{g}_p}{\bar{h}_r - \bar{h}_p}$$

Energy Storage

D. Forms of Energy Storage

5. Heat Storage

HEAT (often waste) is stored as LATENT HEAT

Common in low temp applications

Some high temp applications use a similar approach

↳ solar energy → molten salt

Energy is stored

$$E = M \int_{T_0}^{T} C_p \, dT$$

Mediums

Solid

- salt
- iron
- rock
- brick
- earth

Liquid

- water
- oil
- sodium
- diethylene glycol